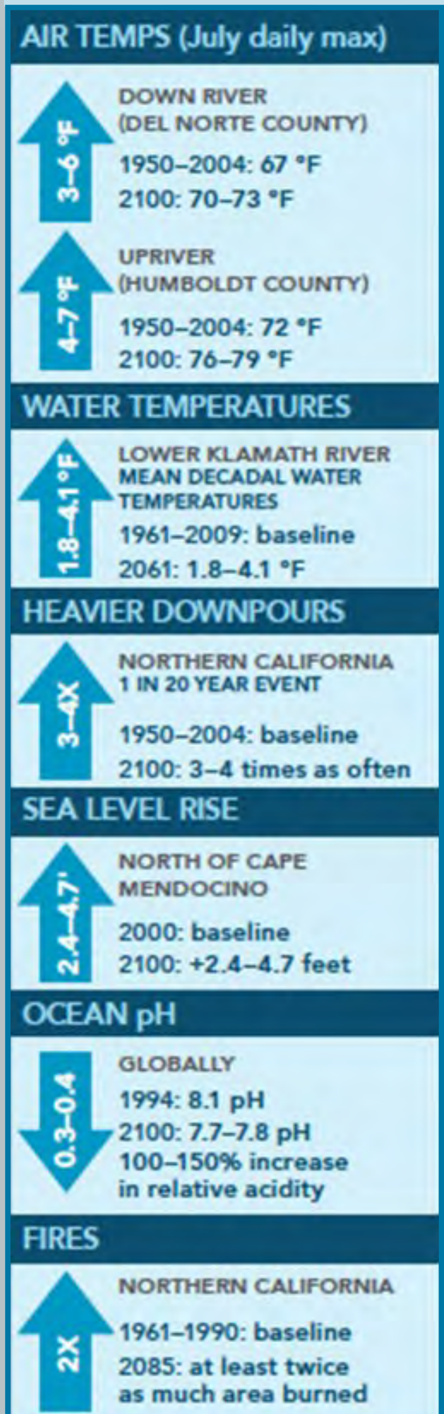
Yurok Tribe
Climate Change Adaptation Plan for Water & Aquatic Resources
2014-2018



Expected Local Climate Change in Yurok Territory

Prepared by the Yurok Tribe Environmental Program in collaboration with the Yurok Tribe community members, staff, and several organizations– the Institute for Tribal Professionals and Adaptation International. Funding was made available through the US EPA Science to Achieve Results (STAR) Program, Grant # 83560401-0.

Dedicated to:

- All Future Generations of Puhlik-lah, Ner-er ner, and Yurok Non-Human Relatives.
- Aa-wok Troy Fletcher Sr.
  Former Yurok Executive Director and Tribal Fisheries Manager. A dedicated and knowledgeable leader whose vision for ecological restoration and protection of the Klamath River helped inspire the initiation of this climate change adaptation plan.

Acknowledgments

We would like to thank the Yurok Tribal Council for their support of the project proposal and continued work on climate change and related issues. We would also like to thank the U.S. Environmental Protection Agency Science to Achieve Results (STAR) Program for funding this project. Finally, during the planning process, we also received insights and support from many Yurok Tribal Members, staff, and additional contributors. We are truly grateful to them for their time, commitment, and wisdom.
Wo-hlklaw'

Tribal Elders

Florine "Fern" Bates
Frank Lara
Axel Lindgren III
Raymond Mattz
Robert McConnell, Sr.
Allen McCovey
Fawn Morris
Bertha Peters

Yurok Committees & Councils

Yurok Natural Resources Committee
Yurok Cultural Fire Management Council
Yurok Cultural Resources Committee
Yurok Language Advisory Committee

Yurok Tribal Members, staff, and others

Judge Abby Abinanti, Yurok Tribal Court
David Anderson, Redwood National Park
Murina Arellano Peptone, Bear River Band of Rohnerville Rancheria
Elizabeth Azzuz, Cultural Fire Management Council
Ronnie Bates
Sarah Beesley, Yurok Fisheries Department
Leanna Begay, Institute for Tribal Environmental Professionals
Mike Belchik, Yurok Fisheries Department
Jake Bell, Adaptation International
Jennifer Brown, Yurok Tribe Environmental Program
Lavinia Brooks, Yurok Transportation Department
Victoria Carlson, Yurok Tribe Language Program
Brad Cass, Smith River Rancheria
Shaonna Chase, Yurok GIS Program
Rose Clayburn, Cultural Resources Department
Nikki Cooley, Institute for Tribal Environmental Professionals
Colleen Davis, Institute for Tribal Environmental Professionals
Vini Dix
Thomas Dunklin, Thomas B. Dunklin Photography
Jim Erler, Yurok Forestry Department
Michelle Fox, The Bridge Studio
Micah Gibson
C. Gonzalez-Maddux, Institute for Tribal Environmental Professionals
Hansi Hals, Jamestown S'Klallam Tribe
Tim Hayden, Yurok Natural Resources Division
Diana Heom, Heom Design and Illustration
Dave Hillemeier, Yurok Fisheries Department
Javier Kinney, Yurok Self Governance
Rosa Laucci, Smith River Rancheria
Sophia Lay, Yurok Planning Department
Ramona Lockerman, Yurok Tribal Fiscal Department
Matt Mais, Yurok Public Relations Manager
Gary Markussen, Yurok Tribe Information Services Department
Manuel Mattz
Robert McConnell, Sr., Yurok Cultural Fire Management Council,
Barbara McQuillen, Yurok Tribe Language Program
Jim McQuillen, Education Department
Barry McCovey, Jr., Fisheries Department
Jene McCovey, Yurok Natural Resources Committee
Louisa McCovey, Yurok Tribe Environmental Program
Walt McCovey Jr.
Rebecca McMahon, Office of the Tribal Attorney
Frankie Myers, Watershed Program
Molli Myers, Transportation Planning
Richard Myers II, Yurok Tribe Environmental Program
Richard Nelson, Yurok Watershed Restoration Department
Austin Nova, Yurok Public Utilities Department
Peggy O'Neill, Planning Department
Elaina O'Rourke, GIS Program
Thomas O'Rourke, Tribal Council
Bill Patterson, Yurok Tribe Environmental Program
Erika Peters, Yurok Tribe Language Program
Chris Peters
Ron Reed, Yurok Tribe Forestry Department
Margo Robbins, Yurok Cultural Fire Management Council
Merk Robbins
Elizabeth Rohlich, Adaptation International
Sue Rose, Institute for Tribal Environmental Professionals
Cheyenne Sanders, Yurok Tribe Office of the Tribal Attorney
Brandon Scott, Yurok Tribe Information Services
Sally Scott
Kathleen Sloan, Yurok Tribe Environmental Program
Jason Soto, Trinidad Rancheria
Jaytuk Steinruck, Smith River Rancheria
Rose Sylvia, Yurok Human Resources Department
Koiya Tuttle, Yurok Tribe Environmental Program
Paul Van Mechelen, Paul's Famous Smoked Salmon
Mia Wapner, Yurok Tribe Environmental Program
Chris West, Yurok Wildlife Program
Tiana Williams, Yurok Wildlife Program
Thomas Wilson, Tribal Council Member
Jan Wortman, Requa Inn
Nicole Wright, Yurok Planning Department
Rhonda Wright, Office of the Tribal Attorney
Brittany Vigil-Burbank, Yurok Tribe Language Program
Nathan Voegli, Yurok Office of the Tribal Attorney
Melinda Yaiva, Institute for Tribal Environmental Professionals

Photo Contributors

Andrew Antonetti, Yurok Fisheries Department
Thomas B. Dunklin Photography and Videograhy
Matt Mais, Yurok Public Relations Manager
Aaron Martin, Yurok Fisheries Department
Louisa McCovey, Yurok Tribe Environmental Program

Executive Summary

The goal of this Adaptation Plan was to assess the vulnerabilities and resiliencies of Yurok waters, aquatic species, and people in the face of climate change and to identify actions and strategies that will allow Yurok lifeways, culture, and health to grow despite the changing climate. And while this Plan does not address all aquatic species nor the many, varied terrestrial ecosystems and resources, it is hoped that these will be the focus of future planning efforts.

A common sight in Yurok Country: salmon being cook on traditional redwood stakes over hot coals.

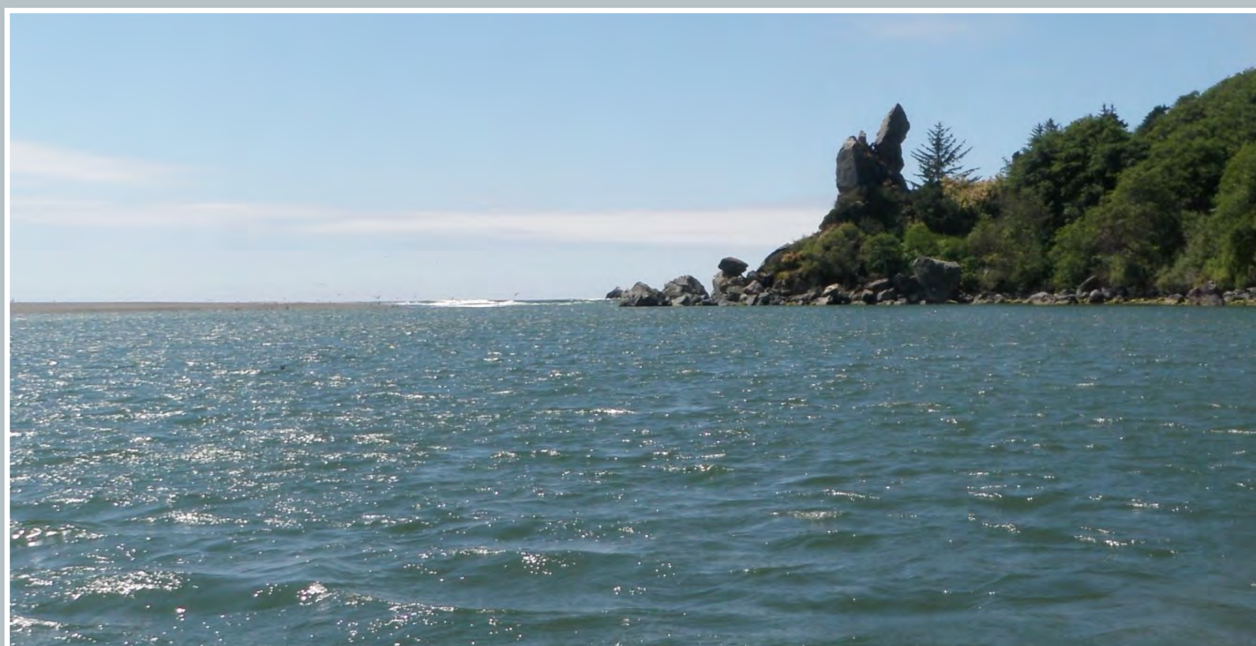
Yurok community members are even now bearing witness to changes that may be linked to climate change, such as rising air temperatures, warmer river waters, and increasing drought. Yurok territory was once a place of abundance where there was always enough fish for everybody to sustain themselves, their families and their communities as a whole. Today, the Yurok Reservation is practically a food desert with the decline in fish populations, the loss of harvesting and gathering sites for terrestrial species such as acorns, and the lack of grocery stores with options for fresh food.

In addition, water quality in the Klamath River system and ocean has been declining and impacts on drinking water threatens a key element of tribal sovereignty – the right to ample, safe, and affordable drinking water. People who once drank water from creeks without second thought are now concerned about possible exposure to *E. coli* and *Giardia*. Youngsters who used to swim in the Klamath River all summer long have grown into adults who no longer do so because of the algae that makes the water slimy and the fear of getting rashes or worse illnesses. Tribal Members worry if they can participate in ceremonies or consume shellfish without risk of poisoning and paralysis when these harmful algal blooms are prevalent. Their health does not just entail the absence of illness or injury. It is a much broader concept that includes spiritual and emotional as well as physical health and the intricate relationships and shared histories that the Yurok have with their waters, lands, and the species within them. If the river is sick, so are the Yurok.

Climate change has been implicated in many of these ecological changes and is expected to increase these effects in the future, however, climate change does not occur in isolation. Both history and our present conditions can either create challenges or provide strengths as we attempt to deal with changing climate and the many resulting impacts. The Yurok Tribe is being pro-active to mitigate the threats to the resources and ecosystem they depend on for their livelihoods, identity, culture, economy, diet, health, spirituality, ceremonies, and overall wellbeing.

Yurok Tribal elders and community members have a wealth of traditional and community knowledge that has informed this adaptation planning process during all stages and provides strength – or adaptive capacity – to enable and empower the Tribe to adapt to climate change. Quotes from them are featured throughout the document including their understandings of how the climate has been changing, insights into species' behaviors and roles within ecosystems, and knowledge on the resilience of ecosystems, people and how non-climatic factors are interacting. Yurok traditional values and practices have consistently been a source of resilience for the Yurok people and have helped the Yurok endure their historic traumas.

During the planning process, over 400 possible adaptation ideas were gathered from Yurok Tribal Members, communities, and Tribal staff. These provide an extensive menu of on ways to move forward for anyone concerned with the expected environmental changes. Some actions may be relatively easy and minimal cost to implement while others may require longer-term sustained effort, however, three overarching adaptation themes emerged that together help restore balance to the ecosystem and support Yurok water and food sovereignty and Tribal health. All three themes support the Yurok concept of health- of Hewecheck in which the health of species, ecosystems, people, and communities are all inextricably linked with one another.



Mouth of the Klamath River with the ocean wave breaking on the sand spit

These united, over-arching themes encourage the community and Tribe's actions to :

- Restore and strengthen holistic, healthy, connected species and their ecosystems.
- Restore and strengthen healthy, connected individuals and their communities, and
- Restore and strengthen the human-environment inter-connections.

But ultimately, building climate resilience to reduce the impacts of climate change and the health risks that may increase from them, will require commitment to addressing and acknowledging these issues. It is hoped that this Climate Change Adaptation Plan and the process undertaken to develop it provided one way to start and intensify the discussion so that planning for the changes ahead can begin. While it is just one stage in a continual cycle of adaptation, restoring balance, and renewal in which Yurok have been engaged since time immemorial, it seeks to address the Tribal community's recognized and urgent need to decrease susceptibility and improve health outcomes. As was repeated over and over, the health of all is integral to the health of one, and healthy ecosystems are inextricably linked to healthy people.

With this Climate Change Plan and other efforts, Yurok leadership on climate change issues is using the power of preparation and taking thoughtful actions to influence their future; taking care of the waters, lands, and species that take care of the Yurok, and improve the health of all. In addition, the longstanding legacy of Yurok environmental stewardship that has been practiced since time immemorial is being revitalized and strengthened as the Tribe builds on their many strengths to prepare for climate change and pursues traditional and innovative actions to maintain subsistence livelihoods, food sovereignty, and Tribal health, not only on the Yurok Reservation but inclusive of the broader Ancestral Territory.

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Additional Information

- The Institute for Tribal Environmental Professionals (ITEP) at Northern Arizona University established its Tribes and Climate Change Program in 2009. The program provides support for and is responsive to the needs of tribes who are preparing for and currently contending with climate change impacts. For more information, please visit our website at: http://www7.nau.edu/itep/main/tcc.
- "Guidelines for Considering Traditional Knowledges in Climate Change Initiatives," A resource for tribes, agencies, and organizations across the United States interested in understanding Traditional Knowledges in the context of climate change: https://climatetkw.wordpress.com/
- "The Climate and Traditional Knowledges Workgroup – CTKW" is an informal group of indigenous persons, staff of indigenous governments and organizations, and experts with experience working with issues concerning traditional knowledges who developed a framework to increase understanding of access to and protection of TKs in climate initiatives and interactions between holders of TKs and non-tribal partners: https://climatetkw.wordpress.com/
- Additional Chapters of the Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources can be found on the Yurok Tribe Environmental Program's Community and Ecosystem division webpage at http://www.yuroktribe.org/departments/ytep/com_eco_division.htm

Yurok Tribe Climate Change Adaptation Plan for Water & Aquatic Resources

Chapter 1 — Introduction to Climate Change in Yurok Country

In This Chapter

This plan is from a purposeful collaboration with the staff and community members of the Yurok Tribe, as well as several organizations, and would not have been successful without each of their contributions. Funding was made available through the US EPA Science to Achieve Results (STAR) Program, Grant # 83560401-0. Online files available at: https://www.yuroktribe.org/departments/ytep/

Our people have always lived on this sacred and wondrous land along the Pacific Coast and inland on the Klamath River, since the Spirit People, Wo'ge' made things ready for us and the Creator, Ko-won-no-ekc-on Ne ka-nup-ceo, placed us here. From the beginning, we have followed all the laws of the Creator, which became the whole fabric of our tribal sovereignty....This whole land, this Yurok country, stayed in balance, kept that way by our good stewardship, hard work, wise laws, and constant prayers to the Creator.

– Preamble of the Constitution of the Yurok Tribe, 1993

In September 2002, an event occurred that intensely affected the Yurok people on spiritual, emotional, and economic levels (Belchik 2004). Starting on September 19th and continuing to the end of the month, an unprecedented and massive fish kill took place in which an estimated 34,000 to possibly double that number of fish perished, mostly in the lowermost 30 miles of the Klamath River on the Yurok Reservation (Belchik et al. 2004; CDFW 2004; Yurok Tribe 2007). The fish were mainly adult fall-run Chinook salmon returning home to spawn (Belchik et al. 2004). However, Coho salmon, steelhead and other fish were lost as well (CDFW 2004; Yurok Tribe 2007). Elders on the Yurok Culture Committee said, "Never in our time, have we, the elders of the Yurok Culture Committee, seen such a mass destruction of our salmon resource" (Belchick et al. 2004). Although the direct causes of the fish kill were pathogens, warmer water temperatures and low river flows due to dam regulation contributed to the disastrous event.

The fish kill served as a sign, reminder, harbinger, and call. It was a sign of how sick the river had become and the deep implications that has for the Yurok people. It was also a reminder of the important role Yurok play as stewards and as a voice for their ancestral home and the ecosystems and species within it. For many Yurok, the fish kill was a warning as well of the potentially profound effects of an increasingly evident and global force

Yurok Youth in traditional regalia

Chapter citation: Cozzetto K[1], Maldonado J[1], Fluharty S[2], Hostler J[2], Cosby C[2] (2018) Chapter 1 - Introduction to climate Change in Yurok Country. In *Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources*. [1] Institute for Tribal Environmental Professionals (ITEP), Northern Arizona University, Flagstaff, AZ. [2] Yurok Tribe Environmental Program (YTEP), Klamath, CA.

shaping the environment – climate change. Rising water temperatures, increasing drought intensities, and lower summer flows are all anticipated with climate change, conditions markedly similar to those that occurred in 2002. Ultimately, the fish kill was a powerful call - to continue and further ongoing Yurok efforts to restore the natural environment and to take new actions to prepare for the emerging climate change challenge. The development of this Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources is one of those actions.

The goal of the Plan is to assess the vulnerabilities and resiliencies of Yurok waters, aquatic species, and people in the face of climate change and to identify strategies that will allow Yurok lifeways, culture, and health to continue and grow. The Plan encompasses both the Yurok Reservation and their broader Ancestral Territory. For Yurok, health does not just entail the absence of illness or injury. It is a much broader concept that includes spiritual and emotional as well as physical health and that encompasses the intricate relationships and shared histories that the Yurok have with their waters, lands, and the species within them. If the river is sick, so are the Yurok. The health of all is integral to the health of one, and healthy ecosystems are inextricably linked to healthy people. For Yurok, this is in the spirit of ***He-we-chek'.*** The theme of *He-we-chek'* guides this Plan.

1.1 Organization and Adaptation Plan Layout

In order to understand the vulnerability of Yurok, their waters, and aquatic resources to climate change as assessed in subsequent chapters, Chapter 1 provides background information that will help set the stage for what follows. It is divided into the following sections: a short overview of climate change and its causes with a summary of key anticipated changes for the Yurok region in Northwest California (Sec. 1.2); a description of previous climate change work undertaken by the Tribe that provided a basis for this Plan (Sec. 1.3); a summary of the Tribe's demographics (Sec. 1.4), background on the Yurok people and Ancestral Territory (Sec. 1.5), and a description of the historical legacies that have disrupted the natural resilience of ecosystems, species, and the Yurok people since the arrival of Europeans on the continent (Sec. 1.6); and a concluding overview of the revitalization of Yurok culture and sovereignty as a guiding force for the Tribe's climate change preparations (Sec. 1.7).

Table 1.1: Climate Change Priority Planning Areas for the Yurok Tribe

- Aquatic Habitats (Chapter 4)
- Drinking Water (Chapter 5)
- Traditional Aquatic Foods including: (Chapter 6)
    - Ney-puy (Chinook Salmon) and Chey-guen (Coho Salmon)
    - Chkwohl (Steelhead)
    - Kah-kah (Green Sturgeon)
    - Key'-ween (Lamprey Eel)
    - Seyk-soh (Marine Shellfish)
    - Key'-ween we' chey-gel' (Spring Seaweed)
- Tribal Members' Health – physical, mental, spiritual, emotional (Chapter 7)

Chapter 2 describes the planning process that the Yurok Tribe has taken to develop their climate change adaptation plan and Chapter 3 provides information on the climate, hydrologic, and ecosystem changes anticipated for the Yurok ancestral territory and region. Chapters 4-6 examine how climate change may interact with historical and other non-climatic factors to impact Yurok resources. Through previous Yurok climate change work and the planning process, nine priority planning areas were established as critically important to the Tribe and have been utilized in this Plan for intensive development – aquatic habitat, drinking water, seven traditional aquatic foods and Tribal Members' health (Table 1.1). Although of equal Tribal importance as traditional food, several species are not considered in this project due to being already impacted with extremely small populations. These include: Hehl-kues-leg (Surf fish), Mokw-chech (Nightfish) and Kwo'-ror' (Candlefish). Chapter 7 provides an assessment of climate change effects on Tribal Members' health with respect to aquatic pathways, taking into account *He-we-chek'* and incorporating the more holistic Yurok view of health and information from all the previous chapters. We conclude the Plan with Chapter 8, which contains suggested adaptation actions that encompass all of the planning areas and general considerations for implementation.

There are associated appendices for Chapters 4-7 that contain comprehensive lists of all the adaptation strategies identified for each of the planning areas during the planning process. Additionally, as community outreach, summary fact sheets for each priority planning area listed above and for each of the species discussed under traditional aquatic foods accompany this Plan.

This Plan is a living document, with the information and strategies presented here intended to be integrated into and implemented along with other Yurok plans and actions and to be subject to ongoing development as information and priorities shift. Its audience includes the Yurok Tribal People, Council, Staff and Committees. The Plan's ultimate objective is to assist the Tribe with their long-term goals of surviving and thriving into the future considering the stresses of climate change.

1.2 What Is Climate Change?

Weather consists of the short-term changes we see in temperature, clouds, precipitation, humidity and wind in a region or a city. Weather can vary greatly from one day to the next, or even within the same day. Climate, on the other hand, is typical weather over longer time periods. Climate change is a shift in typical weather.

"We've never had a situation like this as a tribe. What are we going to do to be ready for this and what does being ready mean?"

– Yurok Chief Judge Abinanti

Earth's climate has changed many times over the course of the planet's history, ranging from ice ages to long periods of intense heat. Until now, these changes have occurred in response to natural events like volcanic eruptions or variations in the amount of energy produced by the sun. However, in the 18th century, during the time of the Industrial Revolution, human activities began to significantly contribute to a worldwide warming trend by amplifying the greenhouse gas effect.

Naturally occurring levels of greenhouse gases allow life to flourish on Earth. Yet over the past two centuries, certain human activities have caused an overabundance of these gases to build up in the atmosphere. People began to burn fossil fuels like coal and oil and deforest the land at rates unprecedented in Earth's history. Carbon dioxide, a by-product of burning fossil fuels, is a major greenhouse gas. The rise in carbon dioxide levels is intensified by deforestation: cutting down the trees that use carbon dioxide to grow. Because all plants are made of carbon, forests are one of the most important storehouses of carbon on the planet (Ingerson 2007). Methane is another major greenhouse gas and is released into the atmosphere during the production and transport of natural gas, oil, and coal; it is much more potent than carbon dioxide, but also does not linger as long in the atmosphere. Human activities, such as transportation, livestock management, and other agricultural practices, also contribute to the amount of greenhouse gases in the atmosphere every year.

As greenhouse gas concentrations increase, too much heat is trapped around the planet. This leads to rising global temperatures, and many other associated effects. The average temperature in the United States has increased by 1.3°F to 1.9°F over the last 100 years, and most of this increase has oc-curred since 1970 (Melillo et al. 2014). 2016 was officially declared the hottest year on record, the third hottest year in a row (NASA 2017).

Climate models project that by the end of this century, annual average air temperatures in the United States will rise roughly 3°F to 5°F under a lower emissions scenario, which would require substantial reductions in greenhouse gas emissions. The models project a 5°F to 10°F rise under a higher emissions scenario assuming we continue on our current path of increasing emissions (Melillo et al. 2014). Rising air temperatures are already disrupting Earth's delicate balance, leading to rapid environmental change.

Yurok community members are even now bearing witness to changes that may be linked to climate change. Fern Bates described how air temperatures have been warming, “That's what I miss. The way it used to be. It changed from when I was growing up though. Because it used to get really cold and freeze. When we would go out into the field and the little puddles would freeze, you could ice skate across the puddles. Little bunches of water would sit around, but now it doesn't get that cold. It doesn't get cold enough to freeze” (Elder Interviews 2014).

In a December 2015 Culture Committee meeting, members noted increasingly severe and more regular ocean algal blooms. These blooms account for the presence of high levels of domoic acid in mussels, crabs, and other bivalves. The deadly toxin has dramatically reduced the harvest of several traditional foods (Yurok Today 2016). Rose Sylvia, the Tribe’s Human Resources Director, described how during the recent multiyear drought she had seen a spring near Pecwon Creek that her family has used for generations completely dry up for the first time, “Those are the kinds of things you see and scare you.” Elders have informed us that historically creeks used to run all year round. With the drought and the pot grow diversions, many smaller creeks and springs are drying up during later summer and fall.

A summary of anticipated climate changes in Yurok country is presented in Table 1.2. These changes are discussed in much more detail in Chapter 3.

Table 1.2 Projected Climate Changes Affecting Yurok Aquatic Resources
<u>Changes in Air Temperatures</u> Rising air temperatures
<u>Changes in Precipitation Regimes</u> Precipitation amounts are uncertain Heavier downpours
<u>Changes in Ocean Processes</u> Rising sea levels > increasing coastal inundation > erosion & intrusion into estuary and coastal aquifers Ocean acidification
<u>Changes in Inland Hydrology</u> Shift from snow to rain > increasing winter flows & floods; Reduced late spring/summer flows in river, creeks, & springs Increasing drought intensities
<u>Changes in Inland Water Quality</u> Warming surface water temperatures > lower dissolved oxygen; Expanding harmful algal blooms & water-borne pathogens
<u>Changes in Fire Regimes</u> Fire seasons are expected to become longer with increased frequency and extent.
<u>Combined Effects</u> Decreasing snowpack, earlier spring snowmelt Warming ocean temperatures > increased harmful algal blooms Heavier downpours > increase surface water sheeting > erosion > increasing turbidity, sedimentation & higher pollutant loadings Fire exposed slopes will further add to effects

1.3 Previous Climate Change Work

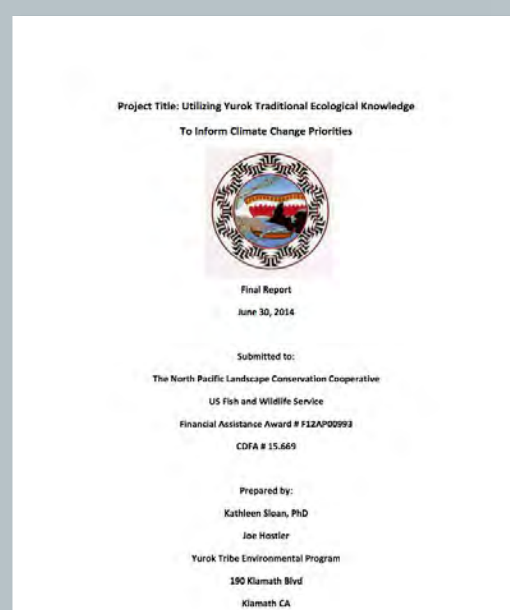
The Tribe is mandated by their Tribal Constitution and cultural traditions to be responsible stewards of the ecosystem and species that dwell within it, and the 2002 Fish Kill emphasized for the Yurok Tribe that that they needed to act. The Tribal Council, concerned about the health of the river, passed resolutions to enable the Yurok Tribal Environmental Program (YTEP) to start planning for the effects of climate change on the Yurok people, lands, waters, and resources.

Yurok Tribe & Climate Change: An Initial Prioritization Plan power point slide.

In 2006, the Environmental Program mailed out a "Healthy River/ Healthy Bodies" survey concerning Tribal Member health and the places, times, and practices that placed them in contact with the Klamath River. Over 350 Tribal Members responded to the survey and many took the time to write personal comments. These have been incorporated into this report in an attempt to honestly and accurately tell their story.

In 2010, with funding provided by the U.S. Environmental Protection Agency's (EPA) Office of Environmental Justice Small Grants Program, YTEP began to develop a Yurok Tribe and Climate Change: An Initial Prioritization Plan with the goal of identifying "community priorities for a Yurok response to a changing environment" (Sloan and Hostler 2011). YTEP staff surveyed the Tribal Council, community members, Tribal staff, and Tribal departments about their concerns regarding climate change. Nearly every single tribal respondent to the survey stated that their main concern was maintaining and preserving traditional subsistence foods and culturally important plants and animals used for ceremonies and medicines. Research for the prioritization plan revealed that some of these trust resources may be at risk to the impacts of climate change. This determined a variety of climate change priority planning areas for the Yurok Tribe including those related to water and aquatic resources that are assessed in this Plan – aquatic habitats, drinking water, traditional food resources, and health (see Table 1.1). Additional key findings from the community scoping included:

- Climate change planning needs to consider the Yurok holistic worldview on the inter-connectedness of all things.
- It is difficult for respondents to compartmentalize impacts and rank priorities. ("It is ALL important")
- Yurok people are very resilient and have survived major past changes.
- Yurok community information, Tribal science, Traditional, and Cultural Knowledge can inform how the Tribe responds to climate change impacts.
- Ecological restoration will improve Yurok resiliency to respond, adapt, and survive climate change.



Project Title: Utilizing Yurok Traditional Ecological Knowledge
To Inform Climate Change Priorities

Final Report
June 30, 2014

Submitted to:
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Prepared by:
Kathleen Sloan, PhD
Joe Hostler
Yurok Tribe Environmental Program
190 Klamath Blvd
Klamath CA

Project Title: Utilizing Yurok Traditional Ecological Knowledge To Inform Climate Change Priorities

> *"We must fix the river. Without it we are not who we should be. I could not imagine what our tribe would be like if something like the fish kill happened 20, 30 years ago. We had no rights, no land and with no fish the Yurok Tribe could not have existed. Get rid of the dams and leave the water flow to the great spirits!!"*
>
> – Yurok Tribal Member, male born 1954

The first two points above – the importance of the interconnectedness of all things and all aspects of the ecosystem– came up over and over in conversations with Tribal Members and staff throughout the planning process for this Plan as well. However, as found in the initial prioritization planning, the community expressed specific concerns about the safety and availability of drinking water and traditional foods, particularly aquatic foods.

In 2014, YTEP received funding from the North Pacific Landscape Conservation Cooperative for a project titled, Utilizing Yurok Traditional Ecological Knowledge to Inform Climate Change Priorities. As part of this project YTEP conducted interviews with Yurok Elders to collect and document Yurok Traditional Ecological Knowledge (TEK). The quotes from elders' interviews included in this Adaptation Plan are drawn from this previous work. A couple of the main findings from the Yurok Elders' interviews include:

- Numerous species were identified to be in serious decline in recent decades. Specifically, salmon, sturgeon, eels, candlefish, surf fish, shell fish, elk, porcupine, and other important subsistence foods. Much of this decline has occurred in the past 100 years and observed within the lifetimes of the participants.
- Yurok Elders have a good understanding of how the environment has changed over a relatively short period of time (less than 200 years) as a result of the changes in resource use, development, extraction and expansion of the modern industrial age. While not always attributable to climate change, these changes often reflect ecosystem loss and environmental degradation that resulted from the loss of autonomy and self-determination regarding the management of resources, lands, waters and ecosystems (Sloan and Hostler 2014).

In 2013, based on this previous community-driven work and on a simple directive from the elders to, "Follow the water and the rest will follow," YTEP in partnership with the Institute for Tribal Environmental Professionals (ITEP), applied for and received funding from a U.S. Environmental Protection Agency, National Center for Environmental Research Science to Achieve Results grant (EPA-NCER STAR).

Table 1.3: Climate Change Priority Planning Areas for the Yurok Tribe

1. What are the baseline conditions of Yurok Reservation water sources and aquatic resources?
2. What are the currently occurring and probable areas of high vulnerability and alternately, high resiliency for Yurok resources, habitats, & ecosystems?
3. What are potential risks and risk reduction strategies to protect Tribal Members from adverse impacts of climate change to water and food resources?
4. What are the most culturally appropriate and applicable plans specific to the Yurok Tribe and Territory regarding probable impacts to climate change?

Awarded in 2014, the grant has resulted in the current project, Climate Change Impacts to Yurok Resources: Identifying, Assessing and Adapting to Changes in Water and Aquatic Resources, Food Security and Tribal Health Impacts (see Table 1.3 for the project's set of research questions). This report, the **Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources** was one of the project deliverables. Adaptation International was brought on to the project to assist with the health assessment, which is included in Chapter 7 of this Plan. The Alaska Native Tribal Health Consortium has been working with the Tribe to assist in the development of the Yurok Environmental Observer, which is a hub of the Local Environmental Observer (LEO) network. In subsequent projects, the Tribe can build on the work undertaken for the aquatic focus of this grant and continue to develop adaptation strategies and actions for other components of the ecosystem, all of which are meaningful to the Yurok Tribe.

Quotes listed, "Yurok Tribal Member, gender, year of birth" are from the Yurok Tribe Environmental Program's 2006 Healthy River/Healthy Bodies Study.

1.4 Community Demographics

The Yurok Tribe is the largest Indian Tribe residing within California with over 6,000 enrolled members. Of these, approximately half the members reside within the local area, either on the Reservation or within 60 miles of the Reservation, clustered to the north of the Reservation in Crescent City (Del Norte County) and south in Humboldt County communities (Hoopa, Eureka, McKinleyville, Arcata, and Willow Creek) (Fluharty and Sloan 2014).

The Klamath River, the traditional highway

As of 2014, nearly 1200 people resided within the Yurok Reservation boundaries, which runs from the Pacific Ocean, including 1 mile along each side of the Klamath River for a little more than 45 river miles. The population is mainly divided geographically into two populated areas, described in relation to the flow of the Klamath River – those 'down river' toward the mouth of the river (Lower Reservation) and those 'up river' (Upper Reservation) (Fluharty and Sloan 2014). The downriver/ Lower Reservation area includes the town of Klamath and the outlying smaller communities of Requa and Klamath Glen. The area is accessible by Highway 101. Commercial water, power, telephone, and solid waste collection services are generally available within the downriver Reservation. As of 2014, the downriver communities consisted of approximately 170 homes and 700 people. This area has one school, one Solid Waste Transfer Station, one fire department, several Tribal Offices, and various commercial enterprises (e.g., restaurants, food vendors, groceries, gas stations, hotels, motels, and RV parks) (Fluharty and Sloan 2014). There is also now a tribal casino in Klamath, which opened in 2016.

The Upper Reservation area includes the town of Weitchpec and smaller communities, like Kenick, Kepel, Pecwan, Wausec, and Wautec. There are no direct roads connecting the Upper and Lower Reservations. Access between the two is by boat or overland for 45 miles of winding travel over the Bald Hills Road, then back along Highway 169, which runs parallel to the Klamath River in unconnected segments. Commercial water, power, telephone service, and solid waste collection services are limited. The upriver communities have a population of about 500, and include several Tribal Offices, one commercial store and gas station, one Solid Waste Transfer Station, two schools, and two fire departments (Fluharty and Sloan 2014).

According to the 2009 Department of Labor statistics, the unemployment rate on the Yurok Reservation was over 30%, double the unemployment rates for Del Norte County and California. An even higher percentage live below the poverty line. It is also important to note that within the Reservation, the upriver portion had higher unemployment rates at nearly 85 percent (Bureau of Reclamation 2012), and the Tribe only controlled about 15% of the Reservation (Bureau of Reclamation 2012).

Automobile travel is limited to remote mountain roads connected by a single primary bridge at Martin's Ferry.

1.5 Yurok Background

Since Noohl Hee-Kon, the beginning of time for the Yurok people, the Yurok have inhabited the most downriver lands of the Klamath River (Yurok Tribe 2007). Yurok Ancestral Territory spanned 45 miles of the coast and intertidal zones of the Pacific Ocean from Little River with a major traditional village at Trinidad Bay, northwards to Damnation Creek including villages and resources of the Humboldt Lagoons, and extended from the mouth of the Klamath River inland towards Bluff Creek and the Karuk Boundary (Sloan 2003; NRC 2004; Yurok Tribe 2007). This territory includes over 133 tributaries and 56 miles of Pacific Ocean coastline. Yurok life, identity, culture, livelihood, economy, diet, health, spirituality, ceremonies, and wellbeing are interwoven with the Klamath River that runs through the center of Yurok Territory. As one Tribal respondent to a 2010 climate change survey described, "The river is like blood flowing thru our veins."

> *"We love to go down to the mouth to go fishing; it is the best part of my life."*
>
> *– Yurok Tribal Member, female, born 1984*

The Yurok people's traditional subsistence diet and practices they derive from the river and coast are a vital part of their cultural identity, creating an intricate connection between them, the species, river, land, and seasons. The River is the lifeline of the Yurok people. It provides the majority of the Yurok's food supply, such as ney-puy (salmon), chikwohl (steelhead), kah-kah (green sturgeon), and key'-ween (lamprey eel). Food resources provided from the ocean are also important to Yurok people, like pee'-eeh yurs (marine mussels) and key-ween we che-qel (spring seaweed), as well as foods offered from terrestrial areas, such as woo-mehl (acorn), ley-chehl (berries), and mey-weehl (elk). Together all these sources supply food for Yurok throughout the year with various fish runs returning, seaweed blooming, shellfish spawning, and fruits ripening during different times. Harvesting of aquatic resources occurred at much higher levels pre-European contact than it does now. Before, people could move throughout the landscape and the only harvest restrictions were cultural; they knew places where they should not fish or gather and places where it was their fishing or gathering spot. Yurok Tribal Member Allen McCovey summed up Yurok fishing rules as "Take what you need and leave the rest" (Elder interviews 2014).

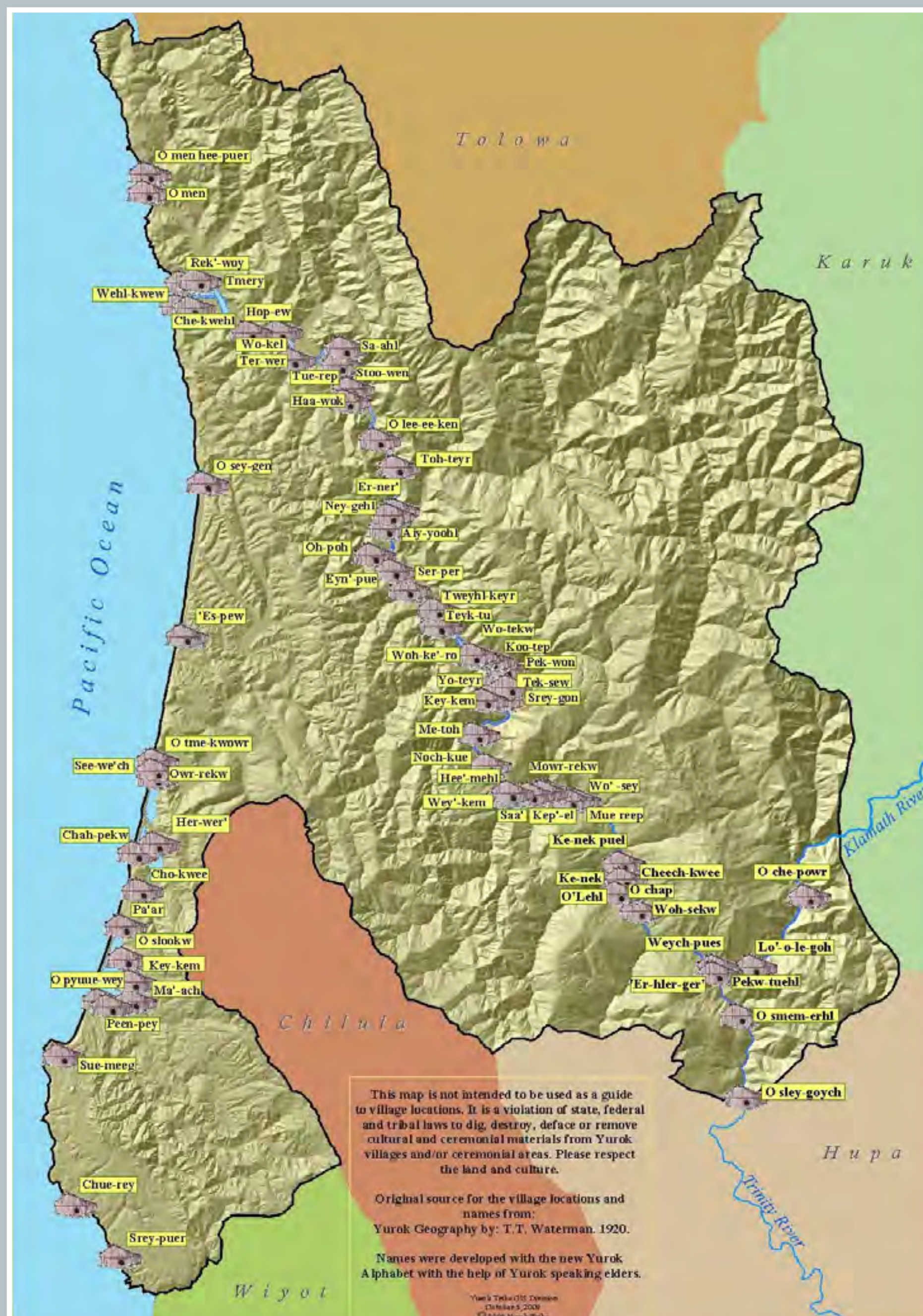
Map of the Yurok Indian Reservation within the larger Ancestral Territory

The Yurok language is also deeply tied to the river, with locations and place names identified in relation to the river. For example, the Karuk Tribe's term for those living 'downriver' from them is 'yurok'. However, the Yurok used the terms pue to refer to 'down river' and pey to 'up river'. Thus, the Yurok people may call themselves by three terms based on the areas where they live; those living downriver on the Klamath are Pue-lik-lo' (Down River Indian), those on the Upper Reservation along the Klamath and Trinity Rivers are Pey-cheek-lo' (Up River Indian), and those on the coast are Ner-'er-ner' (Coast Indian). Another example is the use of place names relating to location on the river. Kenik is the name for the Yurok center of the world, and Kenik-pul is the location of a traditional village and translates as 'down river of Kenik.' The Yurok Village of Rekwoi at the mouth of the Klamath River translates as "Mouth of the river" (Sloan 2003).

There were more than 50 villages in Yurok Ancestral Territory including sites in both riverine and coastal locations, and Yurok people continue to inhabit many of the sites that line the coast, Klamath, and Lower Trinity Rivers (Sloan 2003). Robert McConnell, Sr., President of the Yurok Cultural Fire Management Council, described village sites as being traditionally placed for the local resources, situated near a spring or creek to be utilized for drinking water, and also located based on the sun.

Today, the Yurok Reservation extends one-mile on either side of the lower 46 miles of the Klamath River and covers over 56,000 acres (Sloan, vulnerability assessment). The Klamath River, running through the Reservation, is most recognized for its significant runs of anadromous fish, particularly salmon, returning from the ocean to freshwater to spawn.

In 1993, the modern Yurok Tribe formally organized under a Constitution to exercise their inherent tribal sovereignty and continue to strengthen their traditions and practices. The Constitution mandates that the Yurok people be good stewards of the land and waterways, including to “Restore, enhance, and manage the tribal fishery, tribal water rights, tribal forests, and all other natural resources” (Yurok Tribe Constitution, 1993). The Yurok people continue their cultural, economic, and spiritual ties to the river and ancestral lands through subsistence use and management of traditional resources and through advocating for federally protected trust fishing and water rights (BOR 2012; Fluharty and Sloan 2014).



Map of Traditional Yurok Villages

1.6 Historical Legacies

Climate change does not happen in isolation. It happens within the framework of our political systems, our culture, our infrastructure and more. It also happens within the context of the history that we have experienced and the legacies and traumas that past actions have left behind. As will be discussed in greater detail in subsequent sections, the history of the Klamath River region is one in which the ability of the natural ecosystem and people to recover from change has been disrupted at massive scales. This occurred in particular with the arrival of non-Indian settlers, and because of the actions they pursued that removed traditional Yurok resource management and increased the vulnerability of Yurok resources to climate change. Because upstream influences have downstream effects and because culturally important species move in and out of the boundaries of the Yurok ancestral territory, we discuss historical legacies at a broader scale with a particular eye to legacies that impact the Yurok people and resources. A timeline of significant historical events affecting the Yurok people, lands, and resources is included at the end of this section.

Legacies for Yurok Homelands & Waters

Europeans first reached the Tribe's ancestral territory as far back as the 1500s.

- Fur trapping

In the early 1800s fur trappers began entering the region, with the most well-known fur-trapping expedition into Yurok lands being that of Jedediah Smith (Yurok Tribe 2007). By the summer of 1828, one trapper reported that almost every part of the Klamath basin was "more or less in a ruined state, free of beaver" (NRC 2004). Following the decimation of beaver came the loss of wetland habitat associated with beaver dams. Along the ocean the extensive sea otter fur trade extirpated the entire northern California population and led to the collapse of the kelp-forest ecosystem (Larson et al. 2012; NOAA 2018).

- Mining

In the mid-1800s, with the discovery of gold at Gold Bluffs and Orleans, prospectors and miners started arriving in the Klamath basin (Yurok Tribe 2007). The subsequent mining boom particularly in the Scott, Salmon, and Trinity River watersheds led to the dredging of stream sediments, the leveling of entire hillsides with high-pressure water jets, and the release of mercury used in processing the gold (NRC 2004). Gold mining in the Salmon River continued into the 1990s (NRC 2004). During both World Wars, the demand for metal for armaments increased mining for chromium, cobalt, and nickel that left abandoned slag piles in the Klamath mountains.

- Timber Production & Logging

Mining and miners brought the need for food and timber supplies attracting farmers, ranchers, and loggers to the basin (USFWS 1991; NRC 2004). Commercial timber harvesting in the lower basin began in the 1850s in the Scott River watershed (NRC 2004). In 1881, a joint lumber and fishing venture, the Klamath Commercial

> *"Over the years as logging increased and the hills were stripped of trees, I saw a gradual decline of fish and eels. At one time I could catch candlefish by hand and sometimes was unable to lift my dip net due to so many candlefish. I saw eel baskets full of eels being lifted out of the river. At one time in the past, Terwer, McGarvey and Blue Creek were great fishing, now they are silted and full of logging debris."*
>
> *– Yurok Tribal member, male, born 1933*

Company, was opened near the mouth of the Klamath (USFWS 1991). The Douglas fir and redwood timber industry experienced a boom during the post World War II economy (USFWS 1991). By 1960, non-Indian logging companies had harvested 90% of the original redwood in the Yurok ancestral territory (Yurok Tribe 2007). Extensive logging road networks combined with steep, highly erosive soils have led to high rates of erosion and sedimentation in the lower Klamath basin and associated deterioration in fish spawning and rearing habitat as well as blockages of both upstream and outmigration (NRC 2004). Further, the timber industry used herbicide spraying to control the undergrowth's competition with larger conifers, and Yurok communities are concerned that herbicide-containing runoff and residues of such herbicides in fish and game may be linked to higher rates of cancer being experienced in the community (O'Malley 2002; see Ch. 7)

> *"The River is who we are – when they take and kill our River we are no more. This is a 200 year ongoing fight."*
> *– Yurok Tribal member, female, born 1954*

Other effects associated with logging include changes in forest composition, a policy of fire suppression, declines in riparian cover and instream cover such as logs, tree roots, and overhanging vegetation, and destabilized streambanks and erosion associated with the removal of large conifers from riparian zones (USFWS 1991). These effects in turn can lead to deteriorating water quality (higher turbidity, higher temperatures, deposition of herbicide residues and breakdown byproducts), which can increase declines in the diversity of aquatic insects that are near the base of the foodweb and can negatively impact habitat for fish, amphibians, and turtles (USFWS 1991).

- Commercial Fishing

At approximately the same time that commercial timber harvesting began in the lower Klamath basin so did commercial fishing with the first non-Indian commercial cannery opening near the mouth of the Klamath in 1876 despite Yurok protests (USFWS 1991; Yurok Tribe 2007). By 1912, three canneries were located on or near the Klamath River estuary with essentially no fishing limits in place (NRC 2004). Major declines in salmon populations were observed in the 1920s (NRC 2004).

- Dams– agriculture, hydropower, & hatcheries

The early 1900s were also a time when engineers started building larger dams in the Klamath watershed. Between 1910 and 1925 seven dams were completed in the upper basin by the U.S. Department of the Interior Bureau of Reclamation as part of the Klamath Project to provide irrigation water and land to farmers (Stene BOR 1994). The project disrupted natural flows and led to the extensive loss of wetlands in the upper basin (NRC 2004; 2008; Powers et al. 2005).

Iron Gate Dam - the lowest dam on the Klamath River

Engineers also started eyeing the Klamath River for hydropower, and between 1918 and 1962, six dams were built on the Klamath's mainstem. In order from upstream to downstream with the date the dam was completed in parentheses, they are the Link River (1921), Keno (1931, rebuilt in 1967 after flood damage), J.C. Boyle (1958), Copco #1 (1918), Copco #2 (1925), and Iron Gate (1962) dams (USFWS 1991; NRC 2004; NRC 2008). The uppermost of these dams, the Link River Dam, is part of both the Klamath Project mentioned above and does not provide hydropower but is used to furnish irrigation water and control to the levels of Upper Klamath Lake. The remaining five dams are part of the Klamath Hydroelectric Project that was initially started by the California Oregon Power Company (Copco) and is now owned and operated by Pacificorps (Pacificorps 2017). The con-

Aerial view of Lewiston Damn and Fish Hatchery on the Trinity River. (Bureau of Reclamation)

struction of the dams on the mainstem starting with Copco Dam #1 in 1918 blocked salmon and steelhead access to hundreds of miles of habitat in the upper Klamath and its tributaries (Yurok Tribe 2007). In addition to stopping fish passage, the dams affect instream flows, water temperature, and spawning gravel quality (USFWS 1994).

In the middle and lower basins, dams have not been built on the Klamath's mainstem. However, some large dams have been constructed on important secondary river tributaries. This includes the Dwinnell Dam completed in 1928 on the Shasta River for the purpose of providing irrigation water for agriculture in the Shasta Valley. On the Klamath's largest tributary, the Trinity River, the Trinity and Lewiston Dams completed in 1962 and 1963, respectively regulate flow for both power production and for diversion to the Sacramento River system and California's Central Valley Project that provides water for agriculture and municipalities in a region that produces one quarter of the nation's food (NRC 2008; USGS 2015). Approximately 51% of the Trinity River's flow on average is currently allocated for California's Central Valley and transferred to the Sacramento River (NRC 2008 p. 47). Storage and diversions associated with these tributary dams disrupt the Klamath lower basin's natural flows and sediment dynamics (NRC 2008)

In order to mitigate the effects of the dams on anadromous fish species (migrating from the sea upriver to spawn), various egg collection stations and hatcheries have been established over the years (CDFW 2017; NRC 2008). Two of the major Klamath watershed hatcheries running today are the Iron Gate Hatchery (operating since 1966) and the Trinity River Hatchery (operating since 1963) (NRC 2004). Both raise and release Chinook salmon, Coho salmon, and steelhead (CDFW 2017). While these hatcheries increase fish numbers, they may be contributing to reduced genetic integrity (NRC 2008) and a weakening of the overall health and survival of the fish runs.

- Cannabis Cultivation (Marijuana)

One of the relatively more recent land uses taking place in Yurok Ancestral Territory has been the cultivation of Cannabis for the marijuana market. While growing marijuana in northern California may stem back to at least as early as the 1960s as part of the countercultural movement, cultivation has risen rapidly in Yurok country since California's 1996 passage of Proposition 215, the Compassionate Use Act. The proposition allows Cannabis to be legally grown and used for medical marijuana purposes. Because of the climate, remoteness, high degree of forests, and sparse populations, Northwestern California has been viewed as an ideal location in which to grow Cannabis (Bauer et al. 2015). Three counties in particular, Humboldt, Mendocino, and Trinity, have become known as the Emerald Triangle and according to some may comprise the top marijuana-producing region in the world (Corva 2014; Bustik and Brenner 2016).

Clearing of forest for commercial *Cannabis* cultivation

In 2016, California passed Proposition 64, the California Marijuana Legalization Initiative, which made it legal for individuals to grow and use marijuana starting immediately after the proposition's passage and which will allow recreational marijuana sales starting in 2018. Marijuana cultivation and usage is still illegal at the federal level and is banned on the Yurok

Reservation by the Yurok Controlled Substance Ordinance.

The cultivation of marijuana, or using the local term, "Cannabis grows," can have an array of impacts on aquatic habitats. These include delivery of sediments into streams as a result of land clearing and logging, impacts on water quality from nutrients, pesticides, and human waste that may wash into streams, and reduced flows from irrigation and surface water diversions. Cannabis is considered a high water use plant with each plant consuming up to 22.7 liters of water per day during the growing season (Bauer et al. 2015). During critical times such as the recent 2013-16 drought, most Yurok consider the Cannabis growers to be "stealing our water," a view which the California State Water Resource Control Board supports and agrees with but labels as un-permitted diversions and illegal withdrawals.

Thousands of adult Chinook salmon died along the Lower Klamath River within the Yurok Reservation in 2002

- 2002 Fish Kill

In September 2002, as noted at the start of this chapter, an enormous fish kill took place profoundly affecting the Yurok people (Belchik 2004). An estimated 34,000 to possibly double that number of fish perished in the most downriver part of the Klamath River (Belchik et al. 2004; CDFW 2004; Yurok Tribe 2007). The fish were mainly adult fall-run Chinook salmon on their final return trip home to spawn. However, Coho salmon, steelhead, and other fish were lost as well (CDFW 2004; Yurok Tribe 2007).

The primary causes of the fish kill were outbreaks of *Ichthyopthirius multifilis* (ich) a protozoan parasite and *Flavobacter columnare*, a bacterial pathogen commonly known as columnaris or cottonmouth (Belchik 2004; CDFW 2004). However a combination of factors contributed to the outbreaks. Low flows from the Iron Gate Dam and a higher than average run of fall Chinook salmon led to high fish densities (Belchik 2004; CDFW 2004). Higher fish densities and warmer water temperatures may have both stressed the fish and provided an ideal environment for columnaris to proliferate (Belchick 2004; CDFW 2004). The lower flows may have impeded fish passage upstream with decreased water depths over certain riffles and may have been implicated in the apparent lack of cues for the fish to move upriver (Belchik 2004; CDFW 2004).

While the Yurok had already been working on dam removal for a long time, the fish kill served as powerful motivation to spur efforts further (Yurok Tribe 2007). With increasing drought frequency and severity as well as rising water temperatures expected with climate change, the fish kill also awakened people to the potentially profound effects that climate change could have on Yurok lifeways and culture. It thus became a driving force for the Yurok to begin climate change preparations.

Legacies for Yurok People and Culture

At the same time that large-scale disruption of Yurok homelands and waters was taking place, so too was the extensive loss of Yurok lives and the repression of the Yurok people and culture.

> *"That component of prayer and giving thanks for the resources is totally what's missing,"*
>
> *– Robert McConnell, Sr., Adaptation Plan Interviews 2016*

- Loss of Lives

By the end of the gold rush era that began in the mid-1800s, at least 75% of Yurok had lost their lives due to either massacres or disease (Yurok Tribe 2007).

- Loss of Land

From the 1850s through the early 1900s, the Yurok also lost much of their ancestral territory through confinement to reservations, through the transfer of their lands to public domain because of pressure from non-Indian settlers, and through the loss of allotted lands due to tax burdens, swindling, and more (Yurok Tribe 2007).

- Suppresion of Traditional Practices & Language

Along with the loss of their lands, starting in the 1860s and continuing into the 1900s, religious and cultural practices were suppressed including the First Salmon Ceremony and traditional dances such as the White Deerskin Dance and the Jump Dance (Yurok Tribe 2007). In 1931, the State of California also banned all forms of traditional burning practices (Yurok Tribe 2007), and in 1934, the Yurok were banned from commercial fishing and gill-netting (see below) (Yurok Tribe 2007).

The suppression of Yurok religion and culture continued through the various educational systems imposed on Yurok children. In the late 1800s, many Yurok children were removed from their families and forced to go to distant boarding schools. There, they were punished for using the Yurok language and practicing ceremonial traditions. By the early 1900s, the Yurok language had become almost extinct (Yurok Tribe 2007). While boarding schools eventually gave way to day schools on the reservation and ultimately to enrollment in public schools, the pressure to forget the Yurok language and culture remained (Yurok Tribe 2007).

- Suppression of Yurok Fishing

In the late 1800s commercial fisheries were established at the mouth of the Klamath River, and many Yurok relocated in order to work at these canneries. The harvesting practices of these commercial fisheries resulted in the depletion of salmon to the point that commercial fishing and the use of gill nets were outlawed in 1934. This included Indian fishing, and literally blocked access to a traditional source of food, as well as the core of the Yurok economy. Although Yurok continued to engage in fishing activities, they did so under the threat of being jailed (Yurok Tribe 2007). In 1973, a federal court ruling allowed for Indians to once again use their gill nets and sell their fish, but the Bureau of Indian Affairs (BIA) defied the order and banned Indian fishing in 1978. When Indians protested the illegal closure, conflicts and violence between Indian fishers and the BIA followed. The BIA closure lasted ten years, during which time traditional Indian fishing practices were deemed illegal and subject to arrest, fines and punishment by the BIA.

"That was the rule on my mom's fishing hole up here [Waukel], you're supposed to give your first catch to your grandma. The younger ones forget to do that."

– Fern Bates, Elder Interviews 2014

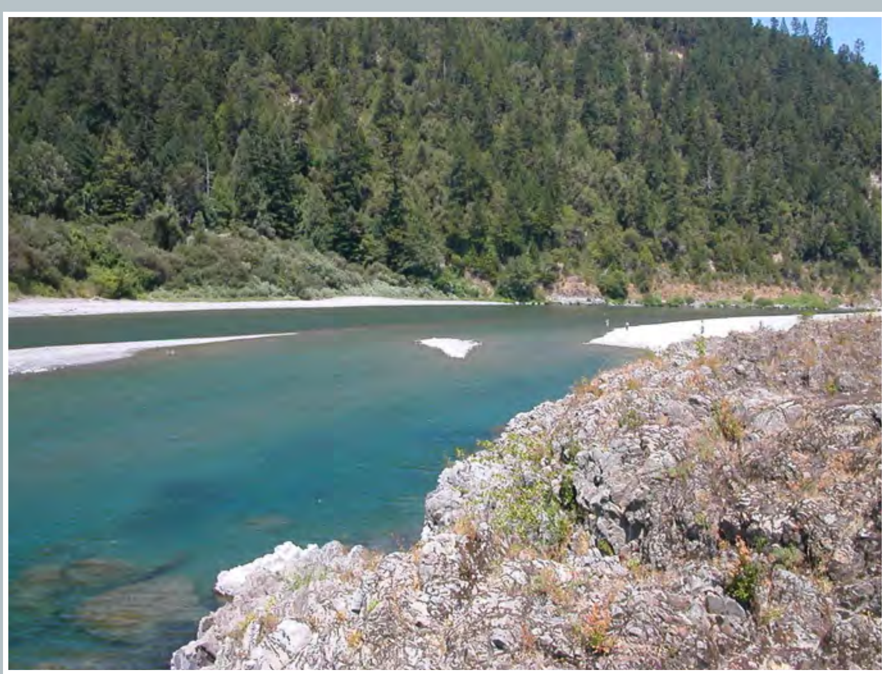
- Disruption in Traditional Values & Attitudes

Alongside the suppression of religious ceremonies, traditional fishing practices, culture and language, has come a rupture in the passing down of traditional values and attitudes to younger Yurok – values and attitudes that have guided Yurok for generations in their interactions with the river, land and all the life within. " Robert McConnell, Sr., President of the Yurok Fire Management Council. explains, "We as people don't do that nearly as much as we used to. I don't think that many of our population at this time understand that connection or practice. To be able to go down to the river and set a net and pull out a really nice beautiful fish is a privilege. If you can't recognize it as a privilege you'll never get to the point where you can see that fish as a beautiful piece that we are given to look over." Judge Abby Abinanti, Chief Judge of the Yurok Tribal Court noted, "Culturally there's a way we act and respect we bring to nature and our food sources and we're not doing it…[this results in] conflict with nature, yourself, your soul, community members."

1.7 Revitalization of Yurok Culture and Sovereignty

> *"Our sacred and vibrant traditions have survived and are now growing stronger and richer each year… and, while much land has been lost, the spirit of the Creator and our inherent tribal sovereignty still thrives in the hearts and minds of our people as well as in the strong currents, deep canyons, thick forests, and high mountains of our ancestral lands."*
>
> *– Preamble of the Constitution of the Yurok Tribe, 1993*

Despite the historic traumas and legacies the Yurok Tribe has endured, they have entered a new era in which the revitalization of Yurok culture and sovereignty is taking place. In the late 1970s and 1980s, traditional dances including the Jump and Brush dances were started once more (Yurok Tribe 2007). Commercial fishing near the mouth of the Klamath resumed in 1987, and traditional Indian fishing is now regulated at the mouth (Sloan 2003). In 1993, the Tribe developed and formally adopted a Constitution, and the U.S. Department of the Interior recognized the Yurok Tribal Council as the governing body of the Tribe (Yurok Tribe 2007). The following year, the Tribe took over managing its fisheries from the Bureau of Indian Affairs and U.S. Fish and Wildlife Service (Yurok Tribe 2007). Yurok language learning is increasing, and educators are taking advantage of digital technologies, the internet, and supplemental curriculum (Yurok Tribe 2007).



Mouth of Blue Creek, Now a Salmon Sanctuary

A major breakthrough occurred when, in 2010, the local Boards of Education in Del Norte and Humboldt counties approved the teaching of Yurok in the high schools to fulfill the language requirement (Atherton 2016). In 2013, a group known as the Weitchpec/Wo-tek Local Organizing Committee revitalized traditional burning practices by organizing a five-acre cultural burn to revive a source of hazel sticks for basket weaving (Yurok Today 2013). The group has since morphed into the Cultural Fire Management Council and is continuing these types of burns.

In 2011, the Yurok Tribe working with California's State Water Resources Control Board (SWRCB) and the Western Rivers Conservancy (WRC), reached an agreement with the Green Diamond Resource Company to begin the purchase of 47,000 acres of their Ancestral Territory in the Lower Klamath River Basin in subsequent years. In order to purchase the land, WRC has been working with the Tribe to obtain grants, low-interest loans, and appropriations from state, federal, and foundation sources (Wallin 2009).

Part of the land acquired will become the Blue Creek Salmon Sanctuary. A large portion of the lands have also become part of the Yurok Tribe's Sustainable Forest Project through which the Tribe is participating in California's Carbon Cap-and-Trade Program (Yurok Tribe 2013). The Yurok Tribe is the first federally-recognized tribe to participate in carbon capture forestry management (Yurok Today 2014). In the Cap and Trade program businesses buy carbon credits to offset their carbon emissions. These credits are then used to finance projects that reduce carbon emissions or sequester carbon. The Yurok Sustainable Forest Project sequesters carbon through forest protection. Funds received from the sale of carbon offsets are being used to repay the loans that helped fund the land purchase (WRC 2017).

In 2010, the Klamath Basin Restoration Agreement (KBRA) and Klamath Hydroelectric Settlement Agreements (KHSA) were signed (Greenson 2016). These were companion agreements between Klamath Basin tribes, including the Yurok, farmers, fisherman, conservationists, and the states of California and Oregon to restore the Klamath Basin fisheries and local economies. They included plans for the removal of four mainstem dams (Copco 1, Copco 2, Iron Gate, and J.C. Boyle) (Greenson 2016). In 2014, the Upper Klamath Basin Comprehensive Agreement was signed, a third piece to pave the way for restoration of the entire basin (Greenson 2016).

Signing of the KHSA amendments was held at Requa, the traditional Yurok village site at the mouth of the Klamath River in 2016.

When Congress failed to pass the legislation enacting the KBRA by the December 31st, 2015 deadline, it seemed as if the dam removal would not move forward (Greenson 2016). However, in April 2016, the Yurok Tribe together with the Karuk Tribe, the states of California and Oregon, PacifiCorp, and the U.S. Departments of the Interior and Commerce signed an amendment to the Klamath Hydroelectric Settlement Agreement. If approved, this amendment will lead to the breach of the four dams in 2021. This would be the largest dam removal project in U.S. history and one of its biggest salmon restoration efforts (DOI 2016; Yurok Today 2016).

The Yurok Tribe has tremendous strength and capacity in their cultural knowledge and connection to resources. By way of all these undertakings, that strength and capacity is being used to leave the old legacy of repression behind. The longstanding legacy of Yurok environmental stewardship that has been practiced since time immemorial is reemerging. And with this Climate Change Plan and other climate-related efforts, Yurok leadership on climate change issues is continuing to increase. Through the power of preparation and taking thoughtful actions, Yurok can influence their future, and by taking care of the waters, lands, and species that take care of the Yurok, the health of all, can be improved.

> "We've been here for a long time. We intend to stay here for a long time."
> – *Yurok Tribal member,* at Climate Adaptation Planning Workshop

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Additional Information

- Additional Chapters of the Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources can be found on the Yurok Tribe Environmental Program's Community and Ecosystem division webpage at http://www.yuroktribe.org/departments/ytep/com_eco_division.htm

Yurok Tribe Climate Change Adaptation Plan for Water & Aquatic Resources

Chapter 2 – Climate Change Adaptation Planning Process

In This Chapter

This plan is from a purposeful collaboration with the staff and community members of the Yurok Tribe, as well as several organizations, and would not have been successful without each of their contributions. Funding was made available through the US EPA Science to Achieve Results (STAR) Program, Grant # 83560401-0. Online files available at: https://www.yuroktribe.org/departments/ytep/

"Suckerfish and eel were gambling and eel didn't have much luck. Eel kept losing. Had nothing left, I'll bet you my clothes. They play and eel loses, eel loses his clothes – lost his scales, so eels don't have scales. I'll bet you my house. Suckerfish wins eel's house. Bet you my wife this time. Loses his wife. Eel's lost his money, clothes, house, wife. One more game, I'll bet you my bones. Eel loses, pulls his bones out and puts them in suckerfish, so suckerfish have lots of bones and eels have no bones. Also lost his kids because wasn't thinking about his choices – we eat lots of eels, but not many suckerfish. The eel wasn't thinking ahead and lost his kids, so he really did lose everything. "

– Story of suckerfish and eel as told by Joe Hostler

The Yurok people have been living in the Pacific Northwest along the Lower Klamath River and coast since time immemorial and have seen many changes in the past. As Robert McConnell, Sr., President of the Yurok Cultural Fire Management Council described, "the Elders believe there is a process this world is going through." The Yurok people are continuing to see changes now in their ecosystem – some new, and unprecedented – that is calling them to plan ahead and be thoughtful in their actions, to continue to survive and thrive, and to ensure their culture and lifeways continue for future generations. One Yurok Tribal member (male, born 1952) explained, "We want to continue our relationship with the Klamath River and the traditional resources our River provides us."

The lack of adequate infrastructure and heavy reliance on surface waters and aquatic resources puts the Yurok Tribe at significant risk of adverse tribal health outcomes resulting from climate changes. Impacts include the potential loss of safe and reliable drinking water and subsistence foods.

However, the Yurok Tribe is being pro-active to mitigate the threats to the resources and ecosystem they depend on for their livelihoods, identity, culture, economy, diet, health, spirituality, ceremonies, and overall wellbeing. Supported by the Yurok Tribal Council, the Tribe is taking thoughtful action to plan for the anticipated changes and to ensure their trust resources are maintained and they continue to thrive as a people. As Jan Wortman, Yurok Tribal member said, "It's going to be different but it doesn't have to be bad."

Yurok Youth in traditional regalia

Chapter citation: Cozzetto K[1], Maldonado J[1], Fluharty S[2], Hostler J[2], Cosby C[2] (2018) Chapter 2 – Climate Change Adaptation Planning Process. In *Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources*. [1] Institute for Tribal Environmental Professionals (ITEP), Northern Arizona University, Flagstaff, AZ. [2] Yurok Tribe Environmental Program (YTEP), Klamath, CA.

2.1 Goals of this Adaptation Plan

On June 27, 2013 the Yurok Tribal Council gave official approval to the Yurok Tribe Environmental Program (YTEP) to develop a Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources (the "Plan"). This enabled YTEP to implement established community engagement strategies throughout the project, as discussed in further detail below.

> *"The Tribe needs to try and stay in front of potential changes by being pro-active, look to help animals, plants and fish to survive."*
>
> – Tribal respondent, Prioritization Plan 2011

In consultation with the Tribal Council, YTEP set that the goals of the Plan would be to:

- Identify current and projected impacts of climate change on tribal water and aquatic resources including impacts on the local environment, human health, and cultural beneficial uses of concern to the Tribal community;
- Assess the vulnerabilities and areas of resilience in tribal water and aquatic resources from the projected effects of climate change;
- Develop recommendations for appropriate adaptation strategies policies and goals for addressing the effects of climate change on the tribal water and aquatic resources;
- Develop potential departmental and programmatic actions and changes consistent with said policies and goals as appropriate to address the effects of climate change;
- Use the collected, "traditional knowledge" from interviews with elders, Culture committee and Natural Resource committee, and community scoping to guide and integrate the best available science;
- Make available the projected impacts of climate change to Yurok water and aquatic resources to the Tribal Membership, the general public, local, state, regional, and national entities that seek to work with culturally appropriate adaptation planning.

on

Yurok Tribal Council, Chairman T. O'Rourke in foreground

The Yurok Tribal Council votes to approve the development of the Adaptation Plan. They stress that Yurok people have always relied the abundant natural resources of the Klamath River, its tributaries and surrounding landscape, as well as the Pacific Coast for cultural, spiritual, subsistence and economic survival. The Yurok traditional lifeway continues today, in spite of the economic, social, and cultural dislocations that the Tribe has experienced over the past 150 years.

2.2 Yurok Adaptation Planning Process

In 2014, YTEP was awarded a three-year Science to Achieve Results (STAR) Grant by the US Environmental Protection Agency (EPA) to develop, among other activities, this document- The Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources (2014-17). This Plan was primarily informed and guided by Yurok tribal knowledge. Specifically, experiences, information, stories, and opinions from the Natural Resource and Culture Committee members, Tribal staff, as well as the general Tribal Membership including elders and community members' input were all sought. In addition, Federal and State agencies were invited to engage with the Yurok and participate in some of the community workshops and outreach activities.

YTEP also engaged outside collaborators to help in the development of the Plan, bringing together diverse knowledge systems in the process. In partnership with the Institute for Tribal Environmental Professionals (ITEP), which has demonstrated experience in working with tribal communities on climate adaptation, YTEP and ITEP began working together in late 2014. ITEP staff provided input, advice, and services to YTEP project leads. YTEP reached out to the Alaska Native Tribal Health Consortium in 2014 to assist in the development of the Yurok Environmental Observer Network. Adaptation International was brought on board in 2016 to assist with the health assessment component (Ch. 7) of the Plan.

Yurok Tribe's previous climate change work

The 2002 Klamath River Fish Kill (Chapter 1/Ch. 1) spurred the Yurok Tribe into action to address increasing environmental changes and the Yurok Tribe Environmental Program was organized. Its mission is to protect the lands, air and water resources of the Yurok Indian Reservation for the benefit of current and future generations of Tribal Members. By 2008, the Yurok Tribal Council, Tribal Members, the Yurok Tribe's Natural Resources and Culture Committees, and other tribal departments had begun to raise concerns over shifting seasons and decreased availability of many traditional foods. In response, YTEP began building staff capacity on climate change science in 2008. A focused effort was made to train staff on climate change models (Ch. 3), understanding potential regional climate change impacts, and methods for conducting vulnerability assessments and initiating adaptation planning (Sloan and Hostler 2014).

2002 Fish Kill in the Klamath River

In 2010, with funding from the U.S. Environmental Protection Agency's (USEPA) Office of Environmental Justice Small Grants Program, YTEP began an initial plan to identify "community priorities for a Yurok response to a changing environment" (Sloan and Hostler 2011). Community scoping for the prioritization plan revealed that the number one priority was to protect and preserve Yurok lifeways, culture, and traditions. In order to implement this it was recommended that YTEP research and help protect the Yurok trust resources that may be affected by climate change impacts. Using the elders' advice to, "follow the water", it was determined that the priority planning areas for the Yurok Tribe's initial climate change plan should focus on the aquatic environment and resources. Areas identified that are the focus of the current Plan include: (1) Aquatic Habitats, (2) Drinking Water, (3) Salmon (Chinook and Coho), (4) Steelhead, (5) Green Sturgeon, (6) Pacific Lamprey, (7) Marine Shellfish, (8) Spring Seaweed, and (9) Human Health.

In 2014, funding and support from the North Pacific Landscape Conservation Cooperative enabled YTEP to assist the Tribe in collecting and documenting Yurok Traditional Ecological Knowledge (TEK) on ecosystem functions, community structure, species behavior, and habitat use. The project included conducting interviews with Tribal Elders to document baseline information on conditions and changes in the overall environment and on specific resources, as observed over their lifetimes (Sloan and Hostler 2014).

"We're all connected... the animals... – they can't live if we can't live – we need to take care of each other."

– Elizabeth Azzuz, Yurok Tribal member, Secretary of Yurok Cultural Fire Management Council

The Yurok Tribe also received in 2014 a U.S. Bureau of Indian Affairs (BIA) Climate Change Grant to host an intertribal workshop to identify tools, best practices, and case studies for tribes to distinguish significant areas that will be impacted by sea level rise (BIA 2014). In 2015, the Tribe received BIA Tribal Cooperative Landscape Conservation Program Funding to prepare a climate change vulnerability assessment for mountain meadows, and also to integrate consideration of climate change effects on habitats and species into management plans and decisions that affect the Klamath estuary (BIA 2015). In 2016, the Tribe received BIA Tribal Climate Resilience Program Funding to conduct a vulnerability assessment for Yurok coastal prairies (BIA 2016). These grants also provided funding to Yurok staff to attend climate change adaptation trainings and capacity building conferences.

The Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources builds upon this previous work, particularly two resulting reports: the Yurok Tribe and Climate Change: An Initial Prioritization Plan and the 2014 report Utilizing Yurok Traditional Ecological Knowledge to Inform Climate Change Priorities (Sloan and Hostler 2011; Sloan and Hostler 2014).

Importance of holistic planning

Two important points continued to be brought up by Tribal members and staff during the development of this Plan – the interconnectedness of all things and all aspects of the ecosystem being equally important. While the funding received for this Plan was to specifically focus on aquatic habitats and resources and Tribal health, the intention is not to separate the priority planning areas or create a hierarchy but rather to create a starting point for adaptation planning efforts.

As described by the concept of He-we-che, the health of the Yurok people depends on the health of the species, which depends on the health of the Klamath River and the health of the entire ecosystem (Ch 1). So while this Plan focuses on particular areas within the system, it was informed by how the ecosystem functions together as a whole. It isn't possible to talk about the river without talking about the fish, without talking about the trees, flowers and plants and the animals; deer and elk, salamanders and birds. They work together, collectively. It is important to keep this holistic Yurok worldview in mind. In particular, the adaptation strategies that are proposed throughout this Plan are designed to consider not only how they can support one species or fish run, or any single tributary, but also how the entire ecosystem as a whole must be restored.

In addition, climate change can often exacerbate other pre-existing issues and stressors. Together both climatic and non-climatic factors contribute to a person's, community's, species', and ecosystem's vulnerability. Climate consists of the pre-vailing weather conditions in an area over a long period of time and non-climatic factors are everything else, such as over-fishing or dams, or the policies that regulate them. It is thus important to account for both the climatic and non-climatic factors when planning for adaptation.

There are several reasons for this. First, non-climatic factors affect how people, other species, and ecosystems experience climate. For example, if clear-cut logging has taken place in a forested watershed and a heavy downpour occurs, much greater erosion into nearby streams may take place than if the forest had not been clear-cut. Thus, the impacts and over-all outcome of the downpour will be different based on a non-climatic factor, logging. Reducing such non-climatic stress-ors provides us with an important way to adapt to climate change.

Second, if we only view climate stressors in isolation and do not address non-climatic factors that also affect a system, we may not achieve the results for which we are aiming. For instance, if our end goal is to have safe drinking water but we do not address septic system leakage, we could have a climate resilient system but still not have safe drinking water. The planning process discussed below strives to take into account the more holistic perspective described in this section.

Planning and implementation process

The Yurok are using a five-phase planning and implementation process to prepare for climate change (Figure 2.1). The process is represented as an iterative, or circular adaptive management approach, which continues to accumulate information and community input for future management decisions. Planning for this Adaptation Plan represents the completion of Phases 1-3. Acting on the Plan, or the implementation process, consists of Phases 4 and 5. This would then prompt future community input on the successes or failures of implementation and moving forward, beginning the other phases again.

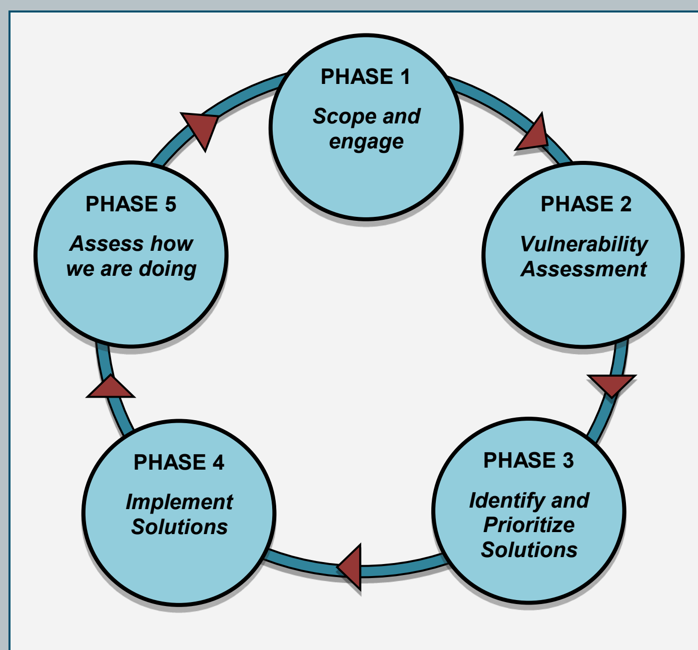

Figure 2.1 The five phases of the Yurok climate adaptation planning and implementation process.

As part of Phase 1 – Scope and Engage - the plan scope (topics covered by the plan) was established and although engagement is discussed as being a part of Phase 1, it takes place throughout the adaptation planning process. The nine priority planning areas covered by this Plan (Table 2.2) were determined as part of previous Yurok climate change work as being critically important to the Tribe. During Phase 1 engagement, local communities, Tribal staff, and Members shared their observations and concerns related to climate change and Yurok water and aquatic resources.

Vulnerability can be generally described as susceptibility to harm, and Phase 2 – the Vulnerability Assessment - identified which climate impacts were already being felt locally and what types of impacts might be anticipated with future climate change. Non-climatic challenges to Yurok water and aquatic habitats were also assessed, as well as existing non-climatic strengths, such as Yurok values and traditional management practices and already occurring restoration work. The vulnerability assessment then evaluated the interaction between climatic and non-climatic factors to describe potential impacts to each priority planning area. The model we used to assess vulnerability is described in more detail below (Sec. 2.3).

Phase 3 – Identify and Prioritize Solutions - involved developing a comprehensive list of adaptation strategies for each priority planning area and beginning to prioritize which strategies to implement first.

Phase 4 – Implement Solutions - will follow the strategies put forward in this Plan. During this phase, YTEP will work in coordination with other Yurok tribal departments and with other partners towards implementing key adaptation strategies proposed in the Plan. Phase 5 – Assess How We Are Doing - will include monitoring how the environment is actually changing as well as an evaluation of how well adaptation strategies are being implemented and how effective they are in supporting the adaptation of Yurok water and aquatic resources to climate change. Periodically, (between every 3 – 5 years) the Plan will be updated based on the monitoring taking place as part of Phase 5, new climate science and projections information that becomes available, and research undertaken to better understand climate change and its impacts.

Vulnerability conceptual model

As noted above, vulnerability can broadly be described as susceptibility to harm. In order to assess the vulnerability of the priority planning areas to climate change, we adapted a vulnerability conceptual model developed by Hans-Martin Füssel and Richard Klein (Füssel and Klein 2006). They define vulnerability as a function of the exposure, sensitivity, and adaptive capacity of a system to climate stressors. This model captures the complex relationships between climatic and non-climatic factors in terms of creating impacts to climate change and thus vulnerability. It is consistent with the Yurok holistic worldview described above. We used this model to understand the vulnerability for each of the priority planning areas (Figure 2.2).

Table 2.1 Key Terms

Stressor: A stimulus or condition (e.g., rising air temperatures) that causes stress to a system.

Vulnerability: Susceptibility to harm

Exposure: The nature and degree to which a system experiences climatic conditions that are stressful

Sensitivity: Non-climatic factors that pose challenges in terms of a system responding to climatic stressors.

Adaptive capacity: Non-climatic factors that are strengths in terms of a system responding to climatic stressors.

Mitigation: Dealing with *causes*. Actions that reduce level of greenhouse gases in the atmosphere.

Adaptation: Dealing with *effects*. Actions that minimize climate change impacts and vulner-

In this adaptation of the Fussel and Klein model, exposure is the extent to which a system experiences a set of stressful climatic conditions. For example, spring run Chinook salmon (the "system") return from the ocean and enter the Klamath River in the spring, then spend the summer in the river before spawning in the fall. This contrasts with fall run Chinook salmon, which return to the Klamath River during the fall and typically spawn within 2-4 weeks after entering the river. This means that the spring run Chinook may be exposed to increasingly warm river temperatures to a greater extent than the fall run.

Sensitivity can be broadly described as non-climatic challenges and adaptive capacity as non-climatic strengths. These are used in terms of whether they reveal a weakness or offer help when responding to climate stressors. For an example of a non-climatic challenge, if dams release less water, this could compound any low flow conditions resulting from the increasing drought intensities expected with climate change and, increase the overall warming of water temperatures (Ch. 4 and 6). In this way, dam management could increase the sensitivity of salmon to low flows and warmer water temperatures. In contrast, the Yurok Tribe's Blue Creek Salmon Sanctuary project to restore and protect cold water will act as a strength countering climate change effects and thereby increasing the adaptive capacity of salmon in terms coping with warmer waters.

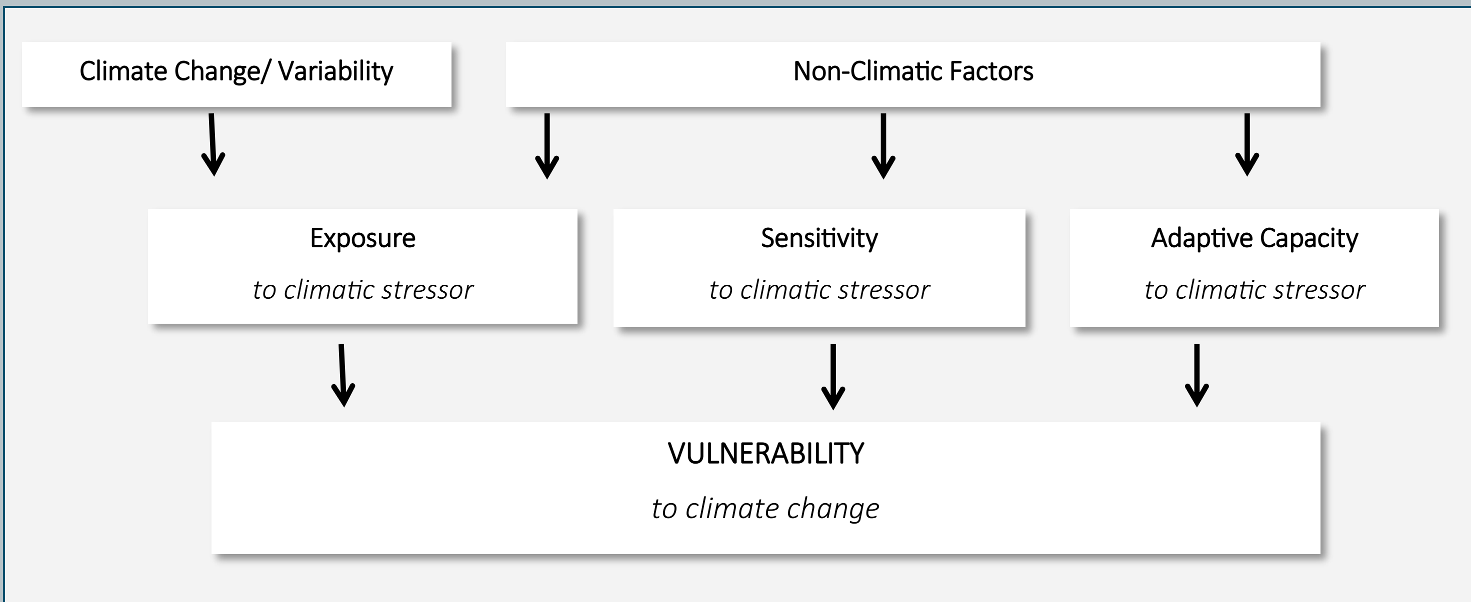

Figure 2.2 Vulnerability Conceptual Model (Adapted from Fussel and Klein 2006)

Methods - Engagement & Information Gathering

As part of the planning process described above, YTEP and ITEP organized three workshops, conducted a series of individual and small group interviews with Yurok resource managers and some community members, and attended several community meetings. The engagement part of Phase 1 took place throughout all of these encounters. In addition, YTEP and ITEP completed an extensive literature review and review of previously conducted Traditional Ecological Knowledge (TEK) interviews to inform the Plan (Elder Interviews 2014).

Table 2.2 Climate Change Priority Planning Areas for the Yurok Tribe

- Aquatic Habitats (Chapter 4)
- Drinking Water (Chapter 5)
- Traditional Aquatic Foods including: (Chapter 6)
  - ◊ Ney-puy (Salmon, including Chinook and Coho)
  - ◊ Chkwohl (Steelhead)
  - ◊ Kah-kah (Green Sturgeon)
  - ◊ Key'-ween (Pacific Lamprey)
  - ◊ Seyk-soh (Marine Shellfish)
  - ◊ Key'-ween we' chey-gel' (Spring Seaweed)
- Tribal Members' health: physical, mental, spiritual, emotional (Chapter 7)

The first workshop took place in April 2015 at the Tribal Headquarters in Klamath. Tribal Chairman Thomas O'Rourke opened the workshop. Mainly resource managers and some community members attended. The workshop's primary focus was to introduce climate change and the adaptation planning process (Phase 1).

To gather input for Phase 2 (Vulnerability Assessment), YTEP-ITEP held Workshop 2 in February 2016. The same 1-day workshop was conducted twice – once at the Tribal office in Weitchpec, and the subsequent day at the Tribal Headquarters in Klamath. Workshop 2 provided an overview of anticipated climate changes in the Yurok region, described the Yurok focus on the nine priority planning areas, and informed participants about resources available for keeping up-to-date on the latest climate change science. The bulk of the workshop, however, consisted of activities to gather input on how climate change might affect the priority planning areas and on how non-climatic factors might increase or decrease the vulnerability of those areas to climate change.

Workshop 3 was designed to focus on Phase 3 (Identify and Prioritize Solutions) of the planning process and took place in April 2016 along with the help of the Alaska Native Tribal Health Consortium. Similar to Workshop 2, the same 1-day workshop was held in Weitchpec, and then in Klamath. The objectives for Workshop 3 included the introduction of the Local Environmental Observer (LEO) Yurok Hub, LEO's potential use for climate change adaptation, review of the Yurok process for climate change adaptation planning, and to introduce information from elder interviews. Most of the workshop, however, was dedicated to identifying and discussing aquatic resource climate change adaptation strategies based on vulnerabilities identified during previous work.

Joe Hostler, YTEP, presenting to Yurok staff and community members at Workshop 2, Klamath, February 2016.

In addition to the workshops, as noted above, YTEP and ITEP staff conducted individual and small group interviews with Tribal resource managers and staff from across Yurok departments. Information from these interviews fed into Phases 2 and 3. The interviews took place during December 2015, February, April, and December of 2016. They provided a pathway to learn from and include tribal staff expertise about specific climate changes of concern as related to the interviewee's department's work, the vulnerability of each priority planning area to climate change, and work that each department is already undertaking as it relates to climate adaptation. In addition, suggestions for strategies on what they thought the Tribe could do to support the adaptation planning of each priority area were sought. Final interviews were conducted In February 2017, when Adaptation International staff held interviews and conversations with YTEP staff and Tribal resource managers and health personnel in Klamath and Weitchpec to develop the Tribal Health Assessment, which is included as Chapter 7 of this Plan.

YTEP and/or ITEP also attended meetings of the Natural Resources Committee (April 2015), the Cultural Fire Management Council (February 2016), and the Culture Committee (January 2017). At these meetings YTEP and ITEP heard from committee members about their key concerns related to climate change, what they had already witnessed and experienced, and ideas they had for adapting. This information fed into Phases 2 and 3. Information gathered as part of an extensive review of Yurok reports and scientific literature also informed Phases 2 and 3. Finally, widespread use was made of elder interviews conducted as part of a 2014 project (please see the section, Yurok Tribe's Previous Climate Change Work, Ch 1). These interviews increased our understanding of how the climate has been changing and quotes from the interviews are included throughout the Plan in blue boxes .

Through all this work, a comprehensive description of the vulnerability (climate impacts, exposure, sensitivity, and adaptive capacity) of each priority planning area was developed and dozens and dozens of potential adaptation strategies were identified. YTEP selected some of these strategies for inclusion in the chapters of the Plan, and included all of the documented strategies in the chapters' corresponding appendices as the depth and breadth of potential strategies suggested is a major community contribution to the adaptation process.

2.3 How to Use This Planning Document

This Plan is a living document intended to be integrated and implemented along with other Yurok plans and actions. YTEP, together with other concerned and participating departments within the Tribal government, is assessing how best to implement the actions under this initiative and how to effectively incorporate such actions into programs and activities. Implementation, monitoring, evaluation, and updating the Plan are all part of the ongoing process to prepare the Tribe for climate change. The Plan has been designed for ease of use and to help the Tribe's staff and community members understand anticipated climate change impacts for their region and assess the best ways to move the Plan towards implementation. To facilitate this, each chapter can be read as a stand-alone document in addition to being read as part of a larger whole. It is hoped that in this way, those interested in a particular focus area of the Plan can pull out that chapter for information. Chapter topics are described in Table 2.3.

Within each of Chapters 4-7, tables are included that highlight 1) the key climate changes that are most likely to occur in Yurok country and their impacts on the Tribe's priority planning areas, and 2) selected adaptation strategies that could help Yurok staff and communities cope with the impacts. Icons have been developed to represent and highlight these climate changes, and are utilized throughout the chapters' text. In addition, appendices for Chapters 4-7 provide comprehensive lists of all adaptation strategies identified, including ones not incorporated into the chapter text as well as additional information for some of the strategies that were included. By providing a full suite of approaches, the appendices can provide tribal resource managers and concerned tribal members with a variety of pathways towards adaptation and implementation. Finally, as an outreach tool, fact sheets have been developed to summarize and accompany this Plan.

Table 2.3 List of Chapter Topics
Chapter 1: Introduction (includes historical legacies)
Chapter 2: Climate change adaptation planning process
Chapter 3: Climate changes in the Yurok Ancestral Territory and region
Chapter 4: Aquatic habitats
Chapter 5: Drinking water
Chapter 6: Traditional Aquatic foods
Chapter 7: Human health
Chapter 8: Cross-cutting adaptation actions

Periodically, the Plan should be assessed for its effectiveness as new information about climate change and its impacts becomes available and as suggested actions or strategies are incorporated into work across tribal departments. Each chapter can be individually updated as appropriate without re-writing the entire Plan. It is recommended that the overall Plan should be updated at least every five years.

Yurok people are very resilient and have survived major environmental and other changes in the past. Their pro-active response to the new threats posed by climate change will enable them to continue to adapt, survive, and thrive now and generations into the future. As articulated by a Tribal respondent to YTEP's initial climate change survey, "Our cultural and spiritual identity must survive. This is imperative - this is who we are."

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Additional Information

- The Institute for Tribal Environmental Professionals (ITEP) at Northern Arizona University established its Tribes and Climate Change Program in 2009. The program provides support for and is responsive to the needs of tribes who are preparing for and currently contending with climate change impacts. For more information, please visit our website at: http://www7.nau.edu/itep/main/tcc.
- "Guidelines for Considering Traditional Knowledges in Climate Change Initiatives," A resource for tribes, agencies, and organizations across the United States interested in understanding Traditional Knowledges in the context of climate change: https://climatetkw.wordpress.com/
- "The Climate and Traditional Knowledges Workgroup – CTKW" is an informal group of indigenous persons, staff of indigenous governments and organizations, and experts with experience working with issues concerning traditional knowledges who developed a framework to increase understanding of access to and protection of TKs in climate initiatives and interactions between holders of TKs and non-tribal partners: https://climatetkw.wordpress.com/
- Additional Chapters of the Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources can be found on the Yurok Tribe Environmental Program's Community and Ecosystem division webpage at http://www.yuroktribe.org/departments/ytep/com_eco_division.htm

Yurok Tribe Climate Change Adaptation Plan for Water & Aquatic Resources

Chapter 3: Climate Changes in Yurok Territory and Region

In This Chapter

This plan is from a purposeful collaboration with the staff and community members of the Yurok Tribe, as well as several organizations, and would not have been successful without each of their contributions. Funding was made available through the US EPA Science to Achieve Results (STAR) Program, Grant # 83560401-0. Online files available at: https://www.yuroktribe.org/departments/ytep/

"When [dogwood] bloomed up at our home place up there, that's when spring salmon was going to come. And it does…And it's the renewal of the River too. Things starting to pop out, and bloom when the dogwood. I've been in the canyon everything's starting to move. Everything's hopping, things coming to life…The climate's right, sometimes dogwood don't bloom and there's no spring salmon."
– Raymond Mattz, Elder Interviews 2014

Our climate is changing. Yurok elders have observed it. Our fish, trees, and people are experiencing it. Scientists are recording it. And they are using computer models to give us some ideas of what to anticipate for the future. This chapter summarizes climate-related changes currently occurring in the Yurok ancestral territory and region and ones projected for the future. We consider effects in seven different areas:

1) Climate elements (such as air temperature and precipitation timing, duration, intensity, and frequency),
2) Ocean and coastal processes (such as ocean temperature and sea levels),
3) Inland hydrology (such as the timing of snowmelt and streamflow),
4) Water quality parameters (such as temperature and oxygen concentrations),
5) Fire regimes (including frequency and extent), and
6) Ecosystem changes (such as shifts in the distribution of fish/wildlife species and changes in distributions and changes in population sizes).
7) Harmful algal blooms (and the toxins they produce)

The information presented below is based on scientific papers and reports, and from information shared by Yurok Tribal members and staff through individual and small group interviews, workshops, and elder accounts of changes taking place. We present information as specific to the Yurok territory as we were able to obtain. Yurok country lies at a crossroads between the weather and climate of the U.S. Southwest and the Pacific Northwest. At times, we consider anticipated changes in both regions.

YTEP staff studying changes to the algal com-

Chapter citation: Cozzetto K[1], Maldonado J[1], Fluharty S[2], Hostler J[2], Cosby C[2] (2018) Chapter 3: Climate Changes in Yurok Territory and Region . In *Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources*. [1] Institute for Tribal Environmental Professionals (ITEP), Northern Arizona University, Flagstaff, AZ. [2] Yurok Tribe Environmental Program (YTEP), Klamath, CA.

3.1 Some Climate Change Model Basics

Projections of future climate changes are obtained through the use of climate models, which are mathematically designed to represent physical processes in the Earth's atmosphere, ocean, frozen layer, and land. The models simulate how the global climate responds to different amounts of greenhouse gases released into the atmosphere. Greater degrees of change are associated with greater emissions of greenhouse gases.

The information presented below is based on several different scenarios of global greenhouse gases released into the atmosphere ranging from low to high[1]. Currently greenhouse gas emissions are tracking just above the highest greenhouse gas emissions scenario (Riahi et al. 2011, Sanford et al. 2014)[2]. This points to the need to really consider the scenarios that project greater amounts of change in the climate, as even these scenarios are based on amounts of greenhouse gas in the atmosphere that are now being exceeded.

Table 3.1 Projected Climate Changes Affecting Yurok Aquatic Resources
<u>Changes in Air Temperatures</u> Rising air temperatures
<u>Changes in Precipitation Regimes</u> Precipitation amounts are uncertain
<u>Changes in Ocean Processes</u> Rising sea levels > increasing coastal inundation > erosion & intrusion into estuary and coastal aquifers
<u>Changes in Inland Hydrology</u> Shift from snow to rain > increasing winter flows & floods; Reduced late spring/summer flows in river, creeks, & springs Increasing drought intensities
<u>Changes in Inland Water Quality</u> Warming surface water temperatures > lower dissolved oxygen;
<u>Changes in Fire Regimes</u> Fire seasons are expected to become longer with increased frequency and extent.
<u>Combined Effects</u> Decreasing snowpack, earlier spring snowmelt Warming ocean temperatures > increased harmful algal blooms Heavier downpours > increase surface water sheeting > erosion > increasing turbidity, sedimentation & higher pollutant loadings Fire exposed slopes will further add to effects

[1]In the projections described in this chapter, two main emission scenario families were considered. One is based on the Intergovernmental Panel on Climate Change (IPCC) 2000 Special Report on Emissions Scenarios (SRES) (USGCRP 2017). These are the A1, A2, B1, and B2 scenarios. The second is based on the IPCC's 2010 Representative Concentration Pathways (USGCRP 2017). These are the RCP scenarios. A1f1 is a high emissions or business as usual scenario. This is comparable to RCP8.5 (USGCRP 2017). A2 is a medium-high emission scenario. B1 is a low emissions scenario and is roughly comparable to RCP4.5 (USGCRP 2017). Finally, RCP2.6 assumes rapid emissions reductions and is much lower than any SRES scenario (USGCRP 2017).

3.2 Changes in Air Temperatures

Air temperatures are on the rise. Globally, according to NASA, 2016 was Earth's warmest year and 2017 its second warmest since record keeping began in 1880 (Fountain et al. 2018). Of the 18 warmest years on record, 17 have occurred since 2001 (NASA 2018)[3]. Between the early 1900s and 2011, temperatures in the Pacific Northwest (Washington, Oregon, Idaho) rose by approximately 1.3 °F, and 2017 was California's warmest summer on record (Dalton et al. 2013; NOAA NCEI 2018).

Locally, Yurok elders have observed changes as well. Bertha Peters noted, "I can remember we used to have icicles hanging down. I just recently this last year or year before seen that again. But I hadn't seen it for a long while" and Fern Bates spoke about the way things used to be, "That's what I miss... Because it used to get really cold and freeze. When we would go out into the field and the little puddles would freeze, you could ice skate across the puddles. Little bunches of water would sit around, but now it doesn't get that cold. It doesn't get cold enough to freeze" (Elder Interviews 2014). Frank Lara also noted, "You're supposed to have a certain climate during certain months. And it's not working that way...Summer's gone by but it's winter, and it's almost summer again" (Elder Interviews 2014).

- Future Change to Air Temperature

In the future, models show continued increasing air temperatures. According to data from the U.S. Climate Resilience Toolkit, by the end of the 21st century under a high emissions scenario, January daily maximum temperatures for Del Norte and Humboldt Counties could increase from 48 and 49 °F, respectively, to

Table 3.2 Average Seasonal Daily Maximum /Minimum Air Temperatures ,°F

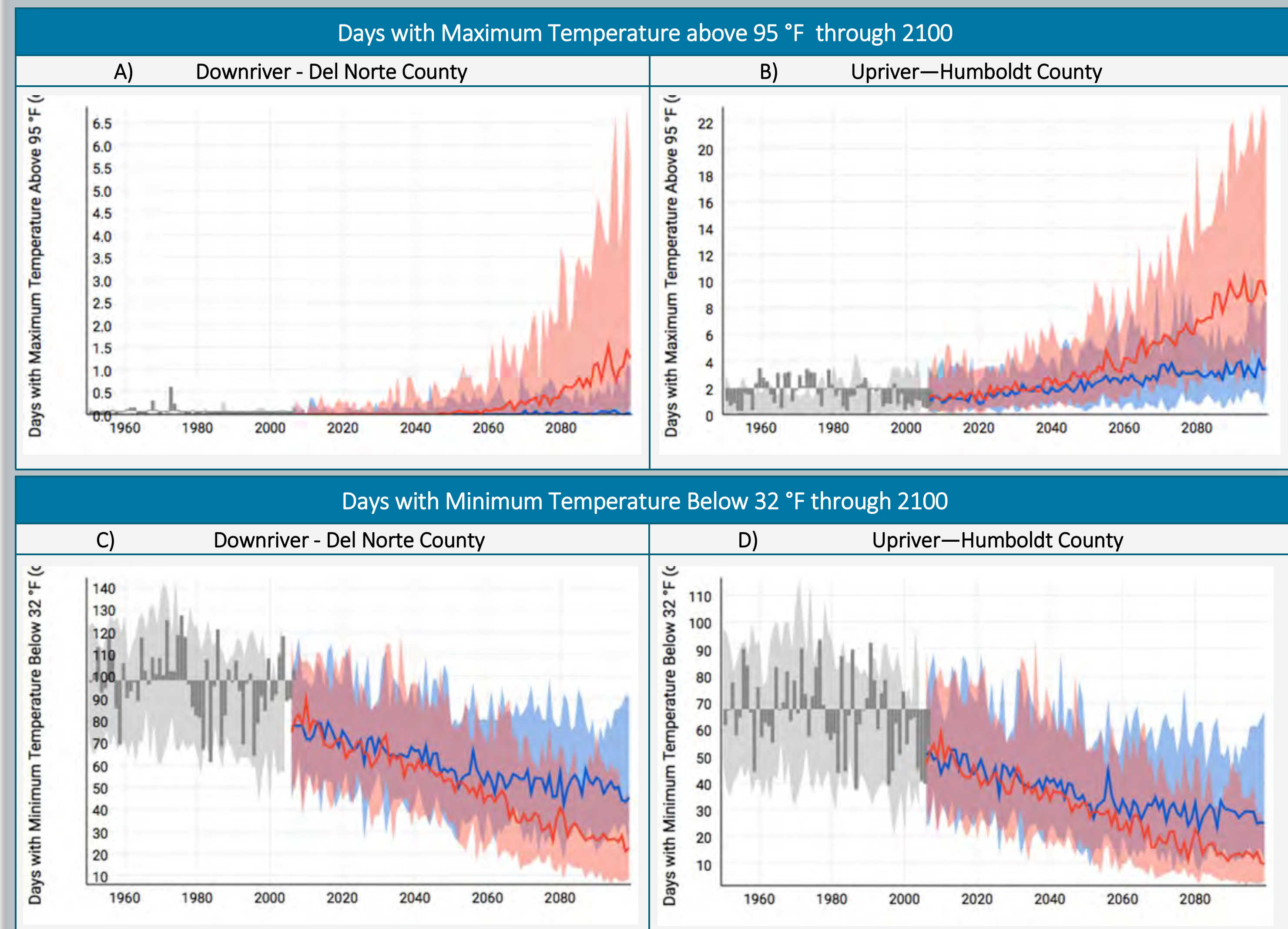
	JANUARY AVERAGE			
	Downriver Del Norte County		Upriver Humboldt County	
	Daily Max	Daily Min	Daily Max	Daily Min
Observed (1950-2004)	48	31	49	33
End of 21st century - model medians (low - high emissions scenarios)	50-52	35-37	51-54	37-39
End of 21st century - model max	< 53	< 39	< 55	< 41
	JULY AVERAGE			
	Downriver Del Norte County		Upriver Humboldt County	
	Daily Max	Daily Min	Daily Max	Daily Min
Observed (1950-2004)	67	44	72	46
End of 21st century - model medians (low - high emissions scenarios)	70 - 73	48 - 51	76 - 79	50 - 53
End of 21st century - model max	< 76	< 54	< 81	< 56

Source of data: U.S. Climate Resilience Toolkit, Climate Explorer (https://toolkit.climate.gov/ climate-explorer2/). The data are county level. Low and high emission scenarios were considered. Projections were generated by global climate models for the Coupled Model Intercmparison Project Phase 5 (CMIP5) and were statistically downscaled. For more information on the modeling process, please refer to: https://toolkit.climate.gov/climate-explorer2/about.php. The low number in the model medians rows represents the median of the low emission scenario model runs. The high number represents the median of the high emission scenario model runs. The model max represents the highest value of the high emissions model scenario runs. The values displayed are for the 30-year period centered around 2075. All numbers in the table have been rounded to the nearest whole number.

[3]Global and U.S. air temperatures records extend back to 1880 and 1895, respectively (Walsh et al. 2014; Fountain et al. 2018)
[4]The high emissions scenario considered was RCP8.5.
[5]Cayan et al. (2008) provides temperature projections for Northern California for B1 (low emissions) and A2 (medium-high emissions). They are in line with the projections shown here from the U.S. Climate Resilience Toolkit.

as high as 53 and 55 °F (Table 3.2). July daily maximum temperatures could increase from 67 and 72 °F (downriver/upriver) to as high as 76 and 81 °F. Daily minimum temperatures are also anticipated to increase.

In addition, the models show an increase in the total number of days/year with a temperature maximum above 95 °F. This is expected particularly in upriver Yurok Territory under a high emissions scenario where the number of days could rise from an average of 2 days to 9 or possibly as many as 23 days by the end of the 21st century (Figure 3.1b)[6]. Even more pronounced in both Del Norte and Humboldt Counties is the decrease in the total number of days/ year with a temperature minimum below 32 °F. For Del Norte County, this number is anticipated to decline from 98 to possibly between 26 and 49 and maybe even as low as 6 (Figure 3.1c)[7]. For Humboldt County, the number of days/ year below freezing is expected to decrease from about 68 to possibly between 13 and 28 days and maybe as low as 2 (Figure 3.1d).



Source of data: U.S. Climate Resilience Toolkit, Climate Explorer (https://toolkit.climate.gov/ climate-explorer2/). The data are county level. Two emission scenarios were considered, RCP 4.5 and RCP 8.5. These are low and high emission scenarios. Projections were generated by global climate models for the Coupled Model Intercomparison Project Phase 5 (CMIP5) and were statistically downscaled. For more information on the modeling process, please refer to: https://toolkit.climate.gov/climate-explorer2/about.php. The dark gray bars indicate observed values; the light gray bands the model data for the historical period (i.e. hindcasts). The blue lines show the model medians and the blue bands the range in model values for the low emissions, RCP 4.5, scenario. The red lines show the model medians; the red bands the range in model values for the high emissions, RCP 8.5, scenario.

Figure 3.1 Air Temperature Modeling for Del Norte and Humboldt Counties

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[6]The low and high emission scenarios considered were RCP4.5 and RCP8.5, respectively.
[7]The historic average is for the 1960-89 time period.

3.3 Changes in Precipitation and Fog

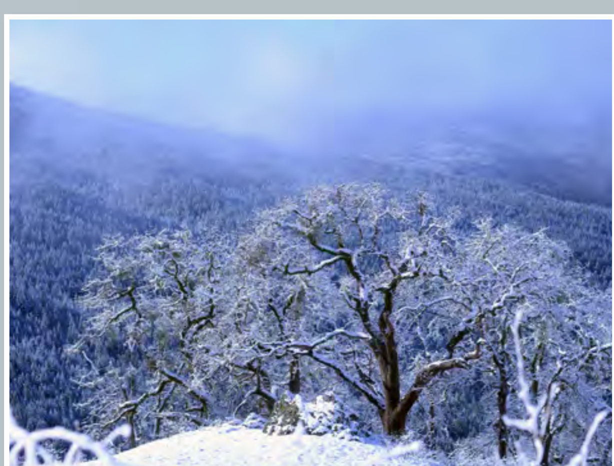
Precipitation is water released from clouds that falls to the ground. It delivers water from the atmosphere to the Earth (USGS 2016). Fog is a cloud that is at or near the surface of the ground or ocean (USGS 2014). Both precipitation and fog are important in Yurok country and may be affected by climate change.

Table 3.3 Key Points on Precipitation and Fog		
Primary Climate Effect	**Secondary Stressor**	**Potential Impacts**
Warmer Air	→	Shift from snow to rain; decreasing snowpack; earlier spring snow melt
Heavier Downpours	Increased run-off	Increase in winter floods > Increasing erosion & sedimentation > Increases in turbidity & nonpoint source pollutant loads
Changes in fog and total precipitation amounts are uncertain.		

Precipitation

In the Lower Klamath River Basin, the annual average precipitation is 79.62 inches (Sloan 2015). This includes both rain and snow. The region is characterized by dry summers and moist winters with the majority of precipitation falling between October and April. According to analyses done for the southwestern and northwestern U.S. of which Yurok country is a part, there are no significant 20th century trends in total precipitation amounts (Dalton et al. 2013; Hoerling et al. 2013).

However, when considering past trends, in California over the last 50 years, more winter precipitation is now falling as rain rather than snow, spring snowmelt is 5 to 30 days earlier, and spring snowpack in lower and middle elevations is declining (Cayan et al. 2008).



Yurok high country and mountains are considered low to middle elevations and snow fall and snow pack are expected to decline in these areas.

In addition to total annual average precipitation, we can also consider precipitation extremes. Nationwide, heavy downpours are increasing, in particular in the Midwest and Northeast (Walsh et al. 2014). The Southwest is not exhibiting a clear trend (Hoerling et al. 2013), and in the Pacific Northwest, metrics for changes in extreme precipitation are mixed. One study does show a 12% increase in the heaviest 1% of all daily events from 1958-2012 (Dalton et al. 2013; Walsh et al. 2014). Locally, Yurok tribal members have reported heavier downpours taking place. For example, in response to a question asking if it rained harder nowadays than before, Elder Bertha Peters said "you know sometimes it rains and sometimes it just pours down. I say it's like in the cowboy movies, how it's raining just hard. And the rain just draining off of them. I notice that because of the road. How it makes ditches in the road more so than it used to. You could ditch a road out and then it would be in the ditches but not in the spillways. Not all the time, just once in a while."

[8] The NOAA 2016 citation refers to the U.S. Climate Resilience Toolkit. Precipitation data for Del Norte and Humboldt Counties corresponding to RCP4.5 (low) and RCP8.5 (high) emission scenarios were examined. Model medians showed little change in mean daily precipitation (which translates into total annual precipitation). However, ranges in model values were wide, which points to the lower certainty discussed.

- Future Change to Precipitation

In general, precipitation amounts are more difficult to project than temperatures for a variety of reasons. For example, there are uncertainties in climate models about how to simulate processes such as clouds and the positions of storm tracks approaching the west coast (Reclamation 2011). In addition, models may not adequately capture the topography of mountainous regions. For the region in which the Yurok territory is located, various modeling efforts project little to only slight changes in the overall total amount of precipitation based on the mean annual precipitation, by the mid and end of the 21st century under both low and higher emission scenarios (Reclamation 2011; Cayan et al. 2013; Dalton et al. 2013; NOAA 2016)[8]. However, less confidence is associated with such projections. With air temperatures projected to continue rising, the snow-related trends noted above are expected to continue into the future including shifts in winter precipitation from snow to rain, earlier snowmelt, and declining snowpack (Barnett et al. 2005; Reclamation 2011). Because changes in snow are attributable to rising air temperatures, these projected trends are considered more robust (Hayhoe et al. 2004).

With respect to extreme precipitation, given the ability of warmer air to hold more moisture, climate models in general project increases in extreme precipitation events (heavy rainfall in short periods) (Gershunov et al. 2013; NCAR 2016). One study showed a 13% increase in the number of days with precipitation greater than 1 inch in the Pacific Northwest by mid-21st century under a medium-high emissions scenario (Dalton et al. 2013)[9]. Another study shows that in Northern California, by the end of the 21st century a **1 in 20 year daily heavy downpour would occur nearly twice as often** under a low emissions scenario (rapid emissions reduction) and possibly three to four times under a high emissions scenario (business as usual) (Walsh et al. 2014).

Sunlight shining through the fog

Fog

The presence of fog is important for redwoods for several reasons as it raises the levels of relative humidity that helps reduce redwood transpiration, thereby helping the trees conserve water (Johnstone and Dawson 2010, O'Brien et al. 2013). Redwoods can also absorb fog water directly through their needles (O'Brien et al. 2013). In addition, dense fog can result in fog drip moving from the canopy into the root zone enhancing soil moisture (Johnstone and Dawson 2010; O'Brien et al. 2013).

Participants in Workshop #1 noted that on the Yurok Reservation, fog has been in decline and that this is affecting the coastal redwoods. These redwoods are the tallest living tree species in the world and are long-lived with some trees being over 2,000 years old. A 2010 study making use of long-term airport data inferred a 33% reduction in fog frequency along the northern California coast since the start of the 20th century (Johnstone and Dawson 2010). The authors state that this represents about a loss of about three hours per day during the summer fog season.

Declines in fog frequency may heighten the sensitivity of redwoods to drought. A pattern of natural climate variability, known as the Pacific Decadal Oscillation has phase shifts that occur every 20-30 years (Johnstone and Dawson 2010) and may be correlated to fog frequency and contribute to the current observed decline. In 2012, the US Geological Survey and California Landscape Conservation Cooperative

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[8]The NOAA 2016 citation refers to the U.S. Climate Resilience Toolkit. Precipitation data for Del Norte and Humboldt Counties corresponding to RCP4.5 (low) and RCP8.5 (high) emission scenarios were examined. Model medians showed little change in mean daily precipitation (which translates into total annual precipitation). However, ranges in model values were wide, which points to the lower certainty discussed.

[9]This is the 2041-2070 mean minus 1971-2000. The medium-high emissions scenario is A2.

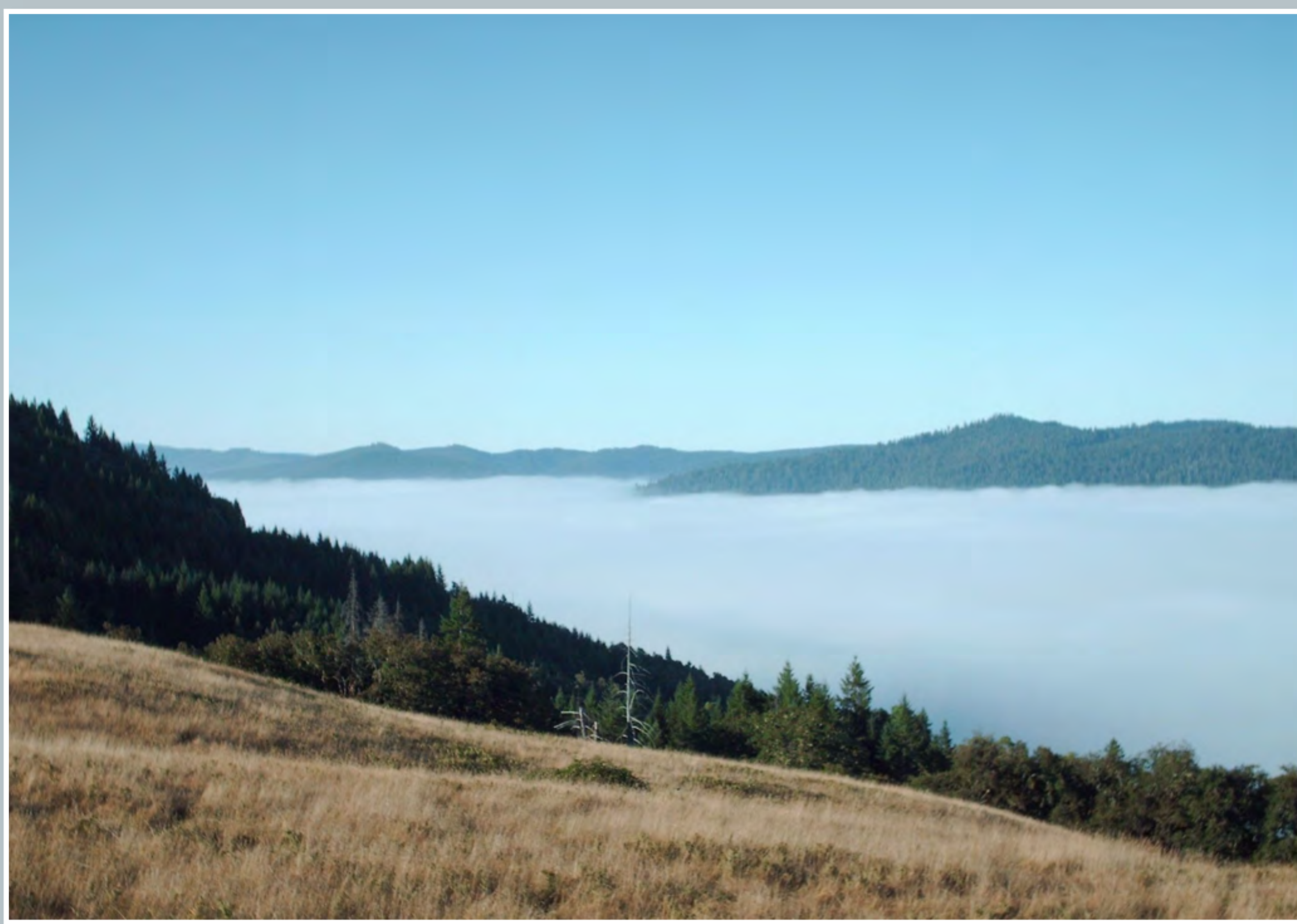
[10]This is the 2081-2100 change with respect to 1981-2000. The low and high emissions scenarios are RCP2.6 and RCP8.5, respectively.

started a Pacific Coastal Fog Project to gather and provide “ecologically relevant fog datasets .

- Future Changes to Fog

In addition, other factors affecting fog formation include ocean water upwelling, air mass downwelling, and microscopic aerosol particles that include sea spray, fungi, pollen, and dust (Torregrosa 2014). Because the development of fog is the result of interactions between atmospheric, oceanic, and terrestrial systems, each with a broad range of variability, future trends in fog with climate change are highly uncertain (Torregrosa 2014) and the Pacific Decadal Oscillation shifts every 20-30 years (Johnstone and Dawson 2010).

More specifically, the interaction between coastal wind-driven upwelling of ocean water associated with the California Current and the downwelling of air masses associated with an atmospheric Hadley circulation cell plays an important role in fog formation (Torregrosa 2014).



View from Bald Hills Road of thick fog that can still fill the lower elevations, flowing like a river. In the Yurok language mo-’oh-peer describes fog in general but they also recognize a warm fog, “Her-we-merp’. To-meek’ is a thick, deep fog that Tribal Members currently report as often seeming thinner than in the past.

3.4 Changes in Ocean and Coastal Processes

The Pacific Ocean and coast regions have been experiencing a variety of changes that are expected to continue and increase in the future with climate change.

Table 3.3 Key Points on Ocean and Coastal Processes

Primary Climate Effect	Secondary Stressor	Potential Impacts
Warmer Air	Less oxygenation	Chance of increased dead zones
Sea Level rise	Increased coastal inundation	Increased erosion Habitat loss for shellfish
Ocean Acidification	Reduced shell formation	loss of food chain components > less fish food >less fish & shellfish
Heavier Downpours	Increased run-off	Increased nutrient loading > possible increased HABs

Ocean Temperatures

Ocean temperatures are warming. Over the past 100 years, temperatures in the ocean's upper layer have increased by 1.3°F (0.6 °C) (Hoegh-Guldberg and Bruno 2010)[11]. In the future, ocean surface temperatures may rise as much as 4.7 °F (2.6 °C) by 2100 (Nicholls et al. 2007)[12]. There may be localized variations in sea surface temperatures. For example, estuaries and coastal seas that are shallower and have limited exchange with the open ocean may experience greater temperature increases (Altieri and Gedan 2015).

Sea Level Rise

Sea levels are rising and the rate of sea level rise (SLR) is increasing. Between 1880 and 2013, global average sea levels rose by about 8 inches (USEPA 2016). However, nearly a third of this increase (about 2.6 inches) has taken place since just 1993 (Lindsey 2016).

Climate change contributes to sea level rise because of thermal expansion associated with warming ocean temperatures (NASA 2016). It also contributes through the melting of land ice including ice from glaciers, ice caps, and ice sheets. Local factors can contribute to SLR as well so that local SLR may be more or less than the global average (NOAA 2017). In Yurok country, one local factor involves plate tectonics (NRC 2012a)[13].

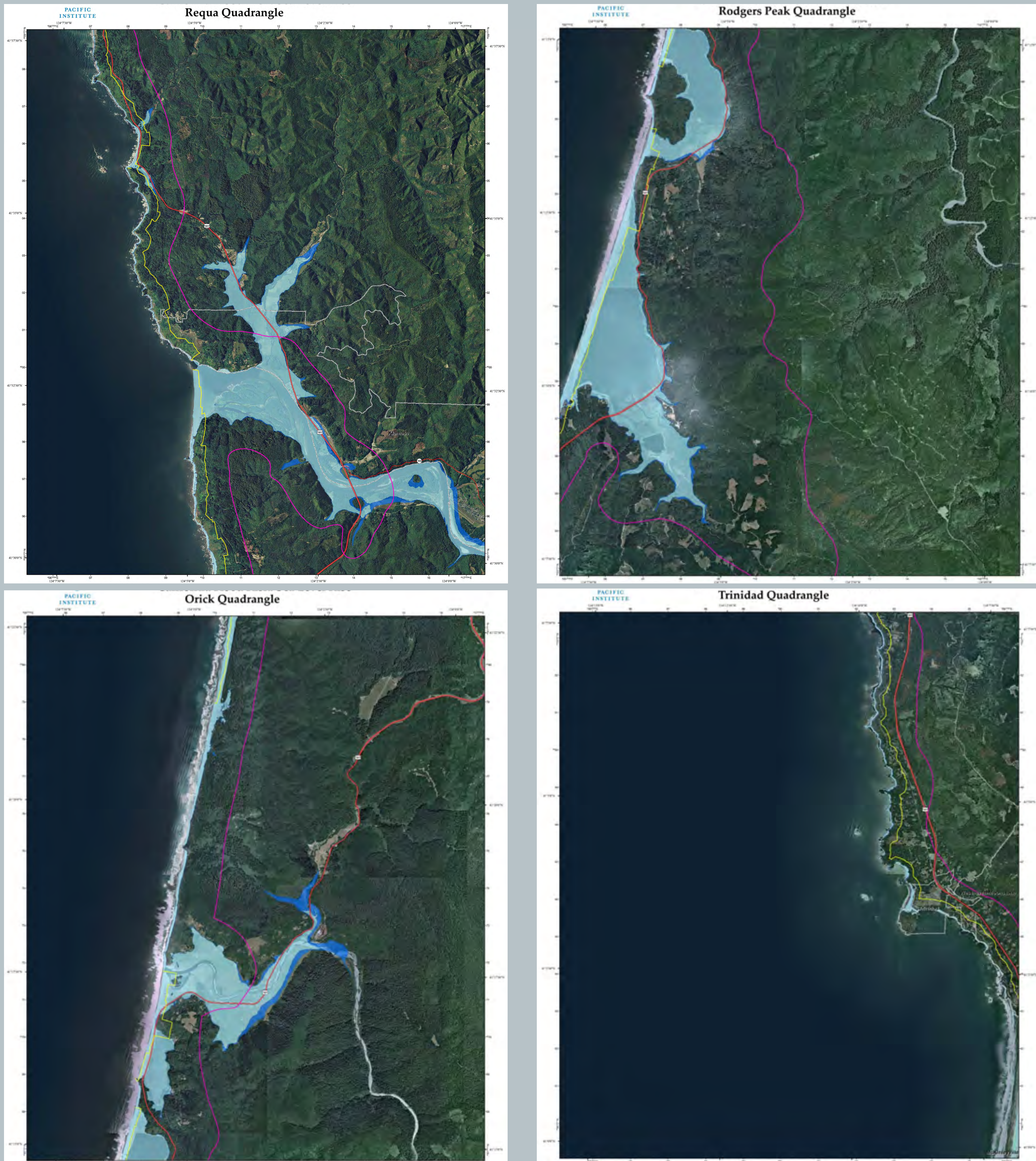
Table 3.4 Sea Level Rise Projections

	Medium Emission Model	High Emission Model
By 2100	24"	56"

Source of data: NRC 2012a

In terms of plate tectonics along the California coast, Cape Mendocino is a transition point. South of Cape Mendocino the land is subsiding or sinking, which effectively increases SLR (NRC 2012a). However, north of Cape Mendocino, which includes the Yurok Reservation and ancestral territories, land is being uplifted, which effectively decreases SLR (NRC 2012b).

[11] This refers to global average temperatures of the ocean's upper layer.
[12] This refers to global mean sea surface temperatures and a 1980-99 reference period.
[13] Another factor In Yurok country that affects sea level rise is the El Niño-Southern Oscillation. The warm El Niño phase raises sea levels along the west coast of the U.S. The cool La Niña phase lowers them.



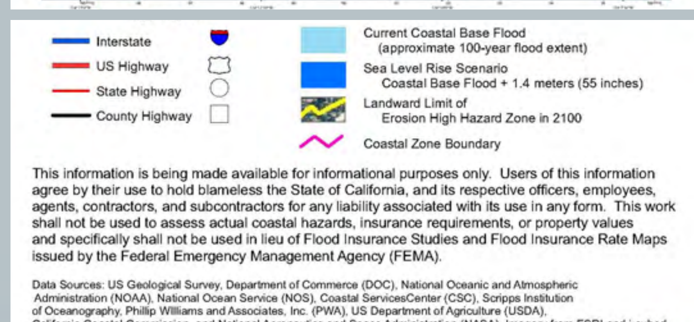


Figure 3.2 Yurok Coastal Areas of Yurok Territory

A 1.4-meter rise in sea level is projected by the end of 2100 under a high emissions scenario (A2). For more details on model specifics, please see Heberger et al. 2009. Source: Pacific Institute, downloaded from: http://www2.pacinst.org/reports/sea_level_rise/gmap.html.

Taking this into account, by 2100 north of Cape Mendocino, sea levels are expected to increase by approximately 2 feet for a medium greenhouse gas emissions scenario, and by 4.7 feet for a high emissions scenario, as compared to the year 2000 (Table 3.5, NRC 2012a).

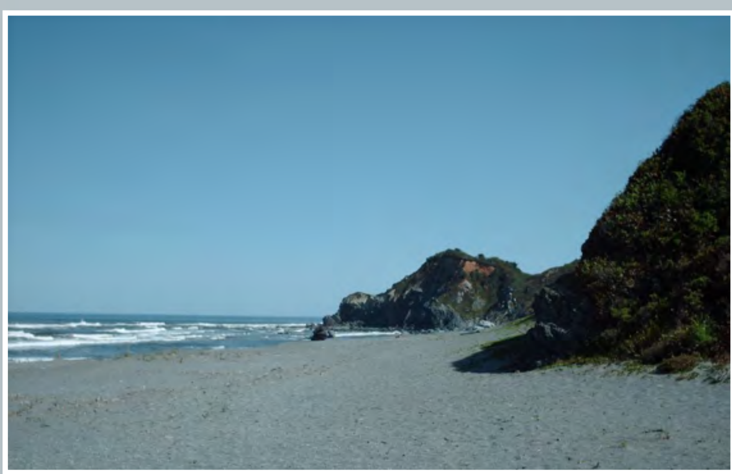
- Coastal Inundation and Erosion

In addition, other factors Rising sea levels can affect shorelines in several ways. They can contribute to coastal inundation of wetlands and other low-lying areas (Figure 3.2) (NRC 2012a). They can also exacerbate the erosion of beaches, dunes, and cliffs, and increase the salinity of estuaries (NRC 2012a). Where rivers discharge into the ocean, rising sea levels can worsen flooding by causing water to back up (Heberger et al. 2009). In addition, the erosion of dunes and sand spits can expose areas to inundation that were previously protected.

Table 3.5 Projected Cliff Erosion Distances in Yurok Country By 2100

	Average Sea Level Rise	Maximum Sea Level Rise
Omen Hipur to Welkwa (Del Norte County)	230 –279 ft	558—1312 ft
Osegen to Srepor (Humboldt County)	82– 98 ft.	492—541 ft

The low end of the range of values is for a 3.3 ft (1 m) sea level rise and the high end is for a 1.4 m (4.6 ft) sea level rise, which roughly corresponds to a high emissions scenario. (Revell et al. 2011).



Sandy beaches in Yurok Territory are mostly confined to the south of Espau and include beaches in Humboldt Lagoon areas of

Sea level rise can also contribute to increased erosion by allowing greater wave energy to disperse higher up on the shoreline, potentially directly against dunes or cliffs (Heberger et al. 2009). The degrees of erosion between dunes and cliffs will differ because of their differing resistances to erosion (NRC 2012a). One study projected cliff and dune erosion distances along the California coast from Santa Barbara to the Oregon border (Revell et al. 2011). Moving from north to south, projected cliff erosion distances from the traditional Yurok villages of Omen Hipur to Welkwa (Del Norte County) and from Osegen to Srepor (Humboldt County) are presented in Table 3.4. We do not present dune information because dune formations in Yurok Ancestral Territory are minimal.

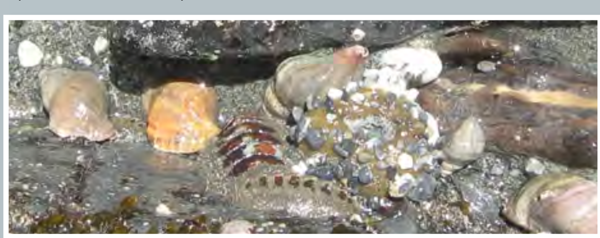
Rocky areas such as south of Omen, (looking toward Hidden Beach) in Del Norte County could experience possible sea level rise of over a thousand feet

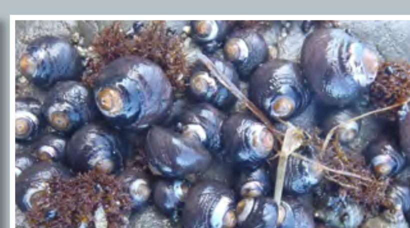
The 1,312 foot value for cliff erosion in Del Norte County noted in the table above was for the location of maximum cliff erosion for the entire California coast examined. This location was approximately 1.9 miles south of the Klamath River and was associated with a geologic unit known as the Franciscan complex (Revell et al. 2011).

Ocean Acidification

As greenhouse gas emissions continue to increase globally, the oceans are absorbing additional carbon dioxide from the atmosphere. The added absorption has contributed to a lowering of ocean pH[14]. As pHs decrease, conditions become more acidic. Hence, this is known as ocean acidification (Waldbusser et al. 2011). Lower pHs could potentially disrupt shell development, in for example, marine mussels, and affect the reproduction and growth of marine organisms (Ingram et al. 2012). Globally, surface ocean pH has dropped from a preindustrial value of 8.2 to 8.1 (Orr et al. 2005; Kennedy 2010). Ocean surface pH is now 0.1 pH units lower than preindustrial values (Orr et al. 2005). By the end of the 21st century, under a higher emissions scenario, surface ocean pH is expected to become an additional 0.3-0.4 units lower (Orr et al. 2015)[15]. While this change may seem small numerically, because the pH scale is logarithmic, a change of 0.3-0.4 units actually represents a 100-150% increase in the relative acidity of the oceans from today's levels. Estuaries may be more susceptible to acidification because they are less buffered than marine systems and because their location along coastal regions may result in their receiving additional acidic inputs (Waldbusser et al. 2011). Changes in upwelling could also affect acidification. The California Current is an ocean current moving southward along the U.S. west coast including along Yurok territory (Snyder et al. 2003). Wind-driven upwelling associated with the California Current brings deep, cool, and nutrient-rich water to the surface. This upwelling helps make west coast fisheries extremely productive (Gewin 2010) however, upwelling also seems to be intensifying ocean acidification (see below) (Lachkar 2014).

Sea rocks including False Klamath Rock and their associated near shore habitats are highly utilized harvest areas for shellfish such as marine mussels and Martha Washington clams which may have thinning shells due to ocean acidification. This makes them vulnerable to prey.





Other marine shellfish include dogwinkles & marine snails, seen above, as well as limpets and various clams. Note small chiton amongst the dog winkles in picture above.

Recent times have seen an increase in wind-driven upwelling along the California coast although there may be spatial nuances to this increase (Snyder et al. 2003; Jacox et al. 2014). For example, one study found upwelling increases throughout much of the CCS within 31 miles (50 km) of the coastline but trends differ further off shore (Jacox et al. 2014).

[14]pH is a scale from 0 to 14 used to indicate how acidic or basic an aqueous solution is. Values below 7 are acidic. Values equal to 7 are neutral, and values greater than 7 are basic. The pH scale is logarithmic, which means, for example, that a pH value of 2 is ten times more acidic than a pH of 3 and 100 times more acidic than a pH of 4. Similarly, a pH value of 10 is ten times more basic than a pH of 9 and 100 times more basic than a pH of 8

Potential climate change effects on upwelling are uncertain. According to one hypothesis, because warming trends are anticipated to be stronger inland versus over the oceans, temperature and associated atmospheric pressure gradients will increase, driving more intense winds. This would increase upwelling (Bakun 1990; Jacox et al. 2014). However, warming ocean temperatures could also lead to greater thermal stratification in which lower density, warmer waters remain on top, which could inhibit upwelling and mixing of the water layers (Harley et al. 2006; Jacox et al. 2014).

Coastal Dead Zones

Coastal dead zones are areas with low (hypoxic) or no (anoxic) oxygen. Dead zones result in fish kills as well as the mortality of other marine organisms including less mobile bottom-dwelling species such as starfish and sea cucumbers (PISCO 2008; Gewin 2010). They can also cause more subtle effects such as changes in species' community structure, the alteration of traditional marine organism migration routes, and a reduction in livable habitat (CENR 2010). The number of coastal dead zones is increasing, with more than 400 systems now being affected worldwide (Diaz and Rosenberg 2008). In 2007, the Oregon-Washington shelf dead zone covered approximately 3,320 square miles making it the second largest along the continental U.S. (CENR 2010).

Hypoxic events have occurred off the coasts of Oregon and Washington, some within approximately 150 miles of the Klamath River Estuary (Chan et al. 2008). However, these events seem to be driven by changes in the wind patterns that bring deeper, nutrient-rich but oxygen-poor waters to the surface (Gewin 2010).

Higher rates of nutrient[15] inputs (such as from agricultural operations, industrial waste discharges, or urban runoff) are one of the main drivers of this coastal dead zone rise (Diaz and Rosenburg 2008; CENR 2010).

Starfish are often killed by low oxygen conditions in coastal dead zones. The traditional food, *met-knoh* or gumboot chiton/China slipper (Cryptochiton stelleri) lives in the same habitat and may also be at risk.

In the future, climate changes could contribute to the formation of hypoxic areas through various mechanisms (Altieri and Gedan 2015):

- Warmer water holds less oxygen.
- Warmer water could increase the metabolic oxygen demand of marine organisms.
- Warmer water could decrease water column mixing of surface with bottom waters), contributing to oxygen stress.
- Impacts from increases in storm intensity are being debated; could either contribute to increased nutrient loadings that contribute to the reduction of oxygen, or they might help oxygen stress by mixing the water column.

In terms of the shifts in oceanic and atmospheric conditions leading to the hypoxia off the Oregon and Washington coasts, these seem to be consistent with projected climate changes (PISCO 2008; NSF 2009). However, there are not enough data available to conclusively predict climate change impacts on the many different processes that contribute to coastal dead zones (Gewin 2010).

[15] The naturally occurring nutrients in these waters help make west coast fisheries extremely productive. However, if the winds and upwelling persist with no slack periods, phytoplankton blooms may result from excess nutrient inputs. As the phytoplankton die, their decomposition uses up oxygen in the water. The persistence of upwelling also prevents higher oxygen surface waters from mixing with and replenishing lower oxygen bottom waters. This combination can lead to oxygen deficits and hypoxia (Gewin 2010).

3.5 Changes in Inland Stream and Groundwater Hydrology

Klamath River Flows

Shifts in flows are of concern to the Yurok as they see the connections between all organisms, such as people, fish, deer, elk, bobcat, and salamanders to water. Traditionally, the flow regime of the larger Klamath River mainstem and its major Upper Basin tributaries has been dominated by the seasonal melting of snowpack and is thus characterized by a springtime pulse in flow followed by a drop to baseflow levels from groundwater and springs with occasional inputs from summer storms (NRC 2004). Warming air temperatures are impacting snowpack (Sec. 3.2) and declines are being observed both worldwide and in California with more winter precipitation falling as rain rather than snow, earlier snowmelt, and lower spring snowpack (Cayan et al. 2008; Walsh et al. 2014). With air temperatures projected to continue rising, these trends are expected to continue into the future and affect streamflows (Barnett et al. 2005; Reclamation 2011), however due to the multiple dams within the basin, flows are currently controlled by reservoir releases.

Table 3.6 Key Points on Stream and Groundwater Hydrology

Primary Climate Effect	Secondary Stressor	Potential Impacts
Warmer Air Increasing Drought	More winter rain & less snow Decreased snowpack Increased summer water demands	Increased winter flooding; Lower spring & summer flows
Heavier Downpours	Increased surface runoff	Increase in winter flooding > channel enlargement & incision > increased turbidity

- Future Change to Flows

More winter precipitation falling as rain rather than snow is expected to increase streamflows during the winter (Reclamation 2011) which is already the regime in the Lower KLamath Basin and can be expected to be intensified. A reduction in snow would lead to less runoff in the late spring through late summer. Warmer air temperatures, with either the same or reduced precipitation, would lead to greater evaporation and possibly greater transpiration as well, potentially also contributing to lower summertime streamflows (Reclamation 2011). Because these hydrologic changes are attributable to rising air temperatures, these projected trends are considered more robust than changes attributed to precipitation projections alone as precipitation projections have more uncertainty associated with them (Hayhoe et al. 2004). The Bureau of Reclamation, California Department of Water Resources and the Oregon Water Resources Department are partnering to conduct a Klamath River Basin Study in which future water supply and demands are being projected taking into account climate change (USBR 2015; USBR 2017). As of the writing of this plan, an administrative draft has been completed and has been submitted to undergo the review process[16]. This study could be a source of information for future plan updates. With the multiple social and political controls and drivers in the Basin it is difficult to project how climate change will impact flows within the Lower Klamath Basin.

[16] Personal communication with Arlen Nickel, Senior Project Manager, Bureau of Reclamation on March 9, 2017.

Drought

Droughts are a recurring climate feature that occur in most parts of the world (Dai 2011). They can last from weeks to years and are the result of precipitation deficits (Dai 2011). Other factors, however, such as humidity and wind can play important roles. In a study of droughts in California, for example, researchers found that droughts were almost twice as likely to occur when dry conditions coincided with warmer than average air temperatures (Diffenbaugh et al. 2015). As droughts persist they can result in soil moisture deficits, extremely low streamflows, lowered groundwater tables, and increased wildfire risk (Diffenbaugh et al. 2015). In California, the occurrence of drought years over the past two decades has been greater than during the preceding century (Diffenbaugh et al. 2015). According to the Yurok Hazard Mitigation Plan, some droughts affecting the Yurok Reservation region include those during 1929-34, 1975-77, and 1987-92 (YT 2013).

What was a rushing creek turned into a dry, rocky gulch in the late summer early fall of 2015. Many wetlands, catchments, springs and drinking water sources went dry during recent droughts.

Drought and associated low flows were identified as contributing factors during a September 2002 event in the Klamath River during which over 33,000 adult salmon and steelhead were killed (CDFG 2014). Both California as a whole and the Yurok ancestral territory are emerging from what has been a severe multi-year drought. For some locations in California, this drought began in 2012 and is continuing into 2018. Data analyzed through the end of 2015 indicate that 2012-15 was California's driest and warmest four consecutive year period on record (He et al. 2017). According to the U.S. Drought Monitor, the Yurok ancestral territory was in some state of drought from the end of April 2013 into March 2016 (NDMC 2017). Yurok country then had abnormally dry conditions during the summer of 2016 and since October 2016 has been drought-free. Yurok elder Frank Lara noted, "I've never seen it like this. Dry, dry, dry."

Working on this climate adaptation plan in the midst of a severe multi-year drought, a number of Yurok tribal members and resource managers noted various associated impacts. One of the most concerning was the drying up of creeks and springs, in particular upriver, with implications for both drinking water and fish. Tim Hayden, Natural Resources Division Lead, discussed how there is no longer enough water to go around as a result of the drought and growing demand.

- Future Change to Droughts

A 2015 study notes that climate change is expected to increase the probability that precipitation deficits and warmer temperatures will co-occur in California, which would likely increase drought intensity in California (Diffenbaugh et al. 2015). Considering the impacts already felt after the recent droughts during this decade (2010-217), this is of concern to resource managers and community members alike.

Floods

Like droughts, floods are a recurring climate feature. However, they occur when there is a rise in surface water levels, often from an overwhelming amount of precipitation and impacts that can often be tied to the effects of drought. Drought can bake the earth to become nearly impenetrable bricks that cannot absorb water. Then as a result of run-off from heavy downpours, or the sudden melting of snow, or a combination of both the normal channels of the mainstem Klamath River or the smaller creeks and streams cannot confine or hold the volume of water. This then forces a rise in water levels and as it spreads over the landscape, flooding.

According to the Yurok Hazard Mitigation Plan, the lower and middle sections of the Klamath River are particularly vulnerable to flooding (YT 2013). Two types of flooding have typically occurred: rain and snowmelt-driven floods. Nearly all of the most damaging floods have been rain-based ones during the November-March timeframe resulting from storms lasting several days. Many of the floods in relatively more recent times seem to have happened around Christmas time or New Year's Day notes Senior Fisheries Biologist, Mike Belchik. He also points out that in some of the floods, rain on snow events have been implicated. Significant floods on the Yurok Reservation in the 20th century are listed below (YT 2013).

Historic postcard showing what was downtown Klamath during the 1955 flood that devastated most of the area.

- ***December 1955 flood***: More than 1,000 residents on the Reservation were forced to evacuate. The Pecwan School, Martin's Ferry Bridge, and Klamath Bridge were washed away.
- ***December (Christmas season) 1964 flood***: Over 98% of Klamath was destroyed. This included all of downtown Klamath and a school being swept away. In Klamath Glen, 60% of homes were destroyed. Sediment washed down by the floods "effectively filled all of the pools in the South Fork of the Trinity River," notes Fisheries Biologist Barry McCovey and may have contributed to the decline of sturgeon in that location. Elder Allen McCovey remembered that there was a lot of snow before the flood and "then a warm rain…[that] washed everything out."
- ***December 1996 - January 1997 flood***: Rain-on-snow was implicated in this flood as well with unusually warm rains causing widespread melting of an above average snowpack. A power substation was inundated leaving Klamath residents without power for days.
- ***December 2005 – January 2006 flood***: Flooding from heavy rains closed down portions of U.S. Highway 101 in Yurok country. Flooding on the Reservation also occurs because of unplanned releases from dams located near the Reservation (YT 2013).

- Future Change to Flooding

With climate change, the shift in winter precipitation from snow to rain may potentially result in more rain-based floods in the Klamath and its major tributaries during the wintertime. At the same time, the snow to rain shift will likely mean fewer and less intense snowmelt-driven floods during the spring and early summer (Gershunov et al. 2013). In addition, rain-on-snow events may become more likely with climate change (YT 2013). As has been observed historically in Yurok country, sometimes if heavy rain is combined with extensive snowmelt at the same time, this can lead to severe flooding (McCabe et al. 2007). A 2007 study showed that in the Western U.S., the frequencies of rain-on-snow events were increasing at higher elevations (McCabe et al. 2007). The study also showed that such events were decreasing at lower elevations because snow wasn't lasting as long at lower elevations due to warming temperatures. In addition to shifts in precipitation from snow to rain, as noted above, an increase in heavier downpours is anticipated and this too may contribute to increased flooding.

3.6 Changes in Water Quality

Surface Water Temperatures

Mean monthly water temperatures in the lower Klamath River range from 37- 43 °F in January to 68 - 73 °F in July or August (Bartholow 2005). Currently this is the only portion of the river accessible to salmon. Maximum summertime temperature in the part of the Klamath River below its confluence with the Trinity River may be as high as 80 °F for up to 10 days per year (Bartholow 2005). These 80 °F days are already exceeding both chronic and acute salmonid[17] temperature thresholds (Chapter/ Ch. 6).

Table 3.7 Key Points for Water Quality

Primary Climate Effect	Potential Impacts
Warmer Air	Increasing air temperatures and the resulting increases to evaporation decrease water quantity/availability.
Increasing Drought	More intense droughts can concentrate contaminants in creeks and other water bodies.
Warmer Water	Warm water temperatures make conditions better for both marine & freshwater harmful algae as well as flat worm growth & proliferation.
Heavier Downpours	Heavier downpours increase run-off and move pollution and nutrients into creeks, rivers, and marine waters.
Rising Sea Level	Potentially decreasing efficacy of coastal septic systems that will allow septic discharge into surface waters

Water temperatures in the lower Klamath River below Iron Gate Dam are rising. According to one study, for the 40-year period from 1962-2001, annual average water temperatures likely increased by about 3.6 °F (Bartholow 2005)[18]. In addition, there was a 36 day increase in the number of days during which daily average temperatures exceeded the 59 °F chronic salmonid threshold. Suitable cold water salmonid habitat in the river decreased by approximately 20.4 miles[19].

The changes in water temperatures did not appear to be related to changes in water availability. Instead, they were consistent with air temperature changes in the Klamath Basin. The Pacific Decadal Oscillation may have been a contributing factor. The recent 2013-16 drought in Yurok country also contributed to extremely warm water temperatures that were associated with low flows. Yurok Fisheries Biologist, Sarah Beesley described water temperatures as being hotter than she had ever seen them in 16 years. Yurok tribal member, Micah Gibson, former assistant director of the Yurok Water Division, described how water temperatures both reached higher peaks and did so earlier in the year. Whereas it used to reach 70 - 72 °F at monitored locations, temperatures sometimes reached as high as 79 °F and this was occurring in late June or early July as opposed to August or September. High temperatures were sustained until almost October. Another major issue was that there was only a 1 - 1.5 °F decrease at night, not providing any relief for the fish.

[17] The fish in the salmonid family include salmon and trout.
[18] These results are from a study using a water temperature model that incorporated observational data and estimated missing data.
[19] Suitable cold water habitat is defined as habitat having daily average summer water temperatures below the 59 °F chronic salmonid threshold.

- Future Change in Water Temperatures

In the future, rising air temperatures, changes in seasonal runoff, lower flows from drought, and potentially increasing reservoir evaporation could all contribute to rising stream and lake temperatures (Delpla et al. 2009; Kaushal et al. 2010; Udall 2013). Yurok Fisheries Biologists, Mike Belchik and Tim Hayden are also concerned about the loss of snow as a source of cold water.

Water temperatures do not increase linearly with air temperatures. Instead, processes such as evaporative cooling, which also increase with stream temperature, can cause temperatures to start to level out. Nevertheless, it is possible for temperatures to reach 86 °F or higher (Mohseni et al. 2002; Bartholow 2005).

Low flows and still water not only offers good habitat for Harmful Algal Blooms but allows surface waters to warm and the concentration of contaminants to increase.

Dam Removal

Tribal members and resource managers noted during a workshop that if snow pack is going to be lost, then dam removal is one of the most important responses to climate change. With the signing of an amendment to the Klamath Hydroelectric Settlement Agreement last year in 2016, the removal of four dams from the Klamath River in 2020 currently seems to be on track (Ch. 1).

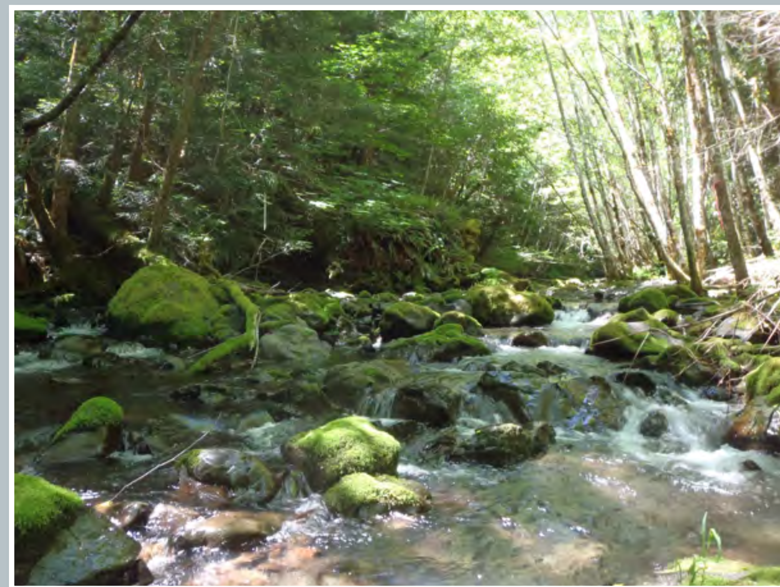
A 2005 US Geological Survey (USGS) study investigating the dam removal effects on Klamath River temperatures and salmon, shows that the dams typically deliver warmer than recommended water during salmon's fall upstream migration and spawning period (Bartholow et al. 2005). The removal of dams would then benefit salmon during this adult life stage. However, the dams also typically deliver cooler water during the spring and early summer. Their removal might result in warmer water than currently experienced by juvenile salmon during the period when they are growing and out-migrating, thus potentially having some detrimental thermal effects during this life stage. Thermal changes are greatest in those reaches of the Klamath River closest to the current reservoir locations and decrease in a downstream direction (Bartholow et al. 2005).

A second 2011 USGS study investigated both the effects of dam removal by itself and dam removal in combination with climate change on the Klamath River's temperatures (Perry et al. 2011). The study shows similar results to the 2005 USGS investigation. When only dam removal is considered, the study results indicate that dam removal would lead to a 3.6-7.2 °F decrease in river temperatures near the Iron Gate Dam during October and a 1.8-3.6 °F increase during May. Again, temperature changes are less in the lower reaches within Yurok Territory.

When climate change is considered, by 2061, mean decadal water temperatures along the Klamath River were 1.8 - 4.1 °F greater than those during the 1961-2009 timeframe (Perry et al. 2011). At the current Iron Gate Dam location, mean annual water temperatures with the dams removed were about 1.8 °F less than those with dams remaining in place. Below Scott River, however, there was little difference between the dams-in and dams-out scenarios.

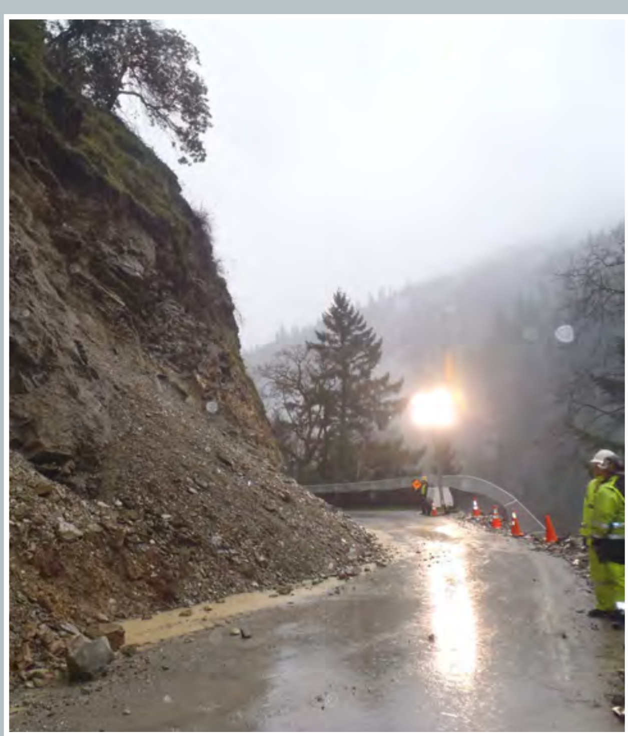
Groundwater Quality

The effects of climate change on groundwater systems are not well understood (Taylor et al. 2013). However, in general, it seems that saltwater intrusion into coastal freshwater aquifers is likely to occur (i.e., the movement of saltwater into freshwater aquifers) (Green et al. 2011; Taylor et al. 2013). Factors potentially contributing to this may include sea level rise, storm surges, changes in recharge, and very importantly, increased groundwater pumping from coastal aquifers. This increased pumping could result from increased irrigation water demands as air temperatures rise as well as demands from population growth and other factors (Taylor et al. 2013). Increased groundwater pumping could also potentially allow poorer-quality groundwater to leak into upper layers (Green et al. 2011).



Changes to riparian vegetation through fire, drought, or other impacts and activities can alter shading that cools water temperatures.

Other Anticipated Water Quality Changes



In 2015, the first heavy winter rain storm wasn't until February. After years of drought, this storm generated over a dozen landslides and road slips that carried sediments and any associated contaminants into the Reservation's surface waters, both creeks and the mainstem of the Klamath River.

Warmer water holds less oxygen and could thus lead to dissolved oxygen decreases in aquatic ecosystems (Murdoch et al. 2000). Increasing rain events associated with shifts in winter precipitation from snow to rain, associated increasing wintertime floods, potentially increasing rainfall intensities, and greater wildfire frequency and areal extent could all contribute to increases in turbidity and sedimentation aquatic systems (Cromwell et al. 2007). These same factors could also contribute to higher pollutant loadings if rains wash nutrients, contaminants, waste, and sediments into surface waters, and if flooding overwhelms wastewater treatment capabilities (USEPA 2014). Storms that follow long dry periods could result in particularly high loadings. Heavier precipitation events could also lead to increases in the occurrence of waterborne diseases such as Giardia and Cryptosporidium, which can be transmitted through drinking water or recreational use (Hunter 2003; Karl et al. 2009). This can occur because heavier rainfall can cause water to flow through new pathways (Hunter 2003).

3.7 Changes in Fire Regimes

Fires are of concern to water quality because of potential associated increases in turbidity and sedimentation (Cromwell et al. 2007). Between the 1970s and 2005, the annual average reported burn area of forest fires increased by approximately 300% (Corringham et al. 2008; Wilder et al. 2013). Reduced precipitation, along with past land management of wildfire suppression, have contributed to the unprecedented size of fires in the U.S. during the past decade (Steenburgh et al. 2013).

According to the California Department of Forestry and Fire Protection (January 2018), the top five fires and 14 of the 20 largest wildfires recorded in California in terms of acres burned have occurred since 2002 (CAL FIRE 2018b). Fires in Siskiyou and Trinity Counties in northern California are on the top 20 list (CAL FIRE 2018b). More recently, there have been a number of fires in or adjacent to Yurok country including those listed below (CAL FIRE 2018a).

- **Oct. 2009**: Wilson Fire - 5 miles north of Klamath - 265 acres
- **Oct. 2012**: Arrow Complex Fire – Blue Creek, southeast of Klamath – 90 acres
- **Sept. 2014**: Bald Hill 3 Fire – 1 mile northwest of Hoopa – 210 acres
- **June 2015**: Bald Fire – off Bald Hills Rd., 15 miles east of Hwy 101, Orick – 20 acres
- **July 2015**: Queen Fire - 5 miles southeast of Pecwan – 158 acres
- **Aug. 2016**: Tully Fire – off of Hwy 169 and Martin's Ferry Rd, near Weitchpec, 599 acres. This fire was found to have been started by arson.
- **July 2017**: Marble Fire - Six Rivers National Forest – 319 acres
- **August 2017**: Translator Fire – Hoopa Valley Indian Reservation – 40 acres.

- Future Change to Fire Regimes

In the future, rising air temperatures are expected to lead to earlier snowmelt and thus longer growth seasons for vegetation that produces fuel and longer fire seasons. In forested areas in the west, higher temperatures, increased drought, and longer fire seasons are all expected to increase wildfire frequency and size (Brown et al. 2013; Fleishman et al. 2013). Several studies have projected future fire regimes in the Pacific Northwest and in northern California. Results from two of these project:

Westerling et al. study (2011)[20]: This study considered lower and medium-high emissions scenarios and several population growth and development scenarios. The study projected that by 2085, the forest burned area in northern California would increase by at least 100%.

Spracklen et al. study (2009)[21]: This study considered a medium emissions scenario and projected a 78% increase in annual mean burned area in the Pacific Northwest by the 2050s.

More intense fires are expected as both vegetation and the air surrounding it warms and moisture decreases

[20]This study made use of the output from three General Circulation Models and of the B1 (lower) and A2 (medium-high) emission scenarios. The change projected is that relative to a 1961-1990 reference period.

[21]This study made use of the output from one General Circulation Model and of the A1B (medium) emissions scenario. The change projected is that relative to a 1996-2005 reference period.

3.8 General Ecosystem Changes That May Occur

Changing climatic and hydrologic conditions drive ecosystem changes. As a framework to think about those changes, we present general categories of changes that may occur or be accelerated by climate change. These include:

- Habitat loss and conversion (Mawdsley et al. 2009; NFWPCAP 2012)
- Shift in species' geographic ranges (often polewards or either upward or downward along elevational gradients) (Mawdsley et al. 2009; Tillman and Siemann 2010)
- Changes in population sizes (Mawdsley et al. 2009; NFWPCAP 2012)
- Effects on survival and reproduction (Mawdsley et al. 2009)
- Changes in phenology (timing of life cycle events) (Tillman and Siemann 2010)
- Mismatches in ecological relationships (Mawdsley et al. 2009; NFWPCAP 2012)
- Increased spread of invasives or non-native species (Mawdsley et al. 2009)
- Increased spread of wildlife diseases, parasites, and zoonoses (diseases transmitted from animals to humans) (Mawdsley et al. 2009; NFWPCAP 2012)
- Changes in stratification (persistence or non-mixing of different layers of water within for example a lake) and eutrophication (excessive richness of nutrients) (Murdoch et al. 2000, Tillman and Siemann 2010)
- Altered nutrient cycling and productivity (Tillman and Siemann 2010)
- Increased size and duration of harmful algal blooms (HABs) (Paerl et al. 2011; O'Neil et al. 2012).

Many of these changes are discussed in more depth in subsequent chapters, however, in general with rising air and water temperatures, the Yurok Tribe may expect to see changes in the local ecosystems. Species composition is of particular concern as cool water-adapted native species may be out-competed by those that have higher tolerances and affinity for warmer water. Of critical concern for the Yurok are possible damage to and loss of anadromous fish such as salmon and sturgeon.

Also, as noted above, phenology is the study of the timing of life cycle events and is something that the Tribe has done since time immemorial. For example, Walt McCovey Jr., Yurok elder, explained how when the mulberry bush blooms, sturgeon are supposed be in the River and when the dogwood blooms there is spring salmon in the River and it is the end of eel season. On the Yurok Reservation, community members have already noted changes in phenology. For example, seaweed is being collected one month earlier than in the past and flowers are blossoming earlier instead of coinciding with fish runs.

A final ecosystem response to climate change that is of great concern to Yurok is the already occurring increase in toxic algae species that rapidly respond to warmer conditions with often massive growth and become harmful algal blooms (HABs) that can impact the health and wellbeing of Members (Glibert et al. 2005). HABs are discussed more in the next section.

3.9 Changes in Harmful Algal Blooms

When some algae reproduce in large numbers they may cause problems and form what is known as a harmful algal bloom (HAB) (Glibert et al. 2005). In some cases, problems result from the sheer biomass of the bloom, which can lead to low oxygen conditions when the algae decompose. This can contribute to the coastal dead zones described in Section 3.4 above. In other cases, blooms are harmful because the algae produce natural biotoxins that can cause human illness and death as well as kill pets, livestock, fish, shellfish, and other wildlife (Glibert et al. 2005; Paerl et al. 2011). HABs occur in both freshwater and marine environments.

Blue-green algae, or cyanobacteria, can produce a wide range of more than a hundred compounds including hepatotoxins (affecting the liver), neurotoxins (affecting the nervous system), and dermatotoxins (causing skin irritation). These toxins, cumulatively known as cyanotoxins, are a growing public health and environmental threat for both aquatic and terrestrial life (Merel, et. al 2013)[22]. One cyanotoxin of particular concern in Yurok country is microcystin, produced by species of *Microcystis* which typically occurs in freshwaters (Ch. 7). However, its expansion into estuarine and coastal marine waters is starting to be documented in locations around the world including the Klamath River Estuary (Preece et al. 2017). This may be due in part to the ability of some cyanobacterial cells to remain dormant and survive for extended periods in sediments until favorable conditions occur. Genetic fingerprinting has shown that the Iron Gate reservoir is the source of the downstream *Microcystis*, indicating that *Microcystis* can survive passage through a hydroelectric dam and downstream transport that can be greater than 186 miles (300 km) (Otten et al. 2015). Currently, microcystin levels unsafe for humans occur regularly in the Klamath River, its reservoirs, estuary and periodically in local coastal waters such as the lagoons in Yurok Territory.

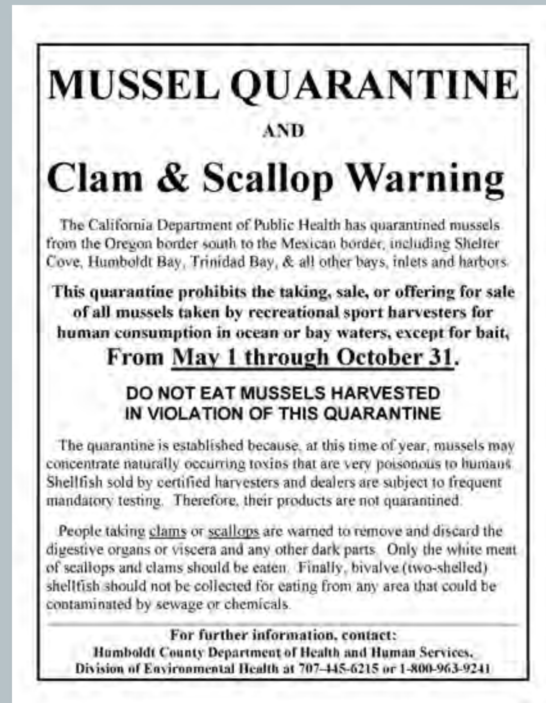
HABs have over 80 associated toxins depending on the species make upof the bloom. These can impact Tribal Members' health from exposures during recreational use of the River, as well as commercial and subsistence fishing, as well as cultural and ceremonial uses. In the picture above you can see the 'pea-soup' green of the Klamath River as it passes the ceremonial dance-grounds of Sregon during the HAB event of 2014.

Microcystin Warning

[22] Microcystins are carcinogenic to the liver and general tumor promoters (increasing number and mass of tumors) and can cause headaches, abdominal pain, vomiting, nausea, diarrhea, and blistering around the mouth.

[23] When people consume shellfish contaminated with PSP toxins, they can experience symptoms ranging from a slight tingling or numbness to respiratory paralysis (WDOH 2015dl). If levels are high enough, PSPs can be fatal (WDOH 2015dl).

In marine waters several problematic species exist; a diatom that produces the neurotoxin domoic acid (DA), that is responsible for the neurological disorder known as amnesic shellfish poisoning (ASP) and a dinoflagellate algae that produces red tides and the associated paralytic shellfish poison (PSP) [23](Ch. 7). These toxins are present not only in the water but are bio-accumulated in the heavily utilized local shellfish such as the freshwater, river and marine mussels, making them unfit to eat (Ch 7). The Yurok Tribe works in partnership with the California Department of Public Health to test the marine mussels in Yurok Territory and notifies the public and Tribal Members of times when they become unsafe. During algal blooms, the concentration of biotoxins may increase dramatically simply because the shellfish are filter-feeders and consuming more of the toxic algae.



MUSSEL QUARANTINE

AND

Clam & Scallop Warning

The California Department of Public Health has quarantined mussels from the Oregon border south to the Mexican border, including Shelter Cove, Humboldt Bay, Trinidad Bay, & all other bays, inlets and harbors.

This quarantine prohibits the taking, sale, or offering for sale of all mussels taken by recreational sport harvesters for human consumption in ocean or bay waters, except for bait,

From May 1 through October 31.

DO NOT EAT MUSSELS HARVESTED IN VIOLATION OF THIS QUARANTINE

The quarantine is established because, at this time of year, mussels may concentrate naturally occurring toxins that are very poisonous to humans. Shellfish sold by certified harvesters and dealers are subject to frequent mandatory testing. Therefore, their products are not quarantined.

People taking clams or scallops are warned to remove and discard the digestive organs or viscera and any other dark parts. Only the white meat of scallops and clams should be eaten. Finally, bivalve (two-shelled) shellfish should not be collected for eating from any area that could be contaminated by sewage or chemicals.

For further information, contact:
Humboldt County Department of Health and Human Services, Division of Environmental Health at 707-445-6215 or 1-800-963-9241

- Future Change in HABs

The number and intensity of harmful algal blooms (HABs) worldwide is on the rise in both marine and freshwater ecosystems (O'Neil et al. 2012). Climate changes such as warming water temperatures, rising carbon dioxide levels, and increasing salinities may interact with non-climatic factors to continue this trend (Paerl and Paul 2011; O'Neil et al. 2012). These non-climatic factors can include nutrient enrichment, human transport of algae between different water bodies, and changes in food webs due to aquaculture and overfishing (Paerl and Paul 2011; O'Neil et al. 2012).

The marine HAB event in 2012 turned the waves a reddish-brown color, a classic 'red-tide' and resulted in the closure of shellfish harvesting along the coasts of three states; Washington, Oregon, and Northern California.

In addition, drought leading to low flow conditions has already contributed to localized HABs in downriver access areas, boat ramps, parks, and the Klamath River Estuary, and this is anticipated to continue with climate change. If HABs occur during late spring or at the end of summer/early fall, they can coincide with fishing seasons, contribute to increased risk of toxin exposures to both Tribal and community members as well as visiting tourists and recreational fishing. Yurok resource managers and communities are concerned about possible implications for both human health and economic impacts and consider that the toxins released from HABs may possibly be the most relentless periodic and possibly harmful of the contaminants in the Klamath Basin.

3.10 References

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Additional Information

- Institute for Tribal Environmental Professionals (ITEP) at Northern Arizona University established its Tribes and Climate Change Program in 2009. The program provides support for and is responsive to the needs of tribes who are preparing for and currently contending with climate change impacts. For more information, please visit our website at: http://www7.nau.edu/itep/main/tcc.
- "Guidelines for Considering Traditional Knowledges in Climate Change Initiatives," A resource for tribes, agencies, and organizations across the United States interested in understanding Traditional Knowledges in the context of climate change: https://climatetkw.wordpress.com/
- "The Climate and Traditional Knowledges Workgroup – CTKW" is an informal group of indigenous persons, staff of indigenous governments and organizations, and experts with experience working with issues concerning traditional knowledges who developed a framework to increase understanding of access to and protection of TKs in climate initiatives and interactions between holders of TKs and non-tribal partners: https://climatetkw.wordpress.com/
- Additional Chapters of the Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources can be found on the Yurok Tribe Environmental Program's Community and Ecosystem division webpage at http://www.yuroktribe.org/departments/ytep/com_eco_division.htm

Yurok Tribe Climate Change Adaptation Plan for Water & Aquatic Resources

Chapter 4 – Aquatic Habitats

In This Chapter

This plan is from a purposeful collaboration with the staff and community members of the Yurok Tribe, as well as several organizations, and would not have been successful without each of their contributions. Funding was made available through the US EPA Science to Achieve Results (STAR) Program, Grant # 83560401-0. Online files available at: https://www.yuroktribe.org/departments/ytep/

There was just prairie and Thunder said to Earthquake, "I want to have water there so people can live...Thunder ran in the sky and helped by breaking down the trees and Earthquake ran and sank the ground...The Earth quaked and water flowed over it as Kingfisher and Earthquake poured it from their abalone shells... As they filled in the ocean, the creatures which would be food swarmed into the water... Earthquake sank the land deeper to make gullies and the whales came swimming through the gullies where the water was deep enough for them to travel. The salmon came running through the water... Now the water creatures were there. Now Thunder and Kingfisher and Earthquake looked at the ocean. "This is enough," They said. "Now the people will have enough to live on. Everything that is needed is in water."

– How Thunder & Earthquake Made Ocean, Yurok Myth

The headwaters of the Klamath River arise in southern Oregon at the base of Upper Klamath Lake (Benke and Cushing 2011). The river then flows into northern California where four main tributaries – the Shasta, Scott, Salmon, and Trinity Rivers – enter the Klamath mainstem, providing over 40% of the mean annual flow (BOR 2016). The Trinity River, the largest of these, joins with the Klamath near the Yurok community of Weitchpec. At the confluence of the Trinity and Klamath Rivers, the Klamath turns north moving 44 miles through Yurok territory before discharging into the Pacific Ocean near Requa.

Along its journey from Upper Klamath Lake to the ocean, the Klamath River travels over 250 miles, draining a nearly 16,000 square mile (10,000,000 acre) watershed that has been inhabited by Native peoples for thousands of years, including the Yurok. Today, the Yurok inhabit the most downriver part of the lower basin. While the 85 square mile Yurok Reservation currently spans a one-mile stretch of land on each side of the Klamath River from Weitchpec to the Pacific Ocean, Yurok ancestral territories stretch far beyond (Yurok Tribe 2007).

Mussel harvesting with Traditional Burden Basket

Chapter citation: Cozzetto K[1], Maldonado J[1], Fluharty S[2], Hostler J[2], Cosby C[2] (2018) Chapter 4 – Aquatic Habitats. In *Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources*. [1] Institute for Tribal Environmental Professionals (ITEP), Northern Arizona University, Flagstaff, AZ.
[2] Yurok Tribe Environmental Program (YTEP), Klamath, CA.

At one time, the Yurok had over fifty villages at both coastal and river locations extending along the Pacific Ocean north towards Damnation Creek and south towards Little River and also extending inwards and upriver towards Bluff Creek (NRC 2004; Yurok Tribe 2007). The Yurok made use of the gifts provided by the various habitats in the region - by the Klamath River and the tributaries that feed into it, by various estuaries along the coast, by the ocean, and by a land that traditionally has been characterized by Douglas fir, tan oaks, and closed-cone pine forests in drier areas and by the majestic presence of redwoods in areas with fog and high moisture (Benke and Cushing 2011). These redwoods include some of the tallest, largest, and most ancient trees in the world and are considered by the Yurok to be sacred living beings standing as guardians over Yurok sacred places (Yurok Tribe 2007).

Traditional Yurok House

Although each habitat is important to the Yurok people – marine waters, freshwater, terrestrial, and air – and are seen as part of an interconnected and integrated whole, in this chapter we focus on aquatic habitats in the Yurok ancestral territory, in particular (1) freshwater quantity, (2) channel form, (3) freshwater quality – cold water availability and access, (4) freshwater quality that is not temperature-related, and (5) estuaries and ocean. For each section, we start with a summary of climate change effects on each specific habitat. Next, we consider how non-climatic factors may increase or lessen climate change effects. Then we conclude with ways that Yurok managers, community members, and others have identified to increase the resilience and health of these aquatic habitats and ultimately the resilience and health of the Yurok people with whom the habitats are so inextricably linked.

4.1 Instream Flows

Traditionally, the flow regime in the Lower Klamath River Basin - or pattern of how much water is moving downstream - has been characterized by an increase in flow during the winter rainy season. In the mainstem, this is further increased by springtime snowmelt in the Upper Basin, which extends high flows into May. Then the flow regime decreases to lower baseflow provided by groundwater and springs with occasional inputs from summer storms (NRC 2004). However, flows in the Lower Klamath River Basin have been changing. Climate change is expected to exacerbate this with the low flow, dry periods becoming drier at the same time that rainstorms becoming heavier. Flow declines can contribute to problems for fish temperature thresholds and passage, and, as the recent 2013-16 drought showed, they can also negatively affect the ability of Yurok people to access drinking water from springs and creeks. Alternately, flow increases leading to flooding could scour fish eggs and degrade drinking water quality. Flows are also important at an even deeper level, "The river is like blood," noted one elder, "flowing through our veins."

> "You know we had that winter water from the Trinity that kept the river high. You know that was the main river for keeping the river high down here."
>
> – Raymond Mattz, Elder Interviews 2014

Climate Change Impacts on Instream Flows

Rising air temperatures that are a result of climate change can lead to decreased snowpack and earlier snowmelt (Chapter 3/Ch. 3). This, in turn, can result in reduced flows in the mainstem during the spring and summer. Additionally, rising air temperatures can lead to greater evaporation and possibly greater transpiration, and thus to increasing summertime water demands from, for example, forests, farmers, and marijuana growers (BOR 2011). Together with the increasing drought intensities expected under climate change, these various factors could contribute to lower summertime flows (Ch. 3).

Table 4.1 Key Impacts s on Instream Flows

Primary Climate Effect	Secondary Stressor	Potential Impacts
Warmer Air	More winter rain & less snow Decreased snowpack	Increased winter flooding; lower spring and summer flows
Increasing Drought	Increased summer water demands	
Increased Wild Fire	Reduced vegetation post-fire	Increased surface runoff > Increase in winter flooding > channel enlargement and incision > **increases in turbidity**
Heavier Downpours	→	
Combined Effects	Tree die-off from disease/ insects	Temporary increased flows

Because rising air temperatures can lead to more winter precipitation falling as rain rather than snow, they could also contribute to an increase in winter streamflows and possibly to more wintertime flooding, in particular, if rain on snow events result in extensive snowmelt (Ch. 3). Changes in precipitation amounts are less certain, however, when rain events do occur, their intensity may be greater and could also contribute to flooding (Ch. 3; Walsh et al. 2013).

With climate change and earlier snowmelt, the wildfire season is expected to be longer, and wildfires are anticipated to increase in frequency and extent (Ch. 3). This could play a role in streamflows. Reduced vegetation cover post-fire has been linked to snowmelt occurring earlier by 1-2 weeks because of greater exposure of the snowpack to sunlight and wind (Luce et al. 2012 p. 23). In addition, if fires are of higher intensity they can sometimes create water-repellant layers in soils, which can lead to temporary increases in rapid runoff (Luce et al. 2012 p. 21).

Climate change could also favor some forest pathogens and contribute to enhanced tree die-off from disease or insect outbreaks. Tree die-off could also contribute to higher flows. Some research suggests that in forests in which more than 20% of trees die and in which annual precipitation is greater than 20 inches, flows could increase because of declines in water being drawn in by tree roots and in precipitation being intercepted and evaporated from tree branches (Matonis 2013). Tree die-off could also further fuel wildfires in the heavily forested Yurok landscape affecting streamflows as described above.

Existing challenges (sensitivity)

The expected local climate changes will interact with already existing non-climatic stressors to impact flow regimes. These non-climatic stressors include historical and current legacies from dams, logging, fire suppression, and marijuana cultivation.

> *"Dams. The dams have changed the River…The natural flow of the River has been stopped by the dams. Not enough water flows through anymore, and the water has no strength. It is shallow."*
>
> - Fawn Morris, Elder Interviews 2014

Dams- instream flow management

Several large dams were constructed in the Klamath River basin between 1910 and the 1960s (Ch. 1). These were a part of (1) the Klamath Project to provide irrigation and land to farmers in the Upper Basin, (2) the Klamath Hydroelectric Project to provide power, and (3) the Trinity River Diversion to provide power and to divert water out of the Klamath River basin to farmers and municipalities in California's Central Valley (USFWS 1991; NRC 2004; NRC 2008; USGS 2017). All of these dam projects disrupt natural flows in the Klamath River system (NRC 2004; Powers et al. 2005; NRC 2008). For example, in the case of the Trinity River Diversion, approximately 51% of its flow that historically fed the Klamath River is transferred to the Sacramento River system (NRC 2008). In addition, notes Yurok Fisheries Biologist, Sarah Beesley, the dams associated with the Klamath Hydroelectric Project have led to the loss of floodplain soils downstream that help maintain the water table and groundwater flow into the tributaries.

Trinity Dam Release, 2014

https://www.kqed.org/news/146081/judge-rejects-bid-to-block-emergency-water-to-klamath-salmon

Current instream flow management for the dams poses a variety of issues to maintaining healthy water levels in the Klamath River basin for fish, other aquatic species such as frogs and turtles, wildlife, and for the Yurok people. Operations plans for the Klamath Project, for example, are based on water year (October 1-September 30) classifications (wet, above average, average, below average, dry) that may already be outdated, notes Yurok Fisheries Biologist Tim Hayden. The plans are also developed annually rather than for longer timeframes, which can make management difficult during times of extended, multiyear drought.

In addition, both Hayden and Yurok Fisheries Biologist Barry McCovey point out that water releases from the dams are often managed for specific endangered or threatened species, not ecosystems. This does not seem to work particularly well even for the species being targeted. Moreover, there are competing endangered species interests in different river segments on the Klamath and between the Sacramento and Klamath Rivers, which are linked because of the Trinity Diversion Project. So again, ecosystem-wide health does not seem to be considered from an Agency management perspective. Finally, notes Hayden, major demands for water from the Klamath River system come from "big" agriculture and municipalities that lie outside the Yurok Ancestral Territory and supersede the needs of the natural environment. In particular, during times of water shortage such as the recent 2013-16 drought, the river is often overallocated.

> "They're valuing the firs over the fish."
>
> – Yurok Cultural Fire Management Council Meeting

> *"It was more prairie than it is now. Even over across by Aunt Lizzy's over there where Olmo's have now. That's all grown up. It was more prairie like. It was all cleared and they planted grain over there. There were different places that was more prairies than how it is now. It's all grown in. Out where there was prairies, when the timber companies came in, I was told they planted trees in there."*
>
> - Bertha Peters, Elder Interviews 2014

Timber Production & Logging

Logging and an associated U.S.-wide policy of fire suppression, including prohibitions of cultural burning practices, have left their imprint on the balance between water used by forests for their growth and water stored by forests for release into groundwater, creeks and streams. This delivery of water into ecosystems may be in the form of slowed runoff of rainwater and snowmelt after storms or in the water held and percolated downward to become cool, groundwater baseflow that feeds streams on a more consistent, in-between storm basis (Matonis 2013). In a post-heavily logged world, Elders, community members, and resource managers, tell us that forests are not what they used to be. They remember open forests that you could walk through and in which prairies were an integral part of the overall forest landscape (Natural Resources Committee Meeting April 2015; Weitchpec Workshop 2 Feb. 2016; Cultural Fire Management Council Meeting Feb. 2016). Logging, the suppression of cultural burning, and fire suppression in general have contributed, in contrast, to forests that are often overstocked with trees and overgrown with brush.

Timber companies have systematically contributed to the loss of prairies by planting them with marketable, timber producing firs (Yurok Today 2012). For those prairies not planted over, fire suppression allowed trees to encroach into them, also leading to their loss (Yurok Today 2012;

Asarian and Walker 2016). One study showed that between 1875 and 1998, prairies in the Bald Hills at the eastern edge of Redwood Creek were reduced by 44% (Frishcle 2008). Furthermore, according to Councilman Tom Wilson, Sr., up to 85% of Yurok prairies across the ancestral territory have been lost (Yurok Today 2014). Additional studies in progress by YTEP indicate that the loss of these culturally and ecologically valuable habitats may actually be closer to 95%.

Upper Mawah Creek, dense brush and overstocking of trees leads to unhealthy forests and diminished water quality & availability.

These altered forests and prairies have contributed to major concerns that water yields to creeks may not be as high as they once were, resulting in lower flows and higher water temperatures (Sec. 4.3). Although the number of scientific studies on forest water yields in the region is limited, these together with international studies indicate that this is likely to be the case (Risley and Laenen 1999; NRC 2004; Farley et al. 2005; Smerdon et al. 2009; Asarian and Walker 2016; PPIC 2016). In terms of prairie conversion, on an annual basis, conifers evaporate the water captured on their needles throughout the year (Nisbet 2005). The evaporation of water captured on grasses however, tends to be low, leading to greater groundwater recharge, which ultimately contributes to streamflows (Farley et al. 2005; Nisbet 2005; Aranda et al. 2012; UK Forestry Commission 2017)[1]. Another concern is related to flow timing. During high precipitation periods, like winter rains, prairies can, for example, hold and store water in both the thick layer of dead and composting leaf mold and the rich upper layer of highly interconnected root zones. They then release it later on during low flow periods like summer (Podolak et al. 2015). Loss of this functionality could be detrimental in a warming world in which, summer flows are expected to decrease (Ch. 3). Managers with the Yurok Tribe Wildlife Program as well as community members also noted the need for prairies and meadows to support elk herds, smaller mammals, birds and other species important to Yurok such as edible bulbs and medicines.

Cannabis Cultivation (Marijuana)

Large-scale cultivation of Cannabis for marijuana products and the plants' associated water consumption is a relatively recent issue that has arisen in the Lower Klamath River watershed despite it being illegal to cultivate on the Yurok Reservation (Ch. 1). Yurok staff report that they have already seen an increase in illegal Cannabis grow operations on and off Reservation to supply both the local state medical market that opened up with the passage of the California Compassionate Use Act (Proposition 215) and for the black market that ships to the nearby states of Colorado, Washington, and Oregon where recreational use is already legalized. In addition, with the passage of California's Proposition 64 in 2016, making the growth and sale of recreational marijuana legal in the state starting in 2018, it is expected that marijuana production will continue to increase.

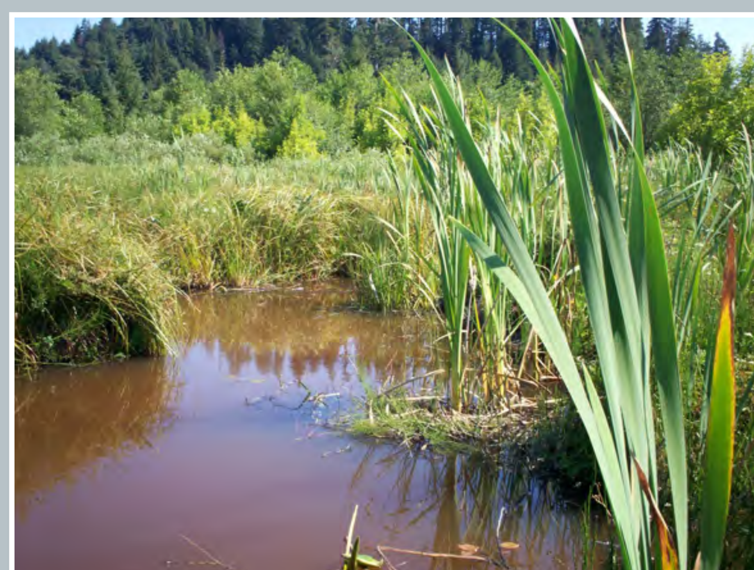
Large Scale Cannabis Grow Site

[1]For example, some studies indicate that dense forests may warm earlier, in the late winter/ early spring, decreasing snowpack water storage and that greater interception of precipitation and evaporation may occur than in non-dense forests (PPIC 2016). Other studies indicate that clearcuts planted with young regenerating stands of trees have high evapotranspiration rates in the decades following their planting, which can contribute to lower streamflows, although the initial clearcut would increase flows (Asarian and Walker 2016).

In addition to the many social and cultural problems and complaints from the Tribal community, marijuana has severely impacted the local environment. The California Regional Water Quality Control Board, North Coast Region reported in Order No. 2015-0023 that, “increased cultivation throughout the North Coast Region has resulted in significant waste discharges and a loss of instream flows associated with improper development of rural landscapes on privately-owned parcels, and the diversion of springs and streams, to the cumulative detriment of beneficial uses ofwater.” Primary among these impacts felt within Yurok Ancestral Territory is the dewatering of local springs and creeks as marijuana is a high water-use plant with each plant consuming an estimated five to six gallons of water per day averaged across the growing season (Bauer et al. 2015).

Based on aerial photographs, during 2015, approximately 34,550 marijuana plants were grown within the Yurok Reservation. Together these plants consumed an estimated 25 million gallons of water during the 4-month growing season (Appendix 4.1). This is enough water to supply 2,300 people on a daily basis using a typical U.S. per capita water consumption value of 90 gallons per day (USGS 2016a). These estimates are considered conservative given the presence of leaky irrigation lines and evaporation from makeshift storage pools found during Operation Yurok marijuana raids.

One critical concern arises from the fact that the outdoor Cannabis growing season, occurs over the same time period as the Klamath River fish runs and generates huge water withdrawals. During the 2013-16 drought when water levels were running low and water temperatures were running high, strong sentiments arose that “marijuana growers were stealing water from our fish” (Yurok Today 2014b). A recent study of Cannabis cultivation in Humboldt County also suggests the risk of streamflow impacts from water consumption due to Cannabis’ irrigation could result in the complete dewatering of streams (Butsic and Brenner 2016). Tribal concerns with the dewatering of watersheds range not only from their own human uses but also for all life, including the plants and animals of the area that are also dependent on the water. It is often expressed that marijuana growers have brought “un-balance” to the natural world, the importance of balance being a deeply felt cultural and ceremonial concept, central to Yurok beliefs.



Wetland Plants hold soils and filter contaminants, preventing them from entering waterways

Loss of wetlands

Wetlands are habitats that slow the movement of surface waters and allows water filtration. This acts not only to protect water quality but influences water flow and availability. Depending on their underlying geomorphology they can generate ponds, or act like a sponge to store rain, snowmelt, surface water runoff, and flood waters during the wetter winter/spring season and then slowly releases it during the drier summer months (Audubon Washington 2000; Pollack et al. 2015; USEPA 2018), or allow it to percolate and recharge groundwater aquifers. Wetland vegetation such as trees and root mats also slow surface water runoff and floodwaters (USEPA 2018). In combination with water storage this decreases the height of flood waters and lessens erosion (USEPA 2018). Wetlands along stream channels also provide areas of slower flow compared to the fast-moving water in the main channel. Young fish, amphibians, and turtles that utilize these wetland habitats expend less energy fighting the current and more energy feeding and getting big. In addition, wetlands can act as refuge for these young aquatic animals during floods so that they don't get swept away downstream (Audubon Washington 2000; Jones et al. 2005; Bury et al. 2012).

North America's largest rodent, beaver, build dams that help create and maintain wetlands (Pollock et al. 2015). Fish biologist Sarah Beesely noted that they are native to the basin and are currently present throughout the Lower Klamath, although their population status is unknown" (personal communication Feb.10, 2018). However, beaver populations are still recovering from their effective eradication in the Klamath basin during the early 1800s as a result of Euro-American fur trapping (Chapter 1).

Monitoring

Although the Yurok Environmental Program and Fisheries Department have been monitoring the mainstem Klamath River for decades, little work has been done on the numerous smaller tributary creeks that drain into the Reservation and are critical for both the health and welfare of the tribal membership and the continuation of the Klamath fisheries. Four Public Water Systems and over 200 households on the Reservation use these creeks and associated springs for the domestic and drinking water needs. The extended drought in California has strained the capacity of these creeks to provide sufficient flow and this has been exacerbated by water withdraws for marijuana production both on, adjacent to, and off Reservation in the headwaters.

The lack of monitoring on these numerous creeks is a severe problem in attempts to protect the water needs of the Tribe and of the local watershed environments, in particular in light of the California Water Resources Control Board Cannabis Cultivation Policy. This policy specifies that Cannabis growing operation cannot take greater than 50% of the wet season instream or high flow conditions. However, without monitoring and actual flow numbers, both the allocation of the waters and any enforcement for taking more than the allotted quantities has no supporting data.

Yurok Environmental Staff- monitoring flow of Pine Creek

Yurok strengths (adaptive capacity)

In addition to the challenges they face, the Yurok also have existing adaptive capacity to address the impacts on instream flows. Almost since the mainstem Klamath River dams were installed, the Yurok have been working to remove them. Despite a variety of twists and turns, the removal of four of the mainstem dams as part of an amended Klamath Hydroelectric Settlement Agreement (Ch. 1) seems to be on track for the year 2020.

Following the devastating fish kill in September 2002 (Ch. 1), the Yurok developed what is effectively a fish disease early warning monitoring program, says Yurok Fisheries Biologist Barry McCovey. If disease levels exceed certain thresholds, the Tribe relays this information to the Bureau of Reclamation's Klamath Project so that they can use this information to justify the release of greater flows, which are generally inhibited by the dams.

Another important instream flow tool that the Yurok have at their disposal are water rights that go back to time immemorial. The U.S. government reserved by necessary implication waters within Indian Reservation boundaries (Winters v. U.S. 207 U.S. 564) at the time of the establishment of the Yurok Reservation in quantities sufficient to sustain beneficial uses for the Yurok people. Although Yurok Reservation water rights are recognized, they have not yet been adjudicated and quantified. In addition with recently purchased lands including the Blue Creek Land Acquisition, the Yurok have received the associated private water rights (see Adaptive Capacity in Sec. 4.3).

Yurok Cultural Fire Management Council , 2017

Through the Blue Creek land acquisition in combination with their reservation lands, the Yurok have the opportunity to manage forests for clean water and water yields. Part of this management could incorporate cultural burns to restore prairies, which could have water quality and quantity benefits. The Yurok Cultural Fire Management Council is reintroducing the traditional Yurok practice in a modern context that comprises adaptive capacity in the form of Yurok knowledge passed from generation to generation.

Partners in Operation Yurok Enforcement Actions

As part of an effort to address the problem of illegal marijuana cultivation and water usage, the Yurok have partnered with a variety of California and federal agencies including the California National Guard and the Humboldt County Drug Task Force to implement Operation Yurok to stop irrigation to and destroy marijuana plants grown unlawfully in their ancestral territory (Yurok Today 2014b). These drug raids have been occurring on an annual basis since 2014. The impact of the recent legalization of marijuana cultivation in California (Ch. 1) on these operations while marijuana remains illegal on the Yurok Reservation is unclear.

Adaptation strategies: Water Quantity/ Improving Instream Flows

All of the strategies in the adaptive capacity section represent actions that the Yurok could continue and build on as part of their adaptation efforts. There are also additional adaptation actions that could help address some of the climatic and non-climatic sensitivities identified above. Some key strategies for consideration are below.

Protection and Restoration

- Continue the process to remove four mainstem dams by 2020 as part of the Klamath Hydroelectric Settlement Agreement, would help restore natural flow regimes.
- Continue reconnecting streams and their floodplains to store water underground.
- Restore beavers/ install beaver dam analogs to create impoundments to recharge the water table and increase baseflows (Pollock et al. 2015).
- Carry out cultural/prescribed burns to reduce water consumption by brush and to restore and expand prairies that help infiltrate water. The Yurok Cultural Fire Management Council could potentially assist with this.

Resource Management

- Delineate groundwater aquifers to aid with later development of a Yurok ordinance to protect groundwater recharge zones.
- Continue fish disease early warning monitoring program that informs Bureau of Reclamation decisions to release greater flows from the Klamath project when disease levels are high.
- Advocate for changes to the Klamath Project and Trinity River Diversion flow management to become more holistic (e.g., manage the projects together for ecosystems and multiple years).
- Manage forests to increase water yields (Aranda et al. 2012).
- Increase flow monitoring in tributaries important for drinking water and fish to better understand changes.

Legal and Policy

- Promote the protection of Yurok water rights.
- Continue enforcing against illegal marijuana activities that impact water quantity and quality.
- Complete Yurok Tribe Wetlands Protection Ordinance

Water Demand Management

- Strengthen collaborative work with the greater Klamath basin and Central Valley farmers to reduce large-scale water demand.
- Educate water users on water storage and forbearance: increasing water storage during rainy winter season so don't use water during drier summer season (Schremmer 2014).

Note: For a comprehensive list of all strategies identified during this project, please see Appendices.

4.2 Channel Form

Streams in their natural state can be messy and complex, changing form from upstream to down and over the course of time. They twist and turn, water moves faster in some places, slower in others; there may be pools, riffles, and sand bars, boulders standing staunchly in their paths, and logs that have fallen across their way. Some flow may veer off into side channels while the remainder stays the course. Streams carry not only water but also sediment that gets deposited in some places and scoured out of others. All this complexity provides the diversity in habitat that is key for benthic macroinvertebrates, the “bugs” that feed the fish, amphibians, and reptiles, and that is crucial for various activities like feeding, reproduction, and transitioning from baby fry to juveniles then adults.

Channels in the Klamath River system, though, have been changing form becoming more simplified and degraded, disconnected in some cases from flood plains and wetlands, from the main stem, and from the groundwater that feeds them. Climate change could exacerbate this degradation and continue to disrupt important linkages.

Table 4.2: Key Impacts s on Channel Form

Primary Climate Effect	Secondary Stressor	Potential Impacts
Warmer Air Heavier Downpours	More winter rain not snow →	Increased rain on snow events > Increase in winter flooding > Channel enlargement & incision > Increased erosion & sedimentation
Increased Wildfires Increasing Drought	Less stream-side vegetation Less stream-side vegetation	Increased erosion & sedimentation
Combined Effects	→	Increased sedimentation > In-fill of spawning beds, & pools > Decrease in floodplain connectivity

Climate Change Impacts on Channel Form

Climate change could affect channel form by altering flow regimes and sediment transport (Lord et al. 2009). Climate change could also lead to increased wildfire activity and changes in forest disturbances such as disease and insect infestation, which in turn could affect flow regimes, erosion, and sedimentation - and thus channel form (Pike et al. 2010).

In Yurok country, heavier rains, shifts from snow to rain, and increases in rain on snow events could all contribute to increased flooding, particularly during the winter wet season. This could lead to channel enlargement and incision and put rivers in an unstable state (Goudie 2006).

In combination with increasing wildfire frequency and extent and also with the legacy from logging roads (see below), increased flooding could lead to greater erosion and sedimentation into streams. Fires and tree die-off from disease or insect infiltration can also lead to increased flooding if water is not retained in the tree canopy or infiltrated into the land

Pine Creek Mouth, note large sediment bar

(Pike et al. 2010). In addition, rising air temperatures and heavier rains could precondition hillslopes to fail, and intense rainstorms could then trigger landslides and increase stream sedimentation (Pike et al. 2010).

At the other end of the spectrum, increasing drought intensities could interfere with some of the benefits that higher flows do provide. For example, higher flows known as channel maintenance flows can maintain or restore channel width, depth, and topographic diversity, reduce the encroachment of riparian vegetation into and associated narrowing of river channels, and increase the connectivity between rivers and their floodplains, which can include side channels and off channel wetlands and ponds (Goudie 2006; Cramer et al. 2012; Shea et al. 2016). All of these, in turn, provide the diversity of habitats needed by fish and aquatic insects for feeding, reproduction, and as respite from high water temperatures and predators (Poole and Berman 2001; Cramer 2012; Shea et al. 2016).

Higher flows known as flushing flows can improve spawning gravel by loosening it and removing fine sediments so that fish eggs aren't suffocated (Audubon Washington 2000; Shea et al. 2016). In addition, flushing flows can also scour fine sediments from pool habitats that may serve as cold water refuges for fish and remove fine sediments from riffles so that they provide better habitat for the aquatic insects that are important fish food sources (Cramer 2012; Shea et al. 2016). Through substrate mobilization, flushing flows may also be able to disrupt the life cycle of a type of worm that serves as a host for a fish parasite known as Ceratomyxa shasta (Som et al. 2016). C. shasta infects juvenile salmon in the Klamath River and has caused juvenile fish kills, which can be as devastating to the yearly population as adult fish kills but which are not as readily apparent because juvenile bodies dissolve in the water leaving no carcasses behind as evidence.

"Dams. The dams have changed the River. The River has cut a deeper bed and is no longer a natural channel. The natural flow of the River has been stopped by the dams. Not enough water flows through anymore, and the water has no strength. It is shallow."

- Fawn Morris (Elder Interviews 2014)

Existing Challenges (sensitivity)

The climate changes discussed above will interact with already existing non-climatic stressors to impact channel form. These non-climatic stressors include historical and current legacies from dams, logging, mining, and marijuana cultivation.

Dams- instream flow management

Dams can affect the magnitudes, frequencies, and timing of flows and alter the movement of sediments within river systems (Shea et al. 2016). All of this, in turn, can influence channel forms. As discussed above, periodic high flows perform many important functions. By contributing to reductions in flow magnitudes and frequencies, dams may interfere with these environmental processes. Below Iron Gate Dam, for example, from 2000 to 2016, flows resulting in the mobilization of sediment have occurred in only five of the 17 years, and flows to remove vegetation encroachment have not occurred since 1997 (Shea et al. 2016). Dams can also interfere with processes such as floodplain connectivity (Shea et al. 2016).

In addition to altering flows, dams also impede the transport of sediment including gravel downstream. Salmon and steelhead build their nests, which are called redds, in gravel. The gravel must be small enough that a female can move it with the motion of her body and tail to create the nest but also large enough to allow the flow of water and oxygen around the eggs (Audubon Washington 2000). Different-sized gravel may be better suited for different species. The Klamath dams may be causing the riverbed to coarsen so that larger gravels and cobbles unsuitable for spawning remain near the dam spillways while smaller-sized gravels are forced further downriver and are not replenished from above the dams, thus decreasing the availability of good spawning grounds in the off-channel pools (Saldi-Caromile et al. 2004; NRC 2008).

> *"The forest used to have trees and now it has brush. That's about as near a description to it. Fir, Redwood, Tan Oak…. Like I said the diversity of the land. Everything was there. Redwood cedar, all them trees. The last time I was in there maybe 25 years ago, it was like walking through someone's hedge. So brushy you couldn't hardly move."*
>
> - Allen McCovey (Elder Interviews 2014)

Timber Production & Logging

In the lower Klamath basin, logging started in the mid-1800s and peaked in the 1950s (NRC 2004). Logging can influence flow regimes as noted above and thus channel form. In addition, the attempts of timber companies to float logs downstream in an efficient manner contributed to what Yurok Fisheries Biologist, Sarah Beesley, and others have dubbed "bowling alley syndrome." To facilitate log drives with minimal interruptions, logging companies cleared the way by harvesting wood out of streams, blasting streambeds to remove large rocks, boulders, and other obstructions, and blocking off side channels and wetlands (Sedell et al. 1991; NRC 2008). This straightened, smoothed, and simplified channel forms, depriving streams of much of their natural complexity that is important for fish and other aquatic species in many of their various life stages.

Historic Timber Harvesting in Turwer Creek Watershed

In addition, while dams may starve a channel of gravel in key sizes, past logging practices have, in contrast, overwhelmed streams with sediment (Lisle 1989; NRC 2004). Clearcuts and extensive unpaved and unrocked road networks in combination with steep slopes and highly erosive soils leads to this sedimentation. According to Rich Nelson, manager of the Yurok Watershed Restoration Department, there are often as much as six miles of road per square mile of logged area to allow for logs to be transported to lumber mills. Without rehabilitation, these roads from past logging still deliver huge quantities of sediment to the river system today. This can occur after intense storms and is exacerbated by people driving on them, further loosening soils.

Excessive fine sediments can fill in spaces between gravel impeding water flow and depriving fish eggs of needed dissolved

Example of Historic Hydraulic Mining

oxygen and hindering the removal of metabolic wastes (Lisle 1989; Saldi-Caromile et al. 2004). They may even "cement" the substrate in a way that hinders salmon from creating their nests (Saldi-Caromile et al. 2004). Fine sediments that remain suspended in the water column can clog fish gills (Matonis et al. 2013). Gravels transported into the system can cut off the surface flows of tributaries from the main stem causing them to flow underground. Together with fine sediments, this can fill in deep pools that once served as cold water refugia.

Other factors contributing to channel form degradation

During the mid-1800s, the California Gold Rush came to the Klamath basin, in particular the Scott, Salmon, and Trinity River watersheds. The subsequent mining boom led to the dredging of stream sediments and the leveling of entire hillsides with high pressure water jets (NRC 2004). In some lower basin locations, in-channel gravel mining also took place (N RC 2004; NRC 2008). All of these activities have affected channel form, reducing spawning gravel and decreasing the diversity of habitat types. The decrease in habitat diversity can, in turn, contribute to declines in invertebrate populations feeding fish and in juvenile fish carrying capacity (NRC 2008). Clearcuts from Cannabis cultivation can lead to increased sedimentation, and the past policy of fire suppression may contribute to increasing stand-replacing fires and associated erosion.

Yurok Watershed Restoration Department- working on logging road rehabilitation and stabilization

Returning channel forms to a more natural state via restoration activities can be challenging because of funding needs, difficulty in accessing remote locations that may need restoration, and checkerboard land ownership on the reservation. These factors also make it difficult to locate and assess rehabilitation measures needed for roads from past logging, which as noted above are major contributors to sedimentation in the basin.

Yurok strengths (adaptive capacity)

In addition to the challenges they face, the Yurok also have existing adaptive capacity to address factors influencing channel form. As noted above, the Yurok have been working with various partners on the removal of four of the mainstem dams in 2020 and with a different set of partners on marijuana raids. The Yurok have a Cultural Fire Management Council whose members can assist with cultural burns, which could help reduce large catastrophic fires and associated erosion. Through the Blue Creek land acquisition, the Yurok now have a greater land base on which to conduct relevant restoration efforts.

In addition, the Yurok have two already established programs that have been collaborating on restoration since the late 1990s (Beesley 2014). The Yurok Watershed Restoration Department focuses on logging road rehabilitation, slope stabilization, and the removal of stream crossings to reduce sediment loads into the river system. The Yurok Fisheries Department conducts projects to restore channel form including, for example, reintroducing wood jams into streams and reconnecting streams to their floodplains and to off-channel habitats.

The Yurok Forest Management Plan includes riparian buffers in which logging is limited. This can assist with decreasing sediments entering streams. In addition, Green Diamond Resource Company, which is the largest private land holder on the Reservation, has an Aquatic Habitat Conservation Plan that also includes riparian management zones, slope stability

Protection and Restoration

- Continue the process to remove four mainstem dams by 2020 as part of the Klamath Hydroelectric Settlement Agreement, would help restore natural sediment regimes in the Klamath River
- Restore channel complexity.
- Reduce upland sediment mobilization and transport.
- Increase land base on which to conduct restoration projects

Resource Management

- Adjust instream flow management from dams to include (1) flushing flows that loosen spawning gravel and remove fine sediments, and (2) channel maintenance flows that maintain/ restore natural channel, riparian habitat, and increase the connectivity between the Klamath River and is floodplains.
- Manage forests to lower sediment yields through: vegetated riparian buffers, slope stability measures, road construction practices, wet weather use limitations, uneven-aged silviculture, and other harvest-related sediment control measures (Sullivan 2011, add in reference)
- Cultural/prescribed burns to decrease the occurrence of large, catastrophic fires and associated erosion.
- Increase Yurok wildfire fighting capacity to help minimize large, catastrophic fires and associated erosion.

Legal and Policy

- Explore whether the Yurok Tribe should use their jurisdiction under USEPA's Treatment as a State rule to list the Klamath River and/or tributaries as impaired waters and establish total maximum daily load (TMDL) for sediment under the Clean Water Act Section 303(d) (USEPA 2016b).

Education and Outreach

- Educate the community to not drive on unrehabilitated roads to help prevent sediment loosening.
- Provide information on energy efficient wood stoves, which could help decrease amount of wood taken out of river and creeks

Note: For a comprehensive list of all strategies identified during this project, please see Appendices.

4.3 Freshwater Quality – Cold Water Availability & Access

Water temperatures in the Klamath River have been warming (see Ch. 3). Climate change is expected to intensify this trend. For cold water fish, like salmon and steelhead, excessive warming can be stressful at best and lethal at worst. It can cause fish to crowd into cold water refugia where disease can spread, or it can delay migration timing (see Ch. 6). Sedimentation in the basin cuts off fish escape routes to cold water tributaries and fills in escape places like deep pools. Sedimentation can be exacerbated by climate change as well (see below). Warmer waters can also play a role in increasing harmful algal blooms. All together this creates impacts not only for fish but also for the Yurok people who depend on them and on the water as well.

Table 4.3: Key Impacts on Cold Water Availability and Access

Primary Climate Effect	Secondary Stressor	Potential Impacts
Warmer Air	Decreased snowpack Earlier snowmelt	Results in overall, warmer waters
Increasing Drought	→	Lower spring & summer flows allows greater warming of mainstem surface waters
Increased Wild Fire	→	Smoke cools stream temperatures however, loss of riparian vegetation and shading increases stream temperatures post fire.
Combined Effects	→	Filling in of deep pools that provide fish cold water refugia due to increasing erosion and sedimentation resulting from heavier downpours and greater wildfire frequency and extent

Climate Change Impacts on Cold Water Availability & Access

Traditionally, cool water has been abundant in the Klamath River system. However, climate change is expected to be one factor altering that pattern. Rising air temperatures can contribute directly to warming waters (Luce et al. 2012). They also lead to decreased snowpack and earlier snowmelt (see Ch. 3), which can result in less cool water heading downstream in the spring and summer.

Anticipated increasing drought intensities could also contribute to lower flows (see Ch. 3). Low flows are also associated with enhanced warming (Luce et al. 2012 p. 28).

The combined effect of warm air temperatures and low flows was evident during the 2013-16 drought in Yurok country. Yurok Fisheries Biologist, Sarah Beesley discussed the Klamath River reaching temperatures of over 77 °F for more than a week, which she had never seen before in her nearly two decades working with the tribe.

Heavier downpours and increased wildfire frequency and extent, both anticipated with climate change (see Ch. 3), could contribute to increasing erosion and sedimentation in streams, with fire suppression acting as an exacerbating factor for increasing wildfires. As will be discussed more below, deposition at the mouths of creeks where they discharge into the

Klamath River can prevent fish from accessing cooler tributary waters. Sediments can also fill in deep pools whose cooler waters provide relief from the heat. Ironically, notes Tribal Member Micah Gibson, smoke from the wildfires sometimes acts to cool Klamath River temperatures and may help prevent fish kills. However, if fires burn riparian trees, then post-fire, loss of vegetation shading the stream could contribute to warmer water temperatures the following years until vegetation is re-established (Luce et al. 2012).

Existing Challenges (sensitivity)

As was the case with instream flows, the climate changes discussed above could interact with already existing non-climatic stressors to compound the problem of warming water temperatures. These stressors include historical legacies from dams, logging, mining, and wetland loss as well as current impacts from agriculture and commercial *Cannabis* grows. These anthropogenic factors have disrupted the natural ability of watersheds to deliver cooler groundwater to streams, of riparian zones situated along riverbanks to cool waters, and of instream channels to provide colder refuges within a thermally complex aquatic environment.

> "I never did enjoy swimming in the Klamath when I was a kid because it was so cold up where we lived. It's different down at the Glen, it was more open and got more sunlight it got warmer. But up our way it was all redwood trees. All the way up the river, until about the early 50's they really started logging hard up the river. They started cutting all the fir and stuff. That's when the Korean War got over and they started to make houses. So they started logging big up there and rafting logs down the river."
>
> - Raymond Mattz (Elder Interviews 2014)

Dams

Yurok Senior Biologist Mike Belchik explained that a number of large-volume, cold water springs are located in the Upper Klamath River Basin, above the Iron Gate Dam. The dams block the flow of this cold water downstream, sending it instead into reservoirs. During the summer, reservoir water near the surface may warm and because it is less dense than cooler water it stays near the surface while colder water stays near the bottom (USGS 2016b). Depending on where a dam's release point(s) are and how far the reservoir has been drawn down, water entering a river from a reservoir can be a different temperature than free-flowing rivers (USGS 2016b). According to one study, the Copco and Iron Gate dams delay the warming of Klamath River mainstem during the spring by about three weeks and the cooling of river waters during the fall by about two weeks (Campbell et al. 2010). The dams also block upriver passage of salmon to these springs. In addition, dam regulation may introduce artificially low flows downstream of the dams, which can also result in warmer waters.

1910—Example of timber harvest of old growth Spruce

Timber Production & Logging

Logging and fire suppression significantly changed the landscape, increasing the overstocking of forests with trees and decreasing coverage by prairies, both of which can reduce movement of cooler groundwater to streams from associated watersheds (see Sec. 4.1). In riparian zones, old growth redwoods and spruce were stripped from the banks of creeks and eventually replaced with deciduous trees like alders. The fish though, explains Yurok Fisheries Biologist Sarah Beesley, are keyed in to the redwoods. The towering trees provide lots of shade to cool the waters and are resistant to fire. A recent study showed that summertime fog drip from redwoods can contribute to increased streamflows during the dry season (Sawaske and Freyberg 2015).

In addition to upland and riparian influences, the stream channel itself can affect water temperatures. The "bowling alley syndrome" noted above is associated with logging and mining activities and disrupts natural instream cooling mechanisms. This is because the simplification and smoothing of stream channels decreases the thermal complexity of streams. This is a problem as it is a stream's complexity that allows fish to find colder refuges within stream waters (NRC 2008). Large woody debris, for example can slow the mixing of cooler groundwater with warmer stream water permitting cool water pockets to form (Bisson et al. 1987); instream logs can cause localized scouring and the formation of pools with their cooler waters (Cramer 2012); log jams spanning stream channels can shade streams leading to cooler temperatures (Poole and Berman 2001), and the connection of streams to side channels can provide access to cooler waters as well.

> ""I've seen the correlation between big elk herds [in prairies] and big fish. Those fir trees are depleting our cool water coming down the watershed. My kids are living those changes so stressful to me."
>
> - Yurok Cultural Fire Management Council Meeting

Yurok Fisheries Restoration Project to add stream complexity back into the watershed by mimicking beaver habitat

Complex streambed topography can also enhance groundwater-surface water interactions contributing to cooler stream temperatures (Poole and Berman 2001). The connections between streams and their floodplains and side channels allow waters to recharge aquifers that provide cooler baseflow to streams during low flow periods (Poole and Berman 2001). Also, as noted in Section 4.2, logging clearcuts and roads have been major players in the massive sediment loading in Lower Klamath Basin streams. These sediments have filled in deep pools that have historically served as cold water refuges and in some cases have completely cut off fish access between the Klamath mainstem and cool water tributaries by driving the tributaries underground and making river bar dams that fish can't swim over.

- Other factors contributing to warming waters

Called nature's engineers by some, beaver and their dams influence local hydrology. Under certain conditions, these dams contribute to cooler waters. Deeper waters in the ponds and channels that develop behind beaver dams can act as cold water refugia for fish, amphibians and turtles. Also, by creating wetlands and redirecting water towards floodplains and existing wetlands during wetter seasons, beaver dams can increase groundwater storage ultimately leading to higher baseflows (Pollock et al. 2015 p. 1,4, 6). This cool baseflow can be important during drier summer months (Audubon Washington 2000). The near extermination of beaver in the region during the early 1800s still contributes to low beaver populations today and the loss of the cooling effects of beaver dams.

Clearcuts associated with marijuana cultivation, similar to the effects of clearcut logging practices, contribute to in-channel sedimentation that may block fish access to cold water tributaries or may fill in the deeper and cooler pools (Yurok Today October 2014c). As noted in Sec. 4.2, funding, checkerboard land ownership, and difficulty accessing remote locations can pose additional challenges in carrying out restoration projects. California regulations limiting riparian zone disturbance can prevent the planting of replacement tree species (such as redwoods) that were there before logging activities.

Yurok Strengths (adaptive capacity)

Table 4. 4 Recognized Cold Water Refugia

Creek	River Mile	Area (acres)
Hunter-Mynot-Spruce	1.3	14,964
Salt-High Prairie	1.1	3,776
McGarvey	6.8	5,689
Blue	15.9	80,167
Pecwan	24.5	17,651
Roach	30.6	18,668
Kep'el	32.2	5,392
Coon	35.0	423
Miners	35.9	3,002
Tully	37.4	11,201
Pine	39.6	31,633

All of the existing adaptive capacity identified in Sec. 4.2 is also applicable for addressing cold water availability and access. In addition, the Yurok, together with the California Water Resources Control Board, have a list of cold water refugia in the Lower Klamath Basin recognized as critical fish habitat. Also of particular note is the relatively recent land acquisition of part of the Yurok Ancestral Territory (Yurok Today 2015) from the Green Diamond Resource Company to create a cold water salmon sanctuary in the Blue Creek watershed and a community forest that spans multiple tributaries' watersheds (Yurok Today 2015).

This land acquisition is being realized through a partnership between the Yurok and the non-profit organization Western Rivers Conservancy (Yurok Today 2015). Together they are taking advantage of the federal New Markets Tax Credits Program to catalyze investment in low-income communities, grants from the California Wildlife Conservation Board and the California Coastal Conservancy, funding from an anonymous foundation, and a grant and low-interest loan from the David and Lucile Packard Foundation (Yurok Today 2015; WRC 2017). The loan will be repaid through the sale of carbon offsets and through profits from a sustainable forestry program within the community forest (WRC 2017).

Yurok Environmental Program staff recording local site data for transfer to regional Forest Service model database.

Finally, a project was completed in which the U.S. Forest Service Northwest Stream Temperature database (NorWeST) was used to project future temperatures for streams in the Yurok Ancestral Territory (Asarian 2017). This effort showed that Yurok streams had among the lowest sensitivity to rising air temperatures among the 23 geographic units representing the western U.S. (Asarian 2017). Average August stream temperatures were projected to rise by 0.8 °F (0.4 °C) in the coolest streams in the territory and by 1.4 °F (0.77 °C) for the warmest streams by the 2080s (Asarian 2017)[2]. In the Klamath River mainstem, the hottest reach was projected to reach average August temperatures of 74.8 °F (23.8 °C) (personal communication with Eli Asarian, October 17, 2017). The hottest streams overall were the Eel River and some of its forks, which were projected to reach average August temperatures of 79.3 °F (26.3 °

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[2]This is for the 2080s (2070-2099 time period) as compared to a current period comprising 1993-2011 (Asarian 2017; Isaak et al. 2017)

[3]The modeling used the A1B greenhouse gas emissions scenario (Asarian 2017). We consider this to be a medium emissions scenario (see Ch. 3).

Further upriver, The Nature Conservancy has been working with state, federal, and other partners to protect and restore the Shasta Big Springs Ranch containing three miles of the upper Shasta River and 2.2 miles of Big Springs Creek. Upon completion of the restoration, the waterways are expected to provide cool waters for salmon and steelhead year round (TNC 2017).

C) (personal communication with Eli Asarian, October 17, 2017)[3]. It should be noted that this was for a medium greenhouse gas emissions scenario and that, currently, we are on a higher emissions trajectory (Science Daily 2008; Cayan et al. 2009; Isaak et al. 2017). Temperatures during unusually low flow years were not projected nor were potential changes in maximum stream temperatures assessed.

Adaptation Strategies: Water Quality/Cold Water Availability & Access

All of the actions noted in Tables 4.2 and 4.4 for maintaining and restoring instream flows and channel forms and reconnecting streams with groundwaters will also help cool water temperatures during the summer. In addition, all of the strategies in the adaptive capacity section represent actions that the Yurok could continue and build on as part of their efforts to combat climate impacts. There are also additional adaptation actions that could help address some of the climatic and

Protection and Restoration

- Remove dams: diminish water warming reservoirs, restore natural flow and sediment regimes, allow fish, amphibians and turtles access to upriver cold water refugia and springs
- Protect/ enhance thermal refugia: create deeper pools, reduce sedimentation, deepen creek channels
- Allow beaver to return: they will naturally increase wetlands, stream complexity, and depth (Asarian and Walker 2016, Williams et al. 2015)
- Improve shading in riparian areas and increase redwood planting where possible
- Restore high elevation wetlands and coastal prairies to store water for release later on as baseflow (Williams et al. 2015)

Resource Management

- Yurok/ Western Rivers Conservancy creation of the Blue Creek Cold Water Salmon Sanctuary
- Advocate holistic tribal water use and allocations planning that takes into account the importance of temperature as a criterion.
- Support protection of cold water springs such as The Nature Conservancy's Shasta Big Springs Ranch

Legal and Policy

- Support the passage of the tribal ordinance to protect wetlands and fostering the planting of native species such as redwoods to enhance cold water habitat.
- Finalize Yurok Tribe "Treatment as State," that could allow creation of Yurok Total Maximum Daily Loads (TMDLs) for water temperature for the Lower Klamath River.

Education and Outreach

- Develop community events such as yearly youth-oriented 'Help Your Watershed Days' to remove new sediment deposits, deepen channels, and reconnect creeks to the Klamath River so fish can access colder tributary water.

Collaboration

- Continue collaborations to help guide restoration work outside of the Yurok Reservation that could provide cold water sources and refugia for basin-wide benefits for fish and water quality.

Note: For a comprehensive list of all strategies identified during this project, please see Appendices.

4.4 Freshwater Quality – Non-temperature Related

Water quality in the Klamath River system has been declining. People who once drank water from the creeks without treatment or a second thought are now concerned about possible exposure to E. Coli and Giardia. Youngsters who used to swim in the Klamath River all summer long have grown into adults who no longer do so because of algae choking up the water and the fear of getting rashes. Generations of fish moving through pristine waters have become generations swimming in a varying cocktail of manmade chemicals. Climate change is expected to worsen water quality issues and disrupt their trust that once existed between the Yurok people and the safety of their aquatic environment and resources.

Table 4.5: Key Impacts s on Freshwater Quality: Non-temperature Related

Primary Climate Effect	Secondary Stressor	Potential Impacts
Warmer Air Heavier Downpours Increased Wild Fire	Decreased snowpack, early snowmelt Increased run-off Reduced riparian vegetation Use of fire retardants	Increase in winter floods > Increasing erosion & sedimentation > Increases in turbidity & nonpoint source pollutant loads including ammonia & phosphorous concentrations from fire retardant
Warmer Water	→	Increase harmful algal blooms Lower dissolved oxygen levels
Rising Sea Level	→	Increasing estuarine salinities & saltwater intrusion into coastal aquifers Decreasing efficacy of coastal septic systems
Combined Effects	→	Decreased availability of safe drinking water sources

Climate change effects on freshwater quality (non-temperature related)

As noted above, climate change can contribute to warmer waters, and warmer waters, in turn, hold less oxygen and can also simultaneously increase the oxygen demands of some aquatic organisms (Murdoch et al. 2000; Ficke et al. 2005). This could lead to overall lower oxygen concentrations and associated impacts to aquatic life. Heavier rains could cause water to flow through new pathways leading to increases in Giardia and Cryptosporidium (Hunter 2003; Karl et al. 2009). Heavier rains, shifts from snow to rain, and increases in rain on snow events could all contribute to increased flooding, particularly during the winter wet season. In combination with increasing wildfire frequency and extent and the legacy from logging roads (see Sec. 4.3), this could lead to greater erosion and sedimentation into streams and rising levels of water turbidity (Cromwell et al. 2007). Such factors could also contribute to increases in nonpoint source pollutant loading if rains wash nutrients, contaminants, waste, and sediments into surface waters, and if flooding overwhelms wastewater treatment capabilities (USEPA 2014). Nonpoint source pollutant loads may be particularly high after periods of extended drought.

Retardants used to fight wildfires may be ammonium and phosphate based (USDA FS 2005; Sham et al. 2013). An increase in the use of such retardants associated with increasing wildfires could contribute to short-term increases in nutrient levels and associated eutrophication (Sham et al. 2013). Un-ionized ammonia can be toxic to aquatic species (USDA FS 2005). Warmer waters could favor some bluegreen algae such as Microcystis (see Ch. 3 for more details) (O'Neil et al. 2012). In addition, sea level rise and/or increased drought intensities may lead to higher estuary water salinities that could favor at least one strain of Microcystis, which has a higher salt tolerance in comparison to most other freshwater phytoplankton (O'Neil et al. 2012). The production of the associated toxin, microcystin can increase with salinity as well (O'Neil et al. 2012). Altogether, this could lead to increases in harmful algal blooms and the release of associated biotoxins into the waters (see Chs. 5 and 7). Furthermore, if increasing drought intensities result in Cannabis growers, tribal residents, and others transferring water from contaminated water sources to other parts of the watershed that are not contaminated, this could contribute to the spread of the harmful algae. Finally, not only are the toxins a problem, but the decay of algal blooms (harmful or otherwise) could lead to lower dissolved oxygen concentrations.

Fire Retardant being dropped on Tully Fire in 2016

Sea level rise in combination with other factors such as storm surges, changes in recharge and increased groundwater pumping could contribute to increasing saltwater intrusion into coastal groundwater aquifers (Heberger et al. 2009; Green et al. 2011; Taylor et al. 2013). Sea level rise and heavier precipitation events could also lead to higher water tables that could affect septic systems' ability to function. One of the main ways septic systems treat wastewater is through microbial activity. For this, they need a certain volume of soil, or leach field, that contains sufficient oxygen for the activity to take place. Rising water tables could decrease the volume of such soils available for treatment (Cooper et al. 2016; Mihaly 2017). This, in turn, could result in septic system failure and the introduction of pathogens and nutrients into groundwater, surface runoff, and the coastal ecosystems (Cooper et al. 2016; Mihaly 2017).

Existing challenges (sensitivity)

In addition to the potential climate change effects discussed above, non-climatic stressors also affect water quality, and climate change will interact with these, sometimes exacerbating the impacts. These non-climatic stressors include historical and current legacies from dams, logging, marijuana growth, and mining as well as prairie and wetland loss and challenges with waste management.

In 2014, drought conditions, low flows, and an early Spring warming combined to generate localized algal blooms in the Klamath estuary that were 'seeded' by previous years' inuts from upper reservoirs.

Harmful Microcystis algal blooms have already started to occur in the Copco and Iron Gate reservoirs over the past decade and genetic fingerprinting has indicated that the Microcystis has been transported from the reservoirs over 186 miles downstream from the reservoirs through the entire length of the Lower Klamath River system until it flows into the Pacific Ocean (Otten et al. 2015). Nonpoint source nutrient inputs and microbial recycling of Upper Klamath Lake organic matter and nutrients are believed to be the causes of the blooms together with stratified and warmed water in the reservoirs (Otten et al. 2015). In addition, the extensive draining of wetlands in the Upper Klamath Lake region may have liberated nutrients increasing nutrient loadings to the lake (NRC 2004).

The use of pesticides and herbicides by timber operations to control insect infestations, to slow the spread of forest diseases, and to eliminate the forest understory can negatively impact water quality. However, not only are the timber companies applying pesticides but the use and, in some cases, improper storage of pesticides, diesel, and gasoline for marijuana growing operations can also have toxic environmental effects (CWB 2013; Yurok Today 2013b, 2014c). Furthermore, excessive fertilizers applied for growing marijuana could contribute to the development of harmful algal blooms, which can cause decreased oxygen levels leading to suffocation of native fish and aquatic life (Levy 2014).

Fertilizers are delivered by the tractor-trailer load

During some Operation Yurok marijuana raids, both solid and human waste with the potential to pollute local tributaries has been removed (Yurok Today 2014c). At some marijuana growing locations, human latrines have been situated near tributaries, potentially contaminating them with *E. Coli* and other waterborne diseases. Septic systems that are not maintained or are beyond their life expectancy and feral or unfenced cattle that defecate in or near tributaries can contaminate streams with waterborne pathogens such as *E. Coli*, *Cryptosporidium*, and *Giardia*.

Other contributors to water quality issues on the reservation include the loss of prairies and wetlands (see Sec 4.1) both of which have the potential improve water quality (Stillwater Sciences 2012; American Rivers 2016; USEPA 2017). Illegal dumping of garbage and trash burning in riparian areas can also impact water quality. In some locations in the middle Klamath basin including the Scott, Salmon, and Trinity Rivers, mercury was used in the processing of gold from mining and may still have consequences today (NRC 2004). Checkerboard land ownership on the reservation can be a barrier to restoration efforts to address some of the water quality issues and also to regulation enforcement. This has been recently compounded by non-tribal members purchasing reservation land for the purpose of illegal marijuana cultivation (Yurok Today 2013b). Finally, the Yurok Tribe Environmental Program (YTEP) has a significant amount of water quality data but has limited statistical analysis expertise to identify significant trends.

Yurok strengths (adaptive capacity)

Yurok also have strengths in place that can be considered adaptive capacity to address water quality issues. As noted above, the Yurok Tribe Fisheries Program and Watershed Restoration Department are implementing process-based restorations and the Yurok Forest Management Plan designates riparian buffers, which can collectively benefit critical components of water quality. The expanded Blue Creek/Bear Creek land management/ acquisition described in Section 4.3 can also improve water quality by allowing for increased restoration efforts and regulation enforcement.

Tully Creek Monitoring Station: in order to monitor several remote creeks, YTEP has installed Passive solar devices that allow continuous data to be recorded. To compliment their full time staff, YTEP relies on the Watershed Stewards Project which is a joint Americorp and the Civilian Conservation Corp program.

In 2001 YTEP developed a Water Quality Control Plan for the Yurok Indian Reservation (YTEP 2004; YTEP 2017). This plan establishes water quality standards for both surface and groundwaters as well as an anti-degradation policy (YTEP 2004). Enforcement jurisdiction and procedures are outlined in the Yurok Tribe Water Pollution Control Ordinance (YTEP 2004). In addition, YTEP along with the Yurok Fisheries Program has established a monitoring program for the mainstem of the Klamath River, the Klamath River estuary, and many of the tributary creeks that flow through the exterior boundaries of the Yurok Reservation including priority creeks such as Blue, McGarvey, Ke'pel, Achelth, Gist, Tulley, and Turwar Creeks (YTEP 2004). YTEP has purchased passive Polar Organic Chemical Integrative Samplers for pesticides monitoring, and the US EPA Science to Achieve Results (STAR) grant that is funding the development of this adaptation plan has enabled YTEP to expand its monitoring of surface drinking water sources for temperature-driven water-borne toxins, pathogens, and diseases.

In 2007, YTEP established a Wetlands Program. Although the focus has been on wetlands in the Klamath River Estuary, currently the focus has shifted to updating the US Fish and Wildlife Service *National Wetlands Inventory* (NWI) and conducting biological assessments of upriver wetlands. Finally, the 2012 Yurok Indian Sustained Yield Lands Forest Management Plan states that one of its long-term goals, based on feedback from the Tribal Council, departments, and members, is to eliminate the use of herbicides.

The Yurok Tribe is also partnering with others in more regional monitoring efforts such as the Klamath Basin Bluegreen Algae Workgroup, the Klamath Tribal Water Quality Consortium, and the Klamath Basin Monitoring Program. These partnerships can provide important data for identifying and solving water quality problems. In the Upper Klamath River Basin, above Upper Klamath Lake, nearly 101,136 acres have been converted from irrigated agriculture to artificial wetlands since the 1980s, partly to improve nutrient retention (NRC 2004). The effects on water quality though are unclear (NRC 2004).

Adaptation strategies: Water Quality/ Non-temperature Related

All of the strategies noted in the prior tables that help increase streamflow, reconnect streams to floodplains and wetlands, and decrease the occurrence of large, catastrophic stand-replacing wildfires can also help improve water quality. In addition, all of the strategies in the adaptive capacity section represent actions that the Yurok could continue to build on as part of their efforts to address climate change. There are also additional adaptation actions that could help address some of the climatic and non-climatic sensitivities identified above. These are included on the following page.

Protection and Restoration

- Remove dams and impoundments that retain nutrients and warm waters that generate harmful algal blooms.
- Restore wetlands functions: filters, buffers, protects water quality

Resource Management

- Manage watersheds for multiple objectives including water quality
- Develop Yurok program to remove cattle from riparian areas and streambanks
- Increase statistical analysis and integration of scientific data into land management decisions (for example, trend analysis and benthic macroinvertebrate monitoring)

Legal and Policy

- Livestock: Develop Yurok livestock ordinance to fence in cows
- Marijuana: Continue Cannabis raids earlier in the growing season (July) so that less water is withdrawn and less pollution occurs; Target fines/restitution monies from illegal Cannabis for water quality improvements and protection
- Nutrient TMDLs: Finalize Yurok Tribe "Treatment as State," that could allow creation of Yurok Total Maximum Daily Loads (TMDLs) for nutrients for the Lower Klamath River and area's tributaries.
- Pesticides: Enforce existing Yurok resolution banning the use of pesticides on the reservation, which eliminates chemical runoff into tributaries
- Septic systems: Develop Yurok standards governing minimum distance between leachfield bottom and top of the groundwater table that consider factors like sea level rise, increasing precipitation intensities (Mihaly 2017).
- Develop Yurok Tribe Wetlands Protection Ordinance (in progress)
- Develop wildfire retardant use zones to minimize impacts to water quality in critical habitat & drinking water sources.

Education and Outreach

- Educate about the dangers of transferring water between watersheds, which could spread HABs to upland creeks.
- Conduct outreach with the community about the negative effects of illegal trash burning and dumping on water quality and expand education about alternative methods of disposal.
- Educate community about proper construction and location of outhouses and pit toilets so don't contaminate water and septic system maintenance, inspection, and pumping (Mihaly 2017).

Community Events

- Local Environmental Observer (LEO) Yurok Hub: citizen science web and cell phone-based observer network that allows members to report observations such as time and location of harmful algal blooms.
- Develop an "Adopt a Tributary" program: this could involve citizen water quality monitoring, documenting inappropriate water use, and more (Yurok Today 2013b)

Collaboration

- Support continued collaboration and restoration of Upper Klamath Basin, especially wetlands, and the monitoring of associated water quality that impacts downstream communities and the Yurok reservation.

Note: For a comprehensive list of all strategies identified during this project, please see Appendices.

4.5 Estuaries and Ocean

The Klamath River estuary and wetland complex is located in Southern Del Norte County. The Klamath River is within the Columbian province, which extends along the Northern Pacific coast from Cape Mendocino to Vancouver Island. Mountainous shorelines with rocky foreshores are prevalent. Estuaries in this province are strongly influenced by freshwater runoff and the tidal range varies from large to moderate. The Klamath estuary is short and small even though the Klamath Basin is the second largest drainage in California (Bricker, 2007). In addition to providing critical habitat for native plants and wildlife, both the Klamath estuary and associated wetland complex serves as a vital nursery and staging area for spring and fall-run Chinook salmon, Coho salmon, steelhead trout, coastal cutthroat trout, sturgeon, eulachon, flounder, and lamprey (Wallace 1995, Wallace 1998). It is likely that tens of millions of juvenile salmonids migrate through the estuary every year on their way to the ocean (Wallace 1995). Estuary rearing allows juvenile fish to physiologically adapt for ocean survival and to amass growth prior to ocean entry. Studies conducted in Oregon suggest ocean survival of juvenile Chinook salmon was greatly increased when fish entered the ocean at larger sizes (4.7-6.3 inches) (Nicholas and Hankin 1989). Although the estuary wetlands provide habitat and passage way for anadromous fishes, they lack extensive tidal flats and tidal marshes, which normally occur in larger estuaries (Wallace 1991). Due to size constraints, the productivity and function of the Klamath River's estuary and associated off-estuary wetlands play an increasingly significant role.

> "The ocean used to be in a lot better shape too seems like. I used to do a lot of fishing in the ocean when I got married with Diane. That's all I did was fish on the beaches. Perch. Perch pogies for the crab fisherman. 300-400 a day. I just loved fishing."
>
> – Raymond Mattz (Elder Interviews 2014)

Table 4.6: Key Impacts s on Estuaries and Ocean

Primary Climate Effect	Secondary Stressor	Potential Impacts
Warmer Water Heavier Downpours	→ Increased run-off	Increasing nutrient loading > More frequent harmful algal blooms & associated concerns about shellfish contamination from toxic algae > Increasing coastal dead zones
Rising Sea Level	→	Inundation or inward migration of low-lying coastal wetlands; enlargement of the Klamath River Estuary Altered tidal ranges Changes to estuarine salinity gradients Increasing coastal erosion & storm surge Inundation of traditional shellfish gathering rocks
Ocean Acidification	→	Negative impacts on shell development Possible disruption of marine food webs
Combined Effects	→	Increase in invasive species > loss of traditional resources Lower estuarine water quality including temperature, salinity, turbidity, oxygen, nutrients, and pH

Currently, the Pacific Ocean and Klamath River estuary and wetland complex in Yurok Ancestral Territory are changing. Ocean temperatures are warming, and sea levels are rising (Hoegh-Guldberg and Bruno 2010; Lindsey 2016; USEPA 2016a). In addition, the ocean is becoming more acidic and the number of coastal dead zones around the world is increasing (Diaz and Rosenberg 2008; Orr et al. 2005). Low flows from California's extended drought (2008-2009, and 2013-2016) have caused near closure of the Klamath estuary and outflow of the river into the ocean from an enlarged sand spit. This can lead to the obstruction of spawning fish migrating from salt to freshwater and/or juvenile fish migrating from fresh to saltwater. Also localized harmful algal blooms have occurred in the Klamath Estuary, where none have occurred before. Tribal members worry if they can complete ceremonies or consume shellfish without risk of poisoning and paralysis when these harmful algal blooms are prevalent. All of these changes will likely have a negative impact on the availability of reliable traditional food species such as salmon, sturgeon, and shellfish, consequently leading to adverse effects to Tribal Members' health and well-being. Climate change has been implicated in many of the ecological changes occurring and is expected to further exacerbate these synergistic effects in the future.

Rocky shoreline in Yurok Ancestral Territory

Climate change effects on estuaries and the ocean

Global mean sea surface temperatures (SST) may increase by as much as 4.7 °F by 2100 (Nicholls et al. 2007). SST rise may vary locally. For example, estuaries and coastal lagoons that are shallower and have limited exchange with the open ocean may experience greater temperature increases (Altieri and Gedan 2015).

Along the Pacific Northwest coast north of Cape Mendocino, sea levels may rise by as much as 4.7 feet by 2100 as compared to the year 2000 (NRC 2012)[5]. This will likely lead to an upsurge in seawater inundation to the low lying coastal wetlands, altered tidal ranges, migration of estuarine salinity gradients, and inundation and/or inward migration of wetland species and habitats such as fish nurseries (NRC 2012; USEPA 2009). New brackish and freshwater wetland areas may be created as this seawater inundates low lying inland areas or as the freshwater table is pushed upward by the influx of seawater (Pfeffer et al. 2008).

In Yurok country, some Yurok resource managers speculate that inundation could result in the enlargement of the estuary. Traditional shellfish gathering rocks could one day be under water. Sea level rise could also contribute to increased coastal erosion. Cliffs in some locations in Yurok country could erode by as much as 1300 feet (see Ch. 3) removing cultural and traditional coastal resources. If precipitation intensities increase, this too could lead to increased flooding of coastal areas due to higher peak streamflows (USEPA 2009). Heavier downpours could also affect estuarine water quality by altering nutrient and sediment loads (Glamore et al. 2016).

[5]This is under a high greenhouse gas emissions (A1fi) scenario.

[6]pH is a scale from 0 to 14 used to indicate how acidic or basic an aqueous solution, such as the ocean, is. Values below 7 are acidic. Values equal to 7 are neutral, and values greater than 7 are basic. The pH scale is logarithmic, which means, for example, that a pH value of 2 is ten times more acidic than a pH of 3 and 100 times more acidic than a pH of 4. Similarly, a pH value of 10 is ten times more basic than a pH of 9 and 100 times more basic than a pH of 8.

The oceans are also acidifying due to increased absorption of carbon dioxide that is emitted from human activities (see Ch. 3). By the end of the 21st century, under a higher emissions scenario, surface ocean pH is expected to become an additional 0.3-0.4 units lower (Orr et al. 2005). While this change may seem small numerically, because the pH scale is logarithmic[6], a change of 0.3-0.4 units actually represents a 100-150% increase in the relative acidity of the oceans from today's levels (Orr et al. 2015). Estuaries may be more susceptible to acidification because they are less buffered than marine systems and because their location along coastal regions may result in additional acidic inputs (Waldbusser et al. 2011). Ocean acidification can affect shell development in some species, and shellfish larvae and juveniles may be particularly vulnerable (WSBRPOA 2012; Barton et al. 2015; CCC 2017). Pteropods (free-swimming snails) and copepods (small crustaceans) that are eaten by fish may experience shell-thinning and population declines, which is of significant concern because of the potential for disrupting marine foodwebs (WSBRPOA 2012). Some research indicates that rising carbon dioxide in seawater may affect the neural function and sensitive skeletal structure in some marine fishes (Chan et al. 2016).

Spit Formation– 2015 low flows in the Klamath River allowed sand to form nearly interlocking bars.

Anticipated increases in drought intensities could affect the dynamics of the spit on the Klamath estuary. During lower flows, Yurok Water Division Manager Matt Hanington notes that the spit becomes a dogleg formation that almost closes the estuary off from the ocean causing the estuary to become essentially freshwater. Sometime this happens during August and September. However, with the 2013-16 drought, this occurred as early as June or July, affecting the movement of fish both into and out of the Klamath River. Sea level rise may also affect the dynamics of the spit..

Coastal dead zones with low (hypoxic) or no (anoxic) oxygen are on the rise with more than 400 systems now being affected worldwide (Diaz and Rosenburg 2008; see Ch. 3). Climate change could contribute to increasing coastal dead zones through various mechanisms (Bijma et al. 2013; Altieri and Gedan 2015). Warmer waters hold less oxygen and could increase the metabolic oxygen demand of marine organisms (Altieri and Gedan). Warmer waters could also decrease water column mixing (the mixing of surface waters with bottom waters), contributing to oxygen stress (Altieri and Gedan 2015). Coastal dead zones have occurred off the coasts of Southern California, Oregon, and Washington, some within approximately 150 miles of the Klamath River Estuary (Chan et al. 2008). The potential summertime occurrence of these dead zones is becoming an annual threat (Gillies 2012; Floyd 2017). The events seem to be driven by shifts in the wind patterns that bring deeper, nutrient-rich but oxygen-poor waters to the surface (Gewin 2010). Although there are not yet enough data available to say that the shifts are conclusively linked to climate change, they are consistent with projected climate changes (PISCO 2008; NSF 2009; Gewin 2010).

Yurok Tribe Environmental Program staff sampling Pacific Ocean off the Klamath River spit to test for HABs– 2017

The number and intensity of harmful algal blooms (HABs) worldwide is on the rise in marine ecosystems (O'Neil et al. 2012). The Klamath estuary already has localized microcystin blooms. Climate changes such as warming temperatures and rising carbon dioxide levels may interact with factors such as nutrient enrichment to continue this trend (Paerl and Paul 2011). In the Klamath estuary, increased drought intensities could lead to low flow conditions during which a growing sand spit formation closes the estuary off from ocean influences, enhancing suitable conditions that could lead to increased prevalence of HABs. Yurok resource managers and community members are concerned about possible shellfish contamination from toxic algae that cause human health dangers such as Paralytic Shellfish Poisoning (PSP), or Amnesiac Shellfish Poisoning (ASP) (see Ch. 3.2, Ch. 6, and Ch. 7).

The coastal upwelling that takes place in the California Current System, brings water rich in carbon dioxide and nutrients and low in oxygen to the surface (Strong et al. 2014; Chan et al. 2016). As noted above, the carbon dioxide of upwelled waters is increasing because of the oceans' increased absorption of carbon dioxide emitted from human activities (Strong et al. 2014; Chan et al. 2016). This can exacerbate surface ocean acidification (Strong et al. 2014). If climate change increases the frequency and duration of upwelling events, then ocean acidification could worsen in upwelled areas (Strong et al. 2014). However, the potential effects of climate change on upwelling are uncertain (see Ch. 3).

The suite of climate changes discussed above could potentially act both individually and in concert act to increase the introduction of invasive species into estuaries and coastal environments (Williams and Grosholz 2008). Similarly, also as noted above, they could alter estuarine water quality processes including temperature, salinity, turbidity, oxygen, nutrients, and acidity/alkalinity (Glamore 2016).

Wetlands in Salt Creek were converted to pasture where cattle contribute nutrients including ammonia and nitrogen into the surface waters and estuary of the Lower Klamath River

Existing challenges (sensitivity)

The climate changes discussed above will interact with non-climatic stressors that affect the ocean and estuaries. As noted above, natural global processes such as upwelling can affect ocean acidification levels. In addition, the El Niño Southern Oscillation (ENSO), a form of natural climate variability, also affects acidification because it influences upwelling off the California coast with La Niña events producing stronger upwelling and thus lower pH levels (Crozier 2015; Jacox et al. 2015). The deposition of sulfur dioxide and nitrogen oxides from fossil fuel combustion can also be a factor in acidification as can the deposition of ammonia from agricultural fertilizers (Center for Ocean Solutions 2012; USFS 2017). Nutrient runoff from septic system wastewater treatment can contribute as well, in particular when it results in excessive plant and algal growth (Chislock et al. 2013; USEPA 2016b). The high rates of photosynthesis and respiration associated with this excessive growth produce carbon dioxide can lead to elevated pH levels

[7]The warming of surface waters can enhance water column stratification by lowering the density of surface waters. This could discourage mixing with and replenishing of oxygen in bottom waters where hypoxia typically occurs (Altieri and Gedan 2015).
[8]The nutrients in these waters help make west coast fisheries extremely productive. However, if the winds and upwelling persist with no slack periods, phytoplankton blooms may result. As the phytoplankton die, their decomposition uses up oxygen in the water. The persistence of upwelling also prevents higher oxygen surface waters from mixing with and replenishing lower oxygen bottom waters. This combination can lead to oxygen deficits and hypoxia (Gewin 2010).

(Chislock et al. 2013). In addition, when algal blooms and other excessive plant growth decompose, this can result in severe oxygen depletion. Thus, increased acidification and hypoxia frequently co-occur (Center for Ocean Solutions 2012; Chislock et al. 2013; Chan et al. 2016; Gobler and Baumann 2016).

Klamath River Estuary:
Looking upriver with the Ocean & sand spit at picture bottom

Wetlands such as those in the Klamath estuary have also been affected by a variety of non-climatic factors. These include conversion into grass pastures for cattle, fill to form the present-day Klamath town site, groundwater withdrawal, sedimentation from past forestry practices, and the incursion of invasive species such as reed canary grass, and salvinia,(YTEP 2009). The effects of wetland degradation surrounding the Klamath estuary have been strongly felt by the Yurok Tribe, particularly as lost nursery areas for multiple fish. A critical factor that challenges Yurok work to address climate change effects on the estuaries and ocean is limited participation in off-reservation and private land owner management of these resources.

Yurok strengths (adaptive capacity)

In addition to the challenges they face, the Yurok also have existing adaptive capacity to address ocean and estuary issues. As noted in Section 4.4, in 2007, YTEP established a Wetlands Program, which has inventoried and assessed the Lower Klamath River's estuary and associated wetlands, using the California Rapid Assessment Method (CRAM), to identify priority restoration sites in its Klamath River Estuarty (KRE) Wetlands Restoration Prioritization Plan (YTEP 2009), and has instituted wetlands water quality monitoring (YTEP 2011).

A Wetlands Program Plan was completed in 2011 with the Yurok Tribe Fisheries Program and Yurok Tribe Water Resources Division (YTEP 2011). Several baseline monitoring studies in the estuary have been conducted including a Klamath River Estuary Nutrient and Phytoplantkon Dynamics Study, a Klamath River Estuary Continuous Water Quality Parameters Study, and a Klamath River Estuary Bathymetry Study (Yurok Today 2013a). An additional study assessed the potential impacts of various sea level rise scenarios on culturally significant resources located in different wetland classes, including a worst-case scenario of a 6.6 feet (2 meter) sea level rise (Yurok Today 2016). A second climate change-related study is underway examining rates of sedimentation in the estuary and how this might interact with sea level rise and geologic uplift in the region from plate tectonics to affect the estuary (Yurok Today 2016).

The Yurok Tribal Fisheries Program is also a member of the Steering Committee of the Pacific Marine and Estuarine Fish Habitat Partnership, which is a consortium of partners whose mission is to restore West Coast fish habitat in both estuaries and nearshore marine waters (PMEP 2017). Finally, the Yurok are also combatting ocean acidification through their participation in California's cap-and-trade program, which contributes to the reduction of greenhouse gases in the atmosphere, a major strategy for addressing ocean acidification.

Note: For a comprehensive list of all strategies identified during this project, please see Appendices.

Adaptation strategies: Estuaries and Oceans

Protection and Restoration

- Remove dams to help restore natural flow regimes to keep the Klamath River Estuary spit from closing off .
- Identify, restore, and protect critical estuarine and ocean habitats of vulnerable species or life stages such as nursery grounds, spawning grounds, and areas with high diversity such as wetlands (USEPA 2009)
- Preserve and restore native seagrasses and kelp beds that reduce ocean acidification by absorbing carbon dioxide and sequestering carbon in sediments. They also produce oxygen to offset dead zones (USEPA 2009; WSBRPOA 2012; NOAA 2015; Chan et al 2016).
- Participate in efforts to develop a blue carbon credits market that could provide funding for preservation and restoration of estuary and coastal wetlands, seagrasses, intertidal marsh restoration (Ullman et al. 2013; REA 2015).

Resource Management

- Increase research and monitoring of local ocean and coastal areas including traditional coastal village areas, lagoons, the estuaries (for example, carbon chemistry, plankton, water quality)
- Reduce carbon dioxide emissions contributing to ocean acidification
    - ◊ Maintain the Yurok Tribe's current participation in California's Carbon Cap and Trade Program.
    - ◊ Develop Yurok Climate Mitigation Plan to reduce greenhouse gas emissions.

Legal and Policy

- Nutrients: Development of Yurok Total Maximum Daily Loads (TMDLs) under Yurok Treatment as Statement to decrease nutrient contributions to ocean acidification in estuaries. (Center for Ocean Solutions 2012; USEPA 2016b).
- Invasive species: strengthen enforcement of ordinances preventing invasive species introduction (USEPA 2009)
- Strengthen recognition of Yurok sovereignty to includes near-shore habitats that are part of ancestral territories
- Explore participation in National Estuary Program/National Estuarine Research Reserve System while maintaining tribal sovereignty. Could open up restoration/research funding opportunities (Center for Ocean Solutions 2012).
- Develop Yurok Tribe Wetlands Protection Ordinance (in progress)

Education and Outreach

- Incorporate school curriculum emphasis on interconnectedness and impacts of global processes that are also a part of the Yurok holistic world view. One topic could be ocean acidification and could make use of curriculum developed by the Suquamish Tribe, Northwest Indian Fisheries Commission and others http://www.oacurriculumcollection.org/
- Outreach to tribal administration and members to use energy efficiency measures and conserve energy on all levels to reduce carbon impacts on ocean acidification.

Community Events

- Ner-er-ner Lifeways Appreciation Week: Beach habitat monitoring by local students (Suquamish Tribe 2015); Ocean species identification workshops (Suquamish Tribe 2015); Week-long school science projects (Suquamish Tribe 2015)
- Local Environmental Observer (LEO) Yurok Hub: community-based network that allows members to report observations such as time, location of marine harmful algal blooms, invasive species, etc.

Collaboration

- Collaborate when others respect Yurok interests/rights to establish ocean acidification refuges & migration corridors.
- Continue collaboration to characterize tribal cultural landscapes needed in coastal and ocean planning processes- (Yurok THPO, Bureau of Ocean Energy Management, National Oceanic & Atmospheric Administration, and others)

4.6 Research Needs, Ideas and Questions

Through the process of conducting the vulnerability assessment, we also identified research needs and data gaps with respect to how aquatic habitats may respond to climate change. These are identified below.

Watershed

- How do forests and forest management contribute to and/ or impact aquatic habitats?
- Could metrics for logging road rehabilitation be used by other departments for habitat restoration planning?
- What is the relationship between prairies, groundwater infiltration, and tributary baseflows?
- How do our local prairies affect water quality?
- How can traditional and community knowledge inform prairie restoration work?
- How are water levels in springs and tributaries altered after prescribed burns and/or wildfires?
- What are the effects to water quality from burning on stream banks and riparian areas?
- Baseline study of reservation groundwater to identify aquifer locations, depths, water quality, if confined/ unconfined, locations of recharge areas, and which springs are fed by which aquifers.
- Can more wetlands be restored at mainstem/ tributary confluences?
- Can side channel ponds be effective fish habitat in the Lower Klamath River?

Cold Water Refugia

- Increase research and monitoring of local ocean and coastal areas including traditional coastal village areas, lagoons, the estuaries (for example, carbon chemistry, plankton, water quality)
- Compare current and potential vegetation shading in the riparian areas of key tributaries that could improve utility of cold water refugia to fish. Could make use of aerial or satellite photos.
- Investigate how redwood reintroduction affects water quantity and temperature.
- How do tributaries' headwater wetlands and their restoration contribute to cold water refugia?

Klamath River Estuary and Marine Habitats

- How might the estuary change through time under different sea level rise scenarios (including factors such as uplift and sediment inputs)?
- How might salinity levels and gradient be affected? Would the estuary become saltier, fresher, or a mixture?
- How far upstream might the salt wedge move?
- Might the estuary become bigger, which could potentially be a benefit?
- How do sea level rise, ocean wave dynamics, and increasing drought intensities affect estuary sand spit dynamics and the connectivity of the sand spit to the ocean?
- Set up a study to assess the effectiveness of seagrass/kelp bed restoration projects on reducing localized ocean acidification (Chan et al. 2016)

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Additional Information

- The Institute for Tribal Environmental Professionals (ITEP) at Northern Arizona University established its Tribes and Climate Change Program in 2009. The program provides support for and is responsive to the needs of tribes who are preparing for and currently contending with climate change impacts. For more information, please visit our website at: http://www7.nau.edu/itep/main/tcc.
- "Guidelines for Considering Traditional Knowledges in Climate Change Initiatives," A resource for tribes, agencies, and organizations across the United States interested in understanding Traditional Knowledges in the context of climate change: https://climatetkw.wordpress.com/
- "The Climate and Traditional Knowledges Workgroup – CTKW" is an informal group of indigenous persons, staff of indigenous governments and organizations, and experts with experience working with issues concerning traditional knowledges who developed a framework to increase understanding of access to and protection of TKs in climate initiatives and interactions between holders of TKs and non-tribal partners: https://climatetkw.wordpress.com/
- Additional Chapters of the Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources can be found on the Yurok Tribe Environmental Program's Community and Ecosystem division webpage at http://www.yuroktribe.org/departments/ytep/com_eco_division.htm

Yurok Tribe Climate Change Adaptation Plan for Water & Aquatic Resources

Chapter 5: Yurok Drinking Water Sources and Systems

In This Chapter

This plan is from a purposeful collaboration with the staff and community members of the Yurok Tribe, as well as several organizations, and would not have been successful without each of their contributions. Funding was made available through the US EPA Science to Achieve Results (STAR) Program, Grant # 83560401-0. Online files available at: https://www.yuroktribe.org/departments/ytep/

> *"Springs were for drinking water... during the dry summers, particularly around Pecwan, the springs were dug deeper and cleaned out of silt. If they're on banks, you have to be careful not to dig below them or you'll loose the water altogether, but you dig back into the bank. The stream (creek) flow was used for irrigation and such but drinking water was always from the COLD springs, if it's cold it was good...we looked at the cup and if it was sweating because the water in it was cold, then it was good water."*
>
> – Betty Jackson, Culture Committee December 11, 2015

In the memories of elders, Yurok country is awash in water – winter rains, summer fog, cold perennial springs, and the ever-steady flow of river and creek water as it pours over riffles, swirls into eddies, and dawdles in deep pools. In recent times, however, recollections of abundant, healthy, and free water to drink have transitioned into realities of springs drying up during a multi-year drought, fear about pesticide and nutrient levels, *E. coli* outbreaks, and indignation at having to pay for a trust resource that was once available at no charge. Climate change may add to these impacts on drinking water and to threats on a key element of tribal sovereignty – the right to ample, safe, and affordable drinking water.

Climate change is giving rise to shifting ecological conditions and increases in extreme events. In Yurok country, these changes are expected to decrease source water quantity, alter the timing of supplies, increase water demands, degrade water quality, necessitate increasing and/or more advanced treatment, and damage water supply infrastructure (USEPA 2016a). Difficulties achieving compliance with environmental regulations may result. The costs of treating water, responding to water supply emergencies, and repairing damage to equipment and infrastructure, are all anticipated to rise (USEPA 2016a).

YTEP testing water for contaminants

The Yurok Tribe has over 6,000 members and is the largest tribe in California, however less than half currently live on the Reservation due to its re-

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[2] Yurok Tribe Environmental Program (YTEP), Klamath, CA.

mote location, lack of employment opportunities, and limited availability of basic utilities. Many residents obtain their water from private individual or small community systems. In the town of Klamath and outlying, downriver areas, water is supplied by the Klamath Community District from various wells and primarily bought from privately owned PWSs. In addition, the Tribe operates six public water systems (PWSs) for the communities of Requa, Turwer, Wautec, Keppel/Notchco, Weitchpec, and the area upriver from Kennick (Patterson 2015, Workshop 1).

The Yurok Tribe Public Utilities District (PUD) was formed in 2000 to deliver safe, treated drinking water to residents on the Reservation, including to critical facilities such as schools and health clinics (see Table 5.1). The downriver systems for Requa, Klamath and Turwer are each supplied by groundwater, and the three upriver systems are each supplied by surface water intakes located on various creeks (see Table 5.1). All PWS water is chemically treated through chlorination to remove pathogenic organisms. Surface water sytems also have a pre-treatment to remove sediments and turbidity by passing the water through roughing filters. The water is then further treated by routing through slow sand filters. Some individuals and PWSs use redwood storage tanks that may offer natural anti-bacterial properties in the wood. However, most water from PWSs is stored in steel tanks. Elders have reported that traditionally they were told to only store water in redwood, and all agree that this makes the water taste good. They further expressed that they hope that all Yurok know this taste, even today's younger generation.

Despite efforts to install PWSs throughout the Reservation, the rough mountainous terrain prevents those residents living in remote areas from receiving service. Approximately 670 residents continue to rely on their own individual systems primarily supplied by springs or surface water from creeks (Yurok Tribe 2015). Those who can afford it or have been serviced by the Indian Health Service, have roughing and sand filtration for their systems, and some have installed inline filters. However many do not treat their water in any way (Patterson 2015, Workshops 1 and 2). Some residents have access to water vending machines located at the Tribal offices in Morek-won and Weitchpec. They utilize the vending machines during emergencies such as when wildfire reponders were forced to destroyed their private systems while cutting fire breaks, or during bacteria outbreaks that make their drinking source waters unsafe to use. These vending machines are supplied with water from Yurok PWSs and are run by the Yurok Public Utilities District.

This chapter focuses on potential climate change impacts to drinking water supplies on the Reservation both for PWSs and for residents who obtain their drinking water through their own means.



Supplying safe drinking water to schools is a priority for the Yurok Tribe . Picture on left is Margaret Keating Elementary School that enrolls the highest number of downriver children and the picture in the center is Jack Norton Elementary school, the largest school enrolling upriver children. In addition there are several smaller facilities including the Weitchpec Elementary/Charter School in the picture at the right, and Head Start and Community Centers

Note: Sources for Table 5.1 include Fraser and May 2011 a, b, c; Yurok Tribe 2015

Table 5.1 Yurok Tribe Drinking Water Systems , Public Water Systems (RWS) and Private Systems			
Population Served/ Critical Facilities	Water Source	Finished Storage	Notes on Some Climate Change Sensitivities
REQUA PWS - Residential (~95 people) - Requa Resort & Campgrounds (~50 people per day during summer)	Salt Creek Well & National Parks Well	INSERT SOME-THING HERE	-Susceptible to possible flood contamination and salt water incursion from both storm events and rising sea levels -System dependent on electricity for pumping
TURWER PWS - Residential (~545 people)	Maple Street Well	200,000 gallons	-Susceptible to flood and sea water contamination and possible salt water incursion
KENICK PWS **- Residential (~25 people)**	Owl Creek; supplemented by two springs	**15,000 gallons**	- Sediment from runoff during storms increases turbidity of water and taxes the small treatment system capabilities - Underground cistern is under direct influence of surface water and susceptible to contamination from storm run-off
WAUTEC PWS - Residential (~60 people) - Jack Norton Elementary (~50 people) - Wautec Church - Wautec Fire Station	Achelth Creek	20,000 gallons	- Sediments from winter storms contributing to erosion often overwhelm the single roughing filter, sometimes forcing it offline -Source watershed has Cannabis grow operations that pull water from the same creek and place fluctuating demands on water -Creek runs basic during winter/spring adding to corrosivity of water and metals leaching/precipitation from distribution lines & valves
KE-PEL/ NOTCHKO PWS - Residential (~90 people) - Neil McKinnon Community Center (variable day use) - Yurok Head Start, Early Head Start Programs (~25 students)	Ke'pel Creek (west fork)	- 80,000 gallons (Ke'pel) - 10,000 gallons (Notchco)	- Sediments from winter storms contributing to erosion often overwhelm the single roughing filter, sometimes forcing it offline - Source watershed has Cannabis grow operations that pollute the creek with fertilizers and may lower the groundwater table supplying the creek.
WEITCHPEC PWS - Residential (~150 people) - IHS Clinic - Weitchpec Elem. School (~40 people) - Weitchpec Tribal Offices, Community Ctr.	Gist Creek	100,000 gallons	- High turbidity flows in winter from upslope private land use taxes system -Tested positive for Giardia, rising air & water temperatures may allow increased growth
PRIVATE SYSTEMS - Residential (~670 people) - Weitchpec Church - Pec-tah Fuel Mart - Tully Creek Community Center, Tribal Offices, & Wildland Fire Station	Various springs and creeks	Various	- Typically sourced by small, low flow creeks and springs that are vulnerable to changes in groundwater table from drought and variable demands of Tribal PWS as well as *Cannabis* grow operations. - Sedimentation from winter storms and contaminated surface runoff can overtax systems

5.1 Climate Change Effects on Drinking Water

Climate change can impact drinking water in a variety of ways. It can affect water quantity, quality, the timing of water availability, increase source water demands, alter treatment requirements, or affect water supply infrastructure in other ways. Yurok community members have noted that more energy will likely be needed to treat water and that this will not only raise treatment costs but, if fossil fuels are used, could also contribute to climate change in the process (Workshop 2). They expressed concerns that cultural knowledge of where and what qualities make good water sources will change and that rather than being able to rely on themselves to supply water, they will become increasingly dependent on the Tribe (Workshop 2). Finally, in the midst of the 2013-16 drought, community members were angry that, without adequate safe drinking water, some community members with medical conditions had to relocate, moving into surrounding off Reservation communities, and they voiced fears that threats to their drinking water might ultimately affect the ability of Yurok people to remain living in their ancestral home (Workshop 2). These different climate stressors are discussed below along with key impacts to drinking water.

Rising air temperatures

Climate change can affect drinking water supplies and also increase water demands.

Water quantities, timing, demand:

Higher air temperatures can lead to reduced water availability through increased transpiration by vegetation, the drying of groundwater recharge zones such as wetlands, and evaporation from soils and surface waters. All of these can decrease surface water flows and groundwater recharge (USEPA 2015a). In addition, rising air temperatures are expected to continue contributing to earlier snowmelt and to shifts in winter precipitation from snow to rain, resulting in a declining snowpack (Chapter 3/Ch. 3). This could decrease the slow recharge of groundwater aquifers that snowpack provides and contribute to higher winter and lower late spring and summer flows in the Klamath River and its major tributaries (Vose et al. 2012; Maier and Carpenter 2015; USEPA 2015a). Although Yurok do not currently obtain drinking water from the Klamath River or its major tributaries, such as the Hoopa Valley Tribe does with the Trinity River, this type of trend could affect future water supply decisions. Finally, the increasing water loss from plants noted above could, in turn, result in greater water demands from and usage by forests, farmers, and marijuana growers both on and off reservation. This could further decrease supplies available for drinking water in particular during the summer (BOR 2011; Jha and Pathak 2016).

Water quality:

The decreasing groundwater recharge described above can result in higher concentrations of minerals and salts thereby increasing salinities of groundwater as less water reaches deeper levels underground (Jha and Pathak 2016). Also, rising temperatures inside steel water storage tanks can lead to issues with disinfection byproducts as chemical reactions proceed at faster rates (USEPA 2002). Furthermore, rising air temperatures can contribute to the warming of water sources, which has additional consequences for bacterial and pathogen growth that can lower water quality (Pandey et al. 2014; PSR 2014).

Increasing drought intensities:

Another anticipated climate change for Yurok country involves increasing drought intensities (Ch. 3). Droughts are expected to affect water quantity and quality in ways that are similar to rising air temperatures. Rising air temperatures, in fact, may exacerbate the effects of drought (Diffenbaugh et al. 2015). Drought may also affect water supply infrastructure.

Table 5.2 Key Impacts on Drinking Water

Primary Climate Effect	Secondary Stressor	Potential Impacts		
		Water Quantity	Water Quality	Infrastructure
Warmer Air	Decreased snowpack Early snowmelt Increasing water demands	Surface water: - Higher winter flows - Lower late spring/ summer flows Groundwater - Less recharge	Surface water - Warmer water enhancing pathogen growth Groundwater - Higher salinities Treated water - Higher levels of disinfection byproducts	- May increase impacts below
Increasing Drought	Decreased snowpack Early snowmelt Greater evaporation	Surface water - Decreasing supplies - Drying of springs Groundwater - Less recharge - Increased withdrawals	Surface water - Warmer water enhancing pathogen growth - Potential *Microcystis* contamination Groundwater - Higher salinities & contaminant concentrations	- Loss of viable wells - Intakes may suck mud
Heavier Downpours	Increased run-off Winter flooding	Surface water: - Temporary high flows Groundwater - Less recharge	Surface water - Increases in turbidity, organic matter, pathogens, & pollutants Groundwater - Contamination through well casings/ heads	- Increased filter run times, disinfection levels, supplies - Intake clogging with debris/ sediments - Damaged distribution systems - Road slides/closures - Loss of power, phones
Increased Wild Fire	Reduced riparian vegetation Use of fire retardants	Surface water - Post-fire increases in runoff & flooding	Surface water - Increases in nutrients, organic carbon, metals, sedimentation, & pH - Septic systems damage could increase microbial contamination	- Shorter filter run times, increased backwash frequency, more sludge - Potentially higher levels of disinfection by-products - Damage to buildings, intakes, well casings, power
Warmer Water	Increased growth-harmful algal blooms, bacteria, & pathogens	→	Surface water - Increases in pathogens, & algal toxins Groundwater - Wells unaffected unless under direct surface water influence	-More sludge, shorter filter run times, increased backwash frequency -More advanced treatment needed to remove toxins
Rising Sea Level	Saltwater into coastal aquifers' Decreasing efficacy of coastal septic systems	Surface & Groundwater -Decreased availability of safe drinking water sources	Surface & Groundwater -Saltwater intrusion	- Corrosion of valves, pipes and buried infrastructure
Combined Effects	→	Rising costs & fears that will not have an adequate supply of safe drinking water.		

Water quantity:

As was observed during the recent 2013-16 drought, drought can decrease surface water flows in tributaries and dry up springs important to Yurok community members for drinking water supplies (Workshop 2, Yurok Planning Department). They can also increase declines in snowpack and reservoir levels (USEPA 2015a; USEPA 2016c). In addition to reductions in surface water flows, drought could also simultaneously lead to reduced groundwater recharge and increased regional groundwater withdrawals to meet water demands (Taylor et al. 2013; USEPA 2014). Both of these would lower groundwater levels. Surface water supplies might also be taxed by demands that remain high or may increase with warmer air temperatures often associated with drought.

Wautec PWS intake on Achelth Creek. Note a result of the drought and high water demands of the community allow very little water to escape the intake pool to maintain flows in the creek for wildlife and ecosystem.

Water quality:

Drought can also affect water quality. For instance, by reducing flows, droughts contribute to warmer water temperatures (Ch. 3). In the future, droughts may also influence larger wildfire frequency and size, resulting in impacts on turbidity and sedimentation from increased erosion (Ch. 3). Storms that follow long dry periods could result in particularly high loadings of sediments and other pollutants because the dried soils form a barrier to downward water percolation(Ch. 3). As flows decrease, pathogens may be more concentrated than normal (Stanke et al. 2013). During the 2013-16 drought, increased saltwater influence in some of the groundwater wells near Klamath was noted (Workshop 2).

Yurok resource managers have also raised concerns that if during drought, water is transported from the mainstem Klamath to tributary watersheds, for example for the irrigation of marijuana or fire suppression, this could lead to the spread of *Microcystis*, a toxic bluegreen algae (Workshop 1). Community members noted that drought could have indirect effects on water quality as well. If water is hauled in plastic bottles in response to the drought and the bottles get warm, this could increase ingestion of plastic byproducts (Workshop 2). The disposal of the plastic water bottles could also cause environmental impacts. There are also emotional and spiritual consequences of taking water from another location which stems from the Yurok traditional, holistic belief that everything is where it should be. By removing water from somewhere else you are upsetting the balance as that place may need the water and that could be someone else's sacred place (Workshop 2).

Infrastructure:

Drought could also affect drinking water infrastructure. If groundwater levels are lowered, uneven settling of the soils may occur leading to pipe breaks (Wols and van Thienen 2014). Drinking water could leak out and non-potable water and liquids could infiltrate into the distribution system (Wols and van Thienen 2014). During the 2013-16 drought, it was reported that surface water intakes began sucking in mud, and pumping and filtration in some PWSs were impacted by increasing sediment and turbidity associated with the drought (Workshop 1).

Heavier downpours:

Rainfall intensities are anticipated to increase with climate change (USGCRP 2014; Maier and Carpenter 2015; USEPA 2015a). This could affect water quantity, quality, and infrastructure.

Water quantity:

Heavier downpours during the winter rainy season, either by themselves or in combination with rain on snow events, could lead to increases in winter flooding (Ch. 3). The effects on groundwater recharge are less clear. If greater precipitation intensities saturate soils quickly, then a higher proportion of the rainfall may run off rather than percolate into the ground (AWWA 2011).

Water quality:

In surface waters, heavier downpours and associated flooding could lead to increases in surface sheeting and runoff that carries increased sediments, nutrients, organic matter content, and microbial pathogens, all leading to higher turbidity and contaminant loads in general (AWWA 2011; WHO 2012:18; Jha and Pathak 2016). This could particularly be the case, as noted above, after long dry periods. Community members noted slimy clumps or 'slugs' of algae and other material that has the capacity to harbor harmful bacteria such as E. Coli in the water supply following floods (Workshop 2). Flooding can also lead to the contamination of groundwater and the drinking water it supplies if floodwaters enter the top of the well, cracks in the cap or casing, or from other entry points into the landscape in the vicinity of the well (WDNR 2016b). Wells located in pits or low-lying areas may be particularly susceptible to contamination (WDNR 2016a).

Infrastructure:

Changes in the quality of source waters may require operational modifications, for example, alterations to filter run times or in disinfection (AWWA 2011). Changes may also ultimately necessitate the implementation of additional treatment processes (Jha and Pathak 2016). In addition, heavier downpours and associated flooding could inundate and damage public water supply infrastructure leading to disruptions in service. Facilities that, in particular, might be affected are those located in current or anticipated future riverine floodplains or infrastructure in areas that might be subject to coastal flooding due to a combination of sea level rise and heavier downpours (AWWA 2011). Affected infrastructure could include water supply intakes, pump stations, and distribution systems (USEPA 2015a).

For example, increased flooding could erode the banks supporting concrete water supply intakes. In addition, during past flood events, sediments clogged some intakes making it necessary to go out during rain events and dig the intakes out (Workshop 2). Flooding could also damage secondary infrastructure causing, for example loss of power or cell phone coverage that could affect PWS operation (USEPA 2014). Finally, flooding could make it unsafe for water system operators to do their jobs (USEPA 2014). In particular, access to the treatment plants could be affected by landslides and/or flood waters (Workshop 2). If roads are closed, water system operators either may not be able to reach these communities and systems or, given the remote locations, it may take an extremely long time. This also means that community members may not be able to drive to locations to obtain safe drinking water, or again, that it might involve a trip of several hours.

Increasing Wildfires:

Rising air temperatures and increasing drought intensities are expected to contribute to and increase in wildfire frequency and extent in Yurok country (Ch. 3). Wildfires can affect water quantity, quality, treatment and water supply infrastructure.

Water quantity:

The loss of vegetation and soil exposure in burned areas can contribute to post-fire increases in runoff and flooding (WRF 2013; USGS 2018).

Water quality and treatment:

Water quality impacts may be variable and can include increases in nutrients, turbidity/sedimentation, organic carbon, metals, and pH (from ash deposition) (WRF 2013).

Infrastructure:

Increases in turbidity and sedimentation may result in shorter filter run times, increases in the backwashing frequency needed, and greater amounts of sludge that must be disposed. If organic matter reacts with disinfectants, higher concentrations of disinfectant by-products may result (WRF 2013). Fires also have the potential to directly damage water supply infrastructure including buildings, source water intakes, and well casings, and secondary infrastructure such as power supplies. Microorganisms, chemicals, and fire retardants could contaminate fire-damaged well systems. If fire damages septic system components, this could contaminate water supplies as well (Waskom et al. 2013). Community members also expressed concerns that heavier downpours combined with increased wildfires could lead to more landslides occurring (Workshop 2). Landslides have the potential to directly damage infrastructure and could also make roads impassable. With few roads leading into and out of some communities, this could pose challenges for operators trying to reach public water supply systems, potentially resulting in situations with unsafe drinking water.

Rising water temperatures:

Water temperatures are expected to rise with climate change (Ch. 3) and could influence the growth of bacteria and pathogens (Pandey et al. 2014; PSR 2014). When combined with factors such as higher nutrient levels, this could potentially lead to increases in algal blooms (USEPA 2015b). Many types of bluegreen algae, for instance, grow more optimally at higher temperatures, which could affect both water supply quality and treatment (O'Neil et al. 2012).

Water quality:

Many pathogens including some bacteria have increased growth during warm spells and that could impact the safety of drinking waters. In addition, some algal blooms can produce toxins that cause human illness and death as well as kill fish and wildlife (Glibert et al. 2005; Paerl and Paul 2011). These are known as harmful algal blooms (HABs). Pets can also be affected if they consume algal scum or mats, lick their fur after swimming in contaminated waters, or drink contaminated water (USEPA 2015b). *Microcystis* HABs have already occurred in the Klamath River mainstem, and if they move out of the mainstem into tributaries, many of the Yurok surface drinking water supplies could become unsafe(YTEP). Algal blooms and their toxins typically do not affect groundwater wells unless those wells are under the direct influence of surface water (USEPA 2015b).

Infrastructure:

Algae may physically decrease filter run times, increase the frequency of backwashing needed, and increase the amount of sludge that must be disposed (Brubaker 2010). If toxins are present, more advanced treatment may be needed to remove the toxins (USEPA 2015b). This could increase costs for public water systems, and those not connected to a PWS could become unable to safely use their traditional surface water source while a bloom is occurring.

Sea level rise:

Rising sea levels could affect water quality and drinking water infrastructure in low lying areas such as the Klamath estuary and the downriver PWSs.

Water quality:

As sea levels rise, the movement of saltwater into coastal freshwater aquifers (saltwater intrusion) is likely to occur and could affect the viability of and/or treatment costs associated with using such aquifers as a drinking water supply (Green et al. 2011;Taylor et al. 2013; USEPA 2015a). In addition, sea level rise in combination with heavier downpours could lead to rising water tables that could affect septic system functioning (Ch. 4.X). This could result in septic system failure and the introduction of pathogens and nutrients into groundwater and surface runoff (Cooper et al. 2016; Mihaly 2017).

Infrastructure:

Sea level rise could also lead to the loss of coastal wetlands that can buffer coastal drinking water infrastructure (USEPA 2015a). In combination with high tides and heavier downpours, it can also exacerbate storm surge flooding, which can inundate drinking water sources such as those that supply Requa, Klamath and the Glen (AWWA 2011; Maier and Carpenter 2015; USEPA 2015a). The saltwater intrusion noted above could contribute to the corrosion of buried infrastructure as well (AWWA 2011).

5.2 Existing Challenges (sensitivity)

In addition to potential climate change impacts on drinking water quantity and quality, a variety of non-climatic factors can adversely affect drinking water on the Yurok Reservation increasing the sensitivity of Yurok water supplies to climate change. Key factors are described below.

Individual/households:

Most Yurok who are not on a public water system do not currently test their water and only minimally treat their water. This can increase their vulnerability to pathogens or other pollutants with concentrations that may increase as described above under climate change scenarios. While boiling water is one alternative for killing pathogenic bacteria, viruses, and protozoa, one challenge with algal toxins is that currently there are no point-of-use treatment devices that people can use in their homes to remove the toxins (USEPA 2015b).

Public Water Systems:

Various aspects of public water systems (PWSs) can increase their sensitivity to climate change. These include:

Source waters:

Resource managers and community members noted that water systems at Wautec and Weitchpec already have seasonal problems with turbidity that results in customer complaints of cloudiness (Workshop 1) . They also noted that the Lower Klamath River and a number of its larger river tributaries are on the USEPA 303(d) list of impaired waters and that the Klamath River mainstem has regular, yearly elevated levels of a harmful algae, *Microcystis* (Workshop 1). Although the mainstem is not currently utilized as source water for the PWSs, it is often considered as a potential source when planning for population and economic growth. However, impaired conditions can add to the challenge of using these waters as drinking water sources.

Infrastructure age:

One factor that could make infrastructure more sensitive to climate change is infrastructure age; older infrastructure is more prone to failure. Mechanical and electrical components in treatment plants and pumping stations may have lifespans of 15-25 years while associated concrete structures may have lifespans of 60-70 years (ASCE 2011). Distribution infrastructure may last from 60-95 years (ASCE 2011) depending on its components. For example, community members noted that there are leaks in the distribution system that have not been repaired (Workshop 1). This not only generates the waste of clean, treated water and the associated costs, but leaks also have the potential to allow back infiltration into the system and may become a contmaination source.

Vending machines

In addition, a key component of providing safe drinking water for community members has been the installation of water vending machines for use by households not connected to a PWS and also for use during emergencies. These vending machines are typically supplied by water hauled from Yurok PWSs . During the 2013-16 drought, the water vending machines were, at times, not operational (Yurok Planning Department). Issues that arose with respect to the machines included finding people qualified to drive the water truck to supply the machines and also people having access to the tokens needed to receive water from the vending machines (Workshop 2). In addition, the vending machines are considered part of the Yurok Public Utilities District and must be maintaned, monitored, and operated by certifed operators that are already in high demand and unable to service the machines.

Treatment processes:

Some processes within Yurok PWS treatment systems are at times offline and not operational. These include the roughing filters at the Wautec, Ke'pel, Kennick and Weitchpec PWSs (Fraser and May 2011a, b, and c). Roughing filters are filters made of coarser materials such as rock or gravel that are used to pre-treat water (WHO 2004). In addition to reducing the coliform bacteria in water, they can also decrease the suspended solids that could rapidly clog the slow sand filters used in the treatment process (WHO 2004; Nkwonta et al. 2009). Given potential increases in sediment loadings associated with anticipated heavier downpours and increases in wildfires under climate change, the roughing filters being offline could increase the sensitivity of Yurok water systems to these changes. In addition, the treatment processes of both the PWSs and private drinking water systems throughout the Yurok Reservation do not have the ability to remove chemicals such as pesticides, endocrine disruptors (chemicals that interfere with hormone systems), or algal toxins (USEPA 2016d).

Storage:

Challenges associated with water storage may include storage capacity, storage tank maintenance and cleaning, and time spent in water storage tanks. For instance, resource managers mentioned the need for larger water storage tanks (Yurok Planning Department). By way of example, on the Upper Reservation, the storage tanks for the public water systems only have enough capacity to hold two to three days worth of water, which would be inadequate to maintain a supply to residents in case of emergency failure of the source water supply or treatment (Yurok Today 2014).

Example of a typical private storage tank.

Storage tank maintenance and cleaning is also important. Without this, sediments may accumulate over time (USEPA 2002). This could contribute to microbial growth, increased disinfectant demand, the formation of disinfection by-products and increased turbidity levels (USEPA 2002).

The age of treated water in storage tanks can also become an issue. If water spends too much time in storage, this can result in the disinfection products to becoming depleted and not being able to adequately protect water from microbial contamination(USEPA 2002). The potential for the formation of disinfection byproducts also increases with time spent in storage (USEPA 2002). Finally, nitrification, another potential health concern, could occur if storage times are lengthy (USEPA 2002).

Communication and power:

The remote monitoring of the systems and general communication necessary for proper operation of the PWSs infrastructure is difficult (Workshop 2). Some have no internet, telephone service, no cell phone coverage available, and/or satellite phones do not work. Power is also sometimes not reliable at certain locations and off-grid technologies such as solar panels may not work well because of factors such as shading (Workshop 2). This makes the transfer of online data and operation of electrical pumps and automated disinfection systems unreliable.

Financial capacity:

Smaller drinking water systems face inherent financial challenges because they are unable to take advantage of economies of scale to reduce costs and because smaller populations cannot supply enough utility revenues to support operations (USEPA 1994; Maier and Carpenter 2015). All of these factors hinder the ability of small drinking water system operators to maintain their systems, to upgrade them with newer technology, and to provide ongoing training and education for staff members (USEPA 2001; Maier and Carpenter 2015).

In addition, the Yurok Tribe Planning Department noted that, currently, the water rates do not adequately support the operation of the Yurok PWSs. They also noted that better metering is needed so that costs accurately reflect water usage. Challenges with funding through the Indian Health Service (IHS) were also discussed, in particular that IHS provides help with infrastructure building and installation but does not provide resources for operational costs beyond a transition period after a water system is installed and also that they do not provide funding for maintenance. Furthermore, Yurok resource managers noted that the Tribe currently does not have a water conservation plan and that without such a plan, the Tribe was unable to access certain funds such as those associated with the 2014 California Proposition 1, Water Bond, which enacted the Water Quality, Supply, and Infrastructure Improvement Act of 2014.

A final financial issue is that the Tribe does not currently have lab facilities to test drinking water quality for contaminants such as bacteria, pesticides, and Microcystis. Samples must be sent off-reservation, which can be quite costly and can thus limit the amount of data the Tribe is able to obtain (Workshop 1).

Staffing and institutional memory:

Currently, limited staff, between one to three people, run all six Yurok PUD water supply systems. This can prove challenging in particular during times of emergency when increased monitoring, maintenance, and operational processes may be required and there are insufficient personnel to run the public water systems. In addition, the turnover of water operators has been high. This can create gaps in the passing down of knowledge from operators experienced with the systems to new operators.

Emergency communication:

Community members also expressed concerns with respect to communication during emergencies such as the timeliness of getting notices about water issues and receiving incomplete information (Workshop 2). Examples of the latter included being informed not to use the water but not being told why or being told not to drink the water but not being informed on whether they should also not be bathing or washing dishes with the water (Workshop 2). In addition, it is not always clear which entity and/or person should be informed of water problems such as springs drying up during the recent 2013-16 drought (Workshop 2).

Contamination Sources:

Feral or unfenced cattle that defecate in or near tributaries and springs can contaminate water sources with waterborne pathogens such as E. Coli, Cryptosporidium, and Giardia (CFMC Meeting). Another probable source is poorly maintained septic systems that can result in microbial contamination of water supplies (WHO 2012:18). Most residences and Tribal-buildings on the Reservation use septic systems for wastewater disposal except for the downtown Klamath area. A number of these systems were installed in the 1960s and ’70s and thus may be exceeding the typical life expectancy of such systems, which can range widely from 20-40 years depending on factors such as maintenance and septic tank materials (GBSS 2016; SESSC 2017; YTEP). In addition, many homeowners may not be maintaining their systems and may not even know where they are located because this knowledge has not been passed on to them (CFMC Meeting).

Land Use Practices:

Another challenge for the Tribe with respect to addressing drinking water quantity and quality issues is lack of control over the watersheds supplying their drinking water (Workshop 2). As of 2012, 85% of the Reservation was non-Indian controlled (BOR 2012). In addition, community members pointed out that they have limited control over which resources are coming onto the Reservation from further upriver (Workshop 2). Several of these land uses that are outside of Tribal control have significant impacts on the availability and quality of Yurok drinking water; principally timber harvesting and marijuana production.

Large-scale commercial logging has historically taken place on the majority of Reservation land. Logging can contribute to issues with both water quantity and quality. Historic logging practices, for example, still impact watersheds today. Logging, the loss of prairies through conversion to forests, the suppression of cultural burning, and fire suppression in general have contributed to forests that are often overstocked with trees and overgrown with brush (Ch. 4). This can lead to increased water uptake by forests and decreased groundwater recharge and, in turn, decreased baseflows for streams (Ch. 4).

In terms of water quality, erosion from unrehabilitated logging roads introduces huge quantities of sediment into the Klamath River system, contributing to issues with turbidity and any pollutant loadings associated with the sediments (Workshop 2, Ch. 4). Most Tribal Members have to remove their drinking water intakes from streams and creeks during the winter months as the turbidity and sediments washing down the hills can destroy their private systems. The harvest of old growth redwoods and spruce has reduced shading as well as less bank stability for riparian areas. This decreased shading along with the straightening of stream channels and removal of large woody debris and boulders from streams to facilitate log passage all contribute to surface water warming, which in turn can contribute to harmful algal blooms (Ch. 4). Finally, the Green Diamond Resource Company manages a large percentage of the land either on or adjacent to the Yurok Reservation for timber harvesting. Pesticides used in this management may enter the creeks as runoff, potentially contaminating drinking water supplies (Workshop 2, Ch. 4).

In conjunction with logging, there is a growing presence of large-scale, commercial cultivation of Cannabis for marijuana products that has arisen in the Lower Klamath River watershed despite it being illegal to cultivate on the Yurok Reservation (Ch. 4). In addition to social problems that can arise from Cannabis growing (e.g., gang-related intimidation), marijuana cultivation is also affecting water quantity and quality in areas that are important drinking water sources for the Yurok Reservation (Workshop 2). Marijuana is considered a high water use plant, with individual plants consuming an estimated six gallons of water per day averaged across the growing season (Bauer et al. 2015). Localized water demand estimates were calculated by Freshwater Environmental Services based on counts from aerial photographs taken during 2015, which visually show the number of marijuana plants being grown within the watersheds of those creeks that originate or flow through the Yurok Reservation. The water demand estimates are considered conservative given the presence of leaky irrigation lines and evaporation from makeshift storage pools found during Operation Yurok marijuana raids. By way of example, in the Gist Creek watershed that supplies water for the Weitchpec Public Water System, an estimated 2,000 gallons of water per day is withdrawn for marijuana cultivation. In some watersheds, such as that of the Mareep River with multiple grow operations, an estimated 11,700 gallons is withdrawn per day (Thiesen et al. 2016).

Potential water quality impacts from marijuana growing include the improper storage of herbicides, fungicides, and rodenticides (Yurok Today 2013b, 2014c). Community members are concerned about the possibility of runoff picking up these toxins and contaminating drinking water sources (Workshop 2). In addition, excessive fertilizers applied to the soil for growing marijuana could contribute to the development of harmful algal blooms (Levy 2014). At some marijuana growing locations, human latrines have been situated near tributaries, potentially contaminating the tributaries with E. Coli and other waterborne diseases. If undertaking efforts to remove pesticides and waste, Yurok resource managers are unable to work directly with county officials for their removal, but must instead involve the USEPA, which can add additional challenges.

5.3 Yurok Strengths (adaptive capacity)

In addition to the challenges they face, the Yurok also have existing adaptive capacity to address impacts on drinking water. Key factors contributing to adaptive capacity include aspects of: existing infrastructure, planning and assessments, and monitoring.

Public Water System Infrastructure:

During previous droughts, brackish water has infiltrated some wells (Workshop 2). The Tribe negotiated with Green Diamond to use their wells as an alternative water source (Workshop 2). In addition, Yurok PWS infrastructure has undergone some relatively recent upgrades to enhance the resiliency of the systems to climate and other changes.

Remote monitoring:

The Yurok Public Utilities District typically only has one to two people operating all six of its public water systems. This means that an operator is not always on site. As of 2011, the Tribe had installed solar-powered, remote monitoring systems on the water systems at Weitchpec, Ke'pel, and Wautec. These systems monitor variables such as chlorine used for disinfection, turbidity, pH, and water temperature. The data are then uploaded via satellite link and can be viewed by an operator at another location via the internet, 24 hours a day. The system thus allows operators to ascertain when water quality is becoming poor or if a system may be running out of water and when a site visit may be necessary (Yurok Today March 2011). This allows operators to allocate their time more effectively.

Water metering:

Also as of 2011, the Tribe had installed new water meters on Requa Hill (Yurok Today March 2011). Such meters can assist the Tribe with monitoring, leak detection, and accurately charging for water usage.

Increasing storage capacity/ upgrading infrastructure:

The Tribe is continuing to add storage capacity to and upgrade its PWS infrastructure. For example, the Tribe got a nearly $1 million grant to improve the Requa PWS by replacing aging water mains and installing new storage tanks at higher elevations to reach more residents (Yurok Today March 2011).

Existing, bolted steel, finish water storage tank for the Kenick Public Water System.

Leak detection equipment: I

In 2016, the Tribe purchased leak detection equipment and began repairing leaking pipes and valves in distribution infrastructure (Workshop 2).

A common water bladder or 'dam' used by Cannabis growers to store the massive amounts of water that they need to sustain their high water demand crop.

Planning and assessments:

The *Yurok Tribe Indian Sustained Yield Lands Forest Management Plan* contains several elements protecting water quality included designated riparian buffers and plans to eliminate the use of pesticides for forest management (Yurok Forestry Department 2012). The *Yurok Drought Contingency Plan* focuses on drinking water and outlines options for responding to drought as well as recommendations for improving drought response and lessening potential impacts (Yurok Tribe 2015). Also, *Source Water Assessments have been completed for the downriver PWSs* (YTEP 2018). These assessments identify potential threats to and protection measures for drinking water sources (YTEP 2018). Finally, community members noted that the Yurok Tribe has a strong planning department that knows how to get grants and that can assist with finding funding for water system improvements (Workshop 2).

Monitoring:

The Director of the Yurok Tribe Environmental Program (YTEP) is investigating the possibility of starting a Reservation water quality laboratory that could test for certain key water quality parameters such as bacteria (Workshop 1). In addition, under a USEPA Science to Achieve Results grant, YTEP tested drinking water at 20 locations for cyanotoxins and waterborne pathogens such as *Cryptosporidium, Giardia lamblia, and Legionella* (Workshop 1). These results provide basline information.

YTEP staff utilizing current water quality lab.

Other:

Community members noted that the Yurok Tribe has sovereignty. The Tribe can develop its own ordinances and protect water the "Yurok Way" (Workshop 2). For example, the Tribe is in the process of developing a Wetlands Protection Ordinance that will encompass source waters like springs, which also provide drinking water to the community. In addition, the Tribe participates in annual Operation Yurok efforts to locate and remove illegal marijuana grows on Yurok lands. These seizures of marijuana and removal of associated pesticides and latrine waste help prevent further water quality contamination from the grows. Finally, for emergency response, the Yurok Tribe owns a 750-gallon potable tank wagon (Yurok Tribe et al. 2015).

5.4 Adaptation Strategies

All of the strategies in the adaptive capacity section represent actions that the Yurok could continue and build on as part of their adaptation efforts to help address their area's climatic and non-climatic sensitivities. Key strategies to consider are listed below. They are divided into four categories: water supply management, water demand management, water system management, and emergency response. A comprehensive list of adaptation strategies is included in Appendix 5.1.

Water supply management adaptation strategies

These focus on ecosystem management, particularly wetlands. Wetlands act like giant sponges, that absorb and hold vast quantities of water and then release it slowly, and in Yurok country, they help maintain both the quantity and quality of drinking water supplies.

Diversify Water Supply

- Have multiple water sources for each public water system for emergency use during drier years (USEPA 2015a).
- Encourage individuals to develop a rain water harvesting and storage program for irrigation.
- Explore alternative water sources for non-drinking uses such as toilet flushing, garden irrigation, washing clothes.
- Coastal communities could investigate portable solar distillers, small-scale desalination systems (USGS 2016).
- Individuals could consider costs and benefits of connecting to an existing PWS.

Source water protection - ecosystem management strategies

Management jurisdiction, agreements

- Increase ownership for management and jurisdiction of drinking water source watersheds.
- Develop co-management agreements with agencies owning land that affect Yurok drinking water quantity and quality (e.g., U.S. Forest Service, National Park Service, state parks).

Management plans

- Manage forests to increase water yields (e.g., consider conifers vs. prairies contributions to groundwater recharge) (Aranda et al. 2012, Vose et al. 2012)
- Prioritize hazards fuel reduction to protect drinking source waters from post-fire erosion (e.g., prescribed burns, & manual thinning) (WRF 2013; USEPA 2015a).

Legal

- Increase enforcement of the Yurok Controlled Substance Ordinance to protect source waters from associated fertilizer and pesticide use and runoff.
- Establish source water protection zones and restrictions that protect water quantity and quality.
- Support the continued development of a Yurok wetlands ordinance that protects water quality.

Protection and restoration (Also see Chapter 4 strategies)

- Reduce sediments into drinking sources (e.g., logging road rehabilitation, maintain riparian buffer strips) (USEPA 2015a).
- Increase groundwater recharge, reduce runoff to improve quality (e.g., prairie restoration).
- Naturally store and attenuate floodwaters (e.g., wetland restoration).

Note: For a comprehensive list of all strategies identified during this project, please see Appendices.

Water system management adaptation strategies

These ideas focus on improving water supply infrastructure.

Treatment systems

- Develop and recruit governing board to insure PWS maintenance, monitoring, and procedures required by US Safe Drinking Water Act requirements are being met.
- Investigate whether remotely monitored and operated package plant water treatment systems could be useful in a Yurok context and increase climate resilience (USEPA 1994).
- If cost of installing distribution lines is prohibitive, explore Point of Entry treatment systems (home treatment systems) run by a PWS or explore mobile water purification wagon run by PWS. (USEPA 1994; Markham 2013).
- Modify treatment processes to handle increased sediment loads, for example by building detention ponds to allow solids to settle before entering the plant (CDPHE 2012; USEPA 2016b).
- If harmful algal blooms become an increasing problem, investigate the possibility of modifying treatment processes to include powdered activated carbon to treat microcystins that may be present during blooms (USEPA 2015b).

Operation and maintenance

- Ensure that adequate disinfectant levels without excessive disinfection byproducts are maintained in PWS storage and distribution systems as these may be affected by warmer water temperatures.
- Identify and repair leaks in all systems to minimize water loss and contaminant infiltration (WHO 2012).
- Plan for increased staffing requirements for future climate change. More monitoring time may be needed, more emergency personnel may be required, and more advanced treatment processes may need increased staff (NRC 1997).

Storage capacity

- Increase storage capacity by adding additional tanks for private and public systems.
- Investigate methods to enhance natural ground water storage, for example through the use of permeable surfaces so that rainfall can be absorbed and stored underground (Swinomish Tribe 2010).

Monitoring

Monitoring programs, methods

- Investigate the installation of off-grid power sources in upriver systems to allow for the use of remote sensing monitoring instruments to facilitate real-time data collection (ANTHC 2011a).
- Develop data collection forms & database to store and process sales, production, & monitoring data (Yurok Tribe 2015).
- Develop early warning system for harmful algal blooms including monitoring for visual observations of algal mats, raw water pH spikes, increased turbidity, decreased filter run times, and possibly higher chlorine demand (USEPA 2015b).

Education and outreach

- Develop educational materials on and a program to assist homeowners who are not on PWSs with monitoring their drinking water and with the development of inspection, cleaning, and maintenance schedules (Workshop 1).

Financial preparedness

- Develop a funding plan for upgrades and increased monitoring and emergency response costs that may be needed with climate change and associated changes in water quality and extreme events, such as floods.
- Explore whether purchasing insurance for Public Water Systems may be a viable and beneficial way to help address costs associated with emergencies (USEPA 2015a).

Note: For a comprehensive list of all strategies identified during this project, please see Appendices.

Water system management adaptation strategies, continued

Source water protection – both public and private

Education and outreach

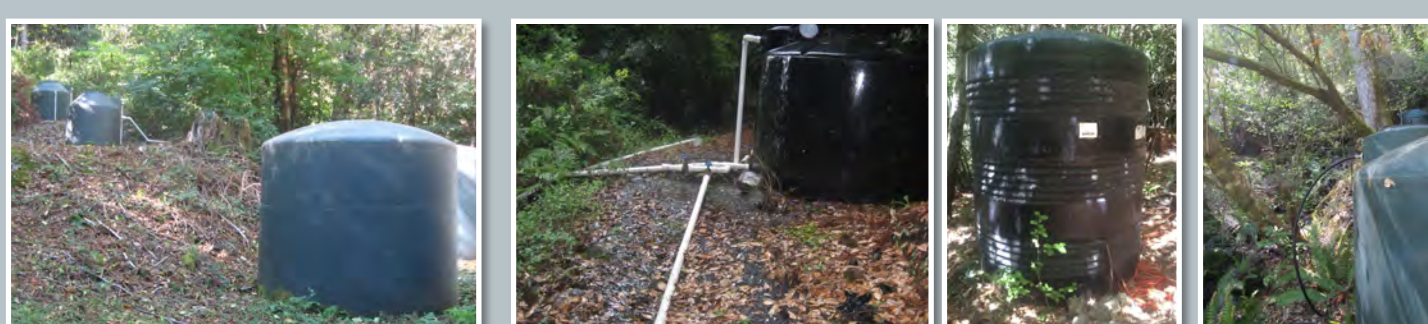
- Teach community members where to locate and how to build sanitary collection boxes (Workshop 2).
- Develop outreach materials about proper construction and location of outhouses and pit toilets and about septic system maintenance, inspection, and pumping so don't contaminate water (Mihaly 2017).
- Educate community members and marijuana growers about the dangers of spreading harmful algal blooms by transferring water from the Klamath River to smaller watersheds.
- Develop outreach materials to inform community members about the signs and dangers off waterborne pathogens.

Legal and Policy

- Explore agreements or obtain rights to water sources that may become important in the future with climate change.
- evise/update Water Pollution Control Plan to strengthen protections of water quantity & quality (WHO 2012).
- Finalize Yurok Environmental Ordinance that specifies human sewage dumping regulations (WHO 2012).
- Consider developing Yurok ordinance to require owners to fence in livestock.
- Develop Yurok standards for septic systems governing minimum distance between leachfield bottom and top of the groundwater table considering factors like sea level rise and increasing precipitation intensities (Mihaly 2017).
- Upgrade the land use plan to include source water protection actions (Yurok Planning Department).

Infrastructure

- For wells: ensure that new wells are sited outside of projected coastal and riverine flood zones and areas of potential saltwater intrusion from sea level rise in coastal areas (JST 2013).
- Test and if needed, disinfect water supply wells after major flood events (SITC 2010; Jamestown S'Klallam 2013).
- For springs: construct safe collection boxes with overflow elbows or tees (WHO 2012).
- For rainwater catchments: ensure that filters and first flush mechanisms are in place and that storage tanks are made mosquito-safe (WHO 2012).
- For all surface water intakes: install and maintain screens, roughing filters, and sediment traps.
- For all septic and sewage treatment facilities: monitor septic system performance and fix leaking tanks in the vicinity of the withdrawal point (e.g., well heads and intakes) (WHO 2012; Mihaly 2017).
- For all new PWSs: consider vulnerability to sea level rise, projected risks of coastal and inland flooding, and other potential climate change factors before developing and siting (USEPA 2015a).



Typical water storage on gravity fed systems on the Yurok Reservation

Water demand management adaptation strategies

These focus on minimizing the amount of water that is used in a system. These strategies include both water conservation (changing behaviors) and water efficiency (changing infrastructure).

Water conservation and efficiency

Education and outreach

- Promote training for individual households on leak and minor plumbing repair (USEPA 2016a:14).
- Provide a tribal telephone hotline or website for customers to report leaks to Public Utilities (USEPA 2016a:14).
- Research funding for a tribe-wide program to replace less water efficient appliances such as toilets, showerheads, and faucets, with more efficient ones in homes, businesses, and tribal offices (USEPA 2013b).
- Provide sanitary installation information for outhouses/composting toilets, that use little to no water (Workshop 2).

Legal and policy

- Add water line leak inspection as part of the Yurok Real Estate Division's assignment review process (USEPA 2016a:16).
- Develop tribal water use regulations with enforcement provisions to prosecute water waste and excessive water use.
- Finalize adoption of Yurok Tribe Drought Contingency Plan and enforce water use restrictions during droughts.

Infrastructure

- Continue inspections and replace/repair of leaking public water system distribution lines.
- Install production meters (amount of water entering the distribution system) and sales meters for all PWSs (Yurok Tribe 2015). Consider investing in automated meters that can provide real-time water leak information (USEPA 2016a:14).
- Seal intake structures with grout for Weitchpec, Ke'pel/Notchco, Wautec, and Kenick PWSs (Yurok Tribe 2015).
- When installing new equipment, use pressure reducing valves & flow restrictors, to decrease leak volume (USEPA 2013b).
- Optimize backwashing practices to lower water use during water supply treatment (USEPA 2013b).

Emergency preparedness and response adaptation strategies

Theses focus on actions that will help prevent the disruption of water supplies and protect public health if drinking water quality or quantity is compromised until such time as safe and adequate water supplies can be restored. Climate change is anticipated to result in increasing extreme events (e.g., floods, fires, and droughts) and thus water supply emergencies.

Monitoring

- Monitor intakes and keep clear of sticks, logs, & other debris (for fires and floods) (CDPHE 2012).
- Monitor filters and increase backwashing, as necessary (for fires, floods, HABs) (CDPHE 2012).
- Ensure emergency field kits are available for frequent raw water testing to predict treatment needs (USEPA 2015a; CDPHE 2012).

Storage capacity

- Increase treated water storage in case system is offline for a long period of time during emergencies (USEPA 2011:14)
- Implement procedure to top off water storage tanks before emergencies (USEPA 2014).

Collaboration and agreements for sharing

- "Negotiate and enter into mutual aid agreements with nearby tribes and agencies" (Yurok Tribe 2015).

Planning
- Develop multi-hazard emergency response and mitigation plans for PWSs (e.g., for flood, fire, drought, harmful algal blooms) (AWWA 2011; CDPHE 2012; USEPA 2014). - Implement a process to document lessons learned about how extreme weather and other emergency events have affected PWSs (Maier and Carpenter 2015).
Communication pathways
- Develop communication pathways among water quality (e.g., YTEP), water supply (e.g. Yurok Public Utilities District), and wildlife (e.g., Yurok Wildlife Department) personnel, as well as local veterinarians to ensure that water contamination issues that may first be indicated via wildlife and/or pet illness are communicated to relevant personnel in all sectors. - Develop risk communication plans for drinking water contamination and/or water shortages (CDC 2013, USEPA 2015b:4). - Designate a single contact person to report to for water contamination or shortages, for example dry water springs. - Provide open comment system for feedback on emergency response & water-related needs (Workshop 3). - Identify communication methods to ensure that all affected people are notified of water contamination/ shortages. - Work across agencies to ensure that consistent messages are being delivered (USEPA 2016a).
Emergency treatment
- Maintain equipment & supplies for emergency filtration/treatment of drinking water (such as point-of-use treatment). - For longer lasting emergencies, explore advanced purchasing, renting, or borrowing larger scale portable/packaged treatment units such as the military, State National Guard, and large NGO/private sector utilizess. (USEPA 2011).
Water stockpiles and hauling
<u>Emergency water stockpiles</u> - Stockpile and maintain emergency water supplies at key locations (SITC 2010) <u>Bulk water transport and distribution</u> - Purchase truck certified to haul treated or potable water or arrange to rent or share such a truck with other public water systems (USEPA 2016a; USEPA 2016b). - Identify and implement truck disinfection, maintenance, and operational procedures (USEPA 2016a). Purchase or rent trucks according to what roads can handle. - Identify hauling routes with roads rated for truck's filled weight. (USEPA 2016a) - Improve the token system for distributing water through water vending machines. <u>Packaged water transport</u> - Have pre-approved vendors for bottled water & have contracts to be implemented in case of an emergency (USEPA 2011). Choose glass bottles to reduce impacts from plastic byproducts and environmental disposal issues (Workshop 2) - Stage pre-packed water at locations at communities that may be cut off from water hauling during emergencies (for example communities with a single main access road). Ensure that water is stored in safe manner for drinking.
Emergency power if outages
- Purchase or make arrangements to rent backup power generators (USEPA 2016). These could potentially be shared across public water systems. - Maintain fuel onsite or have multiple ways to obtain fuel (USEPA 2016b). - Further develop onsite, off-grid power including solar, wind, inline microturbines (USEPA 2015a). - Secure generators and other power sources against extreme events (USEPA 2016b). - Arrange with power company to have priority restoration after an outage (USEPA 2016b).

Note: For a comprehensive list of all strategies identified during this project, please see Appendices.

5.5 Research Needs and Data Gaps

Through the process of conducting the vulnerability assessment, we also identified research needs and data gaps with respect to how aquatic habitats may respond to climate change. These are identified below.

Source water

- Model how fire frequency and severity may change in the future to inform the implementation of or updates to fire management plans and their potential drinking water impacts (USEPA 2015)
- Model flood risk for future climate change (e.g., heavier downpours, sea level rise) and how it might affect drinking water sources and infrastructure (USEPA 2015)
- Model sea level rise and storm surge dynamics to understand potential impacts to coastal drinking water sources and infrastructure , particularly for lagoon areas (USEPA 2015a).
- Develop models to understand potential changes in surface water quantity and quality with climate change (e.g., occurrence of harmful algal blooms) (ANTHC 2011a; USEPA 2015b).
- Study the ability of coastal wetlands to buffer drinking water sources and infrastructure against storm surges given rising sea levels and potentially changing storm severities (USEPA 2015a).
- Study how springs might react under different climate change scenarios (Workshop 2).
- Conduct a study on aquifer locations, depths, and which springs and tributaries are fed by which aquifers (Workshop 1).
- Use the aquifer study to model projected future conditions including water levels and potential saltwater intrusion into coastal aquifers (USEPA 2015a).
- Project future water demands on the Reservation considering changes in population & development (NRC 1997).
- Continue the Yurok Wildlife and Fisheries' Departments' efforts to work with the Tribal Council to establish and implement feral cattle removal strategies (Workshop 2).
- Increase baseline monitoring of surface and groundwater resources (Workshop 2).

Infrastructure

- Identify PWSs at higher risk for coastal /riverine flooding from climate change and develop plans to increase their resilience to flood impacts (SITC 2010). If necessary, consider potential relocation of such facilities (USEPA 2015a).
- Identify PWSs that may be at higher risk from wildfires under climate change and prioritize the development of plans to increase their resilience to fire impacts
- Conduct an engineering study to evaluate if existing treatment systems will be able to deliver safe drinking water in sufficient quantities given anticipated changes to source water quantity and quality with climate change; include increased turbidity/sedimentation, harmful algal blooms and saltwater intrusion (ANTHC 2011a; USEPA 2015a). Identify treatment alternatives if necessary.

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Additional Information

- Additional Chapters of the Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources can be found on the Yurok Tribe Environmental Program's Community and Ecosystem division webpage at http://www.yuroktribe.org/departments/ytep/com_eco_division.htm

Yurok Tribe Climate Change Adaptation Plan for Water & Aquatic Resources

Chapter 6 – Traditional Aquatic Foods

In This Chapter

This plan is from a purposeful collaboration with the staff and community members of the Yurok Tribe, as well as several organizations, and would not have been successful without each of their contributions. Funding was made available through the US EPA Science to Achieve Results (STAR) Program, Grant # 83560401-0. Online files available at: https://www.yuroktribe.org/departments/ytep/

When Wo-no-ye-'eek [Creator] first came to the Klamath River, he saw that there was no food for the people... The Immortals (woge) only wanted salmon to go up on one side of the River to make sure they knew where they could get salmon. But they never caught anything so they made it so the salmon would come up both sides. A man from the village of Welkwau (south side of the mouth of the Klamath River) wanted to learn how to fish at the mouth of the River so he went to Koowetsik and asked the headman to show him how to harpoon fish. The headman agreed... When Nepwo came through the mouth of the River, the headman acted as if he was going to spear it. He would make thrusting motions with his spear but not actually spearing it, at the same time, he was praying for more salmon to come up the River. These ritual actions demonstrated to Nepwo that Yurok were sincere in the proper treatment of salmon and Nepwo informed the other salmon that it was good to come into the Klamath River. – Salmon and Koowetsik Story as retold in Kroeber, 1978

The traditional subsistence diet and practices are a vital part of Yurok cultural identity. The Yurok People, often self-described as salmon people, have managed and relied upon an abundance of salmon and other aquatic species in the Klamath River and Pacific Ocean since time immemorial. Many traditional Yurok stories, such as "How Fish Came to be in the River" speak to the deep relationship between the Yurok, aquatic species, and the river. The Tribe has a vital interest in the viability and survival of the wild, native Klamath River salmon species, ney-puy in Yurok, and all other traditional food resources.

Yurok health and well-being are intimately connected with the health of both the ecosystems and the species within them (Chapter 1 & 7/ Ch. 1 & 7). For Yurok, the spirit of Hewechek - "I live, I am healthy, I get well, I survive "- weaves together the fabric of the relationship between Yurok, traditional aquatic species, and the surrounding environment. Climate change impacts now threaten this intercon-

Preparing his nets for harvesting of ney-puy.

Chapter citation: Cozzetto K[1], Maldonado J[1], Fluharty S[2], Hostler J[2], Cosby C[2] (2018) Chapter 6 – Traditional Aquatic Foods. In *Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources*. [1] Institute for Tribal Environmental Professionals (ITEP), Northern Arizona University, Flagstaff, AZ.
[2] Yurok Tribe Department of Environmental Quality (YTEP), Klamath, CA.

nection, exacerbating the non-climatic stresses on traditional aquatic species. This could result in significant wide-reaching effects for Yurok people beyond a singular focus on the loss or diminished traditional aquatic resources themselves (Table 6.1).

Yurok territory was once a place of abundance where there was always enough fish for everybody to sustain himself or herself. As a Yurok Tribal Member recalled in a survey for the Yurok Tribe Climate Change Prioritization Plan (Sloan and Hostler 2011), "I remember there being so many fish, you never worried about bringing some home." However, today traditional aquatic species are threatened with population decline in the Yurok territory due to the cumulative effects of climatic and non-climatic factors (Ch 1 & 3). Table 6.2 shows the projected climate changes affecting Yurok water resources and traditional aquatic foods that could result in economic, health, cultural, and spiritual impacts on the Yurok Tribe. Tribal Members could experience increased food insecurity with less subsistence foods available, multiple health effects (Ch. 7), economic impacts, as well as increasing competition and tensions between Yurok and

Table 6.1 Effects for Yurok people from climate change impacts on traditional aquatic foods	
Economic	- Costs associated with store-bought foods to replace the loss of subsistence sources - Loss of income from commercial fishing - Additional costs of travel to limited number of available and viable harvesting sites
Social	- Increasing competition between Yurok and non-Yurok, heightening tension between people. - Less socializing by reduced time spent in fishing and harvesting activities together (Donatuto et al.2014) - Youth less able to participate in traditional & knowledge sharing due to loss of traditional species
Cultural	- Traditional Knowledges could become less applicable, for example: shifts in the phenology or timing of natural events could change such as the timing of the bracken fern unfurling no longer coinciding with the best time to gather Key'-ween we' chey-gel' (Spring Seaweed) - Foods not available at the traditional times, in traditional locations; impacting ceremonies and spiritual practices - Youth less able to participate in traditional fishing and harvesting practices and knowledge sharing - Loss of species/fish used by Yurok for regalia such as traditional sturgeon glue
Health	- Increased food insecurity with traditional foods becoming less reliable, less available and/or of questionable quality - Health effects from relying more on processed foods; increased diabetes, cancer, and heart disease - Mental health stress from fear of potential loss of traditional foods and practices versus exposure to toxins in: shellfish consumed; the waters while fishing; and drinking water sources - Stress from economic, social, and cultural impacts from not being able to provide for families - Stress from having to spend more time fishing rather than other activities - Stress from further erosion of cultural resources and lack of ability for traditional/subsistence lifestyle - Multi-generational trauma from disruption of the relationship between Yurok, traditional aquatic species, the environment, and from not being able to carry out traditional practices

non-Yurok fishers. Tribal Members could also experience loss of traditional knowledge of how species behave and interact within a specific place (Duerden 2004; Viles 2011).

Nearly every respondent to a Tribal survey stated that their main climate change-related concern for the Yurok Tribe was maintaining and preserving traditional subsistence foods, cultural use plants and animals used for ceremonies and medicines. As one Tribal respondent stated, "I hope the native foods and fish are protected so we can enjoy and benefit 100 years from now." (Sloan and Hostler 2011).

Table 6.2 Projected Climate Changes Affecting Yurok Aquatic Resources
Changes in Air Temperatures - Rising air temperatures
Changes in Precipitation Regime - Precipitation amounts are uncertain - Heavier downpours
Changes in Ocean Processes - Rising sea levels > increasing coastal inundation > erosion & intrusion into estuary and coastal aquifers - Ocean acidification
Changes in Inland Hydrology - Shift from snow to rain > increasing winter flows & floods; - Reduced late spring/summer flows in river, creeks, & springs - Increasing drought intensities
Changes in Inland Water Quality - Warming surface water temperatures > lower dissolved oxygen; - Expanding harmful algal blooms & water-borne pathogens
Changes in Fire Regimes - Fire seasons are expected to become longer - Increased frequency and extent.
Combined Effects - Decreasing snowpack, earlier spring snowmelt - Warming ocean temperatures > increased harmful algal blooms - Heavier downpours > increase surface water sheeting > erosion > increasing turbidity, sedimentation & higher pollutant loadings - Fire exposed slopes will further add to effects

While a key strength of the Yurok is the variety of traditional foods – from diverse aquatic species such as ney-puy (salmon) to key'-ween we' chey-gel' (spring seaweed) to terrestrial species such as acorns and elk. While each animal and plant species is important to Yurok People, the current focus of the Yurok climate change planning process includes the effects of climate change.

This chapter starts with an introduction to the traditional aquatic species included in this Plan and a summary of the potential climatic impacts on these species and the Yurok Tribe. The chapter then covers existing conditions of food sovereignty and subsistence, and the extensive potential impacts on Yurok People. Following are sections on each of the priority traditional aquatic species that community members identified in interviews and workshops during the information gathering phase of this plan.

In each sub-sections, we first look at the species' life cycle to better understand how climate change might affect the species at different life stages and in different habitats. We then cover the current and potential climate impacts on each species, as well as the existing challenges or sensitivities that exacerbate these impacts, and the existing strengths or adaptive capacity to mitigate the impacts. Each section includes strategies that the Tribe can pursue to help the species adapt to the cumulative climatic and non-climatic stressors. The chapter then concludes with a section on research needs and data gaps.

6.1 Yurok Traditional Diet and Food Sovereignty

Yurok have always depended year round on diverse aquatic species for their diets, health, livelihood, economy, ceremonies, and wellbeing. Figure 6.1 illustrates the times throughout the year when different species could be traditionally harvested from the river and the overlap in their availability which gave a year-round abundance of fresh foods. It is strong Yurok belief that they are all interconnected with each other and the Yurok themselves as stewards.

Table 6.3 Important Traditional Aquatic Food

Traditional Aquatic Foods including:

- ◊ Ney-puy (Chinook Salmon) and
- ◊ Chey-guen (Coho Salmon)
- ◊ Chkwohl (Steelhead)
- ◊ Kah-kah (Green Sturgeon)
- ◊ Key'-ween (Lamprey Eel)
- ◊ Seyk-soh (Marine Shellfish) & Pee'eeh yurs (River Mussels)
- ◊ Key'-ween we' chey-gel' (Spring Seaweed)

Important traditional species not in this project due to extremely small populations currently returning to Yurok Territory

- ◊ Hehl-kues-leg (Surf fish)
- ◊ Mokw-chech (Nightfish)
- ◊ Kwo'-ror' (Candlefish)

However, in the preliminary stages of developing this Plan, YTEP held workshops and discussions with Tribal Members and staff to decipher which specific aquatic species were most significant for Yurok food traditions and sovereignty. Although it was an often repeated admonishment that none were more important than another, it was agreed upon that for this plan the following species in Table 6.3 were identified as priority species for the focus of the Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources. *Ney-puy* (Chinook and Coho Salmon), *chkwohl* (steelhead), *kah-kah* (green sturgeon), *key'-ween* (Pacific lamprey), *seyk-soh* (marine shellfish), and *key'-ween we' chey-gel'* (spring seaweed) were chosen to be the focus of this Plan because these species (1) are significant for Yurok food sovereignty and practices, and (2) are indicator species of ecosystem conditions throughout the year.

> *"Salmon is our families lifeblood – it provides (food) nourishment all year round. We fresh canned, smoked and canned smoked fish, even the heads and tails, heart and other inner parts are eaten. The backbone is dried and used for soup in the winter. Fish guts used to fertilize (food) gardens. The Redwood trees that grow on my family allotments depend on the Klamath River for water. The Klamath River is the heart and veins of our watershed – the web of life on which the Tribe depends and for what we our, Yurok! Down River People! It is what our circle is: What we live, we eat, and sing songs about."*
>
> – Yurok female, born 1959 [2]

Although of equal Tribal importance as traditional food, several species are not considered in this project due to being already impacted with only extremely

[1]Eulachon (candlefish), for example, which are rich and healthy to eat, used to be very important to Yurok People and there were always mass quantities available. Today, they are no longer an available resource to the Tribe. The drastic loss of candlefish started in the 1980s and is thought to be due to the Lewiston, Trinity, and Iron Gate dams being put in and changing the flows in the Trinity and Klamath Rivers. In addition to candlefish, starry flounder, which were once caught along with salmon, are no longer seen in the Klamath River.

[2]All quotes formatted, "Yurok Tribal Member, gender, year of birth" are from the Yurok Tribe Environmental Program's 2006 Healthy River/Healthy Bodies Study.

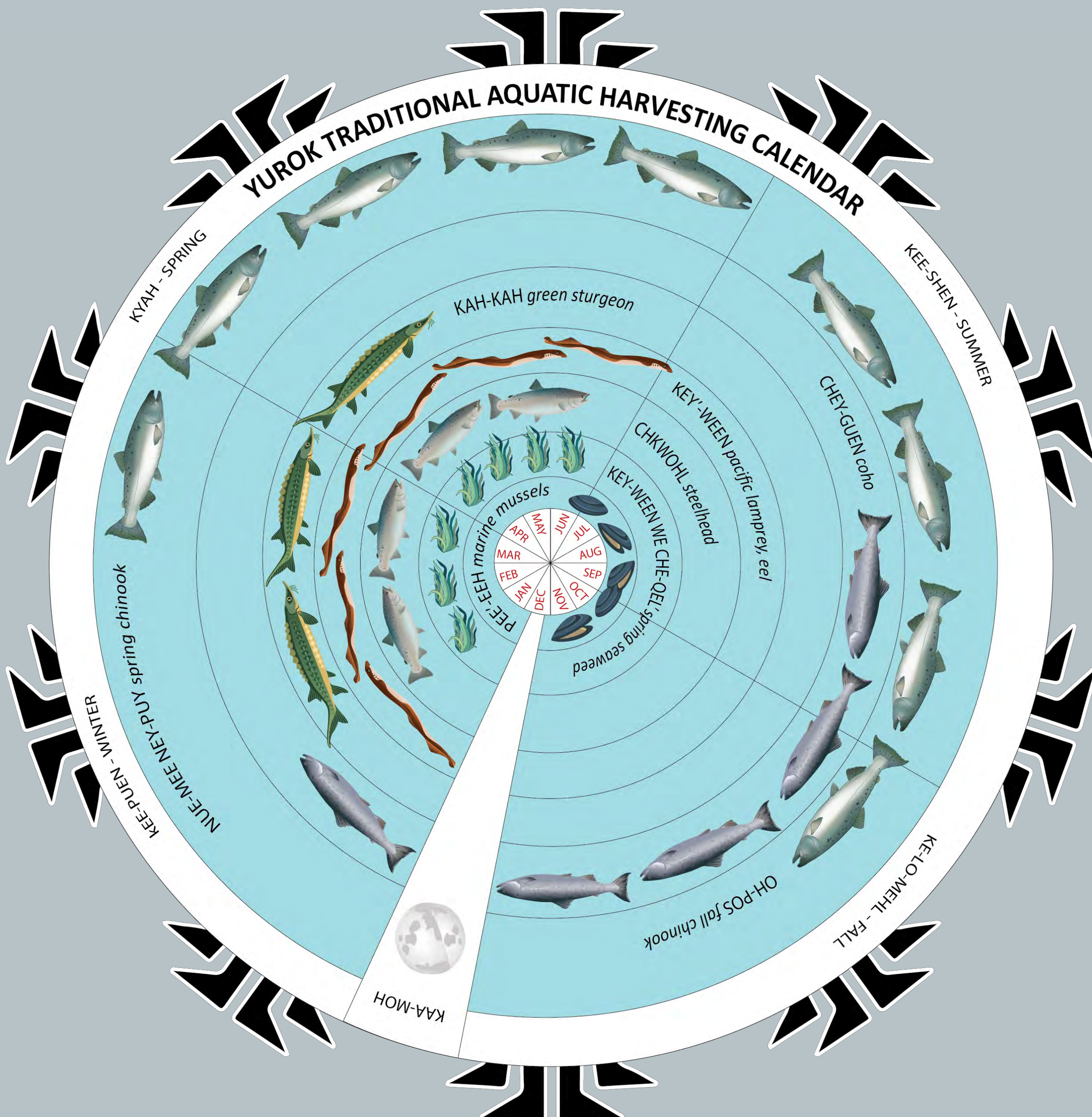

Figure 6.1 Yurok Traditional Aquatic Harvesting Calendar for Priority Species for this Plan

small populations returning to Yurok Territory. These include Hehl-kues-leg (Surf fish), Mokw-chech (Nightfish) and Kwo'-ror' (Candlefish)[2]. These are not the only aquatic species, however, of significance to the Yurok Tribe. Some species, which the Yurok used to harvest, have disappeared or are nearly gone, or have had Tribal access to them blocked or denied. Many of them were from the ocean's near shore habitats such as the monkey faced eel, abalone, and various rock fish.

Existing Challenges (sensitivity)

Today, nearly all species have been reported to have smaller and shorter harvest times. The Yurok Reservation is practically a food desert with the decline in fish populations, as well as loss of harvesting and gathering practices for terrestrial species such as acorns, and lack of grocery stores with options for fresh food. Ninety-nine percent of the food is trucked in, leaving Tribal Members extremely vulnerable to any effects, such as flooding, which could cut-off roadways to truck in food. Available food options are limited predominantly to the small market inside the gas stations in Klamath and at Pectah, across the river from Weitchpec, which contains mostly expensive and processed foods. Further, a University of California-Los Angeles (UCLA) study found that food insecurity[3] for Tribal Members residing in the ancestral area was three times that of the surrounding local counties, largely related to the decreased access to salmon fishing due to impacts from dams and commercial fishing (U.S. Bureau of Reclamation 2012:3 and 46).

> *"We want to continue our relationship with the Klamath River and the traditional resources our River provides us with."*
>
> – Yurok male, born 1952

In addition to the economic benefits derived from the commercial fisheries, fish play multiple roles for Yurok Tribal Members, with an almost equal number of males and females benefiting from fishing (Yurok Tribe 2006). In the Yurok 2006 Healthy River, Healthy Bodies Study, Tribal Members expressed the importance of fish in their lives (Yurok Tribe 2006). Of the 336 Yurok Tribal Members that returned surveys, over 79% responded that they rely on fish for household food, almost 66% share fish with family and friends, nearly 42% use fish for cultural/social reasons, almost 32% use fish for ceremonial/religious purposes, and nearly 15% rely on the income from selling fish during the commercial season.

Robert (Bob) McConnell, Sr., President of the Yurok Cultural Fire Management Council, noted in a conversation about planning for climate change that when he was younger, families used to catch enough fish for the year in a few days and then spend their time canning, smoking, and processing. The entire family gathered together for different parts of the process however, now, because of the declines in fish populations, mostly male, Tribal Members have to go out everyday of the season, taking time away from community and family gatherings, and other stages of the fish preservation process. In 2016, Bob only got 13 fish, including what was gifted to him, whereas normally he would get about 30 and harvest 50-60 to distribute to others. These impacts are being felt especially upriver, with fishers having to go downriver for fish because upriver fish are reported as now being diminished in both quality and quantity.


Surfish were plentiful on Klamath River Spit in 1999

The decreased availability of traditional subsistence foods, along with historical legacies and existing socio-economic conditions, has increased Yurok Tribal Members' risk of food insecurity and both their physical and mental health which is gone into more detail in Chapter 7. However, despite these challenges the Yurok Tribe faces to its food sovereignty, the Tribe has entered a new era in which the revitalization of Yurok culture and sovereignty is taking place. In the late 1970s and 1980s, traditional dances including the Jump and Brush dances were started again (Yurok Tribe 2007). Significant to subsistence fishing in particular, in 1994, a year after the Tribe developed and formally adopted its Constitution, and the U.S. Department of the Interior recognized the Yurok Tribal Council as the governing body of the Tribe, the Tribe took over managing its fisheries from the Bureau of Indian Affairs and U.S. Fish and Wildlife Service (Yurok Tribe 2007).

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[3] According to the UCLA study, a family was considered food insecure if their income was less than 200% of the federal poverty level (U.S. Bureau of Reclamation 2012:46).

Proceeds from the Tribe's participation in California's Carbon Cap and Trade Program and a partnership with the Western Rivers Conservancy has enabled the Tribe to purchase approximately 37,000 acres of its ancestral territory in the Blue and Bear Creek watersheds for the benefit of the Yurok People and the species that live there (Yurok Today 2015a). And in April 2016, the Yurok Tribe, together with the Karuk Tribe, the states of California and Oregon, PacifiCorp, and the U.S. Departments of the Interior and Commerce signed an amendment to the Klamath Hydroelectric Settlement Agreement. If approved, this amendment will lead to the removal of four dams on the Klamath's mainstem and will be the largest dam removal project in U.S. history and one of its biggest ney-puy (salmon) restoration efforts (U.S. Department of the Interior 2016; Yurok Today 2016c). With all these changes, the legacy of Yurok environmental stewardship is reemerging, including pursuing traditional and innovative strategies to maintain subsistence livelihoods and food sovereignty, and adapt to the effects of climate change.

Existing strengths (adaptive capacity)

As Yurok face risk of increased food insecurity, they are taking action. The Yurok Tribe has many existing strengths to adapt to climate change and impacts on traditional aquatic species. Some of these strengths are highlighted below.

Tribal values

The Yurok Tribe works to take care of its people. Traditionally sons and nephews give their early catches to their family elders (Grandmothers and aunties) to ensure that their needs are met first. Recently, there has also been an Elders' Fishery, for which commercial fishers are required to donate their first three fish caught for Tribal staff to distribute to Yurok elders.

Tribal knowledge:

Robert McConnell, Sr. discussed at a recent Culture Committee meeting about the term peyleen chey wey, or big hunger. At least several generations ago, there were no fish or acorns available for a sustained period of time. Frank Lara remembered the term from his grandparents, "The inland people had to travel to the coast to trade for dried fish, rock fish and other coastal foods" (Yurok Today 2016a). This indicates that the Yurok People have had to adapt to food shortages in the past. They developed innovative strategies and continued to thrive.

Yurok tribal knowledge teaches fishers where to catch ney-puy (salmon) and other traditional aquatic species. As Yurok Tribal Member, Axel Lindgren III explained, "Salmon used to run in the bay. They used to run in Trinidad Bay, they still do. I caught one inside that, between Pilot Rock and Prison Rock, right in there...yeah people think they don't do that anymore, you have to go 100 miles out to catch salmon, but actually they are right in the bay at times. That's something you're taught." Yurok People rely on getting their food from the environment and the river; they readily see and feel the impacts more than those who get their food at a grocery store. Yurok Tribal members could lead the way in understanding and adapting to the impacts they are witnessing and experiencing.

Inhabiting diverse ecosystems

Yurok People are both coastal and river people. Tribal members discussed at one of the climate adaptation planning workshops how this could help them fulfill needs and continue to access traditional foods even if certain fish runs go down. For example, if some fish runs decrease in the river, they could still have the opportunity to keep having traditional foods by harvesting pee'-eeh yurs (marine mussels) at the coast. This means the need to maintain and redevelop reciprocal relationship of Pohlik-lah (coastal) and Ner-er-ner (river) traditional villages.

Cultural practices

The Yurok Tribe's use of diverse cultural practices, such as language revitalization, beading and basket weaving classes, sharing grief stories, sweat lodges, and spiritual camp, all support the mental, emotional, and spiritual health of individual Tribal Members and the Tribe to adapt to both changing environmental and social conditions, including but not limited to concerns of food sovereignty.

Traditional food processing methods: At a recent Culture Committee meeting, Committee Member Bertha Peters suggested that practicing the traditional food processing methods, which sustained the Tribe since the beginning of time, will help Yurok People get through the times when resources are sparse (Yurok Today 2016a). Yurok hold canning and preserving classes for food security and for teaching the younger generation traditional food processing. In 2016, Yurok youth and other Tribal Members participated in an Indigenous food sovereignty conference in Klamath to share ideas for supporting traditional foods.

Cultural burns

Another traditional practice is the revival of cultural burns, which can protect alternative food sources such as acorns by killing the weevil pest that affects acorns (Robert McConnell, Sr., interview, Dec. 2015). Some Tribal Members and others believe the Yurok could use fire not only to help restore the landscape, but also assist ney-puy (salmon) with upriver migration by using the smoke from sequential burns along the Klamath River to cool the river. Yurok Tribal members witnessed recently a cooling in river temperatures when wildfires spread and the thick smoke layered over the river.

Community food programs and gardens: Yurok have community gardens, a Yurok Food Distribution Program out of Crescent City that distributes food commodities to Native Americans on or near reservations, and a Tribal program to distribute traditional foods to elders.

Legal

In response to the Federal Food and Drug Administration's (FDA) approval of genetically engineered "AquAdvantage" salmon, in December 2016 the Yurok Tribal Council, in partnership with the Northern California Tribal Court Coalition, passed the first Tribal Genetically Engineered Organism (GEO) Ordinance in the U.S. The Ordinance helps protect Yurok food sovereignty and allows for enforcement of violations through the Yurok Tribal Court (Yurok Today 2016b). This ordinance followed the Yurok Tribe enacting a resolution in 2013 that opposed genetically engineered salmon. Another important precedent is that the state of California recently recognized tribal harvest as separate from commercial and recreational (Williams 2013), in the establishment of California Marine Life Protected Areas which helps sustain Yurok's access to traditional foods.

Adaptation strategies

There are a number of adaptation strategies to the effects of climate change that the Yurok Tribe could implement to enhance food security and traditional diet for Yurok Tribal Members.

TABLE 6.4 Traditional Diet And Food Security: Adaptation Strategies

Ensure ecosystem health to reinvigorate diverse food systems
- Restore prairies to increase elk, which could be an alternative food source if fish runs continue to decrease in size. - Engage communities in restoration activities – heal the land, heal the people – *Hewecheck*. - Decrease nutrient inputs that increase HABs such as nitrogen & phosphorus from agricultural run-off (JST 2013). - Work with academia to identify or develop environmental predictors of harmful algal blooms (HABs) (JST 2013). - Continue *Cannabis* raids early in the growing season (July) so that less water is withdrawn & less pollution occurs.
Monitor food source availability and Tribal–wide alert systems
- Continue Yurok monitoring & posting of public health threats: both electronically and at physical locations - Use the Local Environmental Observer Network to post disease outbreaks, toxin levels, and any other relevant information, to alert each other if conditions change and create unsafe conditions, and also to alert each other when conditions improve and encourage continued use of traditional subsistence resources (for example, ANTHC 2015).
Legal and Policies
- Continue use of flexible harvest regulations that can adjust to changing conditions and migrating times. - Enforce Yurok Resolution banning pesticides on the reservation, to eliminate chemical runoff into tributaries. - Increase & protect Tribal Member access to traditional harvesting sites throughout Yurok Reservation and Ancestral Territory ; negotiate with agencies such as the parks system, or private landowners for access to existing sites and expand to new locations outside rising sea level zones (Viles 2011).
Food production/ alternative food sources
- Continue introducing individual/family/community gardens for alternative food sources. - Continue to conduct cultural burns to enhance ability of forest to support terrestrial traditional foods such as acorns and hazelnuts that could supplement traditional aquatic foods (ICT 2014). - Investigate health inspection requirements that need to be met to use food from school gardens in schools. - Make more use of some under-utilized areas such as clear-cut or flood plain areas to plant orchards and create gardens including both up river and downriver communities (Workshop 1). - Continue introducing healthier and affordable foods at gas stations on the Yurok Reservation.
Collaboration
Start a 'food run collective': have a scheduled, dedicated public transit run or have a group take turns driving to supermarkets and buying food so each individual family doesn't have to go & can save gas money and also support Tribal Members without transportation. Develop an equipment sharing program canning supplies; or eel baskets; or if need to fish at new sites or use new harvesting materials.
Education, Communication & Outreach
- Consider creating a pamphlet on traditional Yurok fishing practices for distribution with all fishing permits. - Continue classes on canning & preserving of traditional foods for both food security - Continue to expand diverse cultural practices such as language revitalization, beading and basket weaving classes, sweat lodges, and camps to support the mental, emotional, and spiritual health of individual Tribal Members - Document stories, knowledge, and cultural traditions related to traditional aquatic species and harvesting sites, including uses and relationship to Yurok and within an ecosystem that may be changing.
Emergency preparedness to enhance use of traditional food resources
- Establish emergency fishing and harvesting options and distribution strategy to ensure Yurok Tribal Members maintain access to traditional aquatic foods during floods, fires, or other emergencies (AFPC 2015; Snyder 2017). - Maintain a supply of traditional foods that is reserved for emergency use only, and/or during years that the runs are affected and is rotated as part of regular stock management (Snyder 2017; AFPC 2015).

6.2 NEY-PUY / Salmon

Table 6.5 Key Climate Impacts on *Ney-puy* / Salmon

Primary Climate Effect	Secondary Stressor	Potential Impacts
Warmer Air Increasing Drought	More extreme low flows	- Disconnection of cold water tributaries from mainsteam > decreased spawning, increased fish stress and mortality - Lack of sufficient flows to flush polychaete worms from the system > higher concentrations parasites > increasing infection rates
Warmer Water	→	- Impaired smoltification - Overcrowding in cold water refugia > increasing disease & parasite infection rates - Impact migration cues > shifting migration times - Increased stress - Increased mortality
Heavier Downpours	Increased erosion	- Scouring and/or burying redds and eggs - Sedimentation infilling of cold water pools & refugia - Increased river bars disconnecting tributary access
Rising Sea Level	Changing estuary salinity & size	- Affects juvenile growth & survival (possibly positive) - Impacts smoltification process & timing
Ocean Acidification	Reduced plankton	- Potentially reduced food supplies > smaller salmon growth > reduced survival

'Oh-pos or Fall run and Nue-mee ney-puy or Spring run are Chinook salmon (*Oncorhynchus tshawytscha*). Chey-guen or Coho (*Oncorhynchus kisutch*) is another salmon that is individually recognized and mportant to the Klamath River system and the Yurok Tribe. The more generalized, inclusive term of ney-puy is for salmon as a group. Currently, *ney-puy* are threatened with population decline in the Yurok territory due to the cumulative effects of climatic and non-climatic factors, resulting in economic, health, and cultural impacts on the Yurok Tribe. The following sections illustrate the threats to and impacts on *ney-puy*, and strategies that the Tribe can pursue to help the species adapt.

Climate impacts to *ney-puy* (salmon) could be significant to both the species and the Yurok People. To better understand the extent of potential climate impacts on *ney-puy*, it is important to consider the *ney-puy* life cycle. Climate impacts in one life stage can impact body size or timing in the subsequent life stage and may have cumulative effects throughout the species' life that determine the full risk to a particular population (Williams et al. 2016).

Life history of Ney-puy

Both Chinook and Coho salmon are anadromous; they are born in freshwater rivers, migrate out to the ocean, and then usually only return to their home rivers once before becoming 'spawned out and dying (Board 1999). Scientists think ney-puy (salmon) use the Earth's magnetic field like a compass to guide them to the river they came from and then use smell memories to locate their places of birth (Andersson 2003; USGS 2016b).

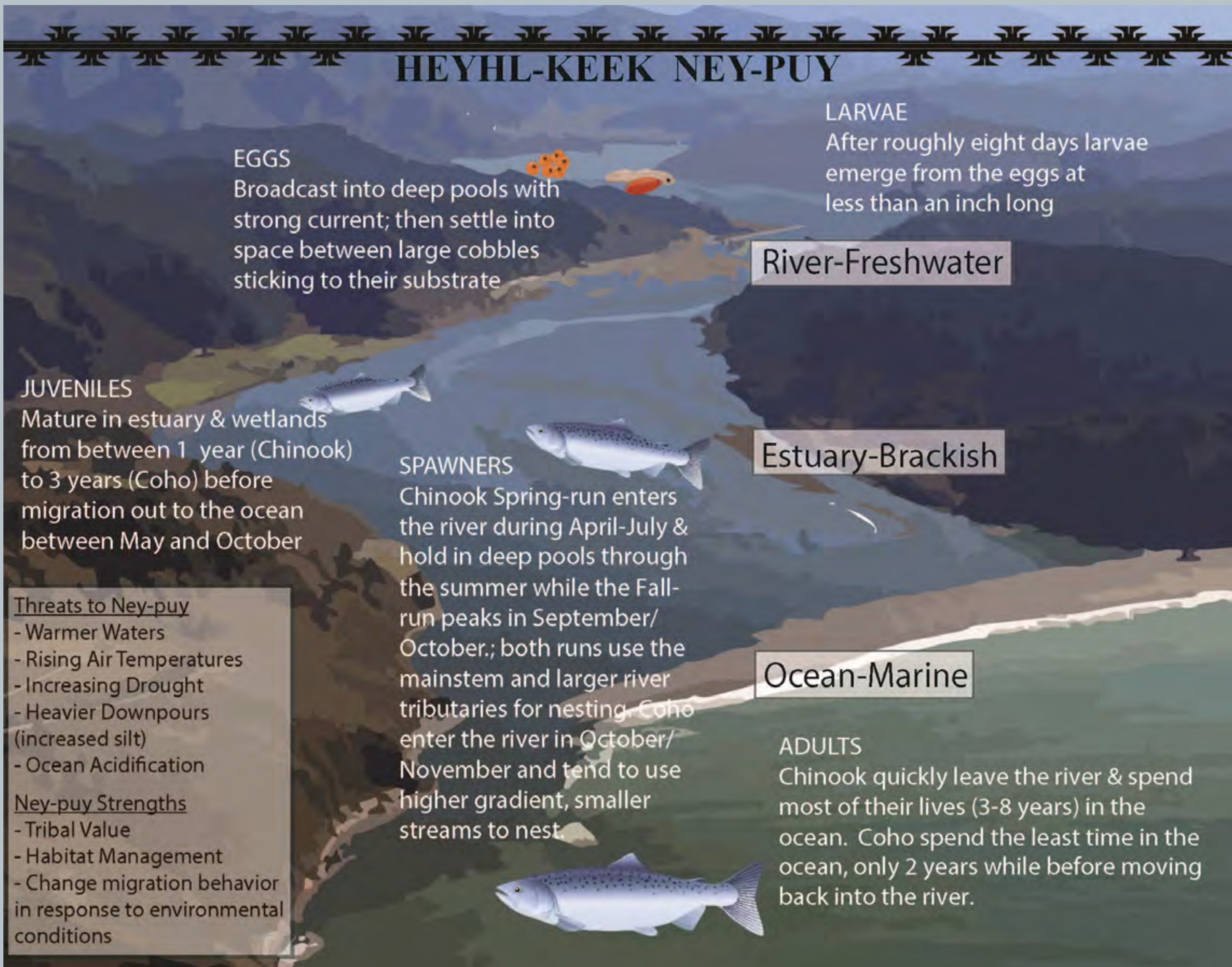


Figure 6.2 Salmon Use of Habitats within the Klamath River

Although rare, some ney-puy can grow to as long as five feet and weigh over 100 pounds. Ney-puy size is correlated to both their age and their genetics such as those from Blue Creek who are reported to be consistently the largest. When returning from the ocean, ney-puy stop eating after moving into freshwater and begin living on the body fat that they have stored from the time spent in the ocean eating zooplankton, small invertebrates and other fish such as herring (Andersson 2003; USGS 2016b)

‘Oh-pos and Nue-mee ney-puy

There are two main runs of Chinook salmon (*Oncorhynchus tshawytscha*) returning to the Klamath River system after their time in the ocean. The runs are named for the time of year in which the salmon enter the river. The exception are the scattering of "jacks," 2-year old males that return younger and physically smaller than the main run individuals. The King Salmon, Fall Chinook, or ‘oh-pos in the Yurok language, is the largest ney-puy (salmon) in the Pacific Northwest (NWF 2017). They live approximately three to eight years and on average grow to be about three feet long and weigh 30 pounds (Salmon Fishing Now 2015; NWF 2017).

> *"The salmon is like the miner's 'canary' – if it is sick or dying it is a sign that our people are sick and dying too. If it is abundant and thriving – so are the people."*
>
> – Yurok female, born 1959

Nue-mee ney-puy, the Chinook spring run – commonly known as 'springers' – enters the Klamath between April and July, (although the fish entering later in June/July seem to be mainly of hatchery origin) (NRC 2004:269). Yurok call the nue-mee ney-puy true salmon, named after their mythical leader Nepewo. The Yurok commemorate the nue-mee ney-puy in their First Salmon ceremony held at the mouth of the Klamath in April. 'Oh-pos, the late summer/fall run, may start entering the Klamath in late July, but peaking in early September and continuing into late October (Andersson 2003; NRC 2004:264). A third, late fall Chinook run may have also existed however, it is either poorly documented or perhaps the sub-population has been extirpated from the Klamath (Moyle 2002; NRC 2004:264).

'Oh-pos (fall run Chinook) has what some call an ocean-type life history as most of their lives are spent in the ocean. The young juvenile 'oh-pos spend less than a year in freshwater, rearing in the Klamath River Estuary before migrating out to the ocean within their first year. Then on their return trip to the Klamath, they also spend a limited time in freshwater, typically running upriver and spawning within 2-4 weeks after entering the Klamath in the late summer and fall (Andersson 2003; NRC 2004:264-265).

In contrast, the nue-mee ney-puy (spring run Chinook) have what some call a stream-type life history with a longer freshwater residency than the 'oh-pos (fall run Chinook). The young nue-mee ney-puy spend a year or more in streams before their seaward migration (Andersson 2003; NRC 2004:268-9). Upon their homecoming, they enter the river between April and July and then hold in deep pools through the summer months before joining the 'oh-pos to spawn that peaks in October (NRC 2004:269).

Chey-guen (Photo curtesy Thomas Dunklin)

Chey-guen

Coho salmon, or chey-guen, are considered to be among the more acrobatic in the salmon world, being really good jumpers, which can allow them to access higher gradient stream reaches than other salmon (Board 1999:35). However in the Klamath River system, the dams close off nearly two-thirds of their spawning range. They generally overwinter as juveniles in the Klamath Estuary and have a three to four year lifespan. They are smaller than Chinook with an average length of 1.8–2.2 feet long and weight of 7-13 pounds (Moyle 2002). In the Klamath River chey-guen, make their spawning run primarily in October and November, and juveniles out-migrate to the ocean primarily in April and May (USGS 2016b).

Klamath River chey-guen (Coho) also spend considerable portions of their life in freshwater, longer than other salmon. Chey-guen fry move out of their nests between February and July, after which they may spend up to a year and a half (14-18 months) in low gradient streams and in the Klamath Estuary before moving into the ocean the following year (NRC 2004:254-5). After two years in the ocean, they return to the Klamath in the fall with peak in-migration occurring between late October and mid-November and peak spawning occurring in November and December (NRC 2004:254; Olswang 2017).

Despite these differences, whether they're Chinook or Coho, they have similar life stages including egg/alevin, fry/juveniles, smolts, and adults. Figure 6.2 shows the different times and places they occupy in the Klamath River system to help understand how climate change may affect ney-puy at different life stages in different ways.

Climate Effects on Ney-puy

All ney-puy (salmon) are exposed to different climate-related stressors during different parts of their life cycle. Young ney-puy are exposed to climate-related stressors such as warmer water and lower flows in the river when they are eggs and juveniles, and again when they return to the river as spawning adults. In addition, when ney-puy migrate to the ocean as juvenile smolts, they are exposed to changing ocean conditions such as ocean acidification (Moyle et al. 2008). On their return into the Klamath, if there are low flows, it is said that they are unable to smell their home and will not come into the river. Ney-puy may also delay upstream migration if water temperatures are excessively high (Carter 2005). Other barriers to running up the river may include low dissolved oxygen levels, shallow water, high water velocities, and high levels of suspended sediment (Andersson 2003).

Both nue-mee ney-puy (spring run Chinook) and chey-guen (Coho) spend a lot of their life in freshwater, exposing them to any changes in river conditions. Because of their longer freshwater residencies adult nue-mee ney-puy and juvenile chey-guen may be more affected by changes in river water quality and quantity than other fish (NOAAa 2016). This potentially exposes them to increased mortality at each of their different life stages. In particular, adult nue-mee ney-puy are exposed to longer durations of warmer summer temperatures because they spend an extended time in the river during the summer when temperatures are at their highest. This exposes them longer to increased temperatures.

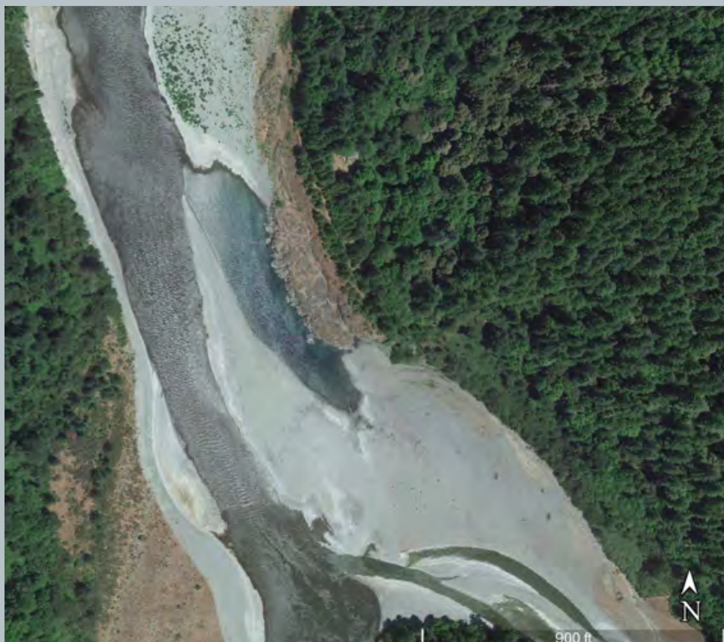
> *"We used to be able to tell which salmon were not from the mouth, because they would sometimes have a muddy taste. Now I don't eat any salmon that aren't from the mouth for fear of eating toxins and diseased fish."*
>
> – Yurok female, born 1964

Deep pools are particularly important for all the anadromous fish in the Klamath system, but nue-mee ney-puy (spring run Chinook) and chey-guen (Coho) who spend their summers in the mainstem (see below), which is typically warmer than the streams and creeks (Andersson 2003; NWF 2017; Olswang 2017). All salmonids use cold water refugia once the water temperature goes above 68oF (20oC) (Strange 2011:4). Juveniles have a higher survival rate when they can benefit from complexity in the creek systems as they use 2 main strategies during development. First is to drift feed: placing themselves in the relatively high velocities in the central part of stream channels, which uses less energy by taking advantage of food that floats down to them. A second strategy is to move out of the strong currents to rest behind boulders and large woody debris. These boulders and large woody debris are critical to their survival as they also help create deeper, cool pool pockets and provide cold water refuges from warm summer water temperatures (Ch. 4).

During the Yurok climate change adaptation planning workshops, Yurok Tribal Members and Tribal staff voiced concern about what will happen to the ney-puy (salmon) population as a result of climate change. Will ney-puy be vulnerable to drought conditions? Will their spawning grounds be impacted by lower flows in the river and warmer water temperatures? Below we go into more detail to highlight the climate change effects on ney-puy in the Lower Klamath Basin.

Warmer waters

Surface waters are expected to warm with climate change due to a variety of factors including rising air temperatures and lower summer flows due to declining snowpack, earlier snowmelt, and increasing drought intensities (Ch. 3 and 4). Increasing wildfire frequency and extent could also lead to loss of riparian vegetation and increases in water temperatures (Ch. 3 and 4). Ney-puy (salmon) are cold water fish, sensitive to temperature changes in the river. Warmer waters can



Google Earth picture of the Blue Hole Cold Water Refugia. On left of picture is the Klamath River during low flow with exposed gravel bars. Blue Creek mouth can be seen at the bottom of the picture, flowing over the gravel which warms the water. Blue hole is fed from underground seeps and springs.

have lethal and sub-lethal effects on ney-puy because of physiological thresholds (Tables 6.4 and 6.5). For example, the warmer waters could stop ney-puy's smoltification process that develops saltwater adaptations and can also increase adult mortality during spawning migrations, both would result in ney-puy population decline (Pörtner et al. 2014). Also, the incubation period of their eggs is temperature dependent and can be anywhere from two to five months but might be shortened if water temperatures are warmer which reduces their viability.

As the river temperature goes up, both juvenile and adult ney-puy could die if they stay in the Klamath River, unable to survive when chronically exposed to water above 77°F (25°C) for more than a week duration (Carter 2008). The nue-mee ney-puy (spring run Chinook), which spends all summer in the river, has already seen massive population loss, in large part because of increasing water temperatures and having no place to cool down as a result of decreased cold water refugia.

Warmer water temperatures also support increased densities of the parasites *Ceratomyxa shasta* and *P. minibicornis.* This in turn extends exposure for migrating salmonids, both as juveniles and adults if they are forced to spend time holding up in the refugia of cooling pools/holes. Warmer water also affects migration timing, a significant factor for disease potential in ney-puy (salmon) (Chiaramonte 2013; Miller et al. 2014). In 2014 and 2015 juvenile Chinook salmon collected above the Trinity River confluence during the peak out-migration period (May-July) and 81% and 91% of those sampled were infected with C. shasta(True et al. 2015). If a juvenile ney-puy (salmon) gets C. shastaon out-migration, there is a good chance it will die unless it quickly makes it to the ocean where the saltwater kills the parasite. Fish infected with *C. shasta*are also likely to be more prone to mortality because of increased stress that makes them susceptibility to other pathogens (e.g., *Parvicapsula minibicornis*), to predation in general, and have a compromised osmoregulatory system, which enables maintaining the body's salt and water balance, that is essential for re-entering the ocean (Som et al. 2016).

Warmer water alone, isn't the only concern. Increasing drought intensities could reduce the magnitude and frequency of high flow events (Ch. 3), which typically flush away the polychaete worms that act as hosts for the parasite C. Shasta; reduced high flows could contribute to increasing infection rates of the disease in fish (Som et al. 2016).

Yurok used to depend more on nue-mee ney-puy (spring run Chinook) for smoking and preserving, but that has now switched to the 'oh-pos (fall run Chinook) because the nue-mee ney-puy was so heavily impacted during the 2013-2016 drought (Workshop 3). In 2014, there was a massive juvenile Chinook salmon fish kill when an estimated 98% perished due to higher concentrations of *C. shasta*and *P. minibicornis* parasites in the Klamath River during the drought (True et al. 2015). Typically, Yurok are allotted thousands of Chinook for subsistence, but three years after the 2014 juvenile fish kill in 2017 there were only a few hundred returning Chinook and the entire fishery harvest was closed (Workshop 3). A Yurok tribal member who owns a ney-puy smoking business had to buy salmon in 2016 from the Columbia River for his business; this was only the second time this happened in his 16 years of running the business, resulting in a major economic impact (Workshop 3).

Ney-puy will crowd into cold water refugia if the water temperatures in the main stem go above 71.6°C (22°C) (Brewitt and Danner 2014). Yurok Environmental Specialist Micah Gibson recalled during the 2013-2016 drought, seeing 200,000 young ney-puy in one cool creek mouth because the water got so warm in the mainstem that they had to stay there and could not migrate out to the ocean. The water temperature in the Klamath River had already reached the juvenile ney-puy threshold in early June instead of late July when in normal years their migration is already over (Micah Gibson, interview, Dec. 2015). Also in 2015, because of warm summer water temperatures, over 50,000 salmonids were counted crowded into Blue Creek, and over 125,000 in Bluff Creek, which is about six miles upstream from the Trinity River confluence (Mike Belchik, interview, Dec. 2015).

According to Yurok Senior Biologist Mike Belchik (interview, Dec. 2015), another impact of warming water is that the timing of some runs is off, and now the Klamath River 'oh-pos (fall run) is starting to coincide with the arrival of salmon that run into the Trinity River. This is increasing fish densities and contributing to the overcrowding of salmon in cold water refugia and probably contributing to the spread of disease among adults and juveniles (Moyle et al. 2008; Yurok Tribe Hazard Mitigation Plan 2013; Mote et al. 2014).

Rising air temperatures

Rising air temperatures not only warms surface water but also promotes conditions favorable to wildfires by contributing to greater drought intensities and earlier snowmelt that increases the length of the fire season. Wildfires are expected to increase in frequency and magnitude with climate change, resulting in loss of riparian habitat, and leaving ney-puy (salmon) vulnerable to increased mortality rates from the subsequent acute and potentially lethal spikes in water temperature post-fire (Williams et al. 2009). However, under certain conditions, smoke from wildfires can also cool water temperatures, providing ney-puy with relief; this happened along the Klamath River in 2016.

Increase Drought

Particularly during the summertime due to reduced snowpack and increasing drought intensities, lower flows could result in creeks becoming disconnected from the main stem earlier and for longer stretches than in wet years. With both a further distance to go into the mainstem channel before connecting and with lower levels and less volume of creek water, the gravel beds at the mouths of the creeks act as a barrier and the creek water seeps through the gravel, going underground with no surface flows. This reduces the number of cold water refugia, their 'rest-stops', and could make it difficult for ney-puy to reach spawning grounds, with adults either being stranded in the pools, or dying from heat stress. There could also be increased disease spread with overcrowding in cold water refugia. This in turn leads to a decline of the ney-puy population. In addition, both egg and newly emerged salmon mortality in-

"We don't have the age classes we used to have coming up the river. Some salmon like to reach 4 years of age, some 5, and there's an occasional 6 year old fish that would be a huge fish. Now days we're catching 2 and 3 year old fish... I'm convinced the only time you should harvest a fish is when it has matured and decided it wants to come up the river. It's lived out its life cycle like it's supposed to, and what's happening with that lack of 4, 5 and 6 year old fish from any given year of being hatched is the genetic diversity isn't being spread over 6 years. The genetics are confined to 2 and 3 and sometime 4 year old fish. We're losing that 5 and 6 year old fish that comes up and spreads their genetics over another age class of fish. I think that's hurting the fish and us in return."

- Robert McConnell Sr., Yurok Tribal Member clude impacts from extreme high or low temperatures, being buried in silt, gravel scouring and shifting, de-watering and desiccation of redds, predation, and high concentrations of toxic chemicals (Andersson 2003; NWF 2017; Olswang 2017).

Furthermore, increasing drought intensities could also reduce the magnitude and frequency of winter high flow events (Ch. 3) that disrupt the life cycle and flush the polychaete worms from the system. These worms act as intermediate hosts for the fish parasite *Ceratomyxa shasta* (*C. shasta)* (Som et al. 2016). The worms pass the parasite along to juvenile ney-puy through the release of spores in the water column. A lack of sufficient high flows could contribute to higher concentrations of *C. shasta*and *P. minibicornis* parasites increasing disease rates (Som et al. 2016).

Heavier downpours

With climate change, the shift in winter precipitation to higher intensity downpours and from the Upper Basin snow to rain, may potentially result in more rain-based floods in the Klamath and its major tributaries during the winter rainy season (Ch. 3). This combination could contribute to more intense flooding leading to the scouring or burying of ney-puy (salmon) redds (nests) with sediment, potentially reducing suitable egg laying habitat and egg survival rates (Williams et al. 2016:12). Further, changes in the intensity of cool-season precipitation could affect migration signals for fall and spring adult migrants, such as chey-guen (Coho)(Williams et al. 2016:12).

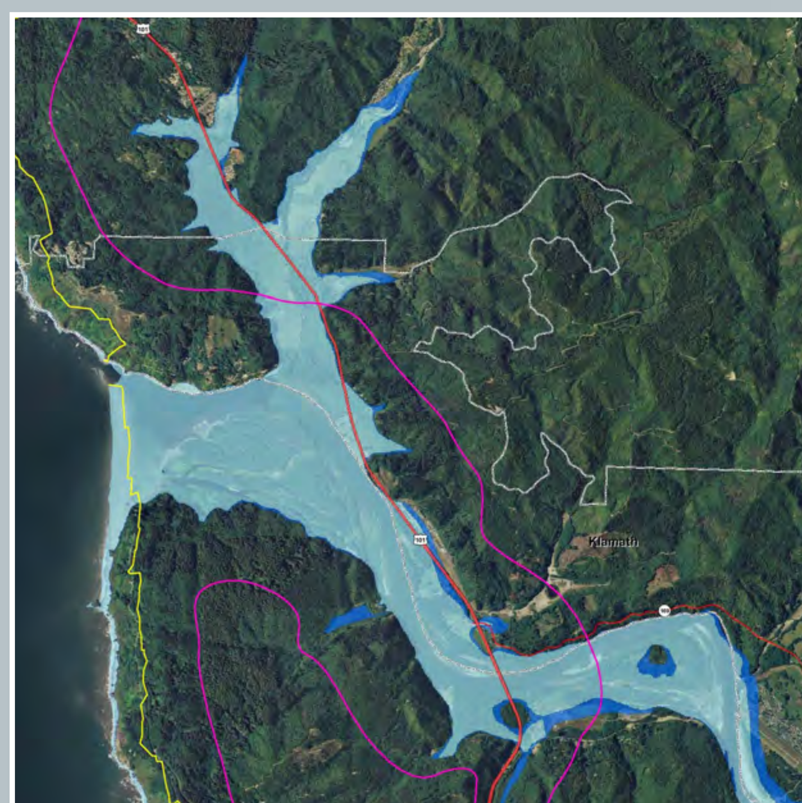
Heavier downpours by themselves and in combination with increasing wildfire frequency and magnitude could increase erosion run-off and sediment loads entering the Klamath River and its tributaries which can suffocate Ney-puy (salmon) eggs (Andersson 2003; Olswang 2017). Richard Nelson, the Yurok Watershed Program Manager, noted that the Ney-puy habitat in the Lower Klamath River is already buried in 3-15 feet of sediment and when these are re-suspended in high flows the sediments can create lesions on gills, resulting in high juvenile mortality (Nelson, interview, Dec. 2015; Salmon and Trout Conservation 2017: 6).

Increasing ocean acidification

This could impact shell development within plankton populations, which is the base of the food web for ney-puy (salmon) when they are in the ocean, thus potentially reducing food supplies for ney-puy (Crozier et al. 2008; Crozier 2015; Williams et al. 2015).

Sea level rise

Along with climatic and non-climatic driven upwelling events and changing freshwater input, sea level rise could change salinity in the estuary, affecting juveniles that spend their rearing time in the estuary (Williams et al. 2016; Ch. 3). Of particular concern is the uncertainty of juveniles' temperature requirements and where the ney-puy (salmon) go and what conditions they might experience in the estuary during their smoltification process and transition from fresh to saltwater beings (NOAAa 2016). Damaged estuaries could mean the decline of tribally significant species such as ney-puy and loss of fishing and gathering sites, resulting in loss of access to subsistence and commercial fishing and traditional knowledge about the species' behavior in these specific places (Viles 2011).



Detail crop of the Pacific Institute's map for sea level rise projections in the Klamath River Estuary. Light blue overlay is one possible scenario. For more information see Chapter 3.

Existing challenges (sensitivity)

There are numerous existing challenges influencing ney-puy (salmon) vulnerability to climate change. Some of these challenges include:

Nue-mee ney-puy, the Chinook 'Springer'

Overharvesting

Historic canneries that contributed to commercial overharvesting in the Klamath River as well as current ocean commercial fishing and overharvesting is a continuing issue. In addition, to the huge number of fish caught historically, the canneries in Requa also wasted a lot of fish, which is against Yurok Traditions and continues to generate feelings of loss for Tribal Members (Workshop 2).

Hatcheries

The Iron Gate and Trinity River hatcheries were created on the Klamath and Trinity Rivers to mitigate salmonid losses due to large dams (NRC 2004:71). Although the following effects from the hatchery operations are being managed to reduce the impacts, with millions of juvenile chey-guen (Coho), Chinook salmon, and chkwohl (steelhead) released each year (NRC 2004:71), these hatchery fish bottleneck or reduce genetic diversity, compete with the wild ney-puy (salmon), are less disease resistant, and often carry more pathogens from hatchery conditions to infect the wild stock (Barry McCovey Jr., Yurok Tribe Fisheries Biologist, interview Dec. 2015; also Workshop 2). As one Yurok tribal member said (male, born 1986), "If something isn't done soon, our children will all eat hatchery fish instead of native fish." Wild chey-guen are especially at risk from competition with hatchery chey-guen during migration and from competition with and predation by large numbers of hatchery-released Chinook salmon and chkwohl (steelhead) coming into the main stem when chey-guen smoltification is occurring (NRC 2004:8).

Hatchery fish continue to influence wild ney-puy survival even once they migrate out to the ocean. Intraspecific competition from hatchery fish and other factors such as abundance of prey, and density of predators determines ney-puy survival during the life stage when they are in the ocean (NRC 2004:260).

Dams

Dams in the Klamath River block upriver passage of ney-puy from upstream spawning and rearing habitats for chey-guen (Coho) and Chinook, including the areas of the preferred cold water springs. According to Yurok Tribe Senior Biologist Mike Belchik, the dams also block water from the large-volume, cold water springs located in the Upper Klamath River Basin, above the Iron Gate Dam, from moving downstream, instead they send the cold water into warming reservoirs (interview Dec. 2015). Water entering the river from a reservoir can be a different temperature than free-flowing rivers (USGS 2016b; Ch. 4). Ney-puy cue into water temperatures to determine when to migrate upstream to spawn. Warmer water temperatures in the summer and early fall affects the migrating ney-puy (Ch. 3). The ney-puy migration cues are out of sync with the temperature shifts. The ney-puy that used to run in August in cooler years, according to Belchik, are now waiting for the cooling waters and coming about three weeks later in September.

In addition to altering flows, dams also impede the transport of the gravel size preferred by ney-puy downstream. Ney-puy build their nests (redds) in specific-sized gravel; dams are causing smaller-sized gravel to be pushed downstream and larger gravel that is unsuitable for spawning remains near the dam spillways, decreasing the availability of suitable spawning grounds in the off-channel pools (Ch. 4).

The 2002 adult fish kill in the Klamath River was primarily caused by outbreaks of the ich parasite, *Ichthyophthirius multifiliis* and *Flavobacterium columnare. F. columnare,* commonly refered to as columnaris or cottonmouth is a bacterial pathogen, that thrives in low flows from the Iron Gate Dam and warmer water temperatures. In addition, the warm weather forced a high number of 'oh-pos (fall adult Chinook) to hold up their migration upriver and that led to high fish densities; increased stress on ney-puy and provided an ideal environment for the spread of columnaris (Belchik et al. 2004; Ch. 1).

Further, there appear to be more *C. Shasta*-hosting polychaete worms in the river system than there used to be; this was particularly the case during the recent 2013-2016 extreme drought years with lower flows and higher water temperatures (True et al. 2015). The worms release spores that affect both adult and juvenile Ney-puy (salmon), but are only lethal to juveniles (Barry McCovey Jr., interview, Dec. 2015). According to Barry McCovey Jr., a Yurok Tribe Fisheries Biologist, there are more worms in the river closer to the dam. This is due to dams impeding flow, and climate change could be exacerbating the situation; with the recent drought, there are a lack of winter flood events to flush out the worm hosts that carry C. shasta(McCovey Jr., interview, Dec. 2015).

Example of a temporary 'splash' dam used in historic logging operations. Downloaded from: https://www.fs.fed.us/

In 2014, there was also a massive juvenile Chinook salmon fish kill due to higher concentrations of *C. shasta*and *P. Minibicornis* parasites in the Klamath River during the drought (True et al. 2015). When adult fish kills happen, such as occurred in 2002, it is obvious as 20-30 pound rotting carcasses can be seen. But juvenile fish kills are more hidden. The young carcasses degrade and dissolve very quickly. Their impacts may not be felt for 3-4 years later but they affect the species' life cycle and future ney-puy (salmon) generations. Ney-puy are being impacted on both ends of the life cycle, both the out migration as well as those returning to spawn.

Logging

Historic logging practices in the Lower Klamath basin have resulted in "bowling alley syndrome" These "bowling alleys" were created by blasting streambeds to remove obstructions and blocking off side channels and wetlands to float logs downstream (Ch. 4). This process has simplified channel forms and deprived streams of their natural complexity, which is vital to ney-puy (salmon) and other aquatic species in various life stages.

Cannabis grow site where illegal clearing and grading occurred within the Yurok Reservation in 2015.

Erosion from un-rehabilitated historic logging roads continues to overwhelm streams with sediment today, including fine sediments that can impede water flow and deprive fish eggs of needed dissolved oxygen (Lisle 1989; Saldi-Caromile et al. 2004). Increasing sediment loads hinder the removal of metabolic wastes and can "cement" the substrate, hindering ney-puy (salmon) from creating their nests (Saldi-Caromile et al. 2004). The fine sediments that remain suspended in the water column can clog fish gills (Matonis et al. 2013). Fine sediments and gravel can fill in deep pools that once served as cold water refugia, leading to further diminished refuge options for migrating ney-puy populations (for further details, see Ch. 4).

Cannabis cultivation

Similar to the effects of clear-cut logging practices, improperly constructed roads, land grading, and clear cuts associated with Cannabis cultivation contribute to in-channel sedimentation that may block fish access from the main stem to cold water tributaries or may fill in the deeper and cooler pools (Yurok Today 2014b; Ch. 4).

Mining

The mid-Klamath tributaries that were once nue-mee ney-puy (spring run Chinook) strongholds have been compromised by both past and on-going land use practices. Hydraulic mining and other large-scale gold mining operations that were prolific in the mid-Klamath and Trinity, and for which the effects are still felt throughout the watershed, have negatively affected native salmonid populations (Yurok Fisheries Biologist Sarah Beesley, personal correspondence June 2018).

Invasive species

Incursion of invasive species such as reed canary grass in the estuary can choke out side-channels and smaller tributaries, colonize and clog streams and wetlands and alter hydrology by trapping silt and constricting waterways; it can also lower dissolved oxygen, which can impact growth and development of different life stages of ney-puy (salmon) (Belisle et al. 2008; Carter 2008:26). Bullfrogs, carp, and large mouth bass are also as a possible threat and cause for concern for Klamath estuary management.

Increasing water demands: Climate change and a growing population could increase agricultural demands for water in response to a longer growing season and hotter summer temperatures. Such an increase in demands could affect both the amount of water needed to be held in the reservoirs and the availability of in stream flows for ney-puy (salmon) (Ch. 4).

Inherent biological traits

Ney-puy (Salmon) only spawn in their natal spawning grounds. Being dependent on such a specific spawning location increases ney-puy sensitivity to both climate and non-climatic threats to their spawning habitat. Juvenile nue-mee ney-puy (spring run Chinook) and chey-guen (Coho) spend summers in the river and are exposed to warmer water temperatures and sensitive to low flows. In addition, with a three-year rather than a multi-year lifespan like Chinook, one bad year could be devastating for future runs. Because of physiological temperature thresholds, ney-puy are also sensitive to warming water temperatures caused by both climatic and non-climatic factors. In Tables 6.4 and 6.5, for reference, we present temperature thresholds that were suggested as being protective of the various life stages of chey-guen, Chinook salmon, and chkwohl (steelhead)[3].

Table 6.6 Chronic Temperature Thresholds

Life Stage	Maximum Weekly Maximum Temperature (MWMT) (°F /°C)
Adult Migration	68 / 20
Adult Migration plus Non-Core[5] Juvenile Rearing	64.4 / 18
Core[6] Juvenile Rearing	60.8 / 16
Spawning, Egg Incubation, & Fry Emergence	55.4 / 13

Source: Carter 2008.

Table 6.7 Lethal Temperature Thresholds

Life Stage	Lethal Threshold (°F / °C)		
	Ney-puy (Chinook)	*Chey-guen* (Coho)	*Chkwohl* (Steelhead)
Adult Migration & Holding	77 / 25	77 / 25	75/ 24
Juvenile Growth & Rearing	77 / 25	77 / 25	75/ 24
Spawning, Egg Incubation, & Fry Emergence	68 / 20	68 / 20	68/ 20

Source: Carter 2008.

[3]These thresholds were based on a literature review conducted to inform the establishment of Temperature Total Maximum Daily Loads (TMDLs) for the North Coast, California region (Carter 2008). The Maximum Weekly Maximum Temperatures are considered to be representative of chronic thresholds and the lethal temperature thresholds are considered to be acute (Carter 2008).

[4]All The Maximum Weekly Maximum Temperature (MWMT) "describes the maximum temperatures in a stream, but is not overly influenced by the maximum temperature of a single day" (Carter 2008).

[5]Non-core is defined as "moderate to low density salmon and trout rearing usually occurring in the mid or lower part of the basin" (Carter 2008).

[6]Core is defined as "areas of high density rearing" (Carter 2008).

Existing strengths (adaptive capacity)

The Yurok Tribe has many ways to help *ney-puy* (salmon) adapt to climate change. Overall, Yurok tradition informs that if the Yurok People take care of the *ney-puy* (salmon), the *ney-puy* will take care of them. Some of these strengths are highlighted below.

Yurok Fisheries staff monitoring and recording the numbers and sizes of fish caught during commercial harvest season of 2014.

Habitat management

The Yurok Tribe has developed the Blue Creek Sanctuary Plan, including the following proposed changes near the mouth of Blue Creek (500 feet upstream to ½ mile downstream of confluence with the Klamath River): (1) from mid-June to mid-September to protect migrating *ney-puy* (salmon) and *chkwohl* (steelhead), and (2) from mid-September to mid-December to protect genetically distinct *'oh-pos* (fall run Chinook) from sudden and stressful temperature changes if caught in the cooler Blue Creek and released into the mainstem, which can be as much as 10 °F warmer. There are similar regulations for the mouths of the Salmon, Scott, and Shasta tributaries (Yurok Today 2015a).

Blue Creek is the main cold water refuge between the mouth of the Klamath and 55 miles up where it meets the Trinity River; it is about 18 miles upstream of the mouth of the Klamath and serves as a key spawning habitat for Chinook. The Tribe is undertaking major restoration projects, such as the Blue Creek Salmon Sanctuary Phase II, which will restore and protect the Blue Creek Watershed and cold water refuge (Yurok Today 2015a).

The Yurok Tribal Fisheries Program has been utilizing the bathymetry map of the river to identify deeper, cooler locations. Further, The Nature Conservancy has been working with state, federal, and other partners to protect and restore the Shasta Big Springs Ranch containing three miles of the upper Shasta River and 2.2 miles of Big Springs Creek. Upon completion of the restoration, the ranch is expected to provide cool waters for *ney-puy* (salmon) and *chkwohl* (steelhead) year round (TNC 2017; Ch. 4).

Ney-puy Management

The Yurok Tribe has a robust and expansive Fisheries Program that carries out diverse activities to support *ney-puy* and other aquatic species' populations, including but not limited to long-term monitoring of 1) spawning success rates to guard against undetected low spawning success periods (Strange 2010), 2) *ney-puy* use of thermal refuge areas, and 3) salmonids populations in the estuary wetland complexes and McGarvey Creek to build on existing knowledge of their life cycles in this and other similar tributaries (Antonetti et al. 2012).

To help with *ney-puy* (salmon) management and survival, the Yurok Tribe closes the fishery for both subsistence and commercial Klamath catch 3–4 days each week during their fishing season to help *ney-puy* reach their spawning grounds and to allow them to migrate to the upriver Tribes for their subsistence and traditions (Moser et al. 2016).

Also, as part of the Five Counties Salmonid Conservation Program (5C), formed in 1997, the northwestern California Counties of Del Norte, Humboldt, Mendocino, Siskiyou, and Trinity agreed to collaborate on a proactive, positive response to the federal listing of *chey-guen* (Coho) as a threatened species by striving to provide "for the conservation and restoration of salmonid populations to healthy and sustainable levels and to base decisions on watershed rather than county boundaries" (5C Program 2018).

Inherent biological traits

Ney-puy (salmon) also have many traits that help them to adapt, such as variability of Chinook age when spawning, so an entire generation won't be wiped out if there is a fish kill. Hopefully, the genetic diversity in *ney-puy* has not disappeared, but rather is dormant. If the habitat is restored, *ney-puy* will be able to take advantage of it (Mike Belchik, interview Dec. 2015). Individual *ney-puy* runs have behaviors that are adaptive, such as *'oh-pos* out-migrating before high summer temperatures. Salmonids can also change their behavior in response to environmental changes, for example by changing the timing of upstream adult and downstream juvenile migrations.

Adaptation strategies

Key adaptation strategies the Tribe could implement to support ney-puy (salmon) with the effects of climate change are included in the following table.

Table 6.8 Ney-Puy /Salmon: Adaptation Strategies

Ney-puy /Salmon Habitat Management
- Continue to utilize the bathymetry map of the river to identify deeper, cooler locations to conserve. - Initiate innovative "roll out the red carpet" techniques, such use of solar-powered cooling/oxygen stations - Continue to rehabilitate historic logging roads to reduce sediment deliveries to aquatic habitats (Ch. 4). - Consider sequential cultural burns to generate smoke to cool waters and assist migration, "call the salmon home." - Monitor benthic macroinvertebrate to identify areas with high diversity & productivity for juveniles (WRIA 2005). **- Engage in holistic conservation & restoration** to increase ney-puy resilience (Beechie et al. 2013). Focus should include all critical habitats for all life stages and include include: • spawning habitat and cold water influences via dam removal, • river/tributary connectivity, for example, creating step pools where tributaries discharge into the main stem, • wetland-estuarine connectivity and habitat to help fish transition from fresh to salt waters, • instream complexity, for example, by adding log jams, boulders, and woody debris • stream and streamside habitats, providing shade along banks.
Ney-puy /Salmon Species Management
- Increase Tribal input into fish hatchery programs to minimize harm done to wild stocks (Mote et al. 2003). - Continue to support existing robust Yurok Tribal Fisheries Program. - Consider experimenting with closing hatchery operations for a period of time to assess effects on wild fish (NRC 2004). - Design future monitoring efforts in a manner that covers a complete 3-year chey-guen (Coho) life cycle. - Consider installing Stream-width Passive Interrogation (SPI) antenna arrays closer to creek mouths - Investigate alternative options for Passive Integrated Transponder (PIT) detection systems in mouths of estuary creeks - Investigate determining non-natal from natal fish by assessing tissue sample genetics. - Continue spawner surveys to collect information on redd locations and adult habitat use. - Continue monitoring of juvenile upstream and downstream movements, particularly from fall through late spring.
Ney-puy /Salmon Legal and Policies
- Continue efforts to change California's catch & release sport fishing regulations to minimize stress and mortality during times of higher than average temperatures and spawning (Yurok Today 2015b). - Advocate for multi-year management decisions to release adequate cold water from the Trinity River reservoirs to reduce downstream water temperatures to aid smolt outmigration (NRC 2004; Kibel 2014). - Enforce the proposed changes in the Blue Creek Sanctuary Plan to protect migrating ney-puy (salmon). - Lobby for reopening consultation on environmental impact statement written for Chey-guen (Coho) - Finalize and adopt the Yurok Tribe Wetlands Protection Ordinance, which has already been initiated.
Ney-puy /Salmon Collaboration
- Seek funding to work with landowners & timber companies on stream restoration to support ney-puy populations. - Engage in collaborations to restore the Shasta and Scott Rivers, which have been degraded. The two rivers have high potential for restoration of chey-guen (Coho) and other anadromous fish (NRC 2004:309).

6.3 CHKWOHL / Steelhead

For the Yurok, chkwohl or steelhead (*Oncorhynchus mykiss*) have been a buffering subsistence food to changes in the ney-puy (salmon) runs, providing a plentiful food source if the 'oh-pos (fall salmon runs) are low. Chkwohl are renown for being the best fighters when caught with hook and line, making them a favorite with sport fishermen. This has provided Tribal Members not only sport but also economic opportunities as guides to the historic throngs of recreational fishermen who visited the Klamath River, which was known as the Steelhead Capital of the World.

However, today chkwohl are threatened with population decline in the Yurok territory due to the cumulative effects of climatic and non-climatic factors, resulting in economic, health, and cultural impacts on the Yurok Tribe. The following sections illustrate the threats to and impacts on chkwohl and some strategies that the Tribe can pursue to help this species adapt. First we look at chkwohl life history in the Klamath system to better understand how they might be affected by climate impacts at different life stages and in different habitats.

Climate Effects on Chkwohl

Chkwohl (steelhead) are exposed to climate-related stressors in the river, streams, and estuary when they are eggs, juveniles, and spawning adults. As smolts migrate to the estuary and then into the ocean, they are exposed to changing estuary and ocean conditions such as rising water temperatures and ocean acidification (Moyle et al. 2008). Most impacts will be the same as for salmon except that chkwohl prefer colder water temperatures and higher dissolved oxyen.

Chkwohl are vulnerable to climate change effects such as rising water temperatures, increas-

Table 6.9 Key Climate Impacts on Chkwohl / Steelhead

Primary Climate Effect	Secondary Stressor	Potential Impacts
Warmer Air Increasing Drought	More extreme low flows	- Disconnection of cold water tributaries from mainsteam > decreased spawning, increased fish stress and mortality - Lack of sufficient flows to flush polychaete worms from the system > higher concentrations parasites > increasing infection rates
Warmer Water	Decreasing dissolved oxygen	- Increased stress > Increased mortality
Heavier Downpours	Increased erosion	- Scouring and/or burying redds and eggs - Sedimentation infilling of cold water refugia - Increased disconnected tributary access
Rising Sea Level	Changing estuary salinity & size	- Affects juvenile growth & survival (possibly positive) - Impacts smoltification process & timing
Ocean Acidification	Reduced plankton	- Potentially reduced food supplies > less growth > reduced survival

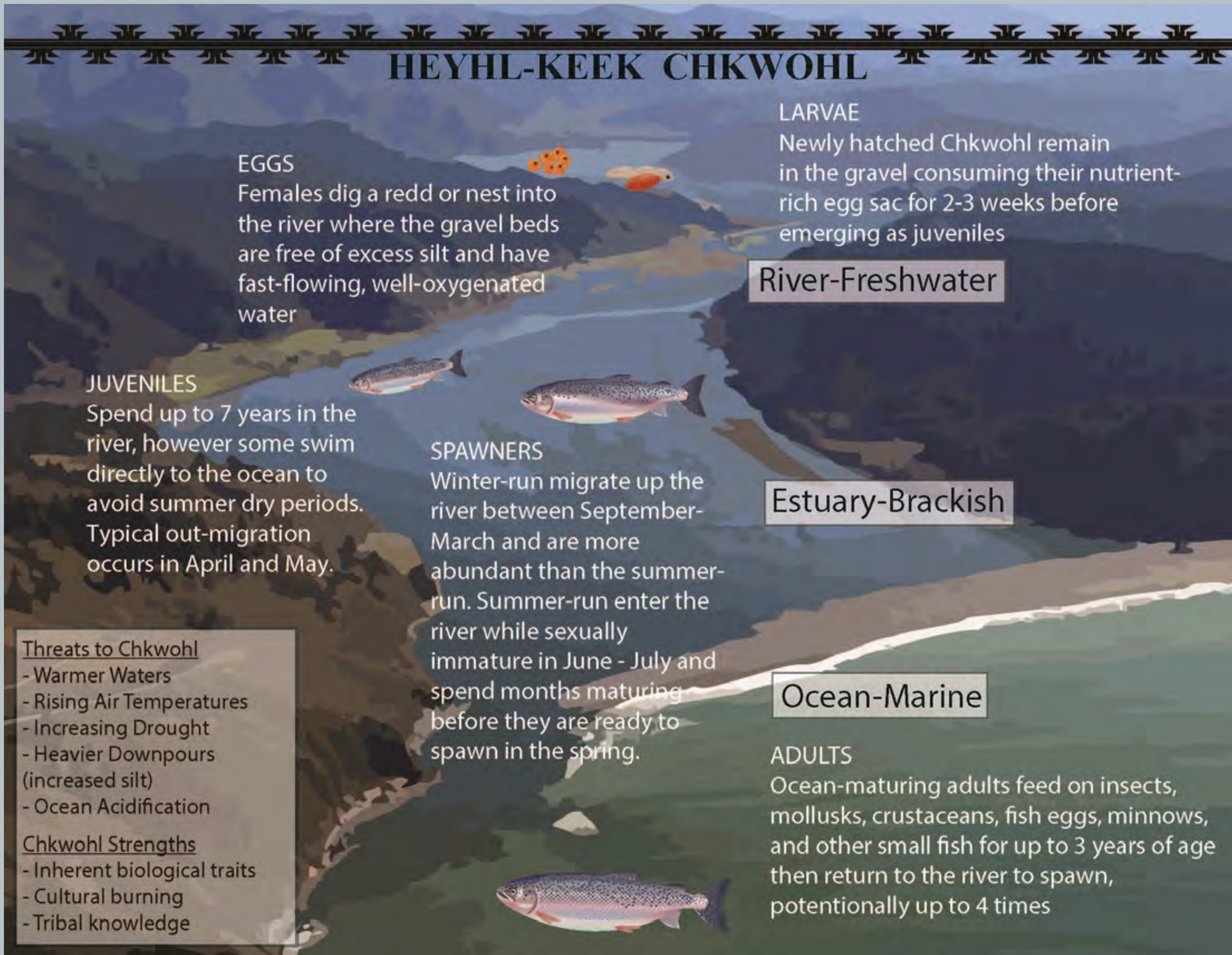


Figure 6.2 Steelhead Use of Habitats within the Klamath River

ing drought intensities, reduced snowpack, altered stream flow patterns, heavier rain events, and changing ocean conditions. Below we include details about these effects on chkwohl in the lower Klamath basin.

Warmer waters

Klamath River mainstem waters are expected to warm with climate change due to a variety of factors including rising air temperatures and lower summer flows due to declining snowpack, earlier snowmelt, and increasing drought intensities (see ney-puy / salmon section 6.3 above; also Ch. 3 and Ch. 4). Yurok Senior Biologist Mike Belchik explained that any species dependent on summertime cold water, including chkwohl (steelhead), is having problems (interview, Dec. 2015).

Warmer waters could lead to more frequent die-offs of chkwohl as spawning adults move through warmer river corridors during summer and fall (Rieman and Isaac 2010). Warmer waters also limit chkwohl growth, survival, and reproductive capacity and have metabolic costs (Doctor et al. 2014; Myrvold and Kennedy 2015; Williams et al. 2015). For summer-run fish, the maximum temperatures listed in the life cycle section above and Table 6.5 are now being routinely exceeded, leading to large congregations in thermal refugia (Barry McCovey Jr., personal correspondence, June 2018). This increases risk of disease outbreak of *C. shasta* and *P. minibicornis* in salmonids (see ney-puy / salmon section 6.3 above). Chkwohl in the Klamath River show evidence of *C. shasta* in about 38 days at water temperatures above 50oF (10oC) (Leitritz and Lewis 1976).

If temperatures rise above the optimal or sub-optimal range for chkwohl (steelhead), habitat suitable for their survival increasingly shrinks and becomes fragmented (Williams et al. 2015). To cope with this some juvenilles swim directly to the ocean and avoid rearing and growth in the estuary to avoid hot dry summer periods (UC 2018). Further, warmer waters, combined with degraded riparian habitat, could enhance conditions for invasive species, resulting in chkwohl (steelhead) being more susceptible to predation by and competition with invasive species (Williams et al. 2015). Warmer waters also result in decreased dissolved oxygen levels, which chkwohl are sensitive to in their development (see chkwohl life cycle section above). The end result would be chkwohl population decline (Wade et al. 2013).

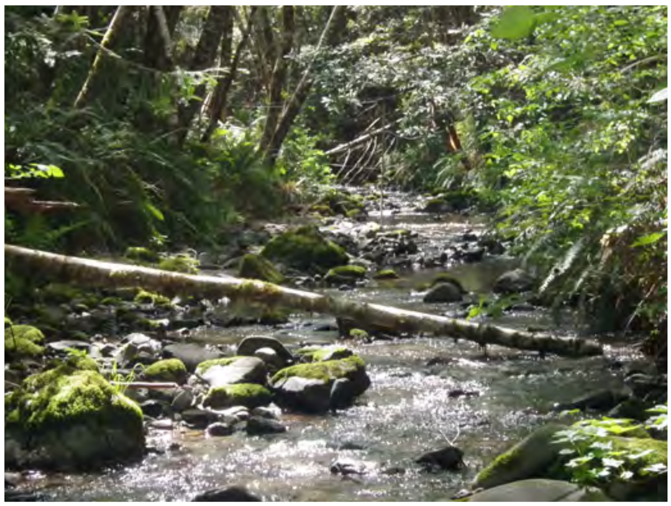
In addition to rising temperatures of the Klamath River and its tributaries, ocean temperatures are also predicted to warm (Ch. 3). Adult *chkwohl* (steelhead) in the ocean are adapted to water that is 48°F to 53°F (9°C to 11.7°C) (Fulton 2004). Higher temperatures could affect their ability to survive and thrive.

Rising air temperatures

Rising air temperatures contribute to decreasing snowpack and increasing drought intensities, both of which can lead to lower flows in the Klamath River during the late spring and summer (Moyle et al. 2008; Williams et al. 2015). Lower flows, along with warmer waters, during the late spring and summer could impact cues on migration and affect chkwohl (steelhead) during their migration to the ocean and summer spawning run. Further, increasing amounts of winter rainfall, as opposed to snowpack, could mean that Lower Klamath tributaries, identified as cold water refugia for chkwohl, may be significantly impacted (Sloan 2015).

Increased wildfires

Rising air temperatures can also exacerbate conditions for wildfires, which are expected to increase in frequency and magnitude with climate change (Ch. 3). Wildfires, combined with heavier downpours, can increase threats of landslides and debris flows, which can result in increasing sediment loads that block channels, fill in spawning areas, and impede fish movement, leading



Upper photo: Shows upper reaches of Tectah Creek: prime chkwohl habitat- cold, highly oxygenated water
Middle: In 2015 the Creek 'dried-up' by October from drought and water withdrawals
Lower: The drought conditions resulted in isolated pools that disconnected access to the Klamath River and stranded fish and other aquatic life in ever decreasing habitat.

to potential extreme degradation of fish populations and habitats (Williams et al. 2015). This could result in reduced access to spawning grounds and cold water refugia. This is of particular concern during chkwohl life stages in the river. Alevins in particular and emerging fry could be affected by fine sediments, which reduce the amount of available oxygen (Fulton 2004).

Heavier downpours

The climate-induced shift in winter precipitation from snow to rain, in combination with heavier downpours, may result in more rain-based floods in the Klamath and its major tributaries during the winter rainy season, leading to more extreme high flows (Ch. 3). Winter floods can scour streambeds and increase erosion (Williams et al. 2015). This could potentially impact habitat for spawning winter-run chkwohl in particular.

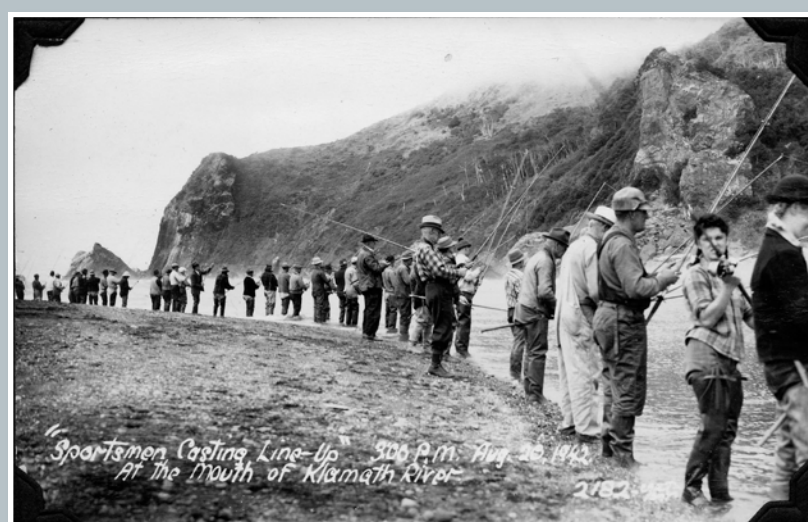
Further, the shifting timing and conditions of lower summer flows and higher winter flows, along with increasing summer water temperatures could affect migration timing of juvenile and adult salmonids, including chkwohl (Rieman and Isaak 2010). Spring runoff and peak flows can serve as significant behavioral cues, with shifts in their timing to earlier in the season potentially changing fish migrations (Williams et al. 2015).

Sea level rise

Sea level rise, along with climatic and non-climatic driven upwelling events and changing freshwater input, could change salinity in the estuary (Williams et al. 2016; Ch. 3), affecting chkwohl juvenilles and smolts.

Existing challenges (sensitivity)

Chkwohl (Steelhead) along the Northern California coast are not at immediate risk of extinction. They are listed as a threatened, but not endangered, species (Williams et al. 2016). However, there are numerous existing challenges influencing chkwohl vulnerability to climate change. Some of these challenges include:



Recreational, sports-fishermen with their rod and reels line the bank of the Klamath River

Overharvesting

Historic overharvesting in the Klamath River is a continuing issue. Robert McConnell, Sr., President of the Yurok Cultural Fire Management Council, described how the Trinity River used to be known as the 'Steelhead Capital of the World'; where sport fishermen could go to the river in the morning, catch a limit of 10, then go back in the afternoon and get another limit of 10. Nowadays the limit is one and it has to be a hatchery fish. As McConnell, Sr. expressed, "That overharvesting played into what we're dealing with today" (interview, Dec. 2015).

Hatcheries

Another issue is reduced genetic variability from hatchery production (NRC 2008). The threat to wild, native chkwohl (steelhead) is potentially increased by competition and predation from hatchery fish (Moyle et al. 2008). Release of hatchery fish to supplement the declining chkwohl population raises concerns about reduced growth and survival, displacement, and increased predation on the natural chkwohl populations (Yurok Tribal Fisheries 2013).

Dams and culverts

Infrastructure-driven issues, such as the culvert placed at Parker Creek (south side of Tsurai Traditional village) inhibit chkwohl from swimming upstream to get to the creek (Axel Lindgren III, Elder Interview 2014). In addition, the Iron Gate, Dwinnell, and Lewiston Dams all affect chkwohl runs (Moyle et al. 2008). Dams and culverts also block chkwohl access to spawning grounds and result in chkwohl habitat degradation (NOAA Fisheries n.d.).

Logging

Past habitat management activities, including logging, have led to excessive sediment delivery to critical chkwohl spawning and rearing habitats, such as fluvial habitats of McGarvey Creek, and reduced thermal complexity (Moyle et al. 2008; Antonetti 2012; Ch. 4). The excessive sediment continues to limit the quantity and quality of habitat available for juvenile and adult salmonids, and decreases productivity of salmonids utilizing the drainage (Antonetti 2012).

Agriculture

Agricultural impacts, including but not limited to Cannabis cultivation, have been felt in streams throughout the Upper Klamath and Trinity River basins. The impacts from runoff of nutrients and sedimentation from agricultural production are often increased by reduced surface flows through water diversions for irrigation (Moyle et al. 2008). Increasing sedimentation, as discussed in the climate effects section above, can result in potential extreme degradation of chkwohl populations and habitats (Williams et al. 2015).

'Open grow' *Cannabis* plots allow fertilizer, insecticide and other contaminants to seep into groundwater

Inherent biological traits

Juvenile chkwohl spend up to seven years in the river (NOAA Fisheries 2016b). During this extended time when compared to other salmonids, they are exposed to river conditions, such as water quality and quantity, for the majority of their lives. Chkwohl could be affected at different life stages when the water temperature shifts beyond critical thresholds (Wade et al. 2013; see Tables 6.4 and 6.5 for temperature thresholds relating to chkwohl life stages.

Existing strengths (adaptive capacity)

The Yurok Tribe has many existing strengths to help chkwohl (steelhead) adapt to climate change. Many pertain to an expansive knowledge base of both scientific and traditional knowledges. For example, the Yurok Tribal Fisheries Program

(YTFP) has been monitoring salmonid populations, including chkwohl (steelhead), in key habitats such as the McGarvey Creek watershed since 1997. Tribal concerns over decreased anadromous fish runs and a need for baseline data to monitor habitat and population trends was acted upon and YTFP began and has increased its monitoring efforts over the years (Antonetti 2012). Also, water quality parameters have been researched by YTEP since the program was started, and galvanized to expand its efforts by the 2002 fish kill. These efforts are further supported by Yurok's cultural burning practices that can help reduce threats of large wildfires, decreasing susceptibility to landslides and debris flows that result in increasing sediment loads.

Inherent biological traits

In addition to human efforts, chkwohl (steelhead) have a number of traits that enable them to adapt to a changing climate, such as being able to survive in small isolated habitats and short reaches when creeks are blocked from connecting to the mainstem Klamath during low flow periods. They are born in creeks but quickly start moving around and utilizing habitats throughout the stream system. Chkwohl have flexibility to changing conditions, such as being able to stay in freshwater longer if they need to, and can spawn multiple times (Workshop 2).

Adaptation strategies

There are a number of adaptation strategies the Yurok Tribe could implement to support chkwohl adapting to the effects of climate change, which are included in table below. Many of the adaptation strategies listed for ney-puy (salmon) in Section 6.2 are also applicable for chkwohl and are not repeated again here.

Table 6.10 Chkwohl/ Steelhead: Adaptation Strategies

Chkwohl /Steelhead Habitat Management
- Innovative management design: See strategies to cool the river for *ney-puy* (salmon), also applicable for *chkwohl* (steelhead). - Coordinate watershed-scale actions that both increase fish resilience and mitigate climate change impacts (e.g., restoring connectivity of floodplains and high-elevation habitats) through each life stage (Wade et al. 2013; also Rieman and Isaac 2010). - Restore favorable instream conditions to benefit multiple species and desired ecosystem function instead of single species (Moyle et al. 2008). - Restore degraded *chkwohl* habitat, water quality, and instream flow (NOAA 2016). - Remove or modify dams that affect *chkwohl* migration (NOAA 2016). - Preserve key *chkwohl* habitats such as Blue Creek as buffers against potential climate change issues (Yurok staff interview Dec. 2015). - Continue cultural burning practices to reduce threats of large wildfires and decrease landslides and debris flows resulting in increasing sediment loads into streams.
Chkwohl /Steelhead Management
See strategies for *ney-puy* (salmon) management, also applicable for *chkwohl* (steelhead).
Chkwohl /Steelhead Monitoring
Use temperature sensitive tags to infer *chkwohl* location to track habitat use in thermally heterogeneous environments (Brewitt and Danner 2014).

6.4 KAH-KAH / North American Green Sturgeon

For the Yurok people, kah-kah or the North American green sturgeon (*Acipenser medirostris*) are considered sacred beings and traditionally they were an important food source during the early spring months, the time of the kah-kah spawning run (McCovey Jr. 2011). Not only is kah-kah meat eaten but also the kah-kah eggs are collected and baked into loaves as a traditional Yurok food. According to Yurok Tribal member Walt McCovey Jr., two types of kah-kah were caught in the Klamath River, kah-kah and white sturgeon.

> *"From the Klamath I mostly miss sturgeon. Haven't had sturgeon for a long time. It used to be plentiful."*
>
> – Yurok female, born 1941

In the past, Yurok fishers knew that kah-kah (green sturgeon) were running upriver to spawn when the dogwood flowers were blooming. However, with changes in the ecosystem, the kah-kah cycle is off and the knowledge of when the kah-kah run occurs is no longer applicable (Workshop 2). Kah-kah rely on deep-water pools in the river, and spend a lot of time in marine and bay habitats, which puts them at increased risk to water quality and quantity issues in those areas. With their spawning range mostly limited to the Lower Klamath and Trinity Rivers, local impacts in the river system could be significant for kah-kah, according to the Yurok Tribe's senior fisheries biologist Tim Hayden. Low water levels expose kah-kah to more harmful toxins, which is exacerbated by kah-kah being filter fish and toxins bioaccumulating in their bodies (Workshop 2). There is concern that with lower water levels in the river in the future, the kah-kah will struggle to migrate upriver and spawn, leading to a loss of kah-kah population (Workshop 2).

Table 6.11 Key Climate Impacts on Kah-kah/ Green Sturgeon

Primary Climate Effect	Secondary Stressor	Potential Impacts
Warmer Air	More extreme low flows	- Affect the timing of kah-kah migrations, incoming & out bound movements - Negatively affect habitat needs for spawning, egg incubation, & larval development - Concentrate toxins in the river, increasing exposure & accelerating impacts
Increasing Drought		
Warmer Water	Decreasing dissolved oxygen levels	- Hinder / shift timing of upriver spawning migration - Negatively impact egg & juvenile development - Increased chronic stress - Increased mortality
Heavier Downpours	Increased erosion	- Suffocation of eggs - Sedimentation infilling of spawning pools
Ocean Acidification	Reduced plankton	- Loss of shellfish > potentially reduced food supplies > stress > reduced survival

Kah-kah's vacuum-like mouth and sensitive barbels that are smell receptors that help it find its food.

Life History of Kah-kah

The kah-kah (green sturgeon) is a large fish that is considered to be a living fossil with a lifespan of over 40 years and an appearance that has changed little since prehistoric times (Oregon Wild 2014; NOAA Fisheries 2015). Some biologists think that the fish may live up to 60 or 70 years (Moyle 2002). Today, the Klamath River system and its tributaries are home to the largest remaining kah-kah spawning population in California, with one estimate that 80-90% of all kah-kah, spawn in the Klamath River basin (Adams et al. 2002; UC 2017; EPIC et al. 2001:53). Pacific-northern distinct population segment (DPS) of kah-kah, including coastal spawning populations from the Eel River north and into the Klamath River, are listed as a species of concern by the NOAA National Marine Fisheries Service due to historical overfishing, dam-induced flow manipulations and reductions, and spawning habitat degradation, modification, and loss (NOAA Fisheries 2006; McCovey Jr. 2011; NOAA Fisheries 2017b, 2018).

Kah-kah (green sturgeon) have shark-like tales, sand paper-like skin, and five rows of scutes (protruding bony plates) that protect them instead of scales (NOAA Fisheries 2015; CBD 2017). They do not have teeth but use a blunt, shovel-like snout and flexible, vacuum cleaner-like "lips" to suck up bottom-dwelling food. Such food may include shrimp, shellfish, and amphipods; however, kah-kah are opportunistic predators and may eat small, disabled, or dead fish as well (EPIC et al. 2001:9; NPS 2014). Yurok fishermen say that kah-kah follow the eel into the river to feed on their carcasses after the eel have spawned out. Having poor eyesight, kah-kah hunt and detect their prey with four very sensitive whiskery barbels on the underside of their snouts (CBD 2017).

Kah-kah (green sturgeon) average 4.5 to 7 feet in length (NOAA Fisheries 2015). Mature females (17+ years old) are larger than mature males (15 years old); virtually all kah-kah greater than 6.5 feet in length are female (EPIC et al. 2001:8). After reaching maturity kah-kah continue to grow, although at a significantly slower rate. For example, male and female kah-kah grow approximately three inches per year until they reach maturity around age 15-20, at 51-59 inches; by age 30 they are about 77 inches, and by 40 years old about 79 inches (EPIC et al. 2001:8). Historically, they were reported to have reached weights of up to 350 pounds (NOAA Fisheries 2015) and are among the largest anadromous fish found in freshwaters worldwide (EPIC et al. 2001). In the Klamath River, the longest documented kah-kah was 90 inches or 7.5 feet in length, and the largest by weight was 180 pounds (SWRI 2003).

They are anadromous like the salmon, born in freshwater, migrate out to the ocean, and then return to the same river they were born in to reproduce, although, notes McCovey Jr., not necessarily to their exact natal spawning grounds like ney-puy (UC 2017). In the Klamath River, kah-kah spawning migrations generally occur May through June (McCovey Jr. 2011). Unlike ney-puy, kah-kah can repeat the cycle of spawning, going back out to the nearshore oceanic waters, and again returning to their natal river to spawn multiple times throughout their long lives. This may occur every three to five years (Adams et al. 2002; NOAA Fisheries 2017a).

Figure 6.2 Kah-kah / Green Sturgeon Use of Habitats within the Klamath River

Unlike ney-puy (salmon) and chkwohl (steelhead), which build nests or redds, kah-kah broadcast spawn, releasing their eggs and sperm into deep pools (greater than ten feet) with strong bottom currents (Israel et al. 2008; CBD 2017). Kah-kah eggs are slightly adhesive, and stick to one another and against the rock walls that form the deep pools or eventually to cobbles once they settle to the pool bottoms (CBD 2017). The kah-kah eggs hatch after only about eight days with larvae emerging that are less than an inch long (CBD 2017; UC 2017). These juveniles live in the river and estuary for one to three years until they reach one to two feet in length, before migrating out to the ocean, where they spend the majority of their lives (NPS 2014).

After spawning, Barry McCovey Jr., Yurok Tribe Fisheries Biologist, noted that sometimes the adult kah-kah (green sturgeon) will leave the river right away after their spring spawning but other times they will stay in the river until the fall or winter before returning to the ocean. McCovey Jr. further explained that in the Klamath, Yurok Tribal Fisheries Program's observations "have shown that if the adults stay, then their fall outmigration is directly related to river discharge (not so much temperature). This generally occurs with the first significant rainstorms of the fall. It can be as early as September or as late as December. The ratio of spring versus fall adult outmigrants is dependent on the spring rains and discharges, i.e., the higher the spring flows the more fish will leave in the spring" (personal correspondence, March 2018). And although limited monitoring data exists, Belchik, Yurok Senior Biologist says that current information indicates that once they exit the river, they turn right traveling north. Important northern localities include the Columbia River estuary, Grays and Willapa Harbors in Washington, and the northern coast of Canada notes McCovey Jr. (see also Adams et al. 2002:i).

Climate Effects on Kah-kah

Kah-kah are exposed to climate-related stressors during all life stages with specific stressors depending on the habitat in which they are living at the time. Kah-kah are highly vulnerable to climate change effects such as higher water temperatures, extended droughts, and altered stream flow patterns (Moyle et al. 2013). Overall, the cumulative climate effects on water quantity and quality (Ch. 4) could reduce kah-kah (green sturgeon's) food supply, affecting them while in the Klamath River. Not only do they need deep pools for spawning, these pools serve as general kah-kah habitat for cool water refugia and areas of potential feeding where river currents deposit and aid in accumulating fish, animal carcasses and other detritus.

Table 6.12 Temperature Thresholds for *Kah-kah*

Life Stage	Lethal
Eggs/Larvae	68°F (20°C) /73°F (23°C) (Adams et al. 2002)
Juveniles	77°F (25°C) (NRC 2004)
Upstream spawning migration	60.8°F (16°C) (SWRI 2003)

Warmer waters

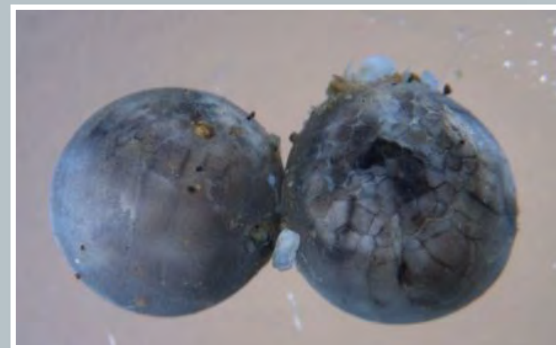
Warmer waters can be lethal to kah-kah, although temperature thresholds can vary for all life stages it also puts chronic stress on kah-kah, impairing their reproduction, growth and immune function (CDFW 2017). Excessively warm temperatures can increase the development of larvae abnormalities and decrease the length of hatched larvae. River water temperatures at 68.9°F-71.6°F (20.5-22°C) contribute to decreased kah-kah hatching success especially during dry water years (Van Eenennaam et al. 2005), such as the recent multiyear drought throughout California. One report suggests that In the Klamath River, the upper temperature tolerance of kah-kah during their upstream spawning migration may be as low as 60.8 °F (16 °C) (SWRI 2003). Another threat to newly hatched kah-kah is that excessively high water temperatures can increase the development of abnormalities, decrease the length of hatched larvae, and decrease overall survival (Israel et al. 2008). In experiments, some larvae appeared to recover from their deformities once temperatures were reduced back to more optimal levels.

There are documented occasions when water temperatures in the Klamath River have exceeded safe thresholds (Ch. 3). Further, with warmer waters and lower water levels, Yurok community members report that the texture of kah-kah meat quality is deteriorating, resulting in Yurok eating less of this traditional food (Workshop 2).

Rising air temperatures and increasing drought intensities

Lower flows, from extended and increasing drought intensities in addition to rising air temperatures leading to less water stored as snowpack, could be a barrier to kah-kah upstream migration (Workshop 2). Lower river levels may also affect the deepwater pools that kah-kah depend on and could also expose kah-kah to increased concentrations of harmful toxins from pesticide runoff (Workshop 2). The timing of adults and juvenile kah-kah entering and exiting the Klamath and Trinity Rivers could change as a result of shifts in river flow and temperature (CDFW 2017). Flowing water is needed to disperse kah-kah eggs and provide sufficient oxygen to the eggs and hinder egg predation (EPIC et al. 2001:5); reduced flows could affect these processes. In addition to lower flows, extended drought and increased drought intensities could also result in loss of seasonal floods, which are needed to flush out sand and silt from substrates that could suffocate kah-kah eggs (EPIC et al. 2001:5).

Lower water levels from extended and increasing drought intensities and rising air temperatures could also expose kah-kah to increased concentrations of harmful toxins from pesticide runoff (Workshop 2). In a 2012 tissue sampling of kah-kah skin, YTEP detected high levels of pesticides that were above the recommended health threshold for human consumption (Sloan and Fluharty 2014).



Sturgeon eggs with jelly-like coating that makes a sticky coating. Photo: UC Davis <https://www.fws.gov/redbluff/rbdd_greensturgeon.html>

Heavier downpours

Fine silt can often endanger the eggs as it can prevent the eggs from sticking to one another and the substrates (EPIC et al. 2001:7). In addition, excessive fine sediment, silt and sand may also suffocate the eggs (SWRI 2003). There could also be a loss of kah-kah (green sturgeon) on the Klamath due to heavier rains contributing to increasing flood events combined with increased wildfires. During these events, landslides are common and excessive amounts of fine sediments could suffocate eggs and prevent them from adhering to the bottom. Sediments also contribute to the infill of deep pools that kah-kah use to spawn. For example, kah-kah used to run in the South Fork Trinity, but after the 1964 flood, which filled in deep pools, kah-kah never went back to the South Fork.

Ocean acidification

The shell development of small, bottom-dwelling marine species such as shrimp and crab (Ch. 3), which kah-kah (green sturgeon) rely upon for food sources (Oregon Wild 2014) may be suppressed with ocean acidification. Further, juvenile kah-kah have limited ability to handle increases in carbon dioxide levels in oceanic waters (CDFW 2017).

Rising Sea Levels

Kah-kah (green sturgeon) are also vulnerable to shifts in ocean and near-shore conditions. Reduced summer freshwater inputs into estuaries would result in greater tidal cycle influences on estuary salinity levels and thus greater salinity variations resulting in cellular stress on kah-kah (Sardella and Kültz 2014). Further, prey type and abundance could be affected in water bodies, impacting nutrient availability and composition, resulting in physiological and biochemical effects, reducing kah-kah growth performance and/or fitness (Vaz et al. 2015).

Existing challenges (sensitivity)

There are numerous existing non-climatic challenges influencing kah-kah vulnerability to climate change.

Overfishing

Kah-kah are particularly susceptible to overfishing by non-Yurok commercial fisheries due to their longevity, delayed maturation, and large size; excessive "mining" of large, mature kah-kah has hindered sustainable harvest rates. Legal size limits targeting white sturgeon do not protect most kah-kah, which are often smaller than six feet (1.83 meters) (EPIC et al. 2001). There are also serious concerns that the three known kah-kah spawning populations may only have a few hundred mature females remaining, making it difficult to maintain a minimal population size and worries about conserving genetic diversity (EPIC et al. 2001; McCovey Jr. 2011). Yurok fishers have reported no longer seeing as many kah-kah or large kah-kah in the Klamath River. In the 1970s, individual fishers might catch 20 kah-kah a night and over 300 for the year; in 2015, the Tribe caught 76 kah-kah total (Workshop 3).

Invasive species

Although there is currently not a problem with bass, they have been introduced in many rivers, bays, and estuaries in other parts of their range and they prey on young kah-kah (green sturgeon) (Moser et al. 2016). Further, alterations to river systems have exacerbated the problem of invasive species, creating habitat conditions that are favorable to various new prey, predators, and competitors (EPIC et al. 2001).

Sedimentation & development of extensive river bars combined with low flow releases from the dams made the Klamath River nearly impassible in 2016

Land use practices

Upstream mismanagement (e.g., road building, logging) have changed the quantity and quality of spawning and rearing habitats in the main stem river by increasing sediment loads flowing into the river and filling in deep pools where kah-kah spawn, impairing water quality and reducing habitat suitability (CDFW 2017; see also Ch. 4). Historical logging practices furthered massive erosion and sedimentation of the local river systems, exacerbating the effects of the 1964 flood. These practices resulted in large-scale changes in river morphology, which contributed to the kah-kah disappearing from the South Fork Trinity River (EPIC et al. 2001).

Dams

Reservoir operations, as well as water diversions, power generating projects, and dredging activities, impair kah-kah habitat by increasing summertime water temperatures, changing fish community structure, altering the river's sediment transport, and modifying natural flow regimes. As a result, flows necessary for suitable kah-kah spawning, rearing conditions, and habitat suitability for eggs and larvae are reduced, as well as possibly destroying or blocking access to rearing habitats, or impeding or delaying downstream migration (EPIC et al. 2001; Moser et al. 2016).

Historically, kah-kah would enter the Klamath in numbers to follow the key'-ween (Pacific lamprey) and feed on their fatty, nutrient rich carcasses after the key'-ween had spawned out and died. After the systematic poisoning of the key'-ween, which were seen as a nuisance species that hindered the operation of dams and their turbine generators, there is significantly less food to support kah-kah populations in the river system.

Inherent biological traits

Kah-kah do not sexually mature until 15 to 17 years-old (NOAA Fisheries 2015); if climate stressors affect them early on, there is concern over what this would mean for population numbers. Further, their reliance on deep-water pools makes them vulnerable to low water levels.

Over the course of their long lives, the benthic feeding habits and slow maturity growth rate of kah-kah (green sturgeon) increases their vulnerability to bioaccumulation of legacy pollutants (e.g., DDT) and pesticides in their system (EPIC et al. 2001; Moser et al. 2016; CBD 2017). This is further exacerbated by lower flows causing toxin levels to concentrate in the river. This poses a distinct risk to Yurok health because, in addition to eating kah-kah, the skin is traditionally chewed to make glue for regalia; with more toxin accumulation in kah-kah, this traditional practice is no longer safe (Workshop 2), and many Tribal members resort to ordering imitation glue online.

Existing strengths (adaptive capacity)

Barry McCovey Jr. (left) and Rocky Erickson (right) of the Yurok Tribal Fisheries Program, surgically implanting an acoustic transmitter into the *kah-kah* (sturgeon's) abdomen to track its movements.

The Yurok Tribe already has many existing strengths to help kah-kah (green sturgeon) adapt to climate change.

Knowledge Base

The Yurok Fisheries Department has a listening device at Aiken to monitor when kah-kah (green sturgeon) move in and out of the river and the Yurok Tribal Fisheries Program has used radio biotelemetry to study in-river movements and migrations of adult kah-kah (for example, see Benson et al. 2005).

Kah-kah Species Management

There is a 4-6 foot harvest range to protect the juvenile kah-kah and highly productive female kah-kah, and a two per year limit on catching kah-kah. Local fishermen have been releasing female kah-kah on a voluntary basis (Workshop 2). The Yurok Tribe has instituted regulations in: 1) deep areas where kah-kah hold during migration to conserve energy, 2) gear restrictions, and 3) handling and holding protocols (Moser et al. 2016).

Inherent Biological Traits

Kah-kah have a number of traits that enable them to adapt to a changing climate, such as being somewhat flexible in where they spawn, returning to their natal spawning river to reproduce as opposed to a specific natal spawning ground (McCovey Jr., interview, Dec. 2015). Kah-kah can produce a large number of offspring, and are scavengers that can eat a diversity of food resources including a wide variety of benthic invertebrates like shrimp and mollusks (NOAA Fisheries 2015). The slow maturation rate and large size of kah-kah helps reduce predation and increases longevity, which allows for many opportunities to spawn as well as reducing the need to spawn in unfavorable conditions (EPIC et al. 2001). Furthermore, kah-kah can survive out of water for a relatively long period of time, even up to several days (McCovey Jr., interview, Dec. 2015), and can live in both fresh and saltwater, acclimating to changes in salinity. For this reason, traditional harvesters kill their kah-kah catch with a spike through its heart as they give thanks.

Overall, kah-kah (green sturgeon) are a long-lived, prehistoric species that has adapted to changes over time. Even though there have been alarmingly high kah-kah mortality rates in recent years for unknown reasons, causing a need of close monitoring, their proven resilience over time is a strong indication that they are not going away tomorrow (Workshop 2).

Adaptation strategies

There are a number of adaptation strategies the Yurok Tribe could implement to support kah-kah (green sturgeon) adapting to the effects of climate change, which are included in Table 6.11 below.

Table 6.13 *Kah-kah* / Green Sturgeon: Adaptation Strategies

Kah-kah / Green Sturgeon Habitat Management
- Re-establish natural kah-kah habitat, including barrier removal/modification to restore natural water flows, river & estuarine restoration including natural bank protection, & removal of non-native species & contaminated sediments (Moser et al. 2016). - Implement flow requirements that promote spawning, incubation, rearing; overall survival (Hildebrand & Parsley 2013); as well as support kah-kah spring out-migration (McCovey Jr. 2011). - Implement eradication programs for non-native species, increased public education and outreach, and increased fines or penalties for the release of non-native species (Moser et al. 2016).
Kah-kah / Green Sturgeon Management
- Use tribal knowledge to teach about kah-kah life, when to catch kah-kah, respect for size restrictions, and killing - Conduct systematic sampling to evaluate the number of adult kah-kah that are not caught and and are returning to their spawning and holding habitats in the Klamath River (Moser et al. 2016). - Current population assessment and monitoring by the U.S. Fish and Wildlife Service, Yurok Tribe, and others should be expanded, particularly for Klamath River populations (CDFW 2017).
Kah-kah / Green Sturgeon Legal and Policy
- Make it mandatory to release females, especially those of peak reproductive ages of 25 to 40 years old (CDFW 2017). - Increase evaluation of fish harvest & enforcement, and heavier sentences and fines for poachers (Moser et al. 2016).
Kah-kah / Green Sturgeon Education and Outreach
- Increased public education and outreach about invasive species that pose a threat to *kah-kah* & the existing laws prohibiting invasive release into the local ecosystem, (Moser et al. 2016).
Kah-kah / Green Sturgeon Collaboration
- Request findings from University of California-Davis' study on Klamath River *kah-kah* (green sturgeon), conducted with the Yurok Council's approval, to provide information around some of the mystery of the *kah-kah* life cycle - Have Yurok students visit the aquatic system at University of California-Davis, where *kah-kah* eggs are being studied.

6.5 KEY'-WEEN / Pacific Lamprey

Key'-ween or Pacific Lamprey (*Lampetra tridentate*) is a tribal trust species for the Yurok of great cultural and subsistence significance to the Yurok Tribe (McCovey Jr. et al. 2007). In recent years there has been a decline in the number of key'-ween, also locally referred to as eels, in the Klamath River. While there is no quantitative data on historical abundance or distribution specific to the Klamath River watershed, there is anecdotal and oral history evidence that suggests a sharp decline in quantity of key'-ween since the dams went in up through the late 1980s (McCovey Jr. et al. 2007). Tribal Members remember when they used to catch tubs full of key'-ween in a day; now they are lucky to get 5-10 when they go 'eeling.' Historically, eels were so plentiful they would clog the turbines generating power in the dams and the government agencies embarked in wholesale poisoning of what they considered a nuisance species.

Although key'-ween (Pacific lamprey) are present in the river throughout the year Yurok use two main traditional methods to harvest key'-ween every year during the late winter during the key'-ween annual spawning migration (Kroeber and Barrett 1960:5). As they enter the river in numbers, enough can be caught to make cleaning and preserving them worth the effort. As they move upriver, specialized basketry traps are used for catching them in pools behind the River's boulders, and along the beach spit at the River mouth special eel hooks are used to snatch them out of the ocean waves. Walt McCovey Jr., Yurok Tribal Member, explained how catching eels requires intense concentration, "If you're not thinking eel, you won't get one." Eels were caught with an eel hook, made of madrone or oak, with a hook and notch on the end. Dip nets can also be used for catching eels, but eels can easily escape from the net so it is not preferred.

Men traditionally use the roots of the river-bar grey willow for eel traps because you can get a good length from the root. Yurok Tribal Member Bertha Peters described how sometimes if Yurok used hazel sticks to make the eel baskets for traps. If these sticks are used, they can be picked in fall when they've grown taller/ bigger and you don't need to time it for when the sap rises to slip off the bark like is re-

Table 6.14 Key Climate Impacts on Key'-ween / Pacific Lamprey

Primary Climate Effect	Secondary Stressor	Potential Impacts
Warmer Air Increasing Drought	More extreme low flows	- Affect the timing of runs, both incoming & outgoing movements occurring earlier - Hinder , stress & negatively impact migrating adults - Reduced habitat for spawning & ammocete devel opment > potential stranding & death - Concentrate toxins in the river, increasing exposure & accelerating impacts
Warmer Water	→	- Detrimentally affect eggs, early stage ammocoetes - Adversely affect juvenile growth & increase metabolic costs in rivers throughout the summer - Potentially shrink adult body size and speed sexual maturation, decreasing fitness for migration.
Heavier Downpours	Increased peak flows > erosion	- Suffocation of filter feeding ammocetes - increased ammocete and juvenile predation if swept away by peak flows/ flooding
Ocean Acidification	Reduced plankton	- Potentially reduced food supplies for ocean host species > reduced growth & survival

Figure 6.2 Key'-ween/ Pacific Lamprey Use of Habitats within the Klamath River

quired in the spring basketry sticks. This is good because you don't want to peel the bark from them as the white wood can be seen by eels, so you leave it on. However, today, most Tribal Members make the traps with steel mesh attached around bicycle rims and folded back inside. With the recurring low flows in the river, good pools to set them in are more and more difficult to locate and so most Members are forced to travel to the mouth to hook them. As a result, fewer people have the practice to either make or set eel baskets, resulting in a loss of opportunities to use them and in turn, this creates an economic hardship for the up-river members who cannot as readily rely on eel to supplement their other food harvests.

Key'-ween are an ancient species at approximately 450 million years old (CRITFC 2018). They are an important ecological component of and indicator species for freshwater streams, spending 60-70% of their life-cycle in freshwater (Dittmer 2013), both before travel into the ocean and once they enter rivers to build nests in cobbled bottoms in which to spawn. They are exposed to climate-related stressors during all in-river life stages (eggs, amnocetes, juveniles, & returning spawning adults], as well as when they are adults in the ocean, which is also undergoing changing conditions (Streif 2008). Understanding key'-ween life history provides more in-depth understanding about key'-ween's particular exposure to climate impacts, and therefore how best to support key'-ween adaptation options to changing climate conditions during different times of their life cycle.

Life History of Key'-ween

Key'-ween are jaw-less fish without bones, scales, or paired fins, which typically help fish move through the water (Streif 2008). They have a sucker-like mouth that is characterized by three large teeth with a number of small ones behind (Streif 2008; CalFish 2018). They are a native anadromous fish, meaning they are born in freshwater, migrate to the ocean where they mature, and then migrate back into favorable freshwater rivers to spawn although not to their original streams.

Key'-ween live for approximately 8-11 years (Streif 2008) and are sexually mature anywhere from three years upward and grow to be about 16-27 inches in length (CalFish 2018). Most of their adult lives are spent in the ocean, as parasitic feeders attached to marine mammals, whales, and other larger fishes such as sharks, tuna, and Pacific salmon (CRITFC 2018). Upon smelling pheromones released by young key'-ween (amocetes) they stop feeding and drop off their host and swim up the nearest river. In the Klamath this is mostly at night between February and June. Researchers believe that the pheromones represent a species specific cue to good habitat, the stronger the pheromones, the greater the number of key'-ween, the more 'proof' of good habitat existing up the river. In this way key'-ween do not necessarily go back to the same river where they were born and can improve their survival chances.

Ammocete of key-ween /eel /Pacific Lamprey
Photo credit: Yakima Nation Fisheries

Approximately 19 days after fertilization in freshwater, dependent on water temperature being about 59oF (15oC), key'-ween (Pacific lamprey) eggs hatch into blind, toothless larvae (ammocetes) and float downstream to where the river has lower velocity and fine substrates to burrow into (Streif 2008). Ammocoetes spend 3-7 years living in fine substrates as filter feeders, nourished primarily by diatoms and algae. Ammocetes can survive high flow events as they age by floating further downstream (Streif 2008) as long as they can find good habitat. Then after 3-7 years, the ammocoetes transform into juveniles (macropthalmia) over several months, from summer to winter. During this time, they develop eyes and teeth, and become free-swimming. They subsequently migrate into the ocean in the late fall through spring where they latch onto a host (Streif 2008) and begin the cycle again.

Adult key-ween /eel /Pacific Lamprey on the Klamath River spit.
Photo credit: A. Nova

Billy Wilson, Yurok Tribal Member, recalled key'-ween coming upriver after the first of the year and sometimes Yurok fishermen would catch the eels in the nue-mee ney-puy (spring salmon) run nets. At the mouth of the Klamath River the younger men hook eels out of the crashing ocean waves on the sand spit and moving upriver, traditional basketry traps are placed in pools behind rocks. These are often made from the long running roots of the river bar willows or longer hazel sticks. Key'-ween might stay in the river for up to a year before they spawn. After key'-ween spawn, they die and Yurok Tribal Members explain that their carcasses are a preferred food for the kah-kah (green sturgeon) that follow the eels into the Klamath River.

Climate Effects on Key'-ween

Key'-ween (Pacific lamprey) are vulnerable to climate change effects such as higher water temperatures, extended droughts, reduced snowpack, altered stream flow patterns, heavier rain events, and changing ocean conditions. Below we include details about these effects on key'-ween in the lower Klamath basin.

Warmer waters

> *"That's another thing you've got to realize when you're fishing down there is the proper way. Whatever that is. The proper way. Like when that guy drowned, Merk told them guys, you guys better leave. He didn't and the tide was coming in. That's another thing, the tides coming in and you can't see it, you better get out of there. That's what happened, he was down there, went after this eels, missed his first shot took another step in and the water came over and swept him right out."*
>
> – Frank Lara, Elder Interviews 2014

During the summer, warmer waters could negatively impact key'-ween (Pacific lamprey) by favoring their competitors and increasing populations of non-native species that prey on larval and juvenile key'-ween (Sharma et al. 2016). Further, larvae survival is optimal in cool water temperatures between 50-64.4oF (10-18oC), with a drastic decline in survival rates when water temperatures reach or exceed 71.6oF (22oC) (CVLCP 2017). Warmer waters also impact adults, potentially shrinking adult body size and speeding sexual maturation, decreasing fitness for upstream migration and their ability to find good habitat for spawning. Finally, warmer waters adversely affect growth and increase metabolic costs for juveniles in rivers throughout the summer which requires more calorie intake, time, and energy spent in foraging for food (Sharma et al. 2016).

As a result of warmer waters, freshwater and marine harmful algal blooms (HABs) are increasing. This leads to high levels of toxins such as domoic acid in seyk-soh (marine shellfish) (Yurok Today 2016a; also Ch. 3). The concern over domoic acid poisoning, which closed the Dungeness crab fishery season in 2016, spilled over to concerns about key'-ween (Pacific lamprey), which can bioaccumulate toxins. In 2016, some of Yurok did not harvest key'-ween due to these concerns, which increased the food insecurities and economic hardship that many were feeling.

Finally, in recent years, when the river reaches the height where it is possible to catch key'-ween (Pacific lamprey) with the basket, the water is warmer than it used to be; the quality of meat declines rapidly in warmer waters, becoming mushy and inedible with a wormy or muddy taste (Workshop 2).

Rising air temperatures

Shifts in timing of snowmelt and peak runoff, as a result of rising air temperatures, could affect key'-ween (Pacific lamprey) migration and reproductive success, which are associated with specific flows during periods of migration and spawning (CVLCP 2017).

Increasing drought intensities

Along with reduced snowpack and rising air temperatures that may lead to lower river flows, increasing drought may decrease the habitat areas for key'-ween (Pacific lamprey) spawning and growth (Workshop 2). This could result in a decline of the key'-ween population. Drought often causes stream reaches where ammocoetes (larvae) reside to dry up leaving the lamprey stranded (Streif 2008). Also, diminished stream flows in late spring and summer due to earlier snowmelt, less snowpack, and drought can hinder key'-ween migration in affected tributaries (Sharma et al. 2016; CVLCP 2017).

Lower river flows due to increasing drought intensities and rising air temperatures can impact Yurok Tribal Members' ability to trap key'-ween (Pacific lamprey) in traditional sites. As they move upriver, they are not as strong a swimmer as ney-puy (salmon) so they'll swim in the slower currents behind boulders and only journey into the mainstem currents when needed. If the pools are isolated and disconnected by low flows, then eel baskets can't be put down in traditional harvesting sites (Workshop 2).

During times of drought, upriver eelers have to travel to the mouth of the river, which requires a car and gas, to harvest key'-ween (Pacific lamprey). This results in an economic burden of needing a car and gas, and in overcrowding of harvesters in one location, as well as being physically dangerous because of the high waves, which become even more dangerous with increasing extreme weather conditions (Workshop 2). Further, this impacts Yurok cultural practices of harvesting at traditional sites, which are owned and/or assigned to families, and affects the traditional tribal management of resources for sustainable harvesting practices. Further, key'-ween seem to now be running earlier in the year during the end of the fall run of salmon ('oh-pos) (October) and with the main run coming in later, often during early Spring (April), which disrupts traditional key'-ween harvest times (Workshop 2).

Key'-ween cleaned, 'flattened' and ready for traditional cooking over the wood fire.

Additionally, lower river flows may concentrate contaminants in the river. During the 2013-2016 drought, a lot of people did not eel because of concern about toxins in key'-ween (Pacific lamprey), which they fear can carry excessive concentrations of toxins (Workshop 2).

Traditionally, Yurok did not harvest during the last lunar month of the year, and then started their 'new year' with eeling in the first full moon in December. However, in conjunction with the recent 2013-2016 drought, Yurok have seen key'-ween (Pacific lamprey) running in October, as opposed to December, and they have also been caught late in April; so they are running both early and late (Workshop 2). With more recent rains, the key'-ween run has been more consistent and is once again occurring when the red bud blooms, indicating it is a good time to catch key'-ween.

Just as the ney-puy (salmon) caught as they leave salt water are reported to taste different than later on when they've adjusted themselves to freshwater, Yurok Tribal Members report that the longer the key'-ween stay in freshwater, the 'muddier' their meat becomes. This means that even though key'-ween may be available throughout the year, to catch them earlier during their migration run when they first enter the river is best (Workshop 2). One advantage of the shift to an earlier time in the year when key'-ween start running into the river is that they have become a favorite contribution for younger members at family reunions, fall harvest festivals, and Thanksgiving.

Heavier downpours

Rain events could lead to increased surface water runoff carrying nonpoint source pollution that reduces water quality, and stressing juvenile filter feeders. Heavier rainstorms could also result in higher peak flows during the winter. This could move larval and juvenile key'-ween (Pacific lamprey) into the mainstem river areas, increasing their vulnerability to predators (Sharma et al. 2016).

Changing ocean conditions could also affect key'-ween (Pacific lamprey). If ocean conditions affect host/food species, this could in turn affect adult lamprey survival and growth (Streif 2008; Close et al. 2010).

"[W]e used to have eels drying behind the stove. That's the part I liked, the one you smoke for a little while. Called them Sloy-eehl. We used to have them around. I remember them going down eeling. I remember slicing them up, drying them…there was always eels. I understand there's not as much now."

– Fern Bates, Elder Interviews 2014

Existing challenges (sensitivity)

There are numerous existing challenges influencing key'-ween (Pacific lamprey) vulnerability to climate change. Some of these challenges are listed below.

Habitat loss

As a result of habitat loss, there are fewer overhanging banks where juvenile key'-ween (Pacific lamprey) can burrow and filter feed. Also, loss of riffle and side channel habitats has reduced areas for building key'-ween redds, spawning and ammocete rearing (Streif 2008).

Dams and reservoirs

In addition, alterations in reservoir levels, water diversions and instream construction projects may dewater locations where ammocoetes occur (Streif 2008), and leave them stranded with no food inputs or out of water altogether.

Invasive species

Since key'-ween (Pacific lamprey) have a wide range and do not return to their natal rivers, they are at-risk of predation by non-native fish species, such as striped bass and catfish in other regions (Streif 2008). Further, key'-ween are not included in tribal fishing regulations, further affecting the population.

Historic legacies

There are a number of historic legacies that continue to have grave consequences for key'-ween (Pacific lamprey). Non-Yurok historically poisoned Key'-ween because federal and state agencies saw them as a nuisance species when they clogged dam turbines, especially on the Eel River. After this, Billy Wilson, Yurok Tribal Member, explained that eels declined. Yurok Fisheries Biologist Sarah Beesley expressed concern that even if/when the dams come out, key'-ween populations might still decrease if ocean conditions are contributing to their decline.

Contaminants

Key'-ween (Pacific lamprey) are exposed to a variety of legacy and emerging contaminants in sediments. These include pesticides, dioxins, and polycyclic aromatic hydrocarbon (PAH) and polychlorinated biphenyl (PCBs) chemicals produced from the incomplete combustion of soft plastics. In particular, ammocoetes, which often cluster in the lower portions of streams and rivers where slopes are low and toxins can therefore accumulate, are susceptible to effects from chemical poisoning, such as accidental spills and chemical treatments (Streif 2008). With high lipid content, key'-ween can accumulate fat-loving contaminants and can carry excessive concentrations of those toxins, which may present significant threat to their survival and productivity (CRITFC 2011).

Eeling at the mouth of the Klamath river involves spotting and snatching key'-ween out of the ocean waves using traditional eel 'hooks'.

When YTEP sampled eels in 2010, they generally came up clean. However, legacy DDT breakdown products and carcinogenic polycyclic aromatic hydrocarbon (PAH) were high in the longer eels and could be a concern for sensitive Tribal Members and pregnant women. Therefore, YTEP recommends that the shorter ones be harvested to limit toxin intake.

Inherent biological traits

Key'-ween (Pacific lamprey) have inherent biological traits that increase their vulnerability to the effects of climate change. Spending 3-7 years filter-feeding in freshwater sediments during their juvenile life stages makes them susceptible to climate change impacts on water quality and quantity (see Ch. 4). Key'-ween are vulnerable to stranding when flows drop too fast, and they have trouble recolonizing without help. If juveniles die off, no pheromones are released to draw adults upstream and they will not spawn.

Existing strengths (adaptive capacity)

The Yurok Tribe already has many existing strengths to help key'-ween (Pacific lamprey) adapt to climate change.

Knowledge base

YTEP can test key'-ween (Pacific lamprey) for the presence of domoic toxins in eel meat, which in recent tests have come up clean.

Collaboration and Research

The Yurok have developed several partnerships, including with the Pacific Lamprey Conservation Initiative (U.S. Fish and Wildlife Service, 2017) to promote the conservation of lamprey. In cooperation with the Hoopa and Karuk Tribes, the Yurok conducted a radio telemetry study to gather migration behavior and spawning locations for key'-ween (Pacific lamprey), which included tagging 50 key'-ween during summer 2015, and following them with radio antennas.

Inherent biological traits

Key'-ween (Pacific lamprey) have a number of traits that enable them to adapt to a changing climate, such as being relatively tolerant to warmer water temperatures, compared to salmonids, and being more flexible in spawning locale, not needing to return to their natal river to spawn. Also, juvenile key'-ween are tolerant of fine sediment.

Adaptation strategies

There are a number of adaptation strategies the Yurok Tribe could implement to support key'-ween (Pacific lamprey) adapting to the effects of climate change, which are included in the table below.

Table 6.15 *Key'-Ween* / Pacific Lamprey Adaptation Strategies

Key'-Ween / Pacific Lamprey Habitat management
Protect ammocoete habitat and increase spawning regions through dam removal. Focus on restoring the rivers and region holistically, including for *key'-ween*. Pursue protection, restoration, and management actions to support salmonid populations, which *key'-ween* are dependent upon (Moyle et al. 2013). Continue to develop, install, and evaluate friendly structures to assist *key'-ween* passage through artificial barriers such as dams, culverts, and water diversions.
Key'-Ween / Pacific Lamprey Species Management
Regional supplementation/augmentation approach to *key'-ween* restoration, including translocation, propagation, and reintroduction (CRITFC 2011). Teach youth cultural behavior when eeling, e.g., be respectful, quiet and thankful. Publish the Culture Committee's list of what people should know when eeling in the Yurok newsletter; also post the list at the Tribal Office, Yurok Visitors Center, Requa Inn, and near fishing areas. Continue implementing juvenile and adult tagging technology in order to *"evaluate and resolve tributary passage problems"* (CRITFC 2011).
Key'-Ween / Pacific Lamprey Education, Communication, and Outreach
Conduct outreach to community members that skinnier *key'-ween* are less contaminated and healthier to eat.
Key'-Ween / Pacific Lamprey Legal and Policy
Develop tribal ordinance for eels to help address over-harvesting by non-Yurok; Reinforce recognition that *Key'-ween* are a federal trust resource.
Key'-Ween / Pacific Lamprey Collaboration
Continue to share and learn from what others are doing; e.g., Confederated Tribes of the Umatilla Indian Reservation's Pacific Lamprey Research and Restoration Project, Columbia River Inter-Tribal Fish Commission's Tribal Pacific Lamprey Restoration Plan, and Yakama Nation's Pacific Lamprey Program (Yakama Nation Fisheries 2014; CRITCF et al. 2018). Establish regional coordination, collaboration, and cost sharing on research, monitoring, evaluation, and protection/restoration actions (CRITFC 2011). The *key'-ween* from other rivers can finish their lives spawning in the Klamath.

6.6 SEYK-SOH / Marine Shellfish

Marine shellfish species have been an important part of the Yurok's diet, culture, and traditions for thousands of years. These species include a wide range of organisms, including but not limited to multiple clam species (razor, Martha Washingtons, horse neck, cohogs) as well as oysters, pee'-eeh (marine mussels), limpets, ocean snails, gooseneck barnacles, chitons, gumboots, and abalones. Abalone, olivella, and dentalia are all prominent shelled, marine 'snails' or browsers and are used in regalia, and pee'-eeh are often used as spoons and to 'sut/divide' strips of basketry material. Although the breadth of these species in itself is important and acknowledging that no individual species is more important than another, this section focuses primarily on pee'-eeh, marine mussels due to their wide distribution and abundance, their role as ecological keystone species ,and their use as subsistence and traditional resources.

> *"When gathering mussels at Chapek it's harder now than in past. Getting to rocks used to be easier, the ocean is rougher now."*
>
> – Frank Lara, Elder Interviews 2014

Yurok Tribal Members have witnessed changes in marine shellfish, seyk-soh in Yurok, over recent years. Sometimes it is difficult to differentiate whether these changes are related to climate change or not, but they are seeing something different in the species and in the waters. For example, when YTEP staff asked the Culture Committee at a meeting if they had witnessed any potential impacts of global warming, Walt 'Black Snake' Lara responded, "It's already happening here. There is a slippery weed growing on the mussels that I've never seen before" (Yurok Today 2016a). Walt continued discussing how he was taught that it was dangerous to collect pee'-eeh (marine mussels) when one can see sparks under his footsteps, while walking in the wet ocean sand at night. The small flashes of light, which come from a microorganism in the ocean, are a result of bioluminescence. It indicates the presence of an algal bloom or red tide (Yurok Today 2016a). Red tides induce high levels of naturally occurring biotoxins such as the saxitoxin, that can result in paralytic shellfish poisoning (PSP) for shellfish consumers (see Ch. 7) or the Amnesic Shellfish Poisoning that results when domoic acid is at high levels in pee'-eeh (marine mussels), crabs, and even fish. Other toxins include, Diarehic Shellfish Poisoning, and those cyanotoxins associated with the blue-green algae, primarily microcystins.

Life history of Pee'-eeh / Marine Mussels

Pee'-eeh / marine mussels (*Mytilus californianus*) are bivalve (two shells) molluscs; they are filter feeders that feed primarily on plankton, and attach themselves to rocks in clusters. They spend their life stages in exposed near-shore rocks in the intertidal zone. On the north Pacific Coast adult pee'-eeh (marine mussels) typically range from 3-4 inches long (used for chowder) to over a foot (the preferred traditional). They are a dark purple-blue, and often have other animals including the edible gooseneck and acorn barnacles attached to them (California Tide Pools 2018). Although rare in adult pee'-eeh, they can detach the byssal threads and produce new ones to slowly move to a new location (California Tide Pools 2018). The attachment strength of pee'-eeh varies seasonally, with a potential trade-off in energy expended towards the production of byssal threads and energy devoted to reproduction (Monaco and Helmuth 2011).

Key life stages include eggs/larvae, juveniles, and adults. Pee'-eeh (marine mussels) start off as embryos that develop into free-floating larval or mussel spat. The larva spends several weeks floating and feeding on phytoplankton, then settle on a hard substrate to transform into a juvenile (Carefoot n.d.). Pee'-eeh settle in locations based on environmental cues such as water temperature, chemical balances, and close proximity to other mussels (California Tide Pools 2018). They mature in one to six months, then use byssal threads that are extruded from a specialized organ in a small opening in the juncture of the two shells to attach themselves to intertidal rock surfaces and each other (Davenport 2012). After a couple of years the pee'-eeh reaches sexual maturation and is ready to spawn throughout the year, releasing eggs and sperm into the water when triggered by specific environmental factors such as water temperature and tide level (California Tide Pools 2018).

Climate Effects on Pee'-eeh / Marine Mussels and Other Seyk-soh /Shellfish

Below we highlight the climate change effects on pee'-eeh (marine mussels) and other seyk-soh (marine shellfish).

Warmer water

Warmer ocean waters could interfere with pee'-eeh life cycle, particularly during 1) the larvae stage when water temperature is an environmental cue to which locations to settle in, and 2) adult stage for when to release their eggs and sperm into the water (California Tide Pools 2018). Also, warmer waters may promote suitable habitats for invasive species in coastal and estuarine waters (Stachowicz 2002), disrupting clam and oyster food resources and introducing new parasites to seyk-soh (marine shellfish) populations (Partnership for Coastal Watersheds 2015).

Table 6.16 Key Climate Impacts on *Seyk-soh / Marine Shellfish*

Primary Climate Effect	Secondary Stressor	Potential Impacts
Warmer Water	→	- Increasing harmful algal blooms - Increased rates & mortality of sea star wasting disease > disrupting near-shore ecosystem community dynamics > possibly increased pee'-eeh dominance - Potentially favorable conditions for invasive species
Rising Sea Level	Increased tide heights and zones	- Permanently submerge rocky, near shore habitat> loss of traditional harvesting areas - Increased storm surge > increased numbers of pee'-eeh broken free of trocks > increased sand scouring of rocky habitat > loss of individuals and overall bio-diversity
Ocean Acidification	Dissolves calcium carbonate	- Potentially reduced shell development > greater predation & stress - Reduced plankton > limited food for filter feeders

Warmer ocean waters can increase the disease progression and mortality rates of sea star (starfish) wasting disease (SSWD) (Eisenlord et al. 2016). Loss of sea stars, which are the main predator of pee'-eeh (marine mussels), could result in pee'-eeh taking over the intertidal zone and diminishing habitat space for other species, such as chiton, snails, anemones, and potentially also gumboots and abalone (Workshop 3; see also Hellman 2001).

Rising air temperatures

Extreme heat events, induced by rising air temperatures and warmer waters, can also result in die-off of intertidal seyk-soh (marine shellfish) (Hutto et al. 2015). In addition, freshwater and marine harmful algal blooms (HABs) are increasing in frequency due to rising air temperatures and warmer waters (see Ch. 3). HABs can induce high levels of biotoxins in seyk-

Pee'-eeh attach to rocks and are called 'beds' by local harvesters. These rocks are submerged under the waves most of the time but are exposed to the air, sun, and wind during minus tides.

soh (marine shellfish), resulting in potential shellfish poisoning for shellfish consumers (Hutto et al. 2015; Washington State Department of Health 2016). Algal toxins have factored into declines in seyk-soh populations (Pulido and Gill 2013).

Members of the Yurok Culture Committee reported an increase in the regularity and severity of ocean harmful algal blooms, which are responsible for the presence of high levels of different types of toxins (e.g., domoic acid, microcystins) in pee'-eeh (marine mussels), crabs, and other bivalves (Yurok Today 2016a). The deadly toxins have greatly limited the use of seyk-soh (marine shellfish) for community and family sharing, traditional ceremonies, or individual subsistence diets. With increasing HABs in the water, Yurok Tribal Members are unable to harvest and safely consume fresh seyk-soh (marine shellfish) or smoke and preserve them (see Ch. 3 for more details on HABs).

Some Tribal Members have avoided eating pee'-eeh (marine mussels) because they aren't sure if the pee'-eeh are toxic or not. Even when YTEP reports they are safe, Tribal Members are uncertain about how long that lasts. Some Members have fallen back to the Euro-American rule of thumb to only eat seyk-soh (marine shellfish) during months with "R" – September, October, November, and December. However, this is not traditional practice but rather a cultural import. Not only that, but over the last eight years there have been high levels of paralytic shellfish poisoning (PSP) in the locally sampled pee'-eeh (marine mussels) during those months with an 'R'.

Ocean acidification

Calcium carbonate is effected by ocean acidification and results in the thinning of the shells of some seyk-soh and planktonic diatoms by interrupting shell development (Feely et al. 2012; Lynn et al. 2013). This is particularly important during the immature life stages of oysters as well as other seyk-soh (Dupont and Thorndyke 2009; Walsh et al. 2014; Woods Hole Oceanographic Institution 2016). Shells serve to protect clams and pee'-eeh from predators (except sea stars) and from drying out when exposed to air, as well as from high wave actions (California Tide Pools 2018).

In addition to the larger shelled species, if plankton, the base of the food chain, are affected, this would interfere with development of fish and seyk-soh (marine shellfish) who feed on this mostly microscopic community. This could potentially lead to a decline in the seyk-soh population, and result in further decreases in the availability of traditional marine foods. This is a particular risk for pee'-eeh (marine mussels) at all lifestages, who are filter feeders relying on plankton for food. If there is a disruption to plankton, then this change in food availability could result in decreased mussel growth and increased loss of juvenile mussels (Phillips 2004).

Sea level rise

Rising sea levels and associated changing tide heights could submerge pee'-eeh (marine mussel) rocks and other seyk-soh (marine shellfish) beds under deep water at traditional harvesting sites (Lynn et al. 2013). Those that are now described as the sweetest and largest and only accessible at minus tides would become unreachable and unavailable for traditional harvest (Workshop 3). Increased storm surges carry sand that can break the pee'-eeh (marine mussels) free from the rocks, scouring the rocks of the younger life stages, and smothering the older pee'-eeh that continue to hang on. As sea levels rise, access to traditional seyk-soh gathering places is being lost along the Pacific Northwest coast (Swinomish 2010).

Existing challenges (sensitivity)

There are numerous existing challenges influencing the vulnerability of seyk-soh to climate change with a primary concern being the overharvesting by non-Yurok who utilize the practice of stripping entire pee'-eeh beds. They do not leave any pee'-eeh for those who subsequently come to harvest or to re-establish the beds. Some other challenges are listed below.

Habitat management

It is difficult to manage ocean environmental conditions, even in Ancestral Territory due to Yurok's lack of off-reservation land management authority. An important concern are the nutrient inputs into the ocean from agricultural production in the Upper Klamath Basin that affect the degree of ocean acidification locally (Ch. 4) and increase the frequency and duration of algal blooms.

Marine rocks offer habitat for up to 100 different species. This Picture shows pee'-eeh with mekw-cheg/ snails along with barnicles.

Inherent biological traits

Seyk-soh have certain biological traits that increase their vulnerability to climate change effects. Pee'-eeh in particularly are sensitive to shifts in food availability during the larval stage, which could result in effects on juvenile pee'-eeh (Phillips 2004). Also, pee'-eeh are highly efficient filter feeders, which means that heavy metals and organic pollutants can accumulate in their tissues (Hutto et al. 2015). Although the California mussel experiences fluctuations in pH due to seasonal upwelling, it is less tolerant to acidification than other types of mussels (Foo and Byrne 2016).

Seyk-soh / Marine Shellfish Strengths (adaptive capacity)

The Yurok Tribe already has many existing strengths to help seyk-soh (marine shellfish) adapt to climate change. Yurok traditional gathering practices help maintain the seyk-soh (marine shellfish) populations. For example, Yurok traditional practice is to not clean the rock bed clear of pee'-eeh. Yurok Tribal Members have traditionally only harvested on the ocean side where the pee'-eeh are less exposed to tidal fluctuations that require pee'-eeh to close up and stop eating, which in turn slows their growth. In addition, those that dry out during regular low tides become tougher and less sweet. In this way, harvesters take from those areas with the highest resiliency and capacity to regrow the fastest. As Yurok Tribal Member, Frank Lara, explained, "Don't get the mussels that are high up, get the ones that are low and facing the ocean. Don't go down there every day it's a low tide, don't do that. Give them a chance to grow, get back."

Knowledge base

YTEP monitors pee'-eeh toxin levels, sampling once a month when possible, and has field kits available for their local use. They can provide test results back to community members within 2 hours about the presence or absence of toxins in pee'-eeh. If toxins are present, YTEP has developed a partnership with the California Department of Public Health's Shellfish Monitoring Program that allows the levels of toxin in the mussel meat to be quantified, usually within 2-3 days. If it is present but at a low level, then they are safe to eat and this knowledge is available before the next minus tide.

Inherent biological traits

Seyk-soh have a number of traits that enable them to adapt. For instance, pee'-eeh / marine mussels produce a large number of offspring and are able to colonize different rocks (see adult stage of life cycle above). Pee'-eeh are also highly adapted to a wide range of variations of air temperature from daily occurrences of ocean water levels that expose them to the air during allow tide. They are also highly adapted to storm surge and high wave action (Hutto et al. 2015).

Adaptation Strategies

There are a number of strategies that might support seyk-soh adapting to climate change, some are included below.

Table 6.17 *Seyk-Soh* (Marine Shellfish): Adaptation Strategies

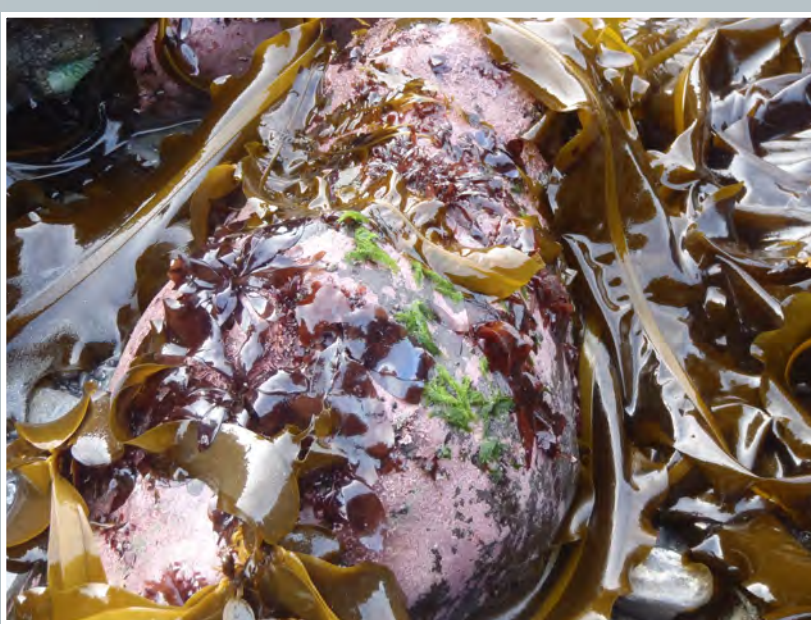
Seyk-soh / Marine Shellfish Habitat management
- Proactively protect and secure higher elevation rocky shore habitat for *seyk-soh* to migrate to in response to sea level rise (Hutto et al. 2015). - Work to re-establish kelp & sea grass beds to protect existing shorelines and reduce wave effects & sand erosion. - Investigate habitat needs and methodologies to restore native oyster populations. - Develop community clam gardens at a Yurok significant site to increase clam productivity and enhance ecosystem health that supports all near-shore species including seaweed (Wall 2018).
Seyk-soh / Marine Shellfish Management
- Consider developing access to alternative sites for *seyk-soh* harvesting based on sea level rise scenarios. - Use tribal knowledge to teach about when and how to harvest *seyk-soh.* - Utilize Local Environment Observation (LEO) Yurok Hub to track, monitor, and archive changes in the environment..
Seyk-soh / Marine Shellfish Collaboration
- Collaborate and partner with agencies to manage and protect habitat. - Collaborate with agencies and industry (e.g., agriculture) upriver to reduce nutrient flow into ocean. - Research and translate lessons from success stories of those working to reduce the occurrence of HABs by decreasing the amount of nutrients that flow into the waters, such as the Great Lakes Restoration Initiative (EPA 2012). - Promote inter-departmental collaboration to utilize the Sea Level Affecting Marshes Model (SLAMM) to map out effects of sea level rise on specific *seyk-soh* habitat and traditional harvesting sites.
Seyk-soh / Marine Shellfish Education, Communication, and Outreach
- Conduct public outreach about sustainable harvesting practices. - Educate and manage recreation users to decrease tide pool souvenir hunting and trampling impacts (Hutto et al. 2015). - Increase more widespread and timely availability of public notices/information about detected toxins in *pee'-eeh*
Seyk-soh / Marine Shellfish Legal and Policy
- Need ordinances and enforcement against unsustainable harvesting practices, such as stripping entire *pee'-eeh* beds. - Restrict amount of waste and non-point source discharges flowing downriver and into the ocean.

6.7 KEY’-WEEN WE’ CHEY-GEL’/ Spring Seaweed (*Porphyra sp.)*

Harvesting key’-ween we’ chey-gel’/ Spring seaweed was once a practice that brought families together, spending time gathering on the beach, and sharing a meal as the key’-ween we’ chey-gel’ dried. The dried key’-ween we’ chey-gel’ cakes are an important cultural and mineral rich subsistence food. It was also reported that sometimes Tribal Members would use key’-ween we’ chey-gel’ to take baths to get impurities out of their bodies (Workshop 2). Community members report that they have growing fears that what may already be a dwindling resource with limited harvesting opportunities will decrease even more with the onset of climate change. Tribal Members shared that traditional times to harvest are off kilter and that they are finding good growth later in the season than expected, or find their favorite key’-ween we’ chey-gel’ beds already harvested in non-traditional ways that prevent the ‘leafy’ regrowth of a second crop. With climate change-induced sea level rise, they worry that key’-ween we’ chey-gel’ traditional harvesting areas may become deep water habitat and inaccessible.

> *“We did seaweed that way, put it out on the logs and dry them before we came home. So we'd just stay there. My mom would cook by the fire, you know the sand, and that's where we'd eat that wonderful [sand] bread.”*
>
> – *Fern Bates,* Elder Interviews 2014

Life history of Key’-ween we’ chey-gel’ / Spring Seaweed



This one rock has 4-5 different types of seaweed growing on and around it. The pinkish colored, flat algae that seems to hug the surface and become part of the rock itself, is the non-leafy life stage of Phorphora.

Seaweeds have very complex life cycles with numerous stages (Harley et al. 2012). Key’-ween we’ chey-gel’ (*Porphyra* sp.), are a type of red algae, whose life cycle stages are organized into complex phases (PAGRCN 2018). In one phase, Porphyra has blades or what looks like leaves that are typically 12 inches (30 cm) or less in length (PAGRCN 2018) that can be reproduced vegetatively. At other times, Porphyra species enter another phase for sexual reproduction where they look very different and form pinkish to reddish microscopic filamentous, growing inside rocky crevasses, or the shells of marine mollusks such as pee’-eeh (marine mussels) (OCNMS 2017; PAGRCN 2018). Reproductive development in Porphyra can be further varied by additional options of having male and female parts either within a single plant or through separate

This freshly exposed rock face during an extreme low tide shows the different 'surf-zones' or habitats that multiple different species of algae utilize

male and female plants (PAGRCN 2018). The seaweed can also reproduce spores both sexually and asexually or simply vegetatively when parts of a plant break off and develop into new individuals, all of which are genetically identical to the parent seaweed (Marine Education Society of Australasia 2015; PAGRCN 2018). These different options are thought to allow it to develop in new habitats and/or re-establish itself after rock scouring storms. While individual Porphyra species are present during a specific period during the year, different species occur in every season throughout the year (PAGRCN 2018).

To survive, seaweeds need salty or brackish water, a surface to which they can attach themselves (Waaland et al. 1987; Marine Education Society of Australasia 2015), and both seasonal increasing light intensity to trigger the 'leafy' growth, as well as shortening of days to trigger its sexual reproduction. Porphyra predators include abalone, limpets, and other grazers (OCNMS 2017).

In Yurok territory, seaweed is found throughout all of its life stages in the intertidal zone, on rocky shores. Although Yurok utilize several different seaweeds, the particular favorite that Yurok harvest is key'-ween we' chey-gel'. This grows in cold, shallow seawater and is exposed to climate-related stressors during all life stages, all the time.

Climate Effects on Key'-ween we' chey-gel' / Spring Seaweed

Key'-ween we' chey-gel' is vulnerable to a variety of climatic stressors. Climatically sensitive environmental variables, including warmer ocean waters, changes in wave heights, nutrient supply via upwelling and run-off, and ocean acidification can affect seaweed survival, growth, and reproduction (Harley et al. 2012). In addition, the alternate generations of Porphyra that grow on and/or inside the shells of marine mollusks/shellfish could make the seaweed vulnerable to climate changes that effect them, such as increases in ocean temperatures, ocean acidification, sea level rise and changes in ocean chemistry (e.g., dissolved oxygen) (Lynn et al. 2013; OCNMS 2017; see also section 6.7 on seyk-soh / marine shellfish). Other main stressors are discussed below.

Rising air temperatures:

At a Culture Committee meeting about the potential effects of climate change on Yurok tribal resources, one participant stated that the best time to pick key'-ween we' chey-gel' (spring seaweed) is after the bracken fern has completely unfurled. "We picked bracken ferns on the way back to Hoopa and we put seaweed on them to dry," Jackson said (Yurok Today 2016a). However, with the onset of a warming climate, the phenology – timing of natural events – could change. Other Tribal Members traditionally use sword fern to separate, dry, and store key'-ween we' chey-gel'. Regardless, a question remains if Tribal Members living upriver in Hoopa would use the unfurling of fern to know it was time to pick key'-ween we' chey-gel' (spring seaweed), or if this relationship will no longer make sense, impacting tribal knowledge about harvesting practices.

Table 6.18 Key Climate Impacts on Key'-ween we' chey-gel' / Spring Seaweed		
Primary Climate Effect	**Secondary Stressor**	**Potential Impacts**
Warmer Air	→	- Altered phenology (timing of growth & flowering) of associated land plants that signal harvest times
Warmer Water	→	- Decreased harvestable 'leaf' production - Increased predation & mortality
Rising Sea Level	Higher storm surge	- Greater storm damage & sand scouring of rocks - Reduced inter-annual survival > later and slower regeneration of leafy stage - Great intra-annual variability in algae productivity and abundance
Ocean Acidification	→	- May impact coralline life stage & genetic variability offered through sexual reproduction > less gametophytes to initiate edible leafy, life stage > reduced overall survival

Warmer ocean waters

Temperatures must have a seasonal drop and a shortened daylight period for seaweed to reproduce sexually and produce the tougher, filamentous phase, and mortality is linked to high temperatures that exceed a physiological tolerance (Harley et al 2012). This usually is associated with the fall season and allows the seaweed to establish itself before the intense winter storms that can destroy all trace of the leafy phase. It is hypothesized that having this dual morphology also benefits the species survival should there be excessive high water temperatures, or summer desiccation, or increased grazing by marine herbivores such as snails, limpets, gumboots, and abalone (Lubchenco and Cubit 1980).

Key'-ween we' chey-gel' has one of the highest caloric values of marine algae (OCNMS 2017). Yet, warmer ocean waters could mean that key'-ween we' chey-gel' population is diminished when the environmental trigger to reproduce are altered. This in turn limits key'-ween we' chey-gel' colonization and reduces harvestable areas of key'-ween we' chey-gel'.

> *"We need to figure out how to take care of resources in that intertidal zone That zone will shift and be impacted in ways we have no clue. We can prepare places for those resources to live, figure out places for those resources to shift their balance."*
>
> - Robert McConnell Sr., Elder Interviews 2014

Sea Level Rise

Increased storm intensities and sea level rise, contributing to higher storm surge heights, could result in more sand being picked up, scouring rock surfaces and stripping off the seaweed. Further, increased wave heights may impact sediment redistribution and alter sand scour dynamics, creating greater intra-annual variability in algae productivity and abundance (Graham et al. 1997; Hutto et al. 2015).

Existing challenges (sensitivity)

Some of the existing challenges influencing key'-ween we' chey-gel' sensitivity to climate change are listed below.

Overharvesting of pee'-eeh (marine mussels) by non-Natives may disrupt the interspecific relationship that seyk-soh (marine shellfish) play in the key'-ween we' chey-gel' (spring seaweed) lifecycle. One study by Aquilino et al. (2009) found that Porphyra perforata grew in significantly greater frequency of occurrence and grew 10 times faster within live pee'-eeh (marine mussel) beds than on bare rocks. In addition, non-native seaweed harvesters do not follow traditional harvesting practices and are scraping the rocks, destroying the holdfast (roots) instead of cutting blades (leaves); harvesting seaweed in this way prevents a second harvest (Workshop 2).

Seaweed cakes trying on traditional sword fern fronds

Agricultural and legacy pollutants in the waters can negatively impact the survival and growth of kelp (Springer et al. 2006), which protects the intertidal habitats, including those that the traditional key'-ween we' chey-gel' prefers.

Inherent biological traits

Seaweed also have certain traits that make them more vulnerable to climate-related factors. For example, the filamentous life stages growing on pee'-eeh (marine mussels) or inside mollusks may be particularly sensitive to ocean acidification. Seaweed have a very complex life cycle with numerous stages; this makes it difficult to understand how climate effects impact any one life stage, as thermal optima and tolerance limits can vary among life history stages (Harley et al. 2012). Porphyra's different life stages are not well studied or understood, making it challenging to protect their vulnerabilities (Workshop 2).

Existing strengths (adaptive capacity)

In 2010 the seaweed in Japan and in northwest Canada tested positive for radiation from Fukusima nuclear disaster, but samples sent to University of Berkeley's nuclear lab returned normal levels from Yurok country.

The Yurok Tribe already has many existing strengths to help seaweed adapt and some key ones are detailed below.

Knowledge base

YTEP has tested the seaweeds, in response to Tribal Members concerns for excessive radiation, contamination, and toxins. Thus far the findings have indicated that the seaweed are not impacted except for very low levels of poly-aromatic hydrocarbons but remain safe to eat (Yurok Today 2014a).

Inherent biological traits

Key'-ween we' chey-gel' (spring seaweed) have a number of inherent biological traits that enable them to adapt to a changing climate. Key'-ween we' chey-gel' can rapidly colonize a newly cleared or scoured location, depending upon favorable environmental conditions (Hutto et al. 2015). In addition, Porphyra grows from the mid

-to-high intertidal zone, thriving in an extremely physically stressful habitat where it is often exposed to extreme changes in temperature, salinity, and moisture, as well as elevated intensities of UV radiation, to which it shows great tolerance (Brawley et al. 2017; University of Maine 2017).

Porphyra's high nutritional value seems to relate to the kind of nutrient requirements needed to survive in the intertidal zone (Brawley et al. 2017). Key'-ween we' chey-gel' variation in identity and concentration of proteins and properties of cell membranes, for instance, help them to adapt to and enhance their functioning within temperatures they encounter; Key'-ween we' chey-gel' have the ability to produce heat shock proteins to repair or remove proteins that have been damaged due to too high or low temperatures (Harley et al. 2012).

Adaptation strategies

There are a number of adaptation strategies the Yurok Tribe could implement to support seaweed adapting to the effects of climate change, which are included in Table 6.19 below.

Table 6.19 Key'-Ween We' Chey-Gel' / Spring Seaweed Adaptation Strategies

Key'-Ween We' Chey-Gel' / Spring Seaweed Habitat Management
Manage recreation users to decrease trampling impacts (Hutto et al. 2015). Identify locations that historically had *key'-ween we' chey-gel'* (spring seaweed) but are in need of restoration. Develop community clam gardens at a Yurok significant site to increase clam productivity and enhance ecosystem health to support all near-shore species such as *Key'-ween we' chey-gel'* (Wall 2018). Create a Nori-like aquaculture to supply *key'-ween we' chey-gel'* and economic opportunities to the community.
***Key'-ween we' chey-gel'* / Spring Seaweed Management**
Continue education and outreach about the Local Environment Observation (LEO) Yurok Hub to track, monitor, and archive changes in *key'-ween we' chey-gel'* quantity, quality, growth, timing, and location. Use tribal knowledge to monitor any noticeable shifts to quality, quantity, growth, timing, and location of *key'-ween we' chey-gel'*. Continue to test seaweed for toxins on a regular basis. Consider alternative sites for *key'-ween we' chey-gel'* harvesting based on sea level rise scenarios.
Key'-Ween We' Chey-Gel' / Spring Seaweed Legal and Policy
Continue and enhance co-management and harvest access agreements with Redwood National and State Parks.
Key'-Ween We' Chey-Gel' / Spring Seaweed Collaboration
Collaborate and partner with agencies to manage and protect habitat. Partner with technical experts to map extent of *key'-ween we' chey-gel'* via aerial canopy and diver-based estimates. Partner with researchers to better understand thermal optima and tolerance limits for *key'-ween we' chey-gel'* life history stages. Promote inter-departmental collaboration to utilize the Sea Level Affecting Marshes Model (SLAMM) to map out effects of sea level rise on specific *key'-ween we' chey-gel'* habitat and traditional harvesting sites.
Key'-Ween We' Chey-Gel' / Spring Seaweed Education, Communication & Outreach
Conduct public outreach about sustainable *key'-ween we' chey-gel'* harvesting practices.

6.9 Research Needs and Data Gaps

While conducting this assessment, we also identified research needs and data gaps with respect to how traditional aquatic species may respond to climate change. These are identified below.

Table 6.20: Traditional Aquatic Species Research Ideas And Questions

Ney-puy / Salmon
- Fill in knowledge gaps about *ney-puy* (salmon) biology in the Klamath When do Juvenilles reach the estuary? How long do they stay there? What are they eating? What are the consequences of salmon migration at suboptimal temperatures? How important is phenotypic plasticity compared with genetic evolution in responding to climate change? And what are the limits to adaptive responses (Munday 2015)? - Study effects of residualization in the Klamath basin- when smoltification stops due to temperatures beyond the physiological tolerance and juvenile fish regress to the parr stage (NRC 2004).
***Chkwohl* / Steelhead**
- What are the effects of temperature on all life stages, (Doctor et al. 2014)? - Can increased flows ameliorate negative effects of increased temperatures and diel variation on *chkwohl* (steelhead)? - Or are the effects of flow linked solely to refuge area (Brewitt and Danner 2014)? - What mechanisms drive individual variation to thermal tolerance (Brewitt and Danner 2014)?
***Kah-kah* / Green Sturgeon**
- Evaluate effects of dam removal on *kah-kah* & reestablishment into habitats made available by removal (CDFW 2017). - Continuous tracking of juvenile *kah-kah*, combined with stream bottom sampling to better understand prey selection and foraging behavior (Moser et al. 2016). - Conduct bioengineering studies to develop structures to maximize passage of *kah-kah* migrants (Moser et al. 2016).
***Key'-ween* / Pacific Lamprey**
-Fill in the knowledge gaps about *key'-ween* biology: What is the pattern and timing of *key'-ween* migration? Where is habitat in Lower Klamth for *key'-ween* filter feeding? What is the timing and triggers of *key'-ween* life stages? How might triggers be affected by climate change? What are thermal tolerances of the different *key'-ween* life stages? Establish age-structure of different life-cycle stages in order to assess survival across ages (Sharma et al. 2016). What are potential climate change effects on the predator-prey relationship (Sharma et al. 2016) Conduct ocean monitoring and sampling for the *key'-ween* adult life stage (Sharma et al. 2016). What are the impacts of increasing freshwater and marine harmful algal blooms and biotoxins to *key'-ween*?
***Seyk-soh* / Marine Shellfish**
- Examine various sea level rise scenarios to protect and/or purchase habitat that could become *seyk-soh* habitat. - Research on ecology, physiology, and oceanography aspects of HABs and interface of marine & freshwater toxins
***Key'-ween we' chey-gel'* / Spring Seaweed**
- Examine effects of various sea level rise scenarios on *key'-ween we' chey-gel'* habitat and harvesting sites. - Research *Porphyra*'s life stages' vulnerability to climate change effects: warming temperatures, sea level rise...

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Additional Information

- The Institute for Tribal Environmental Professionals (ITEP) at Northern Arizona University established its Tribes and Climate Change Program in 2009. The program provides support for and is responsive to the needs of tribes who are preparing for and currently contending with climate change impacts. For more information, please visit our website at: http://www7.nau.edu/itep/main/tcc.
- "Guidelines for Considering Traditional Knowledges in Climate Change Initiatives," A resource for tribes, agencies, and organizations across the United States interested in understanding Traditional Knowledges in the context of climate change: https://climatetkw.wordpress.com/
- Additional Chapters of the Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources can be found on the Yurok Tribe Environmental Program's Community and Ecosystem division webpage at http://www.yuroktribe.org/departments/ytep/com_eco_division.htm


WORKING TOGETHER

Yurok Tribe Climate Change Adaptation Plan for Water & Aquatic Resources

Chapter 7 — Yurok Climate Change and Tribal Health

In This Chapter

This plan is a purposeful collaboration with the staff and community members of the Yurok Tribe, as well as several organizations, and would not have been successful without each of their contributions. Funding was made available through the US EPA Science to Achieve Results (STAR) Program, Grant # 83560401-0. Online files available at: https://www.yuroktribe.org/

> *"I was born and raised on the River. My life is woven with the river and its fish and people. If the River is sick, so am I. So are we all, because it is our spirit and strength. Even though I live in town, I still live and choose to live close enough so I can go to the River whenever I choose. I participate in ceremonies on the River. If it were possible, I would live on the River, to see it and hear it and smell it every day and every night. I will not be completely healthy again until I can look out my front door at night and see the salmon moving up the River as they did when I was a child. It is not the simple fact of eating healthy food from the River that is important… It is the knowing in my mind, heart and spirit that the River itself is whole and healthy. We are merely a reflection of the river, and will never be healthy again until it is".*
>
> --Yurok Female, born 1949

The Yurok people and the Klamath River are intimately interconnected. It is the traditional source for all their needs; their subsistence foods; economic opportunities; as well as spiritual, ceremonial, and other cultural connections. It is widely believed that the health of the River is an indicator of the health of the people whose lives, culture, diet, food sovereignty, economic opportunity, and overall well-being depend on it. For Yurok, health does not just entail the absence of illness or injury. It is a much broader concept that includes spiritual and emotional as well as physical health and encompasses the intricate relationships and shared histories that the Yurok have with their waters, lands, and the species within them. If the river is sick, so are the Yurok. The health of all is integral to the health of one, and healthy ecosystems are inextricably linked to healthy people.

Recent experiences demonstrate the Klamath River's declining health. Fish runs have been significantly reduced and nearly eliminated due to a cascading set of changes in both the environment and policy to meet social and economic demands that have resulted in altered creek flows, release of warmer reservoir water, sediment deposition, and other pollutant exposures. Reports from Federal agencies and Tribal Members document how

Both salmon & the ability to fish are critical

Chapter citation: Nasser, E[1], Fluharty S[2], Hostler J[2], Petersen, S.[1] (2018) Chapter 7—Yurok Climate Change and Tribal Health. In *Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources*. [1] Adaptation International (AI), Austin, TX; [2] Yurok Tribe Department of Environmental Quality (YTEP), Klamath, CA.

decreased access to clean water and traditional aquatic resources from the Klamath River, its tributaries, and the Pacific Ocean, affects Tribal members' health and wellbeing. "Denied access to the river and the salmon is tantamount to denied access to essential cultural and spiritual resources. In these circumstances, poor water quality and unhealthy conditions constitute denied access. Tribal members have indicated that poor water quality has had a detrimental effect on many aspects of their lives (page 104)" (U. S. Department of the Interior, 2012).

"As a kid, there were abundant salmon because you could see the salmon thick in the river from the bridges. You had to row your boat out to rocks that you can walk out to now. Before I went to Vietnam in 1967 the River was high; when I came back after the Dam was built the water had dropped. In my lifetime, I have watched the salmon, sturgeon, and eels become depleted. Salmon, eels, and sturgeon were our main food. We ate one of the three daily. We only ate meat on payday. The rest of the week we ate fish. Now we get fish only occasionally. This year we have not had any fish. My children may not have any salmon in the future". --Yurok Male, born 1946

In addition to existing conditions, the climate changes expected to occur across the Yurok Territory and region include widespread increases in air and water temperatures, changing precipitation patterns, and ocean changes. These are particularly important in determining the overall health risks to the Klamath River and people's health. They include the exacerbation of the health threats tribal communities currently face as well as the emergence of new health threats. This report traces projected changes to climate conditions, through their potential exposure routes to humans, to resulting changes to disease risk. All climate change projection information contained in this section is a summary of the more comprehensive climate change projections described in the larger 2017 Yurok Climate Change Adaptation Plan for Water and Aquatic Resources (the Plan) of which this is a chapter.

This chapter focuses on how changes to water resources, water quantity and quality may impact Tribal members' health and has laid out many of the challenges facing the Yurok Tribe as they begin to act and limit the effects climate change will have on their health. For definitions and descriptions of existing health conditions among Yurok Tribal members this Plan used those reported in the Yurok Environmental Community Health Profile (2011) that looked for linkages between health and environmental contaminants/toxins and then seeks to assess how changing climate conditions may impact Tribal Members' health and wellbeing. Most of these changes will be seen through decreases in subsistence activities and traditional food access, availability, and quality (Ch 6).

Mouth of the Klamath River, where subsistence and commercial fishing was severely restricted or canceled during 2014—2017.

Adaptation International worked closely with community members, Yurok Tribal staff, the Environmental Program (YTEP) and the Institute for Tribal and Environmental Professionals (ITEP) to identify three priority environmental health areas for the Yurok—water resources, subsistence diet, and community mental health. Both primary and secondary impacts from climate changes in these priority areas may increase the risk and prevalence of diseases although in most cases, not all Tribal members will be affected equally.

After review, three priority areas were selected for more in depth research and inclusion in this assessment.

Table 7.1 Priority Environmental Health Areas & Diseases

Water Resources

- ◊ Waterborne pathogens and resulting illness.
- ◊ Rashes from skin exposure to contaminated water.
- ◊ Illness from consumption of poisonous shellfish.

Subsistence Diet

- ◊ Diabetes and resulting kidney disease.
- ◊ Cancer.
- ◊ Heart (cardiovascular) disease.

Community Mental Health

- ◊ Impacts from extreme weather events.
- ◊ Impacts from multi-generational trauma.

While most diseases experienced by the Yurok may be directly or indirectly influenced by climate change, there exist some that for every probable scenario and potential exposure route there was an increased risk of negative health impacts due to localized climate changes. These are strongly connected to climate change can be thought of as "climate-relevant" and we have identified eight that are relevant to the Yurok and are shown in the Table 7.1.

To tell the story of how changing climate conditions can affect health, pathway diagrams were developed for our identified eight climate-relevant diseases. For each, we include 1) a summary of existing conditions, 2) identify particularly significant climate projections, 3) provide a visual pathway diagram describing the route or process of contamination from human exposures to disease risk, and 4) describe how climate change could positively or negatively impact health. To help lessen the impacts of these diseases, each diagram is accompanied by a list of institutional and individual adaptation strategies.

While we highlight climate links to health risks, we do not purport to claim that the health risks are only due to climate change. For example, cancer risk for the Yurok Tribe due to climate-induced changes in subsistence diets is projected to increase, but this is not to suggest that the only reason for possible increases in cancer risk is climate change. There are many contributing, non-climate factors, that affect cancer risk and we will not be considering all those other factors as part of this analysis. (For more information about historical and current contributing non-climate factors, see Chapter 1 of the Adaptation Plan).

> *"The River is the lifeline of the tribe. It needs to be clean and full so the salmon can come back and nourish the people. The salmon is like the miner's "canary" – if it is sick or dying it is a sign that our people are sick and dying too. If it is abundant and thriving – so are the people. It is the responsibility of the tribe and other government agencies to ensure this life line is healthy and abundant for the future generation".*
>
> --Yurok Female, born 1959

The goal of this project is to understand the potential climate change risk associated with each of the eight climate-relevant diseases and to develop effective strategies to protect health and build climate resilience throughout the Tribe and its membership. It is hoped that by identifying a range of strategies the numerous possible intervention points may enable a way forward for both individual Tribal members to reduce their risk and for the tribal government to develop programs and projects to reduce these risks at the community level.

Quotes listed, "Yurok Tribal Member, gender, year of birth" are from the Yurok Tribe Environmental Program's 2006 Healthy River/Healthy Bodies Study.

7.1 Pathway Diagrams

To tell the story of how changing climate conditions can affect health, pathway diagrams were developed for our identified eight climate-relevant diseases. For each, we include 1) a summary of existing conditions, 2) identify particularly significant climate projections, 3) provide a visual pathway diagram describing the route or process of contamination from human exposures to disease risk, and 4) describe how climate change could positively or negatively impact health risk. To help lessen the impacts of these diseases, each diagram is accompanied by a list of institutional and individual adaptation strategies.

Pathway diagrams are a visual tool that draws on a 2016 U.S. Global Change Research Program Climate Health Assessment report (see Figure 1), and was modified slightly for use in this climate change health assessment (Balbus et al., 2016). Each pathway diagram describes the process of how climate change could positively or negatively impact health risk. These are not predictions of how health will be affected by climate change. Rather, they are projections connecting the myriad of exposures, both social and environmental, to potential health risk. Influencing factors at both the individual level (right gray box) and larger institutional or environmental level (left gray box) can affect (both positively and negatively) the individual's or community's health risk.

Model for Pathway Diagrams that seek to link environmental, social, policy, and human activities to health outcomes

Understanding the pathways that may result in potential climate-related illness is critical as not all Tribal Members will be affected equally. Population sub-groups at increased risk are identified by icons and each row in the pathway diagram highlights the diseases likely to affect that group. All eight health pathway diagrams call out which sub-groups are at increased risk of disease with a graphic representation. This information can then be used to identify where increased vulnerability may exist for some segments of the Tribal community. Suggested adaptation strategies are then included in the pathway diagrams to highlight opportunities to reduce risk and build resilience including the differential risks for each of the Tribal sub-populations.

7.2 Differential Risk to Yurok

YTEP Air Monitor in the Klamath Glen

There exists a range of health impacts from climate changes that includes direct and indirect impacts to human health. Direct impacts might include increases in respiratory illness due to greater levels of ground level ozone; increases in allergens or particulates in the air from more frequent or larger wildfires; or potential surges or the geographic expansion of vector borne illnesses such as the West Nile virus. Climate change can also induce or increase indirect impacts that affect the cultural and mental health of tribal communities, such as increases in food insecurity as natural resources decrease move, or are lost with a changing climate.

Tribal communities may also experience greater impacts due to their reliance and cultural connection to the natural environmental for food, revenue, and long standing cultural traditions In many places, rapidly changing ecological conditions will create shifts in phenology and other seasonal patterns that affect the hunting and gathering of important species and change the ideal timing of harvest and preparation of traditional plant and animal species. Also as resources move and adapt to climate changes Tribal access to traditional natural resources becomes more difficult when these shifts force resources off Tribal lands and Reservations.

Not everyone will be affected equally by climate change; rather there will be disproportionate impacts to communities, or segments of communities, that are more vulnerable to climate change. These communities will require targeted approaches and responses to reduce that vulnerability.

External Factors

> *"I no longer live or work along or on the Klamath River. I had to leave due to financial reasons – to keep my job. I can no longer fish or gather. My children are not learning the culture like they should. They are not experiencing all that the Klamath River has to offer."*
>
> --Yurok Female, born 1960

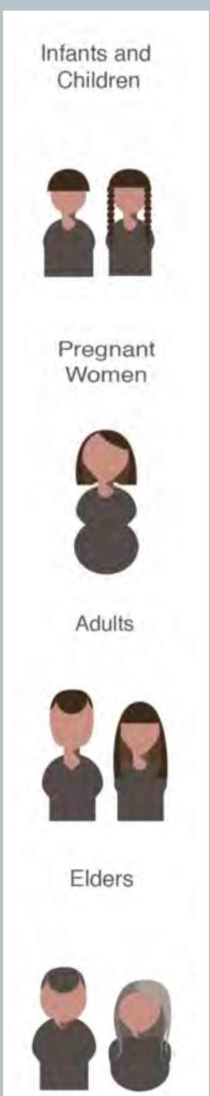
External factors, conditions outside of oneself, can increase susceptibility to health impacts from climate change. For Yurok Tribal Members these external factors can include poverty, low education, unemployment, sub-standard housing conditions, poor nutrition, and other lifestyle choices (exercise, smoking, alcohol consumption). Taken together these create a picture of a populations already susceptible to health impacts from climate change due to weakened external factors. For example, economic struggles are a reality for many individuals within the Tribe. Per a 2012 study, *"The economic conditions on the Reservations in the downcreek sub region are significantly worse compared to those in the downcreek counties; likewise, Tribes suffer significantly greater poverty and food insecurity than the surrounding non-Indian communities in the downcreek sub region (page 83-84)"* (U. S. Department of the Interior, 2012)." Unemployment in the Tribe is approximately 9% (U.S. Census Data, 2000).

Housing conditions are substandard for many Tribal members. According to a Tribal assessment on a subset of the Tribe, *"housing types consist primarily of wood frame or manufactured/mobile homes…[and]…the age of residences range from new, less than a year old, to over 100 years old…Very few had cement foundations and many reported no foundation at all"* (Yurok Indian Reservation Domestic Needs Final Report, 2003:3).Further, a report from the U.S. Department of the Interior Bureau of Reclamation found that, *"Yurok Tribal lands and services are particularly spread out in the remote stretch of about 30 miles around Weitchpec southward along the River with very limited basic services, including telecommunications and electricity"* (2012:27).

Nutrition is also a concern for the Tribe. In research conducted by the Tribe, food insecurity for Tribal members residing in the ancestral area was three times that of the surrounding local counties, largely related to decreased access to salmon fishing due to impacts from dams and commercial fishing (U.S. Department of the Interior Bureau of Reclamation, 2012).

Inherent Factors

Internal factors including all aspects of your personhood that you cannot change. These in addition to the external conditions, contribute to your susceptibility to climate change impacts on health. Examples of these include ***race/ethnicity, age, and gender.*** Age is a key factor due to physiologic and behavioral differences between different age groups (U.S. Environmental Protection Agency, 2017c). The key life stages when considering differential exposure, exposures that are different between age groups, are infants and children; pregnant women; and elders. For this assessment, we also include tribal adults as a subgroup of concern as described below



Infants and Children

35% of the Yurok Tribe are infants and children (less than 18 years old) (U.S. Census Data, 2000). They are more susceptible to health effects of climate change because of their physiologic differences from adults. For example, their bodies are still developing, their activity levels (breathing and heart rate) are generally higher, and they also spend more time on the ground increasing their oral and dermal exposure to contaminants.

Pregnant Women

Pregnant women are also more susceptible to illness, including impacts of climate change on health. This is because their immune systems are less strong as their body focuses on developing the baby, and these changes may decrease their body's response to exposures increasing likelihood for illness (U.S. Environmental Protection Agency, 2017c). Women of childbearing age (defined as aged 15 to 44 years) make up approximately 16% of the Yurok Tribal membership (U.S. Census Data, 2000).

Adults

Healthy adults are not typically defined as being more susceptible to environmental exposures. However, in the case of Native American populations practicing tribal lifeways, climate change impacts on their health are expected to be greater than the general U.S. population and many of the diseases considered in this report will potentially affect the entire tribal community population. For example, all Yurok Tribal members are at risk of being affected by extreme weather events such as flooding that has been known to force relocation, create economic losses, and cause injury and death.

Elders

Elders are those who are 65 years of age or older. Approximately 7% of the Yurok Tribal membership are elders (U.S. Census Data, 2000). Older age makes one more susceptible to climate exposures because of a lower immune system and existing diseases that make them more susceptible to impacts from climate change (U.S. Environmental Protection Agency, 2017a).

Yurok Specific Sub-populations

> *"My health and wellbeing is dependent upon the sacred Klamath River. I am a traditional basket weaver and see that basketry plants - willows, ferns, roots have been effected by the dams on the river. Weaving and gathering has helped me stay healthy in the past".*
> --Yurok Female, born 1960

Similar to many Native American Tribes and communities but location specific and unique to the Yurok experience are additional sub-populations with higher risk due to increased exposures to environmental toxins and contaminants from participating in lifeways (aspects of Tribal life central to their culture). These groups of Yurok members engage in **subsistence activities and commercial fishing**, **gather for cultural items and practice traditional lifeways**, and **participate in ceremonies**. Per the 2014 Yurok Tribe Interim Clean-up Standards, "*Tribal members are integrally related to the environment in ways not typically accounted for in most exposure evaluation models, which reflect exposures largely received in urban and suburban settings and do not consider the extent of tribal environmental contact"* (Yurok Tribe Interim Cleanup Standards, 2015:4). The exposures these subpopulations experience are described below.

Subsistence/Commercial Fishers

Hunting, fishing, and harvesting from the local environment (both for personal subsistence and commercial activity) by their very nature increase a person's interaction with the natural environment. For example, net fishing requires a Tribal member to have their forearms immersed in the water for great lengths of time, as does the collection of freshwater and marine mussels, seaweed, and other foods central to the Yurok way of life. Beyond that, time spent cleaning and preparing subsistence and traditional foods increases exposure to toxins through immersion and accidental inhalation of water. This increased interaction with their environment is integral to subsistence activities and must be considered when aiming to understand the impacts of climate change on health. Thus, in general, risk to Yurok Tribal members is regularly underestimated because of their intricate connection to and interaction with the land, sediments, and waters. The actual disease risk is likely greater than what is generally noted.

Gatherers

Individuals who go out and gather for cultural items and practice traditional lifeways are predisposed to increased interaction with the natural environment that increases their exposure to potential chemical pollutants or toxins. For example, in the collection of reeds for basket weaving, or the soaking of skins for traditional tanning, Tribal Members may accidentally inhale water droplets while wading in the water or digging roots as materials are collected, prepared, and soaked. In addition, they have the potential to absorb chemicals and toxins to their lower limbs, arms, and hands through both water and sediment contact.

Ceremonial Participants

Those engaged in Tribal ceremonial practices are also at increased risk of exposure. Ceremonies are an integral part of the Yurok world view and spirituality, all of which celebrate the intricate connection the Yurok have with nature and the Yurok responsibility as stewards. Many of these practices require that participants be cleansed through sweats and to immerse in and drink the local water resulting in inhalation or ingestion of the water. Regardless of the presence of contaminants or toxins, these activities will occur because of their cultural importance, increasing the exposure for this subset of the Yurok Tribal membership.

7.3 Water Resource Related Health Impacts

Water quality on the Klamath has declined over the last few decades. The six dams that currently exist on the Klamath River's mainstem, *"cause poor water quality (including [higher] temperatures and [resulting significant changes to the] hydrograph) that also contribute to low fish populations and human health warnings, and is aesthetically unappealing (often described as 'pea soup')"* (U. S. Department of the Interior, 2012:28).

Additionally, the legacy of herbicide spraying throughout the reservation on private industrial timber lands, has raised concern among Tribal members about runoff into their drinking water, springs, creeks, and the Klamath River. Pesticides and their degraded bi-products have the potential to decrease water quality and increase chemical exposures to important plants and animal species as well as the Yurok, themselves, when engaged in subsistence activities and ceremonies.

Table 7.2 Water Resource-Related Climate Change Projections

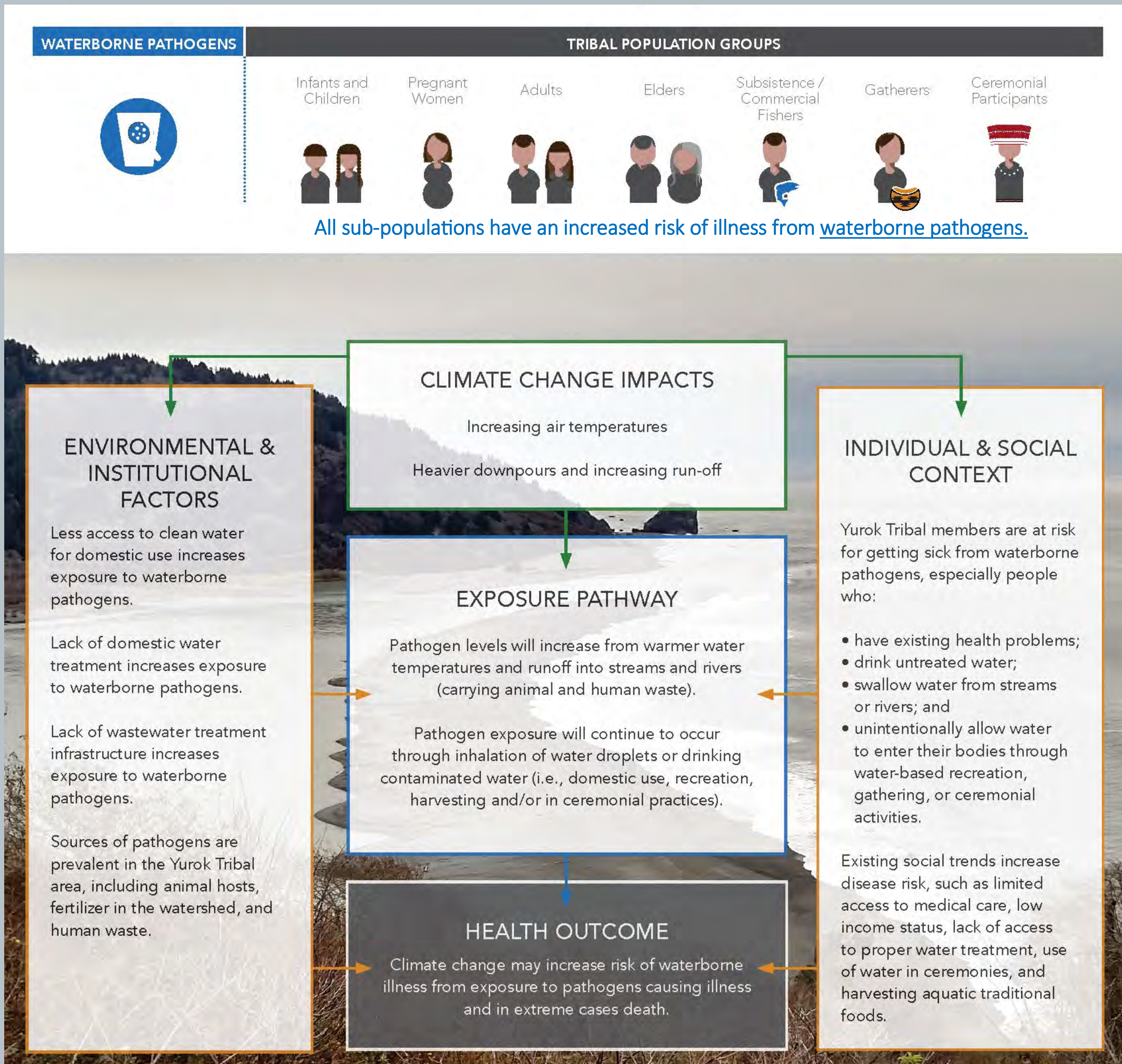
Primary Climate Effect	Potential Impacts
Warmer Air	Increasing air temperatures and the resulting increases to evaporation decrease water quantity/availability.
Increasing Drought	More intense droughts can concentrate contaminants in creeks and other water bodies.
Warmer Water	Warm water temperatures make conditions better for both marine & freshwater harmful algae as well as flat worm growth & proliferation.
Heavier Downpours	Heavier downpours increase run-off and move pollution and nutrients into creeks, rivers, and marine waters.
Rising Sea Level	Potentially decreasing efficacy of coastal septic systems that will allow septic discharge into surface waters

These external factors contribute to 3 prevalent and pressing water-related health concerns for the Tribe: **Waterborne Pathogens** (known *E. coli* exposures, with possible concerns of *Giardia Lamblia,* and *Cryptosporidium)*; **Water-Related Rashes** (freshwater HABs, swimmer's itch), and **Shellfish Poisons** (from marine and freshwater HABs). In addition, Table 7.2 highlights the most important primary and secondary climate changes relative to the three water resource-related diseases. Each section on the three diseases in this chapter ends with these risk factors, both personal and institutional factors, and climate changes summarized into pathway diagrams to visually show how these are influenced and connected to health risk and health outcomes.

Waterborne Pathogens

E. coli, *Giardia,* and *Cryptosporidium* are pathogens that cause gastrointestinal illnesses. *E. coli* is bacteria found in the environment, food, and the intestines of animals and humans, while *Giardia* and *Cryptosporidium* are only found in the intestines of animals and humans. Exposure to these pathogens results in diarrhea, abdominal pain, nausea, dehydration, urinary tract infections, weight loss, and in extreme cases, death. Waterborne pathogens are estimated to cause 8.5% to 12% of acute gastrointestinal illness cases in the United States, affecting between 12 million and 19 million people annually (Trtanj et al., 2016).

Pathway Diagram for Waterborne Pathogens and the Tribe



Waterborne Pathogens and the Tribe

Waterborne Pathogens, in particular *E. coli*, are already reported to be making Tribal members ill, some of whom have sought medical treatment. In late 2016, YTEP tested 38 creeks, many of which are the source for domestic water intake, and 100% of them had *E. coli* present. Following this finding, the Yurok Tribal Council had staff tested 80 homes' domestic water at the tap and 45% (36 of 80 homes) had *E. coli* present.

According to the 2003 Yurok Tribe Domestic Needs Assessment, "Some household's reported hauling in water for drinking and cooking purposes because they are afraid to consume domestic water. Many households reported a lack of water, inadequate water pressure, and poor quality of water during summer months when water levels are low. Very few individ-

Private drinking water intake infrastructure on the Yurok Reservation is varied and often utilizes non-standard structures and piping

ual water systems have a water treatment system. The treatment of a community water system is the responsibility of the system operator, owner, or in some cases volunteer (page 8)" .

Limited domestic water and wastewater treatment infrastructure in some parts of the reservation increases possible transmission of waterborne pathogens. Further, there are additional sources contributing to waterborne pathogens, including the presence of illegal marijuana growers' latrines set up on or near tributaries, as well as their use of agricultural fertilizers that run off into the surface waters and affect local drinking water systems (see Chapter 1). It is difficult to assess the exact incidence of waterborne illness among the Tribe as many of these types of illnesses go underreported and under diagnosed. As part of the 2016 YTEP sampling efforts, an initial survey was conducted and 16% of those sampled reported that someone in the home had been ill from "stomach/diarrhea problems," with only 6% of those seeking medical care. Per a 2016 U.S. Global Change Research Program Climate Health Assessment report, *"On average, illnesses from pathogens associated with water are thought to be under-estimated by as much as 43-fold (page 161)*" (Trtanj et al., 2016). Of note, *Giardia* and *Cryptosporidium* are also pathogens of concern in Yurok waterways, although the latest round of source water testing did not detect *Giardia* and found only a very low presence of *Cryptosporidium* in a single source of water. (For more information about Yurok drinking water, please refer to Chapter 5.)

Waterborne Pathogens and Climate Change

> *"I contracted 'Erythema nodosum' in 2001, a waterborne illness. I believe I contracted it from the upper Klamath River. This condition is usually found in third world countries with slow, stagnant water."*
>
> --Yurok Female, born 1977

For waterborne pathogens, the relevant climate change projections are increasing air temperatures and heavy downpours. Increasing air temperatures may result in increased evaporation, lower creek and river flows, and higher water temperatures. As water quantity decreases, so does quality. With less water, contaminants (e.g., waterborne pathogens) may become more concentrated. Heavier downpours can increase runoff that also increases exposure to waterborne pathogens because the runoff carries waterborne pathogens from their sources (e.g., human latrines, animal hosts) into creeks, creeks, and rivers (Trtanj et al., 2016). According to a 2016 climate and health report, "Extreme precipitation events have been statistically linked to increased levels of pathogens in treated drinking water supplies and to an increased incidence of gastrointestinal illness in children. This established relationship suggests that extreme precipitation is a key climate factor for waterborne disease (page 7)" (Trtanj et al., 2016).

Finally, small groundwater wells or surface water domestic systems where water is not treated are particularly susceptible to waterborne pathogens following heavier downpours as runoff brings additional bacteria and parasites from their source into the water system (Trtanj et al., 2016). Taken together, these climate change impacts have the potential to decrease water quality and increase the presence of waterborne pathogens.

Note: See Appendices for a comprehensive list of adaptation strategies for Waterborne Pathogens.

Adaptation Strategies to Reduce the Risk of Waterborne Diseases

Institutional

- Continue work to identify sources of drinking water contamination.
- Explore funding opportunities to continue regular monitoring of springs, creeks, and domestic water (point of entry in the home).
- Enhance communication efforts between YTEP and the Tribe health clinics on waterborne illness reporting, educ ation, and treatment.
- Expand opportunities for Tribal members to report illness from waterborne pathogens to the Tribal health clinics to better understand the problem.
- Continue and expand outreach and education about the health risks of drinking water contaminated with E.Coli, Giardia and Cryptosporidium to spur action within the Tribal community.
- Increase enforcement of Environmental Protection Ordinance and other existing ordinances on the sources of these contaminants (e.g., leaking septic systems, pit toilets, among other human sources were identified as the predominant problem).
- Expand interdepartmental communication & coordination to enhance Tribal health services and increase resiliency.

Individual

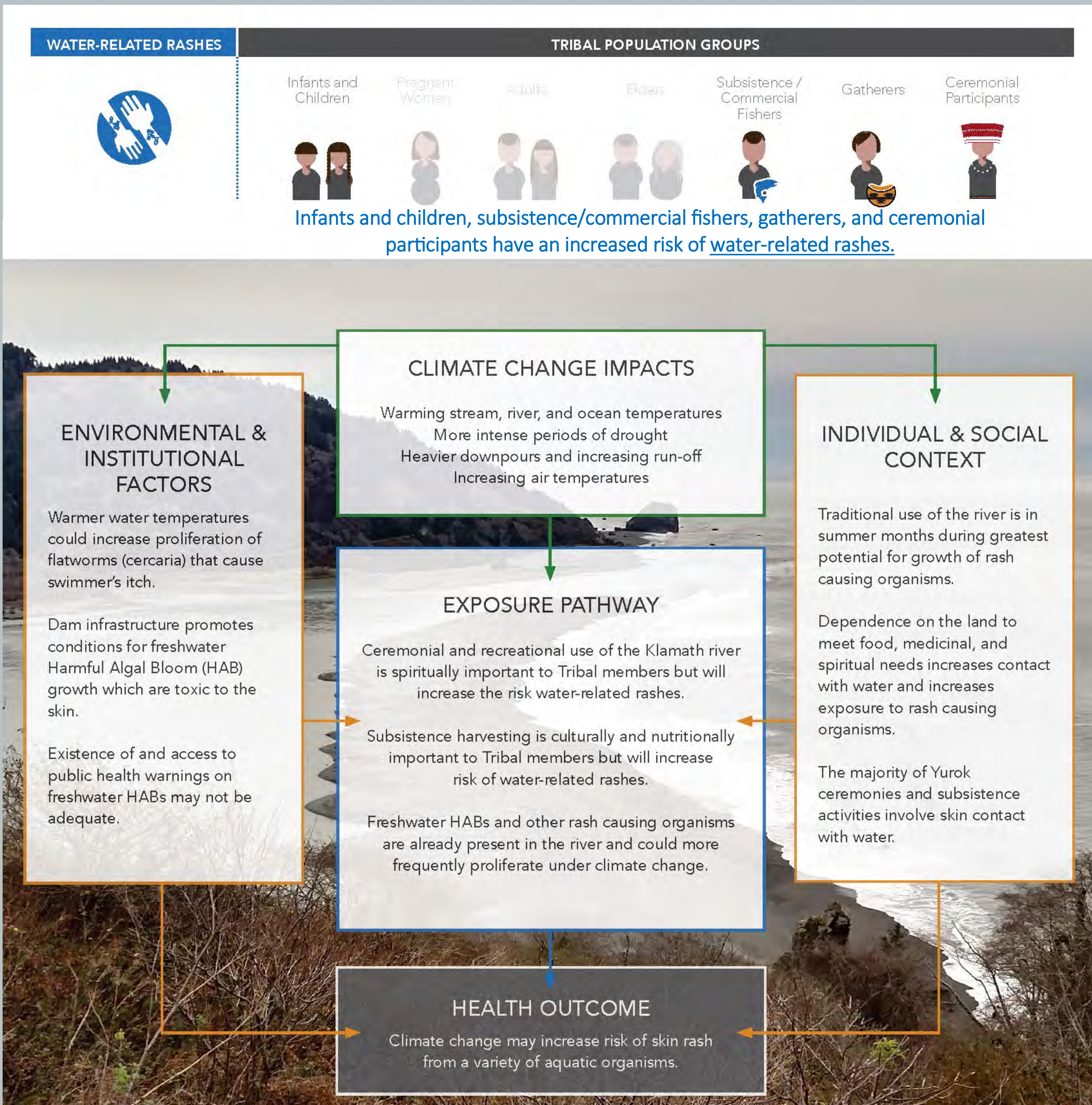
- If possible, consider connecting to the public water system. Think through the cost and level of effort it takes to maintain your own private system and the associated risk of increased health problems, in contrast to the cost of a monthly bill for safe, clean, and treated water.
- Consider installing low cost or alternative filtering systems, including redeveloping springs box systems to move away from creeks as a primary water source.
- Maintain and/or expand existing filtering systems; consider adding in line filters, roughing filters, or a second sand filter.
- Seek medical care when you have medical issues you suspect are related to waterborne pathogen exposure and ask the medical staff to test for E.Coli related problems.
- Store treated/clean water in dedicated, pre-cleaned or sterile containers for drinking and other uses such as tooth brushing.
- Follow sanitary construction, maintenance, and use of septic systems, out-houses, or pit toilets to keep human feces a minimum of 100 feet away from water and off steep or easily erodible areas.

Water - Related Rashes

“Rashes” is a broad term for any change of the skin that affects its color, appearance, or texture. Rashes can affect just a part of the body or spread across the entire surface of the skin. Skin with rashes may have symptoms of itchiness, warmth, bumpiness, change in color, dryness, blistering, and can be extremely painful. Rashes are treated differently based on their cause, but most often involve straightforward treatment of symptoms.

For instance, the rash known as “swimmers itch”, caused by microscopic parasites released from aquatic snails (*Cercaria*) that burrow under the skin, usually does not require medical attention and is commonly treated with corticosteroid cream and anti-itch lotion (Centers for Disease Control and Prevention, 2017b). Skin exposure to Harmful Algal Bloom (HABs) toxins like *microcystin and anatoxin*, can also lead to rashes, hives, or blisters (especially on lips and under swimming suits), that can only be addressed through comfort care of these symptoms (Iowa Department of Public Health, 2017). In addition, algal toxins are potent cancer promoters. (See Chapter 3 for more detailed information about HABs and their associated toxins.)

Pathway for Water-Related Rashes and the Tribe



Water-Related Rashes and the Tribe

Water-related rashes predominantly occur by 1) recreational exposure to slack water areas that harbor flatworms (*Cercaria*) resulting in "swimmer's itch"; and 2) exposure to anatoxins and microcystins associated with freshwater HABs (blue-green algae or cyanobacteria) during recreation, subsistence and commercial fishing, or gathering, cultural, and cer-emonial activities.

In 2006, 336 Tribal members completed surveys about the impacts that commercial and subsistence fishing has on their health as part of the *Healthy Rivers, Healthy Bodies* study. One in ten (*n*31) members reported experiencing rashes following fishing events. Other reports from Tribal members indicate that water-related exposures increase the incidence of rashes, however, the current scale of the problem among the membership is unknown (Fluharty et al., 2014).

Warming waters and low flows, algae support conditions favorable for algal growth

Water-Related Rashes and Climate Change

For water-related rashes, the relevant climate ipacts are warming air and water; increasing drought that concentrate contaminates; and heavier downpours that increase run-off. Warmer water temperatures accelerate the *Cercaria* or flatworm lifecycle, increasing the possibility for dermal exposure and swimmer's itch. For freshwater HAB-related rashes, increases in surface water temperatures facilitate algal blooms and increases their proliferation, particularly in back-eddies and low flow areas. "*Higher temperatures (77°F and greater) favor surface-bloom-forming cyanobacteria over less harmful types of alga (page 9)*" (Trtanj et al., 2016). This increase in temperatures also expands the range and seasonality of HABs.

Another important climate concern for water-related rashes is altered precipitation patterns. More intense drought with longer periods without rain may decrease the flushing of water bodies and create stagnant water, increasing surface water temperatures and HAB proliferation. Heavier downpours that increase run-off, contribute to nutrient loading in river promoting algal growth. "Increasing variability in precipitation patterns and more frequent and intense extreme precipitation events (which will increase nutrient loading) will allow the stagnant, low-flow conditions to favor cyanobacterial dominance and bloom formation (page 9)" (Trtanj et al., 2016).

Finally, increasing air temperatures may increase the risk for all water- related rashes as longer periods of warm weather may increase the amount of time Tribal members spend in the water for recreation. Also, the lower number of salmon returning to the river require longer periods of fishing and water contact in order to meet subsistence and cultural needs.

Adaptation Strategies to Reduce the Risk of Water-Related Rashes

Institutional

- Monitoring to test key water bodies for rash causing organisms.
- Expand existing alert system to identify when water bodies are not safe for recreation or subsistence activities.
- Provide shower facilities near sites frequently used by families with children.
- Continue support and work towards dam removal through decommissioning process, to improve impaired water quality that is currently influencing occurrence of HABs and low flow eddies that may harbor parasites.
- Restore upriver wetlands to decrease agricultural pollution that is currently influencing occurrence of freshwater HABs.
- Work to increase communication/coordination between United Indian Health clinics, social services department and YTEP to enhance climate change outreach & education services for Tribal members and increase resiliency.

Individual

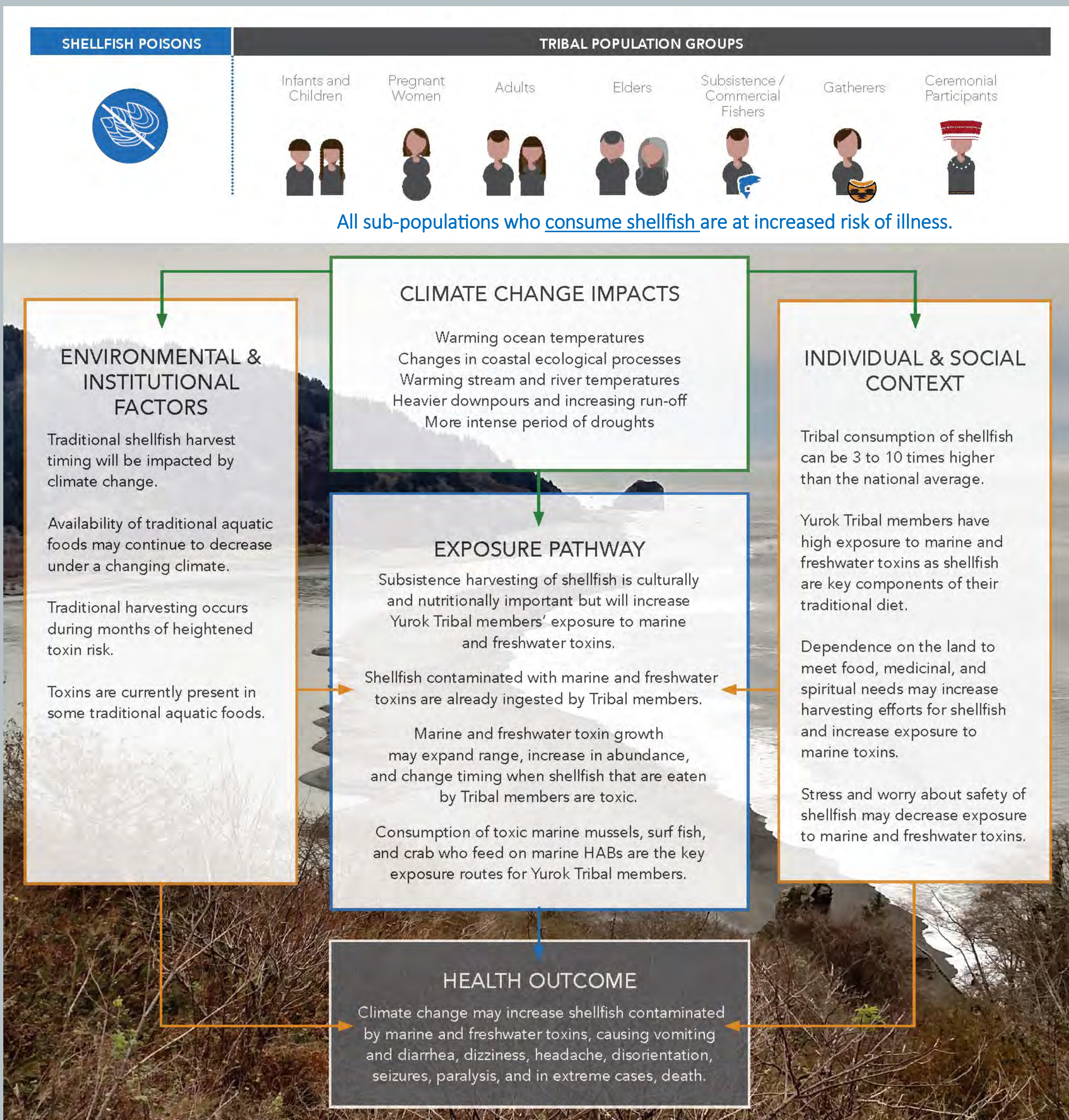
- Avoid contact with water that has an increased potential for pooling of toxins, especially shallow, slow water areas and eddies where gulls and other fowl frequent and freshwater snails often live.
- After contact with high risk water, rub skin vigorously with a towel and/or shower with clean water.
- Monitor available public alert systems to determine if water is safe for skin contact.
- Connect to the Yurok Environmental Observer network to stay informed about water toxins and to notify scientists when and where rashes from water contact are occurring.

Note: See Appendix A for a comprehensive list of adaptation strategies for Waterborne Rashes.

Shellfish Poisoning

Marine and freshwater HABs can cause health risks for those who eat contaminated shellfish. Eating marine or freshwater mussels, night-fish, surf fish or smelt, and crab, which feed on marine or freshwater plankton and algae (or those smaller creatures that do), are the key exposure routes of concern.

Pathway diagram for Shellfish Poisons and the Tribe



Some marine HABs can cause paralytic shellfish poisoning (PSP) and Amnesic Shellfish Poisoning (ASP) when toxins created by the algae build up in shellfish and those shellfish are eaten by Tribal members. PSP and ASP can cause vomiting, diarrhea, dizziness, headache, disorientation, seizures, paralysis, and in extreme cases, death. The toxins associated with freshwater HABs (such as anatoxins and microcystins) bio-accumulate and often concentrated in river mussels. They can be toxic to the brain and liver, and cause a range of similar health symptoms including tumor promotion. What is known is that Tribal members are forces to avoid these important traditional foods as well as contact with the water during HABs. This in turn decreases subsistence, ceremonial, and recreational activities central to their culture. Tribal consumption of shellfish is between three and ten times that of the general U.S. population, demonstrating that the U.S. EPA contamination action levels are a vast underestimate of the real exposures for Yurok Tribal members as they are based on assessment of shellfish consumption in mainstream Euro-American cultures.

Shellfish Poisons and the Tribe

Shellfish poisoning from HAB toxin-contaminated shellfish is another concern for the Yurok Tribe. Consumption of marine mussels, various varieties of clams, crabs, or river mussels during or immediately following a HAB event can cause several illnesses. Of primary concern in the Yurok Ancestral Territory are the aforementioned marine toxins that result in paralytic shellfish poisoning (PSP) and amnesic shellfish poisoning (ASP). These marine organisms are naturally occurring in ocean water, but under certain environmental conditions (e.g., warming ocean temperatures) they can produce toxins that concentrate in shellfish in amounts that are harmful to human health and create a wide range of health effects if consumed.

Pee'-eeh or Marine Mussels (*Mytilus californianus*)

As recently as 2015, high levels of ASP, or domoic acid, were found in crab in the region, leading to a suspension of crab season. In late 2016, it was reported that a Tribal member died from complications from exposure to domoic acid. Despite recent evidence of high domoic acid exposures, *"the impacts of repetitive low-level domoic acid exposure are currently unknown (page 1)"* (Lefebvre et al., 2010). Finally, from a 2014 Yurok Traditional Ecological Knowledge and Climate Change Report, "*shellfish toxins that result in Paralytic Shellfish Poisoning in recent years have been unprecedented and need to be better understood (page 14)*" (Sloan et al., 2014). As part of the effort to establish baseline conditions, YTEP is currently conducting testing and monitoring of marine mussels for PSPs and ASP.

In addition to toxins in marine shellfish, there are also toxins knowns as microcystins in freshwater, or river mussels. For example, during times when HABs are in the Klamath River, freshwater mussels (which are filter feeders) bio-accumulate these toxins. During a YTEP 2010-2012 tissue study, microcystin was documented in mussels at 64.2 parts per billion (ppb), a level above the U.S. Environmental Protection Agency's threshold, or "action level" of 51 ppb in tissue of food.

Pee'-eeh yurs, or Little Mussels are freshwater bi-valves often referred to as river mussels (*Margaritifera falcate*)

Shellfish Poisons and Climate Change

For shellfish poisons, the relevant climate projections are warming ocean temperatures, warming creek and river temperatures, and altered precipitation patterns that increase heavier downpours and run-off or create more intense periods of drought.

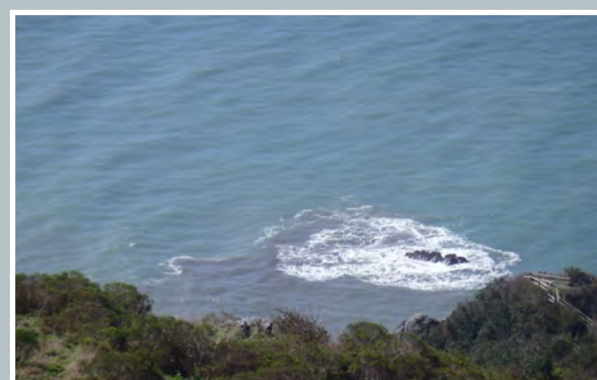
The shellfish poisons of concern to the Yurok are both marine and freshwater HABs. For marine HABs, increased ocean water temperatures, and changes to freshwater inputs, can lead to changes in water density, which in turn affect the seasonal patterns of mixing, stratification, and circulation. The potential weakening or rein-

"You know, people all the way from Weitchpec used to come down to Gold Bluff (to get mussels). They'd fill up a couple gunny sacks, have a picnic and cook some up there. But by the time you get home, if you have half a gunny sack you're lucky. You know -give some to cousins here and there, and older people... got to be cultural thinking. That's what they used to do. Go camp there and stay until they had enough to feed these people. Dry them, smoke them."

-Raymond Mattz, *Elder Interviews 2014*

forcement of upwelling winds will also influence many ecological processes, including the occurrences of marine toxins (Berdalet et al., 2015). These climate related changes could change the geographic range, overall abundance, frequency, and toxicity and timing of HAB growth.

For freshwater HABs, as was mentioned in the Water-Related Rashes section, increased surface creek and river temperatures facilitate blooms and increase proliferation of HABs, specifically *cyanobacteria*, expanding the range and seasonality of when HABs occur. Heavier downpours increase runoff and increase nutrient loading, increasing freshwater HAB toxin loading. More intense periods of drought due to longer periods without rain may decrease the flushing of water bodies and create stagnant water or areas with low water movement, increase surface water temperatures, and enhancing HAB proliferation.



Harmful Algal Bloom, or 'Red Tide' turned the waters below the Klamath River Overlook a dark maroon color in 2014.

Adaptation Strategies to Reduce the Risk of Shellfish Poisonings

Institutional

- Continue to conduct toxin notification and alert system, including posting signs in key fishing and recreational locations, in Yurok newspaper, on the Tribe's website, & through the Yurok Environmental Observer network.
- Continue to partner with the State Department of Public Health for laboratory quantification of toxins, public health alerts, and closures response to biotoxin events.
- Continue public education on the risk of marine toxins and the appropriate response to public health warnings.
- Increase interdepartmental communication and coordination to enhance outreach to Tribal members.
- Continue access negotiation with the National Parks Service & others, to harvest in areas that might have less HABs.

Individual

- Connect to the Yurok Environmental Observer network to stay informed about marine toxins.
- Ensure that marine mussels and other foods have not been gathered during high toxicity times before consuming.
- Eat shellfish for health protective nutrients when it is confirmed they are not toxic.

Note: See Appendices for a comprehensive list of adaptation strategies for Shellfish Poisons.

7.4 Subsistence Diet Impacts

Since time immemorial, the Yurok People have sustained themselves with the riches of the Klamath River Basin and near shore habitat of the Pacific Ocean. The security that this subsistence existence once provided has been dramatically reduced due to impacts to water quantity and quality. This decreased availability of subsistence foods coupled with the baseline economic struggles that many Tribal members face adds to the already high levels of food insecurity experienced in the community.

As has been reported by Tribal members, "Numerous species were identified to be in serious decline in recent decades. Specifically, salmon, sturgeon, eels, candlefish, surf fish, shell fish, elk, porcupine, and other important subsistence foods. Much of this decline has occurred in the past 100 years and observed within the lifetimes of the participants (page 12)" (Sloan et al., 2014). Yet the traditional subsistence diet and associated practices are a vital part of Yurok cultural identity and this Plan as a whole addresses many of the widespread and overlapping impacts to the Tribe.

Historic photo of traditional Yurok dip net used for harvesting surf-fish from the ocean beaches.

Table 7.3 Subsistence Diet-Related Climate Change Projections

Primary Climate Effect	Potential Impacts
Warmer Air	Warming air temperatures can increase the risk of heat waves and increase the levels of ground level ozone and other air pollution– adding to cardio stress
Increasing Drought	Hotter and drier conditions can increase wildfire risk, decrease air quality, and can concentrate contaminants and make shellfish unsuitable for consumption.
Warmer Water	Warming waters, both freshwater and marine temperatures can change habitat suitability for freshwater mussels and other subsistence food. Also increased HABs-limiting Tribal members' ability to harvest shellfish.
Ocean Acidification (CO_2)	Ocean acidification could undermine the food web for salmon and other traditional aquatic foods.

Chapter 5 focuses on climate change impacts to drinking water and Chapter 6 on the impacts to traditional food species. Both also further expand and discuss health issues and it is recommended that these be read in conjunction with this section as each has a slightly different perspective and focus. Table 7.5 lists some of these impacts that are not directly linked to this chapter's focus on the eight "climate-relevant" diseases but that do influence them from the Yurok holistic viewpoint.

Three subsistence diet-related groupings of health outcomes have been identified and will be explored in pathway diagrams: diabetes, cancer, and heart disease. It is expected that climate change could increase the risk of these diseases and will affect the Yurok traditional subsistence diet by decreasing access, availability, and quality of culturally significant subsistence foods.

Table 7.4 Important Traditional Aquatic Food
Traditional Aquatic Foods including: (See Chapter 6) ◊ Ney-puy (Chinook Salmon) and ◊ Chey-guen (Coho Salmon) ◊ Chkwohl (Steelhead) ◊ Kah-kah (Green Sturgeon) ◊ Key'-ween (Lamprey Eel) ◊ Seyk-soh (Marine Shellfish) & Pee'eeh yurs (River Mussels) ◊ Key'-ween we' chey-gel' (Spring Seaweed) Important Traditioanl species not in this project due to limited Tribal Member use as they are already impacted, with extremely small populations currently returning to Yurok Territory ◊ Hehl-kues-leg (Surf fish) ◊ Mokw-chech (Nightfish) ◊ Kwo'-ror' (Candlefish)

The most important primary climate changes relative to these subsistence diet- related diseases are highlighted in the Table 7.3. A detailed summary of changing climate impacts is provided in Chapter 3 of the Adaptation Plan. However, recognizing that this assessment focuses on traditional aquatic foods (Ch 6), we based our health analysis on seven priority aquatic species identified in previous work as described in the larger Adaptation Plan. Unfortunately two culturally important species, surf fish and candlefish no longer run into the Yurok Territory in sufficient numbers to be included in Tribal research and were left of the list of priority species in our project.

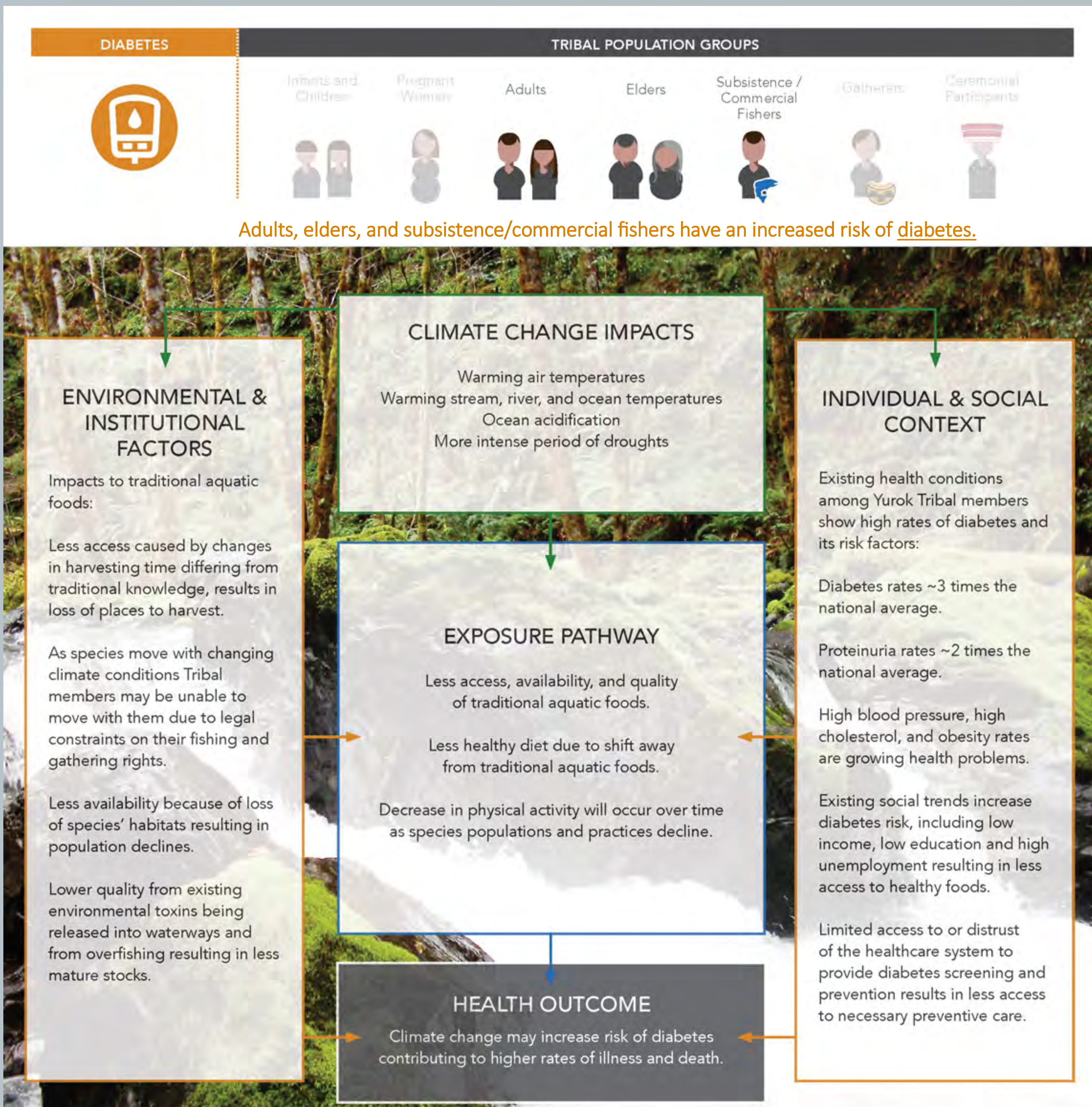
Diabetes

Table 7.5 Effects for Yurok people from climate change impacts on traditional aquatic foods	
Economic	- Costs associated with store-bought foods to replace the loss of subsistence sources - Loss of income from commercial fishing - Additional costs of travel to limited number of available and viable harvesting sites
Social	- Increasing competition between Yurok and non-Yurok, heightening tension between people. - Less socializing by reduced time spent in fishing and harvesting activities together (Donatuto et al.2014) - Youth less able to participate in traditional & knowledge sharing due to loss of traditional species
Cultural	- Traditional Knowledges could become less applicable, for example: shifts in the phenology or timing of natural events could change such as the timing of the bracken fern unfurling no longer coinciding with the best time to gather Key'-ween we' chey-gel' (Spring Seaweed) - Foods not available at the traditional times, in traditional locations; impacting ceremonies and spiritual practices - Youth less able to participate in traditional fishing and harvesting practices and knowledge sharing - Loss of species/fish used by Yurok for regalia such as traditional sturgeon glue
Health	- Increased food insecurity with traditional foods becoming less reliable, less available and/or of questionable quality - Health effects from relying more on processed foods; increased diabetes, cancer, and heart disease - Mental health stress from fear of potential loss of traditional foods and practices versus exposure to toxins in: shellfish consumed; the waters while fishing; and drinking water sources - Stress from economic, social, and cultural impacts from not being able to provide for families - Stress from having to spend more time fishing rather than other activities - Stress from further erosion of cultural resources and lack of ability for traditional/subsistence lifestyle - Multi-generational trauma from disruption of the relationship between Yurok, traditional aquatic species, the environment, and from not being able to carry out traditional practices

Diabetes is a disease that makes it difficult for your body to make or use insulin, a hormone that transfers the energy from the food you eat to your body's cells. If you do not have enough insulin, glucose (sugar) builds up in the blood stream. One reason for kidney disease is having too much glucose in your blood creek over time due to diabetes. Kidney disease is often indicated by proteinuria, meaning the presence of protein in the urine. In healthy people, urine has very little protein. Some risk factors are poor diet and physical inactivity.

[Pathway Diagram for Diabetes and the Tribe]

[Diabetes and the Tribe]



Proteinuria, or the release of protein in the urine, is the most common indicator of pre- diabetic conditions or type 2 diabetes. Both proteinuria and type 2 diabetes are precursors to kidney disease and ultimately kidney failure if left untreated (National Kidney Foundation, 2017). Findings from the Yurok Environmental Community Health Profile Report show a prevalence of proteinuria 2.5 times the national average—2.6% of adult Yurok Tribal Members compared to the national prevalence of proteinuria of 1.1% (Yurok Environmental Community Health Profile, 2011). Further, the report found that the Yurok Tribal members have similar rates as the combined American Indian and Alaska Native National Diabetes Rate, almost 3 times more than the national average for all races (Indian Health Service Disparities, 2017). Per a 2012 report, *"Declining fisheries have contributed to higher diabetes, heart disease, obesity, mortality, and disability rates (page 27)"* due to a decrease in availability of traditional foods, resulting in a shift away from the traditional healthy diet (U.S. Department of the Interior, 2012).

Seaweed cakes shown here, drying on sword fern fronds have traditionally been an excellent means of incorporating the many minerals from ocean habitats.

An often linked condition with diabetes is obesity that is a significant risk factor for proteinuria, kidney disease and kidney failure (Praga et al., 2006). The Yurok Environmental Community Health Profile found that, "*[a]pproximately 17.0% of Yurok adults age 20 years and over are obese, compared nationally to 33.9% of adults age 20 years and over (page 12)*" (Yurok Environmental Community Health Profile, 2011).

Even though Yurok Tribal members' obesity rates are lower than the national average, obesity is an important risk factor to consider, in particular because of its connection to diet and physical activity, both of which could decrease with less access to subsistence lifestyle activities. Further, Yurok community concerns about obesity emerge from a legacy of forest herbicide use such as Atrazine, Garlon-4, and 2, 4, D—used by timber companies to control undergrowth's competition with the larger conifers in the area (Snyder, n.d.). There is widespread fear about pesticide runoff into the Klamath including concerns that these pesticides are endocrine disruptors potentially increasing obesity and diabetes risk.

Eeling at the mouth of the Klamath River is considered a 'Young Man's' activity as it requires a sharp eye, agility, and stamina to spot the lamprey in the ocean waves, rush out over the sand to snag them and return without being caught by the surf and dragged out to sea. With fewer lamprey, both the skill and exercise that this requires is becoming less frequently utilized.

Diabetes and Climate Change

For diabetes, the relevant climate impacts are warming air temperatures, warming creek, river, and ocean temperatures, ocean acidification, and more intense periods of drought. We know that during heat waves, people with diabetes are at increased risk of dehydration and heatstroke. Hotter temperatures also predispose people with diabetes to heart attacks (International Diabetes Federation, 2012). As recently as early 2017, a study found that increasing ambient air temperatures directly increases the incidence of diabetes (Blauw et al., 2017). Further there are concerns that extreme climate and weather events may prevent or limit access to essential regular medication for diabetes and could increase morbidity and mortality (International Diabetes Federation, 2012).

One aspect of this climate health assessment is focused on how climate impacts may affect access and availability to subsistence foods, as eating a traditional diet helps to reduce the risk of disease. Warming creek and river temperatures can change habitat suitability for freshwater mussels and other subsistence foods. Warming ocean temperatures increase the likelihood of marine HABs, limiting Tribal members' ability to safely harvest shellfish. Ocean acidification is a particular problem for shellfish's ability to form their protective shells and could undermine the diatoms and small shelled crustaceans that form a large port of food web for salmon and other traditional aquatic foods.

An important source of healthy Omega-3 fatty acids, salmon strips cut from fillets are hung in a Yurok smokehouse while the fish napes, or cheeks on the rack below

More intense periods of drought due to longer periods without rain may decrease the flushing of water bodies and create stagnant water or areas with low water movement, increase surface water temperatures, and encourage HAB proliferation, making shellfish unsuitable for consumption. Traditional foods, such as shellfish, provide a nutrient-rich and culturally important component of the modern diet, along with their harvesting and processing activities being associated with a less sedentary lifestyle. Such diets and lifestyles provide food packed with essential fatty acids, antioxidants, and protein and are associated with prevention and mitigation of chronic diseases such as diabetes, heart disease, and cancer (Jamestown S'Klallam Tribe, 2013). If the Yurok people shift away from these foods, their risks for developing diabetes will increase as their diet moves towards commodity foods and their physical activity from harvesting becomes more limited.

Adaptation Strategies to Reduce the Risk of Diabetes

Institutional

- Invest in opportunities for "food sovereignty" to return to sustainable food harvesting and replace need for commodity foods.
- Provide opportunities for physical activity.
- Continue and enhance opportunities for fish sharing, including provision of fish for single or pregnant moms and elders.
- Consider reporting to health and social services of proteinuria, diabetes and kidney disease to understand the problem and obtain funds to target prevention of these illnesses.
- Work to increase healthcare funding to expand access for Tribal members including in-home care and testing for those without access to transportation.
- Consider designing and implementing culturally grounded diabetes-prevention education including lessons on the benefits of eating traditional foods modeled after the Centers for Disease Control and Prevention's "Native Diabetes Wellness Program."
- Conduct education about and implementation of healthy foods and healthy eating habits in Head Start programs and schools.

Individual

- Consider eating more traditional foods when available, particularly fish, as a high quality protein, low fat option with excellent health-protective components (e.g., Omega 3).
- Consider seeing a health professional regularly when possible (to catch health problems early).
- Consider increasing physical activity to maintain a healthy body weight.

Note: See Appendices for a comprehensive list of adaptation strategies for Diabetes.

Cancer

Cancer is a condition where cells in the body divide and multiply without control, invading tissues of nearby body systems (National Institutes of Health, 2017). The different types of cancer depend on the body system being impacted. The World Cancer Research Fund estimates that about 20% of all cancers diagnosed in the United States could be prevented through eating a healthy diet, increasing physical activity, and decreasing alcohol consumption (American Cancer Society, 2017a). Further, although darker-skinned people are at lower risk of skin cancer, without protection (e.g., sunscreen, clothing cover, seeking shade), the risk of skin cancer increases (American Cancer Society, 2017b).

Health guidances for HAB-related toxins have cancer risk included in their calculations to help set the levels when it is advisable to avoid contact with waters to lower the risk of developing cancers. Microcystin primarily considered a hepatotoxin, is not only carcinogenic to the liver but is also a general tumor promoter (Falconer 1991; Falconer and Humpage 1996; Fujiki and Suganuma 2011; Merel et. al 2013; Nishiwaki-Matsushima et. al 1992).

"When I was a kid, cancer was something that happened outside, nobody on the river that I knew of caught cancer. And when I came back from Frisco, they were dropping like flies, all go cancer."

—Allen McCovey, Elder Interviews 2014

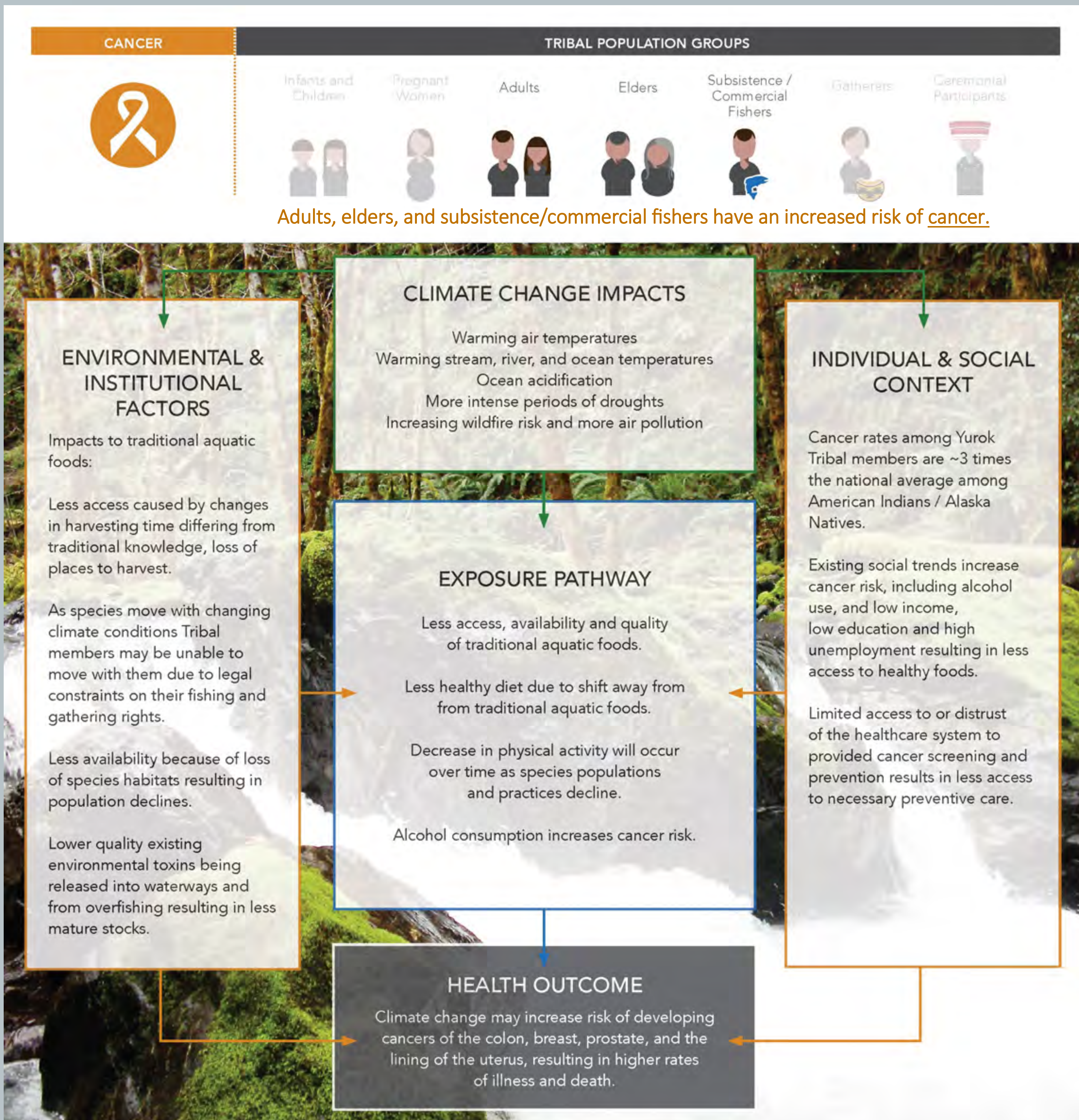
"...you look down Pecwan. There's no more men left down there cuz they all died of cancer. I don't know if they all died of the same cancer but they all died of cancer. There's a few women that have died of cancer from down there. But that's what took most of the people down there... You can go to everyone of those houses down there and see that it was from the Hunsucker's first house, to Ollie's, to Green's, to Nyles', you know right on up the River. All those guys died. Cancer."

—Bertha Peters, Elder Interviews 2014

Also important to consider in the Klamath River system is the presence of other HAB associated toxins, such as anatoxin. This class of toxins impact the nerves and cause skin rashes. Although the human response to exposures to multiple toxins together is currently being researched, it is accepted that when the skin is abraded or compromised the lipid barrier is broken and this in turn allows toxins into the blood stream (Barrett 1969; Bronaugh 1983; Dietrich, D.R., et. al 2008). This is a particular issue for both those engaged in net fishing and basketry weaving as they have roughened, abraded and often broken/cut skin on their hands and forearms from engaging in their respective, cultural activities.

For cancer, the relevant climate changes are warming air temperatures, warming creek, river, and ocean temperatures, ocean acidification, increasing wildfire risk, and more air pollution. As with diabetes, the focus of this assessment was to assess how a changing climate will impact access and availability to traditional aquatic foods and better understand the myriad of health effects that could result from changes to both access and availability of these important resources.

Pathway Diagram for Cancer and the Tribe



Cancer and the Tribe

Per a Yurok Environmental Community Health Profile Report, based on reported diagnoses codes from the United Indian Health Clinic records of Tribal members, *"Yurok Tribal members may have higher rates of cancer and proteinuria than are seen nationally, (page 1)"* and up to three times the national skin cancer rate (YTEP 2011).

Both microcystin and anatoxin from freshwater HABs in the Klamath River are known carcinogens and tumor promoters.

> *"I was raised on the Klamath River in the 60's at Waukell Flat...We didn't need much. Our smoke house was always full with eels, candlefish, mussels, salmon, sturgeon, and we would gather seaweed, surf fish, clams".* --Yurok Male, born 1956

Though not directly tied to climate change, skin cancer does contribute to the mental stress and the baseline of ill health among Tribal members. Cancer risk related to less access to healthy subsistence foods is the focus of this health assessment, including cancers of the colon, breast, prostrate, and the lining of the uterus (National Cancer Institute, 2017).

In addition, Tribal Members document multiple environmental concerns including that the population of various wading and diving water birds (ducks/Anseriformes, coots/Gruiformes, and greebes/Podicipediformes) have drastically declined within living memory, particularly the mud hens or coots. Upland areas offer habitat for other less commonly seen species such as river otters, Roosevelt elk, ring-tail cats, cougars, and lynx. All could be potentially affected by contaminants and toxins as one moves up or down the trophic food chain.

Tribal members frequently offer up the possibility that the various species' declines are the result of contaminant and toxic effects on the species that they have been stewards of for millennia. Many tribal members also regularly report observing internal tumors in individual mammals when they are gutted or butchered. Others report observing that harvested fish have unknown cysts that they must cut out or diseased gall bladders.

Le-gech, or Mud hen (American Coot ,*Fulica Americana)* was a regular on the Yurok diet and elders report that it was always a favorite to throw three in a roasting pan for dinner.

Cancer and Climate Change

As has been mentioned, more intense periods of drought can enhance the prevalence of HABs and concentrate poisons in shellfish making them unsuitable for consumption. The longer periods without rain may decrease the flushing of water bodies and create stagnant water or areas with low water movement, increase surface water temperatures, and encourage HAB proliferation, eliminating access to an important healthful component of the traditional Yurok diet (Hellberg et al., 2012). Finally, a longer wildfire season with more frequent and larger fires can increase exposure to pollutants from wildfire smoke, which is known to increase the risk of cancer.

Warming air temperatures increase ground level ozone and other air pollution, which are known to increase cancer risk (U.S. Environmental Protection Agency, 2017; National Institutes of Environmental Health Sciences, 2010). As with diabetes-relevant projections, warming creek, river, and ocean temperatures degrades water quality and may limit important habitat for subsistence species, making them less available for consumption. This in turn shifts the Yurok diet away from these health protective foods towards commercial and commodity foods (Weaver, 2010). "Ample evidence exists to suggest that increased incidence of stomach and colorectal cancer has a positive relationship with low-income status and the sudden change in dietary practices associated with acculturation, reliance on government commodities, and processed food subsidies (page 274)" (Weaver, 2010).

Note: See Appendices for a comprehensive list of adaptation strategies for Heart Disease

Adaptation Strategies to Reduce the Risk of Cancer

Institutional
- Explore opportunities for "food sovereignty" to return to sustainable food harvesting and replace need for commodity foods. - Expand opportunities for physical activity. - Continue and enhance opportunities for fish sharing, including provision of fish for single or pregnant moms and elders. - Consider improving reporting of cancers through existing health systems to understand the depth of the problem and obtain funds to target these illnesses (cancer burden for Native Americans has been historically underestimated). - Work to increase healthcare funding to expand access for Tribal members. - Consider designing and implementing culturally grounded smoking, alcohol and other cancer risk-prevention education programs. - Consider working to make changes to fire regimes (e.g., cultural burns) to increase access and availability of traditional foods.
Individual
- Consider eating more traditional foods when available, particularly fish, as a high quality protein, low fat option with excellent health-protective components (e.g., Omega 3). - Consider decreasing alcohol consumption to prevent cancer. - Consider seeing a health professional regularly when possible (to catch health problems early). - Consider increasing physical activity to maintain a healthy body weight. - If you are a smoker, consider quitting to eliminate an important risk factor for cancer.

Heart Disease

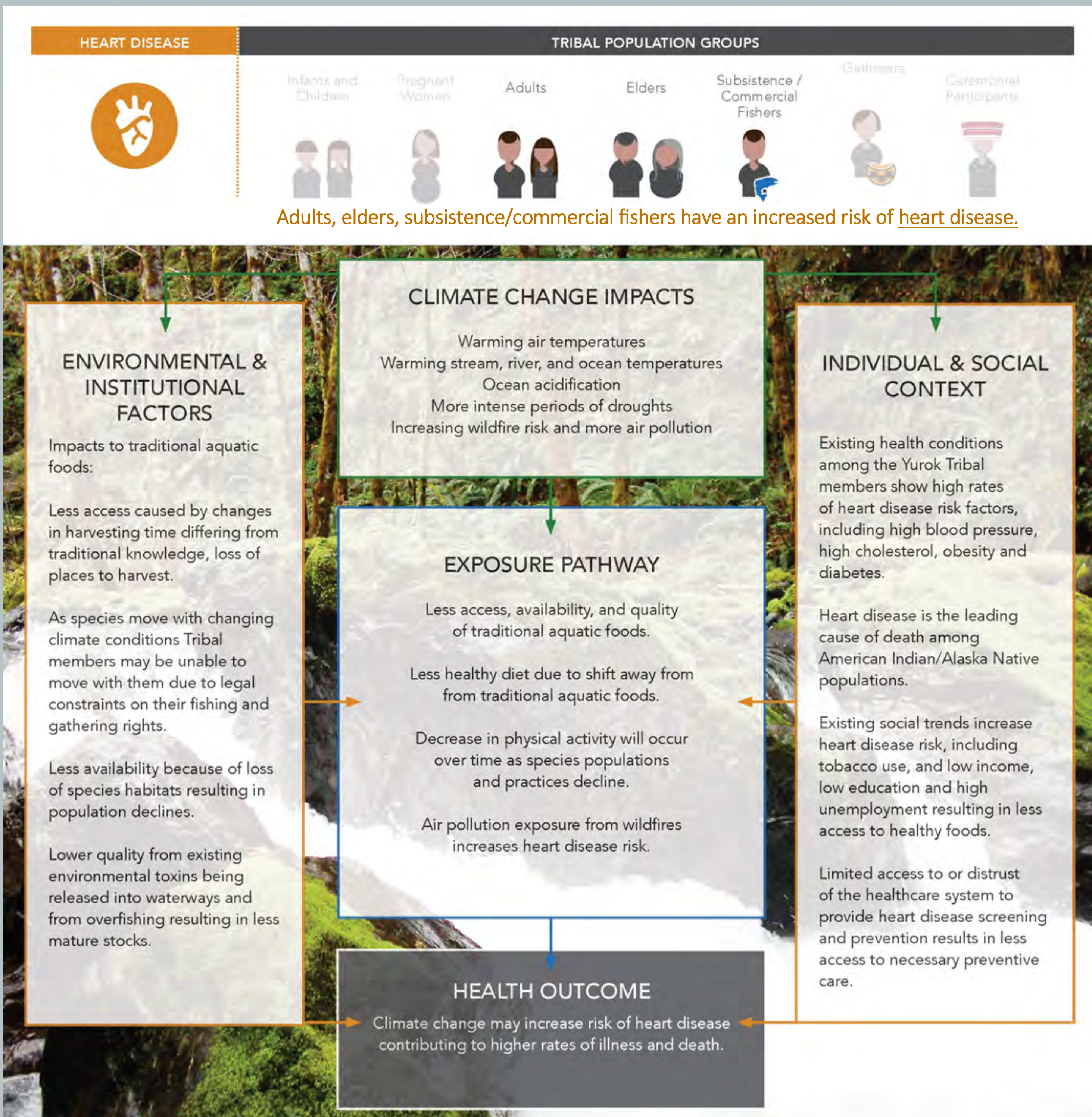
Heart (cardiovascular) disease describes a range of illnesses affecting the heart including narrowed or blocked arteries (which serve blood to your heart) that can cause a heart attack, chest pain (angina), or other heart muscle or valve problems (Mayo Clinic, 2017). Heart disease is the leading cause of death among Alaska Natives/American Indians (Centers for Disease Control and Prevention, 2017a). High blood pressure, high cholesterol, smoking, physical inactivity, and obesity all contribute to the development of heart disease. In addition, exposure to tiny particles in smoke from wildfires (particulate matter) and cracked or leaky wood stoves can increase risk of heart problems such as heart attack.

Net-pulling and rowing of fishing boats and canoes are an integral part of subsistence, traditional life-ways that help lead to a healthy Tribal Membership.

Heart Disease and the Tribe

Heart disease is another health issue for the Tribe. The concern is that a shift away from the traditional subsistence lifestyle could decrease physical activity and lead to a less healthy diet with less access to healthy traditional foods. Obesity is an important risk factor for heart disease. According to a recent report, "The Yurok Tribe has experienced an increase in obesity, diabetes and heart disease rates that coincided with the declining availability of traditional foods, particularly salmon, and that has contributed to higher disability and mortality rates, some of which was documented in a survey by the Yurok Tribe's Healthy River, Healthy People, Traditional Foods Survey (page 83)" (U.S. Department of the Interior, 2012).

Pathway Diagram for Heart Disease and the Tribe



Heart Disease and Climate Change

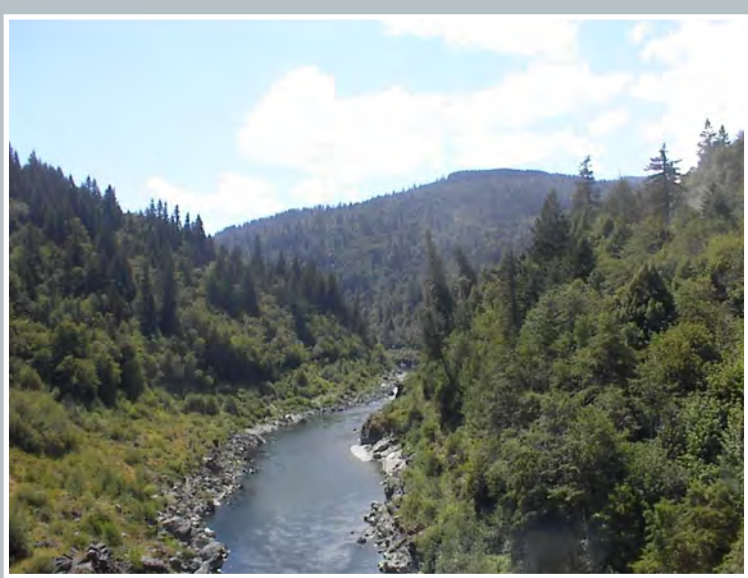
For heart disease, the relevant climate changes are warming air temperatures, warming creek, river, and ocean temperatures, ocean acidification, more intense periods of drought, and increasing wildfire risk and more air pollution.

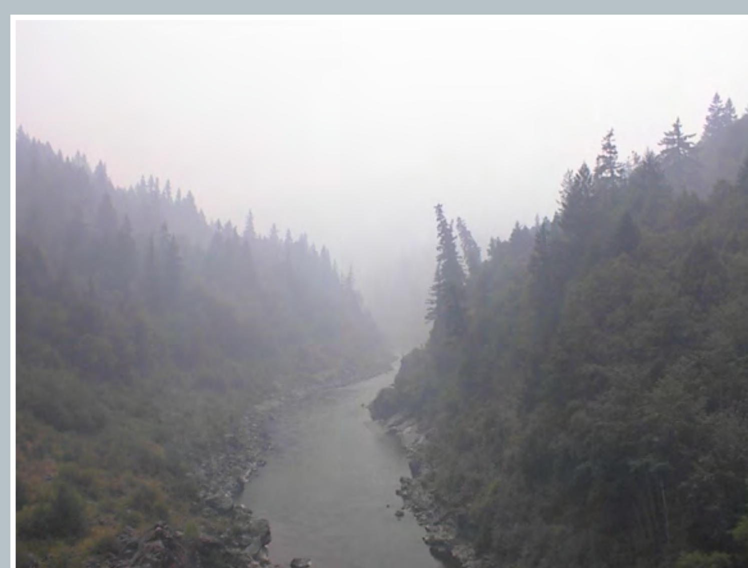
Firefighter, watching the sun beams through wildfire smoke

Extreme heat events due to warming air temperatures worsen chronic diseases, like heart disease. “Prolonged exposure to high temperatures is associated with increased hospital admissions for cardiovascular, kidney, and respiratory disorders (page 44)” (Sarofim et al., 2016). Warming air temperatures also increase ground level ozone, which is known to increase risk for acute heart attacks (Fann et al. 2016). As warming air reduces available moisture to vegetation, wildfire intensity and frequency is expected to increase. As Tribal members are exposed to pollution and particulate matter in the smoke, their risk for heart disease increases.

As with cancer, heart disease risk will increase with a longer wildfire season and more frequent and larger fires though exposure to pollutants from smoke. Anecdotal information of elderly and/or sick Tribal Members abounds after each fire event and tell of smoke “killing” neighbors and loved ones. At the very least, these excessive particulate releases are contributing factors to at least some of the adverse health effects reported during and after the wildfires.

Warming creek, river, and ocean temperatures and ocean acidification decrease the quality and quantity of aquatic traditional foods (see diabetes and cancer sections above). There is an increased risk of the incidence and prevalence of heart disease from less consumption of traditional aquatic foods and less subsistence based physical activity. “Traditional har-





View downriver from Martin’s Ferry Bridge. Top is a typical clear day and the picture on the bottom shows the hazardous air quality that occurs from wildfires nearly every year.

vesting activities and foods may play an important role in modifying health risks and protecting American Indian and Alaska Native peoples from increasingly common chronic diseases such as diabetes, heart disease, stroke and cancer (page 8)" (Redwood et al., 2008).

> *"I am 61 years old and have had 3 strokes. I'm unable to go fishing and hunting anymore and it is very hard and depressing not being able to spend time doing the things I loved and looked forward to. When I was able to fish and eel on Klamath River I felt happy and I felt at home; some of the most rewarding and fulfilling experiences and as a Yurok Tribal member my relationship with the Klamath River was more beneficial health-wise when I was younger and when I was growing up being able to eat traditional resources the River provided the Yurok People".*
>
> --Yurok Male, born 1945

With decreased consumption of subsistence foods, important health protective components that reduce cholesterol levels and boost heart health, such as omega-3 fatty acids, found in salmon or Woo-lew ue pop [sturgeon bread], are lost. Shellfish are packed with protein, contain no unhealthy carbohydrates, and have almost no fat (Yurok Today, 2014).

Climate change is likely to negatively impact access and availability of subsistence foods that have nurtured the Tribe since time immemorial, and point to an uncertain future for subsistence. Access to traditional foods may be limited as, "traditional foods are affected by climate change through habitat alterations and changes in the abundance and distribution of species (page 4)" (Fluharty and Sloan, 2014). Efforts to sustain the subsistence lifestyle will lead to improvements in these health outcomes (Redwood et al., 2008).

Adaptation Strategies to Reduce the Risk of Heart Disease

Institutional

- Look for opportunities to enhance "food sovereignty" to return to sustainable food harvesting and replace need for commodity foods.
- Provide opportunities for physical activity.
- Continue or enhance opportunities for fish sharing, including provision of fish for single or pregnant moms and elders.
- Consider improved reporting of heart disease in order to understand the problem & obtain funds to target prevention of these illnesses.
- Explore ways to increase healthcare funding to expand access for Tribal members.
- Consider designing and implementing culturally grounded educational materials to further the reach of messages to prevent heart disease and its risk factors modeling after the National Heart, Lung, Blood Institute's "Your Choice for Change!".
- Consider providing regular healthcare screening for key risk factors of heart disease, including free health clinic days, health fairs through the schools and cultural centers.

Individual

- Consider eating more traditional foods when available, particularly fish, as a high quality protein, low fat option with excellent health-protective components (e.g., Omega 3).
- Consider seeing a health professional regularly when possible (to catch health problems early).
- Consider increasing physical activity to maintain a healthy body weight.
- If you are a smoker, consider quitting to eliminate an important risk factor for heart disease.

Note: See Appendices for a comprehensive list of adaptation strategies for Heart Disease.

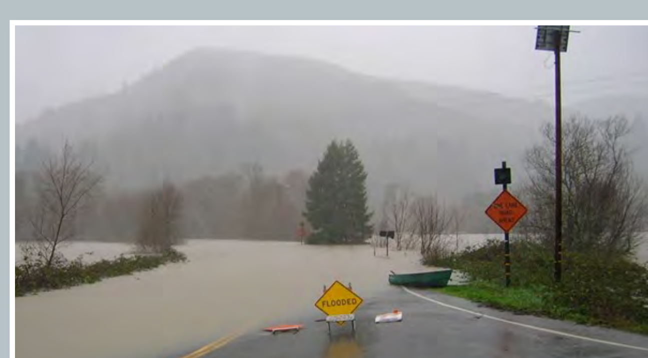
7.5 Mental Health Impacts

Table 7.5 Community Mental Health-Related Climate Change Projections	
Primary Climate Effect	**Potential Impacts**
Warmer Air	Increasing air temperatures and the resulting increases to evaporation decrease water quantity/availability.
Increasing Drought	More intense droughts can concentrate contaminants in creeks and other water bodies and limit the ability to harvest traditional aquatic foods.
Warmer Water	Warming waters encourage growth of harmful algal blooms limiting ability to interact with the Klamath River, swim, harvest freshwater mussels, shellfish, etc.
Heavier Downpours	Heavier downpours can lead to flooding and increase the risk of landslides, destroy infrastructure and homes.
Increased Wild fires	Wildfires can burn homes and destroy traditional harvesting or ceremonial sites and increase air pollution.
Ocean Acidification	Ocean acidification could undermine the food web for salmon and other traditional foods resulting in decreased availability to share traditional practices.

Like many other indigenous people, Yurok Tribal members face a disproportionate share of adverse socio-economic and environmental conditions as compared to the rest of the country (Gamble et al., 2016). However, Yurok people have persevered in their traditional territory despite a wide variety of changes including: extreme social upheaval at the hands of non-tribal settlers; the rapid spread of diseases of European origin; decreases in natural resource abundance; the disruption of ecosystems at a massive scale due to dams, logging, overfishing, fur trapping; marijuana cultivation. In addition, limits have been placed on their rights to access natural resources, and the reduction of the rights to practice traditional culture and speak their native language (see Chapter 1) (Sloan, 2003). These experiences have contributed to community mental health impacts for the Yurok people. We identified two Community Mental Health-related groupings of health outcomes to assess in this report.

The final two pathways explore how climate change may affect community mental health. Specifically, how **mental health issues** could increase in the face of more extreme weather events, and how **multi-generational trauma** occurs due to the climate-related loss of culturally significant plants and animals and the resulting loss of cultural identity (food, sites), self-worth, and/or economic opportunities culminating in depression, alcohol and drug abuse, and/or suicide. One example is the mental health impacts from worry of having to choose between either harvesting traditional foods that might have current health impacts or by not harvesting, contributing to the loss of culture and traditional rules of behaviors, values, and learning that surrounds harvest.

A detailed summary of changing climate conditions is provided in Chapter 3 of the larger Yurok Adaptation Plan. Table 7.5 highlights the most important primary and secondary changes relative to Community Mental Health-Related Diseases.



Floods can isolate individuals from life-saving emergency services as well as damage infrastructure.

Extreme Weather Events

Many persons exposed to climate or weather related natural disasters experience depression, general anxiety, and post-traumatic stress disorder (PTSD), which often occur at the same time. Depending on the type and magnitude of the disaster, most affected people recover over time, although a significant portion develop chronic dysfunction (Dodgen et al., 2016). The National Institute of Mental Health definition of these three illnesses are quoted below.

2005 Flood Damage to Existing Infrastructure

Depression is a common but serious mood disorder. It causes severe symptoms that affect how you feel, think, and handle daily activities. To be diagnosed with depression, the symptoms must be present for at least two weeks. Symptoms include: hopelessness, irritability, guilt, worthlessness, helplessness, loss of interest in activities, fatigue, and thoughts of death or suicide (National Institute of Mental Health, 2017b).

General Anxiety involves more than temporary worry or fear. For a person with an anxiety disorder, the anxiety does not go away and can get worse over time. The feelings can interfere with daily activities such as job performance, school, work, and relationships. Symptoms include: restlessness or feeling wound-up, difficulty concentrating, difficulty controlling worry, and sleep problems (National Institute of Mental Health, 2017a).

PTSD is a disorder that develops in some people who have experienced a dangerous event. People who have PTSD may feel stressed or frightened even when they are not in danger. Symptoms must last more than a month and be severe enough to interfere with relationships or work to be considered PTSD. Symptoms include: re-experience (flashbacks, nightmares), avoidance (of feelings or places), arousal and reactivity (easily startled, tense, difficulty sleeping), and cognition and mood effects (trouble with memory, low self- esteem, guilt or blame) (National Institute of Mental Health, 2017c).

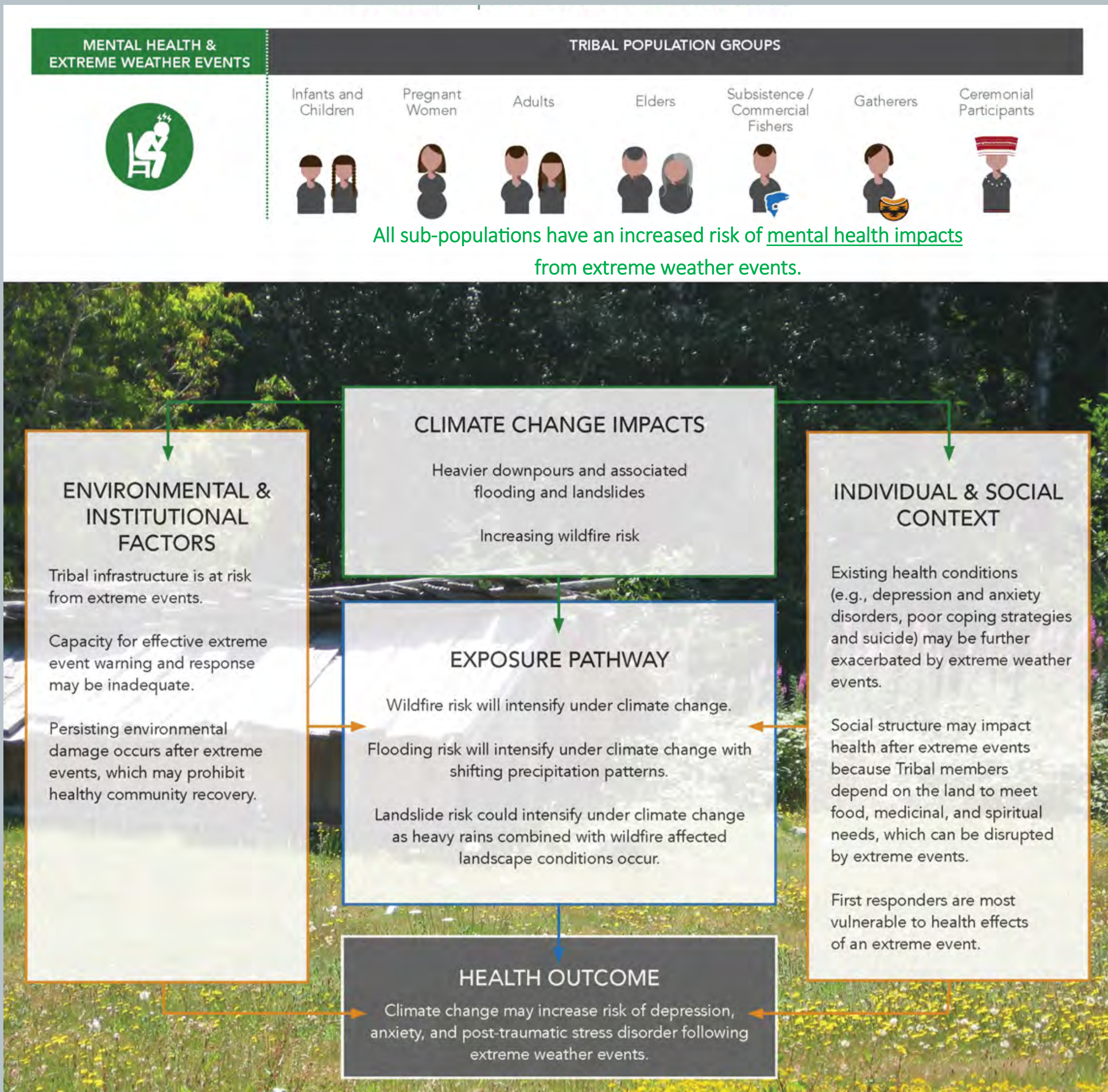
"I wanted to say something about the living houses, sweat houses. The door, you always point it towards the water. The Ocean people point it towards the ocean. The Lagoon People point it towards the lagoon, ...the River. And sweat house, of course, when you come out of a sweat house, if you went in to sweat to purify yourself. And you ran out and jumped in the water and you didn't feel like you were purified at that time, you'd go back and do it again until you felt that you're purified. "

--Axel Lindgren, III Elder Interviews 2014

People aren't prepared for this type of hardship anymore. Maybe a few old timers have enough food and water in storage in the event that conventional sources are cut off for an extended period "of time, but that's it."

— Yurok Elder

Pathway Diagram and Mental Health, Extreme Weather Events, and the Tribe



Mental Health, Extreme Weather Events, and the Tribe

Mental health impacts from extreme weather events are a concern for the Yurok Tribe. Existing mental health conditions are pervasive, including depression and anxiety disorders, hopelessness, and prejudice. Maladaptive coping strategies (e.g., drug and alcohol use, aggression, suicide) are also pervasive in Tribal communities, and in the case of the Yurok Tribe, this is evidenced by a 2016 Tribal Council action declaring suicide an emergency for the Tribe (Bell et al., 2010; Times Standard, 2016).

Extreme weather events can bring about or exacerbate existing depression, general anxiety, or PTSD given the nature of and results from these unexpected and potentially severe occurrences (e.g., forced relocation, injury, and death). Research has shown communities respond with generalized stress and worry around safety of health, property, and community under changing climate conditions (Bell et al., 2010; Bourque et al., 2014). Children, elderly, pregnant and post-partum women, and the impoverished, are more susceptible to negative health outcomes following an extreme event and have more difficulty recovering. These vulnerable populations make up a large subset of the Yurok Tribal membership (Dodgen et al., 2016). First responders, however, are the most vulnerable to health effects of an extreme event. The likelihood of injury and death is significantly higher for first responders, as well as increased rates of anxiety and depression following the event (Yurok Tribe Hazard Mitigation Plan, 2017; Dodgen et al., 2016).

Heavy winter rain storms of 2015 resulted in numerous land slides and road failures like this one on Highway 169, the only paved road access for many.

Many Tribal homes are trailers and burn extremely hot and quick, with an estimated 12-20 minutes total destruction time.

Should an extreme weather event occur, within the Yurok reservation, there are 112 buildings housing 336 people in the "Extreme" wildfire hazard area, and 65 buildings housing 195 people in the "High" wildfire hazard area (Yurok Tribe Hazard Mitigation Plan, 2017). In addition, 143 structures (87% of which are residential) exist within the 100-year floodplain. Local flooding risk will likely increase with climate change. Increased flooding may result in temporary–or under extreme circumstances, potentially permanent– displacement or mandatory relocation of communities within certain areas (Sloan, 2011).

Finally, environmental damage exists after the extreme events. Wildfires and floods continue to affect the local ecosystems long after the first response, through such mechanisms as: impaired watersheds, loss and erosion of soils, increased susceptibility to disease and infestations, and spread of invasive species (Yurok Tribe Hazard Mitigation Plan, 2017). Damage from an extreme event may slow or prohibit community recovery.

> *"Myself, fiancé and children have a limited stock of salmon which we enjoy very much. Just trying to catch one fish for a meal is very rare. The water level has effected the river over the past 14 years. This causes great concern and sadness. Our people depend on the river as it's part of our culture."*
>
> --Yurok Female, born 1981

Mental Health, Extreme Weather Events & Climate Change

For mental health and extreme weather events, the relevant climate changes are heavier downpours that create flooding and landslides, and increasing risk of wildfire. Flooding could destroy infrastructure and homes. In 1964, there was a severe flood, which wiped out the entire town of Klamath and permanently destroyed other riverside villages. Potential climate-related increases in flooding places the Tribal ancestral territory at increased risk of both flooding and landslides. Finally, wildfires can burn homes and destroy traditional harvest or ceremonial sites. *"The risk of wild land and structure fires will go up exponentially if there is not a dramatic change in the weather…Elders, children and infirmed community residents will be most at-risk in the event of an out-of-control forest fire (page 11)"* (Yurok Today, 2014).

Adaptation Strategies to Reduce the Risk of Mental Health form Extreme Weather Events

Institutional
- Consider implementing all Adaptation Strategies in the Multi-Generational Trauma health pathway to develop a base of mental health resiliency in the Yurok Tribal community and respond to existing health conditions. - Work to increase emergency response process, funding and extreme climate and weather events (e.g., firefighting, public safety calls), through enhanced staffing and equipment. - Raise awareness among mental health providers about climate impacts, potential loss of traditional foods, and response. - Expand public education and outreach to people living in or near the fire hazard zones. This should include infor mation about and assistance with mitigation activities such as defensible space, and advanced identification of evacuation routes and safety zones. - Consider establishing programs to discuss and educate residents in flood plain and landslide areas about prepared ness and the resources available during and after emergency events. - Consider conducting door to door education of households who might be at risk or have high needs such as elderly, infants, or the chronically ill.
Individual
- Engage in institutionally organized activities to enhance social cohesion, promote mental wellness, and reinvigorate cultural practices and traditions. - Consider developing emergency evacuation plans and in-home kits to prepare for potential extreme events (e.g., fire, flood). - Visit the elders to get to know them and their lived stories to help you see other paths.

Multi-Generational Trauma

Multi-generational trauma is a reality for the Yurok Tribe. Yurok Tribal members have a long history of dealing with the psycho-social impacts from destruction of natural resources and the loss of traditional aquatic foods (Yurok Tribe Interim Cleanup Standards, 2015). Multi-generational trauma generally refers to a three-phase process (Brown- Rice, 2017):

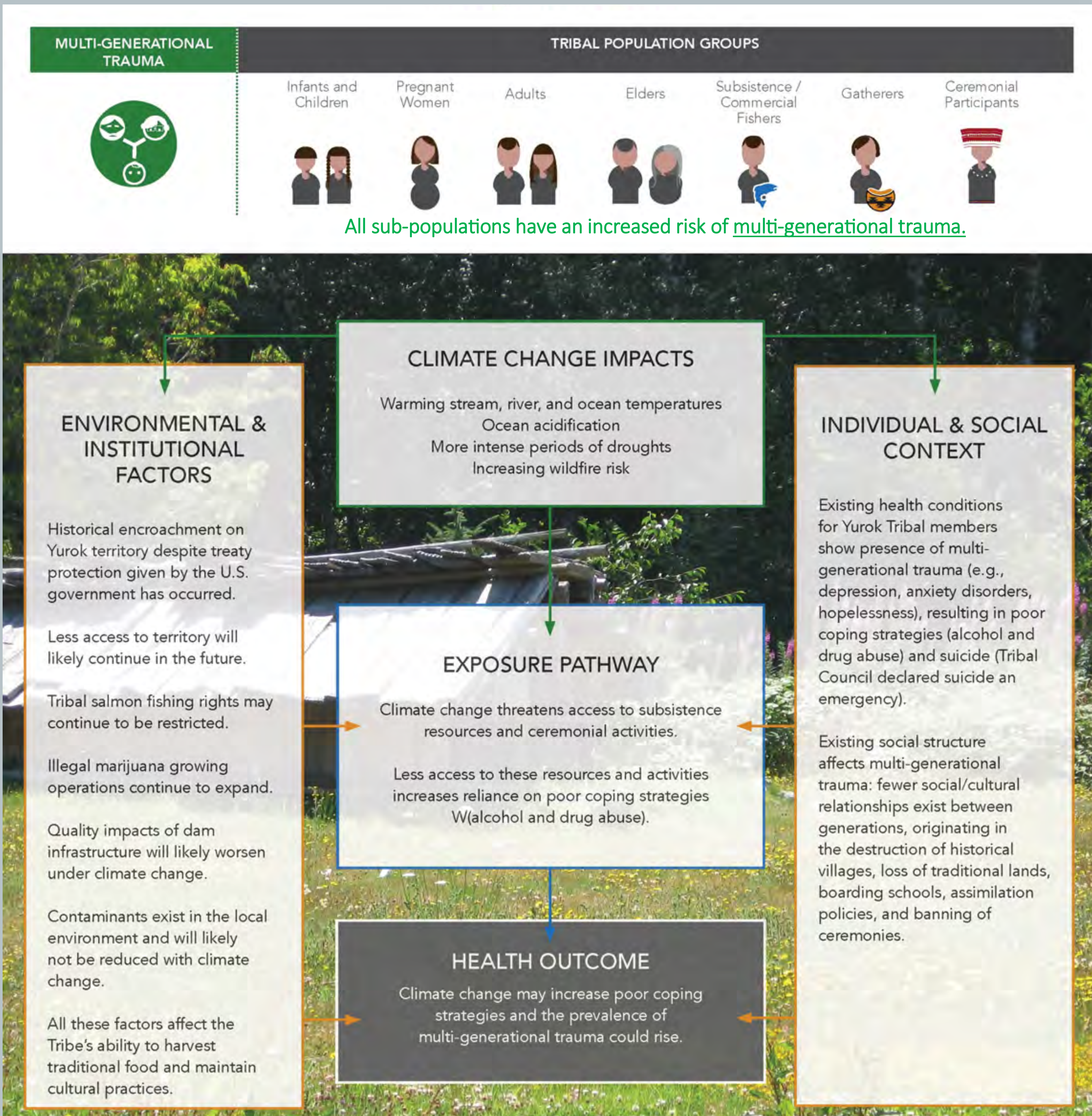
1) Traumatic "loss" of culture, belief systems, family, or traditional resources experienced by one generation.

2) The affected population shows physical and psychological symptoms in response to the trauma which pro motes illness (depression, anxiety) and maladaptive coping behaviors (e.g., drug and alcohol use, violence, and aggression) among the population.

3) This exposes the next generation to these illnesses and maladaptive behaviors, who in turn display similar symptom perpetuating those same outcomes in future generations (American Academy of Pediatrics, 2017)

Note: See Appendices for a comprehensive list of adaptation strategies for Mental Health & Extreme Weather Events

Pathway Diagram for Multi-generational Trauma and the Tribe



Multi-generational Trauma and the Tribe

Mental health conditions are widespread within the Tribe, resulting in feelings of hopelessness and maladaptive coping strategies (drug and alcohol use) and suicide. Further, *"American Indians and Alaska Natives are plagued by high rates of suicide, homicide, accidental deaths, domestic violence...and alcoholism as well as other social problems...We suggest that these social ills are primarily the product of a legacy of chronic trauma and unresolved grief across generations (page 37)"* (U.S. Department of the Interior, 2012).

In conversations with Yurok Social Services Department staff, the need to focus on strengthening Tribal members' connection to their culture as well as work to provide basic needs are critical to combat this cross generational trauma facing the Tribe. "*In addition to the high degree of trauma and stress from losing much of their culture, land, fish, and barter economy, in addition to experiencing high disease and mortality rates, and many important associated factors, Yurok Tribal members have the added stress of meeting basic needs (page 68)"* (U.S. Department of the Interior, 2012). High poverty rates and high unemployment demonstrate that families are struggling to meet their basic needs and lack food security.

The Yurok community has come out in full force for the 2017 Third Annual Suicide Awareness Walk that brings all ages together to show inter-generational support.

In 2016 the Tribal Council declared an emergency after receiving a petition, signed by approximately 200 upper Reservation residents, asking the governing body for help with culturally appropriate prevention after 7 young men and fathers took their own lives in the upriver communities around Weitchpec. All of the suicides were committed within an 18 month span and their ages were between 16 and 31. Local residents identified potential root causes of the feelings of hopelessness to include the geographic isolation, lack of positive activities and the scarcity of job opportunities, in combination with historical and ongoing trauma. Participants of the meeting also emphasized that easy access to illicit drugs, brought in by an onslaught of out-of-town illegal marijuana growers, was another big part of the problem.

Several community gardens have been planted to promote healthy alternatives and relieve stress of food insecurities.

Multi-generational Trauma and Climate Change

For multi-generational trauma, the relevant climate changes are warming creek, river, and ocean temperatures, ocean acidification, more extreme periods of drought, and increasing risk of wildfire. Warmer creek and river temperatures increase the likelihood of freshwater HABs, limiting the ability of Tribal members to safely come into contact with the Klamath River water, increasing the stress over deciding if it is better to possibly lose those cultural activities and aquatic subsistence foods or to continue and risk health impacts for themselves and their children. Also, warming ocean temperatures increase the likelihood of marine HABs, limiting the ability of Tribal members to safely harvest marine shellfish.

Ocean acidification could undermine the food web for salmon and other traditional foods and further decrease their abundance. More intense periods of drought can concentrate contaminates and negatively affect the availability and use of traditional foods. Finally, wildfires could burn homes and destroy traditional harvest or ceremonial sites.

These potential climate changes point to a continued disruption of the Yurok way of life, through loss of subsistence foods, limits to harvesting and decreases in cultural practices that are dependent on having the resource available to teach the proper respect and cultural knowledge sharing around harvesting and spiritual practice. Decreased quality of river water and forest environment inhibits ceremonial practice and activities in these

Local Yurok language classes have been ongoing as a response to build community connections and battle isolation.

locations. Reduction in subsistence food quantity reduces cultural activities and education around these resources form the foundation of Tribal identity (Gamble et al., 2016).

Dietary alternatives to replace subsistence foods (e.g., store-bought foods) do not promote cultural values to the younger generation. The difficulty in meeting basic needs (such as dietary requirements) can result in overwhelming psychological stress (U.S. Department of the Interior, 2012). Enculturation (e.g., promotion of cultural identity) supports psychological well-being and adaptive coping strategies (Bell et al., 2010). Finally, ceremonies originate from the pre-historical period and may be associated with species (e.g., Spring-run Chinook) that are difficult to procure under modern conditions, and that are highly vulnerable to climate change (U.S. Department of the Interior, 2012). Engaging in subsistence activities can reduce multi-generational trauma.

Adaptation Strategies to Reduce the Risk of Multi-Generational Trauma

Institutional

- Develop and expand existing programs to increase youth empowerment, including youth forums, language revitalization, and community organizing trainings to support further reintegration back into culture.
- Provide opportunities to connect people (especially youth) back to the land through land management projects and sustainable food practices.
- Promote opportunities to have community members gather and increase social cohesion and engage in cultural activities as an opportunity for mental health wellness.
- Enhance support for women's and men's groups to increase social cohesion and promote mental wellness (e.g., men's sweat lodge, women's beading and basket weaving classes).
- Teach culturally appropriate ways to express love in a healthy manner through all Tribal programs, ceremonies and gatherings.
- Invest and find additional funds to expand Social Services to respond to impacts from multi-generational trauma.
- Increase cross and interdepartmental collaboration to provide basic services (e.g., economic opportunities, electricity, phones, water) to break the cycle of poverty.
- Develop and expand suicide prevention programs (e.g., modify the Applied Suicide Intervention Skills Training for a tribal context).
- Develop a pamphlet or storybook that retells the Yurok story on how to process grief and live without focus on death

Individual

- Love and care for all children to begin to heal the wounds of past generations.
- Engage in organized activities to enhance social cohesion, promote mental wellness and return to culture.
- Visit with each other to cultivate conversation and relationships.

Note: See Appendices for a comprehensive list of adaptation strategies for Multi-Generational Trauma.

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Additional Information

- The Institute for Tribal Environmental Professionals (ITEP) at Northern Arizona University established its Tribes and Climate Change Program in 2009. The program provides support for and is responsive to the needs of tribes who are preparing for and currently contending with climate change impacts. Their staff played an integral part in all components of this project. For more information, please visit our website at: http://www7.nau.edu/itep/main/tcc.
- "Guidelines for Considering Traditional Knowledges in Climate Change Initiatives," A resource for tribes, agencies, and organizations across the United States interested in understanding Traditional Knowledges in the context of climate change: https://climatetkw.wordpress.com/
- "The Climate and Traditional Knowledges Workgroup – CTKW" is an informal group of indigenous persons, staff of indigenous governments and organizations, and experts with experience working with issues concerning traditional knowledges who developed a framework to increase understanding of access to and protection of TKs in climate initiatives and interactions between holders of TKs and non-tribal partners: https://climatetkw.wordpress.com/
- Additional Chapters of the Yurok Tribe Climate Change Adaptation Plan for Water and Aquatic Resources can be found on the Yurok Tribe Environmental Program's Community and Ecosystem division webpage at http://www.yuroktribe.org/departments/ytep/com_eco_division.htm

Yurok Tribe Climate Change Adaptation Plan for Water & Aquatic Resources

Chapter 8 – Overarching and Key Cross-Cutting Adaptation Strategies

In This Chapter

In times past and now Yurok people bless the deep river, the tall redwood trees, the rocks, the mounds, and the trails. We pray for the health of all the animals, and prudently harvest and manage the great salmon runs and herds of deer and elk. we never waste and use every bit of the salmon, deer, elk, sturgeon, eels, seaweed, mussels, candlefish, otters, sea lions, seals, whales, and other ocean and river animals. We also have practiced our stewardship of the land in the prairies and forests through controlled burns that improve wildlife habitat and enhance the health and growth of the tan oak acorns, hazelnuts, pepperwood nuts, berries, grasses and bushes, all of which are used and provide materials for baskets, fabrics, and utensils.

– Preamble of the Constitution of the Yurok Tribe, 1993

This Adaptation Plan started from the community-driven understanding that climate change planning needs to be holistic and take into account the Yurok worldview on the inter-connectedness of all things. In this way, climate change is considered in the broader context in which it is taking place. Chapters 4-7 discussed the interaction between climatic and non-climatic factors to create impacts on Yurok Tribal Members' water, aquatic resources, and health. Some of these non-climatic factors go beyond the sphere of local ability to affect the Tribe's management of their water and aquatic resources in the face of climate change.

This chapter discusses these existing challenges, as well as strengths, which fall into the areas of communication, funding, staffing, monitoring, education, and traditional and community knowledge. The chapter then identifies key cross-cutting adaptation strategies and more specific paths forward that might be particularly beneficial to pursue in the near-term. These build on already existing Tribal strengths and were chosen with the goal of continuing to empower the Yurok people to take care of the waters, lands, and species that take care of them, and to use their traditional legacy of preparation and

Yurok staff planting seedlings for restoration work

This plan is from a purposeful collaboration with the staff and community members of the Yurok Tribe, as well as several organizations, and would not have been successful without each of their contributions. https://www.yuroktribe.org/departments/ytep/com_eco_division.htm

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8.1 Overarching Non-Climatic Factors

Existing challenges (sensitivity)

There are a number of sensitivities – or existing challenges – that exacerbate the climate factors facing the Yurok Tribe and need to be taken into consideration when developing adaptive strategies to manage water aquatic resources.

Communication

A key existing challenge for the Yurok Tribe is that its departments typically work in silos, with limited interdepartmental consultation and collaboration. Project results and findings are not always shared. This inhibits the ability to restore and manage ecosystems as a whole.

In addition, it can be challenging for Tribal staff to stay connected with the general Tribal membership and what is most important for Tribal Members. Some of this disconnect may be attributed in part to the need for Tribal staff to pursue federal or state funding for projects with goals that may not always align with Tribal Members' interests. Some of the disconnect may be due to lack of funding for community outreach, which is, for example, a barrier to fully implementing the Local Environmental Observer Network. Community attendance at District meetings is often low, and Tribal staff may also not attend meetings regularly. In both cases burnout and other, immediate priorities may play a role. Different methods may be needed to communicate with upriver versus downriver Tribal residents and with Tribal Members who live on- versus off-Reservation.

Difficulties with respect to communicating with federal and state agencies include high turnover on both sides with the associated loss of relationships built and knowledge gained about Tribal concerns and Tribal and federal and state processes. In some locations, lack of cell phone, satellite phone, and internet coverage can inhibit communication. However, at the same time, resource managers and community members are worried that, where there is coverage, attachment to cell phones, video games, tweets, and short texts is increasing at the expense of in-person visits with more extensive listening and of sharing between the generations.

Funding

The Tribe is highly dependent on state and federal grants to fund climate change and natural resource planning and implementation. The processes to secure the agency funds may be complex and difficult to understand and when available, such funding is often insufficient when considering widespread, existing needs. The funding is also typically highly competitive, short-term, and project-based rather than on-going and stable. This can limit Tribes to piecemeal rather than holistic planning and management approaches and makes it challenging for departments or even individual staff to consistently and continuously plan for multiple years and work on long-term processes. Last, but perhaps most important is that it often restricts Tribal departments to state and federal priorities that may not always align with Tribal ones. Strings may also be attached to the funding that don't line up with Tribal goals and values, such as valuing Tribal sovereignty over data generated.

Staffing

Tribal departments can be understaffed and retention of personnel can be low because of the remote location and distance between Tribal offices and communities, both on and off Reservation, requires long commutes. Also, salaries and benefits are often not competitive with similar positions elsewhere. Low personnel retention can lead to disjointed institutional memory in which staff don't pass on knowledge gained and lessons learned. This inhibits new staff from being able to pick up and continue where former staff left off and complicates being able to work on an issue like climate change over the long-term. Turnover in Tribal Council can also present challenges for addressing climate change issues, which span changing political cycles.

Tribal saff may also need to be brought up to speed on changing climate change projections that are continually being updated and has special language associated with it. In particular are the evolving climate change tools, for example for climate change vulnerability assessments and scenario planning. Specific staffing needs noted during interviews with resource managers included lawyers (and resources) to enforce tribal ordinances, a statistician to assist with data analysis and use, and a grant writer with relevant scientific background to assist with preparing restoration project proposals.

Table 8.1 Projected Climate Changes Affecting Yurok Aquatic Resources
Changes in Air Temperatures Rising air temperatures
Changes in Precipitation Regimes Precipitation amounts are uncertain Heavier downpours
Changes in Ocean Processes Rising sea levels > increasing coastal inundation > erosion & intrusion into estuary and coastal aquifers Ocean acidification
Changes in Inland Hydrology Shift from snow to rain > increasing winter flows & floods; Reduced late spring/summer flows in river, creeks, & springs Increasing drought intensities
Changes in Inland Water Quality Warming surface water temperatures > lower dissolved oxygen; Expanding harmful algal blooms & water-borne pathogens
Changes in Fire Regimes Fire seasons are expected to become longer with increased frequency and extent.
Combined Effects Decreasing snowpack, earlier spring snowmelt Warming ocean temperatures > increased harmful algal blooms Heavier downpours > increase surface water sheeting > erosion > increasing turbidity, sedimentation & higher pollutant loadings Fire exposed slopes will further add to effects

Monitoring

Long-term, local datasets are scarce or lacking, and data that are available are not always easily accessible. This can inhibit the understanding of shifts and trends taking place in water quantity, quality, and ecosystems; hinder the assessment of adaptation and restoration effectiveness; impede the enforcement of regulation; and limit the gathering of evidence needed to supporting and obtain grant funding.

Youth education and engagement

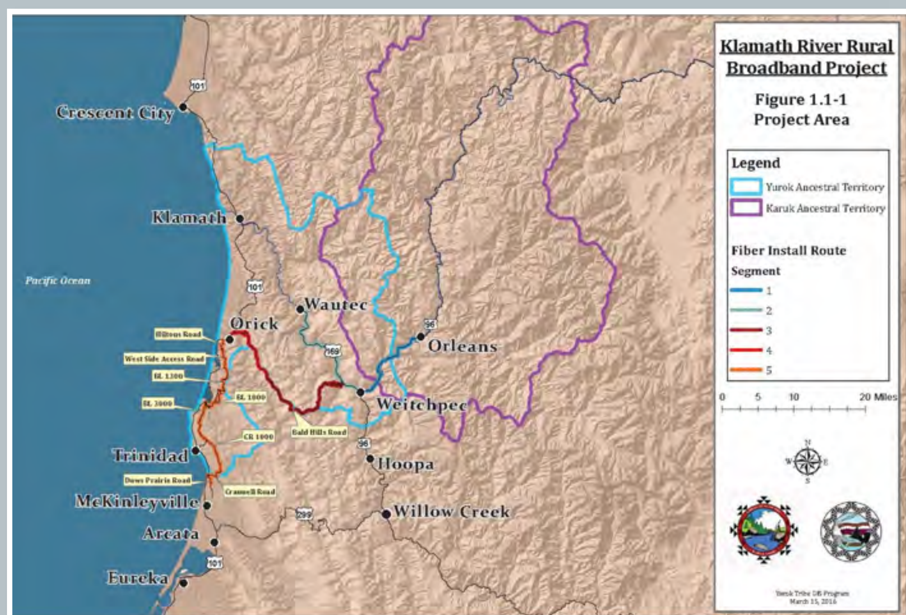
The Tribe faces some challenges in educating the next generation of Tribal leaders and resource managers engaging in climate education and adaptation work. For instance, the rate of absenteeism in the elementary schools is chronic and quite high. For the 2016-17 school year, the rate of absenteeism at Margaret Keating Elementary School was 44.3% as compared to 24.2% for all the schools in the Del Norte County Unified School District and 10.8% for all schools California-wide (CDOE 2018). A student is considered chronically absent if they miss 10% or more of the days they were expected to attend (CDOE 2018). Another concern that was expressed by education staff is the graduation rate for Native students in Del Norte and Humboldt Counties' high schools.

Yurok strengths (adaptive capacity)

The Yurok Tribe also has a great deal of adaptive capacity – or existing strengths – to enable and empower the Tribe to adapt to climate change.

Communication and connection

In 2016, the Yurok Tribe created a new position – Natural Resources Division Coordinator – to enhance collaboration among the programs and departments within the division including the Environmental Program, Fisheries Department, Forestry Program, Watershed Restoration Department, and Wildlife Program.



The Tribe also has a Public Relations Manager who is responsible for producing the monthly *Yurok Today* newsletter and maintaining a Tribal social media presence on Facebook and Twitter. All are helpful resources for Tribal Members and staff to keep up to date on happenings both within the Yurok government, departments, and communities.

Yurok also place a great deal of value on listening to others, especially elders, and they have time-honored traditions of visiting and helping one another, as well as being stewards of the environment. The Tribe builds community and communication through maintaining ceremonies and holding gatherings like the Salmon Festival, which draws both Tribal Members and non-tribal members alike to return to the Reservation. The annual Klamath River Clean-Up event routinely attracts at least 200 and sometimes over 300 people in the spirit of kinship and unity to take care of the river that for generations has taken care of the Yurok People.

To address phone and internet connectivity issues, the Yurok and Karuk Tribes have pursued the Klamath River Rural Broadband Initiative, which has extended high-speed broadband services to Wautec and Weitchpec (Yurok Today 2013). Finally, to enhance connectivity and lessen commute time between upriver and downriver locations on the Reservation, the Tribe is operating a river ferry to transport people back and forth between Weitchpec and Klamath during the summer and early fall months. This traditional route is a more direct route than the current options of traveling between the two locales and cuts the commute from an hour and a half to just a little over 30-35 minutes.

Staffing

A conscious decision by Tribal administrators to enable Yurok to sit at any negotiation table on an equal standing to other Federal and State agencies was to recruit the best scientifically trained personnel possible to represent Yurok values and protect Yurok lifeways. This has resulted in many excellent biologists, planners, engineers, and more working within a wide cross-section of Tribal departments. These staff conduct outstanding research and monitoring and have been able to bring in a wide range of grant funding for infrastructure and natural resource management projects on the Reservation. They are adept at acquiring resources and stretching what they have available to them to complete the most comprehensive work possible. In addition to regular staff, the Yurok Tribe Environmental Program (YTEP) consistently hosts two Watershed Steward Project AmeriCorps volunteers who are a major asset in supporting watershed-related work. Altogether, Yurok staff believe deeply in their roles as stewards of the Yurok Reservation and Ancestral Territory.

Legal

Tribal ordinances (for example, related to yearly fish quotas) can be changed fairly quickly to adjust to increasingly uncertain environmental conditions that may occur with climate change and are designed to include Tribal values and practices such as restorative justice.

Yurok Justice Center and location for the Tribal Court where tribal values are strengthened through traditional restorative justice .

- Education and Engagement

A variety of opportunities exist for Yurok Members to further their education from pre-school through college. This could ultimately support cohorts of Members who can work on climate change adaptation for the Tribe. The Tribe hosts Early Head Start (0-3 year olds) and Head Start (3-5 year olds) programs in Klamath, Ke'pel, and Eureka. The Johnson O'Malley K-12 tutoring program is designed to provide help for struggling students and advocate on their behalf, as well as provide support to parents. At the high school level, the Tribe has helped start Yurok language programs at schools in Hoopa, Eureka, and McKinleyville.

Beyond high school, the Tribe has initiated a telepresence with the College of the Redwoods, a public two-year community college, in which Tribal Members use their smartphones to download information for courses such as such as calculus and political science. To help with the transition between high school or community college and four-year colleges, nearby Humboldt State University participates in a dual enrollment program with the College of the Redwoods and also has an Indian Tribal and Educational Personnel Program (ITEPP) that provides support to Native American students attending the university. In addition, Humboldt State hosts a program, the Klamath Connection, that supports a cohort of freshman taking science and general education courses and engaging in research focused on the Klamath River. Although currently there are not many Native students involved in the program, it is an opportunity into which Native students could tap.

Outside of a strictly academic arena, youth can also participate in the U.S. Fish and Wildlife Service's Klamath Tribal Youth Program, which provides local youth with natural resource management experiences and career education. The Warrior Institute, a non-profit organization based in Hoopa, hosts programs including river, ocean, mountain, fitness, food and farm, language, and arts programs. These are designed to awaken the "warrior spirit" in Tribal youth to actively pursue wellness, balance, and world renewal.

Traditional and Community Knowledge

Yurok Tribal elders and community members have a wealth of traditional and community knowledge that has informed this adaptation planning process during all stages. This includes understandings of how the climate has been changing, insights into species' behaviors and roles within ecosystems, and knowledge of how non-climatic factors are interacting with climatic ones to impact aquatic resources on the Reservation and in the Yurok Ancestral Territory. It also includes identifying adaptation strategies that can increase the resilience of both ecosystems and people.

Adaptation strategies that were identified to address the challenges described above making use of existing Yurok strengths are included in Appendix 8.1.

8.2 Key cross-cutting adaptation strategies

During the planning process, ideas from Yurok Tribal Members, Tribal staff, and a literature review resulted in over 400 adaptation actions being identified. These potential actions provide an extensive menu for Yurok Tribal departments, staff, and Members to choose pathways on how to move forward. Some actions may be relatively easy and require minimal cost to implement while others may require longer-term sustained effort. The actions may become more or less applicable when considering staff and funding sources available to accomplish them. For those that seem out of reach with current resources, they could be used as touch points to focus on building capacity.

In order to focus and guide next steps in executing this climate change adaptation plan, the planning team evaluated the actions identified throughout the process and considered factors such as whether the actions 1) address important areas of concern, 2) are in line with the Yurok holistic world view on the inter-connectedness of all things, 3) provide benefits across multiple habitats and species and 4) the degree of benefit provided and whether they might cause harm in some way.

Taking into account these factors the team honed in on three overarching adaptation themes that together help restore balance to the ecosystem and support Yurok water and food sovereignty and Tribal health. One theme that emerged centered around restoring and strengthening healthy and connected species and ecosystems. A second theme revolved around restoring and strengthening healthy and connected individuals and communities, and a third theme focused on restoring and strengthening human-environment connections. All of these are key components in the Yurok conceptualization of health. For Yurok, health includes spiritual, mental, emotional, and physical health and encompasses the intricate relationships and shared histories that the Yurok have with their waters, lands, and the species within them. If the river is sick, so are the people. The health of all is integral to the health of one, and healthy ecosystems are inextricably linked to healthy people. This is in the spirit of the Yurok word Hey-wec-hek. While these themes are discussed as separate from one another below, we acknowledge that they are intertwined and overlap.

Because of a variety of historic legacies, the natural resiliencies of species and ecosystems in Yurok country and of the Yurok people to climate and other changes have been severely disrupted and the ecosystem is no longer in balance. As a result, the health of the Yurok and their relations in, and relationships to, the natural environment have been compromised. Legacies contributing to this disruption include large dams, destructive logging practices, forced boarding schools, the decimation of beaver and sea otter populations, overharvesting, and the suppression of the Yurok language and of cultural and spiritual practices (Chapter 1/Ch. 1). Healing and transforming the damage done by these past practices and events can help restore balance and lead the way to increased climate resilience.

For each of the three broad themes noted above, the planning team identified different strategies for achieving these goals as well as some more specific approaches and potential next steps or actions.

THEME #1: HEALTHY AND CONNECTED SPECIES AND ECOSYSTEMS

As noted above, many aspects of the ecosystems and species in Yurok country are out of balance and their natural resiliencies to climate change have broken down. To address this and the goal of Healthy and Connected Ecosystems and Species, four broad strategies have been identified. These include:

1. Restore the river
2. Manage/restore the forested watersheds to improve water quantity and quality
3. Restore nearshore habitat
4. Sequester and reduce greenhouse gas emissions

Different approaches and potential actions under these strategies have been identified and are summarized in Table 8.1 and discussed below. In many cases, Yurok are already engaging in practices that increase climate resiliency, in particular, the use of process-based restoration techniques that address root causes of ecosystem disruptions rather than just the symptoms (Beechie et al. 2010). The approaches and actions noted below make use of these already existing Yurok strengths.

Strategy 1 - Restore the river

Since Noohl Hee-Kon, the beginning of time for the Yurok people, the Yurok have inhabited the most downriver lands of the Klamath River. They have observed the connections and complexities of the river and the streams that feed into it and of all the species within them (Ch. 1). Dams, historic logging, *Cannabis* cultivation, and climate change are past legacies and current challenges altering the nature of riverine relationships. Restoring the river and reconnecting it can increase resilience to all these different changes that are or have taken place.

Dam Removal

Ever since dams on the Klamath River mainstem went up during the first half of the 20th century, Yurok have been working to take them down (Ch. 1). They have good reason. Dams and their reservoirs can warm summer water temperatures, lower flows to unhealthy extremes, contribute to harmful algal blooms (HABs) nearly 200 miles downstream, and disrupt natural patterns of flow and of sediment transport (Chs. 3, 4, 5). They also block fish access to traditional spawning territory upriver and the flow of cool water from voluminous instream springs downriver (Ch. 6). All of this has negative consequences for fish habitat and stress levels, the health of recreational and subsistence fishers in mainstem waters, and the dynamics of the sand spit on the Klamath River Estuary, the extent of which can potentially hinder fish movement in and out of the river system (Chs. 4, 6, and 7). Climate change may exacerbate the impacts of the dams or the dams may exacerbate the impacts of climate change. From either perspective, the combination has the potential to be serious and possibly devastating. Dam removal can provide multiple benefits for increasing resilience to climate change.

The extreme drought in California coupled with water withdrawals left the Klamath, the second largest river in California (average discharge of 16,780 cubic feet a second)[1] with still, extremely low flows in 2012, 2013, & 2014.

[1]"Water-Year Summary for Site USGS 11530500". U.S. Geological Survey. Retrieved 2017-01-08. The average discharge is an annual mean based on data from water years 1963 through 2016.

Now after decades of developing relationships and building understanding and rapport, and after many twists and a heart stopping turn when dam removal agreements expired in the U.S. Congress, four of the mainstem dams are scheduled to come out in stages starting in 2021 (Chapter 4/Ch. 4, KRRC 2018). When they do, this multi-partner effort will become the largest dam removal in U.S. history, and it will offer fish populations that have been slammed in recent years by both adult and juvenile fish kills an increased chance for survival and an opportunity for many salmon to finally return home (Chs. 4 & 6).

Potential actions with respect to the upcoming dam removal include:

- Assess near and longer-term impacts of dam removal on fish habitat and drinking water sources, facilities.
- Take relevant preparatory actions.
- Instream/riparian restoration

Dams disrupted natural flows and sediment transport in the river system. Historic logging practices and *Cannabis* clearcuts smoothed, simplified, and disconnected it. To facilitate log drives with minimal interruptions and greater efficiency, logging companies stripped riparian banks of old growth redwoods and spruce and cleared the way instream by harvesting wood out of streams, blasting streambeds to remove large rocks, boulders, and other obstructions, and blocking off side channels and wetlands (Ch. 4). This degrades habitats for fish and other aquatic organisms and disrupts natural mechanisms that streams have for cooling themselves. In addition, massive erosion and sedimentation from old logging roads and *Cannabis* clearcuts have filled in deep holes that serve as cold water refugia and sturgeon spawning grounds and cut off fish access between the mainstem and cooler tributaries.

Yurok restoration efforts include replanting of native willows along stream banks to provide water and fish shade and relief from warming summers.

Restoring the river system's complexity could significantly improve fish feeding and spawning grounds and increase ecosystem resilience to a warming future. Reintroducing large woody debris could for example, slow the mixing of cooler groundwater with warmer surface water thereby permitting cool water pockets to form. Another benefit to the strategic placement of instream logs would be their contribution to localized scouring and the formation of pools to fill with cooler waters (Ch. 4). Restoring complexity to streambed topography from adding rocks and other obstructions could enhance groundwater-surface water interactions contributing to cooler stream temperatures and allow the reconnection of streams with their floodplains and side channels that would allow waters to recharge the aquifers that provide cooler baseflow to streams during low flow periods (Ch. 4). Replanting riparian redwood seedlings that could grow into towering 200-300 foot trees would increase stream shading, and the removal of sediments blocking fish passage from the mainstem into outer stream reaches could provide fish with some cooler respite. The Yurok Tribe's Fisheries Department has been establishing a strong record of instream and riparian restoration work. Continuing and increasing these efforts can be a key adaptation to climate change

Potential Tribal instream/riparian restoration actions include:

- Expand restoration work to include additional creeks and side channels.
- Assemble a set of lessons learned from previous restoration work.
- Develop a plan to coordinate instream restoration with watershed restorations to achieve optimal benefits.

- Develop an *Adopt a Redwood Seedling* program to increase riparian shading.

Potential personal instream/riparian restoration actions include:

- Plant and care for a redwood seedling to increase riparian shading.
- Use energy efficient wood stoves to decrease wood taken from streams to save fish habitat.
- Don't harvest woody debris from streams to save fish habitat.
- Avoid driving on unrehabilitated or seasonal logging roads when wet to decrease erosion.

Explore feasibility of establishing a Yurok Riverine Institute

Research, monitoring, restoration, and other adaptation projects all cost money. One idea discussed is the establishment of a Yurok Riverine Institute that would provide research opportunities and training in traditional Yurok management practices and restoration techniques at a fee, or rent facilities' space to university and NGO researchers. This would make use of Yurok strengths and could help fund various adaptation efforts while at the same time spreading Yurok values (see below) and commitment to stewardship for all beings within the Lower Klamath River basin.

In particular, given that one estimate suggests that 80-90% of all *kah-kah* (North American green sturgeon) spawn in the Klamath River basin, this could afford some unique opportunities for studying the biology of this long-lived (up to 40-70 years) and sacred species (Ch. 6). The upcoming removal of four mainstem dams could also provide a distinct opportunity to study the recovery of a river system and of salmon populations and the populations of other aquatic organisms (Chs. 1, 4, 6). Finally, the Blue Creek Land Acquisition and management via a Traditional Management Plan opens up the possibility of investigating how traditional management of a forested watershed could influence the ecology of streams in the face of climate change.

Potential next steps include:

- Consider potential partners for developing a Yurok Riverine Institute focused on fish biology and restoration science research, and teaching Yurok Traditional Management practices.
- Research models, practices, and lessons learned in establishing similar institutes or related activities (one example is the Menominee Tribe's Forestry Center in Keshena, WI).

Strategy 2 – Manage/restore forested watersheds to improve water quantity and quality

Forested watersheds provide many gifts or ecosystem benefits to those who inhabit them. Their mosaic of trees, prairies, and wetlands provide wood for heating, berries for gathering, elk for hunting, and hazel sticks for weaving. Their infiltration of rain and snowmelt that ultimately feeds streams and wells can also supply clean, cool, and ample water for drinking and swimming, and, if you are an aquatic organism, for living. Historic logging and management practices in Yurok country, however, have changed the nature of forested watersheds and diminished some of the services they supply. Today, many forests in Yurok country are overstocked and their composition changed. Prairies and wetlands have been lost, and a mishmash of logging roads now criss-cross their surface (Ch. 4). All of this can lead to reduced water deliveries, lower water quality, and increased erosion and sediment transport into the river system. As a result, fish and other aquatic organisms could face warmer waters, degraded feeding and rearing habitats, higher pollutant concentrations, and other impacts (Chs. 4, 6). Climate change, with anticipated increases in water temperatures, increasing drought intensities, heavier downpours, and greater wildfire frequency and extent, could exacerbate the changes being experienced. Restoring forested watersheds could help increase aquatic ecosystems' ability to tolerate upcoming climate changes.

Cultural and prescribed burning

Burning is a natural occurrence in forested watersheds. Among the Yurok, it is also a time-honored management tradition.

Burning ensures a healthy supply of basket weaving materials, keeps hazel nut and acorn pests at bay, and rejuvenates grasses consumed by large game like elk and deer (Yurok Today 2013, 2014). Twentieth century suppression of cultural burning and wildfires in general have contributed to forests that are overstocked with trees and overgrown with brush, likely leading to decreased water yields from forests to streams (Chs. 1, 4). Climate change, with anticipated lower summer flows and increasing drought intensities, could intensify this and affect water supplies (Ch. 3). Fire suppression has also led to dangerous levels of fuel loads in forests that can transform what might have been smaller blazes into large, catastrophic fires. Again, climate change can act as an amplifier, increasing wildfire frequency and extent. The vegetation and soil effects of large-scale fires can result in earlier snowmelt, temporary increases in rapid runoff and water temperatures, and increases in erosion and water turbidity, all of which can negatively impact aquatic life and drinking water (Chs. 4, 5, 6).

By decreasing the overstocking of watersheds and helping prevent small fires from becoming larger, devasting stand-replacing ones, cultural and prescribed burning could decrease impacts on aquatic resources and increase the climate resilience of ecosystems and people. Additional benefits include helping to lessen deteriorating air quality that would result from more wildfires while protecting lives and property from wildfire effects. The Yurok Cultural Fire Management Council has been taking a leading role in reintroducing this traditional practice, which was once banned, in a modern context, and has been gaining a variety of experience, lessons learned, and widespread support.

Potential Tribal actions to further the implementation of cultural and prescribed burning include:

- Assemble guiding principles & lessons learned by the Cultural Fire Management Council on burning practices.
- Integrate these lessons into Natural Resources planning.
- Conduct research into how water levels in springs and tributaries are altered after cultural/prescribed burns.
- Conduct research into effects on water quality from cultural burning on stream banks and riparian areas.

Potential personal actions to further the implementation of cultural and prescribed burning include:

- Join the Yurok Cultural Fire Management Council.
- Share observed environmental changes following cultural burns with the Cultural Fire Management Council.

Maintain/restore prairies

When you drive on Bald Hills Road between Highway 101 and Weitchpec, amidst all the trees and around the next bend, you sometimes emerge into a very different landscape, one that gives the Bald Hills their distinctive name. A patchwork of prairies may contain elk grazing, birds of prey watching, and, during spring and summer, flowers bursting in color as they sway in the breeze. An open prairie vista is much rarer now in Yurok country than it used to be. Historic logging practices in which meadows were planted in with conifers took its toll (Ch 4). So did the banning of cultural burning and the general forest-wide policy of fire suppression, which also allowed conifer encroachment into prairies (Chs. 1 and 4). According to a YTEP study that is in progress, the loss of these culturally and ecologically valuable habitats in Yurok Ancestral Territory may be close to 95% (Ch. 4).

Bald Hills Road travels from the cool redwood forests and rises in elevation until it opens out on the ridge tops of prairie/oak habitat.

Prairies can play an important role in the water cycle of forested watersheds. The conifers that in many instances have replaced prairies evaporate water captured on their needles throughout the year (Ch. 4). The evaporation of water captured on grasses however, tends to be low, leading to greater groundwater recharge, which ultimately contributes to streamflows (Ch. 4). In addition, during high precipitation periods, like winter rains, prairies can hold and store water in both the thick layer of dead and composting leaf mold and the rich upper layer of highly interconnected root zones. They then release it later on during low flow periods, like during summer (Ch 4). These kinds of functionalities could boost resilience in a warming world with potentially increasing drought intensities in Northern California. In addition, prairies have the potential to improve the quality of water that emerges as stream baseflow later on and that might potentially be used for drinking (Ch. 4). Prairies also support elk herds, smaller mammals, birds, and other species important to Yurok such edible bulbs, medicines, and hazel sticks for weaving. During years in which fish are scarce, elk could provide a valuable alternative food source. The Yurok Cultural Fire Management Council has experience with conducting cultural burns that could be used in maintaining current prairies and helping restore new ones.

Potential actions with respect to maintaining and restoring prairies include:

- Limit forestry planting of Douglas fir in historic prairie areas.
- Incorporate lessons learned from the Cultural Fire Management Council into action plans.
- Conduct research on relationships between prairies, infiltration, stream baseflows and water quality.

Manage/restore wetlands

Wetlands sometimes have a stinky, stagnant, and discolored reputation as worthless swamps that most people wouldn't consider drinking from. Yet wetlands help maintain the quantity and quality of drinking water supplies. They play a significant role in protecting and sustaining both surface and groundwater supplies for people, fish, plants, and wildlife. In addition, they serve as nurseries for all kinds of life. Wetland habitats store rain, snowmelt, and flood waters like a sponge during the wetter winter/spring season and then slowly release them during the drier summer months, providing water back to the broader ecosystem, keeping water levels up in springs, ponds and rivers (Ch. 4). Wetland vegetation such as trees and sedges' root mats slow surface run-off and floodwater. In combination with water storage, this decreases the height of flood waters and lessens erosion (Ch. 4). Wetlands also improve water quality by settling out sediments and absorbing nutrients and pollutants before they reach rivers, streams, and our drinking water supplies (Ch. 4). Because of these varied and broad-based ecosystem functions, protecting and restoring wetlands could be an efficient and cost-effective way to moderate climate change impacts and preserve drinking water supplies. The Tribe established a Wetlands Program in 2007 and completed a Wetlands Program Plan in 2011 (Ch. 4).

Potential climate change adaptation actions for the Tribe include:

- Develop and execute a Yurok Tribe Wetlands Protection Ordinance.
- Develop outreach on wetland importance (drinking water, fish & wildlife habitat, instream flows, etc.).
- Reintroduce beavers, whose dams will naturally increase wetlands.
- Conduct research on how restoration of tributary headwater wetlands contributes to cold water refugia.
- Land acquisition – purchase uplands with wetlands to allow protection and preservation of drinking water sources.
- Land acquisition – purchase coastal wetlands for conservation & sea level rise protection
- Land exchange– owners exchange property in the floodplain for county-owned land outside of the floodplain

Potential personal actions to protect wetlands:

- Respect wetlands' importance and don't dump waste into wetlands
- Protect wetlands on your property and don't fill

Logging road decommissioning to reduce sediments loads

The Klamath River system is being choked with too much sediment – filling in deep cold water holes, smothering fish nests, causing potentially fatal lesions on the gills of juvenile fish, and cutting cooler tributaries off from the mainstem (Chs. 4, 6). A major source of all this sediment are historic roads used to transport logs from the watershed to lumber mills. There are often as many as six miles of road per square mile of logged area (Ch. 4). Heavier downpours anticipated in the future with climate change may contribute to even more erosion and sedimentation from such areas. Removing sediments from instream channels is one strategy needed; however, the decommissioning of old logging roads helps cut the sediments off at the source. The Tribe's Watershed Restoration Department is making productive strides in logging road decommissioning. However, given the density of the road network, much work remains to be done.

Potential next steps the Tribe could take include:

- Hire grant writer to develop partnerships and pursue funding sources for logging road decommissioning.
- Build partnerships to promote funding for watershed restoration including logging road decommissioning.
- Assess whether any additional technical considerations need to be taken into account to maintain the effectiveness of logging road decommissioning given anticipated changes in climate.

Land acquisition

One major challenge for the Tribe involves a restricted Reservation land-base and limited or lack of input into off-reservation management processes that affect water and aquatic resources important to the Tribe. Land acquisition is one approach to address this. In an innovative move that provides climate resilience as well as helps the Tribe meet other objectives, the Tribe has partnered with the Western Rivers Conservancy to purchase approximately 47,000 acres of land within the Reservation and in their former Ancestral Territory along the Lower Klamath River and Blue Creek. Part of this land will become the Blue Creek Salmon Sanctuary. Blue Creek provides key spawning habitat for Chinook salmon. It is also the main cold water refuge between the mouth of the Klamath and 55 miles upstream where the Klamath meets the Trinity River. As salmon make their journeys upriver, Blue Creek serves as a key "salmon cooling station," a role that will likely become increasingly important in a warming world.

In addition to the sanctuary, some of the re-acquired lands will be restored and sustainably managed as a community forest. The land acquisition and streams within it will be restored and managed according to traditional Yurok management practices and in line with Yurok values, priorities, and holistic worldview in which healthy forests are understood to be key for healthy and resilient rivers.

In order to fund the purchase of lands from the Green Diamond Resource Company, Western Rivers Conservancy has been working with the Tribe to obtain grants, low-interest loans, and appropriations from state, federal, and foundation sources (Chs. 1, 4). Major funding has come from California's Clean Water State Revolving Fund and through the federal New Markets Tax Credits Program to catalyze investment in low income communities. Loans will be repaid through the sale of forestry carbon offsets (see below) and through profits from a sustainable forestry program (Chs. 1, 4).

Potential next actions with respect to land acquisition include:

- Complete and implement the Yurok Traditional Management Plan.
- Conduct research on managing forests holistically for multiple, diverse objectives in a changing environment. These could include freshwater quantity and quality, habitat for terrestrial species, and carbon sequestration.

Strategy 3: Restore nearshore habitat

Kelp forests and eelgrass beds are two important nearshore habitats along the California coast. Kelp forests are composed of dense stands of large and rapidly growing brown algae (NOAA 2017, 2018a). Instead of roots, kelp have holdfasts that allow them to grip onto submerged rocks and grow along rocky coastlines (NOAA 2018b). They can grow in depths of 6-90+ feet, and the algae are equipped with airbladders that help their leaflike fronds stay afloat. Kelp forests support a variety of invertebrates, fish, and birds (NOAA 2018b). They also absorb excess nutrients, thus improving water quality (Jones 2016). In contrast to kelp, eelgrasses grow on soft, muddy or sandy bottoms in depths of up to about 20 feet (CDFG 2010). Eelgrass beds provide important habitat for fish including juvenile salmonids and for shellfish and are a food source for waterfowl (CDFG 2010; NOAA 2014). By trapping sediments and reducing wave energy, eelgrass beds help reduce coastal erosion. The grasses also filter polluted runoff and, like kelp, take in excess nutrients, resulting in improved water quality (NOAA 2014, 2018c).

Climate change, in particular ocean warming, could stress these ecosystems. However, at the same time, restoring these ecosystems could potentially provide some distinctive aquatic resilience to climate change (NOAA 2018b).

Luffenholdtz Creek outflow into the south of Trinidad bed, considered the most northerly remnant of what was once expansive kelp beds that spanned the entire northwest coastline of the Pacific Ocean.

Restore kelp forests and eelgrass beds

Kelp forests and eelgrass beds are among the most productive types of marine ecosystems in the world, absorbing large quantities of carbon dioxide and producing oxygen through the process of photosynthesis (Burns 2018; NOAA 2014, 2018a). In doing so, they provide climate change benefits by removing large amounts of a key greenhouse gas (carbon dioxide) from the atmosphere (Morton 2014; NOAA 2014). In kelp forests, one study indicates that the presence of sea otters can help increase carbon storage by keeping kelp-consuming sea urchins in check (Wilmers et al. 2012). Kelp could potentially be harvested to remove the carbon from the ecosystem, and eelgrasses with their root systems can store carbon underground (Jones 2016; Burns 2018). More and more research also points to another potentially significant benefit, the creation of localized reductions in ocean acidification that could benefit shell-bearing and other organisms in the vicinity (WSBRPOA 2012; Balmer 2014; Chan et al. 2016; Jones 2016).

Potential next steps for the Tribe include:

- Monitor developments in the blue carbon credit market, which could potentially provide funding for adaptation. (Blue carbon is carbon stored by oceans and coastal ecosystems such as kelp forests and eelgrass beds.)
- Research methodologies for restoring kelp and eelgrass beds.
- Establish a Yurok Marine Department.
- Complete and implement the Yurok Ocean Management Plan.

Strategy 4: Sequester and reduce greenhouse gas emissions

This chapter and entire plan discuss a variety of ways to adapt to climate change. However, the ultimate form of adaptation is to sequester greenhouse gases that are already in the atmosphere and reduce future greenhouse gas emissions. Unless this happens, it will be necessary to keep adapting to greater degrees of change and increasing uncertainty. Restoring kelp and eelgrass beds, as discussed above, is one way to decrease greenhouse gases in the atmosphere. Two additional approaches are identified below.

Participation in California's Cap-and-Trade Program

A large portion of the lands that were a part of the purchase described above have become part of the Yurok Tribe's Sustainable Forest Project through which the Tribe is participating in California's Carbon Cap-and-Trade Program. The Yurok

Tribe is the first federally-recognized tribe to participate in carbon capture forestry management in the United States (Ch. 1). In the Cap-and-Trade program, businesses buy carbon credits to offset their carbon emissions. These credits are then used to finance projects that reduce carbon emissions or sequester carbon. The Yurok Sustainable Forest Project sequesters carbon through forest protection. Funds received from the sale of carbon offsets are being used to repay the loans that helped fund the land purchase (Ch. 1). Funds are also being used to implement restoration activities, train Yurok wildland fire crews, and employ Yurok as foresters to assist with the monitoring needed to participate in the Cap-and-Trade Program (Strand 2016). Forests in the program are also open to traditional hunters and gatherers, opening old areas for exploration once again (Yurok Today 2015).

Potential next Tribal steps include:

- Establish a backcountry living station to decrease commute times for staff monitoring forests and conducting projects related to Yurok participation in California's Cap-and-Trade Program
- Develop outreach materials about the importance of the carbon sequestered by the Yurok Forest Project.
- Consider expanding partnerships to increase the amount of forest included in the Cap-and-Trade program.

Potential next personal steps include:

- Use energy in all areas of your life responsibly.
- Plant and care for a redwood seedling to store carbon (plant in partial shade and keep moist in early years).
- <u>Increase hybrid vehicles in Tribal fleet and promote river ferry transport</u>

In 2016, the transportation sector contributed nearly 28.5% of the United States' greenhouse gas emissions (USEPA 2018). One potential way for the Tribe to reduce its emissions would be to increase the number of hybrid cars in its fleet. Hybrids use a gasoline engine in combination with an electric motor and a high capacity battery (O'Dell 2016). The electric motor reduces the vehicle's fuel consumption and thus its greenhouse gas emissions.

The Tribe has already reintroduced a traditional way of traveling (by river) with a modern twist (by ferry). The River Otter, a transit ferry cuts down on commute times between upriver and downriver locations is in operation during the summer and early fall. In addition, as a form of mass transit, a ferry could potentially cut down on greenhouse gas emissions, depending on its fuel efficiency (NPS 2016).

Potential next steps for the Tribe could include:

- Investigate tax incentives and grant options for purchasing hybrid vehicles.
- Continue trainings to allow hiring of backup river ferry captains.

Potential next personal steps include:

- Consider cost of ferry ticket an investment in the future

THEME #2: HEALTHY AND CONNECTED INDIVIDUALS AND COMMUNITIES

Just as species and ecosystems need to be integrated and connected to be healthy and resilient, so do people and communities. The health of one is integral to the health of all, and the health of all is integral to the health of one. The connections and bonds between people and within communities can help both withstand, recover from, and transform the challenges posed by climate and other changes. In conversation after conversation to develop this Plan, we heard that keys to integration and connection included traditional values, right practices, and communication.

Strategy 1 – Continue to reinvigorate traditional Yurok values and practices

Traditional Yurok values and practices are a form of resilience that have helped Yurok survive and thrive amidst the numerous challenges they have experienced (Ch. 1). "[These values] have carried Yurok throughout time," notes Joe Hostler, with the Yurok Tribe Environmental Program, and will help Yurok in a future with climate change as well. One concern repeated again and again during the workshops and interviews for this Plan was that these values and practices were being threatened with being lost and with them a loss of the innate sense of what it means to be Yurok and the right ways of being and relating in the world. "Our elders were our teachers," noted someone at Workshop 3, "and now we're all separated out – we watch TV – we're missing out on those lessons of what we're supposed to do and how we're supposed to do it."

Some of the values that Tribal Members and staff shared included balance, respect, gratitude, reciprocity, and responsibility. This list is in no way meant to be comprehensive, and the meanings of these values as described were highly interconnected and overlapped, being shared among Tribal Members and at the same time, quite individual. Some might use other terms or divide the ideas represented below in different ways. Elders emphasize that, traditionally, each village had their own way of doing things and that beliefs and values passed on might be a bit different from here to there. We share these values and descriptions not with the intention to be definitive but rather as a basis for discussion.

- Balance was talked about in multiple ways. Requa Inn owner, Jan Wortman, discussed balance within a person and how "when your actions are counter to your belief system, you're in conflict internally and then you do stupid things because you're not in balance with yourself. A lot of our young people are in conflict because no one's said this is how you live, how you treat things, how you treat people…when you step outside of that is when you're in conflict with nature, yourself, your soul, with community members." If you're not in balance and healthy within yourself, you won't be able to help anyone else. Elizabeth Azzuz with the Yurok Cultural Fire Management Council shared, "Care for elders, environment, and family – being a good human is what keeps me in balance." Others discussed balance within ecosystems. For example, one participant in Workshop 1 said, "The river is our lifeline. Only through balance can we be assured that there will be a tomorrow." And in a deposition about the 2002 fish kill, Barry McCovey, Jr., Yurok Fisheries Biologist, talked about the ecosystem being "severely out of balance. And the first step in fixing and rebalancing the world would be to attempt to – or to get the river back where it should be" (PCFFA and Yurok Tribe 2005). The Yurok Culture Committee discussed balance between the Yurok and fish, "The Creator placed Yurok people and fish together for reasons of balance and longevity. The Yurok have a responsibility for assuring the fish get up the River. These reasons are codified as Indian Law, first instructions from the Creator to the Yurok People. When the Law is not followed, the balance is not maintained and the fish do not return, the River dries up and the Yurok people dwindle away" (Sloan 2003). Finally, in an award-winning essay for high school students, Yurok youth Merk Robbins wrote about balancing two worlds, "We must now adapt and balance out our native life with the life white man has thrust upon us and live in harmony with them both. For without balance of the two, we cannot live in harmonization" (Yurok Today 2011).

- "Respect," said Yurok elder, Allen McCovey, "is the whole of everything." And Joe Hostler with the Yurok Tribe Environmental Program noted, "Respect is a universal and essential component of Yurok culture." Yurok respect their elders and traditional knowledge. They respect the land, the river, and all species. They respect one another and themselves. For some, respect means to take only as much as they need and not be greedy. For others, it means to be kind and help someone. For still others it means to listen when someone is speaking. Respect helps build a foundation for trust. Gratitude and reciprocity can be ways of showing respect for the Earth and all it provides.

- Gratitude is one way to show respect and was discussed in terms of being both a value as well as a practice. Yurok elder Axel Lindgren III said, "If you go to gather, always remember to say wo'hklaw' (thank you) to Wonoye'eek (Creator) for allowing you to get this. Make a payment back." Robert McConnell, Sr., President of the Yurok Cultural Fire Management Council noted, "That component of prayer and giving thanks for the resources is totally what's missing. We as people don't do that nearly as much as we used to. I don't think that many of our population at this time understand that connection or practice. To be able to go down to the river and set a net and pull out a really nice beautiful fish is a privilege. If you can't recognize it as a privilege you'll never get to the point where you can see that fish as a beautiful piece that we are given to look over."

- Reciprocity plays a role along with balance, respect, and gratitude and some might think of as taking care of one another in an interdependent, natural world. Tribal Chairman Thomas O'Rourke expressed reciprocity as the idea of, "If we take care of the Earth, it will take care of us." In the deposition mentioned above related to the 2002 fish kill (Ch. 1), Barry McCovey, Jr. stated, "The salmon are everything to us. And I think we – as a culture, we are – we have certain obligations towards salmon... as a reciprocity kind of relationship...we should take care of them since they've taken care of us for so long" (PCFFA and Yurok Tribe 2005). McCovey, Jr. also noted "[A]s Yurok people, the Creator put us here to be caretakers of the land that we're so fortunate to live upon. And as caretakers, that means we don't only take from the land but we take care of the land...when things like a fish kill happen, we have an obligation to try and make it right." In the natural world, species are equal partners, sacred beings, and relations. "We have a long-standing agreement, partnership, fellowship, with our fish," said Judge Abby Abinanti. And in another deposition about the fish kill, Frankie Joe Myers stated, "[salmon are] literally spirit brothers, ... spirits that are out there that are real and are living and we have an obligation to protect those fish and other animals and other things and pray for them and seek to make the world in balance (PCFFA and Yurok Tribe 2005). And if we are able to do that, they're going to come back and take care of us." In the natural world, "we are all connected," explained Yurok Cultural Fire Management Council member, Elizabeth Azzuz. "We need to take care of each other." Finally, in Workshop 1, participants expressed that everything depends on something else to be healthy.

- Responsibility is a fifth Yurok value that came up over and over again was – personal responsibility for one's thoughts, feelings, actions, and choices and responsibilities to the broader world as well. During Workshop 3, participants discussed moving away from a self-entitlement attitude that expects the Tribe or federal government to take care of 'me', towards a self-reliant mindset. Judge Abby Abinanti said "my staff is taught to listen, we can make mistakes, you have to adjust and take responsibility." She also noted "we have to work together and at the end of the day, think back to what our responsibilities are to the place, to each other, to the things that don't come to meetings, like fish. They have something to say and we have to mind that."

Values should be related to practices. In the words of Judge Abby Abinanti, "we have to ask what are our values and from those values develop practices." The Yurok have many traditional practices, some noted above, that are expressions of their values. Many have survived suppression and outright banning. These practices may consist of respectful fishing, hunting, and gathering, praying and giving thanks to the Creator for resources, and sharing your first catch with your elders. They may also include elders sharing traditional stories with youth and communities participating in ceremonies (Ch. 7). Women's beading and basket weaving classes have been started that bring older and younger women together for talking and support, and the tradition of men gathering in sweathouses is being revived (Ch. 7). Youth are preparing baskets to distribute to elders during holidays, and with the leadership of the Yurok Cultural Fire Management Council, restoring healthy ecosystems through traditional cultural burning is emerging.

Some of these practices are adjusting to modern contexts, technologies, and tools. New practices are coming about. "Nothing is static," notes Judge Abinanti, "[you] need to be flexible, the culture is flexible, always challenge between young and old and that's okay." But even if the practices change, she says, "the values don't."

Tribal actions to reinvigorate traditional Yurok values and practices could include:

- Incorporate more Yurok history into K-12 education.
- Develop short training for Tribal staff on incorporating Yurok values into their climate change research.
- As part of applying for a fishing license, include outreach on traditional fishing and harvesting practices.

Personal actions to reconnect with traditional Yurok values and practices could include:

- Participate in Yurok summer camps.
- Talk with your elders and others about values and what it means to be Yurok.

Strategy 2 – Strengthen communication and people to people connections

> *"In the old days we used to visit more. Now we don't, we think we don't have time to. Once you do that it takes away from that community...It's something we should try to bring back."*
>
> –Bertha Peters, Elder Interviews 2014

Communication can occur through many means and have a variety of purposes. It can involve increasing awareness so that people can make informed choices, exchanging information to more efficiently achieve goals, sharing observations and knowledge to improve our understanding of and/or adapt to a situation, and brainstorming ideas to come up with solutions to common problems. Through communication, we may reveal our feelings, hopes, and fears. Perhaps at its base, communication is a way to show another person that we are there for them, that they are not alone, that we are interested in who they are, and that we care. In a world of texts, tweets, television, and distractions, communication can also involve something that seems to be increasingly elusive – sitting down with another person face-to-face to listen and share for an extended amount of time. All of these communication processes and outcomes can be important for increasing climate change resilience.

Potential ideas for increasing communication include:

Within and between Tribal departments

- Publish notes online of monthly department directors' meetings.
- Establish monthly interdepartmental walks during which staff can share about their projects.

Between the Yurok government and Tribal Members

Tribal staff could:

- Boost outreach for the Local Environmental Observer (LEO) Network (more information below).
- Increase Tribal staff presentations at community meetings.
- Develop a community communication strategy to respond to climate-related and other emergencies.

Individuals could:

- Attend District meetings.
- Read the Yurok Today newsletter.

Among community members

Tribal staff could:

- Conduct PhotoVoice or video school projects for youth & elders to work together on a story of interest.

Individuals could:

- Visit – talk with your Grandma and Grandpa, aunties, uncles, and others.
- Fish, harvest, and gather with family and community members.

THEME #3: HEALTHY HUMAN-ENVIRONMENT CONNECTIONS

A final and extremely important part of Yurok health are the profound connections between the Yurok people and the waters, lands, and all the species where they live. Just as species and ecosystems as well as people and communities need to be connected to be healthy and resilient so do humans with their environment. In the case of Yurok, this is particularly important. If the Yurok take care of the fish, river, ocean, plants, and wildlife where Yurok live, they will take care of the Yurok. The health of one is integral to the health of all, and the health of all is integral to the health of one. Tribal Members are increasingly concerned that deeper connections with the natural world are diminishing due to historical legacies and modern realities of supporting families and living in a virtual, fast-paced, and distracting environment.

Strategy 1 – Educate and engage the community and youth on healing the land and water

Because of the value Yurok give to connections with place and their non-human relatives, rebuilding these relationships is important. Ways to do this include education about the significance of these bonds and engaging youth and others in time spent outside in ways that will allow them to understand where it is they have come from and how intimately they belong.

Tribal actions to educate and engage the community and youth in healing the land and water include:

- Develop an activity book to teach elementary-age children about the importance of traditional aquatic foods, connection between the river and Tribal health, and about climate change.
- Encourage departments to write small stipends into their grants to hire high school interns during the summer to assist with aquatic species and habitats' research and monitoring.
- Create a yearly youth-oriented community event to remove sediment deposits to help reconnect creeks to the Klamath River so fish can access colder tributary water.
- Develop an Adopt a Redwood Seedling Program to increase riparian shading.
- Boost outreach for the Local Environmental Observer (LEO) Network, a citizen science web/cell-phone based tool, to share observations of environmental changes taking place with Tribal members, managers, & others.

Potential personal actions include:

- Look for/ start Tribal environmental educational and research opportunities and community events.
- Be respectful and practice responsible fishing, hunting and gathering.
- Download, learn about and use the LEO Network cellphone app to share your environmental observations/ photos (leonetwork.org).
- Join the Yurok Fire Management Council.
- Plant and care for a redwood seedling to increase riparian shading and store carbon.
- Participate in the Yurok Tribe Environmental Program Klamath River Cleanup and other community events.
- Consider developing and engage in citizen water quality monitoring.

Strategy 2 – Understand your connections to drinking water

Of all the human connections we have with the natural world perhaps one of the most fundamental is the relationship that we have with the water we drink. In the memories of elders, Yurok country is awash in water – winter rains, summer fog, cold perennial springs, and the ever-steady flow of river and creek water. In recent times, however, recollections of abundant, healthy, and free water to drink have transitioned into realities of springs drying up during a multi-year drought, fear about pesticide and nutrient levels, E. coli outbreaks, and indignation at having to pay for water, a trust resource that was once available at no charge. Climate change is expected to add to these impacts. Understanding that the traditional relationship between Yurok and their drinking water has changed and responding accordingly are becoming increasingly important both in our current world and in preparation for climate change.

Potential next steps for the Tribe to take with respect to promoting understanding of the connections and changes to drinking water include:

- Develop outreach to help community members understand changes in their drinking water that are occurring.
- Promote and educate about rainwater catchments for irrigation water
- Develop a minor plumbing repair program to assist homeowners in reducing leaks.
- Conduct outreach on sanitary spring box construction, and on septic system maintenance.

8.3 Conclusion

This Plan and planning process are just one stage in a continual cycle of adaptation, restoring balance, and renewal in which Yurok have been engaged since they first stood on the banks of the Klamath River and on Pacific Ocean shores. The Plan did not address all aquatic species nor did it address terrestrial species or ecosystems. These could be the focus of future planning efforts. While the Tribal government can work to implement many of the actions in this Plan, we as individuals can each take responsibility for making steps for ourselves. Considering Yurok values and worldviews, one step could be to hold sacred the gifts that we have been given – this day, those around us, the water, food, and air that nourish us, and the world we move through, in the present, past, and the future that we have yet to create - together.

Youth waits to greet people at the Yurok Visitors’ Center.

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Additional Information

- The Institute for Tribal Environmental Professionals (ITEP) at Northern Arizona University established its Tribes and Climate Change Program in 2009. The program provides support for and is responsive to the needs of tribes who are preparing for and currently contending with climate change impacts. For more information, please visit our website at: http://www7.nau.edu/itep/main/tcc.
- "Guidelines for Considering Traditional Knowledges in Climate Change Initiatives," A resource for tribes, agencies, and organizations across the United States interested in understanding Traditional Knowledges in the context of climate change: https://climatetkw.wordpress.com/
- "The Climate and Traditional Knowledges Workgroup – CTKW" is an informal group of indigenous persons, staff of indigenous governments and organizations, and experts with experience working with issues concerning traditional knowledges who developed a framework to increase understanding of access to and protection of TKs in climate initiatives and interactions between holders of TKs and non-tribal partners: