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Judgment Based Habitat Mapping on the Trinity River, 2006

Damon H. Goodman, Aaron C. Martin, Paul P. Petros and John Klochak

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Abstract

The Trinity River is the focus of multifaceted rehabilitation efforts aimed at improving habitat conditions for anadromous salmonids and other aquatic organisms. We applied Judgment Based Habitat Mapping (JBHM) to 20.5 rkm of the Trinity River in the late summer and fall of 2006. Our intent was to: (1) delineate areas of existing high quality habitat for several target species/life stage conglomerates, or guilds, and (2) to evaluate the applicability of the methodology for documenting habitat availability and changes over time. The target species included Chinook salmon (*Onchorynchus tshawytscha*), coho salmon (*O. kisutch*), foothill yellow legged frog (*Rana boylii),* lamprey (*Entosphenus spp.*), western pond turtle (*Clemmys marmorata*) and western toad *(Bufo boreas).* The evaluation produced spatially explicit maps and estimates of habitat availability for six guilds representing preferred habitat for 12 species life-stage pairs. Repeatability of the JBHM method was evaluated through replicate survey sub-sampling. Replicate surveys produced differences in habitat area ratios that ranged from 0.4 to 11.8. Due to the large discrepancies between replicate surveys, we conclude that this methodology is not appropriate for evaluating change in habitat availability in the Trinity River unless repeatability is improved.

Introduction

The Trinity River is currently the focus of a multifaceted habitat rehabilitation effort to mitigate for the impacts of the Trinity River Division (TRD) of the Central Valley Project on fish and wildlife populations (U. S. Department of the Interior 2000). The rehabilitation effort is focused in the Trinity River from Lewiston Dam to the confluence with the North Fork Trinity River where the highest levels of habitat degradation from flow and sediment reduction have occurred. Salmonid rearing habitat, especially for the fry life stage, was identified as the primary limiting factor of naturally produced salmon and steelhead populations in the Trinity River (USFWS and Hoopa Valley Tribe 1999). Several management actions are being implemented to increase limited habitats through an ecosystem, process-based approach to river rehabilitation (Barinaga 1996). Restoration actions include flow management, coarse and fine sediment management and mechanical channel rehabilitation. These management actions are expected to increase salmonid rearing habitat for all life stages, and especially for the fry life stage, and therefore increase the natural production of anadromous salmonids.

To evaluate the effectiveness of the restoration effort, the Adaptive Environmental Assessment and Monitoring Program (AEAMP) was implemented. The AEAMP was designed to evaluate effectiveness of restoration actions in meeting program goals and objectives and implement changes to management actions if necessary. One component of the AEAMP is an assessment of changes in habitat which will be determined by comparing the assessments of a baseline of pre-rehabilitation habitat conditions to habitat conditions following rehabilitation actions and changes resulting from natural processes, both physical and riparian.

Many habitat evaluation techniques have been applied to aquatic ecosystems including some which rely on professional judgment (Arthington and Zalucki 1998, Annear *et al.* 2002). Judgment based habitat mapping techniques utilize direct observation of habitat conditions with expert opinion to estimate habitat availability or condition. They are often applied to develop instream flow regimes on regulated river systems and offer a cost effective alternative to the more data intensive numerical modeling techniques.

The Expert Panel Assessment Method (EPAM) was developed to produce a widely applicable and inexpensive habitat evaluation technique (Swales and Harris 1995). This technique utilized multidisciplinary teams ranking rivers on fish and invertebrate habitat quality at several flows. Surveys were replicated by two panels to investigate error associated with the method. The disparity between the replicated efforts generated criticism over several issues including repeatability, lack of transparency and un-quantified uncertainty (Arthington and Zalucki 1998, Young *et al.* 2004). In an attempt to improve on the shortcomings for EPAM, other techniques have incorporated more quantitative components into judgment based assessments (Arthington *et al.* 2003, Young *et al.* 2004).

Judgment based habitat evaluations have also been applied with spatially explicit techniques. Expert Habitat Mapping (EHM) was a judgment based evaluation technique conducted on the Oak Grove Fork of the Clackamas River, Oregon (McBain and Trush 2003, 2004). The method relied on guilds defined using habitat suitability curves (HSC) and other criteria to represent preferred habitat for target species. The guilds were utilized as a guide to biologists who would then use their expert opinions to delineate areas of habitat on aerial photographs. The survey produced a spatially explicit census of preferred habitat within the study area. This protocol was conducted at several flows to produce flow-habitat relationships.

A similar habitat mapping technique was applied to the Pit River, California (DeVries *et al.* 2003). This habitat evaluation incorporated field measurements with spatially explicit judgment based habitat mapping. This effort utilized aerial photographs, guilds and experimental releases to develop flow habitat relationships. In this effort, polygons were delineated using guild criteria, expert opinion, and depth and velocity measurements to confirm polygon boundaries. Validation diving was also conducted to evaluate habitat suitability curves and polygon delineation.

Herein, we report on the application of the spatially explicit Judgment Based Habitat Mapping (JBHM) on 20.5 river kilometers (rkm) of the Trinity River. This technique is a habitat assessment effort similar to EHM, differing only slightly. Our method adhered strictly to visual observations of guild criteria—namely depth and velocity. If the observed area was determined to be outside the bounds of guild criteria, it was not included on the maps generated in the field as habitat. EHM differs on this point. Under an EHM protocol, visual observations of areas outside guild criteria can be included on the maps as habitat based on the professional opinion of the expert drawing on the map. This might be the case, for example, when examining an area with substantial amounts of large woody debris or other cover. Alternatively, under EHM, areas within guild criteria may be excluded from mapped habitat. Neither of these two examples would be considered under the JBHM methods utilized for this study.

The primary goal of this effort was to evaluate JBHM as a tool for assessing and detecting changes in the habitat of target species coinciding with or subsequent to habitat enhancement efforts (Hemphill 2006). A secondary goal was to collect data for future comparisons of techniques including a two-dimensional habitat-hydraulic model under development by the TRRP and Biomonitoring habitat assessment (Chamberlain *et al.* 2007). The objectives of this pilot effort include selection of appropriate guilds, identification and description of habitats associated with each guild and quantification of these habitats within selected study areas. Additional objectives include an evaluation of the method to assess habitat rehabilitation efforts and facilitate the AEAMP process. Project development for this project was a collaborative effort lead by the Trinity River Restoration Program (TRRP) and carried out by the California Department of Fish and Game (CDFG), Hoopa Valley Tribal Fisheries Department (HVTFD), U.S. Fish and Wildlife Service (USFWS), and the Yurok Tribal Fisheries Program (YTFP).

Study Area

The Trinity River is the largest tributary to the Klamath River. It drains a watershed of approximately 7,679 km^2 in Trinity and Humboldt counties of northwestern California. Lewiston Dam, 182.4 rkm from the Klamath/Trinity confluence, is the upstream limit of mainstem anadromy. Previous studies have delineated the Trinity River from Lewiston Dam to the North Fork Trinity River into 6 physiographic reaches covering 64.15 rkm (Trinity River Restoration Program *et al.* 2006). Reach delineation incorporated a combination of tributary accretions, sediment supply, valley confinement and infrastructure encroachment. For this study, we adopted these reach delineations.

Methods

Survey Areas

Several criteria were used to select areas for implementation and evaluation of the JBHM technique including a comparison with areas evaluated with a two-dimensional hydraulic model, a comparison with the Biomonitoring effort (Chamberlain *et al.* 2007), and the evaluation of a dynamic fluvial area. To fulfill these criteria, JBHM was applied to Reach 1, Reach 6, an area near Sheridan Creek, and the Rush Creek Delta (Figure 1).

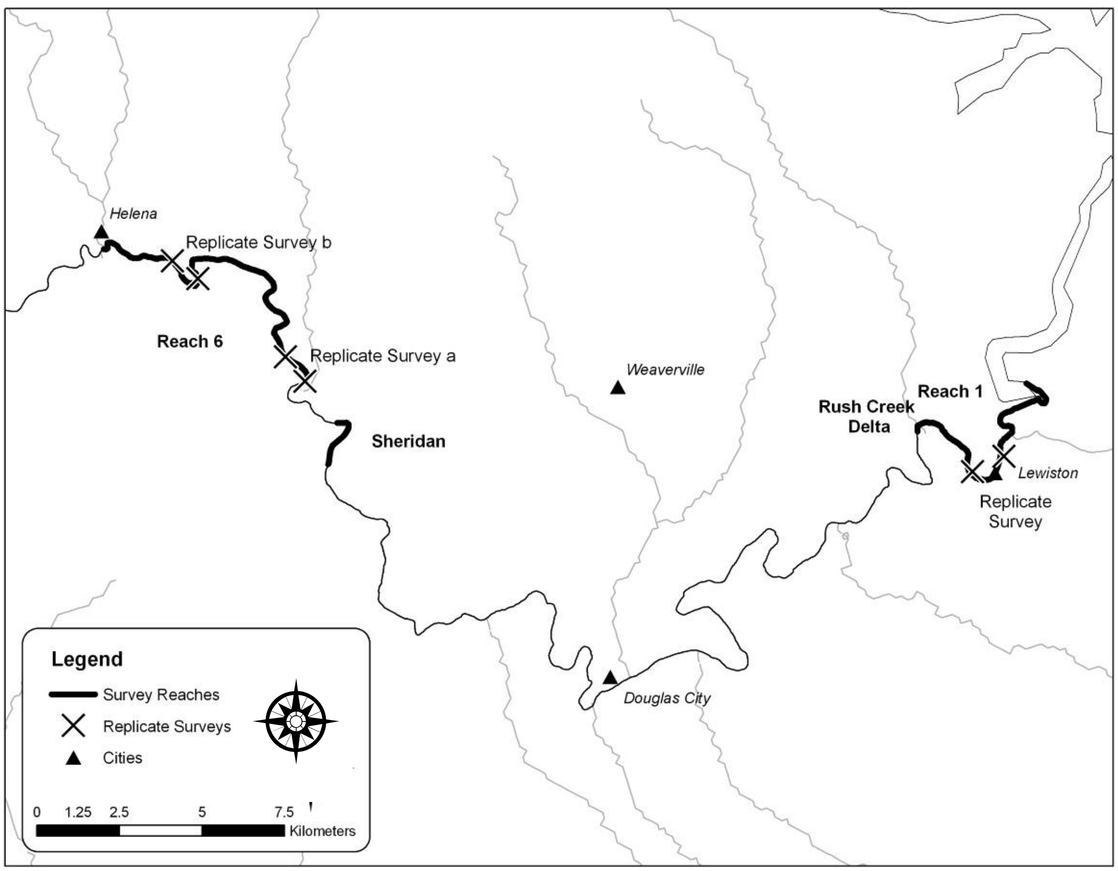

Figure 1. Judgment based habitat mapping survey areas and replicate survey areas on the Trinity River from Lewiston Dam to the North Fork Trinity River.

Reach 1 is the uppermost reach spanning from Lewiston Dam 6.74 rkm downstream to Rush Creek. Reach 1 included the Trinity River adjacent to the hatchery, as well as the Sven Olbertson, Miller and Cemetery side channels, which were constructed for habitat enhancement from 1988-89 (Glase 1994). The Rush Creek Delta, a 400 m feature extending downstream of Reach 1, was mapped to evaluate an area of dynamic fluvial change. The Sheridan Creek section is a 2.15 rkm section of Reach 5, or 19% of the total length of Reach 5. Reach 6 begins at the confluence with Canyon Creek and continued downstream 11.18 rkm to the North Fork Trinity River. From 2004 through 2005, Reach 6 was subject to a bank restoration project designed to remove the riparian berms, lower the floodplain and promote fluvial processes. The project starts just below Canyon Creek (rkm 129.1) and continues downstream 1.6 rkm.

Guild Selection

Target species and life stages were selected by a team of biologists and one hydrologist at a meeting on July 27, 2006. The group was composed of representatives of the California Department of Fish and Game (M. Knectle and W. Sinnen), Hoopa Valley Tribe (R. Franklin), McBain and Trush (B. Trush), Trinity River Restoration Program (J. Klochak), USFWS (C. Chamberlain, D. Goodman and J. Polos), and the Yurok Tribe (A. Martin and T. Hayden). Target species and life stages identified at the meeting were later lumped or eliminated based on field evaluation and group consensus. Species and life stage conglomerates or guilds were then created for field mapping (Table 1). When possible, associated guild criteria were based on habitat use studies that included variables such as depth, mean water column velocity, cover type, distance to cover, substrate and large woody debris dimensions. Two cover types were included: in-water, and out-of-water. In-water cover referred to objects within the water column, which typically provided a velocity break or potential refuge from predators. Out-of-water cover included objects out of the water that typically provided shade or overhead cover. Species with similar habitat suitability values were pooled into single guilds.

Habitat suitability values for the six guilds were derived from a variety of sources. The fry guild was a conglomerate of Chinook salmon (*Onchorynchus tshawytscha*) and coho salmon (*Onchorynchus kisutch*) fry (< 50 mm) habitat suitability values. Depth and mean column velocity values were taken from the Biomonitoring effort to facilitate future comparisons (Chamberlain *et al.* 2007). Distance to cover was taken from habitat suitability data collected on the Trinity River in 2003 and 2004 (YTFP and USFWS unpublished data). The juvenile Chinook salmon (>50 mm) guild was derived from the same sources as the fry guild. Chinook salmon and coho salmon spawning guild was defined using a habitat suitability criteria value of 0.6 from the Trinity River Flow Study for depth, mean water column velocity, and substrate (USFWS and Hoopa Valley Tribe 1999). Chinook salmon holding habitat guild was defined by pool habitat type and minimum depth criteria (>3.04m). Lamprey ammocoete (*Entosphenus spp.*) habitat was defined as areas of low velocity (< 0.05 m/sec), fine substrate and depositional areas excluding areas of anoxic sediments (Potter 1980, Wydoski and Whitney 2003).

The foothill yellow legged frog (*Rana boylii)* and western toad *(Bufo boreas)* require shallow low-velocity areas for egg deposition and larval development and were included in the fry guild (Lind and Wilson 1996; Lind 2004). Large woody debris are important for the basking behavior of western pond turtles (*Clemmys marmorata*) and was used as a surrogate to describe their habitat (Reese and Welsh 1998). Large woody debris were recorded by area and were restricted by minimum length (>3m) and diameter criteria ($\geq$30cm).

Aerial Photographs and Map Creation

Maps were created using the Arc-GIS (ver 9.2) map book utility. To produce maps for the field, we used the most current aerial photos available, including a combination of 2001 (orthorectified), 2005 (rectified using aerial targets), and 2006 aerial photos (rubber sheeted to 2001 photos for JBHM effort; Table 2). Mapping on the most recent photos was particularly important on lower reaches where significant changes have occurred since 2001. Map scale was selected to balance mapping accuracy and feasibility. Coarse map scales made accurate mapping difficult while fine scales created difficulties with orientation and the number of field maps. Two sets of 11" by 17" maps were produced for each survey. Three guild habitats were depicted on each set of maps to avoid errors associated with high levels of overlap (ex. fry and juvenile Chinook salmon habitats). A total of 383 (766 for 2 sets) maps were created for the JBHM effort. The river stationing referred to in this report was derived from United States Geological Survey (USGS) 1:24,000 Digital Raster Graphics (DRG) topographic maps. The resulting rkm route begins with 0 at the mouth of the Trinity River and extended to 182.4 at Lewiston Dam.

Field Methods:

Two days were spent orienting crews to the field methods, and calibrating estimates of water velocities and column depths to measured values. The orientation period was also used to identify and rectify practical difficulties applying the method, such as selecting the most appropriate map scale for field use and the most appropriate methods for documenting encountered habitats. Nine field days were used to apply and evaluate the method including replicate surveys. In general, the survey crew consisted of three to four members on one raft with two individuals mapping habitats. When additional crew members were available, two rafts were used, each with one set of maps. Areas not easily accessible by raft were surveyed on foot (alcoves, side channels, etc.).

The survey methodology included a three step decision making process for mapping habitats. First, a crew member would identify an area that potentially corresponded to a guild definition. The area would then be discussed among the group with respect to guild definitions until a group consensus was reached. Finally, a team member would draw the area on the map confirming with the group about its placement and size. Minimum polygon sizes (minimum habitat sizes) can be found in Table 1.

All surveys were completed at summer base flows, when the release from Lewiston Dam was 450 cfs, and discharge ranged from 497 cfs to 522 cfs at the USGS gauging station above the confluence with the North Fork Trinity River.

Table 1. Target species and life stage of the JBHM technique with associated guilds and criteria applied to the Trinity River, 2006. Cover Codes are as follows: NERA: non-emergent rooted aquatic vegetation, ER: exposed roots, LWD: large woody debris, SWD: small woody debris, H: grass or herbaceous, SS: shrub-scrub (primarily *Salix spp*. and *Rubus spp*.).

Guild	Species and life stage	Min. habitat size	Depth (m) min. max.		Mean water column velocity (m/s) min. max.		Max distance to cover (m)	In water cover	Out of water cover	Substrate (cm)
Fry	Chinook and coho salmon <50 mm fl Foothill yellow legged frog eggs and larvae Western toad eggs and larvae	4.7 (m^2)	0.12	0.61	0	0.12	0.61	NERA, ER, SWD, H, SS	ER, SWD, H, SS	
Chinook salmon juvenile	Chinook salmon 50-200 mm fl	4.7 (m^2)	0.15	1.52	0	0.24	0.61	NERA, ER, SWD	ER, SWD SS	
Chinook salmon holding	Adult Chinook salmon	50% channel width	3.04							
Chinook and coho spawning	Adult Chinook and coho salmon	9.3 (m^2)	0.18	0.64	0.15	0.61				5.1-15.2
Ammocoete	Lamprey ammocoete	4.7 (m^2)			0.05	0.31				< 1
Turtle	Western pond turtle	Min:30 cm Diam. and 3m length						LWD	LWD	

Table 2. Aerial photograph and map information used in the JBHM field effort on the Trinity River, 2006.

		Aerial Photo Year					
		2001		2005		2006	
Study Site	Length (rkm)	# of maps	scale	# of maps	scale	# of maps	scale
Reach 1	6.74	90	1:276	29	1:276		
Rush Creek Delta	0.4					7	1:276
Sheridan	2.15			41	1:207.6		
Reach 6	11.18			38	1:220.8	178	1:267

Replicate Surveys

Repeatability was assessed by conducting replicate surveys including one in Reach 1 and two in Reach 6 (Figure 1). Initial and replicate surveys were conducted at the same flow. The amount of time between initial and replicate surveys varied among segments from approximately one week to one month. For the first survey, a single team would collaborate on visual observations of a given area. Two team members served as drawers, with each of the two drawers responsible for mapping a different guild on an aerial photograph. For the replicate survey, the same team re-examined the same area, although team members rotated responsibilities. Drawers for the replicate survey were different individuals than those of the initial survey. No single drawer repeated mapping the same guild between initial and replicate surveys. One map was produced by the initial survey. A distinctly separate second map was produced by the replicate survey. All mapping for both the initial and replicate surveys used the three-step decision making process included in the survey methodology described above. Replication reaches were determined by a number of criteria; accessibility, channel complexity (include areas with side channels), and overlap with the Trinity River two dimensional modeling reference reaches (TRRP unpublished data). Replicate surveys were conducted during the final week of field work when team members were most experienced with implementing survey methods. The replicate survey conducted in Reach 1 was 24% of the total reach length. Replicate survey 6a was 10%, and survey 6b was 11%, for a total of 21% of the total length of the reach.

Spatial Data Post Processing and Analysis

Post processing of field maps occurred in a series of steps. The maps were first scanned using an automated document scanner to produce digital images (j-peg files) of each map. The resulting files were then divided between USFWS and HVTFD for further processing. Although USFWS and HVTFD utilized different approaches in post processing, the final product was identical.

The images processed by USFWS were georectified using reference points placed at the four corners of each of each map when they were first created and the associated shapefile using ArcGIS (ver 9.2). Polygons on rectified images were then digitized into shapefiles using Arc-Map. Digitizing was restricted to the outside edge of mapped polygons. Data fields associated with each shapefile included guild, survey date, reach, rectified image label and comments.

The images processed by the HVTFD were scanned j-peg images were imported into AutoCAD Land Desktop 2005 for digitizing registration. The original maps were then secured to a CalComp Drawing Board III digitizing tablet and registered to the software environment using tic mark locations. Habitat maps were then digitized using AutoCAD. The habitat polygons were then linked to the database with a centroid with a unique identifier placed in each polygon. Attributes for individual polygons were entered into the database table immediately following individual polygon digitization. A final pass through the polygons with field maps in hand was conducted to check for data thoroughness and quality. The final polygon dataset was exported to ArcGIS shapefile format and delivered to USFWS for data analyses.

The analyses were completed by calculating area and longitudinal position (river kilometer) of each polygon and aggregation by guild. Area (m^2) of each polygon was calculated in ArcGIS using the XTools Pro for ArcGIS desktop (ver. 4.0.0, Build 310). Longitudinal distance was assigned to each polygon in ArcGIS by first converting each polygon to a centroid point shapefile using XTools Pro. Then longitudinal location was associated with each centroid using the ArcGIS linear referencing tool with a river kilometer (rkm) centerline route map of the Trinity River. This analysis produced several duplicate records of single polygons which were manually removed from the resulting database. The data was then exported from ArcGIS into Microsoft Excel and aggregated into a reporting format.

Results

Habitat Availability and Distribution Within Sites

Reach 1

In Reach 1, Chinook and coho salmon spawning habitat was the most abundant habitat with a density of 2,587 m^2/rkm (Table 3). In contrast, turtle habitat was the least abundant area in Reach 1 with a density of 58 m^2/rkm. Within the reach, distribution of habitat area varied by guild (Figure 2). Chinook salmon holding habitat was composed of a few habitats creating a distinct "step-like" pattern. Several other guilds also demonstrated uneven distributions, particularly near the entrance of Cemetery Side Channel (rkm 178.34) where ammocoete, and turtle habitat had distinct increases in habitat area. Fry, Chinook salmon juvenile, Chinook and coho salmon spawning guilds also experienced an increase in habitat area near the side channel entrance, although not to the same extent as the ammocoete and turtle guilds. Fifty percent of the Chinook salmon and coho salmon spawning habitat in Reach 1 was encountered between Lewiston Dam and the entrance to the Sven Olbertson Side Channel (rkm 181.55), a distance that represented only 17% of the length of this reach.

The constructed Cemetery Side Channel was analyzed to assess the relative importance of side channels in providing habitat for various guilds (Figure 3). For this analysis, habitat densities were calculated within Cemetery Side Channel and compared to the rest of Reach 1. Ammocoete, fry, Chinook salmon juvenile and turtle habitat guild densities were greater in Cemetery Side Channel. In contrast, Chinook salmon holding habitat did not exist in Cemetery Side Channel and the Chinook salmon and coho salmon spawning habitat guild had a lower density than the rest of Reach 1.

Table 3. Judgment Based Habitat Mapping survey reaches, survey dates, length of reach, habitat area and habitat density (in parentheses) by guild for the Trinity River, 2006.

			Habitat Area m^2 (Density m^2/rkm)					
Survey Reach	Survey Date(s)	Length (rkm)	Ammocoete	Fry	Chinook salmon holding	Chinook salmon juvenile	Turtle	Chinook and coho salmon spawning
Reach 1	Aug. 9,16,17; Sept. 13	6.74	2,425 (360)	7,272 (1,079)	7,115 (1,056)	8,941 (1,327)	389 (58)	17,434 (2,587)
Rush Cr. Delta	Aug. 17	0.40	26 (65)	182 (456)	0 (0)	554 (1,386)	207 (518)	233 (583)
Sheridan	Aug. 15	2.15	381 (177)	1,123 (522)	524 (244)	1,692 (787)	515 (239)	5,779 (2,688)
Reach 6	Aug. 10 Oct. 4, 5	11.18	1,779 (159)	2,681 (240)	5,864 (525)	6,254 (559)	1,075 (96)	13,656 (1,221)

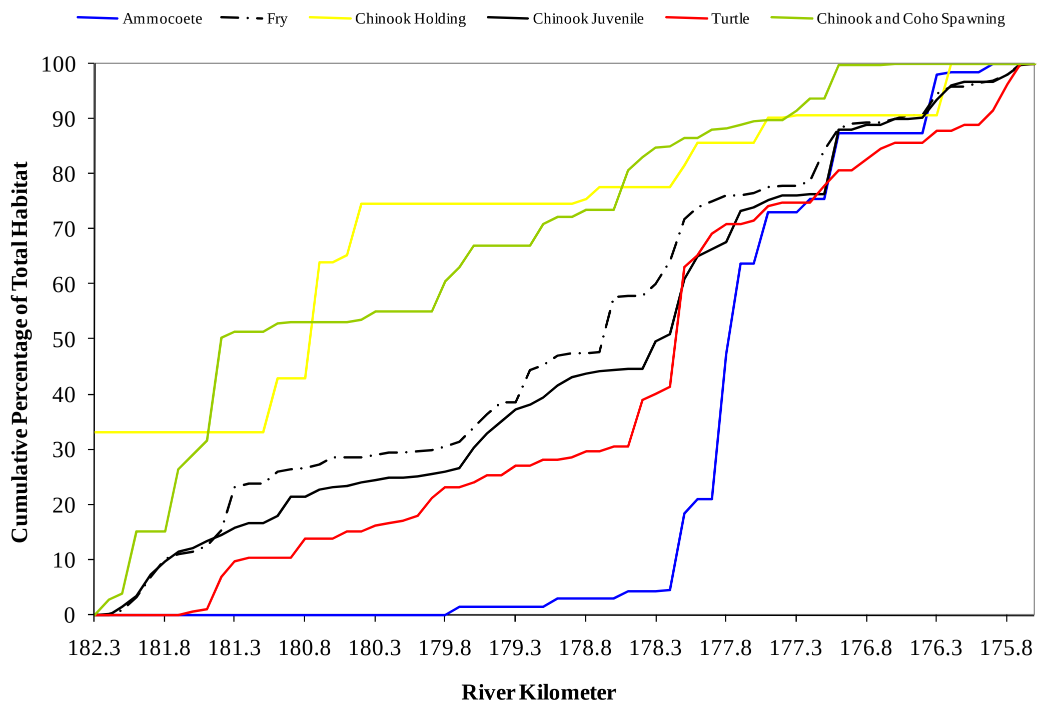

Figure 2. Distribution of habitat from six guilds mapped using JBHM in Reach 1 of the Trinity River, 2006.

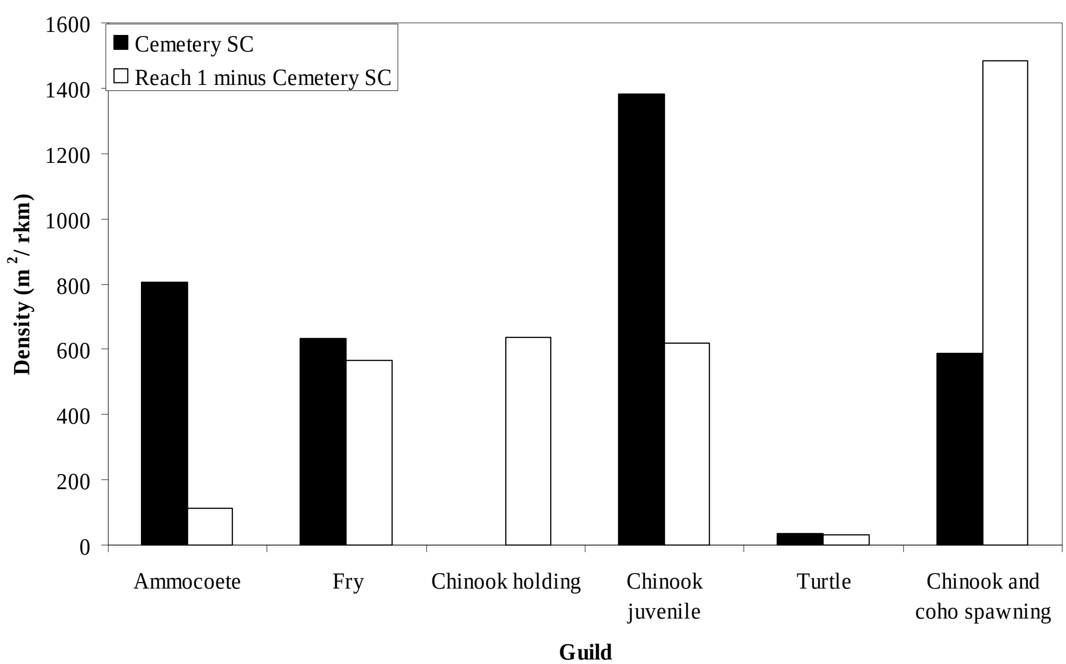

Figure 3. Density of habitat from six guilds mapped using JBHM in Reach 1 without Cemetery Side Channel and Cemetery Side Channel.

Rush Creek Delta

The Rush Creek Delta had a high density of Chinook salmon juvenile habitat (1,386 m^2/rkm) with very little ammocoete (65 m^2/rkm) and no Chinook salmon holding habitat (Table 3). Distribution of habitats within this reach was not assessed due to the small survey area.

Sheridan Reach

Chinook and coho salmon spawning guild was the most abundant habitat in the Sheridan Reach with a density of 2,688 m^2/rkm (Table 3). In contrast, ammocoete, turtle, and Chinook salmon holding habitats had densities of 177, 239, and 244 m^2/rkm, respectively. The longitudinal distribution of habitat varied by type in the Sheridan reach (Figure 4). For example, Chinook salmon holding habitat occurred in only two locations while Chinook salmon juvenile habitat was identified in 36 distinct polygons distributed throughout the survey area.

Reach 6

The most abundant habitat in Reach 6 was for the Chinook and coho salmon spawning habitat guild, with a density of 1,221 m^2/rkm (Table 3). The habitats with the lowest density were for ammocoete and turtle with 159 and 96 m^2/rkm, respectively. In Reach 6, habitat distribution varied by guild (Figure 5). For example, fry, Chinook salmon juvenile, and turtle habitats were represented by many smaller areas, while ammocoete and Chinook salmon holding habitat were represented by a few large areas. Chinook and coho salmon spawning habitat was intermediate with several large areas at rkm 124.3, 124.8, and 128.5 as well as many smaller areas. In several instances, large areas of ammocoete and Chinook salmon holding habitats occurred in proximity, for example at rkm 125.7 and 122.5.

Habitat Availability Among Sites

Among reaches, ammocoete habitat typically accounted for the lowest density, ranging from 65 m^2/rkm in the Rush Creek Delta to 360 m^2/rkm in Reach 1 (Table 3, Figure 6). Fry habitat had the lowest density in Reach 6 and highest in Reach 1, ranging from 240 to 1,079 m^2/rkm. Chinook salmon juvenile habitat density was the highest in Reach 1 and the Rush Creek Delta with 1,386 m^2/rkm and 1,327 m^2/rkm, respectively, and the lowest at Reach 6 with 559 m^2/rkm. Turtle habitat density was low in Reach 1 and highest in the Rush Creek Delta with 58 and 518 m^2/rkm, respectively. Chinook salmon holding habitat was not present in the Rush Creek Delta and had the highest density in Reach 1 with 1,056 m^2/rkm. Chinook and coho salmon spawning habitat had the highest density in Reach 1 with 2,587 m^2/rkm and Sheridan with 2,688 m^2/rkm and the lowest density at Rush Creek Delta, 583 m^2/rkm.

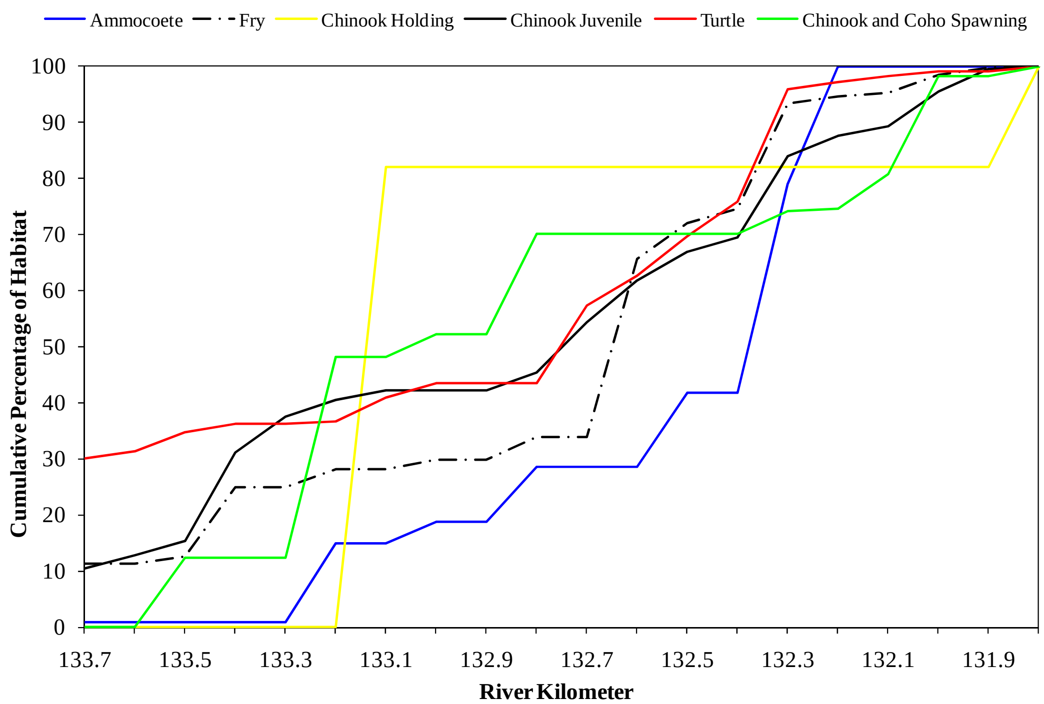

Figure 4. Distribution of habitat from six guilds mapped using JBHM in the Sheridan Creek Survey Reach of the Trinity River, 2006.

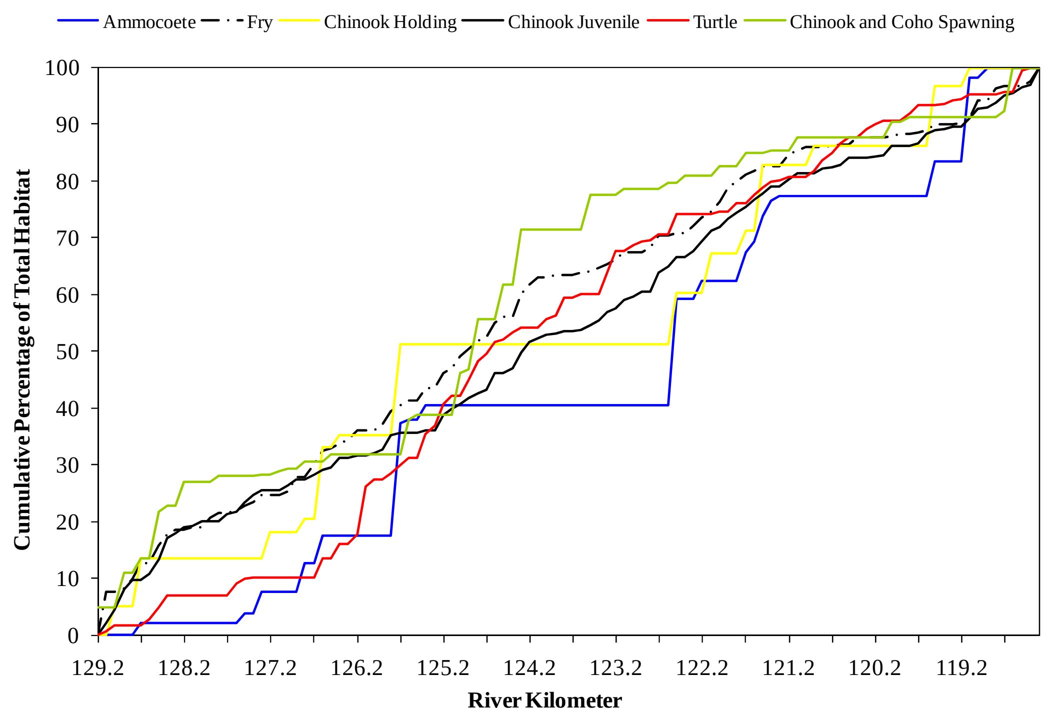

Figure 5. Distribution of habitat from of six guilds mapped using JBHM in Reach 6 of the Trinity River, 2006.

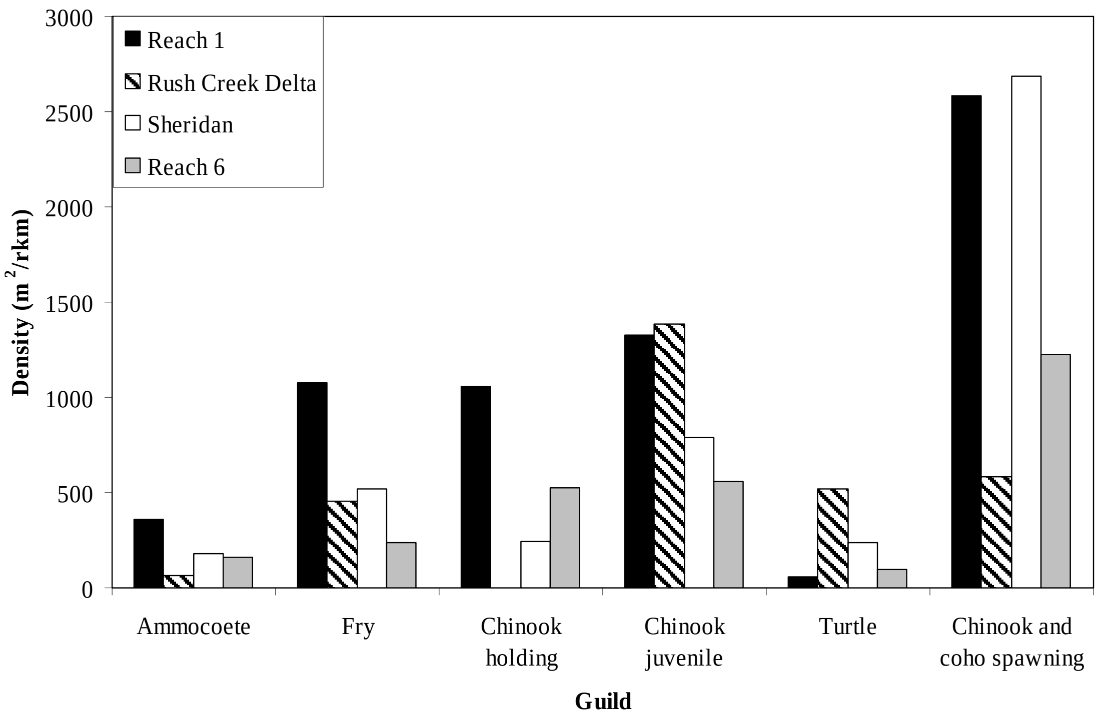

Figure 6. Density of habitat in all survey areas mapped in the JBHM evaluation on the Trinity River in 2006.

Repeatability

Differences between initial and repeat surveys varied by guild and reach (Table 4 and Figures 7-9). The repeat ratio (initial/repeat survey) for ammocoete habitat ranged from 1.1 in Reach 6a to 11.8 in Reach 6b. The fry habitat ratio ranged from 0.5 to 2.7 in Reach 6b and 6a, respectively. The Chinook salmon holding habitat ratio ranged from 0.4 in Reach 1 to 1.6 in Reach 6a. The Chinook salmon juvenile ratio ranged from 1.2 to 2.5 in Reach 6b and 6a, respectively. The turtle habitat ratio ranged from 0.5 in Reach 6b to 1.6 in Reach 6a. The Chinook and coho salmon spawning habitat ratio ranged from 0.7 to 4.6 in Reach 6b and 6a, respectively.

An example of the differences between initial and repeat surveys is presented in Figure 10. Generally, initial surveys resulted in narrower habitat areas than the replicate survey. While habitat was observed to be in proximal locations, along river margins, they were typically offset. The offset errors could result from a combination of observation errors where the habitat was observed to be in a different location among surveys or mapping errors where respective team members mapped the same habitat differently. To a lesser degree there were instances where habitat was mapped in an initial survey and missed in a replicate survey or vice versa. Additional examples are provided in Appendix A.

Table 4. Summary of replicate surveys conducted to evaluate repeatability in the JBHM method including survey length (rkm), and guild area (m^2).

Reach	Length (rkm)	Survey	Ammocoete	Fry	Chinook salmon holding	Chinook salmon juvenile	Turtle	Chinook and coho salmon spawning
		I	473	3,040	790	3,237	163	4,003
1	1.63	II	284	1,700	1,972	2,282	196	1,967
		Ratio I/II	1.7	1.8	0.4	1.4	0.8	2.0
		I	39	509	795	1,211	76	3,716
6a	1.16	II	34	188	492	482	46	810
		Ratio I/II	1.1	2.7	1.6	2.5	1.6	4.6
		I	266	173	1,113	594	140	693
6b	1.27	II	23	339	1,234	495	283	1,064
		Ratio I/II	11.8	0.5	0.9	1.2	0.5	0.7

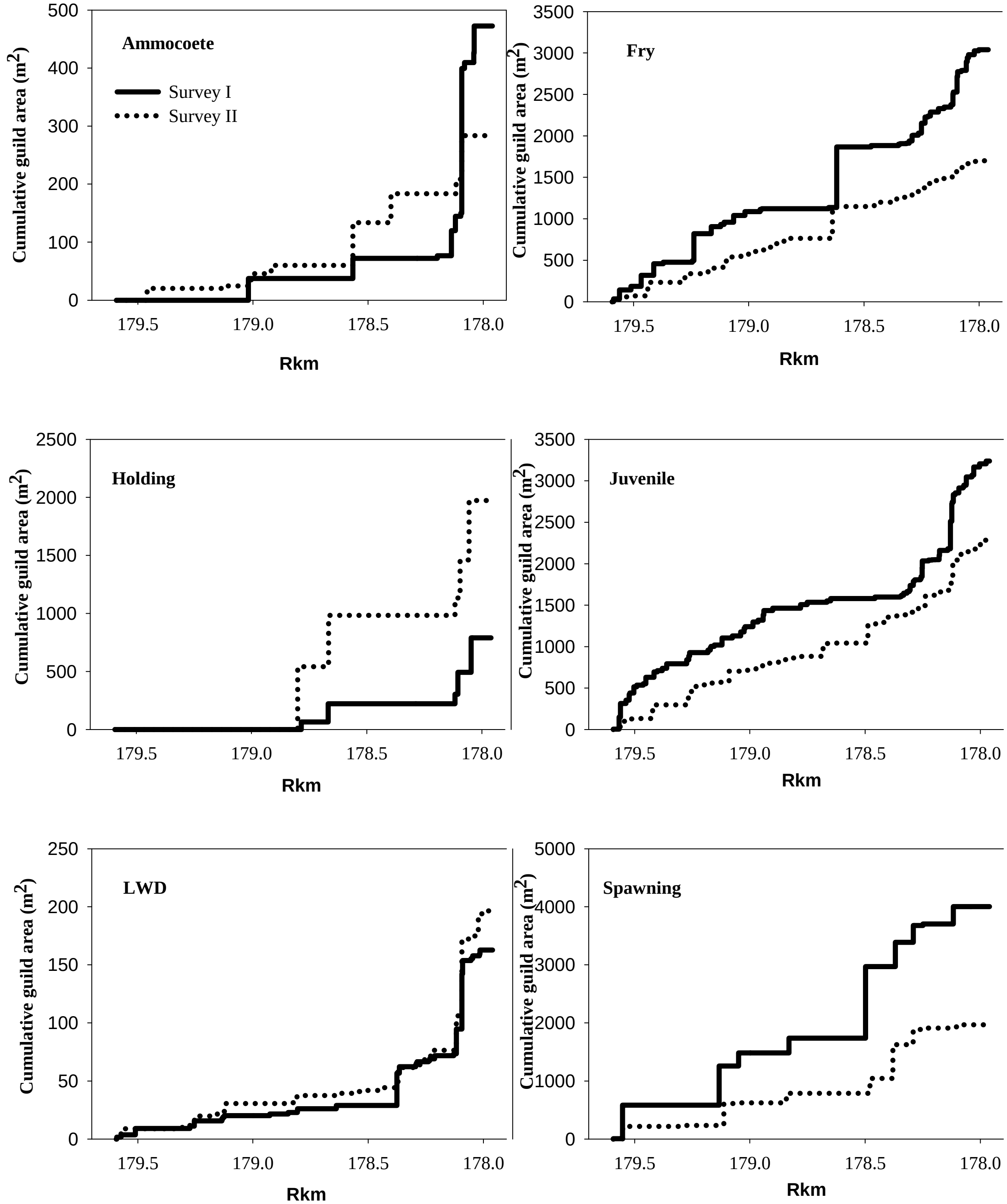

Figure 7. Longitudinal comparison of a replicate JBHM survey of cumulative habitat from six guilds conducted on Reach 1 on the Trinity River, 2006.

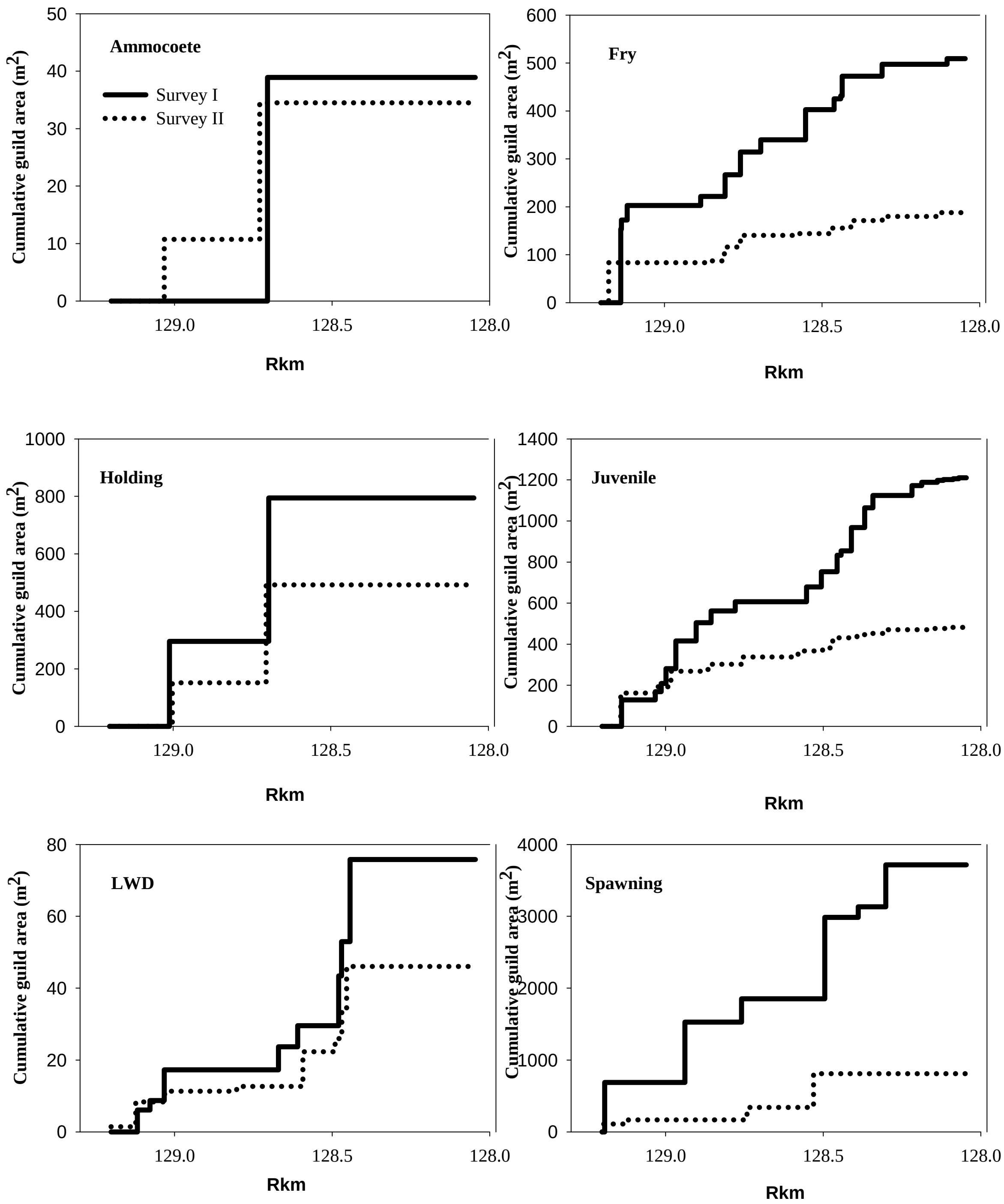

Figure 8. Longitudinal comparison of a replicate JBHM survey 6a of cumulative habitat from six guilds conducted on Reach 6 on the Trinity River, 2006.

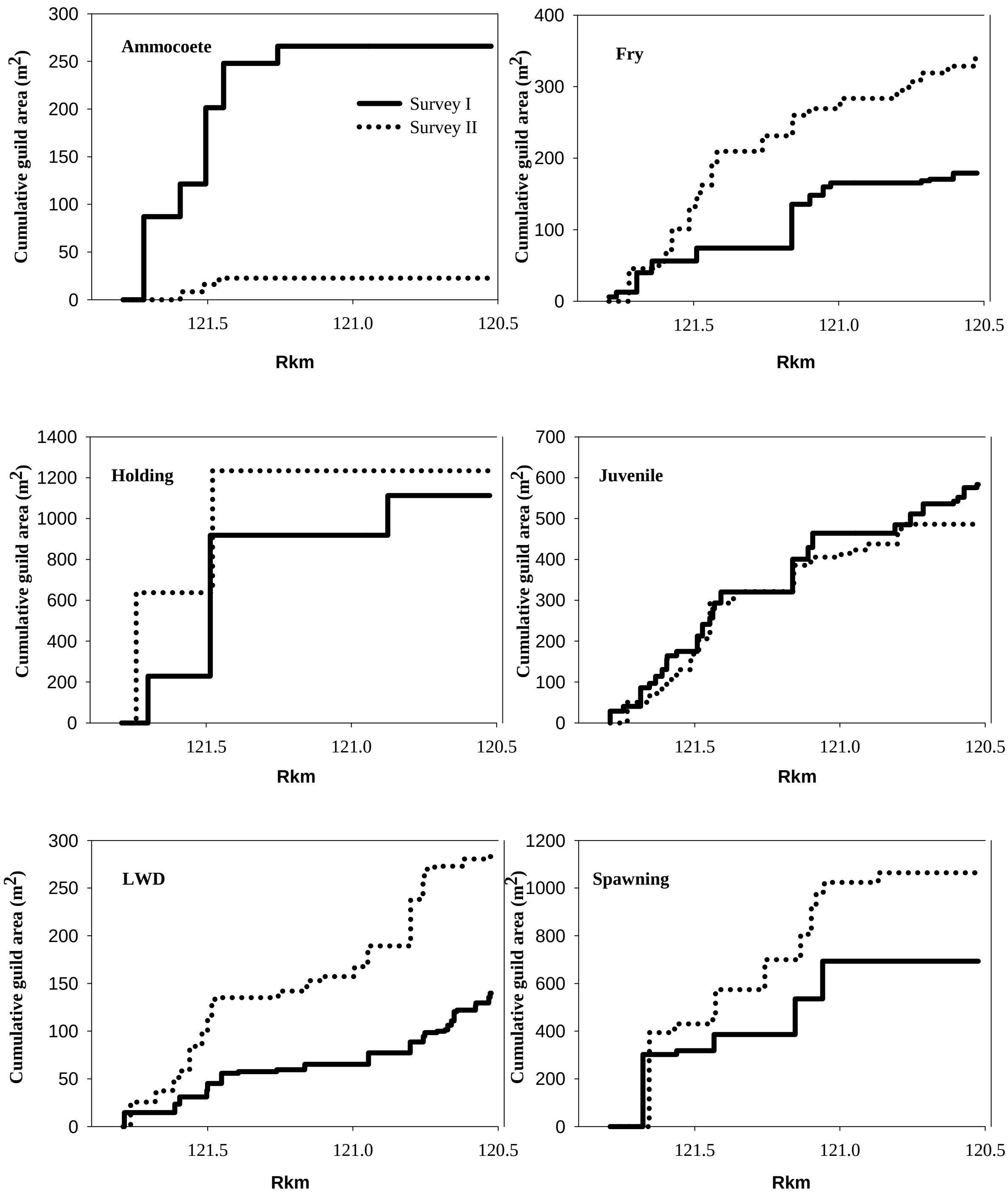

Figure 9. Longitudinal comparison of a replicate JBHM survey 6b of cumulative habitat from six guilds conducted on Reach 6 on the Trinity River, 2006.

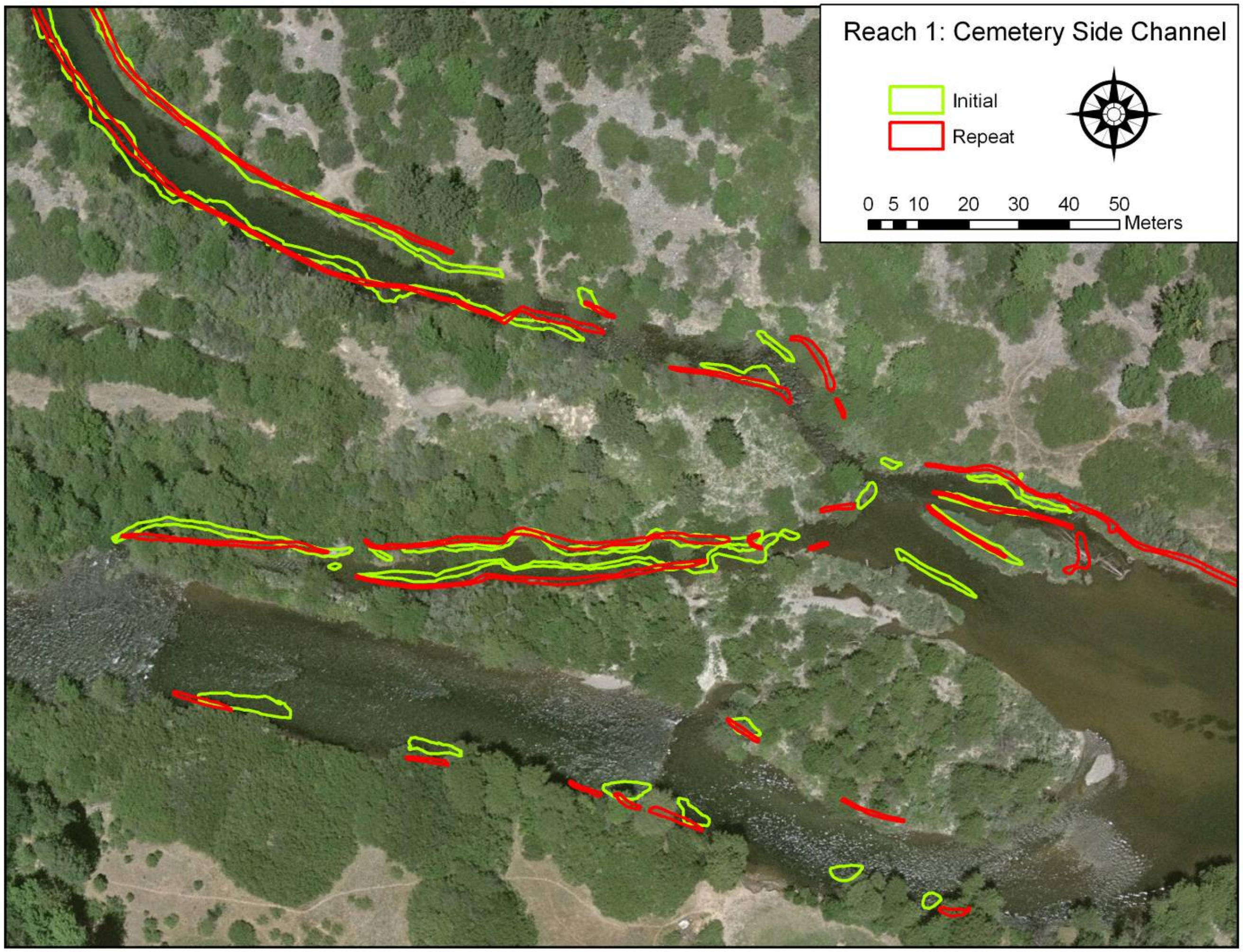

Figure 10. An example of differences between surveys in the evaluation of repeatability in the JBHM effort on the Trinity River, as exemplified by the Chinook salmon juvenile habitat polygons at the entrance of Cemetery Side Channel, 2006.

Discussion

The goals of this project were to: (1) to evaluate JBHM as a tool for assessing and detecting changes in the habitat of target species/life-stages and (2) collect data for comparisons with other habitat assessment techniques.

Field Methods

The potential benefits of the JBHM method include a spatially explicit dataset and a low level of effort relative to more data intensive numerical modeling techniques. This effort was able to map a total of 24.53 rkm (including 4.06 rkm for the replicate surveys) of the upper Trinity River. Estimates of habitat availability at summer base flows (450 cfs Lewiston dam release) were generated for six guilds over 20.47 rkms of the upper Trinity River. Data generated by this project can be compared with other habitat assessment methodologies, specifically the Biomonitoring and 2-D efforts conducted for the TRRP, when data for all of these efforts are available.

The project was completed with participation from five fish biologists, one from each of five participating TRRP partners, and required a total of 155 staff-days at a total expense of $126,013. A total of 40 staff-days were required for pre-project planning including guild development, generation of maps, and field calibration. A total of 45 staff-days were required for actual mapping in the field and 30 staff-days were required for GIS post-processing of maps. Approximately 40 staff days were required for data analysis and reporting.

Unfamiliarity with the methodology used for this project limited the amount of time that was available to conduct the field survey aspect of the study. A substantial amount of time was necessary in the pre-project planning stage which limited the amount of staff time available for field surveys for this effort. While all of these pre-planning tasks would have been necessary regardless of previous experience with the method or who was implementing the project, there were definitely some inefficiencies in this aspect of the project since the study plan had not been fully developed prior to the implementing the project. Since some of the pre-planning efforts such as the development of the guilds have been completed, future implementation of this methodology would not require as much pre-planning effort.

The Rush Creek and Sheridan surveys were different from the surveys in Reach 1 and Reach 6 in that they were focused efforts and did not cover the entire reach. By doing these focused reaches surveys at Rush Creek and Sheridan, we did not fully benefit from efficiencies inherent in the overall method, such as covering greater areas with less precision. These benefits were not fully realized due to logistics such as set-up and take-down in the field.

Repeatability

Previous applications of judgment based habitat evaluation techniques have received criticism for their potential lack of repeatability (Arthington and Zalucki 1998, Young et al. 2004). This lack of repeatability was demonstrated when replicate surveys of the judgment based EPAM survey produced disparate results (Swales and Harris 1995). When reviewing a proposal for the JBHM effort (then referred to as EHM or ExHM), the Trinity River Restoration Program Science Advisory Board (SAB) voiced concerns for the potential lack of repeatability (Andrews et al. 2006). In an effort to evaluate the repeatability of JBHM, we conducted replicate surveys of three sections within the survey reaches.

Replicate surveys produced differences in total habitat area of various guilds, as well as differences in the spatial distribution of habitats. These differences appear to be related to errors which can be categorized as either judgment error, field measurement error, or digitizing error. Judgment error can be defined as imperfect detection of attributes which define habitats, such as over or underestimating depths or velocities. Field measurement error is a product of the difference between the actual size of the habitat and the mapped polygon. Another field related error occurs when a habitat is drawn in the wrong location on the map. The final, and probably least significant source of error is the difference between what is mapped and what is digitized into Arc-GIS.

It is difficult to ascertain why some of the larger differences occurred throughout replicate surveys. Additionally, reaches with large differences between initial and replicate surveys were not consistent among guilds. For example, large differences between initial and replicate surveys are readily apparent in Reach 6a juvenile, fry, and spawning surveys. These differences are less substantial in the same guilds for Reach 1. Similarly, initial and replicate ammocoete surveys varied greatly in Reach 6b, but were seemingly consistent for the other reaches. Because the total error can be attributed to a combination of judgment, field, or digitizing errors, it is difficult to conclude which combination of errors most contributed to the highlighted disparity between initial and replicate surveys for some guilds in some reaches and thus even more difficult to discern strategies for correcting these errors in future monitoring efforts using these or similar methods.

It is possible the errors noted between initial and replicate surveys may have been reduced with additional preparation of field team members. While two days were spent orienting the field team, additional time dedicated to practicing field methods and comparing preliminary results may have called attention to important sources of error earlier or simply improved group agreements on riverine areas likely to meet visual thresholds for qualification or disqualification for inclusion as habitat for a given guild. The participation of other experts with previous EHM or JBHM field experience alongside field crews in pre-monitoring preparation and implementation settings would have also been beneficial. Field participation by additional experts may have enabled early troubleshooting of some sources of error or enhanced common understandings of visual habitat observations. Additional time spent practicing drawing on aerial photographs in the field may also reduce error for future efforts. At times, there may have been agreement on visually observed habitat by all members of the field team, but different individuals may have simply drawn the same habitat differently through the basic exercise of pen on paper.

Evaluations of previous judgment based mapping techniques have suggested standardization of the decision making process through the implementation of a conceptual model (EPRI 2003, Railsback and Kadvany 2008). This conceptual model lists steps in the decision process to help reduce judgment error associated with the technique. Another means to reduce this error would be to physically measure guild parameters rather than relying on ocular estimates. Field measurement error was particularly evident in the application of JBHM on the Trinity River. The width of the Trinity River forced a map scale of approximately one inch equaled 17 to 23 feet. This created difficulties when depicting habitats that were typically a few feet wide, which was the width of the marker (i.e. fry, Chinook salmon juvenile, etc.). As depicted in Figure 7, large differences in habitat estimates from replicate surveys can, in part, be attributed to the width of habitat polygons along the margins of the riverbank due to the large scale of the maps relative to the size of the area being mapped.

In general, the physical size of the upper Trinity River is poorly suited for the map scale required to pragmatically reduce mapping challenges. A smaller stream or river allowing for a printed aerial photograph with larger scale is better suited for this mapping method. With the upper Trinity River being relatively wide and available habitat generally located along narrow margins along either bank, the available scale of the printed aerial photographs were not well suited for capturing this narrow habitat area accurately in all instances.

Judgment errors could be reduced by implementing quantitative measures into the survey methodology. More rigorous planning and pre-deployment coordination among field team members may have reduced judgment errors. Field measurement and habitat location errors could be reduced by implementation of technologies such as real-time digitizing on a field laptop with locations verified by GPS.

Conclusion

The spatially explicit nature of this survey methodology allows for site specific evaluations and recommendations. Difficulties with the method encountered during this study included the lack of repeatability which was demonstrated by the disparity between replicate survey results. The large disparity between initial and repeat surveys appeared to some degree to be related to the scale of the river and the mapping methodology that was employed which limits the utility of this method to evaluate short or long term habitat changes on the Trinity River unless substantial improvements can be made. Utilizing the positive components of this method with a more quantitative structure could lead to a technique more applicable to evaluate long term habitat changes on the Trinity River.

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Appendix A

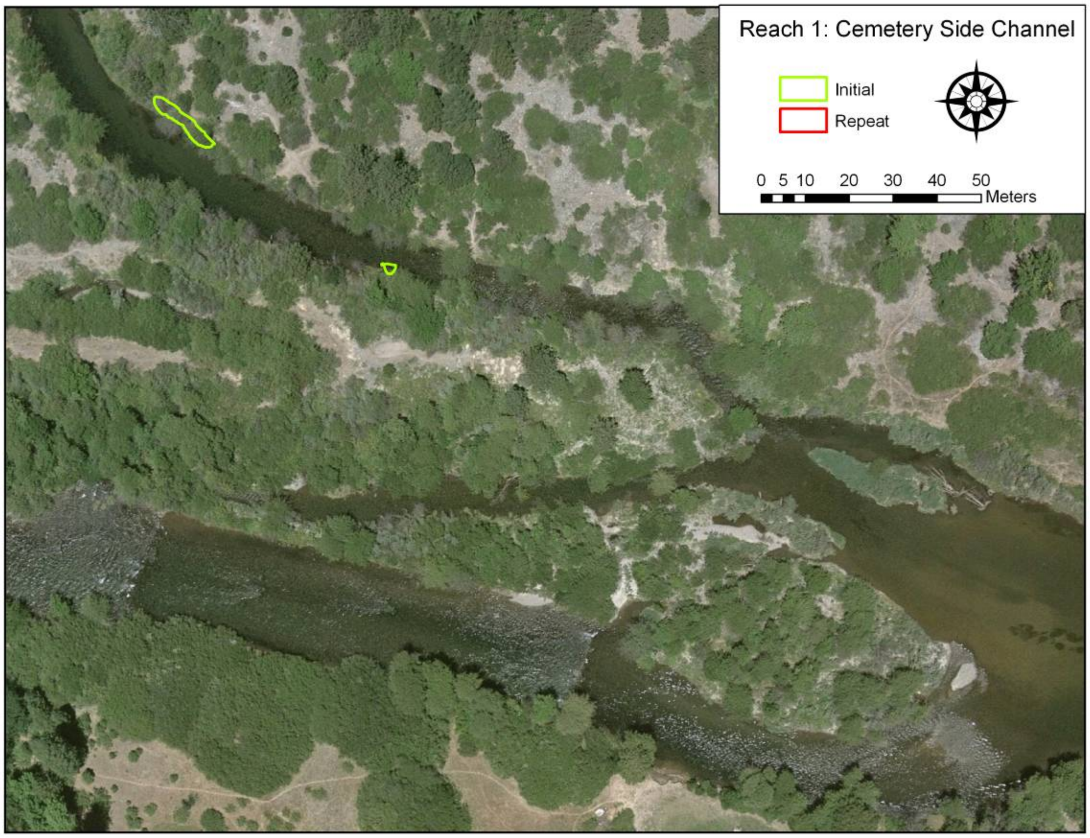

Figure A- 1. An example of differences between surveys in the evaluation of repeatability in the JBHM effort on the Trinity River, as exemplified by the ammocoete habitat polygons at the entrance of Cemetery Side Channel, 2006.

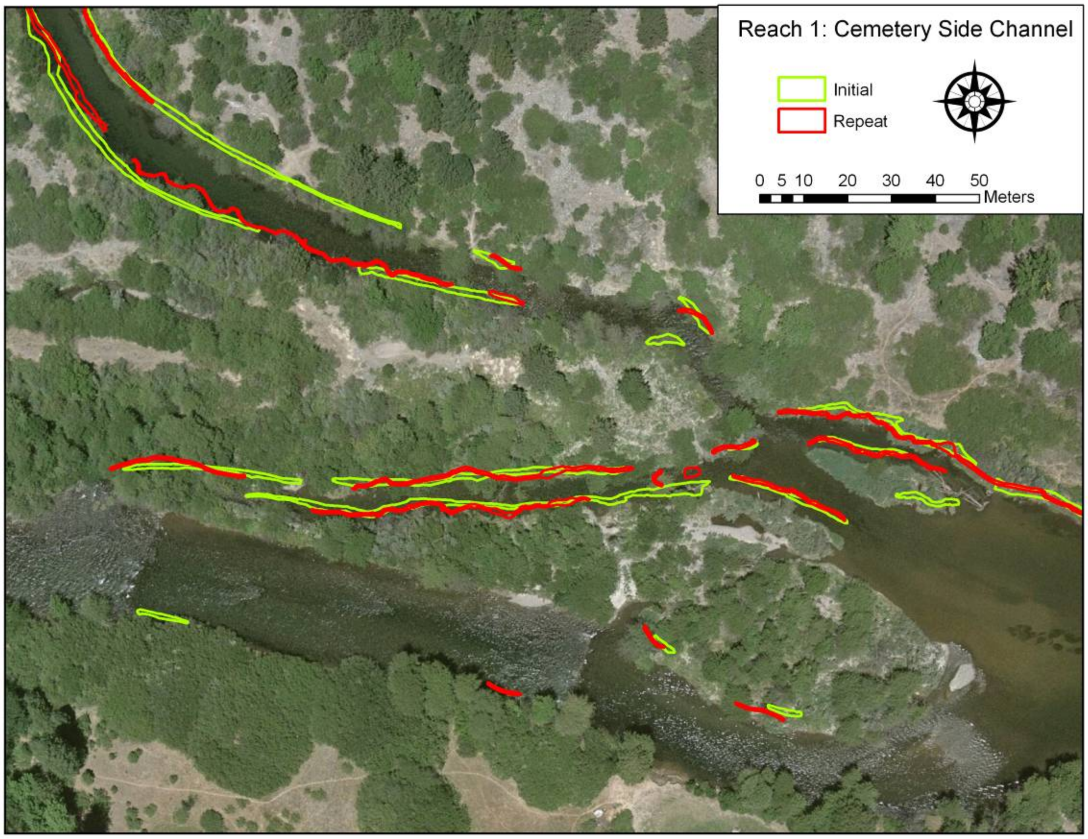

Figure A- 2. An example of differences between surveys in the evaluation of repeatability in the JBHM effort on the Trinity River, as exemplified by the fry habitat polygons at the entrance of Cemetery Side Channel, 2006.

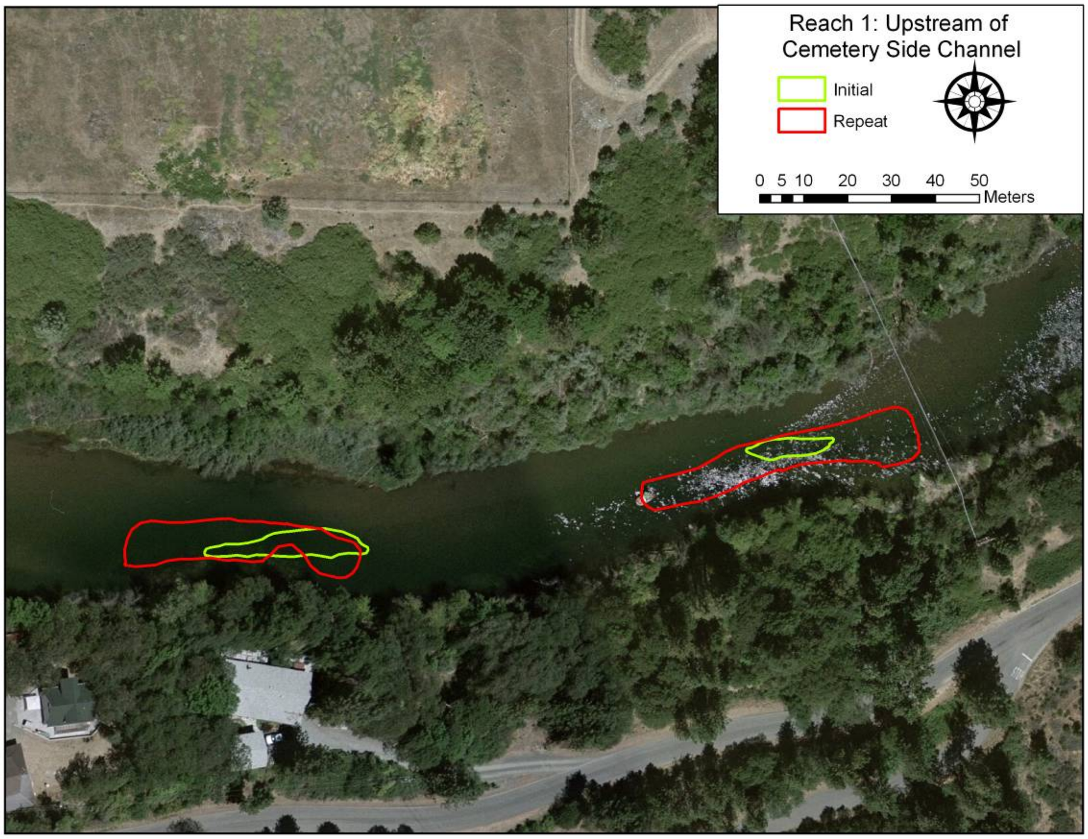

Figure A- 3. An example of differences between surveys in the evaluation of repeatability in the JBHM effort on the Trinity River, as exemplified by the Chinook salmon holding habitat polygons located upstream of the entrance of Cemetery Side Channel, 2006.

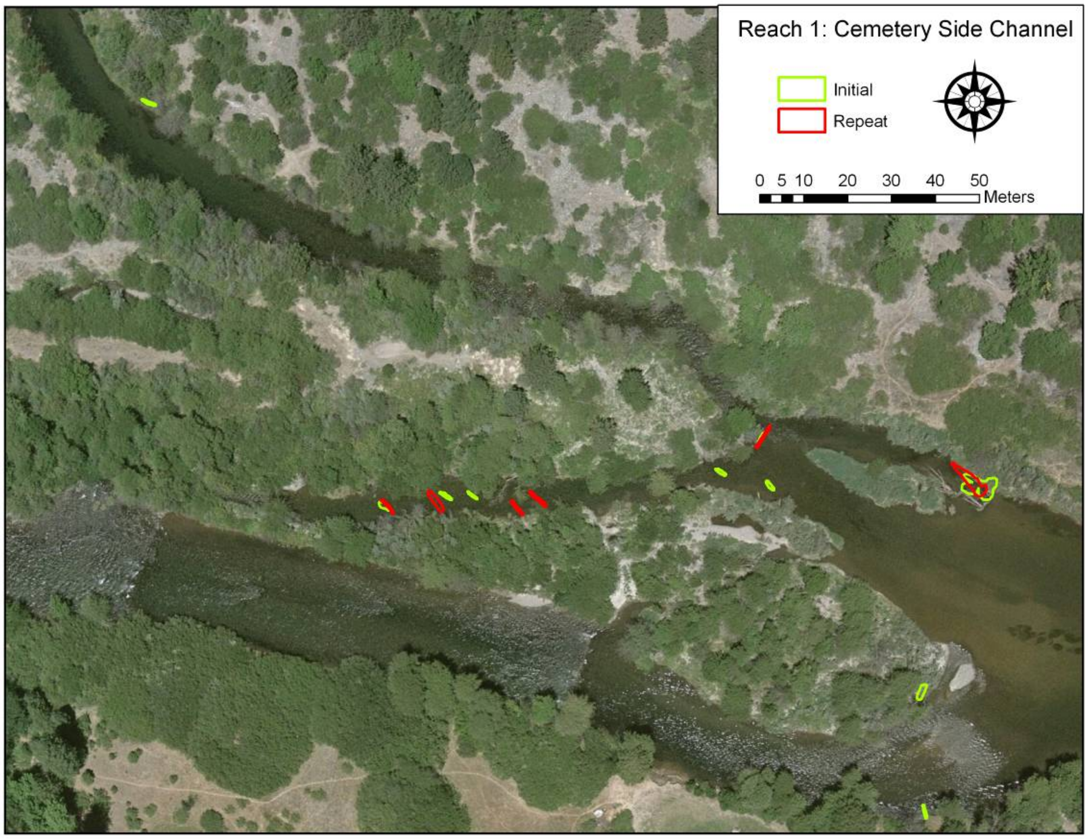

Figure A- 4. An example of differences between surveys in the evaluation of repeatability in the JBHM effort on the Trinity River, as exemplified by the LWD polygons at the entrance of Cemetery Side Channel, 2006.

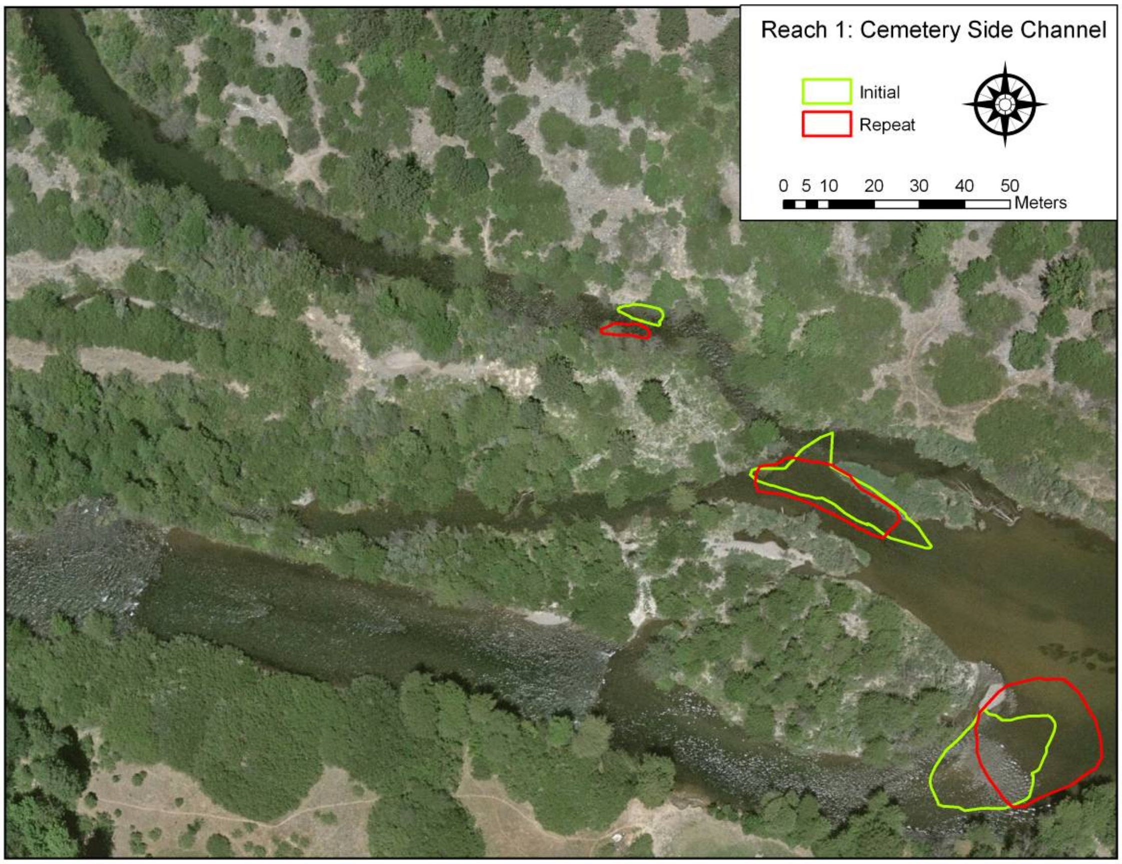

Figure A- 5. An example of differences between surveys in the evaluation of repeatability in the JBHM effort on the Trinity River, as exemplified by the Chinook and coho salmon spawning habitat polygons at the entrance of Cemetery Side Channel, 2006.