Electrofishing Effort Requirements for Estimating Species Richness in the Kootenai River, Idaho

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Abstract

This study was conducted on the Kootenai River, Idaho to provide insight on sampling requirements to optimize future monitoring effort associated with the response of fish assemblages to habitat rehabilitation. Our objective was to define the electrofishing effort (m) needed to have a 95% probability of sampling 50, 75, and 100% of the observed species richness and to evaluate the relative influence of depth, velocity, and instream woody cover on sample size requirements. Side-channel habitats required more sampling effort to achieve 75 and 100% of the total species richness than main-channel habitats. The sampling effort required to have a 95% probability of sampling 100% of the species richness was 1100 m for main-channel sites and 1400 m for side-channel sites. We hypothesized that the difference in sampling requirements between main- and side-channel habitats was largely due to differences in habitat characteristics and species richness between main- and side-channel habitats. In general, main-channel habitats had lower species richness than side-channel habitats. Habitat characteristics (i.e., depth, current velocity, and woody instream cover) were not related to sample size requirements. Our guidelines will improve sampling efficiency during monitoring effort in the Kootenai River and provide insight on sampling designs for other large western river systems where electrofishing is used to assess fish assemblages.

Keywords: sampling, sample size, species richness, Kootenai River, electrofishing

Introduction

Estimating species richness has long been problematic for ecologists in a wide variety of facets (Gould 2000, Gotelli and Colwell 2001, Walther and Martin 2001). While fisheries scientists commonly use this metric to evaluate and monitor fish assemblages, botanists and entomologists, among others, are commonly interested in how to efficiently estimate species richness of different biotic assemblages (Patton et al. 2000, Gotelli and Colwell 2001). For fisheries scientists, optimizing fish sampling effort to save time and resources is of high interest, particularly for projects focused on monitoring fish assemblages in large rivers (Flotemersch et al. 2011). Fisheries scientists are also commonly interested in characterizing fish assemblages or understanding how a management action might affect the occurrence of a given species. Achieving such objectives requires information on fish assemblage structure and species occurrence to monitor responses to management (Moerke and Lamberti 2003). Knowledge of how much effort is required to detect a given level of species richness can help reduce the amount of time spent sampling, while also providing the information needed to evaluate potential changes in species composition. Guidelines for sampling fish assemblages in large western rivers are lacking in the primary literature. However, guidelines are necessary to improve efficiency while maintaining meaningful and comparable

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datasets for monitoring and evaluating the influence of management activities on fish assemblages.

Considerable effort has focused on understanding sample size requirements for systems throughout North America. Sample size requirements for estimating species richness have been studied among a variety of lentic (Bailey et al. 2005, Quist et al. 2007) and lotic (Paller 1995, Patton et al. 2000, Fischer and Paukert 2009, Flotemersch et al. 2011) habitats in many regions of the United States. Much of the previous research has focused on standing waters and small streams of the eastern or midwestern United States, but relatively little work has been conducted on large rivers in the western United States. Neebling and Quist (2011) investigated sample size requirements to detect various levels of species richness with different gear combinations in large rivers in Iowa. Similarly, Flotemersch and Blocksom (2005) evaluated the influence of sampling design and sample size on reach lengths needed to estimate assemblage metrics; however, these studies are limited to rivers of the midwestern United States. Large western rivers tend to be fairly depauperate and have different species composition and assemblage structure than their Midwestern counterparts. Because of these inherent differences, information on sample size requirements using common gears are needed for large rivers in the western United States.

Given the importance and interest in gaining information on large river fish assemblages, development of sampling guidelines has become increasingly critical (Patton et al. 2000). Management actions, such as habitat rehabilitation, are occurring in many large rivers throughout the western United States and such projects are tasked with monitoring the effects of management actions (Moerke and Lamberti 2003, Schloesser et al. 2011, Romanov et al. 2012). Monitoring in most systems focuses on determining if management actions elicit responses from fish assemblages. As such, statistically rigorous sampling designs are needed to provide information that fishery managers can confidently use to assess these actions. Knowledge of species occurrence allows managers to prioritize future projects and better understand the factors structuring fish assemblages.

The Kootenai River is a large floodplain river that originates in British Columbia, Canada and flows through the panhandle of northern Idaho. The portion of the Kootenai River in Idaho is characterized by a prominent floodplain that historically provided a substantial amount of flooded terrestrial habitat during high runoff events; however, many flood-related habitats (e.g., side channels, sloughs, oxbows) in the Kootenai River have been eliminated as a result of instream and shoreline development. The Kootenai River has been extensively altered by anthropogenic disturbance from water development and land use activities (Knudsen 1993). Native fishes in the Kootenai River, some of which provide important fisheries, have declined in abundance from historical levels, especially white sturgeon *Acipenser transmontanus* (Paragamian 2012), burbot *Lota lota* (Paragamian and Hansen 2009), and kokanee *Oncorhynchus nerka* (Apperson 1990). The completion of Libby Dam and construction of levees have been implicated as causes for the decline of fish populations over the past several decades (Paragamian 2012). In addition to habitat loss from water development, Libby Dam has altered the historical flow, nutrient, and thermal regimes which have negatively influenced native fishes in the lower Kootenai River. While the headwaters of the Kootenai River are relatively intact, the lower portion of the Kootenai River ecosystem functions quite differently than it did historically (Knudson 1993). The once large and prominent floodplain that extended throughout the lower Kootenai River has since been replaced by a deep, incised main channel with little floodplain connectivity.

Managers of the Kootenai River have recently instituted a large-scale habitat rehabilitation project focused on improving environmental conditions for native fishes and mitigating for water development (KTOI 2009). Primary objectives of the project are to improve and (or) create side-channel habitat that is scarce along a developed floodplain and to improve degraded habitat in the main channel (KTOI 2009, KTOI 2012). Habitat rehabilitation has been used successfully in many systems to enhance the abundance, growth, and reproduction of target fish species (Moerke and Lamberti

2003, Romanov et al. 2012). Habitat rehabilitation projects have become a popular means for restoring native fish assemblages and have been shown to bring about change in fish assemblage and population structure (Binns 2004, Romanov et al. 2012). However, designs for monitoring and evaluating the success of habitat rehabilitation are often ignored. Furthermore, sampling designs for monitoring changes in fish assemblages, particularly in large western river systems, is lacking in the primary literature. Evaluating the amount of sampling effort needed to detect different levels of assemblage and population indices can improve the efficiency of projects aimed at monitoring trends in fish assemblages and species occurrence (Lyons 1992, Bayley and Dowling 1993, Flotemersch et al. 2011). Often, trends in occurrence of native and non-native fish can inform managers about the expansion or contraction of a species' distribution at small (e.g., river segment; Bayley et al.1993, Angermeier and Smoger 1995) and large scales (e.g., drainage basin; Jennings et al. 1995). Information on occurrence can also be used to identify patterns of colonization and extirpation in relation to management actions.

Managers of the Kootenai River are tasked with the responsibility of conserving native fishes and evaluating the influence of management actions on fish assemblages. Given the onset of a large-scale habitat rehabilitation project occurring in the lower Kootenai River, rigorous protocols are needed for effective monitoring and evaluation. Large river systems usually possess habitat characteristics that are different than habitat in small streams, where most sample size investigations have previously been conducted. For example, large rivers are wide and relatively deep compared to small streams. In addition, small streams in the western U.S. tend to have larger substrate and more overhead cover (Vannote et al. 1980). Other studies have shown that electrofishing is both size and species selective (Shoenebeck and Hansen 2005, Reynolds and Kolz 2012). Electrofishing selectivity is further complicated by the fact that catchability is often related to habitat characteristics (Rogers et al. 2003). Given these sampling issues, understanding the outcomes of sampling effort and the relative influence of habitat has ramifications for monitoring and developing effective sampling designs. As such, the purpose of this study was to determine the number of sampling reaches required to estimate various levels of species richness in the braided reach of the Kootenai River and to describe the relationship between habitat and sampling effort requirements for estimating species richness.

Methods

Site Selection

The Idaho portion of the Kootenai River is delineated into three distinct sections: canyon, braided, and meander sections (Fosness and Williams 2009). The braided section (246–257 river kilometer) was the focus of our study and extends from the confluence of the Moyie River downstream to Bonners Ferry, Idaho (Figure 1). Sampling occurred at seven sites within the braided section of the Kootenai River during the summer (May–September) of 2013. Sites were designated as either side-channel or main-channel (i.e., existing only in the main channel). Because a major focus of this study was to collect information from sites that would undergo habitat rehabilitation in the future, we selected sites based on planned rehabilitation. Main- and side-channel habitats were treated as two separate strata for this study based on inherent differences in habitat characteristics. Three side-channel complexes and four main-channel meanders were designated as sampling sites (hereafter referred to as sites). Each side-channel site was then divided into individual 100-m-long reaches (hereafter referred to as reaches) along the thalweg. Each main-channel site was divided into 100-m-long reaches along both the inside and outside bend. Reaches in side-channel sites were treated as segments containing both banks while reaches in main-channel sites were considered as either the inside or outside bend. Reach lengths of 100 m allowed us to easily enumerate the total distance required during subsequent analyses. A handheld global positioning system was used to georeference the upper and lower terminus of each reach and florescent flagging was placed along the bank to identify the spatial extent of each reach during sampling.

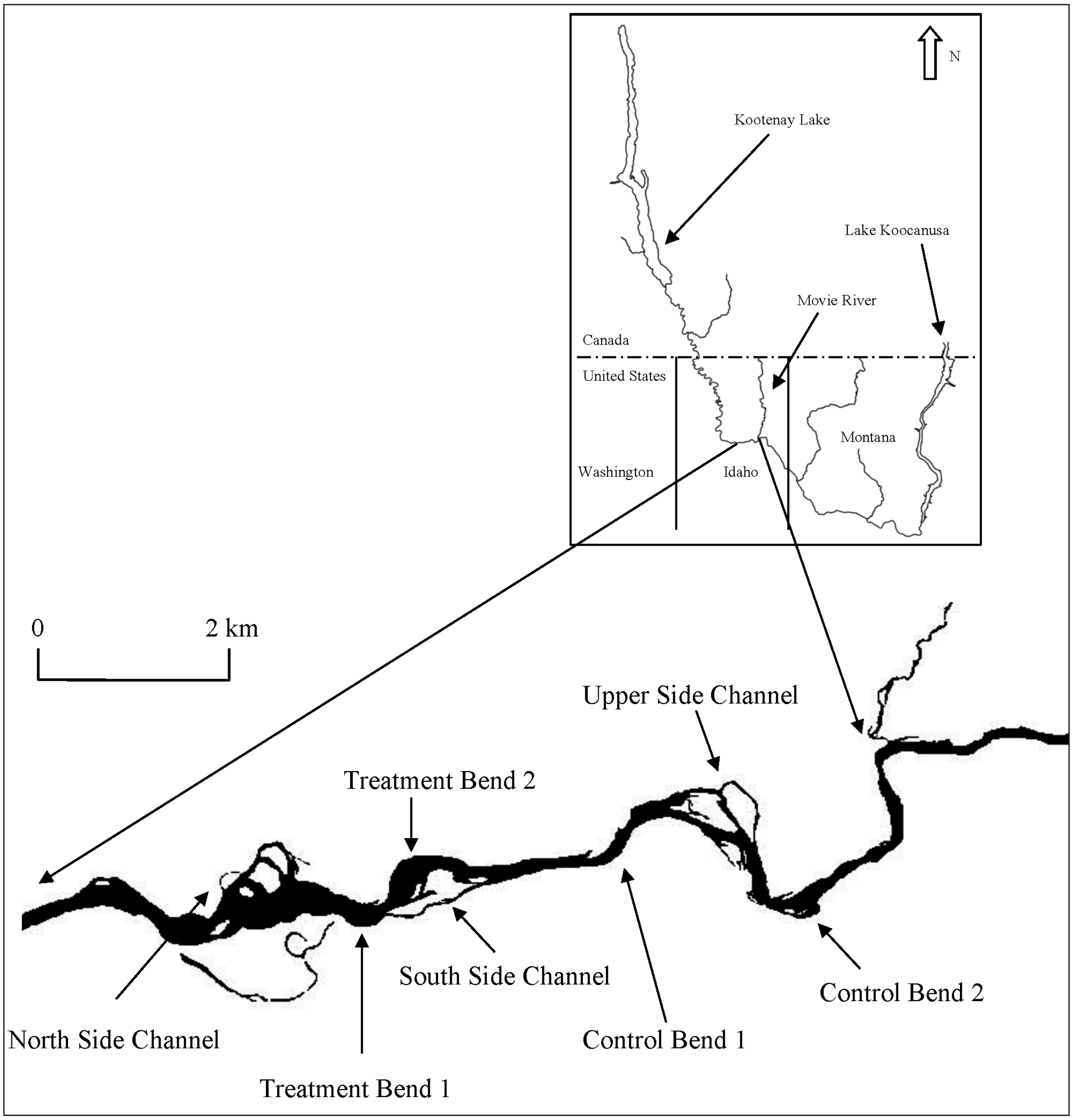

Figure 1. Map of the Idaho portion of the Kootenai River. The braided section is located between the confluence of the Moyie River and the town of Bonners Ferry, Idaho.

Fish Sampling

All reaches were sampled using pulsed-DC boat-mounted electrofishing on a biweekly schedule to account for temporal variability in fish assemblage structure. Previous studies have shown that electrofishing is an effective sampling technique for riverine fishes and is commonly used by natural resource agencies conduct fish surveys (Reynolds and Kolz 2012). As such, sampling was conducted during the day with a boat-mounted electrofisher composed of an Infinity control box (Midwest Lake Electrofishing Systems, Inc., Polo, Missouri) and a 5000 W generator (American Honda Motor Co., Torrance, California). Electrofishing power output was standardized to 3000 W based on ambient water conductivity and water temperature following Miranda (2009). Two netters were stationed at the bow of the boat to collect immobilized fish during sampling. For side-channel sites, electrofishing effort began at the most upstream reach within each site, and a single pass was allocated to both the right and left banks of each reach before proceeding to the next reach. Electrofishing began at the uppermost reach in each main-channel bend and a single pass was conducted along the bank of each reach before proceeding to the subsequent reach. Upon completion of sampling in each reach, fishes were identified to species, measured (total length; mm), and released. Data collected from reaches along the inside and outside bends of main-channel sites were treated independently in all analyses, but were nested within their respective sites. Similarly, data collected from reaches in side-channel sites were nested within their respective site. After processing, all fish were released in a location away from subsequent sampling reaches to minimize the influence of emigration back into the sampling area.

Habitat Sampling

Environmental variables were measured to evaluate the influence of abiotic habitat characteristics on the effort required to attain various proportions of total species richness. Woody debris was measured as the total surface area (m^2) of woody instream cover in each sampling reach. Only woody debris particles greater than 0.20 m in diameter and 0.50 m in length were measured. Estimates of mean water column velocity and depth were obtained from the River Design Group (RDG; River Design Group, Inc., Whitefish, Montana). The RDG has compiled channel morphology and flow data from throughout the braided reach of the Kootenai River to monitor the response of habitat within rehabilitation areas. Water hydraulics were simulated using the flow and sediment transport with morphological evolution of channels hydraulic flow model (FaSTMECH; Nelson 1996). The hydraulic model was calibrated to a range of measured stage data from a detailed gage network from water years 2010 and 2011 (Czuba et al. 2011). Model results were post-processed in ArcGIS (ArcGIS 2000, Esri, Redlands, California) to develop mean depth, mean velocity, associated variances, and shear stress grids for flow conditions that occurred during each fish sampling event.

Data Analysis

Species richness was calculated for each site by month during the field season as the total number of species detected. Two sampling events were conducted during each month of the summer (May–September). The sampling event during each month with the highest standard deviation in species richness was used for subsequent analyses. This allowed for the most conservative estimate of required effort. The effort required to sample 50, 75, and 100% of the species captured in each site (species richness) with 95% confidence was estimated during each month of the field season using a re-sampling procedure. Monte Carlo simulations were used to resample random combinations of reaches within each site (Manly 1991). Simulations were performed to randomly sample (without replacement) combinations of reaches (representing sampling effort) within each site (Patton et al. 2000, Quist et al. 2007, Neebling and Quist 2011). One thousand iterations were performed for each sample size and the total number of species was recorded for each iteration. We assumed that at least two reaches (i.e., 200 m of thalweg [side channels] or shoreline [main channel] distance) could be sampled by fisheries scientists with ease; this was a reasonable assumption given the nature of sampling in large river systems.

For each sample size, the number of times out of 1000 replicates that a given species richness was attained was recorded. This provided raw probabilities for detecting various levels of species richness with each sample size. The mean minimum number of reaches required to sample a given level of species richness (i.e., 50, 75, or 100%) with a 95% probability was estimated. For instance, 12 reaches were sampled during May from the South Side Channel (SSC) and nine species were captured. For a sample size of two reaches, two reaches were repeatedly sampled 1000 times and the number of species from each iteration was recorded. This process was repeated up to the maximum sample size ($n = 12$). Replicates were used to estimate of the probability of observing various levels species richness among different sample sizes (Figure 2).

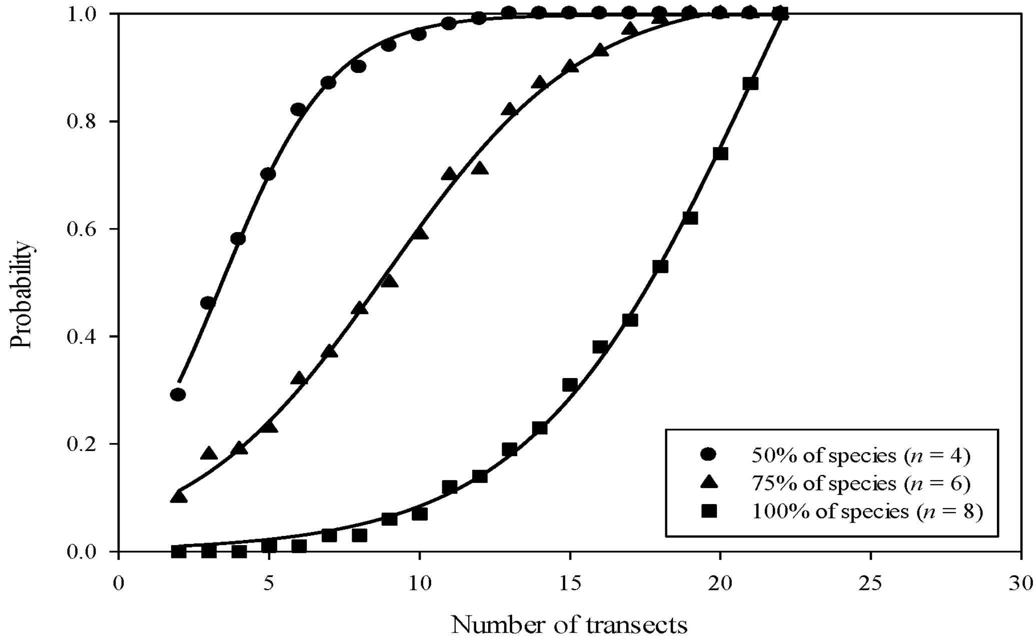

Figure 2. Example of accumulation curves produced from resampling simulations used to estimate sample size requirements for various levels of fish species richness in the Kootenai River, Idaho (2013). These data are from September 2013 sampling in the Upper Side Channel. Each point represents the number of replications during each simulation that a defined number of species was sampled.

Probabilities were subsequently modeled using nonlinear regression methods (Seber and Wild 2006) to assess the number of transects required to sample each percentage of species at some probability of detection. All simulations and analyses were performed using R version 3.1.0 (R 3.1.0, R Core Team, 2012).

We complimented species accumulation models with distance-based estimates of required electrofishing effort to provide further insight to fisheries managers. The number of stream reaches was converted to a measure of distance in meters (measured as the total thalweg [side-channel sites] or shoreline distance [main-channel sites]) required to sample given target levels of species richness (Bayley and Dowling 1993, Patton et al. 2000). Simple linear regression was used to evaluate the influence of environmental characteristics on the distance required to estimate species richness. The total distance required to sample 100% of the species present in a site with 95% confidence was converted to a proportion of the total site length and used as the response variable in regression analyses. We investigated woody cover, velocity, and coefficient of variation (CV) in depth as potential explanatory variables influencing the proportion of each site required to sample 100% of the species. Habitat characteristics used as explanatory variables in multiple regression models were chosen based on their potential to influence sampling efficiency and their known importance to the ecology of fishes occurring in the Kootenai River (Smith et al. 2015). Knowledge of the influence of habitat on species occurrence and detection formed the basis for the models we developed to explain variability in sampling effort requirements. A Type I error rate of $\alpha = 0.05$ was used in all statistical tests.

Results

We sampled 112 reaches comprising seven sites during the summer of 2013, and each site was sampled 10 times. Side-channel sites varied in thalweg length from 1200–2200 m and contained 56 reaches, whereas main-channel sites varied in length from 1200–1500 m in shoreline length and

TABLE 1. Total thalweg or shoreline length (m), mean velocity (m/sec), mean depth (m), mean surface area of woody cover (> 0.2 × 0.5 m; m^2), and channel type of sampling sites in the braided section of the Kootenai River, Idaho sampled during the summer (May–September) of 2013. Standard errors for mean habitat variables are provided in parentheses. Sites include NSC = North Side Channel, SSC = South Side Channel, USC = Upper Side Channel, CB 1 = Control Bend 1, CB 2 = Control Bend 2, TB 1 = Treatment Bend 1, TB 2 = Treatment Bend 2.

Site name	Length	Reaches	Velocity	Depth	Woody cover
			Side channel		
NSC	2200	22	0.31 (0.01)	1.92 (0.06)	48.47 (3.36)
SSC	1200	12	0.80 (0.02)	1.50 (0.04)	12.08 (0.87)
USC	2200	22	0.68 (0.01)	1.48 (0.04)	34.21 (2.82)
			Main channel		
CB 1	1500	15	1.31 (0.02)	2.67 (0.07)	3.43 (0.49)
CB 2	1500	15	1.04 (0.03)	3.35 (0.18)	0.00 (0.00)
TB 1	1500	15	1.05 (0.02)	2.64 (0.08)	0.00 (0.00)
TB 2	1200	15	1.08 (0.02)	2.84 (0.12)	64.62 (6.14)

contained 57 reaches (Table 1). Two side-channel sites were 2200 m in thalweg length and one side-channel site was 1200 m in thalweg length. Two main-channel sites were 1500 m in total shoreline length, one was 1400 m long, and another was 1200 m long. Mean water velocity and depth were higher in main-channel sites than side-channel sites (Table 1). Mean area of woody cover was generally higher in sites that had undergone habitat rehabilitation (i.e, North Side Channel, Upper Side Channel, Treatment Bend 2).

We sampled 20 species representing eight families among the seven sites (Table 1) and sampled between 4–12 species at each reach across all months. Largescale sucker (scientific names provided in Table 2) and mountain whitefish were the most common species and the only species detected at every sampling reach throughout the summer; cumulatively, largescale sucker and mountain whitefish composed 66% of the total catch. Longnose sucker, northern pikeminnow, peamouth, redband trout, redside shiner, and *Cottidae* spp. were detected at every site, but not every reach. Furthermore, although these species were detected at every reach, they were not abundant, making up only 25% of the total catch by number. Species richness was generally higher for side-channel sites than for main-channel sites (Table 3; Figure 3). In addition, species richness increased during the late summer (August and September) in side-channel sites, whereas main-channel sites had higher species richness during the early summer (May and June).

The amount of sampling effort required to sample various percentages of species richness varied by site and month. In general, sites with fewer reaches required less sampling effort to achieve all target levels of species richness during all months (Table 3). Clear patterns emerged among the number of species detected and the distance required to sample various levels of species richness. As would be expected, the number of reaches required to have a 95% probability of sampling 100% of the total number of species generally increased as more species were detected. This was true for most sampling sites, with the exception of the North Side Channel which displayed the opposite pattern (Table 3). For example, in the South Side Channel during May, nine species were sampled with electrofishing and required an average of 354 m to sample 50%, 698 m to sample 75%, and 1019 m to sample 100% of the total estimated species richness (Figure 4). For the South Side Channel during June, the required number of reaches required increased to 399 m for 50% of species richness, decreased to 618 m for 75%, and increased slightly to 1100 m for 100%.

Regression modeling exercises showed little support for environmental covariates hypothesized to influence the proportion of site length required to sample 100% of the estimated species richness.

TABLE 2. Fishes sampled from the braided section of the Kootenai River, Idaho during the summer (May–September) of 2013: NSC = North Side Channel, SSC = South Side Channel, USC = Upper Side Channel, CB 1 = Control Bend 1, CB 2 = Control Bend 2, TB 1 = Treatment Bend 1, TB 2 = Treatment Bend 2 (where X indicates that a species was present at a site). Species are listed alphabetically by common name and scientific name is provided.

Species sampled by site								
Common name	Scientific name	NSC	SSC	USC	CB 1	CB 2	TB 1	TB 2
Burbot	*Lota lota*		X		X			
Brown Bullhead	*Ameiurus nebulosus*	X		X		X		
Brook Trout	*Salvelinus fontinalis*		X			X		
Bull Trout	*Salvelinus confluentus*		X				X	
Brown Trout	*Salmo trutta*		X		X			
Kokanee	*Oncorhynchus nerka*	X	X	X		X	X	
Largemouth Bass	*Micropterus salmoides*	X						
Longnose Dace	*Rhinichthys cataractae*		X	X	X			
Longnose Sucker	*Catostomus catostomus*	X	X	X	X	X	X	X
Largescale Sucker	*Catostomus macrocheilus*	X	X	X	X	X	X	X
Mountain Whitefish	*Prosopium williamsoni*	X	X	X	X	X	X	X
Northern Pikeminnow	*Ptychocheilus oregonensis*	X	X	X	X	X	X	X
Pumpkinseed	*Lepomis gibbosus*	X						
Peamouth	*Mylocheilus caurinus*	X	X	X	X	X	X	X
Redband Trout	*Oncorhynchus mykiss*	X	X	X	X	X	X	X
Redside Shiner	*Richardsonius balteatus*	X	X	X	X	X	X	X
Sculpin	*Cottus* spp.	X	X	X	X	X	X	X
Westslope Cutthroat Trout	*Oncorhynchus clarkii lewisi*	X	X	X			X	
Yellow Perch	*Perca flavescens*	X						

The proportion of site length required to sample 100% of the species was inversely related to CV in depth ($r^2 = 0.14$, $P = 0.03$) and surface area of instream woody debris ($r^2 = 0.14$, $P = 0.02$); the relationship was negative for both variables. While both the CV in depth and area of woody debris were negatively related to distance required to sample all presumably present species, the relationship was not well-supported.

Discussion

Information regarding species occurrence is of importance to fisheries scientists because it allows them to monitor temporal and spatial trends in the distribution of fishes, and can provide insight on the response of fish assemblages to management actions or environmental change. In addition, information on the occurrence of fishes has increased in importance as it can provide insight on colonization rates and range expansion. Obtaining accurate information on species occurrence and species richness requires sufficient sampling effort to ensure that all species are captured and that sampling is efficient.

Overall, the sites sampled in our study displayed variation in monthly species richness and habitat. The amount of sampling effort required to estimate various levels of species richness varied among main- and side-channel reaches, but patterns in effort required to obtain 50, 75, and 100% of the estimated species richness was similar for all months during the field season. Other studies concentrated on evaluating species richness have focused on systems in the eastern or midwestern United States, many of which are small streams or standing waters. Consequently, many studies have developed guidelines using sampling gears that are not appropriate for large rivers (e.g., seining or backpack electrofishing). Neebling and Quist (2011) evaluated sample size requirements to estimate species richness using boat-mounted electrofishing in Iowa rivers. The authors reported that 2500 m were required to have a 95% probability of sampling 100% of the

TABLE 3. Site abbreviation, species richness (*S*), and electrofishing distance (m; [95% CI]) required to attain various percentages (i.e., 50, 75, and 100%) of species richness for each month during the summer of 2013: NSC = North Side Channel, SSC = South Side Channel, USC = Upper Side Channel, CB 1 = Control Bend 1, CB 2 = Control Bend 2, TB 1 = Treatment Bend 1, TB 2 = Treatment Bend 2. Measures of effort are provided as total distance electrofished.

		Percent of total species		
Site	*S*	50%	75%	100%
		May		
NSC	8	587 (248)	965 (283)	1397 (213)
SSC	9	354 (131)	698 (222)	1019 (184)
USC	7	366 (168)	841 (351)	1703 (337)
CB 1	6	320 (119)	700 (243)	984 (256)
CB 2	5	407 (158)	489 (199)	763 (201)
TB 1	6	426 (195)	717 (262)	1076 (268)
TB 2	4	355 (146)	506 (186)	799 (191)
		June		
NSC	7	328 (134)	731 (315)	1532 (316)
SSC	10	399 (142)	618 (198)	1100 (122)
USC	9	350 (149)	906 (354)	1762 (365)
CB 1	5	410 (189)	676 (282)	1041 (302)
CB 2	8	605 (199)	698 (200)	1063 (151)
TB 1	8	330 (122)	575 (217)	1077 (252)
TB 2	5	298 (107)	658 (197)	907 (181)
		July		
NSC	9	394 (152)	977 (389)	1349 (302)
SSC	8	441 (161)	624 (212)	982 (135)
USC	10	565 (250)	903 (304)	1810 (265)
CB 1	7	319 (124)	460 (158)	992 (195)
CB 2	9	444 (175)	720 (195)	1081 (130)
TB 1	8	390 (152)	548 (188)	923 (232)
TB 2	4	296 (109)	439 (147)	651 (147)
		August		
NSC	12	511 (187)	679 (241)	1235 (177)
SSC	8	326 (134)	702 (209)	975 (207)
USC	8	708 (350)	1,216 (458)	1814 (347)
CB 1	4	461 (268)	682 (272)	986 (296)
CB 2	6	482 (219)	500 (113)	784 (252)
TB 1	4	285 (101)	462 (132)	674 (122)
TB 2	4	224 (43)	281 (81)	425 (89)
		September		
NSC	10	374 (127)	766 (207)	942 (221)
SSC	9	398 (136)	615 (262)	991 (195)
USC	8	651 (303)	1,065 (438)	1818 (349)
CB 1	5	357 (146)	635 (228)	845 (281)
CB 2	9	321 (102)	603 (192)	1079 (195)
TB 1	6	466 (209)	982 (249)	1286 (207)
TB 2	4	262 (81)	386 (146)	620 (161)

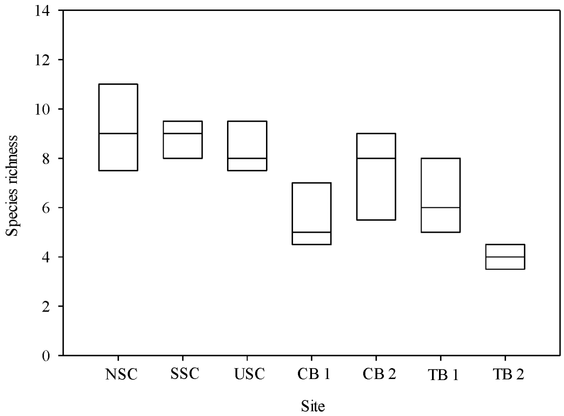

Figure 3. Box plot of species richness for seven sampling sites located in the braided section of the Kootenai River, Idaho (2013). The lines within each box represent the median species richness and the upper and lower portions of each box represent the 75th and 25th percentiles, respectively. Sampling sites include North Side Channel (NSC), South Side Channel (SSC), Upper Side Channel (USC), Control Bend 1 (CB 1), Control Bend 2 (CB 2), Treatment Bend 1 (TB 1), and Treatment Bend 2 (TB 2).

species richness using boat-mounted electrofishing. We did not observe a similar pattern in our study. In fact, we found that the distance required to sample 100% of the total species richness varied from 425–1818 m among all sites and months. More specifically, the amount of effort to sample 100% of the total species richness varied from 425–1286 m for main-channel sites and from 975–1818 m for side-channel sites. The efficacy of using both proportional- and fixed-distance designs for estimating species richness in large rivers has previously been evaluated (Lyons 1992, Flotemersch and Blocksom 2005). Given the former design, our results tend to differ from Neebling and Quist (2011) where the proportion of site length required to estimate species richness in Iowa rivers was approximately 50% of the total site length. Our results suggest that 35–86% of the total site length is required to sample 100% of the species richness in main-channel sites, and 81–86% of the total site length is required in side-channel sites. Therefore, in regard to proportion of the total original site length required to estimate species richness, our results tend to be higher than has been reported in other large river systems. The higher proportion of site length required in our study may reflect the presence of rare species that are patchily-distributed throughout the Kootenai River.

Western rivers are typically depauperate compared to systems in the midwestern and eastern United States. Moreover, fish assemblages in regulated rivers are generally dominated by relatively few, generalist species (Paragamian 2002, de Mérona et al. 2005). The Kootenai River exhibits a similar pattern where the fish assemblage is dominated by a few species. Smith (2013) found that fish assemblage structure and species composition varied throughout the entire lower Kootenai River, and that species richness was highest in the braided section. We found that the fish assemblage in the braided section was largely composed of a few species; however, most species tended to be rare and occurred only in localized areas with suitable habitat. We argue that the high amount of proportional sampling effort required to estimate species richness was an artifact of patchily-distributed rare species.

Previous studies have found that habitat can influence the amount of sampling effort required to characterize species richness. Patton et al. (2000) reported that stream width and stream area were inversely related to the number of reaches required to sample 90% of the species in small southeastern Wyoming streams. Our results suggested that habitat was not closely related to sample size requirements. Although the Kootenai River is composed of relatively homogeneous habitat with little complexity, similar to streams sampled by Patton et al. (2000), we did not observe similar patterns between habitat and sampling effort. However, in general, habitat in regulated rivers tends to be highly homogeneous (Nilsson et al. 2005) while small streams are often unregulated and possess more habitat complexity (Angermeier and Smoger 1995).

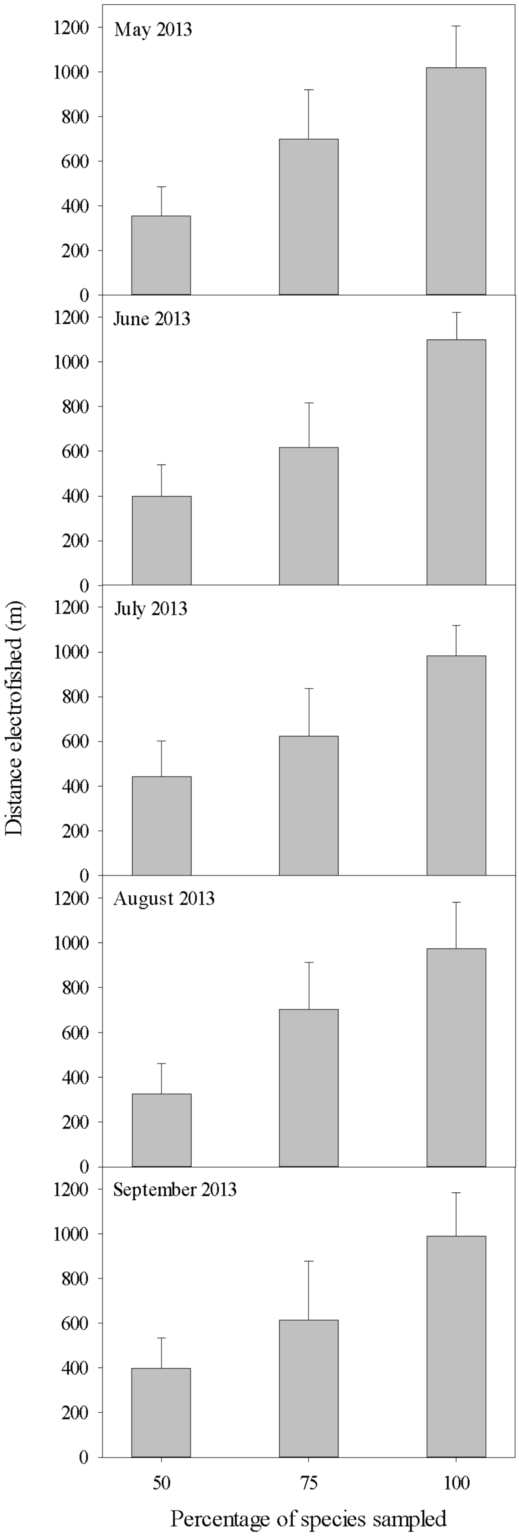

Figure 4. Graphical example of effort (distance) required to sample 25, 50, and 75% of species in the South Side Channel (SSC) of the Kootenai River where twelve, 100-m-long reaches were sampled each month during May–September 2013. Error bars represent one standard error of the mean.

An important consideration surrounding estimation of species occurrence and richness estimation is detectability (MacKenzie et al. 2002). Although detection probabilities were not evaluated in the study herein, they have been estimated for species in the Kootenai River (Smith 2013). Individual species detection probabilities can be coupled with our sampling effort results to provide additional guidance for future fish assemblage monitoring. Smith et al. (2015) provides probabilities of detection for all of the species sampling in our study in addition to information on habitat characteristics influencing occupancy.

Our results suggest that stratification of sampling effort based on habitat characteristics may not be warranted during future monitoring efforts. We found that the relationship between instream woody cover, velocity, and depth was statistically weak and that these variables had little association with sample size requirements. Additionally, our results suggest that sampling 1800 m of thalweg corresponded to a 95% probability of sampling 100% of the observed species richness in side-channel sites. For main-channel sites, sampling 1400 m of shoreline produces a 95% probability of sampling 100% of the observed species richness.

In general, these sample sizes will provide the highest confidence estimates of species richness and avoid unnecessary sampling. In most cases, the most conservative level of sampling effort required for 100% of species richness was close to the total length of each site, particularly in side-channel sites which required more effort than main-channel sites. Future work will also benefit from retrospectively evaluating power to detect changes in species richness given various levels of sampling effort and alternative methods and designs (i.e., multiple pass electrofishing, nighttime electrofishing). In fact, previous work on electrofishing methodology has shown that nighttime sampling is more efficient (Paragamian 1989). Given the relatively low species richness estimates observed in our study, we acknowledge that estimation of detectable changes in species richness may be difficult and require more than the recommended effort described here, but additional work in this area may provide insight on effort requirements for detecting rare species in the Kootenai River (i.e., burbot, white sturgeon). In addition, alternative designs and sampling methods may not significantly reduce the amount of effort required to estimate species richness or increase the probability of detecting rare species. However, the guidelines provided here will allow managers of the Kootenai River to conduct future sampling efforts with reasonable certainty of species richness estimates among main- and off-channel environments using safe and feasible methods. This study is the first of its kind for large coldwater rivers, but future work should focus on similar analyses in other large rivers characteristic of the western United States.

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