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[Article]

Conditional Capture Probability of *Scaphirhynchus* spp. in Drifting Trammel Nets

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Abstract.—Pallid sturgeon *Scaphirhynchus albus* and shovelnose sturgeon *S. platorynchus* are commonly sampled using drifting trammel nets in the Missouri and Mississippi river basins. Despite the fact that drifting trammel nets have been used for decades to sample these species, little is known about the capture efficiency of this gear. We estimated conditional capture probability for drifting trammel nets over known locations of pallid sturgeon and shovelnose sturgeon. In addition, we examined several variables that were predicted to influence the success of capturing a pallid sturgeon or shovelnose sturgeon in a drifting trammel net. Conditional capture probability (the conditioning factor was known presence) varied from 0.37 on the first attempt to 0.51 on the second attempt. None of the variables measured were useful in explaining the success of sampling a fish in a drifting trammel net. Drifting trammel nets are relatively efficient, and we suggest that they continue to be used to sample pallid sturgeon and shovelnose sturgeon in large turbid rivers. The high variability in catch per unit effort associated with sampling pallid sturgeon and shovelnose sturgeon using drifting trammel nets reported in the literature is probably related to the their low abundance (primarily pallid sturgeon) and patchy distribution (both species). Thus, using sampling designs appropriate for species with low abundance or patchy distributions rather than sampling designs commonly used for abundant species with ubiquitous distributions will require less effort because drifting trammel nets are relatively efficient.

Drifting trammel nets are an active gear commonly used to sample pallid sturgeon *Scaphirhynchus albus* and shovelnose sturgeon *S. platorynchus* (hereafter, both species are collectively termed *Scaphirhynchus* spp.; for our purpose, this does not include Alabama sturgeon *Scaphirhynchus suttkusi*) in lotic systems throughout North America, particularly in the Missouri, Yellowstone, and Mississippi rivers (e.g., Hubert and Schmitt 1982; Hurley et al. 1987; Sappington et al. 1998; Bramblett and White 2001; Steffensen and Mestl 2005; Gerrity et al. 2006; Wanner 2006; Drobish 2007). Data from drifting trammel nets are typically used to calculate catch per unit effort (C/f) and subsequently fisheries scientists make decisions regarding the abundance of *Scaphirhynchus* spp. in river reaches. This approach is appropriate if C/f is linearly related to population density, that is,

$$C/f = q(N/A),$$

where C is catch, f is fishing effort, q is catchability, N is abundance, and A is area. However, q can highly influence the relationship between C/f and population density (Hilborn and Walters 1992; Schoenebeck and Hansen 2005; Hubert and Fabrizio 2007).

Catchability is the relationship between resource abundance and the efficiency of the fishing gear (Arreguín-Sánchez 1996). Catchability has been defined as

$$q = c(a/A),$$

where c is fishing gear efficiency, a is individuals in the sampling area, and A is the number of individuals in the overall area of interest (Arreguín-Sánchez 1996). If A and a are equal, then $q = c$. The term catchability is typically synonymous with capture (detection) probability (Lancia et al. 2005). Throughout the remainder of this paper, we will use the term capture probability in order to reduce confusion and maintain continuity with the literature relevant to estimating the capture probability of individual i at least once during the study (Williams et al. 2002; Dinsmore and Johnson 2005). Mark–recapture or depletion methods for estimating population size are the most common methods for estimating capture probability (Williams et al. 2002; Hayes et al. 2007). However, the conditional capture probability can be estimated by sampling locations where the organism of interest is known to exist.

The first objective of this study was to estimate the conditional capture probability (known presence) of *Scaphirhynchus* spp. sampled by drifting trammel nets.

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The capture probability estimated in this study was conditional on a fish being present at the time and location the trammel net was drifted. That is, the location of the fish being sampled was known. This approach was selected as opposed to estimating capture probability from mark–recapture models that sample all possible areas because we were interested in estimating the "highest" capture probability. We removed the uncertainty of sampling where *Scaphirhynchus* spp. were not located. This approach gives an estimate of gear efficiency because *a* and *A* are equal. Thus, gear efficiency and conditional capture probability are synonymous when the area sampled equals the overall area of interest. The second objective was to determine the factors that influenced the success of capturing an individual. Estimating conditional capture probability and gear efficiency, as well as understanding the factors that influence capture probability, give insight into the efficacy of drifting trammel nets for sampling *Scaphirhynchus* spp. This information can also be used to better design sampling programs for species that have patchy distributions or are rare, such as *Scaphirhynchus* spp.

Methods

Conditional capture probability was estimated for *Scaphirhynchus* spp. in the Missouri River above Fort Peck Reservoir, Montana, in 2003 and 2004 during the summer and autumn. Mean water temperature during the study was 16.6°C (minimum = 9.7°C; maximum = 24.6°C). Twenty-one juvenile pallid sturgeon (fork length = 521 ± 13 mm [90% confidence interval around the mean]; mean weight = 455 ± 39 g) and 12 shovelnose sturgeon (mean fork length = 512 ± 37 mm; mean weight = 619 ± 120 g) were implanted with radio transmitters following methods described in Gerrity (2005). Radio-tagged fish were detected using a Lotek Suretrack STR1000 scanning receiver and an omnidirectional whip antenna. Following detection, each fish was located with an Advanced Telemetry Systems directional loop antenna, and the location was marked on a Garmin GPSMAP 168 Sounder. Blind tests with transmitters placed in the river at various depths indicated mean accuracy of this technique to be 2.5 ± 0.9 m. The boat was navigated 75 m upstream from the fish location (measured using the Garmin GPSMAP 168 Sounder), and a trammel net was immediately deployed so that the center of the net drifted over the fish location. Trammel nets were 45.8 m long and 1.8 m deep, with a 2.5-cm mesh (bar measure) inner panel and 25.4-cm mesh (bar measure) outer panels. We believe the size of fish sampled in this study were fully vulnerable to the gear. For example, hatchery-reared pallid sturgeon as short as 250 mm were sampled using drifting trammel nets similar to this study (Kapuscinski 2004). When an obstruction (e.g., shoreline, alluvial bar, woody debris, boulder) prevented drifting the center of the net over the fish location, one end of the net was drifted as close to the obstruction as possible. The trammel net always overlapped the location of the fish greater than the error associated with the location estimate. The net was retrieved after drifting 45 m downstream of the fish location; however, some nets were retrieved before drifting 45 m downstream of a fish location to avoid obvious obstructions. If a drift was unsuccessful (i.e., the radio-tagged fish was not captured), the fish was relocated and another drift was immediately conducted. This process was repeated until the fish was captured, the fish moved to a new location (15-m movement laterally or longitudinally, or 1-m change in depth), or four drifts were attempted. Drifts that were not completed because of snags (i.e., snags that stopped the downstream drift of the trammel net) were not included in the analyses. Bycatch of all species was recorded for each drift attempt.

After all drifts for a location were completed, the Garmin GPSMAP 168 Sounder was used to position the boat over the original fish location and variables thought to influence the success of a drift (i.e., captured fish) were measured. Habitat variables were only measured once per fish location, regardless of the number of drifts. Current velocity at 50% depth and 15 cm above the substrate (hereafter, bottom velocity) was measured with a Marsh-McBirney Model 201 flowmeter. The difference between the 50% depth velocity and the bottom velocity (velocity difference) was calculated to estimate float–lead line torque on the trammel net. Depth profiles were recorded from a Garmin GPSMAP 168 Sounder. Longitudinal-depth (tenth of a meter resolution) profiles were produced by recording depth in 5-m increments while driving the boat from 50 m downstream to 50 m upstream of the fish location along a transect parallel to the current. The coefficient of variation (CV = 100 × SD/mean) of water depth in each profile used as a measure of variability of the river bottom over which each net had been drifted. Substrate composition at each fish location was determined by "feeling" the river bottom with a metal conduit probe (Bramblett and White 2001). Blind tests over areas of known substrate composition found this technique to be 100% accurate. Substrate was classified in two categories: silt and sand (soft, smooth texture) or gravel and cobble (rough texture). Minor snags (i.e., snags that slowed but did not stop the downstream drift of the trammel net) encountered on each drift were also recorded and were classified as none or present. Discharge data for

TABLE 1.—Binary outcome for 123 drifts over pallid sturgeon, shovelnose sturgeon, and both species pooled using drifting trammel nets. Probabilities of success (p_i) are for individual drifts.

		Outcome		
Species	Drift	Successful	Unsuccessful	p_i
Pooled	1	25	43	0.37
	2	7	24	0.23
	3	5	11	0.31
	4	2	6	0.25
Pallid sturgeon	1	16	25	0.39
	2	5	16	0.24
	3	2	9	0.18
	4	2	5	0.29
Shovelnose sturgeon	1	9	18	0.33
	2	2	8	0.20
	3	3	2	0.60
	4	0	1	0.00

sampling days was obtained from a U.S. Geological Survey stream flow gauging station located within the study area.

Conditional capture probability (p_i*) was calculated for the capture attempts (i.e., drifts) as

$$p_i^* = 1 - \prod_{j=1}^{K}(1 - p_i),$$

where p_i* is the probability that individual i was captured at least once given multiple attempts ($j = 1, \ldots, K$; Williams et al. 2002; Dinsmore and Johnson 2005). Logistic regression was used to identify the variables that made an attempt successful (i.e., capture) for the species pooled data only. This decision was made given the similarity in p_i values for pallid sturgeon and shovelnose sturgeon, and the benefits associated with an increased sample size. All variables were used in the global logistic regression model. Then, a simpler model was developed using only those variables that were significant ($P \leq 0.10$) in the global model (SAS Institute, Inc. 1995; Johnson 1998). Substrate and snags were coded as dummy variables in the logistic regression analysis because they were discrete variables (Johnson 1998). Logistic regression analysis was only conducted on the variables from the first drift attempt because multiple drift attempts at the same fish location would have had the same abiotic variable values and caused pseudoreplication. The binary logistic regression model, regression diagnostics, and classification tables were calculated using Statistical Analysis Systems (SAS), version 9.1.3 (SAS Institute, Inc. 2003). We used the CTABLE option in SAS to determine how well the model classified observations.

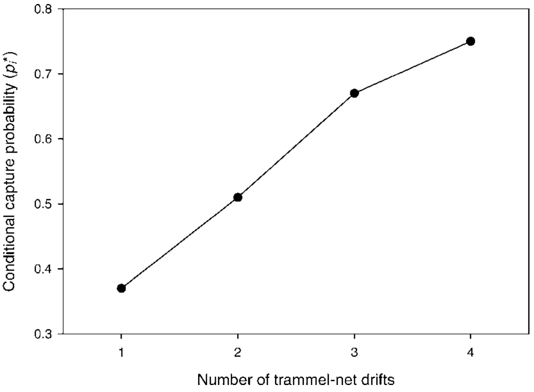

FIGURE 1.—Conditional capture probability (the conditioning factor was known presence) by drift for pallid sturgeon and shovelnose sturgeon (species pooled) captured in drifting trammel nets in the Missouri River above Fort Peck Reservoir, Montana.

Results

One hundred twenty-three drifts were made over radio-tagged *Scaphirhynchus* spp. Thirty-nine of the drifts were successful at capturing a sturgeon (Table 1). Conditional capture probability was 0.37 on the first drift, 0.51 for two drifts, 0.67 for three drifts, and 0.75 for four drifts (Figure 1). Sample size decreased with successive drifts because fish often moved or were captured before four drift attempts were conducted (Table 1). Further, sample size for a subsequent drift did not equal the number of unsuccessful attempts from the preceding drift because some fish moved to a new location before a subsequent drift attempt could be made.

There was no distinct pattern in the variables between the successful and unsuccessful outcome (Table 2). Velocity difference between the surface and bottom, presence of snags, and coefficient of variation of depth for longitudinal-depth profiles were the only variables significant in the overall model (Table 3). The reduced overall model was significant, as was each variable (Table 3); however, the model adjusted R^2 was 0.28, and the model only correctly classified 67% events successful, and had 44% false positives and 28% false negatives.

Discussion

Conditional capture probability for the size of *Scaphirhynchus* spp. used in this study was relatively high. In two attempts, there was a 0.51 probability that a *Scaphirhynchus* spp. would be captured. Capture probability of 0.50 was considered high for Gulf sturgeon *Acipenser oxyrinchus desotoi* (Zehfuss et al. 1999). Conditional capture probability exceeded 0.60

TABLE 2.—Values of variables measured at trammel net drift locations by success type for drifts made on the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,037.3 to 3,124.5), in 2003 and 2004. Snag and substrate were binary data, and the number represents the frequency of events by drift category. All other values are 95% confidence intervals around the means.

Variable	Drift category	
	Successful	Unsuccessful
Bottom velocity (m/s)	0.45 ± 0.04	0.46 ± 0.03
Velocity difference (m/s)	0.19 ± 0.04	0.24 ± 0.03
Depth (m)	1.9 ± 0.2	2.1 ± 0.2
CV longitudinal depth	6.9 ± 1.5	4.8 ± 0.6
Discharge (m^3/s)	146.4 ± 17.1	145.1 ± 13.2
Total bycatch	8 ± 4	4 ± 1
Bycatch of *Scaphirhynchus* spp.	5 ± 4	2 ± 1
Snag present		
Yes	8	6
No	15	35
Substrate		
Smooth	35	19
Rough	6	3

TABLE 3.—Estimate, SE of the estimate, and *P*-value for each variable from the logistic regression analysis on binary success data. The logistic regression models were fit for a successful outcome (i.e., a capture).

Variable	Estimate	SE	*P*-value
Global model			
Intercept	1.03	2.71	0.70
Discharge	0.01	0.01	0.39
Bottom velocity	−0.54	3.22	0.87
Velocity difference	−6.38	3.54	0.07
Substrate	−0.03	0.99	0.98
Snag	−2.36	0.86	0.01
Depth	−0.59	0.55	0.29
CV longitudinal depth	0.27	0.13	0.04
Total bycatch	0.22	0.17	0.19
Bycatch of *Scaphirhynchus* spp.	−0.15	0.18	0.39
Reduced model			
Intercept	0.68	1.11	0.54
Velocity difference	−6.24	3.08	0.04
Snag	−1.44	0.71	0.04
CV longitudinal depth	0.20	0.10	0.04

for the third and fourth drifts. However, we urge caution in interpreting results for the third and fourth drifts because the number of individual attempts was below 30. The conditional capture probability most likely to be transferable to standard sampling conducted by natural resource agencies is 0.37 because it is rare for agencies to conduct subsequent drifts in the identical location. If a trammel net is used in an area that contains a *Scaphirhynchus* spp., there is a 37% chance it will be captured, given similar conditions to this study. Interestingly, recapture efficiency for radio-tagged *Scaphirhynchus* spp. at known locations was 0.31 in the Platte River, Nebraska (E. J. Peters, University of Nebraska–Lincoln, personal communication). The corroboration of results from these studies suggests that the conditional capture probability estimated in this study may be applicable to other systems.

Drifting trammel nets have been used for decades to sample *Scaphirhynchus* spp., but little is known about the efficiency of this gear. It is known that the catch of *Scaphirhynchus* spp. in drifting trammel nets can be highly variable and dominated by zero values (Hubert and Schmitt 1982; Wanner et al. 2007). Coefficient of variation for drifting trammels nets varied from 256 to 949 for juvenile pallid sturgeon sampled in the Missouri River downstream of Fort Randall Dam, South Dakota (Wanner et al. 2007). A minimum sample size of 250 trammel net drifts has been recommended when calculating *C*/*f* for juvenile pallid sturgeon (Wanner et al. 2007). Ninety-seven drifts resulted in only 56 shovelnose sturgeon sampled in the Mississippi River (Hubert and Schmitt 1982). Five hundred thirty-six drifts of gill nets and trammel nets sampled only five pallid sturgeon in the Platte River, Nebraska (Peters and Parham 2008). Conversely, 1,133 shovelnose sturgeon were sampled in 536 samples using drifting gill nets and trammel nets (Peters and Parham 2008). The discrepancy between previous studies and this study is related to sampling area, population size, and patchy distribution. Sampling in areas that do not contain the target organism reduces capture probability. Further, low population abundance increases the chances of sampling areas that do not contain the target organism, thus decreasing capture probability. Patchy distributions can increase variability in *C*/*f*, which subsequently leads to higher samples needed to achieve better precision in *C*/*f* estimates. Our capture probability was conditional because we always sampled a location that contained a *Scaphirhynchus* spp. The conditional capture probability calculated in this study is not directly transferable to *C*/*f* data collected by natural resource agencies because their sampling methods are often random or random stratified. Nevertheless, conditional capture probability can be used to estimate the relative efficiency of sampling programs. For example, capture probability for juvenile pallid sturgeon from mark–recapture data in habitat types thought to contain pallid sturgeon in the Yellowstone River averaged 0.08 for 2 years (M. Jaeger, Montana Fish, Wildlife, and Parks, personal communication). If we assume our sampling methods, habitats sampled, and sizes of fish sampled are similar, we could estimate that about 20% of the sampling in the Yellowstone River occurred over a pallid sturgeon. The latter example is simplistic but illustrates the utility of knowing the conditional capture probability (i.e., gear efficiency).

The variables we measured provided little utility in predicting a successful drift. There is some evidence to suggest that float–lead line torque (velocity difference), snags, and variability in water depth influence drift success. It is likely that we were unable to measure at the scale that influences drift success. We surmise that small idiosyncrasies at the anterior location of individual fish highly influence drift success. For example, a fish located directly on the lee side of a 10-cm-high sand dune may not be captured because the net drifts over the top of the fish. Hubert and Schmitt (1982) suggested that drifting trammel nets likely skip from the crest of one sand dune to another, thus failing to capture fish in the trough of the dune. There were no differences in habitat variables measured for areas where pallid sturgeon were sampled compared with those where pallid sturgeon were not sampled in the Platte River, Nebraska (Peters and Parham 2008). Of the five variables of sampling period, current velocity, turbidity, water temperature, and dissolved oxygen, only sampling period was related to number of shovelnose sturgeon sampled per river kilometer in the Mississippi River, Iowa; however, the coefficient of determination was only 0.09 (Hubert and Schmitt 1982).

Drifting trammel nets are relatively efficient, and we suggest that they continue to be used to sample *Scaphirhynchus* spp. in large turbid rivers. If maximizing catch of *Scaphirhynchus* spp. is the goal of a study, we recommend at least two drifts through locations that are thought to contain *Scaphirhynchus* spp. The high variability associated with sampling *Scaphirhynchus* spp. using drifting trammel nets reported in the literature is likely related to low abundance, patchy distributions, or both. Peery (2004) and Wanner et al. (2007) recommended relatively large sample sizes to detect changes in population metrics of *Scaphirhynchus* spp. Given our estimates of trammel net gear efficiency, we would recommend a more thorough evaluation of how sampling designs for *Scaphirhynchus* spp. are selected. For example, how many zero catches are needed to determine that relative abundance is low? Is relative abundance low or does the species exhibit a patchy distribution? When working with rare species, it is likely that standard sampling methods for abundant species are not applicable. Although we did not test various sampling designs for *Scaphirhynchus* spp., we recommend sampling designs that are more appropriate for rare species such as adaptive cluster sampling (Smith et al. 2004). Jaeger et al. (2007) suggested a habitat-based sampling design for juvenile pallid sturgeon in the lower Yellowstone River because catch rates increased 20–90 times when compared with a completely random design. If the appropriate sampling design is applied, it is likely that fewer samples will be needed because of the relatively high gear efficiency of drifting trammel nets.

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