American Fisheries Society Symposium XX:000–000, 2007
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Distribution and Population Characteristics of Burbot in the Missouri River, Montana Based on Hoop Net, Cod Trap, and Slat Trap Captures

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Abstract.—Although burbot *Lota lota* are native to Montana, little is known about their distribution, life history, and ecology. The objectives of this study were to determine the distribution and population characteristics of burbot in the upper Missouri River basin in north-central Montana and to compare sampling efficiency of hoop nets, cod traps, and slat traps. Hoop nets and cod traps were fished in the Missouri River during March 2005 and 2006, and slat traps were fished during March 2006. In total, hoop nets were fished 572 net nights, cod traps for 94 net nights, and slat traps for 92 net nights. Catch rates of hoop nets and cod traps were higher in 2005 than in 2006, and catch rates of all gear types were higher in the upstream half of the study area. Mean section hoop-net catch rates exhibited a significant inverse relationship with increasing distance downstream from Holter Dam, while catch rates for other gear types did not. Catch rates were not significantly different ($P \geq 0.05$) among gear types. The size (length and weight) and condition (relative weight) of burbot sampled was significantly ($P \leq 0.05$) different among gear types. Length, weight, and relative weight were higher for burbot sampled in hoop nets and cod traps than those sampled in slat traps. Slat traps were effective at sampling small (≤300 mm) burbot. Although most (80%) burbot were recaptured within 10 km of where they were tagged, three burbot moved more than 32 km. We hypothesize that the distribution of burbot in our study reach has changed and relative abundance has increased due to the cumulative effect of upstream reservoirs (Canyon Ferry, Hauser, and Holter) by decreasing the downstream water temperature regimen.cilitated recovery of the burbot populations there. Although sea lampreys have been controlled in Lake Ontario, alewives are probably still too abundant to permit burbot recovery.

Introduction

Burbot *Lota lota*, the only freshwater cod (Gadidae) species, has a circumpolar distribution in northern latitudes (McPhail and Paragamian 2000). In Montana, burbot are native to the three major river drainages (Columbia, Missouri, and Saskatchewan; Brown 1971). Following a petition to list burbot in the Kootenai River as an endangered species Montana Fish, Wildlife & Parks initiated a

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status assessment of burbot populations in Montana (Jones-Wuellner and Guy 2004). Jones-Wuellner and Guy (2004) concluded that insufficient data existed to evaluate the status of burbot in many of Montana's waters, including the upper Missouri River. The authors recommended implementation of studies using standard burbot sampling gear to better understand the status and distribution of burbot populations in Montana.

Spence (2000) determined the effectiveness of hoop nets and cod traps at sampling burbot in lentic water bodies. To our knowledge, similar information is not available for sampling burbot in lotic water bodies. Understanding the effectiveness of different sampling techniques is critical to managing fish populations, especially imperiled fish populations (Spence 2000). Traditional hoop nets have been shown to effectively sample only larger burbot (≥450 mm; Bernard et al. 1991), but we are aware of no studies evaluating nonlethal gears directed at sampling small (≤300 mm) burbot. Obtaining relative abundance information for small burbot provides direct insight into population recruitment. This information is critical for understanding environmental influences on burbot recruitment.

Little information exists regarding distribution, relative abundance, and population characteristics of burbot in the upper Missouri River, Montana. Burbot have been sampled incidentally while electrofishing for trout *Oncorhynchus* spp. in this section of river, since the early 1980s (Montana Fish, Wildlife & Parks, unpublished data), but sample sizes of burbot were typically low and the relationship between electrofishing catch per unit effort and population abundance is unknown. This study was initiated to provide a better understanding of burbot populations in the upper Missouri River, between Holter Dam and Great Falls (a 152-km river reach), Montana. The objectives of this study were to determine the distribution, relative abundance, and population characteristics of burbot in the upper Missouri River in north-central Montana and to compare hoop nets, cod traps, and slat traps for sampling burbot (including small, ≤300 mm burbot) in a large river system.

The study area was located in the upper Missouri River basin in north-central Montana (Figure 1). Sampling was conducted on the free-flowing Missouri River beginning at Holter Dam near Helena, Montana and proceeding downstream 152 km to Black Eagle Dam in Great Falls, Montana. Three reservoirs (Canyon Ferry, Hauser, and Holter) impound the Missouri River immediately upstream of the study area. A variety of habitat changes occur along the 152-km reach. The influence of the upstream dams on discharge and water temperature regimen diminishes progressively downstream. Geological features laterally control much of the upstream river channel where stream gradient is the highest. The river transitions to a highly sinuous channel downstream of the Dearborn and Big Belt mountains (~45 km downstream of Holter Dam; Figure 1) with smaller substrate, increased turbidity, and increased water depth.

Methods

Hoop nets, cod traps, and slat traps were fished throughout the study area. All gear types were baited with previously frozen longnose suckers *Catostomus catostomus* and white suckers *C. commersonii*, both common nongame species in the study area. Hoop nets measured 3.05 m long, maximum hoop diameter was 61 cm, and mesh size was 2.5 cm (bar measure as recommended by Paragamian 2000). Cod trap frames were constructed from 1.3-cm rebar (Spence 2000). The bottom hoop diameter was 1.0 m, the top hoop diameter was 69 cm, and the trap height was 64 cm tall. Nylon mesh (1.3-cm bar measure) covered the structure, and a 25-cm-wide

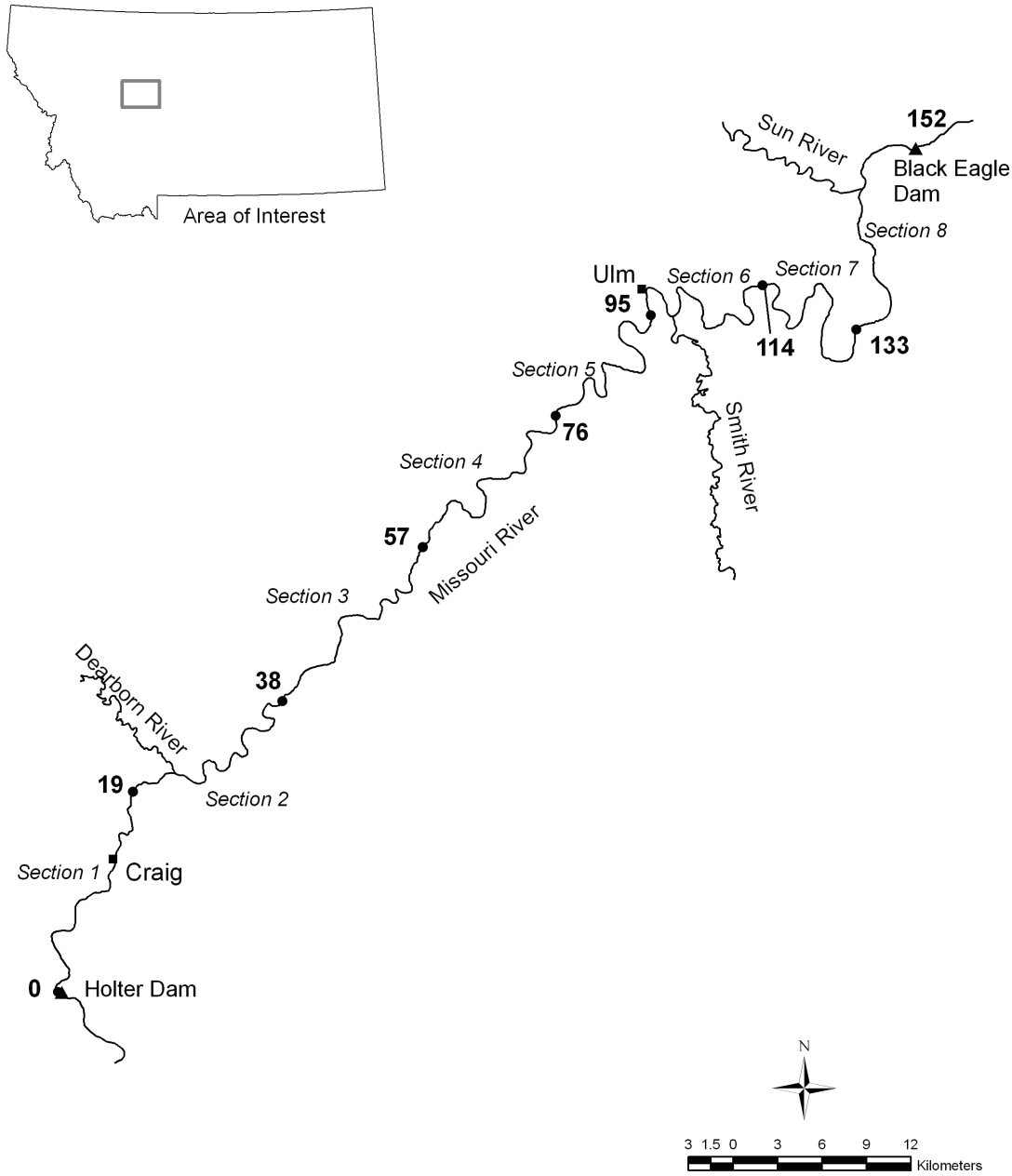

FIGURE 1. The study area on the Missouri River in north-central Montana. Circles indicate section boundaries.

oval-shaped throat entered the trap from the side. Wooden slat traps measured 61 cm long, 30 cm wide, and 30 cm high. The slat trap opening was constructed from a rigid sheet of plastic mesh (6-mm bar measure) formed into a funnel. The throat of the funnel measured 5.7 cm. The maximum distance between wooden slats was 1.6 cm.

All sampling occurred during March 2005 and 2006. The 152-km-long study area was divided into eight sections, each 19 km long. The section sampling order was randomly determined each year. All nets were typically set in the morning and pulled 46–48 h later. Six hoop nets were systematically fished on both sides of the river at approximately 2-km intervals for 6 nights (total of 36 net nights in each section). We systematically fished six hoop nets along the right bank in the upper two-thirds of the section during the first 2 nights, followed by six hoop nets along the left bank in the upper two-thirds of the section during the second 2 nights. Three hoop nets each were simultaneously fished along both banks in the lower third of the section during the final 2 nights. No specific habitats were targeted, as nets were set to avoid extremes for depth and velocity. Generally, hoop nets were set in 1–3 m of water. One cod trap was fished in backwater and eddy areas for 6 nights (three separate sets) in each of the eight sections, but their placement was not systematic as with hoop nets. In 2006, two slat traps were fished for 6 nights (six total sets) in each section. During each 2-night period, slat traps were fished in the same area (i.e., upper third, middle third, and lower third of the section on the first, second, and third 2-night period, respectively) on opposite sides of the river. Spacing between successive slat trap sets averaged approximately 5.9 km. Fish were removed from all gear, weighed, measured, and tagged with Floy and passive integrated transponder tags.

Linear regression analysis was used to identify the relationship between burbot catch rates and the distance downstream from Holter Dam. Body condition was assessed for burbot using relative weight (W_r = [weight of fish × 100]/standard weight at length [W_s]). The W_s equation was from Fisher et al. (1996). Differences in catch rates, mean length, weight, and relative weight among gears were tested using a one-way analysis of variance on ranked data. Multiple comparisons were conducted using Fisher's least significant difference (Ott 1993). All statistical tests were performed with SAS Version 9.1 (SAS Institute 2004). An alpha level of 0.05 was used to determine statistical significance.

Results

During the 2-year study, hoop nets, cod traps, and slat traps were fished for 572, 94, and 92 net nights, respectively. Hoop nets sampled nine species of fish, including rainbow trout O. *mykiss*, brown trout *Salmo trutta*, mountain whitefish *Prosopium williamsoni*, burbot, stonecats *Noturus flavus*, white suckers, longnose suckers, yellow perch *Perca flavescens*, and black bullheads *Ameiurus melas*. Cod traps sampled seven species of fish, including rainbow trout, brown trout, burbot, white suckers, longnose suckers, yellow perch, and common carp *Cyprinus carpio* while slat traps sampled stonecats, burbot, and white suckers. Most burbot were collected with hoop nets (n = 249, 82% of total), followed by cod traps (n = 39, 13% of total) and slat traps (n = 15, 5% of total). Total catch of burbot by gear type closely followed the percentage of sampling effort allocated to each gear type. For example, hoop nets, cod traps, and slat traps represented 75.4%, 12.4%, 12.1% of the total sampling effort, respectively. The mean overall hoop net catch rate in 2005 was 0.55 per net night, compared to 0.33 burbot per net night in 2006. Similarly, mean cod trap catch rates were higher in 2005 than in 2006 (0.46 and 0.36 burbot per net night, respectively). The 2006 average catch rate in slat traps was 0.16 burbot per net night. Overall, mean catch rates among gear types were not significantly different (F = 2.21, P = 0.12).

A spatial pattern of catch rates existed where more burbot were sampled in the upper half of the study area in both years and with all gear types (Table 1). For example,

TABLE 1. Sampling effort (number of net nights = Effort), mean, standard error (SE), minimum (Min), and maximum (Max) for burbot catch rates (# / net night) by year, gear type, and section (upstream to downstream for 19-km sections) on the Missouri River in north central Montana.

Year	Gear	Section	Effort	Mean	SE	Min	Max
2005	Cod trap	1	6	1.00	0.58	0.0	2.0
		2	4	0.00	0.00	0.0	0.0
		3	6	0.83	0.33	0.5	1.5
		4	6	1.67	0.93	0.5	3.5
		5	6	0.00	0.00	0.0	0.0
		6	6	0.00	0.00	0.0	0.0
		7	6	0.00	0.00	0.0	0.0
		8	6	0.17	0.17	0.0	0.5
	Hoop net	1	36	1.47	0.34	0.0	5.0
		2	36	0.67	0.24	0.0	4.0
		3	34	0.82	0.21	0.0	2.5
		4	36	0.47	0.14	0.0	2.0
		5	36	0.25	0.08	0.0	1.0
		6	36	0.47	0.12	0.0	1.5
		7	36	0.14	0.09	0.0	1.5
		8	36	0.08	0.05	0.0	0.5
2006	Cod trap	1	6	0.00	0.00	0.0	0.0
		2	6	1.00	0.29	0.5	1.5
		3	6	0.33	0.17	0.0	0.5
		4	6	1.17	0.67	0.5	2.5
		5	6	0.17	0.17	0.0	0.5
		6	6	0.00	0.00	0.0	0.0
		7	6	0.17	0.17	0.0	0.5
		8	6	0.00	0.00	0.0	0.0
	Hoop net	1	36	0.42	0.26	0.0	4.5
		2	36	0.78	0.21	0.0	3.0
		3	36	0.42	0.15	0.0	2.5
		4	36	0.22	0.07	0.0	1.0
		5	36	0.22	0.07	0.0	1.0
		6	34	0.47	0.25	0.0	4.5
		7	36	0.06	0.04	0.0	0.5
		8	36	0.03	0.03	0.0	0.5
2006	Slat trap	1	12	0.08	0.08	0.0	0.5
		2	12	0.42	0.24	0.0	1.5
		3	12	0.17	0.17	0.0	1.0
		4	8	0.13	0.13	0.0	0.5
		5	12	0.08	0.08	0.0	0.5
		6	12	0.42	0.24	0.0	1.5
		7	12	0.00	0.00	0.0	0.0
		8	12	0.00	0.00	0.0	0.0

the overall mean catch rate for hoop nets in the upstream sections was 0.66 compared to 0.21 per net night in the downstream half of the study area. A significant (P = 0.001) in-

verse relationship existed between section-wide mean hoop net catch rates (both years combined) and river kilometer at the section midpoint (Figure 2). Based on this model, burbot catch rates decreased downstream by 0.13 for each 19-km section. Although catch rates in cod and slat traps were higher in upstream sections and lower in downstream sections, no significant ($P \geq 0.05$) relationship was found between catch rates and river kilometer (Figures 3 and 4).

The size (length and weight) of burbot sampled varied significantly ($P < 0.05$) among gear types (Table 2; Figure 5). For example, the mean length of burbot sampled in hoop nets (mean = 497, SE = 4.9 mm) and cod traps (mean = 448, SE = 18.2 mm) was significantly ($F = 19.53$, $P = 0.0001$) longer than burbot sampled in slat traps (mean = 341, SE = 18.6 mm). Slat traps were effective at sampling small burbot, and more than two-thirds of the burbot sampled in slat traps were between 240 and 360 mm. Body condition (W_r) of burbot was significantly different ($F = 5.06$, $P = <0.01$) among gear types. Mean relative weight of burbot sampled in hoop nets was similar to cod traps, but relative weight of burbot sampled in slat traps was lower than either hoop nets or cod traps (Table 2; Figure 5).

Twenty-six tagged burbot were recaptured during our sampling and by anglers. Most burbot (75%) were recaptured within 10 k of where they were initially tagged. Three recaptured burbot moved more than 30 km (33.3, 41.2, and 47.0 km), and all three of these burbot moved downstream.

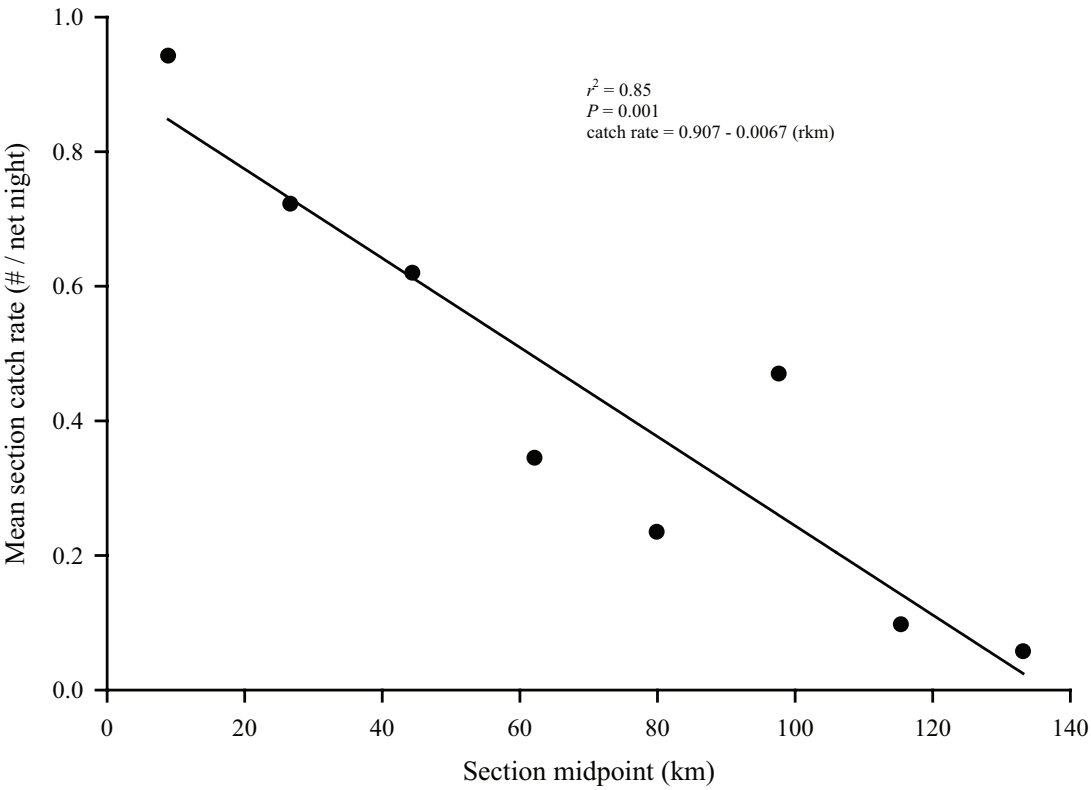

FIGURE 2. Relationship between the mean section-wide catch rate of burbot in hoop nets (2005 and 2006 combined) and section midpoint (river kilometer) on the Missouri River.

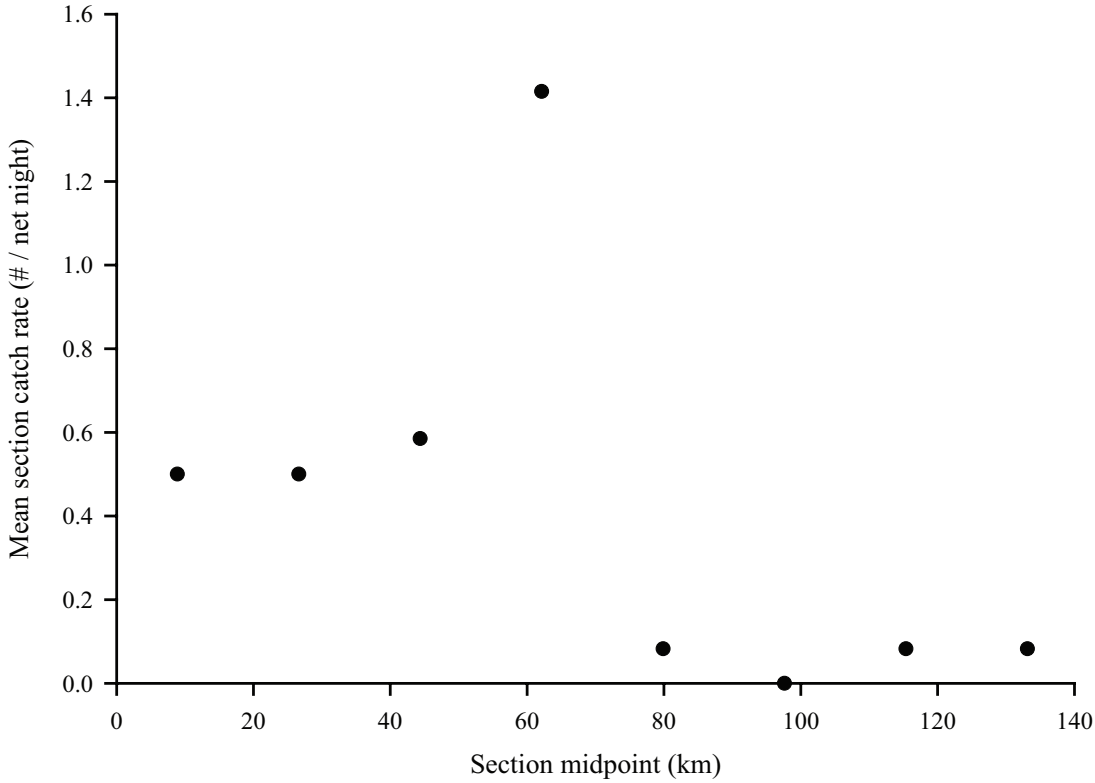

FIGURE 3. Relationship between the mean section-wide catch rate of burbot in cod traps (2005 and 2006 combined) and section midpoint (river kilometer) on the Missouri River.

Discussion

The results of this study show that although burbot are distributed throughout the study area, relative abundance of burbot is higher in the upper half of the study area. The effect of large water storage impoundments on downstream physical habitat and biological communities (i.e., the serial discontinuity concept) has been well developed in the literature (Ward and Stanford 1983, 1995). The three immediately upstream reservoirs (Canyon Ferry, Hauser, and Holter reservoirs) from our study area have reduced (relative to historic) summer water temperatures downstream from the dams. For example, July and August average daily water temperatures in the Missouri River upstream of Canyon Ferry Reservoir were 2.8°C and 3.7°C warmer and maximum daily water temperature was 5.0°C and 5.5°C higher than downstream from Holter Dam in 2004 and 2005, respectively (U.S. Geological Survey [USGS] 06054500 station and USGS 06066500 station, unpublished data). Although no historical distribution or relative abundance data exist for burbot in this section of the Missouri River, we hypothesize that the thermal influence of the upstream reservoirs have had a positive effect on burbot distribution, thereby increasing their abundance in the lower river.

We found that catch rates among all gear types were not significantly different in the flowing Missouri River, whereas Spence (2000) concluded that cod traps were more effective than hoop nets in lentic systems.

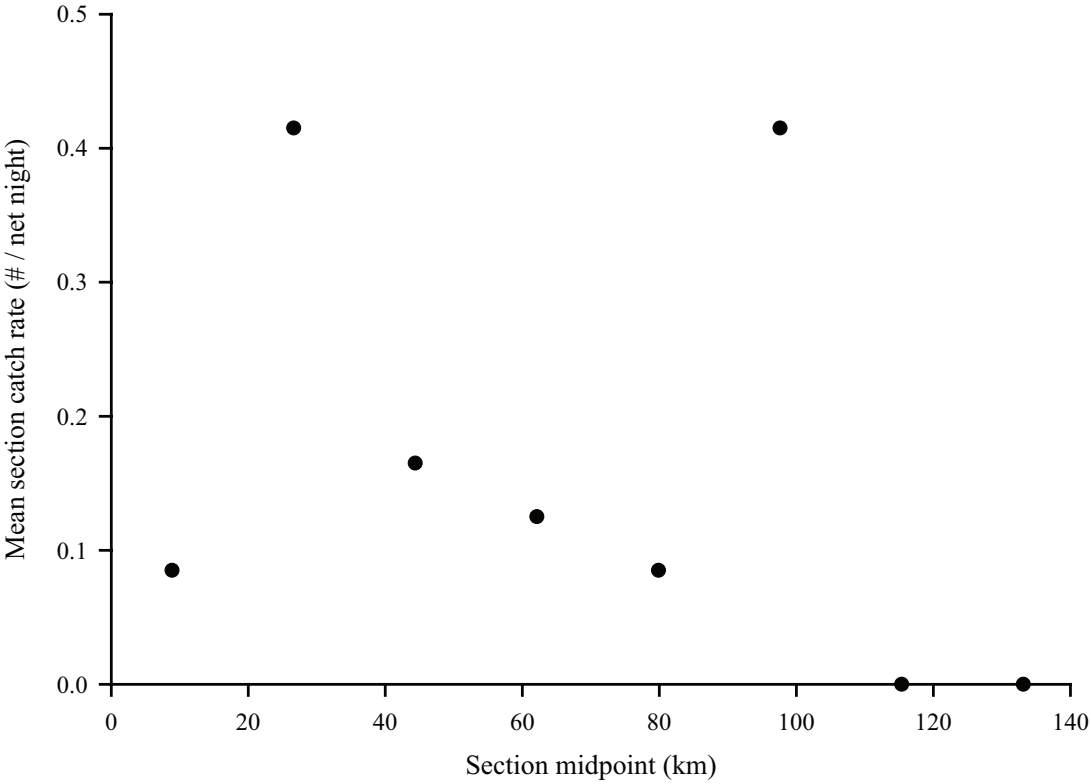

FIGURE 4. Relationship between the mean section-wide catch rate of burbot in slat traps and section midpoint (river kilometer) on the Missouri River.

Spence (2000) speculated that cod traps might have been more effective than hoop nets in lentic environments due to the positioning of bait. Bait is positioned in the cod end of hoop nets, far from the entrance to the net; whereas in cod traps, the bait is positioned directly be-

TABLE 2. Number of burbot sampled, mean, standard error (SE), minimum (Min) and maximum (Max) for length, weight and relative weight (W_r) of burbot sampled by three gear types and year in the Missouri River, Montana.

			Length				Weight				W_r			
Gear	Year	*n*	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max
Cod traps														
	2005	22	439	27.2	147	643	532	82.2	36	1,380	70	1.6	60	86
	2006	15	461	21.3	338	579	551	85.4	150	1,398	70	3.3	52	103
Hoop nets														
	2005	156	503	5.6	300	709	669	23.4	127	1,789	70	0.6	51	87
	2006	94	485	8.8	290	709	628	35.0	114	1,898	70	1.0	46	117
Slat traps														
	2006	15	341	18.6	246	505	213	41.2	59	672	62	2.1	44	73

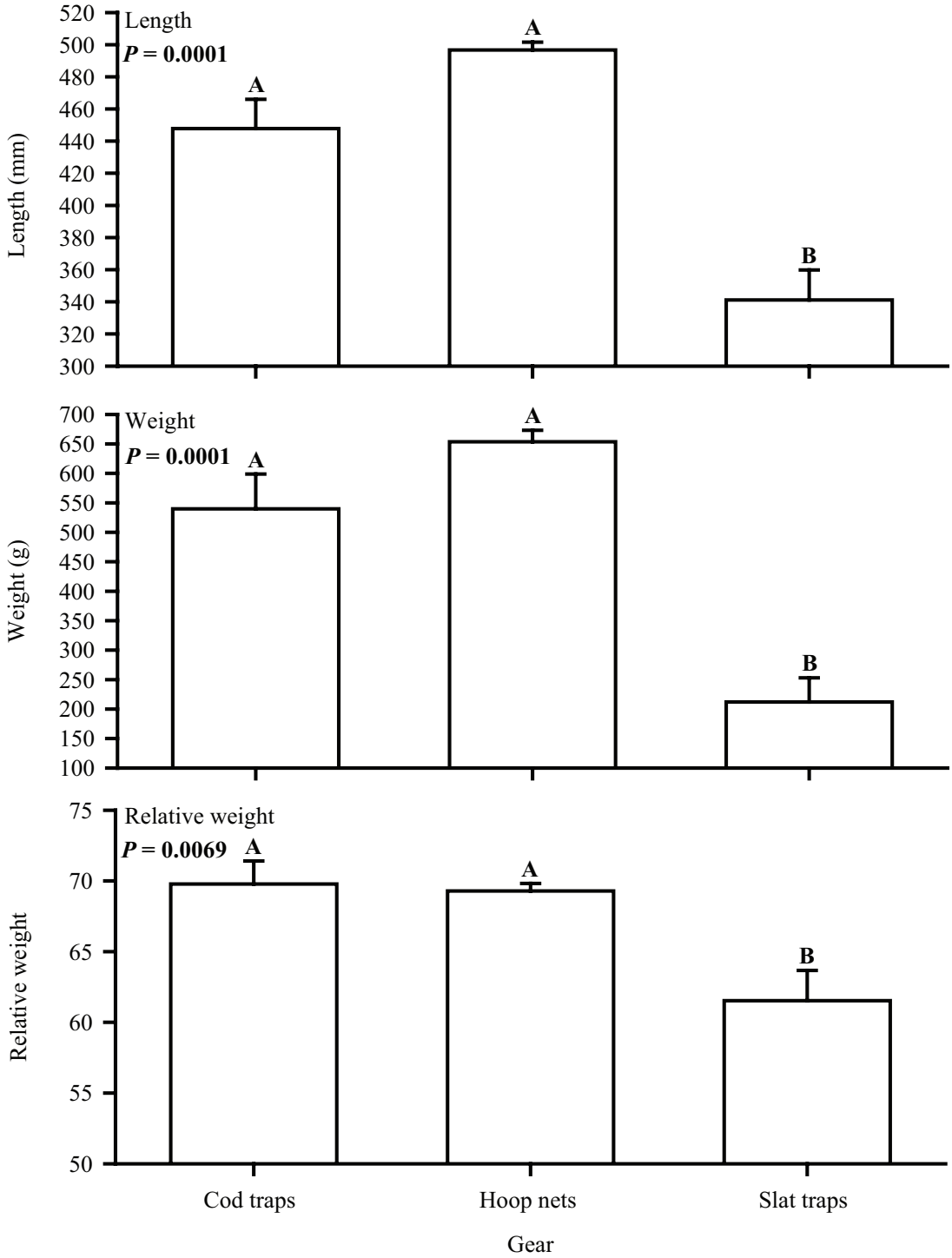

FIGURE 5. Mean length, weight, and relative weight by gear type. Error bars represent one standard error, and means with the same letter designate no significant difference ($P > 0.05$).

hind the throat of the trap. Positioning of bait in hoop nets used in lotic systems is likely less of an issue with regard to efficiency because the cod end anchors the hoop net, causing bait scents to move with the water toward the hoop net entrance.

Catch rates of hoop nets, cod traps, and slat traps all exhibited a similar pattern in relative abundance on a spatial gradient, but we only found a significant inverse linear relationship between hoop-net catch rates and the distance downstream from Holter Dam. Catch rates of cod traps and slat traps were not significantly correlated with distance downstream from Holter Dam, but small sample sizes may have influenced the comparisons. Two exceptions were found with the spatial pattern of slat-trap catch rates and increased distance downstream. Near the confluences of the Dearborn River (21.7 km downstream from Holter Dam in Section 2) and the Smith River (93.5 km downstream from Holter Dam in Section 6; Figure 1), slat-trap catch rates were higher than in other sections of the river. The higher catch rates of small burbot in slat traps near these major tributaries may indicate the presence of better habitat for small burbot.

Sampling small burbot effectively is a limitation of commonly used gear types. For example, Bernard et al. (1991) showed that burbot less than 450 mm total length were not fully recruited to hoop nets. In our study, significant differences existed among length and weight of burbot sampled with the three gear types. Slat traps effectively sampled smaller burbot, as mean length of burbot sampled in slat traps was 153 and 109 mm less than the mean length of burbot sampled in hoop nets and cod traps, respectively. These results suggest that slat traps are an effective tool for sampling small burbot and may be useful in studies directed at obtaining information on year-class strength or identifying important habitats for small burbot.

Our results provide the first quantitative data relative to burbot distributions and relative abundance in the Missouri River between Holter Dam and Great Falls, Montana. Although additional study is required for more temporal distribution data of burbot, our findings provide insight into burbot relative abundance in early spring.

Acknowledgments

We thank the many individuals that assisted with sampling throughout this project. Help from Terry Klementz, Toby Tabor, Barb Furlong, Sally Schrank, Amy Berry, Darrel Beach, Kelly Smith, Paul Hamlin, Ken Frazer, Matt Jaeger, Steve Leathe, Tim Tabor, Anthony Strainer, Dean Linn, Kyle Ferlicka, and Bruce Osterman was critical for the success of the project. Thanks to Dawn Anderson for geographic information systems assistance and support. Thanks to Grant Grisak, Steve Leathe, Nancy Podolinsky, Mike Quist, Vaughn L. Paragamian, David Bennett, and Jody Walters for reviewing this manuscript in draft form. The U.S. Fish & Wildlife Service (State Wildlife Grants Program), Montana Fish, Wildlife & Parks, and PPL Montana provided funding for this project.

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