Status Assessment of Burbot in Montana: Importance of a Standardized Sampling Protocol

Melissa R. Wuellner[1] and Christopher S. Guy, U.S. Geological Survey, Montana Cooperative Fishery Research Unit, Montana State University, Bozeman, MT 59717

Abstract

Burbot (*Lota lota*) are widely distributed throughout Montana and are found in the Kootenai, Missouri, and Saskatchewan drainages within the state. However, little is known about their status. Anecdotal information from Montana Fish, Wildlife and Parks (FWP) and USDA Forest Service (USFS) fisheries biologists as well as licensed Montana anglers indicated a potential decline in burbot abundance in some populations. Surrounding states and provinces reported similar declines and even cases of near extirpation. To address concerns regarding burbot in Montana, we assessed their status by comparing statewide historic and current distributions of burbot and evaluating population characteristics, e.g., relative abundance, size structure, condition, from published and unpublished FWP andUSFS data. Burbot have been sampled using a variety of gears although most sampling effort targeted other species, i.e., rainbow and brown trout (*Oncorhynchus mykiss* and *Salmo trutta*), sauger (*Sander canadensis*), walleye (*Sander vitreus*) and sturgeon (*Scaphirhynchus* spp.) Unfortunately, status assessment of individual populations was difficult due to low sample sizes, inconsistent and non-targeted sampling efforts, and missing information, e.g., gear effort, fish lengths and weights. Undoubtedly, statewide standardized sampling protocols would facilitate a more precise assessment of Montana's burbot population. To that end, we recommend initial sampling efforts for burbot ≥ 450 mm total length use springtime hoop net sets in both lotic and lentic systems. Further, we encourage testing cod traps in lentic systems and slat traps in lotic and lentic systems to determine if these gears offer more effective sampling among a variety of sizes of burbot than hoop nets.

Key words: fishery management, burbot, conservation, *Lota lota*, Montana fishes

Introduction

Burbot (*Lota lota*) have a Holarctic distribution (McPhail and Paragamian 2000) and are the only freshwater members of an otherwise marine family (the cods, Gadidae). In North America, burbot are distributed throughout most of Canada and Alaska (McPhail and Lindsey 1970, Scott and Crossman 1973) and may be found as far south as the backwaters of the Mississippi River north of the 40th parallel (Pflieger 1997, McPhail and Paragamian 2000). Within Montana, burbot are native to the Kootenai, Missouri, and Saskatchewan drainages (Brown 1971, Penkal 1981, Holton and Johnson 2003) but have been introduced to the lower Clark Fork River [L. Katzman, Montana Fish, Wildlife, and Parks (FWP), Thompson Falls, MT, personal communication].

Although first formally described by Linnaeus in 1758 as *Gadus lota* (Nelson and Paetz 1992), this species was widely utilized worldwide before this time. Archaeological records have indicated that burbot flesh sustained the Kootenay Indians of North America during winter months both pre- and post-European settlement (McPhail and Lindsey 1970). During the 18th and 19th centuries, Europeans enjoyed burbot flesh but also recognized uses of the fish's liver oil, e.g., medicinal purposes and lamp oil (Nelson and Paetz 1992). During the Great

[1] Department of Wildlife and Fisheries Sciences, South Dakota State University, Box 2140B, Brookings, SD 57007

Depression, burbot liver processing became economically profitable, and commercial fishing for burbot became popular in many areas of the north central United States, e.g., Lake of the Woods, Minnesota (Eddy and Surber 1943).

With the proliferation of electricity, commercial interest in burbot decreased in the United States. However, interest among anglers has varied widely over time. Many anglers have a negative perception of burbot, referring to them as "trash" or "junk" fish (Fisher 2000, Quinn 2000). Contrastingly, burbot angling has increased in popularity in isolated regions of Canada and the United States over the past 30 yrs (Quinn 2000). In Montana, angler harvest of burbot has increased in both Clark Canyon and Canyon Ferry reservoirs since the mid 1990s (B. Rich, FWP, Bozeman, MT, personal communication), and new popular winter fisheries have been established on other reservoirs, e.g., Newlan Creek Reservoir (T. Horton, FWP, Helena, MT, personal communication).

Despite rekindling interest in burbot, efforts to directly sample and understand burbot population dynamics are lacking in most provinces and states, including Montana. Fortunately, attitudes regarding burbot conservation have become more favorable due to increased angler interest and the threat of declining abundance throughout their range (McPhail 1995, Arndt and Hutchinson 2000, Taylor and McPhail 2000). A recent survey of FWP biologists and licensed Montana anglers indicated that numbers of burbot sampled or harvested have declined in several areas of the state (see Jones-Wuellner and Guy 2004) prompting concern over burbot populations throughout the state. This concern created the impetus for a statewide status assessment of Montana burbot for which the objectives were to 1) compare historic and current statewide distributions, 2) summarize available burbot population data and anecdotal information, and 3) suggest sampling protocols for both lentic and lotic populations of burbot in Montana.

Methods

Several methods were used to determine the current status of burbot in Montana. Firstly, we compared historical and current distribution data and based historical presence data on collection records published by Brown (1971). Present distribution data were based on collection records reported to the Montana Fisheries Information System (MFISH; http://nris.mt.gov/interactive.html) and collection records published by Holton and Johnson (2003). All collection records were mapped in Geographic Information Systems (GIS) layers in ArcGIS (Version 9; ESRI 2004). We calculated and compared the length (rk) of river burbot occupied historically and presently.

Secondly, we examined population data from several sources. Summary information on burbot populations was obtained from the fw published fishery survey reports that contained information on burbot. In February 2003 an electronic request for burbot catch data, e.g., abundance, length, weight, was sent to FWP biologists in all seven management regions. Population characteristics, e.g., relative abundance, size structure, condition, and burbot ecology, e.g., movement, habitat use, food habits, were examined from both published and requested data. Relative abundance of burbot was indexed by catch/unit effort (CPUE). Relative abundance of fish calculated from electrofishing was summarized as number caught/pass or hr of electrofishing; abundance from trap net samples was summarized as the number caught/trap day. We used proportional size distribution (PSD; the number of fish ≥ 300 mm total length [TL]/number of fish ≥ 200 mm TL x 100; Anderson 1980, Fisher et al. 1996, Guy et al. 2007) and proportional size distribution of preferred-length fish (PSD-P; the number fish ≥ 530 mm TL/ number of fish ≥ 200 mm TL x 100) (Wege and Anderson 1978, Guy et al. 2007) to index size structure. Condition was assessed using relative weight (Wr; Fisher et al. 1996).

Results and Discussion

Historic and Current Status of Burbot in Montana

The burbot has a wide distribution throughout the state and is one of the few species that occurs in cold, cool, and warm water rivers. Number of collection records has increased since 1971. Brown's (1971) distribution map included 52 individual sites, and Holton and Johnson (2003) added records in the Poplar, Powder, and Bighorn rivers. The MFISH database included information on the presence of burbot at 98 locations with a potential distribution of ~ 8193 rkm (Fig. 1); this represented an 88-percent increase in distribution from Brown's (1971) data. However, this seemingly drastic expansion since 1970 was due to record deficiency prior to 1970. Further, no populations appear to have been extirpated since 1971.

Review of Published Reports and Solicited Burbot Data

Although we found few published reports that included burbot population data, reports that we located, as well as data provided by FWP biologists, yielded information from 19 water bodies. Biologists that sent us unpublished data were personally contacted to verify conclusions we made from our analysis. Most (79%) of this information came from lotic habitats. Seven areas within the Missouri River and six areas within the Yellowstone River were sampled. Burbot collected in lentic habitats were mostly from reservoir systems.

Kootenai River.—A relatively productive burbot fishery existed in the Montana section of the river before the completion of Libby Dam, an Avista Corp. facility built for hydroelectric power and flood control in 1972 (Hammond and Anders 2003). Subsequently, angler catch rates of

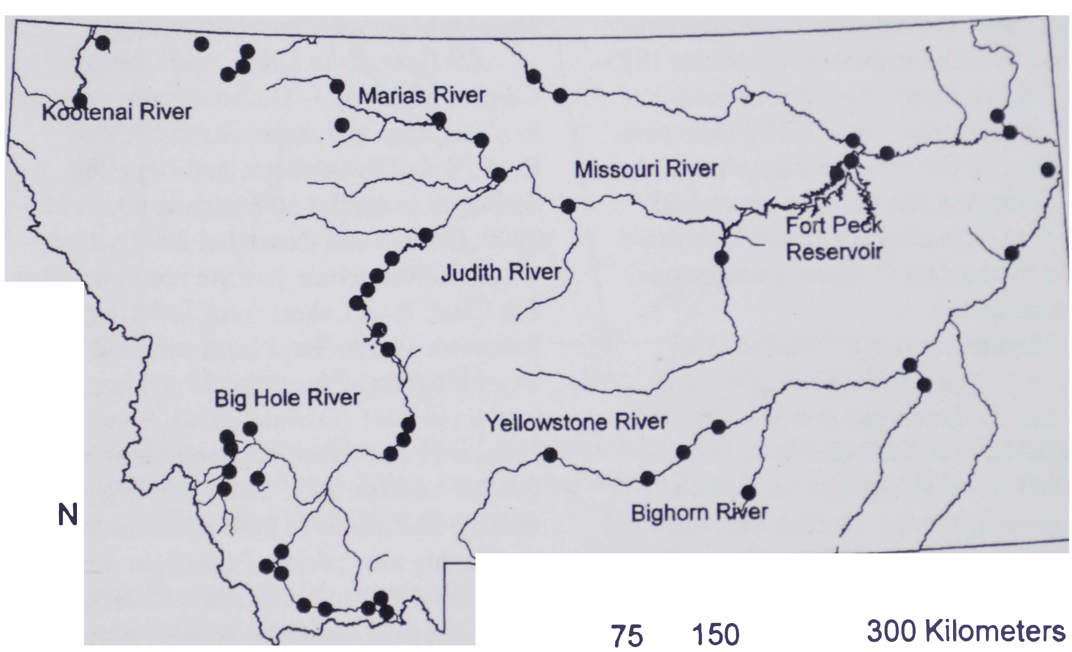

Figure 1. Comparison of historic (Brown 1971) and present burbot distributions [Holton and Johnson 2003; Montana Fisheries Information System (MFISH; http://nris.mt.gov/interactive.html)]. Brown's (1971) distribution is represented by dark circles. Potential distribution provided by Holton and Johnson (2003) and the MFISH database is represented by dark solid lines. Present distributions (8193 rkm) assumed burbot were found in the area between two locations within the same river. Geographically important areas are labeled.

several species have declined over the past two decades, which prompted monitoring of the Kootenai River and Lake Koocanusa fish communities (J. Dunnigan, FWP, Libby, MT, personal communication). Paragamian (2000) attributed declines of most fishes, including burbot, to the operation of Libby Dam that has considerably altered seasonal discharges, particularly during winter months. Winter discharges are presently three to four times greater than pre-construction winter discharges (Paragamian et al. 2000).

Following construction of the reservoir, the burbot population in Lake Koocanusa remained relatively stable (Chisholm and Fraley 1986). However, recent sampling efforts have indicated reduced numbers of burbot in the river downstream of Libby Dam. Burbot have been collected using trap nets in the river below Libby Dam during the winter months, i.e., Dec through Apr from 1991 to 1992 and Dec and Feb from 1993 to 2003, and below Kootenai Falls (50 rkm downstream of Libby Dam) from 1991 to 1999. Burbot abundance apparently declined in both locations since winter 1995-1996 (Fig. 2). Sampling effort remained steady or increased below Libby Dam since 1991 (Fig. 2), but biologists have noted that burbot sampling has become increasingly difficult as a result of consistent high flows created by the dam (J. Dunnigan, personal communication).

Movement patterns (Snelson et al. 2000, Dunnigan and Sinclair 2008) and home ranges (Dunnigan and Sinclair 2008) of burbot have been documented in the Kootenay River (Canadian section) and Koocanusa Reservoir. Burbot were captured using hoop nets in the Tobacco River Bay near Rexford, Montana, in 1995 and 1997 (Snelson et al. 2000); five burbot were implanted with radio tags in 1995, and 11 were implanted with ultrasonic tags between 1995 and 1997. Most burbot moved only short distances and displayed site fidelity within Tobacco River Bay (Snelson et al. 2000). However, two burbot moved from the reservoir to the river and were located near Wardner, B.C. (74 rkm) during spring 1996.

More recently, Dunnigan and Sinclair (2008) captured and implanted acoustic and combined radio/acoustic tags in adult burbot from Koocanusa Reservoir. They tracked burbot weekly during two spawning seasons and an interim period. Home ranges of burbot were several orders of magnitude larger than those reported for other fishes; this may be attributed to the pelagic nature of some prey species sought by burbot in Koocanusa Reservoir rather than spawning behavior (Dunnigan and Sinclair 2008). They detected no discernable patterns in seasonal movement, and most burbot demonstrated high fidelity to the side of the reservoir where originally captured. These results likely indicated that burbot do not migrate to the river to spawn and likely reproduce within Koocanusa Reservoir. Although results of this study appear to contradict those of Snelson et al. (2000), :findings of Dunnigan and Sinclair (2008) are likely stronger due to increased sample size and tracking frequency and more thorough coverage of Koocanusa Reservoir (J. Dunnigan, personal communication).

Elk Lake, Twin Lakes, and Clark Canyon Reservoir.-Burbot occupy several lowland lakes and reservoirs in the Red Rock, Ruby, Beaverhead, and Big Hole drainages in southwest Montana (Oswald 2000, Oswald and Rosenthal 2007); these water bodies include (but are not limited to) Elk Lake, Twin Lakes, and Clark Canyon Reservoir. Burbot have been sampled using a combination of floating and sinking gill nets since 1991 (Oswald 2004). Relative abundance has varied between six and 23 fish/net between 1991 and 2003. In general, relative abundance of burbot has increased during this time period. Patterns in relative abundance may explain trends in the range and mean total length of sampled burbot (Oswald 2004). For example, when relative abundance was high, mean length declined, and the range of total lengths decreased from years of lower relative abundance; this indicated potential affects of intraspecific competition (Oswald 2004). Growth rates were slow and ultimate size for burbot was limited compared to other populations; these

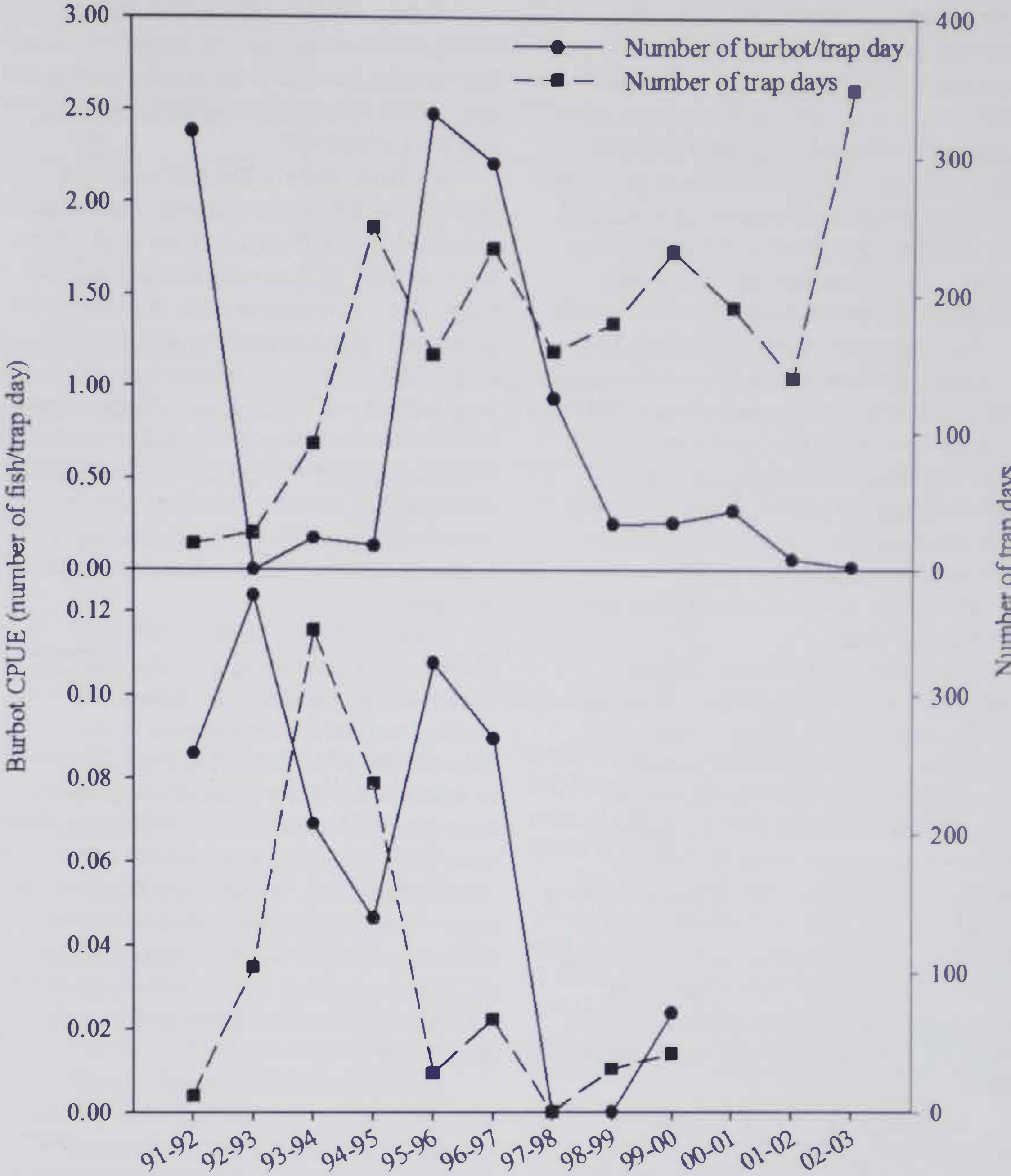

Figure 2. Catch per unit effort (CPUE) and sampling effort for burbot captured by trap nets in the Kootenai River below Libby Dam during winter (Dec-Mar) 1991-2003 (Top) and below Kootenai Falls during 1991-2000 (Bottom).

smaller lengths coupled with the greater relative popularity of abundant Yellowstone and westslope cutthroat trout (*O. clarkii bouvieri* and *O. clarkii lewisi*) may limit the value of burbot in the Elk Lake recreational fishery (Oswald 2004). Burbot sampling with sinking gill nets in Twin Lakes occurred sporadically since 1964 (Oswald 2004). Relative abundance varied from < one fish/net in 1992 to four/net in 1970. In 1998, Oswald and Roberts (1998) reported that burbot composed ~ 23 percent of the total catch by number. However, burbot "dominated" the total catch by number a few years later (Oswald 2004); a change in sampling timing from summer (1998) to autumn (2004) likely explained this pattern.

In 2003 and 2004, modified fyke nets were used in Twin Lakes to minimize mortality of captured fish (Oswald 2004).

Most effort was targeted near observed burbot spawning areas but some burbot were captured in other seasons and locations. Fyke net sampling appeared to sample older, larger fish compared to gill nets (Oswald 2004). Captured burbot were given pelvic fin clips, and subsequent resampling of marked fish indicated high fidelity of burbot to trap net location, particularly to the narrows between the two lake basins (Oswald 2004).

Current sampling efforts in Twin Lakes have employed baited cod traps immediately after ice-off (Hochhalter and Oswald 2007). Relative abundance from cod traps in 2007 was 10 fish/trap. Cod traps and fyke nets have been used to capture and mark burbot with numbered Floy tags in recent efforts to determine abundance (Hochhalter and Oswald 2007); however, results from this study are pending.

Clark Canyon Reservoir supports a relatively popular burbot fishery (Oswald and Rosenthal 2007). Prior to 2006, most information on burbot in this reservoir was obtained from winter creel surveys (Oswald and Rosenthal 2007). Creel data indicated that burbot in Clark Canyon Reservoir were among the largest in the state (Oswald 2002). However, several years of drought appear to have reduced the number and average length of burbot harvested, potentially explaining a reduction in angler use of the reservoir (Oswald and Rosenthal 2007).

Creel surveys have continued, but recent sampling efforts have used baited cod trap sets and modified fyke nets in observed spawning locations in both spring and autumn (Hochhalter and Oswald 2007). Most (90%) burbot were captured using fyke nets at active spawning sites after ice-off (Oswald and Rosenthal 2007). All burbot captured, regardless of gear or season, were given Floy tags in an effort to estimate the population based on mark-recapture data. Oswald and Rosenthal (2007) reported a population estimate of 52,021 ± 22,976. However, autumn sampling did appear to proportionately sample older, larger individuals compared to spring sampling. Thus, population size may have been underestimated (Oswald and Rosenthal 2007). More recaptures are needed to increase the number of recapture events and precision of population estimates (Oswald and Rosenthal 2007).

Big Hole River.—The USDA Forest Service and FWP have sampled most of the tributaries of the Big Hole River in an effort to inventory fish communities. In 2002, 149 burbot were collected in eight streams. Total length of burbot collected varied from 190 to 332 mm; most were smaller than stock length (PSD = 23; PSD-P = 0). Small sizes of burbot collected in these areas suggested that low-order streams in the Big Hole River drainage provide nursery habitat. Better understanding of life history dynamics of burbot in this watershed will require further research.

Missouri River Upstream of Great Falls.—Four river reaches (Craig, Cascade, Hardy, and immediately downstream of Holter Dam) have been sampled in the Missouri River during spring (Mar-Jun) or autumn (Sep-Nov) to monitor rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) populations (FWP, unpublished data). Burbot are difficult to catch during electrofishing as they tend to roll along the river bottom when stunned (T. Horton, personal communication), but all burbot captured are measured for total length and weight.

The Holter Dam and Hardy reaches have been sampled in the past three decades, and most sampling occurred in autumn (Tables 1 and 2). Most fish sampled within the Holter Dam reach were < 530 mm and condition values across all size categories were low (Table 1). Electrofishing effort in this area showed sporadic relative abundance over time (Table 1). However, more recent hoop net sampling efforts in this area showed higher catch rates than in areas further downstream (Horton and Strainer 2008).

Fish captured in the Hardy reach may be in poorer condition than in the Holter Dam section (Table 2), but the total length of fish sampled has varied from 150 to 730 mm. Relative abundance as

Table 1. Catch/unit effort and mean relative weight (Wr) values of burbot incidentally captured by electrofishing in the middle Missouri River immediately downstream of Holter Dam during spring (Mar-Jun) and autumn (Sep- ov) from 1983 to 1993. umbers in parentheses indicate the 95-percent confidence interval.

Year	Season	Number per pass	Mean Wr
1983	Autumn	0.67	76 (7)
1986	Spring	0.80	77 (5)
1986	Autumn	8.50	71 (10)
1987	Autumn	8.00	76 (5)
1993	Autumn	3.00	84 (7)

Table 2. Catch /unit effort and mean relative weight (Wr) values of burbot incidentally captured by electrofishing in the middle Missouri River near the town of Hardy, Montana, during pring (Mar-Jun) and autumn (Sep- ov) from 1981 to 2000. umbers in parenthese indicate the 95-percent confidence interval.

Year	Season	Number per pass	Mean Wr
1981	Autumn	0.50	69 (4)
1992	Autumn	11.00	82 (3)
1993	Spring	1.33	68 (2)
1993	Autumn	13.00	79 (2)
1994	Spring	11.00	71 (2)
1999	Autumn	21.75	69 (3)
2000	Autumn	27.25	67 (4)

indexed by electrofishing may be higher in the Hardy reach than in the Holter Dam reach, particularly in 1999 and 2000. However, these results may be eschewed due to university research and subsequent additional sampling effort in this area during those years (T. Horton, personal communication).

The Craig and Cascade reaches have been sampled twice/yr (spring and autumn) since 1983. Burbot have been collected nearly every spring and autumn from 1983 to 2002 near Cascade and Craig (Fig. 3). Relative abundance appeared to increase over time. However, this trend was likely due to increased interest from and adeptness of field crew in capturing burbot since 1996 (T. Horton, personal communication). Thus, only trends in burbot relative abundance were analyzed from 1996 to 2002. The relative abundance of burbot in both reaches appeared higher during autumn than spring. Several burbot sampled in this stretch were near trophy length (820 mm; Fig. 4) and may provide a unique angling opportunity. Maximum lengths of burbot sampled in these two reaches were similar, but burbot sampled in the Craig reach were generally larger those in the ascade reach (Fig. 4). Burbot of all ize classes in both reaches were in generally poor condition (pooled mean Wr = 78 ± 1).

Biologist working on the Missouri River near Great Falls, Montana, have been studying various aspects of burbot ecology In 2006, a 2-yr spring population assessment and movement study was completed between Holter Dam and Broadway Bay in Great Falls (152 rkm) using hoop nets, cod traps, and slat traps (Horton and Strainer 2008). Results from this study indicated a higher abundance of burbot near Holter Dam than in sections further downstream (Horton and Strainer 2008). Thi result was somewhat surprising as velocity near the dam may be higher than in other sections, and burbot can often not sustain swimming action in water velocities > 25 cm/s for >10 min (Jones et al. 1974). Thus, increased flows downstream of dam often impair fitness of burbot (Paragamian 1993, Paragamian 2000, Kozfkay and Paragamian 2002). However, decrease in downstream water temperature regimes since the construction of reservoirs in the upper Missouri River, i.e., Canyon Ferry, Hauser,

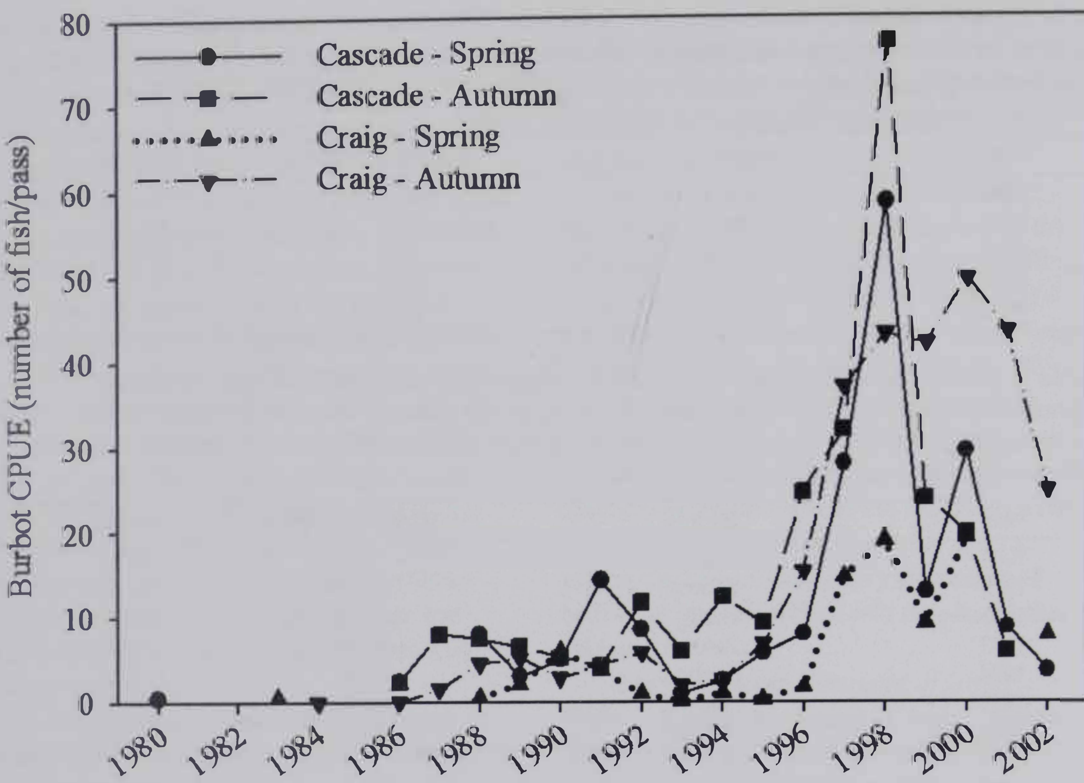

Figure 3. Number of burbot incidentally collected per pass during electrofishing surveys in the mainstem of the Missouri River near the towns of Cascade and Craig during spring (Mar-Jun) and autumn (Sep-Nov) from 1980 to 2002.

and Holter, may have had a positive effect on burbot abundance (Horton and Strainer 2008).

All burbot captured in the upper Missouri River during spring 2005 and 2006 ($n = 303$) were tagged with Floy and passive integrated transponder tags (Horton and Strainer 2008). Twenty-six tagged fish were recaptured during sampling or were returned by anglers. Most of the burbot were recovered within 10 rkm of their original tagging location; three burbot moved >30 rkm and all moved downstream (Horton and Strainer 2008). To date, there is no information on daily or seasonal movements or behaviors of burbot in the upper Missouri River.

Missouri River, Great Falls to Fort Peck Dam.—Burbot were perceived as relatively uncommon in the Missouri River between Great Falls and the Fred Robinson Bridge (B. Gardner, FWP, Lewistown, MT, personal communication). Electrofishing provided limited data on relative abundance of burbot in this section of the Missouri River from 1999 to 2000 (Tables 3 and 4). Many of the burbot captured in this area were larger than quality length (380 mm).

Burbot were often incidentally captured during sturgeon (*Scaphirhynchus* spp.) netting and trawling in the Missouri River mainstem between Fred Robinson Bridge and the headwaters of Fort Peck Reservoir. Pallid sturgeon (*S. albus*) sampling from 1994 to 2002 yielded low numbers of burbot of lengths varying from 100 to 1100 mm. Trawling for age-0 sturgeon in the delta area of Fort Peck Reservoir (RKM 3056) occasionally yields a few age-0 burbot (B. Gardner, personal communication).

Efforts to sample pallid sturgeon in the Marias and Judith rivers following similar protocols to those for the Missouri River have also sampled burbot, but not in great numbers (Anne Tews, FWP, Lewistown, MT, personal communication). Adult burbot in these rivers were typically large, and length of burbot sampled in the Marias River varied from 300 to 650 mm. Only four burbot were collected from the Judith River in 2002.

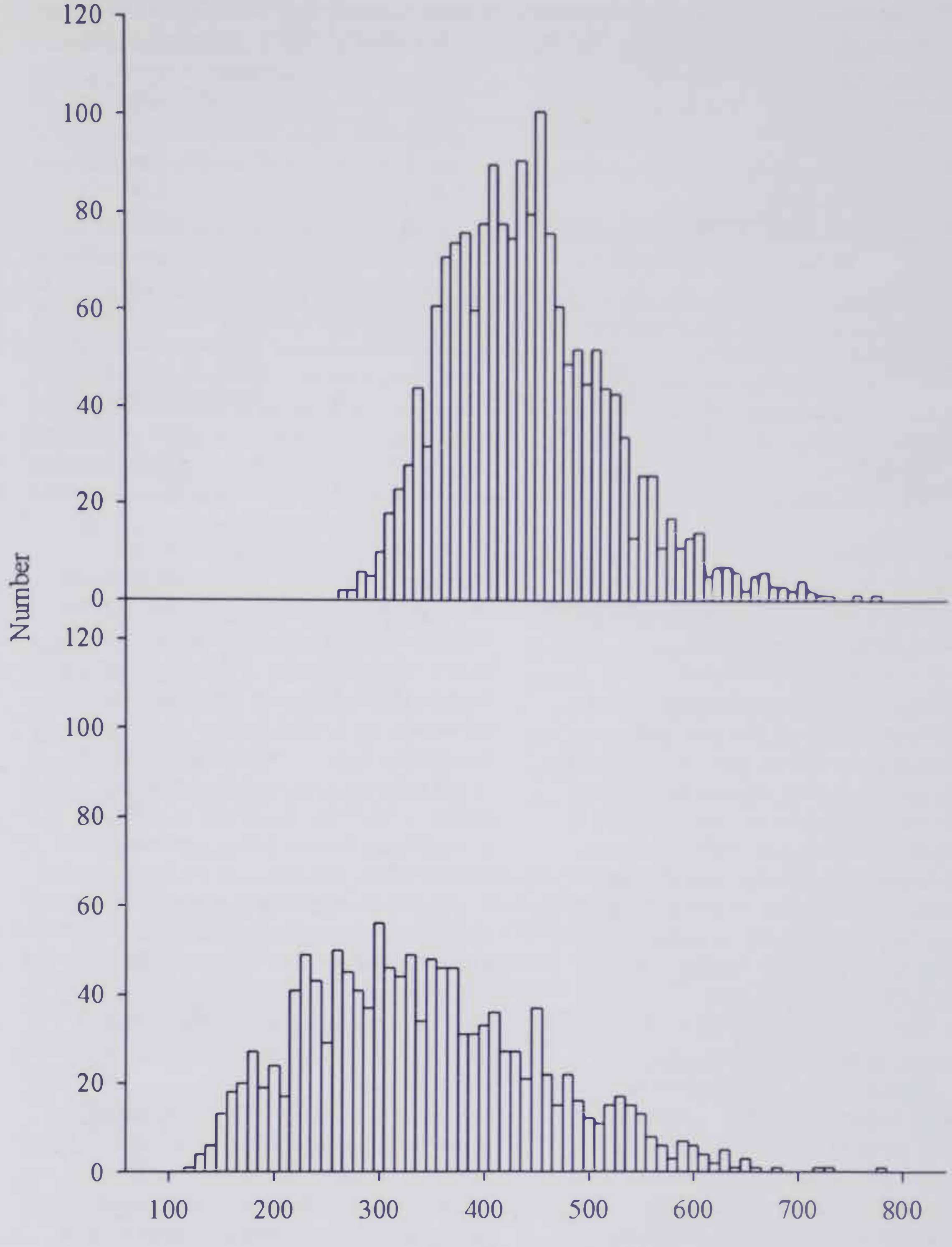

Figure 4. Size structure of burbot incidentally collected during electrofishing surveys in the mainstem of the Missouri River near the towns of Craig (Top; n = 1748) and Cascade (Bottom; n = 1304) during spring (Mar-Jun) and autumn (Sep-Nov) from 1980 to 2002 (n = 3055)

Creel surveys for the Missouri River between the Fred Robinson Bridge and Peggy's Bottom (distance = 35 rkm) indicated little fishing pressure on burbot. In a 2002 creel survey, it was reported that burbot were fished during only two angler days from April through June (Gilge and Perszyk 2002). During these two days,

Table 3. Catch/unit effort of burbot incidentally captured by electrofishing in the Missouri River by station during standardized fisheries surveys in 1999 and 2000.

Location	Number/hr	
	1999	2000
Coal Banks	0.60	0.10
Grand Island	0.90	0.30
Judith Landing	0.30	0.20
Marias River Confluence	0.00	0.20

Table 4. Number and mean total length (mm) of burbot incidentally sampled in the Missouri River by station during standardized electrofishing surveys in 1999 and 2000.

Station	1999		2000	
	n	Mean total length	n	Mean total length
Loma	3	307	4	424
White Rocks	1	406	2	368
Stafford Ferry	23	447	1	742

35 burbot were caught and 28 were kept. Daily harvest and possession limits in this area are presently five fish per day (Montana Fish, Wildlife and Parks 2008).

In contrast to the river, a relatively popular winter fishery exists within Fort Peck Reservoir. However, creel data is lacking and few burbot were sampled in the reservoir due to time constraints resulting from walleye (*Sander vitreus*) sampling in the spring (M. Ruggles, FWP, Fort Peck, MT, personal communication). Anglers have reported catching a variety of sizes suggesting that several year classes were present in the reservoir. Nevertheless, there has been some concern that burbot abundance is declining in the reservoir (M. Ruggles, personal communication).

Missouri River, Fort Peck Dam to North Dakota Border.— Gardner and Stewart (1987) sampled the lower mainstem of the Missouri River and its major tributaries in the late 1970s to early 1980s. They collected 533 burbot during that time. Mean back-calculated lengths at age indicated that burbot grew fastest between ages 5 and 6, coinciding with a shift from insectivory to piscivory. Burbot in this section of the Missouri River grew more slowly at younger ages but more rapidly at older ages compared to other North American populations (Gardner and Stewart 1987). Burbot in this section of the Missouri River did not migrate great distances. In fact, tagging and recapture information revealed only 9 percent of recaptured burbot moved >16 rkm from their original capture site; the largest movement was 19 rkm (Gardner and Stewart 1987). However, these fish were not monitored for diel or other short-term movements. Little information is available on the spawning habits of burbot in the section of Missouri River due to difficulty in monitoring burbot during spawning (Feb; Brown 1971).

Few burbot have been sampled in the Milk River suggesting the species was not abundant (K. Gilge, FWP, Havre, MT, personal communication). Anecdotal observations suggested that the species is associated with tailwaters and riprap of diversion dams.

Yellowstone River.—Burbot have been incidentally sampled in both spring and autumn throughout the Yellowstone River basin. In the upper reach (above and including the Bighorn River) burbot have been sampled in the Bighorn River, Bighorn Lake, and in the mainstem at several locations from Big Timber to Huntley Dam. Unfortunately, burbot were not easily sampled and were rarely targeted (M. Vaughn, FWP, Billings, MT, personal communication). Standardized sampling for other species such as sauger (*S. canadense*) and walleye generally occurs in spring and autumn throughout the upper reach; burbot were more often incidentally collected in the spring. Larger burbot were more common in the Yellowstone River than Bighorn Lake or Bighorn River (Table 5). Condition of burbot in the upper drainage is generally low with no Wr values > 95 (Table 5).

Annual standardized fish community sampling using several gears has occurred at five stations in the lower Yellowstone River (below the Bighorn River) since 1984 (Table 6). Most burbot were sampled by electrofishing; however, a few were sampled by drifting trammel nets, and one was sampled in a trap net. Effort information is not available; thus, calculations of CPUE were not possible.

Burbot captured in the lower Yellowstone River generally do not exceed preferred length (530 mm; Table 7). Penkal (1981) suggested that rearing of juvenile burbot may occur downstream from Forsyth diversion. However, larger fish might possibly move out of the system, experience higher mortality, or were not sampled. Angling most likely had no effect on size structure of the population because harvest of burbot from the Yellowstone River was minimal (V. Riggs, FWP, Miles City, MT, personal communication). Condition values for burbot in the lower Yellowstone River vary between 63 and 155; condition did not appear to differ by length category (Fig. 5).

Management Implications

Broad-scale comparisons of burbot population characteristics and distribution were difficult due to lack of standardized and targeted sampling. Nevertheless, we are confident that burbot have not been extirpated from historical locations described by Brown (1971). However, contemporary concern that burbot abundance has declined in many waters throughout Montana could not be ascertained in this study. Our recommendation is to develop a statewide standardized sampling program for burbot to achieve a better understanding of their status.

In developing a sampling program for any species, life history, efficiency of sampling gear, capture probability, size selectivity, time of year, and other logistical

Table 5. Number, size structure, and relative weight (Wr) of burbot sampled during annual sauger (*Sander canadensis*) and walleye (*S. vitreus*) surveys in the upper Yellowstone River (above and including the Bighorn River) from 1986 to 2001. Size structure is indexed by proportional size distribution (PSD) and proportional size distribution of preferred length fish (PSD-P). Mean Wr is reported by incremental length category [stock to quality (S-Q; 200-379 mm), quality to preferred (Q-P; 380-529 mm), preferred to memorable (P-M; 530-669 mm), memorable to trophy (M-T; 670-819 mm), and trophy (T; > 820 mm)].

					Wr				
Location	**Year**	**n**	**PSD**	**PSD-P**	**S-Q**	**Q-P**	**P-M**	**M-T**	**T**
Bighorn Lake	1997	18	89	22	75	74	83		
	1998	1	0		95				
	1999	3	33		62				
	2000	7	43	14	70	60			
	2001	4	75		68	90			
Bighorn River	1986	1	100	100			85		
	1989	2	100	100			79	78	
	1990	1	0		72				
	1991	5	60	20	71	82	76		
	1996	8	63		75	82			
	1999	2	100			79			
	2000	10	100	40		84	66	73	
Yellowstone River	1989	85	100	86		75	72	74	63
	1995	38	89	50			86	86	80
	1999	10	100	60		74			
	2000	96	95	57	77	70	71	72	

Table 6. Number of burbot sampled during standardized fisheries surveys in the lower Yellowstone River (below the Bighorn River) by location and season [spring (March-June) and autumn (Sep-Nov)] from 1984 to 2002.

	Intake		Fallon		Miles City		Forsyth		Rancher Ditch	
Year	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
1984										
1985										
1986								4	2	9
1987							5			
1988							13	3		
1989										
1990						14				
1991	2									
1992				1		2		7		
1993				1		1		2		
1994		5		2		7		2		
1995		15		3		2		6		
1996		1		2		1	6	4		
1997						1	1	1		
1998		4								
1999	50									
2000										
2001	1									
2002	4					1		1		
Totals	**58**	**27**	**0**	**13**	**1**	**29**	**25**	**31**	**2**	**9**

Table 7. Size structure of burbot sampled during standardized fisheries surveys in the lower Yellowstone River drainage (below the Bighorn River) from 1986 to 2001. Size structure is indexed by proportional size distribution (PSD) and proportional size distribution of preferred length or longer fish (PSD-P).

Year	n	PSD	PSD-P
1985	1	0	0
1986	5	80	40
1987	5	20	20
1988	7	14	14
1989	0	0	0
1990	8	50	13
1991	1	0	0
1992	11	18	0
1993	4	25	0
1994	14	57	21
1995	20	40	10
1996	15	20	13
1997	3	100	67
1998	3	33	33
1999	43	30	14
2000	2	50	0
2001	2	0	0
2002	6	17	0

matters must be considered. Burbot typically occupy the hypolimnion of oligotrophic and mesotrophic lakes (Ryder and Pesendorf 1992), where they tend to be associated with bedrock or rubble substrates (Edsall et al. 1993). Lotic habitat preferences are less understood, but it is believed that burbot in the southwest portion of their range, i.e., Idaho, Montana, and Wyoming, may be restricted to backwater areas of cooler

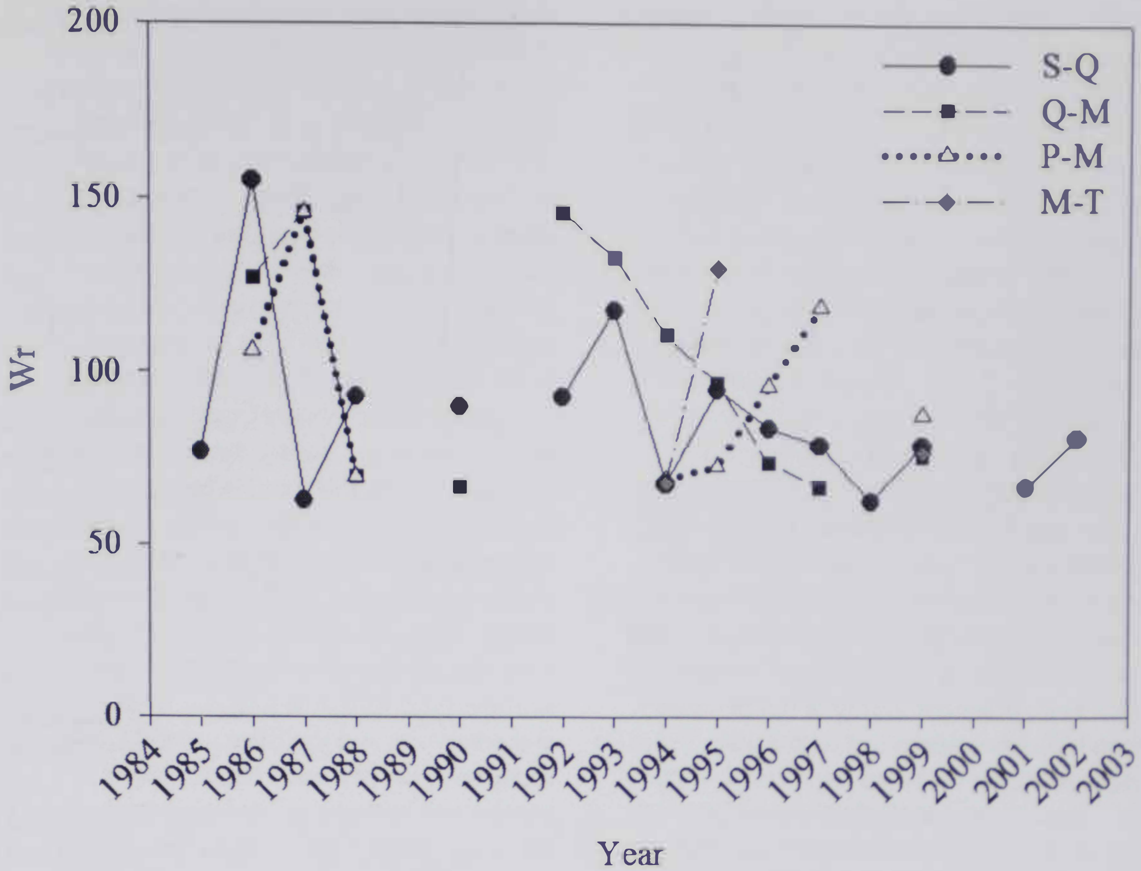

Figure 5. Mean relative weight (Wr) by size category of burbot captured in the lower Yellowstone River (below the Bighorn River) from 1985 to 2002. Length categories are: stock to quality (S-Q; 200-379 mm), quality to preferred (Q-P; 380-529 mm), preferred to memorable (P-M; 530-669 mm), and memorable to trophy (M-T; 670-819 mm).

high-altitude systems (McPhail and Paragamian 2000). Hoop nets are arguably the most effective gear for sampling larger (≥ 450 mm TL) burbot in both lentic and lotic habitats (Lawler 1963, Bernard et al. 1991). Baiting gears with an odiferous prey species such as kokanee *(O. nerka)* has shown to increase sampling efficiency as burbot use olfactory senses to locate prey (Bernard et al. 1991).

An experimental gear has been tested in Duncan River and Kootenay Lake in British Columbia and in Twin Lakes and Clark Canyon Reservoir in Montana that may improve sampling efficiency in lentic ecosystems (Spence 2000; Hochhalter and Oswald 2007). This gear is based on the design of commercial traps used in British Columbia's coastal black cod (*Anoplopoma fimbria*) fishery. Cod traps baited with kokanee were effective in capturing burbot in Kootenay Lake and Spence (2000) found to them easier to transport and store than hoop nets. Spence (2000) also suggested that cod traps were more effective than hoop nets especially during longer sets (>7 days). Hochhalter and Oswald (2007) have documented success sampling with cod traps in Twin Lakes and Clark Canyon Reservoir, particularly in known burbot spawning locations. Based on these results, we recommend continued testing of cod traps in other Montana lentic systems.

Results from Spence (2000) and Hochhalter and Oswald (2007) for sampling burbot in lentic environments differ from those of Horton and Strainer (2008) for sampling in the Missouri River of Montana. Horton and Strainer (2008) found hoop nets were more effective than cod traps in sampling burbot on a 152-km stretch of the Missouri River in March

2005 and 2006. Habitat type may explain these differences. Another reason for this disparity may be related to the fishing duration of the gear. Horton and Strainer (2008) allowed hoop nets and cod traps to soak for approximately 2 days. However, Spence (2000) allowed traps to fish for up to 7 days. Further, positioning of the bait within the gears may affect their efficiency [see Horton and Strainer (2008) for further discussion]. Based on information from Spence (2000), Hochhalter and Oswald (2007), and Horton and Strainer (2008), we recommend the initial use of hoop nets in the standardized protocol for larger fish (≥ 450 mm TL) because use of cod traps has not been thoroughly tested in Montana and because comparisons between lotic and lentic ecosystems is sometimes necessary. However, if comparability is not necessary, then biologists may want to consider experimenting with cod traps.

Gear recommendations listed thus far are largely targeted at sampling burbot ≥450 mm TL Bernard et al. (1991) found that burbot smaller than this length were not fully recruited to hoop nets. Horton and Strainer (2008) reported that slat traps were more effective at sampling burbot ≤ 300 mm TL than hoop nets or cod traps in the upper Missouri River. To our knowledge, no such size selectivity comparison has been completed for these three gears in lentic systems. Relative abundance and size distribution information of small fishes is important as they may provide information on year-class strength and ontogenous habitat use (Horton and Strainer 2008). We recommend that slat traps be tested in lentic and other lotic waters to determine if this gear is appropriate for sampling smaller burbot and to determine whether catches of smaller fish are comparable between these different waterbody types.

Seasonal considerations were equally as important as choice of gear in developing a standardized sampling regime. Burbot are nocturnal fish that spawn in the winter months under ice (Dec–early Mar; Brown 1971, Scott and Crossman 1973) and are most active at this time; however, winter sampling during adverse ice conditions is difficult. Summer sampling yields far fewer burbot per effort due to their relative inactivity (Bernard et al. 1993). Bernard et al. (1993) found that sampling precision is maximized in small and moderate-sized lakes if sampling is done immediately after the lake becomes ice-free in the spring or just before it freezes over in the late autumn or early winter. During the autumn months as the daylight period shortens and water temperatures cool, burbot were equally likely to be active during the day and night (Kroneld 1975). Further, burbot may be moving to staging areas for their winter spawning activities (Kroneld 1975). Thus, autumn may be the ideal season to sample burbot. This observation is supported in Montana by the data we received from southwestern Montana lowland lakes and reservoirs and the Cascade and Craig sections of the Missouri River, where numbers of burbot captured apparently are consistently higher during the autumn months. However, fisheries biologists already experience time constraints during this season while surveying other recreationally important species; therefore, we recommend spring (as close to ice-out as possible) sampling initially with plans to compare autumn and spring sampling efficiencies at a later date.

Studies are currently being conducted in other areas of the burbot's range in North America, particularly in the western U.S. and Canada, to determine habitat use, verify the status of remaining stocks, and assess the impact of dam operations on burbot recruitment (Spence 2000). A standardized sampling protocol in Montana will help fill this paucity of information on burbot life history and population characteristics in the southwest portion of their North American range. Despite the widespread distribution of burbot in Montana, we know little about this native and potentially important recreational species. The state of Montana has a unique opportunity to implement a proactive approach to burbot conservation, which may aid in the management of this species throughout its range.

Acknowledgments

This work was funded by Montana Fish, Wildlife and Parks. We thank Jim Dunnigan, David Fuller, Bill Gardner, Kent Gilge, Travis Horton, Troy Humphrey, Matt Jaeger, Kevin Kapuscinski, Laura Katzman, Scott Opitz, Dick Oswald, Pat Saffel, Brad Schmitz, Anne Tews, Mike Vaughn, and Dave Yerk for providing data and additional information on burbot. We also thank the biologists who completed surveys and provided anecdotal information regarding burbot in Montana waters. Editorial comments by Mark Fincel, Will Schreck, and David Willis (South Dakota State University), as well as David Stagliano, Jim Dunnigan and Travis Horton improved the manuscript. Finally, we thank Ken McDonald and Bob Snyder for their comments and guidance while completing the status assessment report.

Literature Cited

Anderson, R. O. 1980. Proportional stock density (PSD) and relative weight (Wr): interpretive indices for fish populations and communities. Pp. 27-33 *in* S. Gloss and B. Shupp, eds, Practical fisheries management: more with less in the 1980s. New York Chapter of the American Fisheries Society, Cazenovia, NY.

Arndt, S. K. A. and J. Hutchinson. 2000. Characteristics of a tributary-spawning population of burbot from Columbia Lake, British Columbia. Pp. 48-60 *in* V. L. Paragamian and D. W. Willis, eds, Burbot: biology, ecology and management. American Fisheries Society, Fisheries Management Section, Publication Number 1, Bethesda, MD.

Bernard, D. R., G. A. Pearse, and R. H. Conrad. 1991. Hoop traps as a means to capture burbot. North American Journal of Fisheries Management 11:91-104.

Bernard, D. R., J. F. Parker, and R. Lafferty. 1993. Stock assessment of burbot populations in small and moderate-size lakes. North American Journal of Fisheries Management 13:657-675.

Brown, C. J. D. 1971. Fishes of Montana. Big Sky Books, Bozeman.

Chisholm, I. and J. J. Fraley. 1986. Quantification of Libby Reservoir levels needed to maintain or enhance reservoir fisheries, 1985 annual report. Montana of Fish, Wildlife and Parks. Bonneville Power Administration Report Project 3-467, Helena.

Dunnigan, J. L. and C. L. Sinclair. 2008. Home range and movement patterns of burbot in Koocanusa Reservoir, Montana, USA. Pp. 201-211 *in* V. L. Paragamian and D. H. Bennett, eds, Burbot: ecology, management, and culture. American Fisheries Society Symposium, Publication Number 59, Bethesda, MD.

Eddy, S. and T. Surber. 1943. Northern fishes with special reference to the upper Mississippi valley. University of Minnesota Press, St. Paul. 252 pp.

Edsall, T. A., G. W. Kennedy, and W. H. Horns. 1993. Distribution, abundance and resting microhabitat of burbot on Julian's Reef, southwestern Lake Michigan. Transactions of the American Fisheries Society 122:560-574.

Environmental Systems Research Institute, Inc (ESRI). 2004. ArcGIS Desktop, version 9.0. Redlands, CA.

Fisher, S. J., D. W. Willis, and K. L. Pope. 1996. An assessment of burbot (*Lota lota*) weight-length data from North American populations. Canadian Journal of Zoology 74:570-575.

Fisher, S. J. 2000. Early life history observations of burbot utilizing two Missouri River back waters. Pp. 96-101 *in* V. L. Paragamian and D. W. Willis, eds, Burbot: biology, ecology and management. American Fisheries Society, Fisheries Management Section, Publication Number 1, Bethesda, MD.

Gardner, W. M. and P. A. Stewart. 1987. The fishery of the lower Missouri River, Montana. Montana Fish Wildlife and Parks, Helena.

Gilge, K. and K. Perszyk. 2002. Middle Missouri River native species creel census. Montana Fish, Wildlife and Parks Report, Helena.

Guy, C. S., R. M. Neumann, D. W. Willis, and R. O. Anderson. 2007. Proportional size distribution (PSD): a further refinement of population size structure index terminology. Fisheries 32:348.

Hammond, R. J. and P. J. Anders. 2003. Population biology and population genetics reviews of Kootenai Basin burbot upstream from Bonnington Falls, British Columbia. U.S. Department of Energy and Bonneville Power Administration, Portland, OR.

Hochhalter, S. J., and R. A. Oswald. 2007. Southwest Montana native fish research and conservation. Montana Fish, Wildlife and Parks, Bozeman.

Holton, G. D. and H. E. Johnson. 2003. A field guide to the Montana fishes, 3rd ed. Montana Fish, Wildlife and Parks, Helena.

Horton, T. B. and A. C. Strainer. 2008. Distribution and population characteristics of burbot in the Missouri River, Montana: based on hoop net, cod trap, and slat trap captures. Pp. 201-211 in V. L. Paragamian and D. H. Bennett, eds, Burbot: ecology, management, and culture. American Fisheries Society Symposium, Publication Number 59, Bethesda, MD.

Jones, D. R., J. W. Kiceniuk, and O. S. Bamford. 1974. Evaluation of the swimming performance of several species of fish from the Mackenzie River. Journal of Fisheries Research Board of Canada 31:1641:1647.

Jones-Wuellner, M. R. and C. S. Guy. 2005. Status of burbot in Montana. Montana Cooperative Fishery Research Unit, Bozeman.

Kozfkay, J. R. and V. L. Paragamian. 2002. Kootenai River fisheries investigation annual report: 1 Apr 2000 to 31 Mar 2001. Idaho Department of Fish and Game. Bonneville Power Administration Annual Progress Report Project 88-65, Boise.

Kroneld, R. 1975. A working model for the synchronization of light in phase shifting burbot, *Lota lota L.* (Pisces, Gadidae) at the Polar Circle. Revue Roumaine de Biologie 20:147-153.

Lawler, G. H. 1963. The biology and taxonomy of the burbot, *Lota lota,* in Heming Lake, Manitoba. Journal of the Fisheries Research Board Canada 29: 417-433.

McPhail, J. D. 1995. A review of burbot (*Lota lota*) life-history and habitat use in relation to compensation and improvement opportunities. Report prepared for the Habitat Management Division, Department of Fisheries and Oceans, Vancouver, British Columbia

McPhail, J. D. and C. C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fisheries Research Board Canada, Bulletin 173, Ottawa, Ontario.

McPhail, J. D. and V. L. Paragamian. 2000. Burbot biology and life history. Pp. 11-23 *in* V. L. Paragamian and D. W. Willis, eds, Burbot: biology, ecology and management. American Fisheries Society, Fisheries Management Section, Publication Number 1, Bethesda, MD.

Montana Fish, Wildlife and Parks. 2008. Montana fishing regulations. Helena.

Nelson, J. S. and M. J. Paetz. 992. The fishes of Alberta. University of Alberta Press, Edmonton.

Oswald, R. A. 2000. Inventory and survey of fisheries in lowland lakes and reservoirs of the Red Rock, Ruby, Beaverhead, and Big Hole River drainages of southwest Montana. Montana Fish, Wildlife and Parks, Bozeman.

Oswald, R. A. 2002. Inventory and survey of fisheries in lowland lakes and reservoirs of the Red Rock, Ruby, Beaverhead, and Big Hole River drainages of southwest Montana. Montana Fish, Wildlife and Parks, Bozeman.

Oswald, R. A. 2004. Inventory and survey of fisheries in lowland lakes and reservoirs of the Red Rock, Ruby, Beaverhead, and Big Hole River drainages of southwest Montana, 2002-2004. Montana Fish, Wildlife and Parks, Bozeman.

Oswald, R. A. and B. Roberts. 1998. Twin Lakes fish population sampling, 1998. Hochhalter, S. J. and R. A. Oswald.

2007. Southwest Montana native fish research and conservation. Montana Fish, Wildlife and Parks, Bozeman.

Oswald, R. A. and L. R. Rosenthal. 2007. Inventory and survey of the sport fisheries of Clark Canyon and Ruby River reservoirs in southwest Montana. Montana Fish, Wildlife and Parks, Bozeman.

Paragamian, V. L. 1993. Kootenai River Fisheries investigation: stock status of burbot and rainbow trout and fisheries inventory. Idaho Department of Fish and Game. Bonneville Power Admini tration Annual Progress Report Project 88-65, Boise.

Paragamian, V. L. 2000. The effects of variable discharges on burbot spawning migrations in the Kootenai River, Idaho, USA, and British Columbia, Canada. Pages 111-123 *in* V. L. Paragamian and D. W. Willis, eds., Burbot: biology, ecology and management. American Fisheries Society, Fisheries Management Section, Publication Number 1, Bethesda, MD.

Paragamian, V. L., V. Whitman, J. Hammond, and H. Andrusak. 2000. Collapse of the burbot fisheries in Kootenay Lake, British Columbia Canada, and the Kootenai River, Idaho, USA, post-Libby Dam. Pp. 155-164 *in* V. L. Paragamian and D. W. Willis, eds., Burbot: biology, ecology and management. American Fisheries Society, Fisheries Management Section, Publication Number 1, Bethesda, MD.

Penkal, R. F. 1981. Life history and flow requirements of paddlefish, shovelnose sturgeon, channel catfish, and other fish in the lower Yellowstone River system. Montana Fish, Wildlife and Parks Report, Helena.

Pflieger, W. L. 1997. Fishes of Missouri, Missouri Department of Conservation, Jefferson City.

Quinn, S. 2000. The status of recreational fisheries for burbot in the United States. Pp. 127-135 *in* V. L. Paragamian and D. W. Willis, eds., Burbot: biology, ecology and management. American Fi herie Society, Fisheries Management Secton, Publication Number 1, Bethe da, MD

Ryder, R. A. and J. Pesendorf. 1992 Food, growth, habitat and community interaction of young-of-the-year burbot, *Lota lota* (L.), in a Precambrian hield lake. Hydrobiologia 243/244.211-227.

Scott, W. B. and E. J. Crossman. 1973. Fre hwater fishes of anada. Fisheries Research Board anada Bulletin 173· Ottawa, Ontario.

Snelson, S., T. Ostrowski, G. Hoffman, and B. Marotz. 2000. Libby Excessive Drawdown Mitigation Progres Report 1995-1997. Montana Department of Fish, Wildlife and Park . Bonneville Power Administration Report Project 94-10, Helena.

Spence,C R. 2000. A comparison of catch success between two styles of burbot traps in lakes. Pp. 165-170 *in* V. L. Paragamian and D. W. Willis, eds., Burbot: biology, ecology and management. American Fisheries Society, Fisheries Management Section, Publication Number 1, Bethesda., MD

Taylor, J. L. and J. D. McPhail. 2000. Temperature, development and behavior in the early life history of burbot from Columbia Lake, British Columbia. Pp. 30-37 *in* V. L. Paragamian and D. W. Willis, eds., Burbot: biology, ecology and management. American Fisheries Society, Fisheries Management Section, Publication Number 1, Bethesda, MD.

Wege, G. J. and Anderson, R. O. 1978. Relative weight (Wr): a new index of condition for largemouth bass. Pp. 79-91 *in* G. D. Novinger and J. G. Dillard, eds., ew approaches to the management of small impoundments. orth Central Division of the American Fisheries Society, Special Publication Number 5, Bethesda, MD.

Received 28 April 2008
Accepted 18 December 2008