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MANAGEMENT BRIEF

Movement of Lake-Origin Burbot Reared in a Hatchery Environment and Released into a Large River Drainage

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Abstract

Burbot *Lota lota* in Kootenay Lake and the Kootenay River of British Columbia, Idaho, and Montana (U.S. spelling: "Kootenai River") are at risk of demographic extinction. We conducted a pilot study to evaluate poststocking dispersal and movement of hatchery-reared, lake-strain burbot (Moyie Lake, British Columbia) in a riverine environment to determine the potential utility of this hatchery strain for future burbot rehabilitation efforts in this system. We implanted ultrasonic tags into 30 hatchery-reared burbot (ages 2 and 3) and released them into the Goat River, a tributary to the Kootenay River, in October 2009. Dispersal over a distance of 2 km from the Goat River release site to the Kootenay River occurred within 1–9 d after release (mean = 3.1 d; $n = 28$ active tags). Thereafter, 14 burbot remained in the Kootenay River for the rest of the 144-d study period; nine of these fish were observed moving upstream from the Goat River confluence, and five were observed both upstream and downstream from the confluence. The other 14 burbot were observed in Kootenay Lake; of these fish, eight were detected in the lake for the duration of the study, and six were observed to move regularly between the lake and the river. Dispersal distances (distance between the upstream-most and downstream-most detections per individual) within the Kootenay River ranged from 10 to 138 km (mean = 80 km), and tagged fish were detected over a 236-km reach (from 135 km downstream to 101 km upstream of the Goat River confluence). We also observed burbot in the vicinity of known spawning locations during the February spawning season. The observed dispersal suggests that a limited number of stocking locations may be sufficient to allow burbot to access available habitats within a few months postrelease. Our observations therefore suggest that lake-origin, hatchery-reared burbot may be suitable for stocking in a riverine environment.

Efforts to restore burbot *Lota lota* are occurring worldwide to address population declines and localized extirpation (Harzevili et al. 2003; Dillen et al. 2008; Ireland and Perry 2008; Worthington et al. 2009; Stapanian et al. 2010). Habitat degradation is the most common cause of burbot declines; thus, in most cases the restoration of both populations and habitat is critical (KVRI Burbot Subcommittee 2005; Paragamian and Wakkinen 2008; Stapanian et al. 2010). Previous efforts to release larval burbot have been unsuccessful and indicate that the release of juvenile burbot may be the most promising approach for improving survival of stocked burbot and for restoring year-classes (Dillen et al. 2008).

In the Kootenay River of British Columbia (BC), Canada, and Idaho and Montana, USA (U.S. spelling: "Kootenai River"; Figure 1), recruitment has been insufficient to sustain the burbot population, resulting in severe declines and a population that is at risk of imminent extirpation (Paragamian et al. 2008). As a stopgap measure while the impacts of habitat degradation are evaluated and while habitat improvement opportunities are examined and implemented, burbot rehabilitation measures

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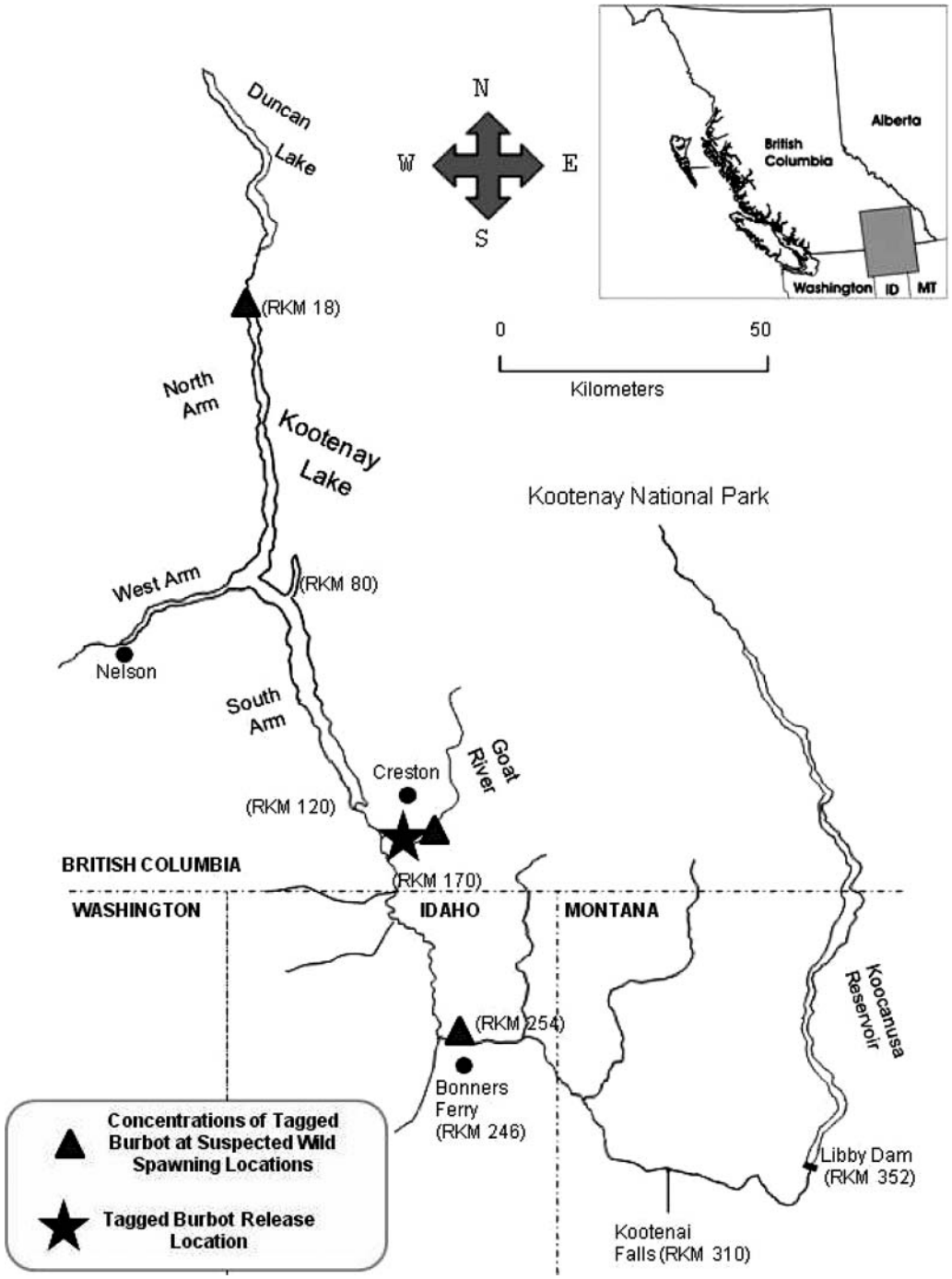

FIGURE 1. Locations of Kootenay Lake, Lake Koocanusa, and major tributaries of the Kootenay River system (British Columbia, Montana, and Idaho), where hatchery-reared progeny of lake-origin burbot were released. The river distances (river kilometers [RKM]) from the northernmost reach of Kootenay Lake are indicated at important access points.

include the release of hatchery-reared burbot to supplement the wild stock (KVRI 2005).

Dispersal capabilities must be evaluated when developing hatchery release strategies because natural environments have significant spatial and temporal variation (Ondrej et al. 2005) and dispersal is the mechanism that allows access to suitable habitat (Neufeld and Rust 2009). The number and location of release sites and the timing of release can play a significant role in the performance and survival of hatchery-reared fish (Niva and Jokela 2000; Justice et al. 2009). If dispersal is not rapid

enough, density-dependent mortality among released individuals or between hatchery and wild progeny may affect survival and performance (Sundstrom et al. 2004; Brennan et al. 2008; Justice et al. 2009). Also, in order to recover the historic spatial distribution of the population, dispersal must be great enough so that hatchery progeny are able to access all habitats within a recovery area.

In this short-term pilot study, burbot from the Moyie Lake (BC) stock (Powell et al. 2008) were reared to ages 2 and 3, tagged with sonic transmitters, and released into the Goat River (BC), which is a tributary to the Kootenay River and is the historic spawning location for the Kootenay River burbot population. Our objectives were to determine (1) the poststocking movements and dispersal of hatchery-reared, lake-origin burbot for 5 months after release; and (2) the response of lake-origin progeny after release into a riverine system. The results from this preliminary study will allow us to refine and design future studies, determine future numbers and locations of hatchery fish release sites, and evaluate the choice of broodstock based on progeny performance.

METHODS

Study area.—The Kootenay River is located in the upper Columbia River basin of North America (Figure 1). The river originates in Kootenay National Park (BC), discharges south into Koocanusa Reservoir (Montana), and turns northwest at the site of Libby Dam (Figure 1). The river passes through the northeast corner of the Idaho Panhandle and turns north before entering Kootenay Lake (BC). The Goat River, a Kootenay River tributary that was the site of hatchery releases in this study, joins the Kootenay River between the Idaho Panhandle and Kootenay Lake. Kootenay Lake is a 39,537-ha, oligotrophic lake that has two major inlets: the Duncan River from the north and the Kootenay River from the south. The lake lies within a north–south aspect valley between the Selkirk Mountains and the Purcell Mountains and discharges through the West Arm (located transverse to the main lake) into the lower Kootenay River, which joins the Columbia River near Castlegar, BC. The primary study reach for this investigation extended from river kilometer (RKM) 18.0 to RKM 282.0 (RKM 0 = northernmost reach of Kootenay Lake; Figure 1).

Burbot culture.—Adult burbot (600–780 mm total length; average weight = 2,500 g) for spawning and egg collection were captured from Moyie Lake by use of cod traps (Neufeld and Spence 2004) and were translocated to the Aquaculture Research Institute, University of Idaho, Moscow. Rearing and spawning occurred in a recycling system where photoperiod and water temperature were generally maintained similar to the natural conditions of the Kootenai River. Eggs were incubated according to the methods of Jensen et al. (2008) and were treated with fungicide to inhibit fungal growth (Polinski et al. 2010). Larvae were hatched and collected within 250-L, black-plastic tanks and were fed a live diet for 30–50 d before weaning onto commercial diets formulated for larval Atlantic cod *Gadus morhua* (Jensen et al. 2008). Burbot were reared until age 2 or 3 prior to tagging and release in this study.

Tagging and tracking.—Thirty burbot (average total length = 385 mm; average weight = 545 g) were tagged with passive integrated transponder tags (Biomark, Inc., Boise, Idaho) and ultrasonic V9–2L tags (VEMCO Division, AMIRIX Systems, Inc., Halifax, Nova Scotia). Ultrasonic transmitters were 9 × 29 mm in length and weighed 4.7 g in air and 2.9 g in water. Two styles of V9 tags were used based on tradeoffs between battery life and pulse frequency. Ten tags were set with a 90–240-s delay time between pulses (nominal delay = 165 s; battery life = 751 d), and 20 tags were set with a delay time of 60–180 s (nominal delay = 120 s; battery life = 573 d). The V9 tags were surgically implanted within the peritoneum by following methods similar to those described by Winter (1996) and Neufeld and Rust (2009). Burbot were monitored in the hatchery for 30 d posttagging to ensure physical recovery prior to release.

The ultrasonic telemetry system utilized VEMCO VR2 and VR2W stationary sonic receivers. Sonic receivers were deployed from Kootenay Lake upstream into Idaho near the Montana border (further described by Neufeld and Rust 2009). In total, 56 "gates" or monitoring sites were established in this range by using a total of 66 receivers. Receivers were spaced between 0.5 and 14.5 km apart (mean = 4.8 km), covered an area from RKM 18 to RKM 282, and could continuously detect burbot movements when tagged burbot passed within range of a receiver. Two receivers were deployed in the Goat River about 2 km apart between the release site and the confluence with the Kootenay River. One of these receivers was located 800 m downstream of the release site, while the second receiver was located 200 m upstream from the Kootenay River confluence and had a detection radius that also included part of the Kootenay River. Because the detection radius of the receiver near the mouth of the Goat River included the Kootenay River, we were unable to positively establish that a burbot had left the Goat River until it was detected on a receiver outside of the Goat River (5 km upstream or downstream of the Goat River confluence). The study period extended from fish release on October 21, 2009, to February 28, 2010.

RESULTS

All 30 tagged, hatchery-origin burbot survived the 30-d observation period after implantation of ultrasonic tags and were released on October 21, 2009, into the Goat River approximately 2 km upstream of its confluence with the Kootenay River (RKM 153.5). Overall, 67,674 detections of tagged burbot were recorded during the 144-d study period. Two tagged burbot (7%) were never detected beyond the release site, and 28 (93%) were detected as leaving the Goat River and entering the Kootenay River.

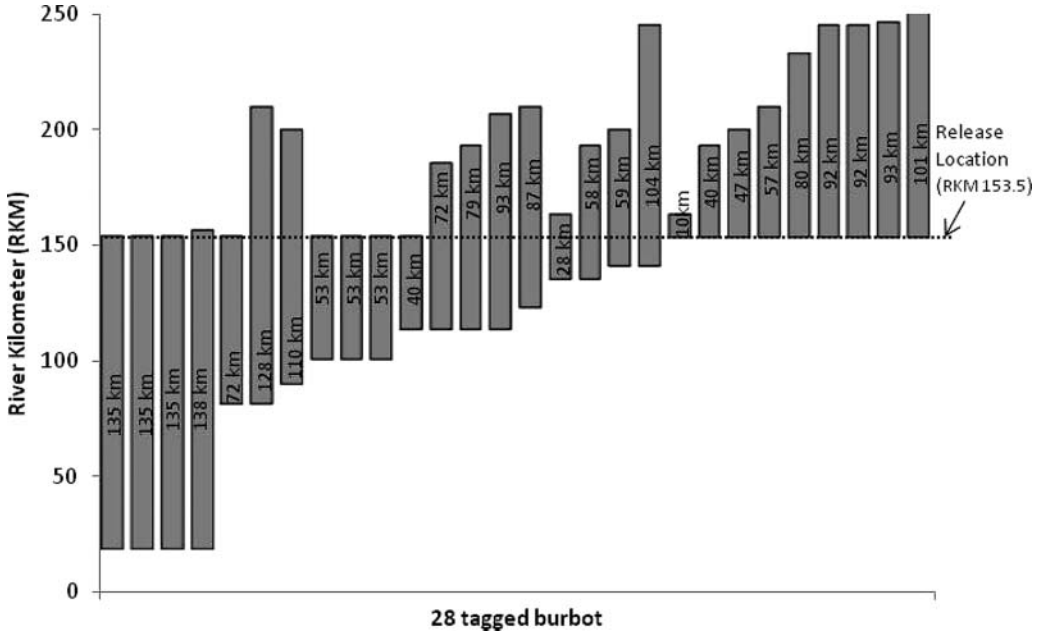

FIGURE 2. Linear extent of the Kootenay River study area (river kilometers [RKM] from the northernmost reach of Kootenay Lake) used by tagged burbot during the study period (October 2009–February 2010). Each bar represents the uppermost and lowermost detection records for an individual, and the distance between these points is noted on the bar.

The number of days for which each tagged burbot was detected in the Goat River ranged from 1 to 9 d, and the mean postrelease residence time in this river was 3.1 d (SD = 1.9 d). By December 15, 2009, 28 tagged burbot were spread out over a 236-km reach of the Kootenay River between RKM 18 (extreme north end of Kootenay Lake) and RKM 254 (above Bonners Ferry, Idaho; Figures 2, 3). The mean distance between the upstream-most and downstream-most detections per individual was 80 km (range = 9.8–137.5 km; Figure 2). In the Kootenay River, upstream travel rates based on time between detections at receiver locations were as high as 14.6 km/d (i.e., 87.5 km over 6 d).

After leaving the Goat River and entering the Kootenay River, 14 burbot remained in the Kootenay River for the entire study period; nine of these fish moved upstream, and five fish used areas both upstream and downstream of the Goat River–Kootenay River confluence (Figures 2, 3). The remaining 14 tagged burbot were detected in Kootenay Lake; eight of these fish stayed in the lake for the duration of the study, and six fish moved regularly between the lake and the river (Figures 2, 3). Of the eight burbot that remained in the lake for the study duration, four moved north to the Lardeau Delta and four stayed near the Creston Delta (Figures 2, 3), although some short-duration movements into other areas of Kootenay Lake occurred infrequently. Other general areas of higher use in the Kootenay River included the 10-km reach directly above the Goat River confluence (RKM 155–165) and several river reaches near Bonners Ferry (RKM 200–210 and 244–254).

We examined detections during the typical spawning period for Kootenay River burbot (late January and February) to identify potential contributions to wild spawning by hatchery-released fish, and we found three locations where tags were concentrated. After initial dispersal, four tagged burbot were again detected in the Goat River—a known spawning location (Paragamian et al. 2000)—between January 3 and February 13, 2010. Three of these fish were detected between February 7 and 13, 2010; this period coincides with data from a weir operated in 2002 (BC Ministry of Environment, Nelson, unpublished data), which identified the first prespawn upstream migrant on February 8 and detected the first postspawn downstream migrant on February 12. An additional four tags were detected together in the same general location at the Duncan Delta (another known spawning location; Figure 1) from February 18 to 28, 2010. The other currently active spawning site in the Kootenay River is at Ambush Rock (RKM 244.5; Paragamian 2000; Paragamian and Wakkinen 2008), where four tagged burbot were present between February 20 and March 4, 2010. This activity of ultrasonic-tagged burbot coincides with the capture of three sexually mature wild adult burbot in the middle of February (Idaho Department of Fish and Game, Coeur d'Alene, unpublished data).

DISCUSSION

This study provides the first record of the release and tracking of age-2 and age-3 burbot in North America. In a companion program, 145 age-0 burbot were released into the Kootenai River drainage of Idaho and BC in fall 2009 (Paragamian

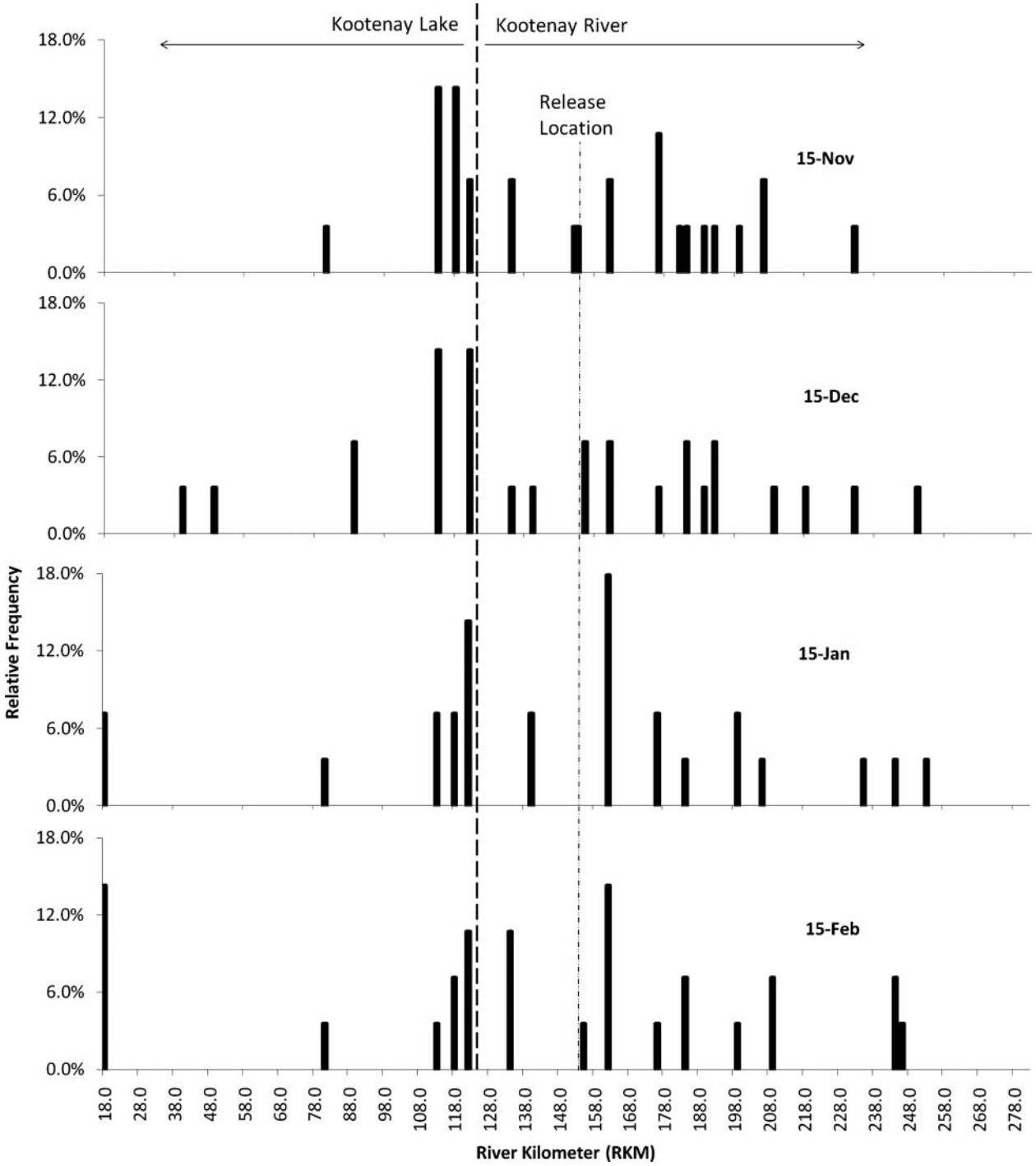

FIGURE 3. Relative frequency distribution of active tags at large for tagged burbot ($n = 28$) in the Kootenay River study area (river kilometers [RKM] from the northernmost reach of Kootenay Lake) on the 15th of each month after release (October 2009).

and Laude, in press), while an undisclosed number of age-0 burbot were released from the Garrison Dam National Fish Hatchery into Lake Oahe, South Dakota (Rob Holm, Garrison Dam National Fish Hatchery, Riverdale, North Dakota, personal communication).

Because our tracking efforts employed a passive array of receivers, mean travel rates could not be reliably obtained in this study and may have been biased low due to movements occurring between receivers. For example, if a burbot was detected as swimming upstream at a receiver, moved an additional distance

upstream but not far enough to be detected at the next upstream receiver, and then moved back to the downstream receiver, no travel distance would be recorded for the time period. Therefore, if we calculated minimum and mean travel rates, the minimum would be 0 and the mean would be biased low. However, we were able to examine maximum directed movement between receivers in this study (up to 14.6 km/d), although these estimates were also probably biased low for the reasons noted above.

We found evidence for the rapid dispersal of hatchery-reared burbot from one release location to most of the known and currently used habitat in the lower Kootenay River drainage below Kootenai Falls, Montana. Initial dispersal from the Goat River, although rapid, was still probably an overestimate because the receiver near the mouth of the Goat River had a detection radius that also included part of the Kootenay River. Therefore, we were unable to positively establish that a burbot left the Goat River until its detection on a receiver in the Kootenay River (5 km upstream or downstream of the Goat River confluence). Once the hatchery-released burbot left the Goat River, further dispersal was rapid. Although the mobility of wild adult burbot has been well documented (Breeser et al. 1988; Schram 2000), this dispersal ability of hatchery progeny had not been previously examined. In our study, total movement distances were greater than the movement of wild burbot monitored during previous studies in the Kootenay River drainage (Paragamian 2000; Dunigan and Sinclair 2008; Paragamian and Wakkinen 2008) but were similar to the results of studies documenting riverine migrations of burbot in other systems (Breeser et al. 1988). Directed movement in this study was rapid in comparison with the findings of Paragamian et al. (2005), who reported average travel rates of 3.36 km/d for wild adult burbot. However, movement distances of up to 125 km have been documented in Alaskan rivers, where one-way directed movements as high as 7.8 km/d were recorded (Breeser et al. 1988). Our ability to identify the cause of the disparity between the current study and other work on burbot movements was limited by the short study period and small sample size.

The rapid directed dispersal observed in our study suggests that a minimal number of stocking locations may be sufficient to allow hatchery-reared burbot to access all available habitats within a few months postrelease. Further investigation will be needed to identify whether the burbot dispersal ability and trends observed in this study are maintained in younger release groups. As imprinting has been observed to be an important aspect for some burbot stocks (Hudd and Lehtonen 1987; Paragamian and Wakkinen 2008), continued tagging and monitoring studies utilizing the methods developed here may be useful in determining the effects of age and stocking location on imprinting behavior. Such information will be important for possible future efforts to establish burbot in the Kootenay River drainage and elsewhere.

Although we were not able to definitively document spawning by hatchery progeny, the temporal and spatial data from some tags indicated that hatchery fish were able to locate spawning sites. Data collected from hatchery progeny that were held and observed in captivity indicate that males and females can mature at sizes as small as 47 cm and 500 g (University of Idaho, unpublished data). Given the proximity of hatchery fish to wild spawning locations in this study and given the data for size at first maturity, we believe that some hatchery progeny may have contributed to spawning in the wild during their first year at large (age 2 or 3).

One critical aspect of this conservation aquaculture program that was necessary to address in the short term and that will be pivotal to long-term success is the ability of hatchery progeny from lake-origin burbot to adapt to and use riverine environments. Although some progeny used Kootenay Lake for part or all of the study period, almost half of the released individuals used the river for the entire study period. Some of these individuals moved into higher-gradient habitats located upstream of the habitat range typically used by wild Kootenay River burbot (Paragamian and Wakkinen 2008). In our short-term study, we found no evidence to indicate that burbot produced from lake-origin broodstock would be unable to disperse or survive in riverine conditions. This suggests that the use of lake-origin broodstock and progeny could be effective in efforts to rehabilitate riverine burbot populations for the purpose of conserving this species. However, longer-term studies are necessary to fully understand adaptation of lake-origin burbot to the riverine environment.

This study lays the foundation for further investigations into identifying trends in burbot dispersal, habitat use, and imprinting behavior. At a broader scale, this study provides proven methods for a telemetry system to track dispersal and survival of hatchery-reared burbot, and these methods can be used by managers involved in burbot fisheries and other conservation aquaculture-related rehabilitation efforts. In addition, our results suggest a plasticity of behavioral responses after release based on broodstock origin (lake versus river) and that managers should not exclude conservation aquaculture brood sources of burbot based on this characteristic alone.

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