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Assessing Pacific Lamprey Status in the Columbia River Basin

Abstract

In the Columbia River drainage, salmonid-based monitoring programs have historically been used to assess status of both adult and juvenile Pacific lamprey. We compared adult lamprey counts at hydropower dams to recent radiotelemetry results and found that the counts underestimated losses between some dams and overestimated passage times through reservoirs. Count data were not correlated with trap captures of adults conducted in the same area and at the same time, likely due to lamprey-specific behaviors that result in inaccurate counts. We recommend maintenance of traditional count protocols, but emphasize the need for continued research to develop an accurate correction factor to apply to these data. Existing salmonid-based sampling for juvenile lamprey is inadequate and we highlight the need for standardized larval lamprey monitoring that provides both abundance and size distributions. Our electrofishing survey for juvenile lamprey indicated that this technique provides critical information on lamprey recruitment and is feasible over large spatial scales.

Introduction

Protecting native anadromous lamprey populations historically has not been a management priority in the United States (Close et al. 2002a). Even though native lampreys are an important element in river ecosystems (Vladykov 1973), the widely-publicized predation of non-indigenous sea lamprey (*Petromyzon marinus*) on game fishes in the Great Lakes has led to the general perception that all lampreys represent a threat to managed fisheries. However, native lampreys are susceptible to many of the same threats facing recently-listed anadromous species: reduced access to spawning habitat, degradation of spawning and rearing areas, and losses of emigrating juveniles to turbine entrainment, and non-indigenous predators (Renaud 1997). Their protracted residence in freshwater also makes lampreys highly susceptible to pollution. Consequently, the notion that lampreys are invulnerable to extirpation has proved false in some systems (Wallace and Ball 1978, Beamish and Northcote 1989).

Pacific lamprey (*Lampetra tridentata*) occur along the west coast of North America from California to Alaska (Scott and Crossman 1973) and there is concern for their status. Indigenous peoples from the Pacific coast to the interior Columbia River have harvested adult lamprey for subsistence, religious, and medicinal purposes for many generations (Close et al. 2002a). In the Columbia River drainage, adult Pacific lamprey support fisheries that have recently experienced dramatic declines and unprecedented regulation (Kostow 2002). Moreover, concerns about the status of Pacific lamprey resulted in a recent petition to list this species for protection under the Endangered Species Act.

The only historical measure of adult lamprey abundance in the Columbia River is based on visual counts made as lamprey pass through the fishways at hydropower dams (Figure 1) during prespawning migrations (Starke and Dalen 1995). As lamprey move upstream through the fishways, they are crowded into a narrow, lighted channel that is viewed from the side via a glass window. Lamprey counting protocols have been inconsistent. For example, at Bonneville Dam (Figure 1), lamprey were counted in 1938-1969, 1993, for a portion of the migration season in 1997, and for the entire season (15 March- 15 November) since 1998. Lamprey were counted at The Dalles Dam from 1957-1969 and since 1996, and at John Day Dam in 1968-69 and since 1996.

The counting protocols were designed to assess adult salmonid abundance and do not necessarily conform to lamprey migration behavior.

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Figure 1. Study area in the Columbia River drainage. Major hydropower dams are denoted with squares.

Typically, counting is conducted during two consecutive 8-hr shifts from 0500 to 2100 Pacific Daylight Time; however, adult Pacific lamprey are primarily nocturnal (Moser et al. 2002). The erratic swimming behavior of adult lamprey at count windows also make them inherently difficult to count (Starke and Dalen 1995) and can result in multiple counts of each individual (Haro and Kynard 1997, Matter et al. 2000). Seasonal migration patterns can also create profound discrepancies in actual and estimated losses at each reservoir. Beamish (1980) reported that Pacific lamprey overwinter in freshwater and this appears to be the case in the Columbia River, where Pacific lamprey are regularly noted during winter de-watering operations at the hydropower dams (Starke and Dalen 1995). Consequently, lamprey counted in one year may actually have entered the system in the previous year.

Similarly, salmonid-based sampling is an inadequate measure of juvenile lamprey abundance. Juvenile lamprey are collected in traps that target salmonid smolts, but lamprey migrate seaward over a longer time period. Consequently, trap operation schedules would need to be expanded to adequately sample the entire lamprey emigration period (Kostow 2002). In addition, the traps are designed to fish the upper portion of the water column and may not be efficient enough to provide accurate estimates of lamprey abundance. Similarly, the use of fyke and scoop nets to sample salmonids at the turbines and turbine bypasses of hydropower dams could provide useful seasonal or diel trends in relative abundance, but are probably not efficient enough to yield reliable abundance estimates (Long 1968).

The life cycle of the Pacific lamprey is complicated, spanning many different habitats over a broad geographic area. Anadromous adults enter freshwater rivers and can migrate hundreds of kilometers to reach spawning sites in tributary streams. Spawning generally occurs in shallow, gravel-bottom riffles. Newly hatched ammocoetes (larvae) drift into areas with fine silt or sand and burrow into the sediment where they filter-feed for 4-6 yr (Close et al. 2002a). Consequently, declines in lamprey may be the result of adult losses at sea, inaccurate counts of migrating adults in rivers, or recruitment failure due to loss of spawning or rearing habitats in streams. Thus, methodologies designed to accurately sample all lamprey life stages are needed to assess the status of this species.

The objectives of this study were to: 1) evaluate the accuracy of adult lamprey counts, and 2) assess the feasibility of conducting large-scale electrofishing surveys of ammocoete distribution, relative abundance, and size structure. A radiotelemetry study has been ongoing at the lower Columbia River hydropower dams to assess obstacles to fish passage (Moser et al. 2002). We used radiotelemetry data and trapping in the fishways to make comparisons with lamprey count data. In addition, we sampled for ammocoetes in nine Columbia River tributaries to assess the efficacy of this method relative to salmonid-based assessment of juvenile abundance.

Study Area

The Columbia River drains over 670,000 km^2 and is highly regulated. Starting in the 1930s, with the construction of Bonneville and Rock Island Dams, the main stems of the Columbia and Snake Rivers were nearly completely impounded over the next four decades (Figure 1). Nine dams on the mainstem Columbia River and four dams on the mainstem of the Snake River are equipped with fishways to pass upstream migrants. Pacific lamprey and other anadromous fishes are confined to parts of the drainage below dams without provisions for fish passage: the Columbia River below Chief Joseph Dam and the Snake River below Hells Canyon Dam (Figure 1). We conducted adult lamprey radiotelemetry, and trapping at three lower Columbia River dams: Bonneville, The Dalles, and John Day. We also sampled for larval Pacific lamprey (ammocoetes) in nine Columbia River tributaries: John Day, Middle Fork John Day, North Fork John Day, South Fork John Day , Umatilla, Walla Walla, South Fork Walla Walla, Tucannon, and Grande Ronde (Figure 1). These sub-basins varied widely in size and discharge levels (Table 1), and are areas where lamprey historically occurred.

Methods

Trapping and Radiotelemetry

In 1998–2000, we set a trap for lamprey inside a fishway at Bonneville Dam. During nights from May to September we deployed the trap against a wall of the fishway and positioned it at the top of a weir. Lamprey moving over the weir entered the trap and were held in a live box until the trap was fished the following morning. All lamprey were counted, and catch per unit effort (CPUE) was determined by dividing the number of lamprey caught by the number of hours the trap was fished. Yearly CPUE was compared to traditional lamprey counts (visual observations at the counting window) obtained during the same time periods in the same fishway. For 2000, we also compared mean weekly CPUE to mean weekly counts for the same fishway using Spearman's rank correlation procedure (Zar 1999).

In each year we surgically implanted uniquely-coded radio transmitters in large adult lamprey that were collected in the trap. These fish were anaesthetized using either 70 ppm tricaine methane sulfonate (MS222) or 60 ppm clove oil, mea-

TABLE 1. Characteristics of the river basins where juvenile lamprey sampling was conducted in northeastern Oregon and southeastern Washington.

River Basin	Distance from Pacific Ocean (km)	Area Sampled (rkm)	Elevation (m)	Drainage Area (km^2)	Annual Discharge (m^3/s)	Precipitation (cm/yr)
John Day	350	64-446	61-2,743	20,979	59.0	<30-127
Umatilla	465	0-124	79-1,768	5,931	13.0	22-140
Walla Walla	505	8-72	81-1,800	4,553	16.1	25-100
Tucannon	623	1-57	165-1,951	1,303	4.7	25-102
Grande Ronde	793	48-330	305-2,438	10,360	86.8	25-152

sured (length and girth to the nearest mm) and weighed (nearest g). A radio transmitter representing less than 2% of the lamprey's body weight was then surgically implanted into the body cavity of each fish following the methods of Moser et al. (2002). In all years we used transmitters that were 7.7 g (3.7 g in water), but in 2000 we also used a smaller (4.5 g in air, 2.9 g in water) transmitter. The fish were allowed to recover for 2 hr prior to release below Bonneville Dam.

Movements of radio-tagged lamprey were monitored by an extensive network of fixed-site receivers located on each dam, at the dam tailraces, and at the mouths of major tributaries. Data from fixed-site receivers (fish code, time and date of passage) were downloaded every 1-2 wk and processed following protocols detailed in Moser et al. (2002). In addition, we conducted regular surveys to locate radio-tagged fish using a portable receiver. For each dam, we determined the number of lamprey that exited at the top of the fishway. In 2000, we added additional receivers to document the number of lamprey that passed each counting window at Bonneville Dam and the time of day that lamprey passed by these windows.

The proportion of radio-tagged lamprey lost in each reservoir was computed by subtracting the number of lamprey that passed each successive upriver dam from the number that had passed the previous dam and dividing by the number that passed the previous dam. We computed losses based on visual counts in the same way (U.S. Army Corps of Engineers 1998, 1999, 2000). For each year, we divided the loss obtained from radiotelemetry by the loss obtained from visual counts for two reaches: between Bonneville Dam and The Dalles Dam, and between The Dalles Dam and John Day Dam. We then computed the geometric mean of these annual ratios for each reach. At Bonneville Dam in 2000, we were also able to determine the exact time that lamprey passed the count window. Based on these data, we determined the proportion of lamprey that would have been missed if counts were only conducted during the day (i.e., the number that passed the window at night divided by the total number that passed the window).

Ammocoete Sampling

In 1999, we sampled for ammocoetes in July-September. We selected sampling sites near the mouth of each river and continued upstream to the headwaters at intervals of 10-16 km, except in the Umatilla River where we sampled every 4 km. The Umatilla River was sampled more intensively because this area was proposed for a lamprey restoration project. Sites were selected based on substrate characteristics, as ammocoetes typically inhabit silty areas (Potter et al. 1986, Young et al. 1990). A 7.5-m^2 area was sampled at each site by making two 11.5-min passes with a backpack electrofishing unit. This unit delivered three pulses (125 volts) per second with a 25% duty cycle, and a 3:1 burst pulse train (three pulses on, one pulse off), causing ammocoetes to emerge from the substrate (Weisser and Klar 1990). Thereafter, 30 pulses per second were applied to stun ammocoetes so that they could be dipnetted (Hintz 1993, Weisser 1994). Ammocoetes were then anaesthetized (50 ppm MS222) and measured (nearest mm total length). After ammocoetes recovered, they were returned to the river. Population estimates were determined for each site using methods described in Zippen (1958) and the Capture software program (White et al. 1982). Population estimates were converted into densities (number m^{-2}) for each site. Length frequency data were pooled for each river and graphed to assess recent recruitment.

Results

Trapping and Radiotelemetry

In the fishway where our trap was deployed at Bonneville Dam, lamprey passage based on count data was 9.4 lamprey hr^{-1} in 1998, 12.7 lamprey hr^{-1} in 1999, and 4.5 lamprey hr^{-1} in 2000. Trap CPUE (lamprey hr^{-1}) in those years was 1.0 in 1998, 0.7 in 1999, and 0.3 in 2000. We found no significant correlation between the mean weekly lamprey abundance obtained using the two methods (counts and trap) in 2000.

In 1998, 1999, and 2000, we released 205, 199, and 299 radio-tagged lamprey below Bonneville Dam. In all years the tagged lamprey were greater than 420 g and ranged in length from 60 to 80 cm. Approximately 90% of the fish released below Bonneville Dam in each year resumed upstream migration and approached the dam (Moser et al. 2002). We recaptured two radio-tagged lamprey in our trap in 1999 and four more in 2000. In addition, four radio-tagged lamprey were taken in tribal fisheries. All recaptured individuals were in excellent condition.

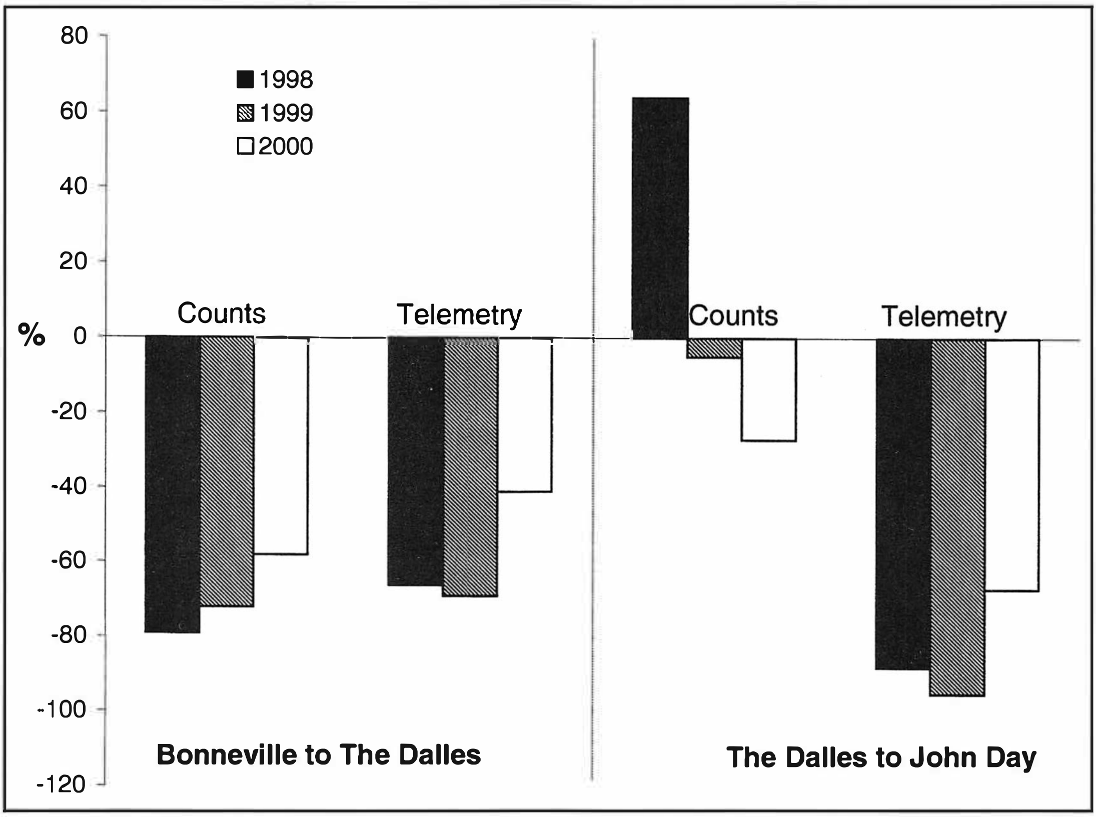

Figure 2. The percentage of adult lamprey lost in each reach (between Bonneville and The Dalles Dams and between The Dalles and John Day Dams) as determined by lamprey counts and radiotelemetry data in 1998-2000.

Radiotelemetry data indicated that lamprey migrated rapidly through the reservoirs and were most active at night. In 1998, mean time to transit the Bonneville Reservoir was 3.5 days and time to transit The Dalles Reservoir was 2.8 days. In contrast, peaks in the counts at Bonneville, The Dalles, and John Day dams indicated that lamprey took 23 days to traverse the Bonneville Reservoir and 35 days to pass through The Dalles Reservoir in 1998 (U.S. Army Corps of Engineers 1998). In 2000, 67% of the lamprey that passed the counting windows at Bonneville Dam would not have been detected because they moved through between 2200 and 0600. In addition, 6% of the radio-tagged lamprey that passed over the dam used routes without count stations (navigation lock and auxiliary water supply channel).

The annual losses we obtained for the area from Bonneville Dam to The Dalles Dam were similar for radiotelemetry vs. count data (geometric mean ratio = 0.83). For this reach the counts yielded slightly higher losses than the telemetry results in all years (Figure 2). However, for the area between The Dalles Dam and John Day Dam, the two methods produced different results. The geometric mean ratio for this reach was 17.98, indicating that the count data underestimated losses relative to radiotelemetry data by a factor of 18, on average. The losses in the reach from The Dalles Dam to John Day Dam based on telemetry were similar to, but consistently higher than, losses based on telemetry for the Bonneville-The Dalles reach (Figure 2).

Ammocoete Sampling

Ammocoetes were not found in the upper reaches of most tributaries we sampled, nor were they found in any of the Walla Walla River sites (Figure 3). Ammocoete density varied among sites sampled (Table 2). Density was highest in the John Day River and its major tributaries, with over 80 ammocoetes m^{-2} collected at one site in the Middle

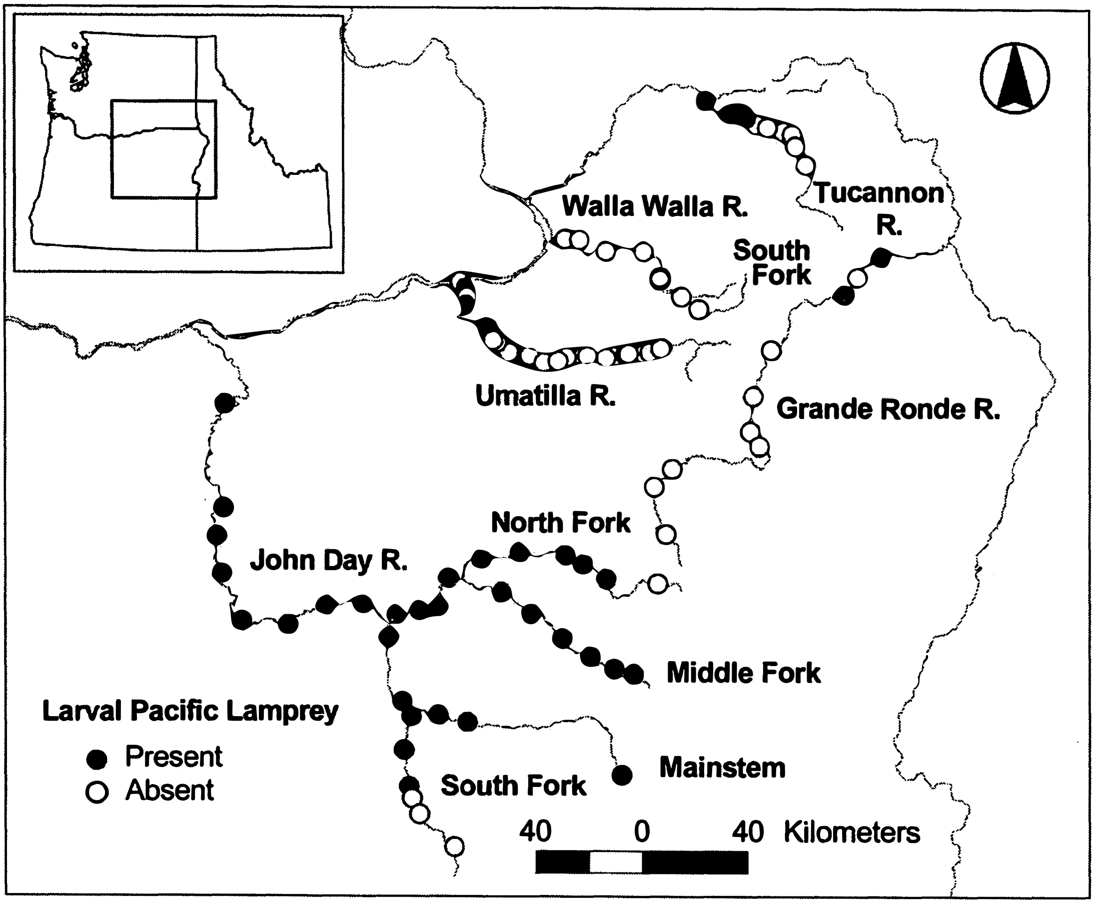

Figure 3. Sampling sites and presence/absence of Pacific lamprey ammocoetes in the mainstem John Day, Middle Fork John Day, North Fork John Day, South Fork John Day, Umatilla, Walla Walla, South Fork Walla Walla, Tucannon, and Grande Ronde Rivers.

Fork. Densities were lowest in the Grande Ronde River, with no more than 2.1 ammocoetes m^{-2} collected at these sites (Table 2). Mean lengths were lowest in the John Day River drainage (except the South Fork), intermediate in the Tucannon, and highest in the Grande Ronde and Umatilla Rivers (Table 2). Examination of length frequency histograms for each sub-basin indicated that sites in the John Day River had larger proportions of lamprey < 60 mm, while the Umatilla, Tucannon, and Grand Ronde collections were dominated by larger year classes (Figure 4).

Discussion

Our data indicated that lamprey counts at hydropower dams are unreliable and can be misleading. Comparisons between counts at consecutive dams and telemetry results indicated that the counts can produce alarmingly low estimates of losses between dams and can greatly exaggerate the time lamprey required to pass through each reservoir. We found no correlation between trap CPUE and the counts made during the same time periods and in the same fishway at Bonneville Dam. This is not surprising, since more than half of the radio-tagged lamprey passed the counting window during the night, when historically no counts have been taken. We also confirmed that lamprey were able to pass via routes that bypass the counting stations as suggested originally by Starke and Dalen (1995).

Laboratory studies indicate that adult lamprey recover rapidly after transmitter implantation, regaining full swimming capability within 24 hr

TABLE 2. Mean Pacific lamprey ammocoete densities and total lengths in each river and mean river temperatures when lamprey were collected. Range in ( ).

River	Number of sites	Lamprey density (number m-2)	Lamprey length (mm)	Water temperature (°C)
Mainstem John Day	13	12.0 (3.8-36.6)	56.2 (20-138)	17.5 (13-20)
North Fork John Day	9	26.7 (0-43.3)	69.6 (12-165)	21.8 (17-26)
Middle Fork John Day	8	32.0 (0-87.1)	63.1 (18-145)	19.6 (15-24)
South Fork John Day	6	14.2 (0-42.4)	90.5 (13-166)	16.0 (12-22)
Umatilla	32	0.6 (0-5.2)	112.1 (29-170)	21.0 (17-26)
Mainstem Walla Walla	5	0	0	23.8 (19-27)
South Fork Walla Walla	2	0	0	13.5 (10-17)
Tucannon	11	5.3 (0-29.8)	77.8 (24-131)	13.7 (9-17)
Grande Ronde	11	0.2 (0-2.1)	98.3 (75-149)	15.3 (4-23)

of handling (Close et al. 2003). Consequently, we believe that our radiotelemetry results accurately reflect lamprey travel rates and passage efficiency at dams, and that they reveal problems inherent to traditional adult lamprey assessment. While dam counts are clearly problematic, they have been taken in a fairly consistent manner and represent the only historical measure of relative abundance. Continued radiotelemetry or passive integrated transponder (PIT) technology should be used to develop an accurate correction factor to be applied to the count data.

In 2000, a surprisingly large number of radio-tagged lamprey were recaptured in our trap and in tribal fisheries, despite relatively low fishing effort. This suggests that a mark and recapture program in tributaries may be a feasible alternative for obtaining absolute abundance estimates of adult lamprey. Tagging studies have historically been used to assess homing (Tuunainen et al. 1980, Bergstedt and Seelye 1995); however, recent tag/recapture studies have produced reliable estimates of adult sea lamprey abundance in tributaries of the Great Lakes (Kasia Mullett, U. S. Fish and Wildlife Service, Marquette, Michigan, personal communication). Tag/recapture studies and counts of Pacific lamprey nests (redds) are being conducted in Cedar Creek, a small tributary of the Columbia River (Stone et al. 2001). While redd counts can provide valuable information on spatial and temporal patterns of lamprey spawning, it is unclear that they can document adult abundance because lamprey may dig more than one redd. Redd sampling in the Umatilla River also indicated that many lamprey redds did not contain viable eggs.

Juvenile lamprey abundance was highly variable (0 – 87 ammocoetes m^{-2}) within and among the rivers we sampled, in spite of our efforts to target primary ammocoete habitat. This result highlights the need to couple habitat delineation with ammocoete sampling to allow adequate stratified sampling at appropriate scales (Pajos and Weise 1994). The aim of our sampling was to provide data on lamprey occurrence over a broad spatial scale. To obtain reliable estimates of relative abundance, higher resolution sampling and detailed habitat mapping are needed (Christian Torgerson, Oregon State University, Corvallis Oregon, personal communication). In addition, standardized electrofishing methodology is critical to ensure that capture efficiency is comparable among sampling programs (Pajos and Weise 1994).

Although tedious and labor-intensive, measuring juvenile lamprey provides important information on individual cohorts. The absence of ammocoetes in the upper reaches of most rivers we sampled indicated that there has been complete recruitment failure in these areas in recent years. We speculate that this is largely due to the presence of large hydropower dams and low-head diversion dams that restrict access of adults to spawning areas that are farthest upstream. The truncated size distributions of ammocoetes collected in the Umatilla and Grande Ronde Rivers further suggest that there has not been recent spawning success in these areas. Unfortunately, reliable ageing techniques have not been developed for lamprey (Barker et al. 1997). Until reliable ageing methods are worked out, we recommend that size data be collected during juvenile lamprey sampling programs.

Current assessment methods for Pacific lamprey in the Columbia River drainage are inadequate. Our data also indicated that lamprey have experienced

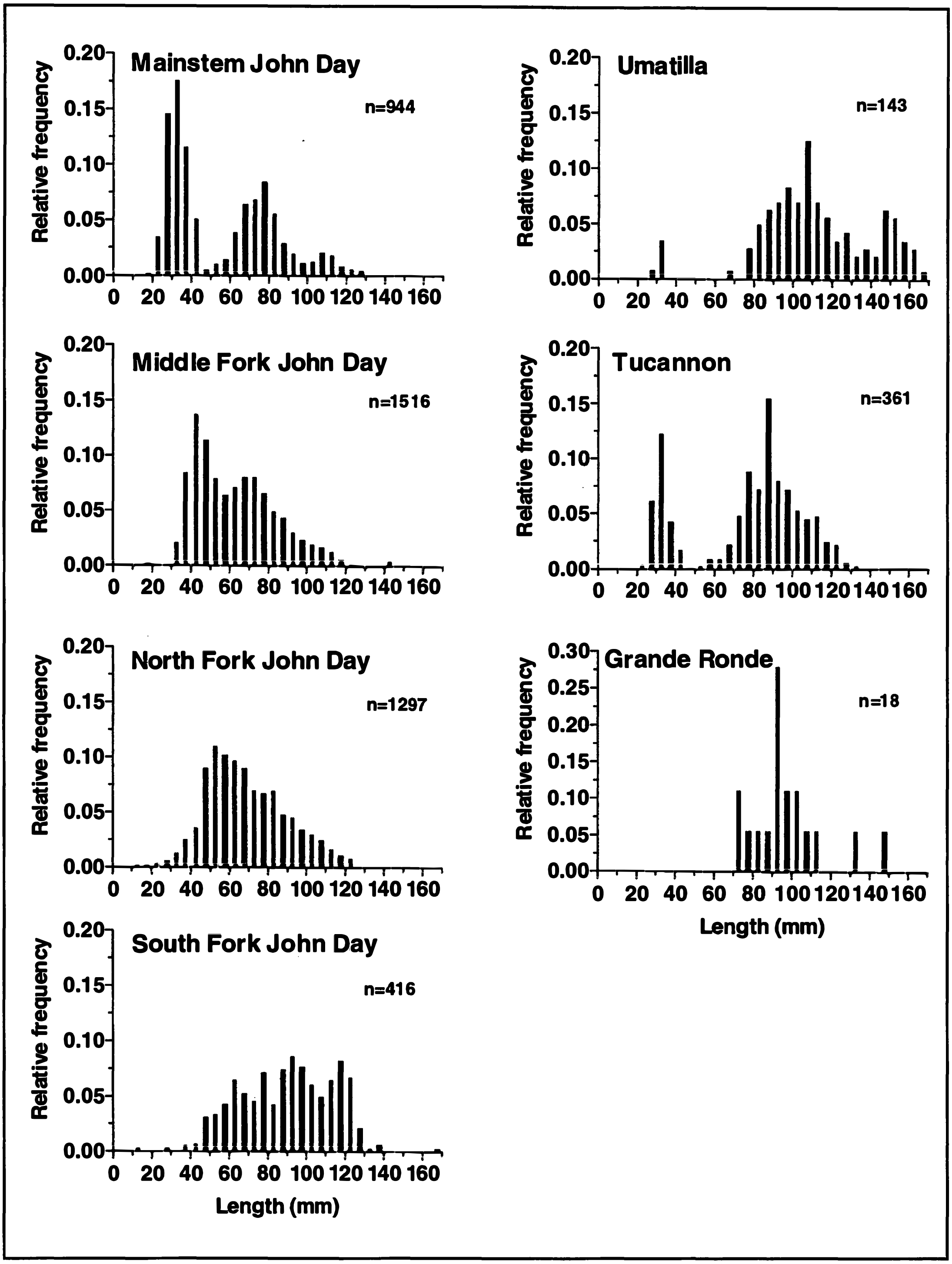

Figure 4. Distribution of larval lamprey lengths (mm) observed in the Mainstem John Day, Middle Fork John Day, North Fork John Day, South Fork John Day, Umatilla, Tucannon, and Grande Ronde Rivers.

poor recruitment in the uppermost reaches of rivers where this fish has historically been captured. These data highlight the need for comprehensive status assessment of Pacific lamprey. We recommend the use of standardized larval sampling, maintenance of historical measures of adult lamprey passage, and the use of other technologies to obtain more reliable estimates of adult abundance. Most importantly, we underscore the need to heighten awareness of threats to native lampreys and to promote collection of lamprey data in existing surveys. Conservation of lampreys can only proceed by changing the established perceptions that these fishes are invulnerable to extirpation and represent a threat to more desirable species.

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