2019 Progress Report: Miller Lake Lamprey

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EXECUTIVE SUMMARY

Miller Lake is home to the Miller Lake Lamprey *Entosphenus minimus*, a native species that occurs only in the Klamath Basin. The smallest predatory species of lamprey in the world, Miller Lake Lamprey average 3 – 6 inches in body length. In the 1950s, Miller Lake Lamprey parasitized introduced trouts (*Salmo* and *Oncorhynchus* species) and Tui Chub *Siphateles bicolor* in Miller Lake. The Oregon Game Commission was concerned that Miller Lake Lamprey compromised trout fisheries in the lake, and in 1958 successfully applied the chemical toxaphene to the lake and tributaries to eradicate this species. In 1959, the Commission constructed a barrier in Miller Creek approximately one half mile downstream of the lake outflow to prevent lamprey from moving back into the lake. Miller Lake Lamprey was believed to have been eradicated entirely until it was rediscovered in the Miller Creek, upper Williamson, and Sycan river drainages in the 1990s. From this point forward the Oregon Department of Fish and Wildlife focused on conservation of the Miller Lake Lamprey. In 2005, the Miller Lake Lamprey Conservation Plan was adopted (OAR 635-500-3885), and the Miller Lake Lamprey Technical Management Team (TMT) removed the barrier in Miller Creek. Since 2010, the primary goal of the TMT has been reintroducing Miller Lake Lamprey back into Miller Lake and its tributaries. Although it is unclear whether Miller Lake Lamprey has recolonized the lake, the species has persisted in tributaries into which it was reintroduced. Additional research and monitoring methods will contribute to future status assessments and conservation efforts for Miller Lake Lamprey. This species is currently on the State of Oregon's Sensitive Species List and it is also an Oregon Conservation Strategy "Strategy Species".

INTRODUCTION

This progress report presents the most up-to-date information on Miller Lake Lamprey *Entosphenus minimus*, including management context, survey data, and conclusions[1]. Miller Lake (Figure 1) is home to the Miller Lake Lamprey (Figure 2), a native species that occurs only in the Klamath Basin and was first discovered in Miller Lake (Bond and Kan 1973). Miller Lake is also known for its trophy Brown Trout *Salmo trutta* fishery, in addition to Rainbow Trout *Oncorhynchus mykiss* and kokanee *O. nerka* fisheries[2]. The resident Miller Lake Lamprey is the smallest predatory species of lamprey in the world, averaging 3 to 6 inches in total body length (Bond and Kan 1973; Lorion et al. 2000). In the 1950s, Miller Lake Lamprey parasitized introduced trouts and Tui Chub *Siphateles bicolor* in Miller Lake. The Oregon Game Commission (Commission) was concerned that Miller Lake Lamprey compromised trout fisheries in the lake, and in 1958 applied the chemical toxaphene to the lake and tributaries flowing into Miller Lake to eradicate them. The toxaphene application successfully eradicated Miller Lake Lamprey in Miller Lake and tributaries flowing into the lake. In 1959, the Commission constructed a barrier in Miller Creek approximately one half mile downstream of the lake outflow to prevent lamprey from moving back into the lake.

Figure 1. Miller Lake is a deep, coldwater lake in the Cascade Range north of Crater Lake (Klamath County, west of Chemult).

The Miller Lake Lamprey was believed to be extinct from 1959 until their rediscovery in the 1990s and re-description to science shortly thereafter (Figure 3). At this time the Oregon Department of Fish and Wildlife (ODFW) focused on conservation. The Miller Lake Lamprey is now on the State of Oregon's Sensitive Species List. The ODFW, recognizing that Miller Lake Lamprey is native to Oregon and do not exist outside of Miller Creek and the upper Williamson and Sycan river drainages, created the Miller

[1] *This report includes minor edits to tables from previous reports (Clemens et al. 2017, 2018). In addition, this report refers to lamprey with eyes as "transformed" to indicate that they could be either juveniles or adults (earlier reports called these fish "adults"). "Juveniles" are eyed individuals observed to be actively feeding (attached to a host), and "adults" are eyed individuals observed in the process of constructing nests, spawning, or post-spawn. "Larvae" are individuals that do not have eyes and have not yet transformed (Clemens 2019).*

[2] *Brook Trout* Salvelinus fontinalis *reside in tributaries to Miller Lake.*

Lake Lamprey Conservation Plan (OAR 635-500-3885; ODFW 2005). This plan formed the basis of ongoing management for Miller Lake Lamprey, and this report fulfills requirements to periodically report the status of Miller Lake Lamprey and the effectiveness of management actions to the public.

Figure 2. Transformed Miller Lake Lamprey *Entosphenus minimus.*

MANAGEMENT

The Miller Lake Lamprey Conservation Plan called for the reconnection of habitats in Miller Lake and Miller Creek through the removal of the human-made barrier in Miller Creek that was installed by the Commission. Other long term conservation strategies in the conservation plan include management of other species — not stocking hatchery trout into streams that Miller Lake Lamprey inhabit to prevent predation on them, and maintaining or providing more opportunities for habitat access and sufficient water quantity. The plan further identified re-establishment of Miller Lake Lamprey into Miller Lake and upper Miller Creek, above the original barrier and large cascade[3]. The conservation plan for Miller Lake Lamprey also called for scientific studies to fill information gaps, and periodic surveys to assess and evaluate population status. The plan identified a desired status for the Miller Lake Lamprey *"…to be distributed widely throughout its historic range, with populations robust enough to withstand stochastic environmental events, and with both the populations and their habitat secure from anthropogenic threats."* Figure 3 provides a high-level summary of years when particular management and survey actions were conducted and when scientific information was published. Table 1 reports survey data and Table 2 reports information on translocations of lamprey into Miller Lake, Evening Creek, and upper Miller Creek that were undertaken to re-establish lamprey into Miller Lake.

The plan identified the formation of a technical team (the Miller Lake Lamprey Technical Management Team; TMT) to monitor Miller Lake Lamprey and manage attempts to reintroduce them back into the lake. This team currently includes the authors of this report. The TMT removed the barrier between Miller Lake and Miller Creek in 2005.

[3] *A substantial cascade exists at the former barrier site in Miller Creek, and it is unclear whether Miller Lake Lamprey can ascend this cascade of their own volition to access upper Miller Creek.*

SURVEY METHODS

Following removal of the barrier in Miller Creek (Figure 3), various locations of the Miller Lake Basin were surveyed for the presence/absence of Miller Lake Lamprey. Survey results informed subsequent decisions by biologists in the TMT for translocation numbers and destinations. The TMT monitored the volitional upstream movement of lamprey once the barrier was removed. This was done via surveys to detect lamprey upstream of the barrier. In 2010, given no evidence of colonization upstream of the barrier, the TMT team decided to actively translocate lamprey above the barrier and into tributaries and Miller Lake (Figure 3).

Backpack electroshockers (AbP-2, Engineering Technical Services, Madison, Wisconsin) were used to survey for lamprey in wadeable areas, following a single-pass, rapid assessment protocol similar to Reid and Goodman (2015), with shocker settings per Schultz et al. (2014). Voltage was adjusted 200 and 300 V as necessary. Small larvae (≤ 50 mm) were considered young-of-year larvae, and hence evidence of recent successful reproduction. Life stages, including "transformed" lamprey are defined above[1].

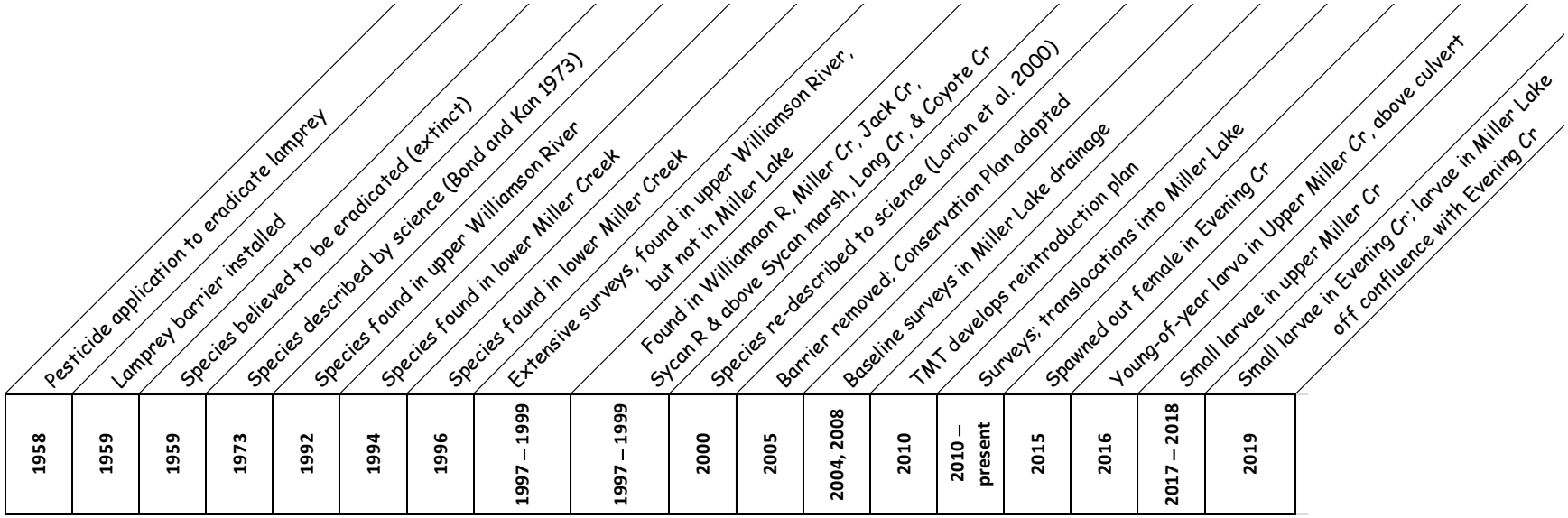

Figure 3. Timeline of management actions and scientific results for Miller Lake Lamprey. The species was recognized by science in 1973. Baseline surveys in 2004 and 2008 found no lamprey in Miller Lake, its inflow tributaries, or the uppermost portion of the outflow tributary, Miller Creek, in the vicinity of the former barrier site, approximately a half mile downstream of the outlet of Miller Lake. For more information, refer to Table 1. "TMT" = Miller Lake Lamprey Technical Management Team.

Table 1. Survey results and observations for Miller Lake Lamprey. Locations referenced are shown in Figure 4. ML = Miller Lake; MC = Miller Cr; LMC = lower Miller Cr; UMC = upper Miller Cr; Evening Cr = EC; Tipsoo Cr = TC; Gideon Cr = GC. Counts do not reflect all observations (i.e., many larvae escaped capture).

Year	Survey locations	No. lamprey	Notes
2004	12 locations from ML down into LMC	~266	70 mins of surveys — lamprey in 4 sites of LMC. None in ML or UMC.
2008	4 locations in MC	29	63 mins of surveys — all in 3 sites of lower MC. No lamprey found in UMC.
2010	LMC	700	over 0.4 km; *collected for translocations — see Table 2*
2011	LMC	632	*Collected for translocations — see Table 2*
	EC	7	Likely from 2010 translocation.
2012	LMC	626	*Collected for translocations — see Table 2*
	UMC	1 [b]	Below Miller Lake Rd (National Forest Service Road 9772)
	ML	0 [a]	
	EC	Present	
2013	LMC	600	*Collected for translocations — see Table 2*
	TC	1	Small larvae (29 mm)
2014	Miller Lake	0	Set gill nets to sample condition of stocked trout (no lamprey wounds or scars were found on trout). Anglers reported seeing lamprey, but no one noticed wounds or scars on the fish they caught (and lamprey presence in the lake has not been corroborated by other means).
	EC, UMC	Present [b]	
	TC, GC	0 [a]	
2015	LMC	400	*Collected for translocations — see Table 2*
	TC, GC	0 [a]	
	EC	Present	Also found spawned out female (6 July).
2016	UMC	0 [a, b]	One young-of-year larva (< 20 mm) found above culvert in UMC, larger larvae found below culvert.
	EC	Present	Low abundance, larger size classes of larvae
2017	LMC	610	Apparent high density observed at this location. *Collected for translocations — see Table 2*
	UMC	4 [b]	3 young-of-the year larvae (20-30 mm — indication of successful spawning; above and below culvert), plus 1 larger larvae (~95 mm)
	EC	33	Larvae found at confluence of EC and ML The larvae were very large (90 – 184 mm) and were likely from past translocations.
2018	Miller Lake	0	Set gill nets to sample Brown Trout to collect gametes for Brown Trout program (no lamprey wounds or scars were found on trout). Anglers reported seeing wounds or scars on the fish they caught (but this has not been corroborated by other means).
	LMC	401	High density; largest number of transformed lamprey (~66) observed to date at this location. Observed juvenile predation on Brown Trout and Brook Trout. *Collected for translocations — see Table 2*
	UMC	> 35 [b]	Larvae present just above former dam site (~60 – 95 mm); also below lake outlet above and below road culvert (2 large larvae ~180 mm).
	EC	16	Large larvae (101 – 179 mm). Two larvae were observed in Miller Lake, off mouth of Evening Creek.
2019	LMC	615	Low number of transformed lamprey (6). *Collected for translocations — see Table 2*
	UMC	19 [b]	Low relative larval densities (no transformed lamprey) between the former barrier site and Miller Lake, though present from the barrier upstream. All larvae of large body sizes (120 – 175 mm).
	EC	44	Wide range of body sizes: 32 larvae from Evening Cr (42 – 190 mm), suggest multiple age classes, including from recent reproduction. Also, 14 of the 46 larvae (48 – 90 mm) were found in Miller Lake, > 63 feet off the confluence with Evening Cr.

[a] Finding no lamprey implies that none occurred. However, lamprey may have escaped detection due to very low population density or by existing in locations that were not surveyed. In addition, detection efficiency may have been low.

[b] Number of larvae found in intermittent sampling between the culvert and Miller Lake.

Table 2. Reintroduction efforts (translocations) by the Miller Lake Lamprey TMT to re-establish Miller Lake Lamprey in Miller Lake. All translocated lamprey were taken from lower Miller Creek. Locations referenced can be viewed in Figure 4. Translocated lamprey were primarily larvae, but ranged from young-of-the-year to transformed individuals. See Table 1 for abbreviations.

Year	Dates	Number of lamprey	Lamprey translocated to	Notes
2010	3, 4 Aug	700	ML (300), EC (300), and UMC (100)	Included 2 transformed lamprey
2011	16, 17 Aug	632	ML (200), EC (232), UMC (200)	
2012	25 Sep	626	ML, EC, and UMC	
2013	28, 29 Aug	600	ML, EC, and UMC	
2014	7, 8 Oct	-	No translocation	
2015	6, 7 Jul & 26 Oct	400	EC and UMC by National Forest Service Road 9772 culvert	20 Oct survey (none translocated)
2016	20 Oct	-	No translocation	
2017	30, 31 Aug	610	ML at outlet into UMC	Included 3 transformed lamprey
2018	13, 14 Sep	401	UMC	Including ~66 transformed lamprey
2019	11,12, 13 Sep	615	UMC	Including 2 transformed lamprey

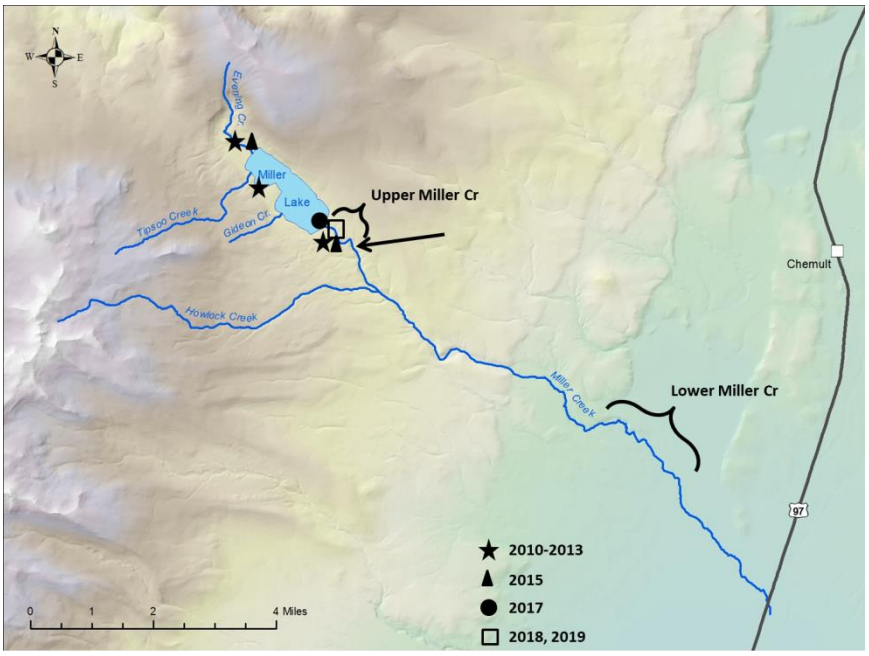

Figure 4. Map of Miller Lake, showing tributaries flowing into the lake from the north and west, and the outflow tributary, Miller Creek. The arrow indicates the site of the former barrier and cascade. Lower Miller Creek has been used as a donor source for translocations of Miller Lake Lamprey (Table 2). Symbols indicate release sites and years.

INTERESTING OBSERVATIONS FOR 2019

- Lamprey translocated into the upper Miller Lake drainage (upper Miller Creek and Evening Creek) during 2010 – 2018 (Table 2) survived. Evidence of successful reproduction (i.e., the presence of small larvae) from these translocations was found in upper Miller Creek during 2016 – 2018, but not in 2019. By contrast, evidence of successful reproduction was found in Evening Creek in 2019 (Table 1; Figure 3).

- The abundance of transformed lamprey in lower Miller Creek appeared to be much lower in 2019 than in 2018 (Table 1). This may be a result of declining numbers, population cycles, or non-random variation from the survey methods; none of these factors can be ruled out.

- The relative abundance of lamprey in upper Miller Creek appeared to be low. Evidence of substrate scouring was observed in this location, which led to the hypothesis that spring freshets in 2019 may have scoured lamprey out of the substrate and flushed them downstream. However, survey intensity varied among years, and the second highest numbers of larvae were counted in upper Miller Creek in 2019.

- Very large larvae were observed in Evening Creek. Based on release years these larvae may be 4 – 9+ years old (Table 2).

- Limited lake sampling revealed larval lamprey in Miller Lake near the mouth of Evening Creek during 2017 – 2019 (Table 1). In 2019, larvae were further out in the lake. It is unclear if this finding is indicative of lamprey recolonizing the lake. There were no reports from anglers of lamprey wounds on trout.

DISCUSSION

The Miller Lake Lamprey Conservation Plan calls for Miller Lake Lamprey to be widely distributed with robust populations able to withstand environmental stochasticity. To achieve this, the TMT has conducted translocations of lamprey from lower Miller Creek to the upper basin since 2010. Results from these reintroduction efforts are generally positive. Lamprey have persisted in the tributaries in which they have been reintroduced and some reproduction (i.e., presence of small larvae) is evident. Assessments of lamprey presence suggest that densities in the reintroduction areas may be low. However, it is unclear what relative densities of lamprey these habitats can support. In the case of upper Miller Creek in 2019, spring freshets may have scoured lamprey out of the substrate and flushed them downstream. This hypothesis could also explain why evidence of successful reproduction (i.e., small larvae) was not found in upper Miller Creek in 2019. The lower number of transformed lamprey in lower Miller Creek in 2019 could be a function of one of four causes: 1) spring freshets scouring the substrate and flushing lamprey downstream, 2) a low period within natural population cycles, 3) some other limiting factor(s), or 4) some combination of 1 – 3.

Survey methods for larval, transformed, and juvenile lampreys vary substantially among studies with regards to gear types, logistics, and sample design (e.g., Torgerson and Close 2003; Dunham et al. 2013; Schultz et al. 2014; USFWS 2014; Reid and Goodman 2015). For many biological and logistical reasons, the data from backpack electroshocking surveys for lampreys is subjective and can be difficult to assess beyond presence/absence. Estimates of lamprey abundance with backpack electroshocking surveys remains elusive because too many variables exist. Lampreys are cryptic and are often burrowed in substrate; this is particularly true for larvae of all lampreys, and for transformed Miller Lake Lamprey. The ecology of lamprey burrowing, combined with myriad other poorly understood environmental factors results in numbers of lamprey that cannot be readily compared across years and locations.

Backpack electroshocking can add to this complexity because it yields unknown detection efficiencies. Nevertheless, the goal of surveys has been to assess the efficacy of reintroduction efforts of Miller Lake Lamprey and backpack electroshocking has been an efficient tool in this regard. The primary objective of these surveys was to obtain presence/absence (distribution) data; the secondary objective was to obtain general population data on the lamprey, using size class as a proxy for age class; and a tertiary objective was to obtain a sense of relative abundance (i.e., the ease with which lamprey were found relative to survey effort).

In summary, translocated lamprey have persisted in the locations into which they have been reintroduced, and some evidence of reproduction has been observed. However, backpack electrofishing surveys suggest that the relative abundance of lamprey may not be increasing at the reintroduction locations. Although the population in lower Miller Creek appears to be relatively stable, population dynamics of Miller Lake Lamprey, both in lower Miller Creek and the lake populations is not well understood.

FUTURE DIRECTION

The Miller Lake Lamprey plan calls for periodic evaluations of the status of Miller Lake Lamprey and the success of implemented management strategies for the species. Monitoring data do not appear to suggest a decrease in the status of Miller Lake Lamprey at this time, and the increased distribution vis-à-vis translocations may be indicative of an increase in status from 15 years ago, when the plan was written. However, the projected status trend of Miller Lake Lamprey is uncertain because the common metrics used to assess population status — distribution, relative abundance, and population dynamics — are not well understood for this species. Questions remain about the resiliency of donor and translocated populations of Miller Lake Lamprey to environmental stochasticity. If the TMT waits until monitoring data suggest significant problems with distribution and relative abundance (as called for in the plan), then it might be too late to modify management actions in ways that will sufficiently benefit Miller Lake Lamprey. Research and monitoring methods in addition to backpack electrofishing surveys will be necessary to improve understanding of the distribution, relative abundance, and population dynamics of Miller Lake Lamprey. These methods may require additional funding to implement. Successful implementation will depend upon the availability of funding and the success of ongoing partnership within the TMT.

CONCLUSIONS

Given the cool water temperatures of the Miller Lake Basin, the small body size and relatively low number of young produced by Miller Lake Lamprey, and generation times that may take several years, a re-established connection of the lamprey population between Miller Lake and Miller Creek may take a long time (Clemens 2017), perhaps decades. Recolonization of Miller Lake Lamprey from lower Miller Creek up into upper Miller Creek may not occur by upstream lamprey movement alone[3]. We now have several years of data available to assess distribution, a sense of relative abundance, and size class data (Table 1). These data suggest persistence of larvae in tributaries into which lamprey have been reintroduced and inconsistent evidence of successful reproduction in these areas. Unsubstantiated observations of lamprey parasitism of trout were purported to have occurred on trout in Miller Lake in

2018 (Clemens 2018); however, no observations of this phenomenon were reported in 2019. It remains unclear whether lamprey have recolonized the lake. Additional research and monitoring methods will contribute to status assessments and conservation efforts for Miller Lake Lamprey.

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