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Miller Lake Lamprey 2021 Progress Report

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Miller Lake Lamprey 2021 Progress Report

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ABSTRACT

Miller Lake is home to the Miller Lake Lamprey *Entosphenus minimus*, a native species that occurs only in the upper Klamath Basin in Oregon. 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 (Commission) was concerned that Miller Lake Lamprey compromised trout fisheries in the lake, and in 1949 the Commission installed log dams and screens on tributaries to Miller Lake to prevent Miller Lake Lamprey from spawning. In 1958 the Commission 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 two primary goals of the TMT have been to reintroduce Miller Lake Lamprey back into Miller Lake and its tributaries, and to monitor the success of these reintroductions. Reintroduction has been somewhat successful, with evidence of persistence and successful reproduction in these locations. Additional research and monitoring 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 a "Strategy Species" for the Oregon Conservation Strategy.

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

[1] *This report includes minor edits to tables from previous reports (Clemens et al. 2017, 2018, 2020). In addition, this report refers to lamprey with eyes as "transformed" or "transformers" 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.*

introduced trouts and Tui Chub *Siphateles bicolor* in Miller Lake (Bond and Kan 1973; Kan and Bond 1981). The Oregon Game Commission (Commission) was concerned that Miller Lake Lamprey compromised trout fisheries in the lake. In 1949 the Commission installed log dams and screens on tributaries to Miller Lake to prevent the species from spawning (Lockwood 1951). In 1958 the Commission applied the chemical toxaphene to the lake and tributaries flowing into Miller Lake to eradicate them (Gerlach and Borovicka 1964). The toxaphene application eradicated Miller Lake Lamprey in the lake and its inflow tributaries. In 1959, the Commission constructed a barrier in Miller Creek approximately one-half mile downstream of the lake outflow (Figure 3) to prevent lamprey from moving back into the lake. The barrier was composed of rock and concrete with a steel plate which created a long ledge.

Figure 1. Miller Lake is a deep, coldwater lake in the Cascade Range north of Crater Lake (Klamath County, west of the town 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 (Lorion et al. 2000; Figure 4). 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 and it is also a "Strategy Species" for the Oregon Conservation Strategy. The ODFW, recognizing that Miller Lake Lamprey is native to Oregon and does not exist outside of Miller Creek and the upper Williamson and Sycan river drainages, created the Miller Lake Lamprey Conservation Plan (OAR 635-500-3885; ODFW 2005). This plan formed the basis of ongoing management for Miller Lake Lamprey, and this progress 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*.

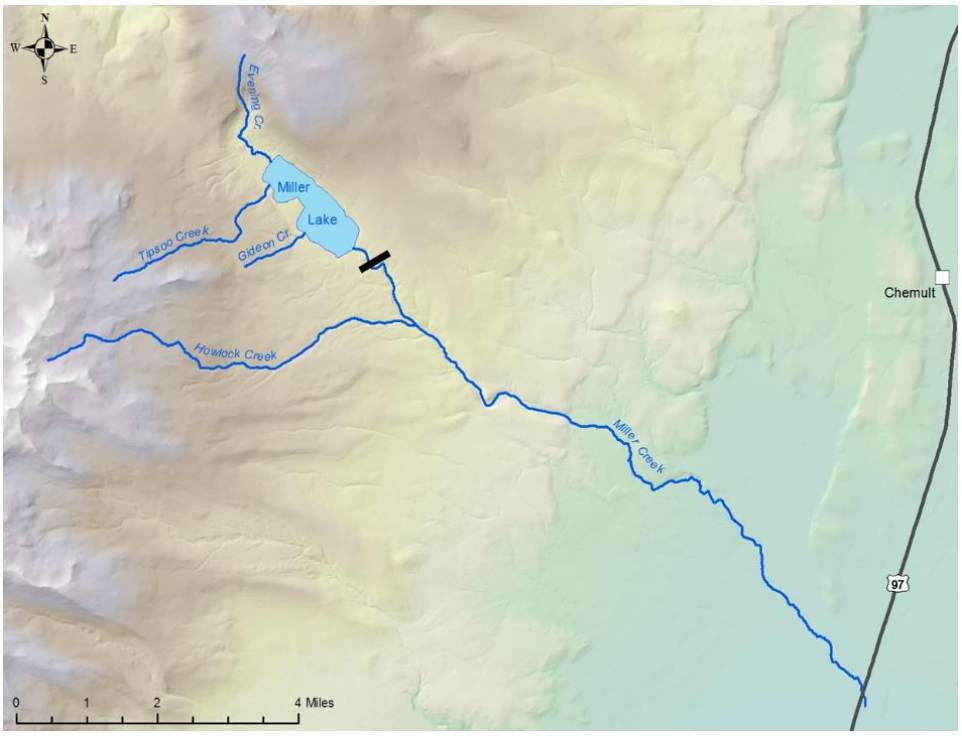

Figure 3. Map of Miller Lake, showing tributaries flowing into the lake from the north and west, and the outflow tributary, Miller Creek. The barrier installed by the Commission in 1959 is shown; this barrier was removed in 2005 (Figure 4).

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 in 1959 (Figures 3 – 4). Other long-term 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 the lamprey 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 4 provides a high-level summary of years when management and survey actions were conducted and when scientific information was published.

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.

METHODS

Following removal of the barrier in Miller Creek in 2005 (Figures 3 – 4), various locations of the Miller Lake drainage above the old barrier site 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 goals were to establish several self-sustaining populations at different translocation sites to increase the likelihood of recolonizing habitats in and around Miller Lake. The TMT monitored the possible 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 Miller Lake and its tributaries (Figure 4). Translocated life stages included both larvae and tranformers[1].

Backpack electrofishers (ABP-2, Engineering Technical Services, Madison, Wisconsin) were used to survey for lamprey in wadeable areas, following a single-pass, rapid assessment protocol like Reid and Goodman (2015), with shocker settings per Schultz et al. (2014). Voltage was 125 – 300 V and adjusted as necessary. Small larvae (≤ 50 mm) found above the old barrier site that were smaller than the original populations of translocated lamprey were considered to have been locally produced, and hence evidence of recent successful reproduction.

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

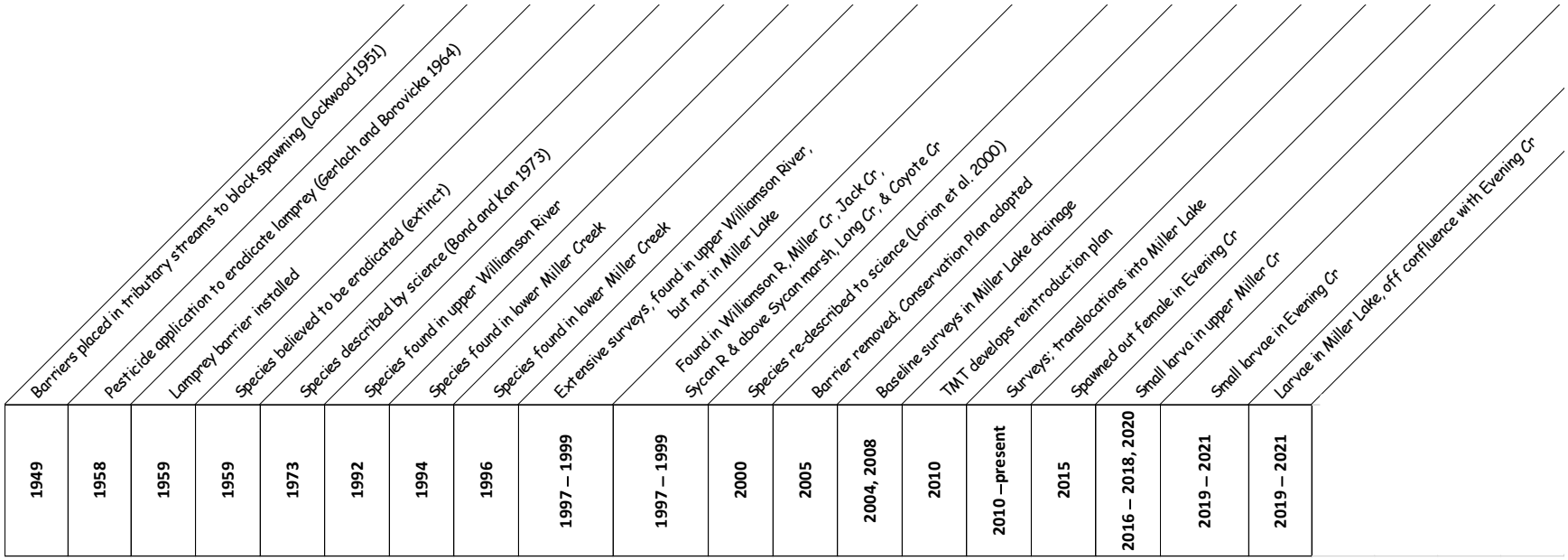

Figure 4. Timeline of management actions and scientific results for Miller Lake Lamprey. The species was recognized by science in 1973. Baseline surveys in 2004 and 2008 found no lamprey in Miller Lake, its inflow tributaries or the uppermost portion of the outflow tributary, Miller Creek, in the vicinity of the former barrier site (Figure 3). "TMT" = Miller Lake Lamprey Technical Management Team.

RESULTS AND 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 surveys since 2004 and translocations of lamprey from lower Miller Creek to the upper drainage since 2010. Therefore we now have 18 years of data available (2004 – 2021) including pre-translocation, to assess distribution, relative abundance, and size class data (Table 1). Table 2 reports information on translocations of lamprey to re-establish them in Miller Lake, tributaries flowing into the lake, and the tributary flowing out of the lake (upper Miller Creek). 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. Lamprey translocated into the upper Miller Lake drainage (upper Miller, Tipsoo, and Evening creeks) during 2010 – 2020 (Tables 1 and 2; Figure 5) survived. Larvae found in the vicinity of the upper Miller Creek translocation area tend to be large and relatively few. However, smaller larvae have also been found as far as 0.4 miles downstream, just above the old barrier site, suggesting that this may be due to downstream movement of translocated populations. Evidence of successful reproduction from these translocations was found in upper Miller Creek during 2016 – 2018 and 2020. Evidence of successful reproduction was found in Evening Creek during 2019 – 2021 (Table 1). No larvae found in Tipsoo Creek in 2021 were smaller than those translocated in 2020; therefore, we have not yet found clear evidence of successful reproduction of lamprey in that creek.

Table 1. Survey results and observations for Miller Lake Lamprey. Some of this information has been updated from earlier reports. General survey locations are shown in Figure 5. 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	ML down to LMC	~266	Lamprey in 4 sites of LMC. None in ML or UMC.
2008	MC	29	No lamprey found in UMC.
2010	LMC	700	over 0.4 km, included 2 transformers; *collected for translocations — see Table 2*
2011	LMC	632	*Collected for translocations — see Table 2*
	EC	Present	Likely from 2010 translocation; ~100 mm size class common.
2012	LMC	626	Most ~50 – 100 mm; included few transformers; *Collected for translocations — see Table 2*
	UMC	1 [b]	~10 mm; below Miller Lake Rd (National Forest Service Road 9772)
	ML	1	
	EC	7	
2013	LMC	~600	*Collected for translocations — see Table 2*
	UMC	Present	~100 – 120 mm
	TC	1	Small larvae (29 mm)
	EC	Present	~60 – 120 mm

2014	Miller Lake	0 [a]	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. Lamprey presence in the lake has not been corroborated by other means.
2015	LMC	415	All > 30 mm. *Collected for translocations — see Table 2*
	UMC	Present [b]	
	TC	0 [a]	
	EC	Present	~50 – 120 mm; also found spawned out female (6 July). No lamprey found at creek outlet into the lake.
2016	UMC	Present [b]	One young-of-year larva (< 20 mm) found above culvert in UMC, larger larvae found below culvert.
	TC	0 [a]	
	EC	Present	Low abundance, larger size classes of larvae (~110 – 140 mm)
2017	LMC	610	High density observed; 20 – 130 mm; including 3 transformers. *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 [a]	Set gill nets for Brown Trout to collect gametes (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).
	LMC	401	High density; largest number of transformed lamprey (~66) observed to date at this location. Sizes ~40 – 110 mm. 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 (~50 – 120 mm); also below lake outlet above and below road culvert (73 – 160 mm; 2 large larvae ~180 mm).
	EC	17	Large larvae (101 – 179 mm). Two larvae 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	22 [b]	Low relative densities (no transformed lamprey) between the former barrier site and Miller Lake. Present from the barrier upstream. All larvae of large body sizes (80 – 175 mm).
	ML	15	Larvae (48 – 90 mm) found up to 70 ft. away from mouth of Evening Creek.
	EC	36	Wide range of body sizes (42 – 185 mm) suggests multiple age classes, including from recent reproduction.
2020	LMC	300	≥ 50 mm, including 6 transformers. *Collected for translocations — see Table 2*
	UMC	Present [b]	50 – 140 mm, including 6 transformers
	ML	15	Larvae (48 – 90 mm) found up to 178 ft. away from mouth of Evening Creek.
	EC	36	50 – 180 mm
2021	LMC	330	~50 – 120 mm. Included 2 transformers. *Collected for translocations — see Table 2*
	UMC	Present	120 – 140 mm
	TC	Present	50 – 100 mm; most ~80 mm
	GC	0 [a]	
	ML	Present	
	EC	Abundant	< 20 – 173 mm

[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. Some of this information has been updated from earlier reports. All translocated lamprey were taken from lower Miller Creek. Locations referenced can be viewed in Figure 5. Translocated lamprey were primarily larvae but ranged from young-of-the-year to transformed individuals[1]. See Table 1 for abbreviations.

Year	Dates	Number of lamprey	Lamprey translocated to	Notes
2010	3, 4 Aug	700	ML (300), EC (300), UMC (100)	Included 2 transformed lamprey
2011	16, 17 Aug	632	ML (200), EC (232), UMC (200)	
2012	25 Sep	627	ML (208), EC (208), UMC (211)	
2013	28, 29 Aug	~600	ML (~200), EC (~200), UMC (~200)	
2014	7, 8 Oct	-	No translocation	
2015	26 Oct	415	EC (~207) and UMC (~208) by National Forest Service Road 9772 culvert	
2016	-	-	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
2020	13, 14 Oct	300	TC	Including 6 transformers
2021	9, 10 Aug	330	GC	

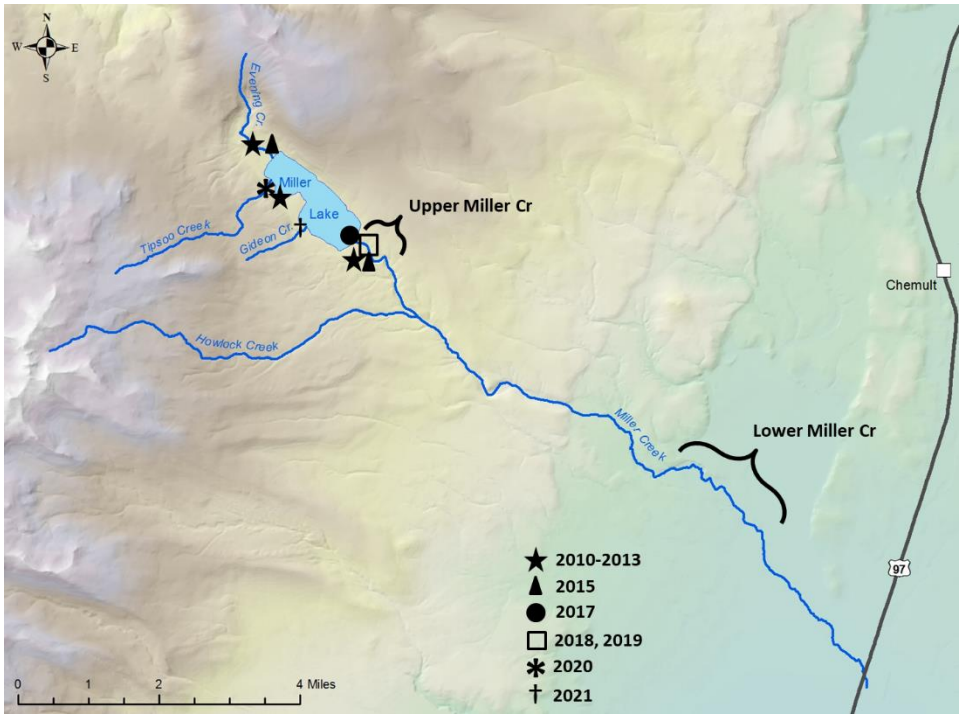

Figure 5. Map of Miller Lake drainage. Lower Miller Creek has been used as the source for all translocations of Miller Lake Lamprey (Table 2). Symbols indicate release sites and years.

Limited lake sampling revealed larval lamprey near the mouth of Evening Creek during 2017 – 2021. These lamprey were up to 70 feet off the mouth of Evening Creek in 2019 and up to 178 feet off the mouth in 2020 (Table 1). This leads us to conclude that the larvae are using the lake habitat, particularly in the vicinity of the tributary mouth. Observations of lamprey parasitism of trout were reported to have occurred on trout in Miller Lake in 2018 (Clemens 2018); however, these could not be confirmed and no observations of this phenomenon have been reported since then.

A qualitative assessment of the available evidence (Table 3) leads us to some conclusions about the status of the source population of Miller Lake Lamprey in lower Miller Creek and the translocated populations in the upper drainage (Table 4). Our surveys suggest that the source population of lamprey in lower Miller Creek is “common to prevalent”, whereas the recipient populations range from “limited” in upper Miller Creek and Miller Lake to “common to prevalent” in Evening Creek (Table 5). However we still do not know the extent to which historical populations moved between these locations for reproduction, larval rearing or parasitism or whether they functioned as isolated populations. Further, whereas a “common to prevalent” status of lamprey in Miller Lake is desirable — as per early Commission reports in the mid-1900s prior to the application of toxaphene — it is not clear what the historical holding capacity of the inflow and outflow tributaries to the lake was and is; thus, it is not clear what the target status should be in these tributaries (Table 5). For example, Kan and Bond (1981)

indicated, "[Miller Lake Lamprey] *apparently had reduced the migration considerably; all spawners in the OS* [Oregon State University] *collection were collected along the lake shore. Few ammocoetes* [larvae] *were collected from the cold tributary streams, but ammocetes were common in deposits of organic detritus along the lake shore. Presumably ammocoetes were present in organic deposits in deeper water, but we have no collections from deeper than about 1 m*".

Table 3. Indicators of successful persistence and/or reintroduction of Miller Lake Lamprey and associated scores.

	Indicator	Survey type	Notes	Reliability [a]	Score
1.	Continued presence	Electrofishing	Indicator of resilience and *potential* for reproduction	Very reliable	4
2.	Observations of adults spawning	Walking surveys	Surveys lacking	Not reliable	1
3.	Repeated presence of small larvae (smaller than the source population)	Electrofishing	Indicator of successful reproduction; small larvae can be difficult to detect	Reliable	3
4.	Relatively abundant	Electrofishing	Indicator of self-sustaining population; subjectively determined by the relative ease with which lamprey are detected relative to survey effort	Reliable	3
5.	Presence of lamprey wounds on trout	Gill net surveys; evidence from anglers	Indication of full expression of life cycle; can be difficult to detect	Reliable	3
	Combined evidence, #1 – 5		–	–	14

[a] Based on "Notes" column: "Very reliable", "reliable", "not reliable".

Table 4. Scores and associated status. The status description indicates the relative contribution of indicators of successful persistence and/or reintroduction and associated scores (from Table 3).

Score	Current status	Status description
8 – 14	**Common – Prevalent**	Multiple indicators
6 – 7	**Limited**	Few indicators
≤ 5	**Rare – Absent**	Indicators lacking

Table 5. Distribution and translocation history of Miller Lake Lamprey in the Miller Lake drainage, along with the sum of scores (Table 3), and associated status (Table 4) of source and reintroduced populations.

	Lower Miller Creek	Upper Miller Creek	Gideon Creek	Tipsoo Creek	Evening Creek	Miller Lake [a]
Lamprey present 1959 – 2005?	Yes	No [b]	No [b]	No [b]	No [b]	No [b]
Lamprey present in 2008?	Yes	No [b]	No [b]	No [b]	No [b]	No [b]
Translocations	–	2010 – 2013, 2015, 2018 – 2019	2021	2020	2010 – 2013, 2015	2010 – 2013, 2017
Lamprey present in 2021?	Yes	Yes	No [b]	Yes	Yes	Yes
Indicators of success [c]	1, 3, 4, 5	1	Too early to tell	Too early to tell	1, 2, 3, 4	1, 3
Status score [d]	13	4	–	–	11	7
Current status	**Common – Prevalent**	**Limited**	**Unknown**	**Unknown**	**Common – Prevalent**	**Limited**
Desired status	**Common – Prevalent**	**Unclear** [e]				**Common – Prevalent**

[a] Emphasis on surveys off Evening Creek confluence.

[b] 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.

[c] From left-most column in Table 3.

[d] Sum of indicator scores from the right-most column in Table 3.

[e] The historical holding capacity of the habitats in these locations and the frequency and extent to which lamprey used them (i.e., intermittently or continually) for spawning, larval rearing or juvenile feeding is not well known.

Larval and transformed lampreys are cryptic and are often burrowed into substrates (Dawson et al. 2015). 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 electrofishing can add to this complexity because it yields unknown detection efficiencies. However, 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).

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. The increased distribution of lamprey vis-à-vis translocations is indicative of an increase in status from that of 16 years ago, when the plan was written. However, the projected status trend of Miller Lake Lamprey is uncertain because two of the three common metrics used to assess population

status — abundance and population viability[4] (distribution is the third metric) — are not well understood for this species[5]. Questions remain about the resiliency of source 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.

ACKNOWLEDGMENTS

This report would not have been possible without the collaborative and committed efforts of the TMT members, including authors of this report, Jane Spangler, Eva Jones; and past members Mike Harrington, Doug Markle, and Stephanie Gunckel.

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[4] *Population viability analysis (PVA) includes quantitative analysis to estimate the probability that a population will persist over time (Gerber and González-Suárez 2010). Birth and death rates, population estimates, and age structures are not understood for Miller Lake Lamprey; this makes PVA for this species impossible at this time.*

[5] *Abundance and population viability are not well understood for any species of lamprey.*

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