A Summary of the Early Field Studies of the Morrison Creek Lamprey and a New Assessment of its Taxonomy

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"Once part of the puzzle is lost, it is even more difficult to see the big picture"

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Abstract

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The Morrison Creek lamprey was originally described as a variety of *Lampetra richardsoni* with the variety name *marifuga*. It was given protection under the Species At Risk Act because it was not found elsewhere and it represented an intermediate stage between parasitic and non-parasitic lampreys. There are no other records of a lamprey that is intermediate between a parasitic and non-parasitic species anywhere in the world, making the Morrison Creek lamprey unique. The variety designation was proposed because it was not known if the Morrison Creek lamprey spawned successfully in the creek; however, it was known that successful spawning occurred in the laboratory. There now is evidence that the Morrison Creek lamprey spawns successfully in the creek. Consequently, it is proposed in this report that the lamprey is a subspecies with the designation *Lampetra richardsoni marifuga*. Evidence is presented to support this subspecies designation. The report also is a compilation of information collected in the early studies in the 1970s and 1980s. Trapping locations are shown as well as catches and length measurements. The information is used to estimate that during the period of maximum catches from mid-June to mid-July, there was an average of 1.5 of the silver-appearing, Morrison Creek lamprey caught each day in the mid to late 1980s, in an area considered to have the maximum abundance of the Morrison Creek lamprey.

Resume

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La lamproie du ruisseau Morrison était auparavant décrite comme une variété de *Lampetra richardsoni* , portant le nom de variété *marifuga*. Une protection lui a été accordée en vertu de la *Loi sur les espèces en péril* parce qu'elle ne se trouvait nulle part ailleurs et parce qu'elle représentait un stade intermédiaire entre les lamproies parasites et non parasites. Aucune autre variété de lamproie intermédiaire entre les espèces parasites et non parasites n'ayant été répertoriée dans le monde, la lamproie du ruisseau Morrison est une espèce unique. La désignation de la variété a été proposée parce qu'aucune preuve de sa reproduction dans le ruisseau Morrison n'avait été enregistrée. On savait toutefois qu'elle se reproduisait en laboratoire. Il a maintenant été montré que la lamproie du ruisseau Morrison pouvait se reproduire dans le ruisseau. C'est pourquoi le présent rapport propose de considérer la lamproie comme une sous-espèce, sous la désignation *Lampetra richardsoni marifuga*. Des preuves sont présentées à l'appui de la désignation de sous-espèce. Le rapport est aussi une compilation de données recueillies dans les premières études sur l'espèce, réalisées dans les années 1970 et 1980. Les lieux de piégeage, les prises et les longueurs mesurées sont indiqués. Les renseignements réunis ont servi à estimer que pendant la période de prises maximales, qui s'étend de la mi-juin à la mi-juillet, en moyenne 1,5 lamproie du ruisseau Morrison argentée était prise chaque jour au milieu des années 1980, dans un secteur considéré comme présentant la plus grande abondance de cette variété.

Importance of the Morrison Creek lamprey

"If the Morrison Creek lamprey is lost, the only known example that may explain why lamprey have survived for 350 million years may be gone forever".

Fossil lamprey have been dated to be about 350 million years old (Figure 1). This is long before the dinosaurs evolved about 230 million years ago and then disappeared about 65 million years ago. Lamprey were also present before the continents separated several hundred million years ago (Figure 2).

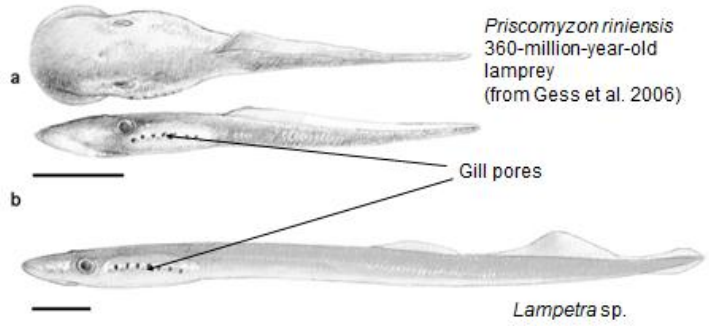


Figure 1. Fossil and modern day lamprey

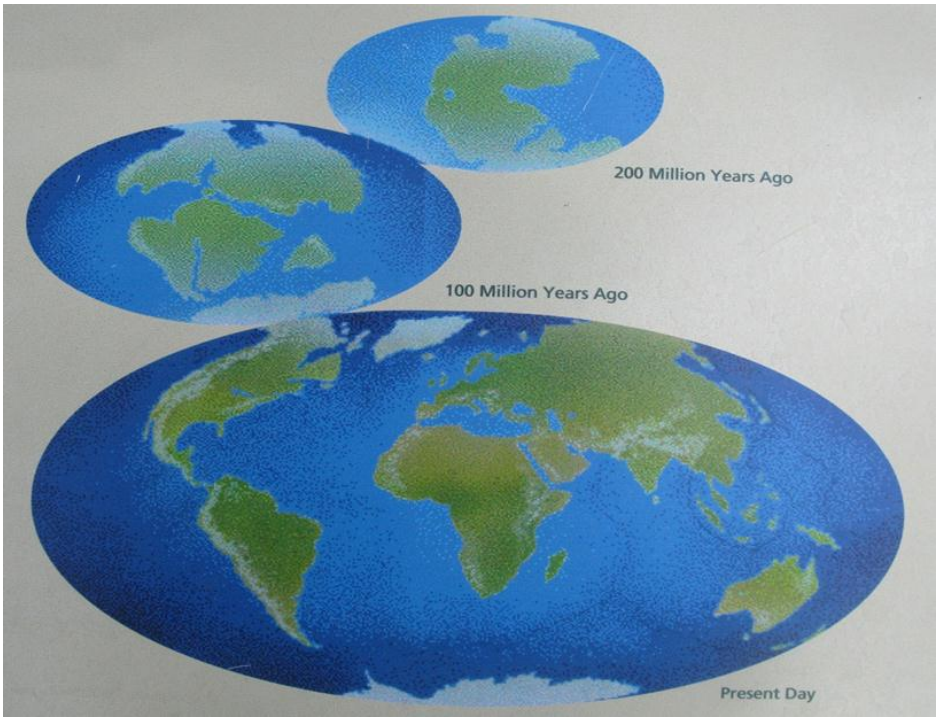


Figure 2. The continents 200 million years ago, 100 million years ago and today

INTRODUCTION

The Morrison Creek lamprey is the only known example on the planet of a population that may be in the process of changing life history types. John Youson and I and our colleagues have published a number of papers (listed at the end of this report) on the Morrison Creek lamprey, but we still do not understand how the Morrison Creek lamprey was produced. We do know that it is essential that it be protected. We know that every year some metamorphosed lamprey become silver-coloured about March and others do not become silver. The non-silver lamprey spawn in the spring and die, as do all *L. richardsoni*. The silver lamprey retain sharp dentition and in the laboratory can feed, grow and spawn in the following year. In the 1980s there were more male silver lamprey than females and the males are almost mature when they have a silver appearance and sharp dentition. The almost mature males can retain their maturity state for a year. The females mature over the second winter following metamorphosis. The silver lamprey appear similar to *L. ayresii*; however, they differ morphologically from *L. ayresii* as shown in the appendix. The silver lamprey also cannot survive in salt water and therefore are not anadromous as are *L. ayresii*. Histological studies indicate that some of the silver Morrison Creek lamprey do not have a successful metamorphosis and thus are not able to survive to spawn. This indicates that the mechanism resulting in the production of the silver Morrison Creek lamprey is faulty. Previously, I thought that all of the non-silver, spawning lamprey in Morrison Creek were *L. richardsoni*. It now appears that this may not be true. It is possible that some of the non-silver lamprey are the Morrison Creek lamprey and are spawning successfully. This interpretation is important because it means that the Morrison Creek lamprey is reproducing and can be classified as a subspecies of either *L. richardsoni or L. ayresii*. Morphologically it is closer to *L. richardsoni*; therefore, I propose that it is a subspecies identified as *Lampetra richardsoni marifuga*. At the end of this report in Appendix I, I include a new and unpublished update of this new interpretation of the Morrison Creek lamprey.

In this report, the Morrison Creek lamprey refers to *L. richardsoni marifuga*. Previously I considered it to be a variety of *L. richardsoni*, but as indicated in the preceding paragraph I am now considering it to be a subspecies of *L. richardsoni*. It is silver in colour from about mid-March through to late summer. Some of the non-silver and larger spawning lamprey probably are either the silver form of Morrison Creek lamprey that are spawning two years after metamorphosis or a population that produces the silver form. If the Morrison Creek lamprey produces both a silver and non-silver form, it would mean that we probably should protect all of the lamprey in the Genus *Lampetra* in Morrison Creek. There are much smaller spawning lamprey, some of which are less than 100 mm that are most likely, *L. richardsoni*. For the rest of this report, when the terminology is the "Morrison Creek lamprey" or *Lampetra richardsoni marifuga,* it refers to both the silver-coloured individuals and the larger non-silver form that spawn in Morrison Creek. If only the silver forms are being considered, they will be specified as "the silver form" meaning the silver-coloured Morrison Creek lamprey. If I use the designation *L. richardsoni*, I believe that I am referring to lamprey that are not the Morrison Creek lamprey.

Importance of the Morrison Creek Lamprey

The protection of the habitat and the Morrison Creek lamprey ensures that the unique Morrison Creek lamprey will survive and be available for study. It is possible that the understanding of the

development of the Morrison Creek lamprey will help us understand how lamprey in particular, and life on the planet in general, is altered by our environment. If the Morrison Creek lamprey is lost, the only known example of a lamprey that may explain why lamprey have survived for 350 million years will be lost forever.

History and Purpose of the Morrison Creek Lamprey Study

In the late 1970s, I began a study of predation by the river lamprey *L. ayresii* on Pacific salmon and herring in the Strait of Georgia. The common name was recently changed to western river lamprey which I will use in the rest of this report. Lamprey trapping in Morrison Creek started in 1978 because there were several specimens in the University of British Columbia fish collection from Morrison Creek that were identified as *Lampetra ayresii*. In the late 1970s, it made sense that if Western river lamprey were in Morrison Creek, they would be easier to collect for laboratory feeding studies than travelling to Vancouver and setting up a trapping study in the Fraser River. It was in 1980 that I first realized that the silver form of Morrison Creek lamprey was probably not *L. ayresii*. I teamed up with John Youson who was a developmental biologist at the University of Toronto. Together, we carried out a number of studies to look at the development of the silver form of the Morrison Creek lamprey particularly during metamorphosis. Results from the investigations are in the publications listed at the end in Appendix 1.

In 2011 and 2012, we repeated the lamprey trapping studies, last undertaken in 1987. The catches of the silver form of the Morrison Creek lamprey in 2011 and 2012 were small compared to the catches in the 1980s. A separate report will be written that summarizes the studies in 2011 and 2012 and recommends new measures to protect the Morrison Creek lamprey.

If the abundance is diminishing, it is important to determine how the early trapping studies could be used to document the decline. Thus, the purpose of this report is to summarize the work done in the 1980s and produce an estimate of the average daily catch of the silver form. This is not a straight forward exercise as the earlier studies were attempts to find specimens and not to determine the abundance of the lamprey in Morrison Creek. The DFO species at risk program provided funding to the produce this report. Ann Beamish, Joy Wade, Lana Fitzpatrick, and Sean MacConnachie helped with the report.

Trap Design and Monitoring Procedures

Metamorphosed lamprey and ammocoetes leave the sediment and swim in rivers, mostly at night. Consequently, they can be captured with a typical trapping system. The trap used in this study had two wings of wire, cloth or plastic mesh that were secured to metal bars pounded into the river bottom (Figure 3A). The mesh size was approximately 1 cm^2. The wings were attached to a tunnel of cloth or wire that was secured to a pipe with a diameter of 10 cm leading into a tank. The end of the pipe in the tank had a tunnel that reduced in diameter to about 5 cm. The exit opening of the tunnel within the tank was positioned about mid depth and about mid center of the tank. The tank had mesh panels on each side and the end to allow passage of water through the tank. The mesh size in the panels was approximately 3 mm^2. The tank was positioned in the river so that it was about 2/3 full of water. The wings, blocked off about 50% of the river flow

and the bottom of each wing was bent inward and anchored to the bottom with rocks and sandbags. A top was attached to the tank to protect the catch from predators and light. The traps were positioned in the creek to allow water to flow passively into the mouth of the trap and out through the mesh that was sealed onto the sides of the tank.

Figure 3A. Typical placement of a trap. In this trap, the tunnel is fine mesh metal screen.

Figure 3B. Once the Morrison Creek lamprey was listed as endangered, all sampling in 2011 and 2012 was conducted at the creek with all lamprey released after they recovered from the anesthetic.

Figure 3C. In 2011and 2012, many mature lamprey (dark colour) were captured that were about the same size as the silver form of the Morrison Creek lamprey (silver colour).

Figure 3D. Another example of the size of mature lamprey (dark colour) that were captured at the same time as the silver form Morrison Creek lamprey (silver colour)

The trapping was remote from the Pacific Biological Station, requiring that we used local residents to monitor the traps which needed to be examined daily to ensure that we did not harm the juvenile coho salmon that were caught at the same time. We needed the lamprey alive and all silver lamprey were put into holding tanks and periodically (3 to 4 days) collected and transported to the Fish Culture Laboratory at the Pacific Biological Station. As a consequence, the estimates of the catches of the silver form of the Morrison Creek lamprey in 1978, 1980, and 1981 were probably close to the true catch but may be inaccurate. However, estimates of catches in 1982, 1983, 1984, and 1987 probably are accurate.

The trap needed to be checked at least once a day to remove debris. From 1978 to 1984 and then in1987, most traps were monitored twice daily by local residents. Juvenile Pacific salmon were counted and put back into the river. Over the years of trapping, there was very little mortality of any salmon or lamprey. On occasion, when there were heavy rains, the trap would become blocked with leaves and debris resulting in some mortality and a reduced ability to catch fish.

Trap Locations

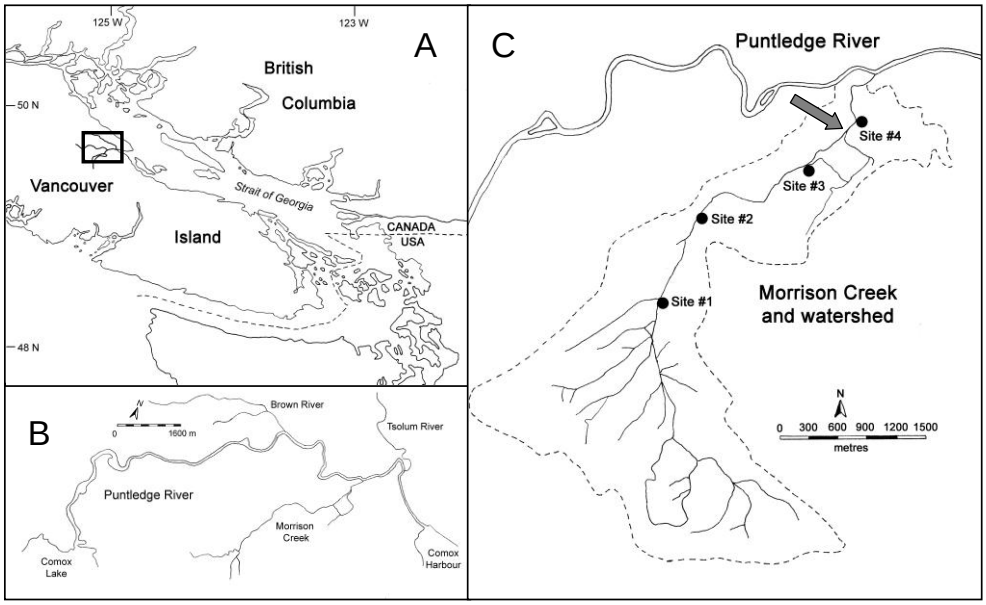
Traps were located in areas where the current flow was reduced and the creek was wider than average. Smooth bottom was preferred but was not always available. In general, it was not easy to find optimal trapping sites. Sites were selected from the area where the creek changed from the swamp-like, braided passages to a creek flowing under Lake Trail Road to the area just before the creek flows into the Puntledge Park area. The intent was to spread out the trapping sites as shown in Figure 4. Trap locations may have changed slightly within a particular site

among years. Electroshocking occurred throughout the creek but most electroshocking occurred in the vicinity of Site #1 at Lake Trail Road (Figure 4).

Catches in 1978, 1980, 1981 and 1982, were mainly to obtain specimens for the laboratory studies. Silver coloured lamprey that were brought into the laboratory were counted and measured. Beginning in 1983, and in 1984 and 1987, reliable field records were available for species and life history stages. The samples for 1982 appear to be an accurate record of the catches in the traps but I am relying on the 1983, 1984, and 1987 catches to estimate relative abundance. Specimens were collected for histological studies that eventually identified the developmental anomalies associated with metamorphosis. It was the existence of these anomalies that indicated the Morrison Creek lamprey was unique among all lamprey. After 1987, I focused on protecting the Morrison Creek lamprey and stopped all sampling. A summary of the sample history is presented in Table 1.

Table 1. Summary of lamprey sampling in Morrison Creek from 1977 to 1988.

Year	Number of silver coloured lamprey	Highlights
1977	2	Silver-coloured lamprey were preserved in a sample of juvenile Pacific salmon captured in fry traps. Specimens found their way to the University of British Columbia fish collection where they were identified as *Lampetra ayresii*.
1978	33 (estimated)	Trapping began at Site #3 (Timberlane Road) from May 1 to June 7, daily catch records were not available.
1980	85 (estimated)	Trapping occurred at Site #3 and at a new site, Site #4 (at Second Street). Trapping at Site #3 from late May to late August and at Site #4 from July 22 to August 25. Catch records are approximate.
1981		In February, 18 metamorphosed lamprey were collected using an electroshocker from the area near the bridge at Lake Trail Road where Morrison Creek emerged from the swamp. None were silver and all were kept alive in the laboratory at the Pacific Biological Station. In mid-March, two were silver and the remaining lamprey matured, spawned and died or died prior to spawning.
1981	85 (estimated)	Trapping occurred at Site #3 from May 16 to July 11 and at Site #2 (Marsden Road) from June 10 to August 25 and at Site #4.
1982	73 (estimated)	Trapping occurred at Site #1 and Site #4 from June 15 to September 17-18. At Site #1 the trap was near Miromar Road and at Site #4 the trap was near Second Street.
1983	66	Trapping occurred at Site #3 at the end of Timberlane Road from May 24 to August 11. Lamprey species and stages were identified at the trapping site for the first time.
1984	112	Trapping occurred at Site #1, Site #2 and Site #3 from May 29 to August 17. Lamprey species and stages were identified at the trapping sites each day.
1985		In August, electroshocking at Site #1 near the bridge on Lake Trail Road over Morrison Creek was used to collect 4 metamorphosing lamprey. By March 1986, one was silver; by June 1986, 3 were in spawning condition and 1 remained silver.
1987	42	Trapping occurred at Site #3 at the end of Timberlane Road from May 1 to July 9. Lamprey species and stages were identified at the trapping site each day.
1988		I determined that the Morrison Creek lamprey was unique and needed to be protected. Sampling was terminated.



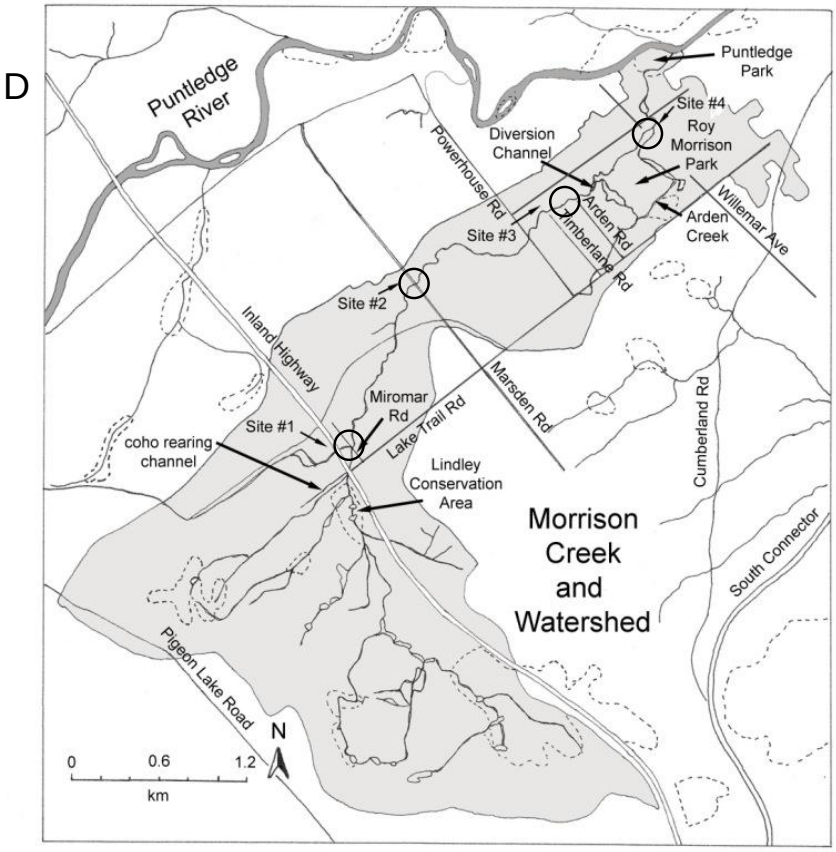


Figure 4. Location of Morrison Creek on Vancouver Island (A,B), and the trapping sites (C,D).

Sampling notes for Table 1

The samples in 1978 were collected for a feeding study of the impact of Western river lamprey (*L. ayresii*) predation on juvenile Pacific salmon and herring. I was not able to acclimate the silver form of the Morrison Creek lamprey to salt water in 1978. This initial failure was puzzling, but it was possible that the acclimation procedures were not appropriate. In 1979, I was able to capture metamorphosed *L. ayresii* from fresh water in the Fraser River and developed procedures for acclimating these specimens to salt water. In 1980, I again tried to use samples from Morrison Creek, without success. It was in 1980, that I began to suspect that the Morrison Creek lamprey was different from *L. ayresii*. In 1981 and 1982, the specimens of Morrison Creek lamprey were now kept in fresh water and allowed to feed. Some fed and some died. It was most unusual for anadromous parasitic lamprey to remain in fresh water and to feed. However, it was difficult to hold the Morrison Creek lamprey in captivity as they would attack each other, resulting in fungus development and death. Ultimately, I was able to keep them alive if they were collected frequently from Morrison Creek and held in separate tanks in the laboratory. The surviving fish fed, grew and, after a summer and a fall of feeding, survived through the winter and spawned "naturally" in the laboratory the following spring. The spawned eggs were viable and hatched.

In 1983 and 1984, the specimens collected in the creek were mostly used to study the developmental biology of the Morrison Creek lamprey. During 1985 and 1986, Dr. John Youson and I considered the results of our investigations and determined that we needed additional samples which were collected in 1987. In 1987, it was clear to us that the Morrison Creek lamprey was unique among all known lamprey on the planet. A priority was to protect this population and no additional sampling was carried out until 2011 and 2012.

Analysis of Catches

Ammocoetes

Ammocoetes were only measured in 1978 and 1981 (Figure 5). In 1978, lengths ranged from 34 mm to 142 mm and from 38 mm to 142 mm in 1981. In 1981, total catches of all ammocoetes were recorded for each trapping site, but not separated from catches of metamorphosed lamprey (Tables 2,3,4). In 1982, total catches of ammocoetes were recorded, but ammocoetes and mature, non-silver coloured lamprey were combined (Table 5). In 1983, at site 3, ammocoetes were counted separately from metamorphosed individuals (Table 6). There were 218 ammocoetes compared to 64 silver form Morrison Creek lamprey and 20 mature *L. richardsoni*. In 1984, ammocoetes were counted at the three trapping sites (Tables 7,8,9). At site 1, there were 80 ammocoetes compared to 4 silver form Morrison Creek lamprey and 27 adult *L. richardsoni* (Table 7). At site 2, there were 178 ammocoetes compared to 39 silver form Morrison Creek lamprey and 39 adult *L. richardsoni* (Table 8). At site 3, there were 205 ammocoetes captured compared to 95 silver coloured Morrison Creek lamprey and 20 adult *L. richardsoni*. The percentage of ammocoetes at each trapping site in 1984 ranged from 54% to 77% and averaged 71%. Catches of ammocoetes were continuous throughout the trapping with no periods of particularly large catches. It was not possible to identify the species of ammocoetes.

Adults

Catches of all lamprey are summarized from field notes in Tables 2 to 13. In 1981 and 1982, the field counts were combined for ammocoetes and adults of both the silver form of the Morrison Creek Lamprey and all non-silver forms which would include *L. richardsoni*. It was difficult to use these data, other than as a comparison with similar aggregations of catches. In 1982, there was a count of the silver form. Preserved specimens were recently measured in 2009 from collections in 1978 and 1981 (Figure 5). In Figure 5, the smallest adults probably were *L. richardsoni* and the largest probably were the Morrison Creek lamprey. The smallest mature *L. richardsoni* was 78 mm which is extremely small and highly unusual (Figure 5A). There were 53 metamorphosed lamprey in the preserved samples from 1981 (Figure 5B). The field notes identified 34 silver forms in 1981 (Table 11) with the smallest and largest silver form specimens measuring 100 mm and 140 mm respectively. Some of the smaller metamorphosed lamprey would be *L. richardsoni* and the largest probably would be the mature silver form. The lengths of the silver form were recorded from field notes for 1982, 1983, 1984, and 1987 (Table 11), and the length frequencies are listed in Table 12 and Figure 6. The mean lengths were very similar in 1981, 1982, 1983, and 1984, but smaller in 1987. There also was no trend in the lengths throughout the trapping period (Figure 7). Total catches from the field notes in 1982 were 73 and there were laboratory measurements for 72 specimens (Table 11). Thus, it appears that virtually all Morrison Creek lamprey were measured for length in 1982. In 1982, the first silver form was captured on June 15 and the last was captured between August 13 and 24. The largest catches occurred in July, with maximum catches occurring around the second week in July (Figure 8). In 1983, only one site had a trap in place. The first silver form was captured on May 25; however, the trap was not installed until May 24. The last silver form was captured on August 11, but the trap was removed on this day, indicating that the silver form could be present after this date. The largest catches occurred from about mid-June until mid-July. In 1983, two Pacific lamprey *Entosphenus tridentatus* were also captured. In 1984, three trapping sites produced 111 silver coloured Morrison Creek lamprey which were the largest catches to date. The largest catch was at Site #3, from about mid-June until mid-July. In 1987, trapping started earlier, but ended in early July (Figure 9). The first silver form was not captured until late May, confirming that in general, it was not until late May that the silver form of Morrison Creek lamprey begins to actively swim within the creek. The largest catches occurred about mid-June through to the end of trapping in the first week of July. In 1987, the average size of the silver form was smaller than in 1982 to 1984. In 1987, the sex of *L. richardsoni* and the silver form was determined for all samples (Figure 9, Table 12). The sex ratio for *L. richardsoni* was equal. The sex ratio of the silver form was strongly in favour of males. The sample of *L. richardsoni* in 1987 provided a good example of the small size of the adults (Table 12).

Abundance Estimates of the Morrison Creek Lamprey

Reliable estimates of daily and total catches were available at site #3 for 1983, 1984, and 1987 as previously mentioned site #3 at the end of Timberlane Road was monitored by the same observers, (Ross and Marjorie Gibson) who lived at the end of the road and allowed us to place the trap adjacent to their property. Site #3 appeared to be closer to the centre of abundance as there were relatively large catches at this site in all years and catches at other sites were smaller. The date of the first catch at Site #3 was consistently at the end of May to early June and the last

catch was around mid-August. If the average daily catches for about one month during the period of maximum abundance (about mid-June to mid-July) were estimated, for Site #3 there were 1.1 silver lamprey per day in 1983; 2.2 silver lamprey per day in 1984; and 1.4 silver lamprey per day in 1987 (Table 13). The average catch per day for the three years was 1.5 silver lamprey. Thus in the mid-1980s at about the centre of abundance of the silver form, one trap was catching about 1.5 of the silver form of the Morrison Creek lamprey per day. This estimate of about 1.5 lamprey per day probably is a reliable index of the abundance of the silver form of the Morrison Creek lamprey during the 1980s. It is relevant to note that the catches of adult non-silver lamprey were much smaller at some sites. Assuming these were all *L. richardsoni* (which they most likely were not), there was an average of about 0.4 adult *L. richardsoni* caught each day, for 1983, 1984 and 1987, or between 3 to 4 more silver forms than non-silver forms. It is likely that some of the non-silver, mature lamprey were mature Morrison Creek lamprey, meaning that the traps were catching more of the silver form compared to mature *L. richardsoni* at this site. At site 1 more adult lamprey believed to be *L. richardsoni* were captured (Table 7). It is probable that more spawning *L. richardsoni* would be captured earlier in the year, making it difficult to compare the abundances of the *L. richardsoni* with the subspecies.

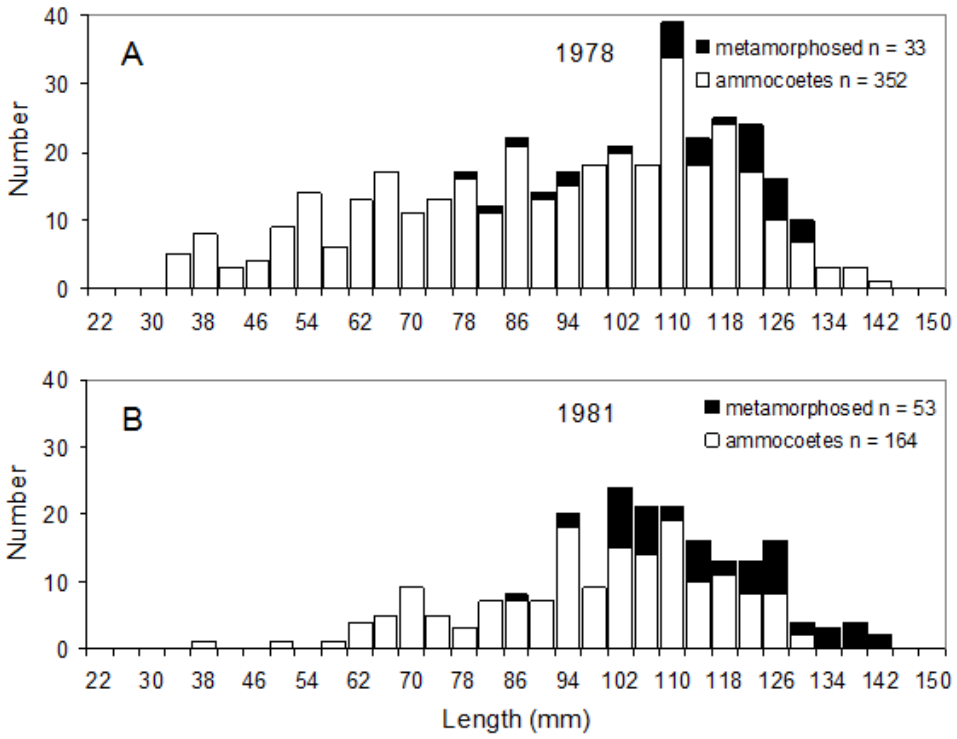


Figure 5. Lengths (mm) of ammocoetes and a combination of adult silver and non-silver forms, labelled as metamorphosed, collected from Morrison Creek in A) 1978, and B) 1981. All lengths are total lengths from preserved samples.

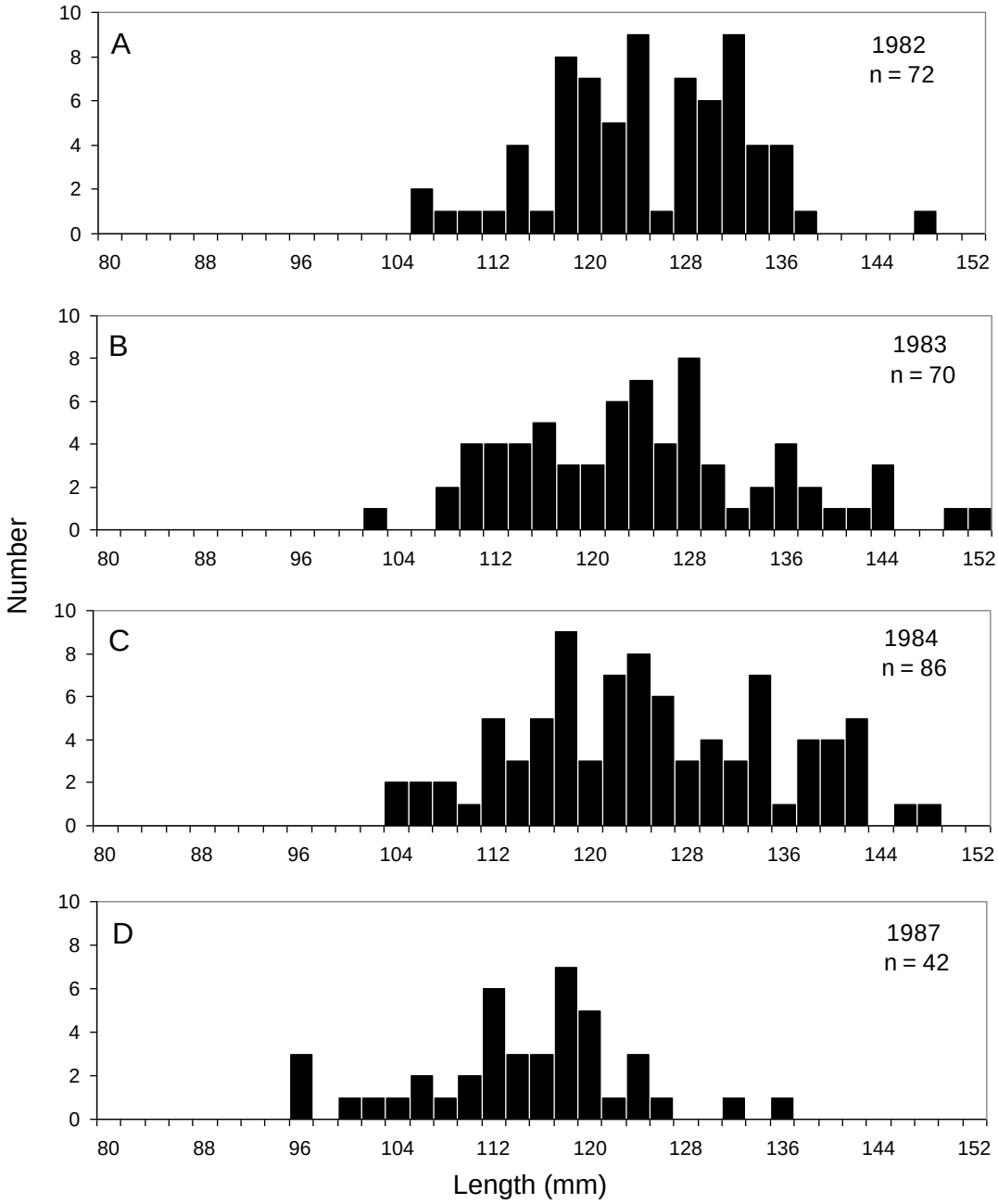


Figure 6. The number and lengths (mm) of the silver form of the Morrison Creek lamprey in A) 1982, B) 1983, C) 1984 and D) 1987.

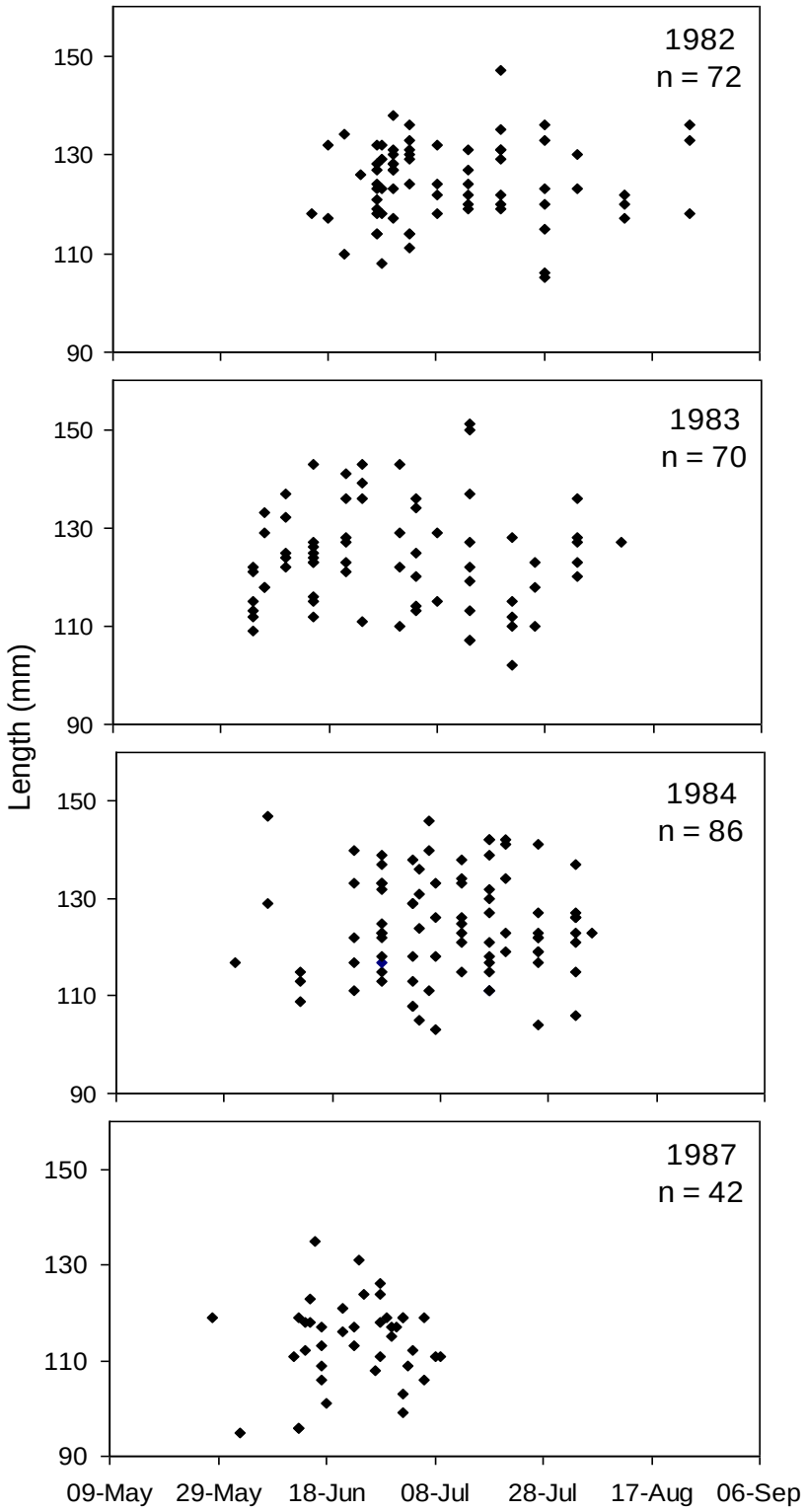


Figure 7. Lengths (mm) of the silver form of the Morrison Creek lamprey throughout the sampling period from all traps.

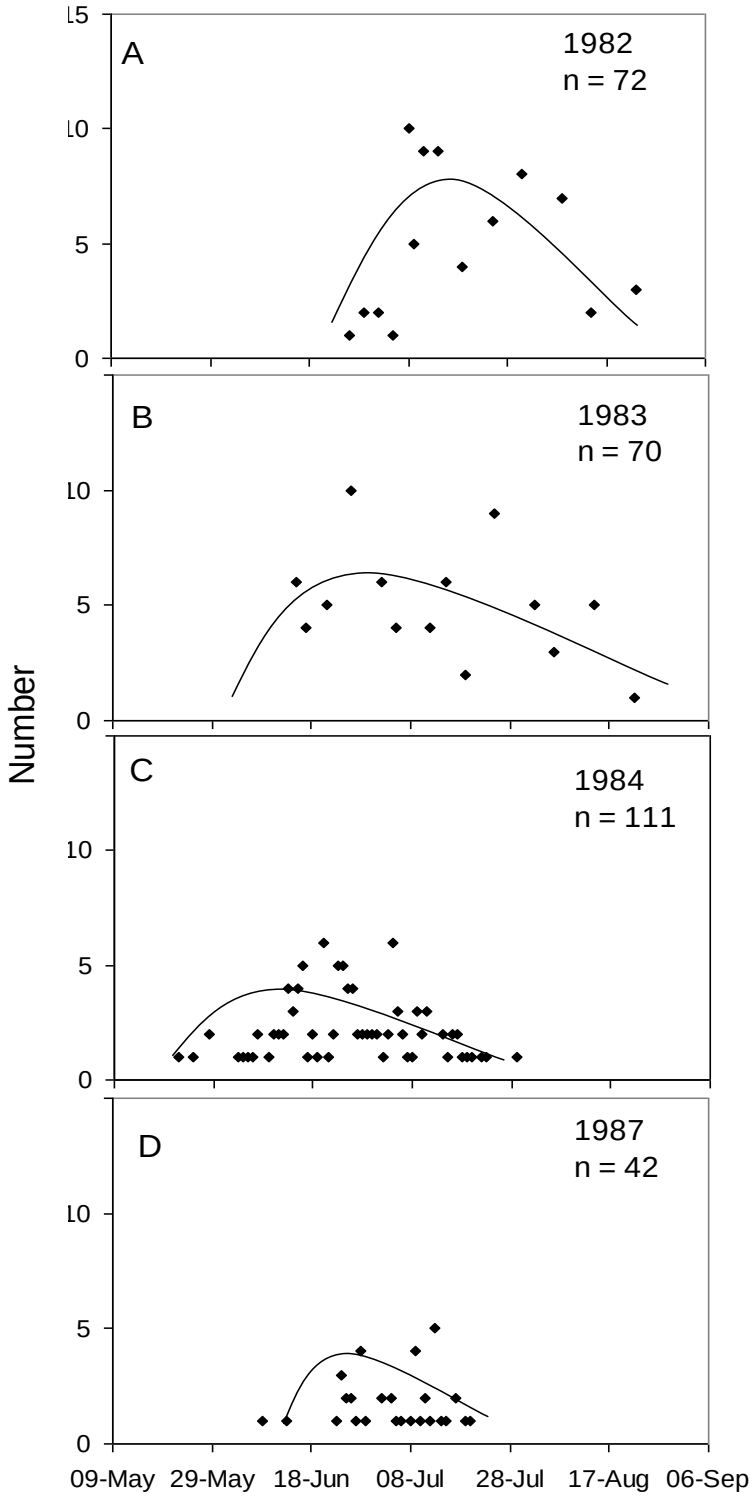


Figure 8. The number of the silver form of the Morrison Creek lamprey caught in the traps, showing the dates of maximum abundance.

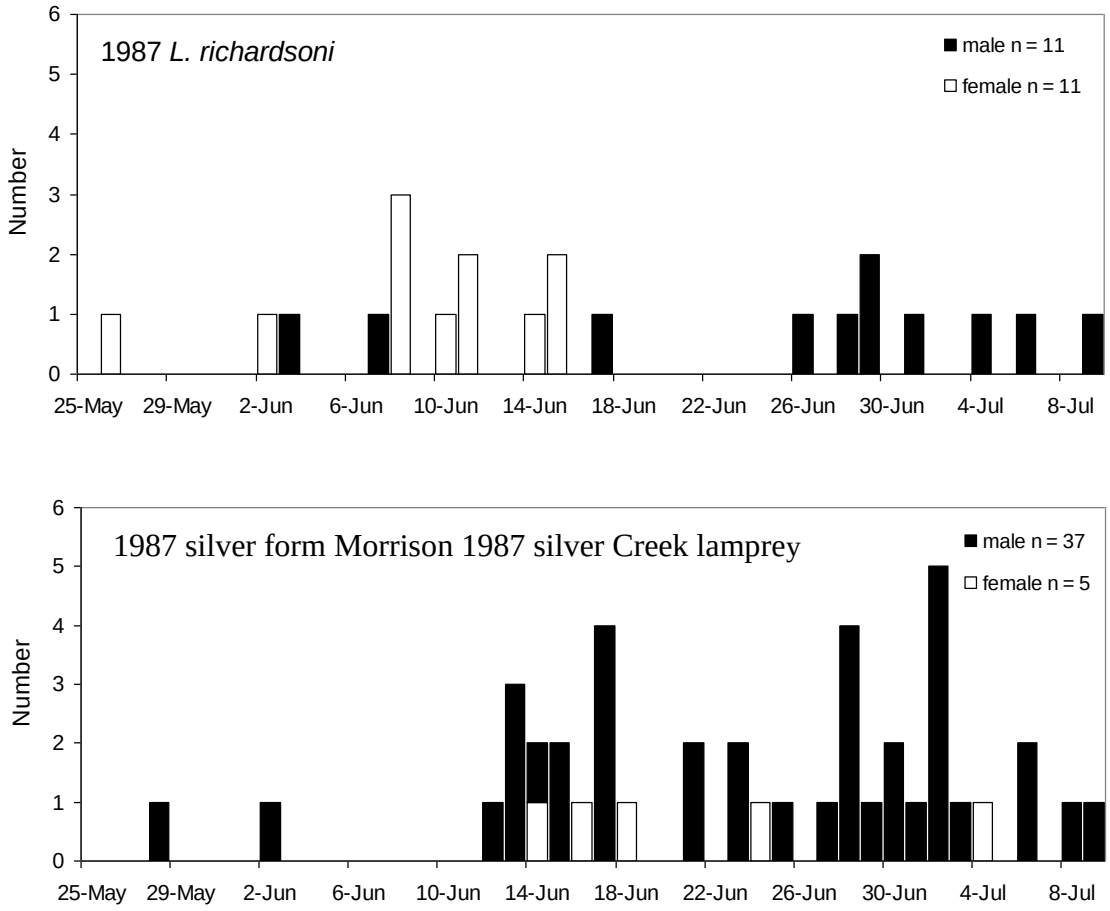


Figure 9. Daily catches of adult *L. richardsoni* and the silver form of the Morrison Creek lamprey in 1987.

Table 2. Catch of all lamprey including adults and ammocoetes of the Morrison Creek Lamprey in 1981 at Site #2, Marsden Road.

Date June	Catch	Date July	Catch	Date August	Catch
10	1	1	10	1	3
11	4	2	9	2	1
12	9	3	9	3	2
13	4	4	14	4	3
14	3	5	4	5	5
15	4	6	2	6	5
16	3	7	7	7	5
17	12	8	12	8	4
18	6	9	8	9	3
19	8	10	9	10	2
20	12	11	7	11	0
21	15	12	5	12	1
22	6	13	5	13	2
23	7	14	7	14	1
24	12	15	3	15	-
25	18	16	1	16	-
26	13	17	2	17	9
27	10	18	3	18	4
28	12	19	5	19	1
29	9	20	7	20	1
30	16	21	4	21	4
		22	7	22	3
		23	5	23	2
		24	6	24	1
		25	3	25	3
		26	5		
		27	3		
		28	2		
		29	4		
		30	5		
		31	5		
Total	**184**		**178**		**65**

A dash (-) indicates that there is no data

Table 3. Catch of all lamprey including adults and ammocoetes of *L. richardsoni* and the Morrison Creek lamprey in 1981 from Site #3, Powerhouse Road.

Date May	Catch	Date June	Catch	Date July	Catch
1	0	1	12	1	7
2	0	2	7	2	6
3	0	3	2	3	5
4	4	4	4	4	5
5	1	5	5	5	7
6	0	6	13	6	11
7	0	7	3	7	6
8	0	8	7	8	6
9	6	9	11	9	4
10	3	10	12	10	3
11	3	11	11	11	4
12	1	12	14	12	
13	1	13	6	13	
14	5	14	8	14	
15	4	15	6	15	
16	6	16	7	16	
17	13	17	8	17	
18	14	18	2	18	
19	4	19	7	19	
20	4	20	6	20	
21	8	21	11	21	
22	4	22	16	22	
23	4	23	7	23	
24	6	24	3	24	
25	7	25	8	25	
26		26	4	26	
27		27	14	27	
28		28	2	28	
29		29	4	29	
30		30	3	30	
31				31	
Total	**98**		**223**		**64**

Table 4. Catch of all lamprey including adults and ammocoetes of *L. richardsoni* and the Morrison Creek lamprey in 1981 from Site #4, First Street.

Date May	Catch	Date June	Catch	Date July	Catch	Date August	Catch
23	11	1	-	1	8	1	10
24	10	2	-	2	8	2	1
25	1	3	0	3	4	3	0
26	-	4	12	4	3	4	1
27	-	5	6	5	12	5	8
28	-	6	-	6	9	6	1
29	-	7	-	7	-	7	7
30	-	8	1	8	5	8	4
31	-	9	5	9	4	9	2
		10	8	10	2	10	2
		11	7	11	-	11	0
		12	5	12	10	12	1
		13	0	13	8	13	1
		14	2	14	6	14	0
		15	6	15	-	15	2
		16	5	16	0	16	20
		17	4	17	1	17	2
		18	4	18	2	18	0
		19	11	19	7	19	0
		20	2	20	0	20	0
		21	2	21	1	21	0
		22	1	22	4	22	0
		23	7	23	4	23	0
		24	12	24	2	24	3
		25	10	25	2	25	7
		26	0	26	6	26	2
		27	4	27	4		
		28	16	28	4		
		29	4	29	0		
		30	7	30	2		
				31	2		
Total	22		141		120		74

A dash (-) indicates that there is no data

Table 5. Catch of all lamprey including adults and ammocoetes of *L. richardsoni* and the silver form of the Morrison Creek lamprey in June, July, August and September, 1982, from Site #1, Lake Trail Road and Site # 4, First Street.

Site #1								Site #4								Catch of the Morrison Creek lamprey at both sites			
Jun	Catch	Jul	Catch	Aug	Catch	Sep	Catch	Jun	Catch	Jul	Catch	Aug	Catch	Sep	Catch	Day	Jun	Jul	Aug
1		1	4	1	0	1	0	1		1	1	1	5	1	1	1			
2		2	3	2	0	2	1	2		2	2	2	2	2	0	2			
3		3	9	3	0	3	0	3		3	1	3	5	3	0	3		9	2
4		4	2	4	2	4	1	4		4	0	4	2	4	2	4			
5		5	1	5	2	5	0	5		5	1	5	6	5	2	5			
6	16	6	1	6	0	6	2	6		6	1	6	7	6	4	6			
7	4	7	2	7	2	7	0	7		7	1	7	8	7	1	7			
8	5	8	4	8	0	8	0	8		8	1	8	2	8	0	8		4	
9	1	9	4	9	1	9	0	9		9	1	9	10	9	1	9			
10	1	10	3	10	0	10	1	10		10	0	10	6	10	1	10			
11	1	11	0	11	3	11	0	11		11	0	11	7	11	1	11			
12	0	12	2	12	0	12	0	12		12	1	12	5	12	2	12			3
13	1	13	5	13	0	13	1	13		13	0	13	2	13	2	13			
14	0	14	3	14	1	14	0	14		14	0	14	0	14	0	14		6	
15	0	15	3	15	0	15	1	15		15	0	15		15	>	15	1		
16	3	16	3	16	0	16	1	16		16	2	16	7	16	1	16			
17	0	17	2	17	0	17	0	17		17	0	17	1	17		17			
18	3	18	1	18	0			18		18	0	18	3	18		18	2		
19	3	19	0	19	0			19		19	0	19	2	19		19			
20	2	20	1	20	1			20		20	1	20	4	20		20		8	
21	3	21	0	21	0			21		21	0	21	3	21		21	2		
22	2	22	0	22	2			22		22	0	22	3	22		22			
23	2	23	1	23	0			23		23	0	23	0	23		23			
24	5	24	3	24	0			24		24	0	24	1	24		24	1		3
25	3	25	2	25	0			25		25	0	25	1	25		25			
26	1	26	2	26	0			26		26	0	26	1	26		26			

Table 6. Catches of ammocoetes of the silver form of the Morrison Creek lamprey (LM), mature lamprey believed to be *L. richardsoni* (LR), and *Entosphenus tridentatus* (ET) in May, June, July and August, 1983, from Site #3, Powerhouse Road.

Date	Catch				Date	Catch				Date	Catch		Date	Catch		
May	Ammocoetes	LM	LR	ET	June	Ammocoetes	LM	LR	ET	July	Ammocoetes	LM	August	Ammocoetes	LM	LR
24	0				1	4				1	7		1	0		
25	3	1			2	3				2	3		2	3		
26	0				3	3				3	5		3	3	5	
27	4				4	3				4	4	6	4	3		6
28	1				5	3				5	2		5	1		
29	3	1		1	6	2	4	3		6	2		6	0		
30	4				7	3				7	3		7	2		
31	6				8	3				8	4	2	8	1		2
					9	2				9	3		9	2		
					10	6	6	1		10	2		10	1		
					11	7				11	4		11	0	2	
					12	3				12	3		12			
					13	0				13	6		13			
					14	4				14	0		14			
					15	4	10			15	1	10	15			2
					16	0				16	2		16			
					17	5				17	2		17			
					18	7				18	0		18			
					19	2				19	1		19			
					20	3				20	5		20			
					21	1	7	2		21	5		21			
					22	2				22	2	5	22			2
					23	1				23	0		23			
					24	4	4			24	3		24			
					25	1				25	2		25			
					26	2				26	0	3	26			
					27	2				27	0		27			
					28	3				28	2		28			
					29	5				29	3		29			
					30	9		2	1	30	6		30			
										31	2		31			
Total	21	2	0	1		97	31	8	1		84	26		16	7	12

Table 7. Catches of ammocoetes, the silver form of the Morrison Creek lamprey (LM) and the mature lamprey believed to be *L. richardsoni* (LR) in May, June, July and August, 1984, from Site #1, Lake Trail Road.

May	Ammocoetes	June	Ammocoetes	LM	LR	July	Ammocoetes	LM	LR	August	Ammocoetes	LM	LR
29	-	1	0			1	2			1	1		1
30	3	2	0			2	2		1	2	0		
31	1	3	1			3	1		1	3	0		
		4	0			4	2			4	0		
		5	1			5	2		1	5	0		
		6	0			6	1		1	6	1		
		7	1			7	3		2	7	0		
		8	1			8	1			8	4		2
		9	0			9	2	1	1	9	0		
		10	1			10	0			10	0		
		11	1			11	0			11	1		
		12	0			12	2			12	0		
		13	0			13	0			13	0		
		14	0			14	1			14	0		
		15	0			15	2	1		15	0		
		16	1			16	1		1	16	0		
		17	0			17	1			17	0		
		18	0			18	2	1					
		19	2		2	19	2		1				
		20	1			20	3						
		21	0			21	2						
		22	2		1	22	1		1				
		23	1		1	23	3		1				
		24	0			24	0						
		25	1		1	25	1						
		26	3	1		26	0						
		27	2		2	27	0						
		28	1		1	28	1		1				
		29	2			29	0						
		30	3		3	30	2						
						31	4		1				
Total	4		25	1	11		44	3	13		7	0	3

Site #1 Totals	Ammocoetes	LM	LR	Total
May/June	29	1	11	41
July	44	3	13	60
August	7	0	3	10
All months	80	4	27	111

Table 8. Catches of ammocoetes, the silver form of the Morrison Creek lamprey (LM) and mature lamprey believed to be *L. richardsoni* (LR) in May, June, July and August, 1984, from Site #2, Marsden Road.

May	Ammocoetes	June	Ammocoetes	LM	LR	July	Ammocoetes	LM	LR	August	Ammocoetes	LM	LR
29	-	1	0			1	3		1	1	2		
30	3	2	4	1		2	1		1	2	3	1	1
31	4	3	3			3	4		3	3	3		1
		4	3			4	2	1		4	1		
		5	2			5	3		1	5	0		
		6	2			6	2		2	6	1		1
		7	3			7	1			7	0		
		8	3			8	0			8	1		
		9	2			9	3		2	9	1	1	
		10	7			10	2		1	10	1		
		11	1			11	4		2	11	2		
		12	3			12	5		3	12	2		
		13	3		1	13	2	1		13	1		
		14	4			14	4	1	2	14	2		
		15	1			15	2			15	0		
		16	1			16	4		1	16	1		
		17	3			17	5	1	1	17	0		
		18	1			18	5		2				
		19	0			19	1		1				
		20	2	1	1	20	2	1					
		21	6	1	1	21	3	1					
		22	0			22	3		1				
		23	2	2		23	3						
		24	0			24	6		3				
		25	2			25	3		1				
		26	1			26	1		1				
		27	1			27	2		2				
		28	0			28	5		1				
		29	1			29	2		1				
		30	1			30	3						
						31	2						
Total	**7**		**62**	**5**	**3**		**88**	**6**	**33**		**21**	**2**	**3**

Site #2 Totals	**Ammocoetes**	**LM**	**LR**	**Total**
May/June	69	5	3	77
July	88	6	33	127
August	21	2	3	26
All months	80	4	27	111

Table 9. Catches of ammocoetes, the silver form of Morrison Creek lamprey (LM), mature lamprey believed to be *L. richardsoni* (LR) and *E. tridentatus* (ET) in May, June, July and August, 1984, from Site #3, Powerhouse Road.

May	Ammocoetes	June	Ammocoetes	LM	LR	July	Ammocoetes	LM	LR	August	Ammocoetes	LM	LR
29	0	1	0			1	6	6		1	0		
30	5	2	2	1		2	2	1		2	1		
31	3	3	2		1	3	2	2		3	5	1	
		4	1			4	5	4	1	4	1		
		5	2	1		5	4	4		5	2		
		6	0			6	6	4		6	0		
		7	2			7	6	4		7	0		
		8	4	2		8	3	2		8	1		
		9	1			9	2	1		9	1		
		10	1			10	2	2		10	0		
		11	4			11	4	2		11	1		
		12	1			12	2	2		12	0		
		13	0			13	1			13	0		
		14	1	1		14	2	1		14	0		
		15	2	1	1	15	6	5	1	15	0		
		16	9	1	2	16	4	3		16	0		
		17	2	1		17	4	1		17	0		
		18	6	2	2	18	4	1					
		19	3			19	4	1					
		20	1			20	2	2					
		21	1	1		21	6	1	4				
		22	3	2		22	6	3	1				
		23	2			23	0						
		24	8	4	2	24	0						
		25	4	3		25	2	2					
		26	4	3		26	1	1					
		27	7	5		27	6	2					
		28	5	1	3	28	2	2					
		29	5	2	2	29	2	1					
		30	4	1		30	1	1					
						31	1	1					
Total													
l	**8**		**87**	**32**	**13**		**98**	**62**	**7**		**12**	**1**	**0**

Site #3 Totals	**Ammocoetes**	**LM**	**LR**	**Total**
May/June	95	32	13	141
July	98	62	73	167
August	12	1	0	13
All months	205	95	20	321

Table 10. Catches of ammocoetes, the silver form of the Morrison Creek lamprey (LM) and *L. richardsoni* (LR) in May, June and July, 1987, from Site #3, Powerhouse Road.

May	Ammocoetes	LM	LR	June	Ammocoetes	LM	LR	July	Ammocoetes	LM	LR
1				1	13			1	4	1	1
2	1			2	6	1	1	2	3	5	
3	7			3	5		1	3	3	1	
4	7			4	6			4	3	1	1
5	4			5	10			5	1		
6	4			6	10			6	7	2	1
7	6			7	5		1	7	2		
8	1			8	7		1	8	4		1
9	6			9	10			9	2	1	1
10	4			10	4		1	10			
11	2			11	2		2	11			
12	4			12		1		12			
13	5			13	4	3		13			
14	1			14	5	2	1	14			
15	4			15		2	2	15			
16	7			16	1	1		16			
17	3			17	7	4	1	17			
18	4			18	6	1		18			
19	2			19	5			19			
20	3			20	4			20			
21	10			21	3	2		21			
22	3			22	3			22			
23	5			23	4	2		23			
24	6			24	5	1		24			
25	6			25	2	1		25			
26	2		1	26	4		1	26			
27	4			27	4	2		27			
28	4	1		28	2	4	1	28			
29	4			29	3		1	29			
30	10			30	2	3		30			
31	27							31			
Total	156	1	1		142	30	14		29	11	5

Site #3 Totals	**Lamprey**	**LM**	**LR**	**Total**
May	156	1	1	158
June	142	30	14	186
July	29	11	5	45
All months	327	42	20	389

Table 11. Lengths of the silver form of the Morrison Creek lamprey from all sites

Year	1981	1982		1983		1984		1987
Date	May 18 – June 29	June 15 – August 24		May 25 – August 11		May 29 – August 5		May 28 - July 9
	Length (mm)	Length (mm)		Length (mm)		Length (mm)		Length (mm)
	100	105	127	102	126	103	123	95
	103	106	127	107	127	104	123	96
	104	108	128	107	127	105	123	96
	106	110	128	109	127	106	124	99
	106	111	128	110	127	108	125	101
	110	114	129	110	127	108	125	103
	112	114	129	110	128	109	126	106
	112	114	129	111	128	111	126	106
	113	114	130	112	128	111	126	108
	114	115	130	112	129	111	126	109
	117	117	130	112	129	111	127	109
	117	117	131	113	129	111	127	111
	120	117	131	113	132	113	127	111
	120	118	131	113	133	113	129	111
	121	118	131	114	134	113	129	111
	122	118	131	115	136	115	129	112
	123	118	132	115	136	115	130	112
	123	118	132	115	136	115	131	113
	124	119	132	115	136	115	132	113
	124	119	132	116	137	115	132	114
	126	119	133	118	137	117	133	115
	126	120	133	118	139	117	133	115
	126	120	133	118	141	117	133	116
	130	120	134	119	143	117	133	117
	130	120	135	120	143	117	133	117
	131	121	136	120	143	118	134	117
	132	122	136	121	150	118	134	117
	134	122	136	121	151	118	136	118
	135	122	138	122		118	137	118
	137	122	147	122		119	137	118
	137	123		122		119	138	119
	137	123		122		119	138	119
	139	123		123		121	139	119
	140	123		123		121	139	119
		123		123		121	140	119
		124		123		122	140	121
		124		123		122	141	123
		124		124		122	141	124
		124		124		122	142	124
		126		125		123	142	126
		127		125		123	142	131
		127		125		123	146	135
						123	147	
N	**34**	**72**		**70**		**86**		**42**
Average	**122.1**	**124.3**		**123.9**		**124.3**		**113.9**
S.D.	**11.28**	**8.11**		**10.68**		**10.69**		**8.84**

Table 12. Length frequencies of the silver form of the Morrison Creek lamprey (LM) and adult, non-silver lamprey in 1987 from all traps. The smallest of the non-silver lamprey are probably *L. richardsoni*

Year	1981	1982	1983	1984	1987	1987
Length (mm)	*L. richardsoni marifuga*	*L. richardsoni marifuga*	*L. richardsoni marifuga*	*L. richardsoni marifuga*	*L. richardsoni marifuga*	*L. richardsoni*
80	0	0	0	0	0	0
82	0	0	0	0	0	1
84	0	0	0	0	0	1
86	0	0	0	0	0	0
88	0	0	0	0	0	4
90	0	0	0	0	0	0
92	0	0	0	0	0	0
94	0	0	0	0	0	2
96	0	0	0	0	3	2
98	0	0	0	0	0	3
100	1	0	0	0	1	3
102	0	0	1	0	1	1
104	2	0	0	2	1	0
106	2	2	0	2	2	0
108	0	1	2	2	1	1
110	1	1	4	1	2	1
112	2	1	4	5	6	2
114	2	4	4	3	3	0
116	0	1	5	5	3	1
118	2	8	3	9	7	0
120	2	7	3	3	5	0
122	2	5	6	7	1	0
124	4	9	7	8	3	0
126	3	1	4	6	1	0
128	0	7	8	3	0	0
130	2	6	3	4	0	0
132	2	9	1	3	1	0
134	1	4	2	7	0	0
136	1	4	4	1	1	0
138	3	1	2	4	0	0
140	2	0	1	4	0	0
142	0	0	1	5	0	0
144	0	0	3	0	0	0
146	0	0	0	1	0	0
148	0	1	0	1	0	0
150	0	0	1	0	0	0
152	0	0	1	0	0	0
N	34	72	70	86	42	22

Table 13. Average daily catch of the silver form of the Morrison Creek lamprey and adults that could be *L. richardsoni* in the area of maximum abundance of the silver form (Site #3) and during the period of maximum abundance

Year	Date	Number of days	Total catch of the silver form	Average daily catch of the silver form	Total catch *L. richardsoni*	Ratio of the silver form to *L. richardsoni*
1983	June 11 - July 15	35	39	1.1	14	2.8 to 1
1984	June 15 - July 15	31	67	2.2	14	4.8 to 1
1987	June 12 - July 9	29	40	1.4	12	3.3 to 1

APPENDIX I

The Morrison Creek Lamprey, *Lampetra richardsoni marifuga* – A new assessment of its taxonomy

Description

The Morrison Creek lamprey was originally described as an intermediate form between *Lampetra richardsoni* and *Lampetra ayresii* with the variety name of *L. richardsoni* var. *marifuga*. The designation of variety is not recognized as a taxonomic rank in zoological nomenclature; however, Beamish et al. (2001) and Beamish (1985) were reluctant to propose that the lamprey was a distinct species or a subspecies because there was no evidence that the variety was reproducing in the creek where it was found. A re-examination of existing specimens and a new field study in 2011 and 2012 provided evidence that the Morrison Creek lamprey probably was spawning and reproducing in Morrison Creek (Figures 3C, 3D). Thus, in this description, the Morrison Creek lamprey is considered to be a subspecies of *L. richardsoni* with the subspecies name of *L. richardsoni marifuga*. The name *mari* from the Latin for "sea" and *fuga* from the Latin for "flight", meaning that the animal avoids the sea as it cannot osmoregulate in salt water.

The silver form of the Morrison Creek lamprey feeds and grows when brought into the laboratory. Feeding continues to the early fall and it is possible to keep some individuals through the winter and into the next spring when they spawn and produce viable eggs and young ammocoetes. The Morrison Creek lamprey is distinguished from *L. richardsoni* in Morrison Creek by its silver countershading and sharp prominent teeth at the same time that *L. richardsoni* are in spawning condition. Metamorphosed Morrison Creek lamprey are larger and probably spawn later than *L. richardsoni* in Morrison Creek. The larger size and later spawning would restrict interbreeding between *L. richardsoni* and *L. richardsoni marifuga.* The Morrison Creek lamprey has an average of 9.8 cusps (range 6-14) on the transverse lingual lamina compared to an average of 13.5 cusps (range 11-17) for *L. ayresii* and 10.5 cusps (range 9-13) for 32 *L. richardsoni* from five other locations. All means are significantly different from each other (ANOVA $p \leq 0.05$) Table 14. Comparisons of the number of cusps on the transverse lingual lamina between the species and subspecies in Morrison Creek have not been possible because the cusps in mature *L. richardsoni* are obsolete, preventing accurate counts.

The average number of cusps on the transverse lingual lamina are 7.9 for the Morrison Creek lamprey, 11.1 for the *L. ayresii*, and 8.6 for *L. richardsoni* from five different rivers. There is no significant difference between the Morrison Creek lamprey and *L. richardsoni*, but both the Morrison Creek lamprey and *L. richardsoni* have significantly fewer cusps than *L. ayressii*.

The Morrison Creek lamprey is distinguishable morphologically from *L. richardsoni* in other locations. The average disc length / total length of the Morrison Creek lamprey of 0.062 is significantly larger than the average disc length / total length of 0.046 for *L. richardsoni* from other locations (Table 15 A, B). Similarly, the prebranchial length / total length of the Morrison Creek lamprey of 0.134 is significantly larger than the prebranchial length / total length of 0.105 for *L. richardsoni* from other locations (Table 15 A, B). The morphological comparisons distinguish the Morrison Creek lamprey from *L. richardsoni* from other locations and from between *L. ayresii* and early and late spawning lamprey in Morrison Creek. The key findings were that the Morrison Creek lamprey is distinct from the sample of *L. richardsoni* from 10 other locations and there are significant differences in the body proportions between the early and late spawning forms. It is also noteworthy that all characters between the early spawning form and *L. richardsoni* from the 10 other locations were significantly different (Table 4B). It is also noteworthy that

the smaller disc, shorter prebranchial length and smaller eye of the *L. richardsoni* from the 10 locations distinguish it from *L. ayresii*.

An electrophoretic analysis that examined 21 gene loci of the Morrison Creek lamprey and lamprey presumed to be *L. richardsoni* from Morrison Creek showed that the two forms were more similar to each other than either form was to *L. ayresii* or *L. richardsoni* from other rivers. Thus, there is evidence that the Morrison Creek lamprey and *L. richardsoni* in Morrison Creek are collectively more distinct from *L. richardsoni* from other locations and *L. ayresii* than they are from each other. However, the morphological comparisons distinguished the early spawning form from the late spawning form.

What the Morrison Creek lamprey is not, is clearer than what it is. The Morrison Creek lamprey is not a natural hybrid between *L. ayresii* and *L. richardsoni* because *L. ayresii* have not been observed in Morrison Creek and the silver form of the Morrison Creek lamprey appeared each year from 1977 to 2011. The electrophoretic study, the teeth counts and the morphological comparisons, all distinguish *L. ayresii* from the Morrison Creek lamprey. Thus, the silver form of the Morrison Creek lamprey is not *L. ayresii* based on its dentition and because of differences in the body proportions. The silver form of the Morrison Creek lamprey also differs in body proportions from *L. richardsoni* from other locations but the body proportions of the silver form of the Morrison Creek lamprey are closer to *L. richardsoni* than *L. ayresii*. The larger size, silver colour in the summer, ability to feed, and later spawning time distinguishes the Morrison Creek lamprey from the non-parasitic, smaller and earlier spawning lamprey presumed to be *L. richardsoni* in Morrison Creek. The relatively large abundance of the silver form in the 1980s and the evidence of lamprey spawning later in July and August indicate that the Morrison Creek lamprey most likely is reproducing in the creek. The relative large abundance of the silver form in the 1980s indicates that the Morrison Creek lamprey are not dying before they reproduce as it would be unlikely that a life history strategy would produce relatively abundant individuals that do not contribute to the reproductive potential of a population.

Colour

Recently metamorphosed Morrison Creek lamprey have a darker dorsal than the lighter pigmented ventral area. In the spring about March, this darker area becomes a bright silver colour and the ventral area becomes a white colour. The pattern is typical of *L. ayresii* that are feeding in salt water. However, the counter shading is not as extensive as found on feeding *L. ayresii*. The counter shading disappears by about mid-August and in the laboratory by September when the animal becomes uniformly dark. Ammocoetes of the Morrison Creek lamprey have not been distinguished from *L. richardsoni* ammocoetes. However, no ammocoetes with the colour pattern reported for *L. ayresii* have been found in Morrison Creek. This is very good evidence that the Morrison Creek lamprey is much closer to *L. richardsoni* than *L. ayresii*.

Systematic notes

The Morrison Creek lamprey was originally thought to be an intermediate step in the evolution of *L. richardsoni* and given the designation of a variety *marifuga*. Recent studies have found that the Morrison Creek lamprey matured and probably spawned in the creek (Figure 3C, 3D). Thus, a new designation as a subspecies is proposed. A specimen in the University of British Columbia collection was identified as *L. ayresii* and Beamish (1980) reported incorrectly, that the silver coloured lamprey in Morrison Creek was *L. ayresii*.

Table 14. Number of cusps on the (A) transverse and (B) longitudinal lamina of the Morrison Creek lamprey, *L. ayresii* and *L. richardsoni* from five locations in British Columbia

A	Number on transverse lingual lamina														
Sample	6	7	8	9	10	11	12	13	14	15	16	17	N	Ave	SD
Morrison Creek lamprey	2	3	4	25	19	21	2	2	1	-	-	-	79	9.8[1]	1.43
L. ayresii	-	-	-	-	-	8	6	25	8	13	2	4	65	13.5[1]	1.56
L. richardsoni	-	-	-	3	13	13	2	1	-	-	-	-	32	10.5[1]	0.88

[1]All means are significantly different from each other (ANOVA $p \leq 0.05$)

B	Number on longitudinal lingual lamina												
Sample	5	6	7	8	9	10	11	12	13	14	N	Ave	SD
Morrison Creek lamprey	3	3	25	23	17	7	1	-	-	-	79	7.9[2]	1.23
L. ayresii	-	1	-	-	5	8	19	9	9	1	52	11.1	1.44
L. richardsoni	-	-	8	10	2	-	4	1	1	-	26	8.6[2]	1.77

[2]There is no difference in the mean number of cusps on the teeth of the Morrison Creek lamprey and *L. richardsoni* (ANOVA $p \geq 0.05$). All other means are significantly different (ANOVA $P \leq 0.05$).

Table 15A. Morphometric measurements for the species or populations used in this study.

Group	Species	Sample Size	Average Total Length (TL) in mm (SD)	Disc Length / TL (SD)	Branchial Length / TL (SD)	Prebranchial Length / TL (SD)	Eye Diameter / TL (SD)	Postorbital Length / TL (SD)
(1)	Morrison Creek lamprey	91	128.2 (±17.45)	0.062 (±0.0051)	0.101 (±0.0057)	0.134 (±0.0079)	0.026 (±0.0033)	0.028 (±0.0020)
(2)	*L. ayresii*	73	138.7 (±38.97)	0.067 (±0.0062)	0.100 (±0.0058)	0.138 (±0.0124)	0.030 (±0.0054)	0.026 (±0.0021)
(3)	*L. richardsoni* from 10 locations	95	136.6 (±22.83)	0.046 (±0.0065)	0.096 (±0.0059)	0.105 (±0.0094)	0.021 (±0.0026)	0.026 (±0.0021)
(4)	*L. richardsoni* spawning before mid-June	16	92.6 (±0.96)	0.061 (±0.0068)	0.106 (±0.0115)	0.134 (±0.0139)	0.031 (±0.0038)	0.031 (±0.0039)
(5)	Morrison Creek lamprey spawning in July and August	12	110.8 (±1.17)	0.055 (±0.0074)	0.093 (±0.0089)	0.113 (±0.0114)	0.024 (±0.0039)	0.026 (±0.0032)

1. determined by selecting for small size, **2**. determined by large size and late spawning

Table 15B. Results of Analysis of Variance (ANOVA) on morphometric measurements of groups used in this study. The * indicates a significant difference (ANOVA $P \leq 0.05$). NS indicates that there is not a significant difference (ANOVA $P \geq 0.05$).

Group	AverageTotal Length (TL)	Disc Length / TL	Branchial Length / TL	Prebranchial Length / TL	Eye Diameter / TL	Postorbital Length / TL
1 vs. 2	NS	*	NS	NS	*	*
1 vs. 3	NS	*	*	*	*	*
1 vs. 4	*	NS	*	NS	*	*
1 vs. 5	NS	*	*	*	NS	NS
2 vs. 3	NS	*	*	*	*	NS
2 vs. 4	*	*	*	NS	NS	*
2 vs. 5	*	*	*	*	*	NS
3 vs. 4	*	*	*	*	*	*
3 vs. 5	*	*	NS	*	*	NS
4 vs. 5	NS	NS	*	*	*	*

Distribution

The distribution is restricted to one creek on Vancouver Island, British Columbia. Morrison Creek is a small stream that originates approximately 35 km from its confluence with the Puntledge River in the city of Courtenay. The Puntledge River flows from Comox Lake into the Strait of Georgia. The Morrison Creek lamprey has not been found in the Puntledge River or in Comox Lake.

Biology

The Morrison Creek lamprey and *L. richardsoni* begin metamorphosis in July, but develop differently. *L. richardsoni* matures over the winter following metamorphosis and spawns in the spring and then dies. The Morrison Creek lamprey has a silver colour with sharp cusps in the year following metamorphosis. The silver colour is lost in the fall and the individuals mature over the winter and spawn in the late spring and summer of their second year after metamorphosis. The Morrison Creek lamprey feeds and grows when brought into the laboratory. Feeding continues through to the early fall of the year following the onset of metamorphosis. Individuals in the laboratory mature after feeding and spawn in the spring about two years from the onset of metamorphosis.

Observations in the late 1980s indicate that the silver form of the Morrison Creek lamprey were about 80% males. The gonad of most of these males was almost mature in the summer and the intestine was fully functional. It is most unusual for lamprey of any species to have a mature gonad and a fully functional intestine. The gonad development of most male Morrison Creek lamprey was more typical of the development found in the nonparasitic lamprey *L. richardsoni* in Morrison Creek. In contrast, female Morrison Creek lamprey and a few male Morrison Creek lamprey were not mature. These fish had a less developed intestine and liver. The Morrison Creek lamprey retained significant portions of the larval kidney which normally degenerates during metamorphosis. In fact, the Morrison Creek lamprey was found to be unique among holarctic lamprey because it lacked a cranial pancreas. It appeared that some Morrison Creek lamprey had not completed internal metamorphosis at the time of capture, despite having fully developed external characteristics that were typical of fully metamorphosed, parasitic forms. These abnormalities indicated that metamorphosis was not normal.

The mature lamprey believed to be *L. richardsoni* were significantly smaller (average length about 93 mm) than the average length of the Morrison Creek lamprey (about 130 mm) collected at the same time. The sex ratio of the mature *L. richardsoni* was about equal. Spawning lamprey and the silver form of the Morrison Creek lamprey were captured from late May until late August. The largest catches of the silver form in traps occurred at the end of June, usually following a heavy rain. In the 1980s, the catches of the silver form were generally larger than the catches of lamprey presumed to be *L. richardsoni*. The equal sex ratio of the early spawning lamprey, or *L. richardsoni*, and the highly skewed sex ratio of the silver form of the Morrison Creek lamprey may indicate that the population dynamics of *L. richardsoni* is more stable. It is important to note that the *L. richardsoni* in spawning condition early in the spring are also very small relative to *L. richardsoni* in other rivers. In 2011 and 2012, more, larger spawning lamprey were caught than in the 1980s. Some of these spawning lamprey were larger than the silver lamprey (Figure 3C, 3D). It is possible that these larger lamprey were mature Morrison Creek lamprey. The absence of the silver form of the Morrison Creek lamprey after late August is interpreted from the laboratory study to indicate that they were maturing in preparation for spawning in the next spring and summer lost their silver colour and began to mature in preparation to spawn in the following year. The capture of spawning lamprey in late July and August in the 1980s is now interpreted as an indication that these fish were most likely the spawning Morrison Creek lamprey that were the silver form the previous

year. It is also possible that the Morrison creek lamprey produces a silver form and a non-silver form. This would mean that some of the Morrison Creek lamprey do not have an extended parasitic phase where they remain silver in appearance during the summer and spawn in the following year. If some Morrison Creek lamprey are the silver form and some are the non-silver form, the non-silver form may spawn in the first summer following metamorphosis with the silver form spawning in the second year following metamorphosis. Both of these forms would not *be L. richardsoni*, although the non-silver form would appear to be *L. richardsoni*, except that it is larger than the earlier spawning *L. richardsoni* in Morrison Creek.

An explanation of the Morrison Creek lamprey

It is possible that the ancestral *L. richardsoni* that found its way into this drainage area developed an ability to delay maturation after metamorphosis and expand the period of potentially parasitic ability that *L. richardsoni* have for a few weeks immediately following the completion of metamorphosis in the fall. Thus, the Morrison Creek lamprey may be an example of an ability among nonparasitic lamprey to return to a parasitic life history strategy. This would indicate that the ability to evolve back to the ancestral parasitic life history type remains within the genotype of *L. richardsoni* and possibly within the genotype of other nonparasitic lamprey. The Morrison Creek lamprey may now be evolving either away or towards *L. richardsoni* in Morrison Creek. Alternatively, the Morrison Creek lamprey may represent a unique example of a population that produces two life history types and differs morphologically from *L. ayresii* and *L. richardsoni* in other locations.

Youson (2004) reviewed the research that was carried out on the Morrison Creek lamprey. He identified the following five possible explanations for the existence of the Morrison Creek lamprey: 1) the Morrison Creek lamprey is a relic of a primitive, ancestral form of *L. richardsoni*, 2) the Morrison Creek lamprey represents a midpoint or an intermediate stage in a two-step process that occurs when a nonparasitic species evolves from a parasitic ancestor, 3) the Morrison Creek lamprey represents an interval in evolution when both, paired species (*L. ayresii* and *L. richardsoni*) existed in the same habitat, 4) the Morrison Creek lamprey is separate from *L. richardsoni*, 5) there is a single, larval population that responds to environmental factors by producing two life history types. The very small size of the early spawning *L. richardsoni* is evidence that there is an environmental influence in the development of the Morrison Creek lamprey. The reduced size also occurs for the mature Pacific lamprey *Entosphenus tridentatus*, that have been captured are also small (n = 7, average size = 181 mm) relative to the sizes observed in other populations (Beamish 1982).

The reason for the success of lamprey is not understood, although I have speculated that their survival is related to their ability to change life history types through changes in their phenotype. A taxon that can live in fresh water or salt water, can feed on plankton or can parasitize other fishes is able to adapt to the extreme changes in habitat that have caused the extinction of many other species over the past millions of years including the dinosaurs. According to this speculation, a particular species of lamprey would contain a large number of genes of which only some are used to produce the particular life history type and morphology. Life history types are species-separating characteristics in lampreys and thus the genes that actively produce a particular life history type result in a distinct species. Lamprey species are maintained through homogamy which means that males and females must be of similar size to reproduce as the spawning act in lampreys requires a precise positioning of the genital structures of the male and female. In Morrison Creek, genetic isolation could be achieved because the larger Morrison Creek lamprey are not able to reproduce with the smaller non-parasitic *L. richardsoni*.

According to my speculation, the environment around a particular species can alter the genes that are active, or activate the inactive genes, resulting in changes in development and metabolism that alter the life history strategy and morphology. If a non-parasitic species retains the ability to produce a parasitic life history type, it could be this change that is occurring in Morrison Creek. The change could be adaptive by an activation of inactive genes or the change from one life history type to another may also be associated with metamorphosis. The environment in Morrison Creek, or some other factor or factors may be affecting the silvery appearance in all *L. richardsoni* to a few weeks. It is possible that disruptions during the metamorphosis result in a silver form, with sharp dentition persisting through the summer and maintaining a parasitic life history.

In fishes, it is known that the maturation processes is linked to the production of enzymes that initiate maturation or enzymes that disable the enzymes causing maturation. If the enzymes are not disabled, the fish will begin to mature. The silver form of the Morrison Creek lamprey would have the mechanism regulating maturity disabled. The disabling is imperfect and related to changes regulating maturity possibly during metamorphosis. Thus, there is a population in Morrison Creek that continues to produce the Morrison Creek lamprey resulting in the morphological differences between the Morrison creek lamprey and *L. richardsoni* in other rivers and between the Morrison Creek lamprey and the Western river lamprey *L. ayresii*.

Protection of the Morrison Creek lamprey

The life history of the Morrison Creek lamprey needs to be studied in Morrison Creek. Genetic analysis using DNA stock identification is currently being carried out among the Morrison Creek lamprey, the presumed *L. richardsoni* in Morrison Creek and *L. richardsoni* from other locations and to *L. ayresii*. Monitoring of in Morrison Creek lamprey is needed to assess the health of the populations. An immediate need is to ensure that the habitat that is critical to the survival of the Morrison Creek lamprey is protected. The unique biology and life history of the Morrison Creek lamprey identifies a need to classify the Morrison Creek lamprey. The morphometric measurements indicate that the Morrison Creek lamprey is closer to *L. richardsoni* than *L. ayresii*. Therefore, an appropriate subspecies designation for the Morrison Creek lamprey is *Lampetra richardsoni marifuga*. The designation will ensure that the Morrison Creek lamprey is recognized and protected. It may also be appropriate to consider that all lamprey in Morrison be protected.

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