U.S. Fish and Wildlife Service

Juvenile Pacific Lamprey Use of a Pollution Abatement Pond on the Entiat National Fish Hatchery

U.S. Fish and Wildlife Service
Mid-Columbia River Fishery Resource Office
7501 Icicle Rd.
Leavenworth, WA

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On the cover: Pacific lamprey macropthalmia collected from the pollution abatement pond at Entiat National Fish Hatchery. USFWS photograph by Mark C. Nelson.

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Final Report

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Abstract. – The Mid-Columbia River Fishery Resource Office investigated juvenile Pacific lamprey (*Lampetra tridentata*) use of the pollution abatement pond at the Entiat National Fish Hatchery on the Entiat River, WA. On October 28, 2004, 123 juvenile lamprey (84 ammocoetes and 39 macropthalmia) were collected from the pond. Ammocoete densities in enclosures in the pond averaged 21.8/m^2 (SD 20.5) and the estimated population size in the pond was 36,450 ammocoetes (95% CI: 3,276 - 69,624). Using ponds to rear juvenile Pacific lamprey at salmon hatcheries in the National Fish Hatchery System of the Pacific Northwest could provide a low cost and low maintenance technique to supplement or reintroduce Pacific lamprey into depleted watersheds. The redesign or construction of new abatement ponds should consider the possibility of lamprey culture. Investigations into lamprey use of the abatement pond at Entiat NFH should continue, and further studies designed, funded, and implemented.

Table of Contents

List of Figures

List of Tables

Introduction

Populations of several species of lamprey have significantly declined in the Pacific Northwest during the last few decades (Close et al. 1995, BioAnalysts 2000). The anadromous Pacific lamprey (*Lampetra tridentata*) is impacted by many of the same factors affecting Pacific salmon, including loss of habitat and barriers to migration. The basic lamprey life cycle of filter-feeding ammocoetes, out-migrating macropthalmia, ocean foraging and migration of spawning adults is known (Beamish 1980). However, the specific knowledge of Pacific lamprey biology and ecology, as well as factors limiting their populations, is lacking (Lamprey Technical Group 2005).

In the Columbia River basin, little is known of the life history and biology of Pacific lamprey (Close et al. 1995). Abundance estimates of Pacific lamprey in the Columbia River are limited to counts of up-migrating adults and out-migrating juveniles at mainstem hydropower dams (BioAnalysts 2000). In mid-Columbia tributaries, most of the information concerning Pacific lamprey comes from limited observations, unpublished data, and anecdotal information (BioAnalysts 2000, Nelson et al. 2004).

The Pacific lamprey is known to be present in the Entiat River (Meeuwig et al. 2004, Nelson et al. 2004), and information on the abundance and distribution of lamprey is of interest to several agencies and entities in the watershed (Chelan County Conservation District 2004). Larval lampreys have been found in the pollution abatement pond at the USFWS Entiat National Fish Hatchery (Bill Edwards USFWS, pers. comm.; also cited in BioAnalysts 2000). To increase our knowledge and understanding of Pacific lamprey, MCRFRO biologists investigated the use of the abatement pond by juvenile lamprey. This report summarizes the results of that investigation.

Study Area

Entiat National Fish Hatchery (Entiat NFH) is located at river km 11.2 on the Entiat River (Columbia River rkm 779) in Chelan County, Washington (Figure 1). Entiat NFH is one of three hatcheries in the Leavenworth National Fish Hatchery Complex. This complex was authorized as mitigation hatcheries for the Grand Coulee Dam- Columbia Basin Project in 1937 and re-authorized by the Mitchell Act in 1938. Currently, the Entiat NHF spring Chinook salmon program releases 400,000 smolts into the Entiat River.

The hatchery is located on 13.9 hectares of land on the west bank of the Entiat River (Figure 2). Fish culture facilities include two adult holding ponds, thirty raceways, an incubation and rearing building, six wells, a river intake structure, a screen chamber, an aeration building, and a pollution abatement pond. The abatement pond receives waste water (effluent consisting of fecal material and uneaten food) when the raceways, adult holding ponds, and tanks in the rearing building are cleaned. The abatement pond also receives surface water from the Entiat River.

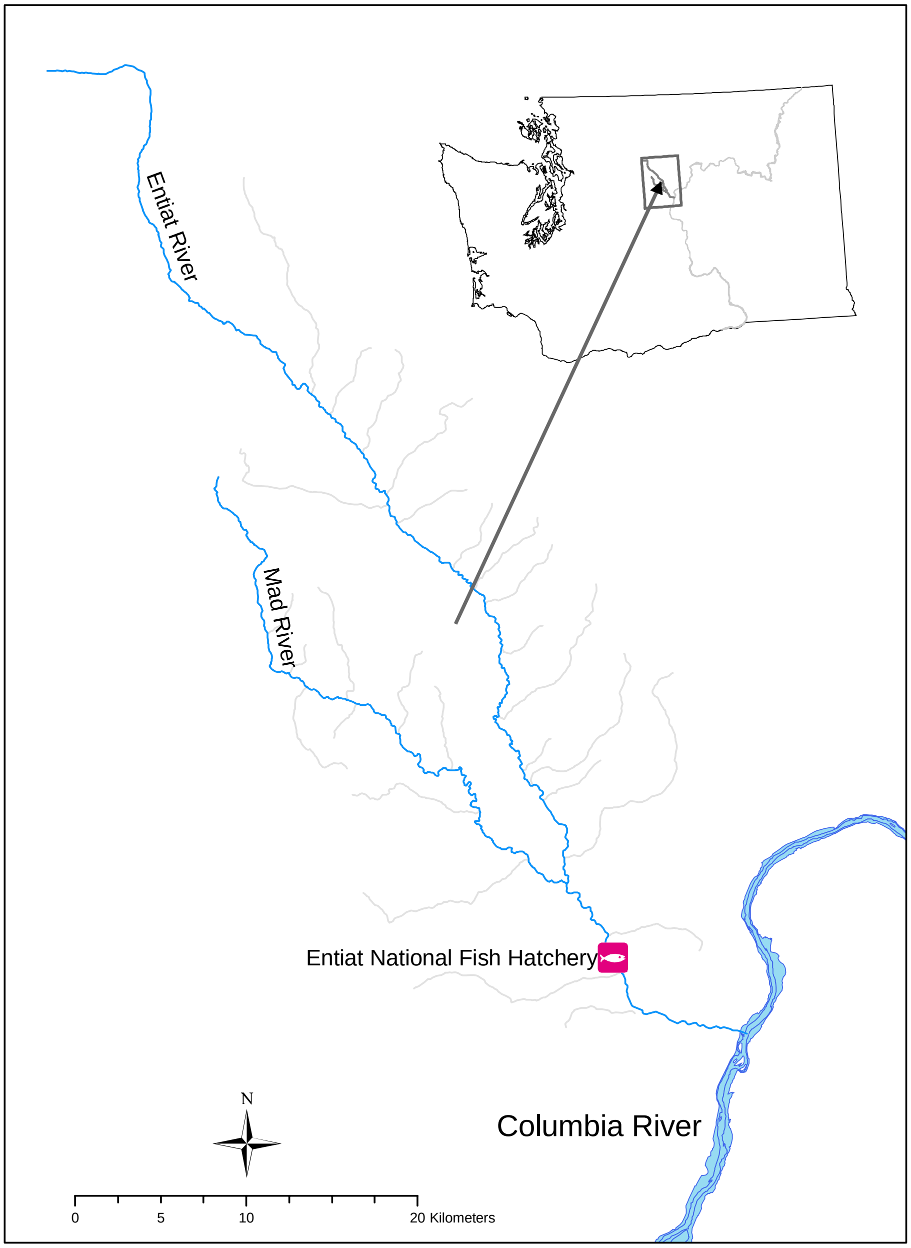

Figure 1. Location of Entiat National Fish Hatchery on the Entiat River, WA.

Figure 2. Aerial view of Entiat National Fish Hatchery.

The abatement pond was constructed in 1979 and is a single dugout earthen pond, consisting of an inlet ditch and settling basin (Figures 3 and 4). The walls of the settling basin are sloped and rip-rapped, and the ditch banks are vegetated with grass. When the raceways, tanks, and holding ponds are cleaned, waste water flows through regulated pipelines into the settling basin. Fresh surface water from the Entiat River flows through a pipeline regulated by a valve in the inlet structure at the head of the pond, over an elevated concrete sill, through the inlet ditch and into the settling basin. The ditch is 3 m x 15 m and the settling basin is 15 m x 107 m, a total area of 1,672 m^2. The settling basin is approximately 2.4 m deep, and the height of the water in the pond is maintained by a concrete wall fitted with dam boards at the outflow structure. Normally, the water flows over the wall, but the pond can be lowered approximately 1.2 m by opening a valve in the bottom of the concrete wall. This design prevents the settled effluent from draining into the river.

Figure 3. Settling basin of abatement pond, with water level drawn down.

Figure 4. Concrete inlet structure with valve, inlet ditch, and settling basin of abatement pond.

Methods

Several methods were used to collect the juvenile lamprey from the pond. The water level in the pond was temporarily lowered to expose the sediment on the banks and in the ditch (Figure 3). This enhanced the ease of collection of specimens as stranded individuals were simply picked up and swimmers were easily collected with hand nets.

A Smith Root Model 12 battery powered backpack electro-fisher was used to collect lamprey from the submerged sediment at the pond edge and in the ditch. After observing larval lamprey reaction to test shocking, the frequency was set at 30 Hz and the output voltage at 600 volts.

To estimate larval densities, we constructed 6 enclosures from four 55 gallon plastic barrels obtained from the hatchery. The barrels were thoroughly rinsed, and the top and bottom were cut off. Two barrels were cut in half to make four 38 cm tall enclosures and two barrels were left whole to create 76 cm tall enclosures. The tall enclosures (A and B) were pushed into sediment in deeper water where the ditch enters the settling basin, while the short enclosures (C, D, E, and F) were pushed into sediment in shallower water of the ditch (Figures 4 and 5). The surface area of sediment within an enclosure was 0.24 m^2.

When the pond was lowered, the enclosures were dewatered and the electro-fisher was used to collect ammocoetes inside each enclosure. Three series of electro-fishing current on (3 seconds) followed by an observation pause off (10 seconds) were repeated 3 times in each enclosure. To get a total count of larvae in the enclosures and to estimate electrofishing efficiency, the top 150 mm of sediment was removed from the enclosure and sieved through a number 16 screen to collect any remaining ammocoetes.

All collected lamprey were identified to species based on pigmentation for ammocoetes (Richards et al. 1982) and dentition pattern for macropthalmia (Wydoski and Whitney 2003), then measured (± 1 mm) and weighed (± 0.1g). Genetic samples were collected using a fingernail clipper to remove a small amount of tissue from the tip of the caudal fin (Figure 6). Samples were placed in small numbered vials containing 100% ethanol and archived at USFWS Abernathy Fish Technology Center.

The clipped lamprey were held in a live box placed in the outfall of the abatement pond and were used in trials to determine the retention of lamprey in the trap box of the rotary screw trap operated by MCRFRO. Eventually the trap will be used to estimate migration and the population size of juvenile Pacific lamprey in the Entiat River.

Figure 5. Sampling enclosures in dewatered ditch of abatement pond.

Figure 6. Clipped caudal fins of macropthalmia and ammocoete.

Results

On October 28, 2004, the abatement pond was drawn down and 123 juvenile lampreys were collected. All 84 ammocoetes and 39 macropthalmia were identified as Pacific lamprey. Of the collection methods, picking up stranded lamprey (Figure 7) was the most effective while electro-fishing was the least effective (Table 1). Several juveniles were observed swimming to deeper water and were unavailable for collection. Genetic samples were collected from 50 ammocoetes and 31 macropthalmia (see Appendix 1).

Figure 7. Ammocoete stranded on top of sediment after pond was drawn down.

Table 1. Number of Pacific lamprey collected using different collection methods.

Lamprey stage	Total collected	Stranded & Picked Up	Electro-fished	Enclosures
Ammocoete	84	62	1	21
Macropthalmia	39	35	4	0

Length of ammocoetes ranged from 26 to 177 millimeters and weight ranged from 0.2 to 8.5 grams (Appendix Table 1). Length of macropthalmia ranged from 137 to 177 mm and weight ranged from 4.4 to 8.3 g (Appendix Table 1). The frequency distribution of ammocoete and macropthalmia lengths indicates peaks at 70 mm, 120 mm, and 160 mm size classes, suggesting that three or more age classes may be present in the pond (Figure 8).

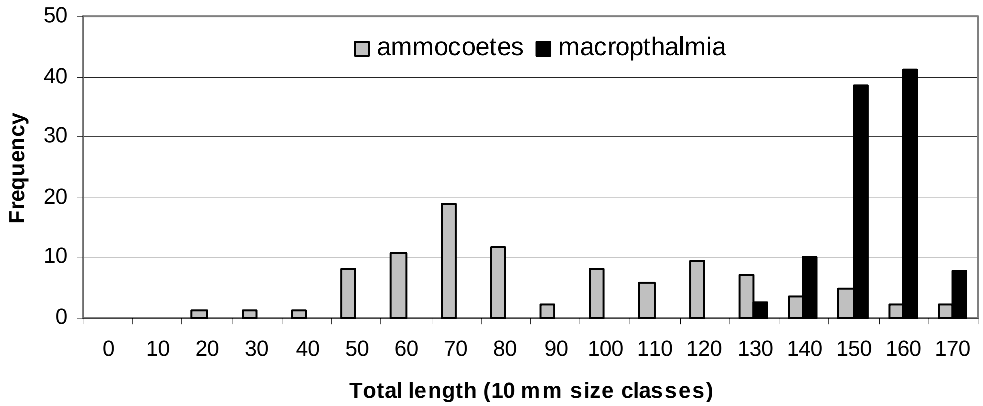

Figure 8. Frequency distribution of size classes of ammocoetes and macropthalmia collected from Entiat NFH abatement pond.

Ammocoetes appeared to use different areas in the abatement pond than macropthalmia. Most of the ammocoetes were collected in the "upstream" half of the pond, near the head of the settling basin and in the inflow ditch, while macropthalmia were collected along the sides of the "downstream" half of the settling basin. The "upstream" half of the basin was shallower and contained deeper sediment deposits while the substrate along the walls of the lower pond was primarily cobble covered with a thinner layer of sediment.

Several ammocoetes were captured in the enclosures, but none had emerged from their burrows, and sieving was most effective collection method. Electrofishing in enclosures averaged only 16% efficiency, perhaps due in part to the dewatering and the type of electrofishing unit. Enclosures A and B enclosed sediments of fine silt and mud and contained the highest densities of ammocoetes, while enclosures C and D enclosed sediments of coarse sand and contained low densities of ammocoetes (Table 2). Two enclosures (E and F) were undercut by flowing water and were not sampled. Larval densities in the enclosures averaged 21.8/m^2 (SD 20.5) (Table 2). Expansion of the mean density in the enclosures to the whole pond results in an estimated population size of 36,450 ammocoetes (95% CI: 3,276 - 69,624).

Table 2. Number and density of ammocoetes collected in enclosures.

Enclosure[1]	# Electro-fished	# sieved	Total ammocoetes	Density (#/m^2)
A	1	9	10	41.6
B	5	4	9	37.5
C	0	1	1	4.1
D	0	1	1	4.1
			Mean Density:	21.8
			Standard Dev:	20.5

1- Enclosures E and F were undercut by flowing water and not sampled.

Discussion

The two stages of juvenile lamprey require specific habitats: sediment for ammocoete burrows and cobble for macropthalmia resting/over-wintering cover (Beamish 1980). The abatement pond at Entiat NFH appears to provide both habitats, although the exact amount and distribution are unknown. Ammocoetes feed by filtering plankton, algae, and other organic material, and all are probably present in the nutrient rich water of the pond. It is not known at what stage the juveniles enter the pond, how long they reside, or when they leave, but several age classes are probably present (however, note that accurate age assignation based on length can be difficult, see Meeuwig and Bayer 2005). The mean density of ammocoetes in enclosures in the pond is similar to or greater than values reported for streams elsewhere in the Columbia River Basin (Close et al. 2001) (Table 3). The range and spatial variability of densities in the enclosures are also similar to other studies (Close et al. 2001, Close 2002) (Table 3). While the Entiat NFH observations are based on a small sample size, they suggest the pond may have the potential to rear significant numbers of lamprey and thus deserves further investigation.

Table 3. Mean densities of ammocoetes from rivers in the Columbia River Basin.

River	# of sites	Mean density (no./m^2)	SD	Range
Mainstem John Day	13	12.0	9.0	3.8-36.6
North Fork John Day	9	26.7	13.7	0.0-43.3
Middle Fork John Day	8	32.0	27.1	0.0-87.1
South Fork John Day	6	14.2	17.6	0.0-42.4
Umatilla	32	0.6	1.5	0.0-5.2
Walla Walla	5	0.0	0.0	0.0
South Fork Walla Walla	2	0.0	0.0	0.0
Tucannon	11	5.3	9.5	0.0-29.8
Grande Ronde	11	0.2	0.7	0.0-2.1

Note- Data taken from Table 2 in Close et al. (2001).

Pollution abatement ponds at hatcheries are operated under permit from the U.S. Environmental Protection Agency (EPA). EPA is expected to issue new rules for the National Pollution Discharge Elimination System (NPDES). This may require upgrades to current abatement ponds in the National Fish Hatchery System, including the possibility of redesign or new pond construction to ensure compliance with the new permits (Julie Collins USFWS, personal communication). We propose that redesign and new construction of abatement ponds consider the possibility of lamprey culture, since artificial propagation and transplantation may be necessary for the restoration of Pacific lamprey upriver of Bonneville Dam (Close *et al*. 1995, Lamprey Technical Workgroup 2005). The use of outdated, obsolete, or redesigned abatement ponds at salmon hatcheries could provide a low cost and low maintenance technique to supplement or reintroduce lamprey into depleted watersheds. Seeding larvae into this predator free and nutrient rich environment could produce high survival of lamprey, and the homing of returning adults to this “natal” stream (Beamish 1980) could re-establish a spawning population. In addition, the high densities of ammocoetes in the pond could provide a concentrated pheromone signal to induce passing adults to enter the tributary (Bjerselius *et al*. 2000, Vriese and Sorenson 2001, Yun *et al*. 2003) and re-establish or supplement the spawning population.

Lamprey are difficult to rear in laboratory conditions (Meeuwig et al. 2004) and abatement ponds could be used to rear lamprey for scientific studies on genetics, identification and life history requirements. Basic information like rates of growth, food preferences, and physiological responses to environmental stress such as disease could be investigated. Ponds could also be a location for PIT tagging macropthalmia for migration and passage studies at Columbia River hydro-electric dams.

Currently, the organic material in abatement ponds is considered waste and must ultimately be disposed. The possibility that filter feeding and subsequent excretion of fecal material into the sediment by burrowed ammocoetes may reduce nutrient levels in the water column should be explored. It may be feasible to redesign an abatement system that could exploit the nutrient potential of the waste to rear lamprey and reduce the phosphorus and nitrogen loads in the pond.

There are approximately 245 hatcheries in the Pacific Northwest, including 19 in the National Fish Hatchery System (StreamNet 2002). Ponds at these facilities could be used for the potential supplementation and re-establishment of Pacific lamprey populations. Literature and data sources should be searched to determine which species of lamprey were historically present in tributaries with hatcheries and whether lampreys are currently present. The type of abatement pond at each hatchery should be examined to determine if it is outdated or obsolete and potentially suitable for rearing juvenile lamprey. Hatchery managers should be surveyed to determine whether support may be available to implement a lamprey rearing program.

Recommendations

Specific investigations into lamprey use of the abatement pond at Entiat NFH should be continued. Studies that could be designed, funded, and conducted at the hatchery include:

1). Measurement of habitat in the pond and its suitability for lamprey.
2). Measurement of nutrient levels and productivity in the pond.
3). Assessment of the stage, entrance and residence times of juveniles in the pond.
4). Growth, survival, and transformation rates of ammocoetes.
5). Types and prevalence of diseases potentially associated with lamprey culture.
6). Determination of best design and methods of using ponds as rearing habitat.

Abatement ponds at hatcheries in the National Fish Hatchery System should be evaluated for suitability of lamprey culture, redesign and new construction of ponds should consider the possibility of lamprey culture, and any obsolete ponds should be retained for lamprey culture or off-channel habitat for anadromous species.

Acknowledgments

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The cover USFWS photograph of Pacific lamprey macropthalmia collected from the pond was taken by M. Nelson. All other USFWS photographs were taken by J. Jones and M. Cooper.

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Appendix

Appendix Table 1. Length, weight, stage, genetic sample # and capture location of all Pacific lamprey captured in the pollution abatement pond at Entiat National Fish Hatchery on October 28, 2004.

ID #	Length (mm)	Weight (g)	Stage	Genetic Sample #	Capture Location
73	84	1.4	ammo	136-62	A (sieved)
74	89	1.1	ammo	136-63	A (sieved)
75	81	1.0	ammo	136-64	A (sieved)
76	67	0.6	ammo	136-65	A (sieved)
77	65	0.5	ammo	136-66	A (sieved)
78	62	0.3	ammo	136-67	A (sieved)
79	170	7.7	macro	136-68	Shore
80	139	3.6	ammo	136-69	Shore
81	153	6.5	macro	136-70	Shore
83	177	4.6	macro	136-71	Shore
84	149	1.6	macro	136-72	shore
86	52	n/a	ammo	136-73	B (electrofished)
87	65	n/a	ammo	136-74	B (electrofished)
88	98	1.4	ammo	136-75	B (electrofished)
89	62	0.3	ammo	136-76	B (electrofished)
90	69	0.8	ammo	136-77	C (sieved)
91	73	0.7	ammo	136-78	Ditch
92	75	0.8	ammo	136-79	Ditch
93	170	7.2	ammo	136-80	Ditch
94	72	0.5	ammo	136-81	Ditch
1	155	6.0	macro	139-01	Shore
2	153	5.9	macro	139-02	Shore
3	160	5.8	ammo	139-03	Shore
4	129	3.2	ammo	139-04	Shore
5	157	6.1	ammo	139-05	Shore
6	134	4.0	ammo	139-06	Shore
7	149	5.6	macro	139-07	Shore
8	129	3.5	ammo	139-08	Shore
10	163	7.2	macro	139-09	Shore
12	162	6.5	macro	139-10	Shore
13	108	2.1	ammo	139-11	Shore
14	134	3.6	ammo	139-12	Shore
17	148	n/a	ammo	139-13	Shore
18	164	7.7	macro	139-14	Shore
19	82	1.2	ammo	139-15	Shore
20	57	0.4	ammo	139-16	Shore
21	152	5.4	macro	139-17	Shore
23	87	1.2	ammo	139-18	Shore
24	121	2.7	ammo	139-19	Shore
25	89	0.8	ammo	139-20	Shore
26	151	5.6	macro	139-21	Shore

ID #	Length (mm)	Weight (g)	Stage	Genetic Sample #	Capture Location
27	160	6.9	macro	139-22	Shore
28	73	0.7	ammo	139-23	Shore
29	177	8.5	ammo	139-24	Shore
30	62	0.4	ammo	139-25	Shore
31	161	8.0	macro	139-26	Shore
32	88	1.2	ammo	139-27	Shore
34	70	0.7	ammo	139-28	Shore
35	144	4.2	ammo	139-29	Shore
36	127	2.8	ammo	139-30	Shore
38	155	5.4	ammo	139-31	Shore
39	149	5.6	ammo	139-32	Shore
40	163	7.1	macro	139-33	Shore
41	153	6.1	macro	139-34	Shore
42	161	5.8	ammo	139-35	Shore
43	157	7.1	macro	139-36	Shore
44	162	6.3	macro	139-37	Shore
45	137	4.4	macro	139-38	Shore
46	155	5.2	macro	139-39	Shore
48	109	1.8	ammo	139-40	Shore
49	102	1.8	ammo	139-41	Shore
50	63	0.6	ammo	139-42	Shore
52	146	4.7	macro	139-43	Shore
53	153	5.1	macro	139-44	Shore
54	147	4.4	macro	139-45	Shore
55	161	6.0	macro	139-46	Shore
56	153	5.6	macro	139-47	Shore
57	170	8.3	macro	139-48	Shore
58	162	6.5	macro	139-49	Shore
59	154	6.1	macro	139-50	Shore
60	169	7.4	macro	139-51	Shore
61	153	5.4	macro	139-52	Shore
62	157	5.5	macro	139-53	Shore
63	116	2.0	ammo	139-54	Shore
64	106	1.5	ammo	139-55	Shore
65	78	0.6	ammo	139-56	Shore
66	60	n/a	ammo	139-57	Shore
67	78	n/a	ammo	139-58	Shore
68	74	0.4	ammo	139-59	Shore
70	115	2.7	ammo	139-60	A (sieved)
71	102	1.8	ammo	139-61	A (sieved)
82	164	3.0	macro	no genetic sample	Shore
1001	161	6.9	macro	no genetic sample	Electrofished
1002	161	7.0	macro	no genetic sample	Electrofished
1003	150	6.8	macro	no genetic sample	Electrofished
1004	155	6.7	macro	no genetic sample	Electrofished

ID #	Length (mm)	Weight (g)	Stage	Genetic Sample #	Capture Location
1007	165	7.6	macro	no genetic sample	Ditch
85	46	n/a	ammo	no genetic sample	B (electrofished)
1024	54	n/a	ammo	no genetic sample	Ditch
1023	57	n/a	ammo	no genetic sample	Ditch
1018	59	n/a	ammo	no genetic sample	Ditch
1006	71	n/a	ammo	no genetic sample	Ditch
1022	71	n/a	ammo	no genetic sample	Ditch
1009	72	0.7	ammo	no genetic sample	Ditch
1027	74	n/a	ammo	no genetic sample	B (sieved)
1020	75	n/a	ammo	no genetic sample	Ditch
1025	75	n/a	ammo	no genetic sample	B (sieved)
1026	75	n/a	ammo	no genetic sample	B (sieved)
1019	82	n/a	ammo	no genetic sample	Ditch
1021	89	1.2	ammo	no genetic sample	Ditch
1016	103	2.0	ammo	no genetic sample	Ditch
1013	108	2.0	ammo	no genetic sample	Ditch
1010	111	2.5	ammo	no genetic sample	Ditch
1015	112	2.3	ammo	no genetic sample	Ditch
1017	113	2.4	ammo	no genetic sample	Ditch
1012	124	2.9	ammo	no genetic sample	Ditch
1014	124	3.0	ammo	no genetic sample	Ditch
1029	125	n/a	ammo	no genetic sample	D (sieved)
1008	132	3.3	ammo	no genetic sample	Ditch
1011	134	3.4	ammo	no genetic sample	Ditch
1028	139	4.3	ammo	no genetic sample	B (sieved)
1005	150	5.4	ammo	no genetic sample	electrofished
22	167	7.1	macro	no genetic sample	Shore
47	167	7.5	macro	no genetic sample	Shore
69	26	n/a	ammo	no genetic sample	A (electrofished)
51	34	n/a	ammo	no genetic sample	Shore
9	51	0.4	ammo	no genetic sample	Shore
33	51	0.2	ammo	no genetic sample	Shore
11	71	0.9	ammo	no genetic sample	Shore
15	89	1.3	ammo	no genetic sample	Shore
16	96	1.7	ammo	no genetic sample	Shore
72	127	3.5	ammo	no genetic sample	A (sieved)
37	159	5.4	ammo	no genetic sample	Shore

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