Attachment 2

Oregon Lampreys:

Natural History
Status
And
Analysis of Management Issues

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February 25, 2002

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Executive Summary

The jawless lampreys are remnants of the oldest vertebrates in the world. Oregon has somewhere between eight and a dozen species of these primitive fishes. Their taxonomy is obscure because different species tend to look very similar through most of their life cycle, and they have not been well-studied in Oregon. Lampreys occur in the Columbia Basin, including the lower Snake River, along the Oregon coast, in the upper Klamath Basin, and in Goose Lake Basin in southeastern Oregon. They all begin life in fresh water where juveniles burrow into silt and filter feed on algae. As some species approach adulthood they migrate to the ocean or to lakes where they briefly become ecto-parasites, feeding on other live fishes by attaching to them with sucker disc mouths. Other species remain non-parasitic. In addition to some enigmatic species identities, we generally have very little information about the detailed distributions, life histories and basic biology of lampreys.

Lampreys became a conservation concern in the early 1990s when tribal co-managers and some Oregon Department of Fish and Wildlife (ODFW) staff noted that populations of Pacific Lampreys, *Lampetra tridentata*, were apparently declining to perilously low numbers. Pacific Lampreys were listed as an Oregon State sensitive species in 1993 and were given further legal protected status by the state in 1996 (OAR 635-044-0130). Lamprey status is difficult to assess for several reasons: 1) Most observations of lampreys in fresh water are of juveniles and it is difficult to tell the various species apart, even to the extent that the various species are clearly designated; 2) Data on lampreys is only collected incidental to monitoring of salmonids. The design and efficiency of the data collection effort is not always adequate for lampreys; and 3) We have very few historic data sets for lampreys. Therefore, we often cannot determine how the abundances and distributions we see now compare with those in the past.

The limited data that we have suggests that lampreys have declined through many parts of their ranges. The most precipitous declines appear to be in the upper Columbia and Snake basins where we have some historic data from mainstem dam counts. Pacific Lampreys have declined to only about 200 adults annually passing the Snake River dams. We also have evidence of declines of Pacific Lampreys in the lower Columbia and on the Oregon coast, although our data is quite limited. We have little to no information about any of the other species of lampreys. We are not even sure whether some of the recognized species, like the River Lamprey (*L. ayresi*), are still present in Oregon.

This paper concludes with an analysis of management issues for Oregon lampreys. Our biggest problem is poor information, ranging from not knowing basic species identity to having inefficient or no systematic monitoring of lamprey abundance and distribution. ODFW continued an annual harvest on Pacific Lamprey in the Willamette Basin in 2001, but we lack the necessary information to assess the affects of the harvest on the population. Major habitat problems that affect lampreys include upstream passage over artificial barriers, a need for lamprey-friendly screening of water diversions, and urban and agricultural development of low-gradient flood plain habitats.

Chapter 1

Natural History of Oregon Lampreys

Introduction:

The Superclass Agnatha, the jawless fishes, are an ancient assemblage with origins in the Ordovician Period, about 500 million years ago. Many of the first great advances in the evolution of vertebrates occurred in early agnathans, including the development of bone cells, paired limbs, sensory-line systems, dentine tissue, complex eyes and muscles, and the inner ear. The group radiated into many spectacular forms in the mid-Paleozoic, many of which were characterized by elaborate bony shields and body armor. In all cases the agnathans lacked the jaws that would later characterize all other vertebrates. With the radiation of jawed and, later, bony fishes, most agnathans became extinct. By the end of the Devonian Period (about 350 million years ago) only the hagfishes and the lampreys remained (Long, 1995). Modern agnathans lack body armor and paired fins and have simple, elongated bodies. Still jawless, they include members that are filter feeders, scavengers, and ecto-parasites. The parasitic members feed on other live fishes by attaching themselves with an oral sucker disk, cutting the host's flesh with rasp-like teeth, and feeding on the host's blood. Parasitic lampreys produce an anticoagulant to keep the blood flowing during their meal. The host is left with a round sucker scar.

Lampreys have a colored history with humans. Much of what is known about basic lamprey biology is based on research of the parasitic sea lamprey, *Petromyzon marinus*, that has been conducted as part of an extensive effort to eradicate them from the Great Lakes in North America. This species was introduced into the Great Lakes where they contributed to declines of Great Lakes fisheries. Lampreys have been viewed as a threat even where they are native and live in harmony with their own ecosystem (Farlinger and Beamish 1983, Bond and Kan 1973). Some people appear to find the parasitic behavior of some lampreys to be repulsive, a view that is perhaps also sustained by their sliminess and perceived homely appearance. However, lampreys, like all native species, have an intrinsic existence value. Many people find their macabre nature to be fascinating.

Some people also value lampreys for use as food, as a traditional source of medicines and for scientific interest. Fatty and highly nutritious, they are valued as a traditional source of food by Native Americans (Pletcher 1963, Hammond 1979, Downey et al. 1993, Close et al. 1995, Downey et al. 1996, Jackson et al. 2001). Asian people use them as a source of essential oils for traditional medicines. Pacific lampreys were harvested in large numbers at Willamette Falls during the 1940s to be used as a source of vitamins (Mattson 1949) and they have been used as a source of anticoagulants. They are also a delicacy in some European cuisine. Because of their important position in the evolutionary history of vertebrates, they are common subjects for study and dissection in college science classes.

The nutritious, slow-swimming lampreys are also a valued food for some predator and scavenger species (Close et al. 1995, Hammond 1979). Many other fishes eat lamprey eggs and early emerging larva. Older ammocoetes may be partially protected from predators by an unpalatable skin, residence in burrows, and a tendency to leave their burrows only at night (Pletcher 1963). Adults of anadromous species are eaten in the ocean by marine mammals and larger fish (Beamish 1980). Lampreys appear to be targeted by some mammalian and avian predators during migrations to and from the ocean (Roffe and Mate 1984, Merrell 1959). Adult lampreys die after spawning, feeding scavenger species like sturgeon and contributing rich nutrients to freshwater ecosystems. Observations of lampreys made at Willamette Falls in the 1800s and on the Fraser River in 1948 indicate that lampreys were historically extremely abundant at some times of the year (McDonald 1894, Pletcher 1963) and possibly their declines have lead to imbalances and disruptions in natural predator-prey systems and nutrition cycles.

Oregon has two familiar lamprey species. The Pacific Lamprey (*Lampetra tridentata*), with a distribution along the coast and inland to the Snake River Basin (Figure 1), is a large, parasitic species and has received the most management and research attention. This species was listed as an Oregon State sensitive species in 1993 due to a perceived serious decline in abundance since the 1950s (Weeks 1993, Close et al. 1995) and was given further legal protected status by the state in 1996 (OAR 635-044-0130). The little, non-parasitic Western Brook Lamprey (*Lampetra richardsoni*), with a coastal distribution and inland in the Columbia Basin to the confluence of the Snake River (Figure 2), is also recognized as a familiar species but has received little attention. Additional species have also been described in Oregon. The 1995 status review of native fish species in Oregon, conducted by Oregon Department of Fish and Wildlife (ODFW), recognized four species of lamprey in the state (*L. tridentata, richardsoni, lethophaga,* and *ayresi*) (Kostow 1995). There are additional enigmatic groups: some are formally described species but may be local variants of other species, others may be new, undescribed species. One species, the little Miller Lake Lamprey (*Lampetra minima*) was declared to be extinct in the 1970s as a result of an intentional eradication program conducted by the state of Oregon (Bond and Kan 1973). The species was rediscovered in the upper Klamath basin in the late 1990s (Lorion et al. 2000).

Species Identification Challenges:

Lamprey taxonomy and field identification has always been difficult. Species are generally identified based on adult characteristics. The most commonly used traits are adult tooth patterns and adult life history traits. The major life history traits that influence taxonomy includes parasitic versus non-parasitic, and anadromous (or adfluvial) versus resident. Spawning adult size may also be an identifying characteristic (Beamish and Neville 1992, Lorion et al. 2000).

But lampreys are adults for a relatively short period of their lives. Some species, such as the River Lampreys *L. ayresi*, are rarely seen in freshwater even if they are abundant (Beamish 1980, Beamish and Youson 1987). Juvenile lampreys, called ammocoetes or larva, are small, worm-like and eyeless, with small filter-feeding mouths, delicate gill slits and narrow fins. On casual observation they are nearly identical across all *Lampetra* species. Field keys for ammocoetes of Pacific Northwest species have been developed (Richards et al. 1982) but they are based on subtle variations in color that have been unreliable across the range of the species. Efforts to improve the keys are underway (Bayer et al. 2001). Meanwhile, ammocoetes are the most frequent life stage observed during abundance monitoring making status assessment of different species difficult.

Older ammocoetes undergo an extensive metamorphous. In a parasitic species this change leads to a life stage of parasitic feeding. In nonparasitic species the change results in a reproductive adult. The process of change can be very protracted. It begins with a year or more of retarded length growth while lipids are accumulated (Potter 1980). Near the end of that period the lamprey stops feeding and begins an extensive morphological and physiological transformation that may take from two to eight months depending on the species. All species develop eyes and more distinctive fins at this life stage. Their naso-pineal organ, sensitive to light and chemical stimulus, enlarges. The shape of the head, especially the oral disc, enlarges. As appropriate by species, there are changes in the gills, in the gut, in blood chemistry and osmoregulation, and development of the gonads (Pletcher 1963). If the species is parasitic, the rasping teeth begin to develop and at the end of metamorphous the lamprey is parasitic. If the species is adfluvial or anadromous downstream migration occurs late in this period and at the end of metamorphous the anadromous lampreys have physiologically adapted to salt water. During the process of metamorphism, characteristics are changing and can be misleading causing field identification mistakes. Most commonly, some parasitic lampreys species at early states of metamorphism are mistaken for adult brook lamprey because they have eyes but development of their parasitic oral disks is still incomplete. However, lamprey at late stages of metamorphism can be more readily assigned to species.

More difficult, the taxonomy of the genus is unsettled. Within *Lampetra*, closely related species occur in groups called “paired”, “sister” or “satellite” species. Oregon has two lamprey groups that correspond to two subgenera. These can be distinguished by adult tooth pattern and also by conserved molecular genetic markers. Subgenus *Lampetra* includes the Oregon species *L. ayresi* (which is parasitic), *L. richardsoni*, and *L. pacifica* (which are both nonparasitic). All other Oregon species are in the subgenus *Entosphenus* (Docker et al. 1999). Species within a subgenus can be very similar during metamorphism until the teeth of the parasitic forms are well developed. Mistakes of identity can even occur between subgenera during early stages of tooth development. Adults within a subgenus that have similar life histories also can be difficult to distinguish and species have been split, grouped, and split again in the systematics literature. Species within a complex may be differentiated primarily by adult size at spawning (Lorion et al. 2000). There is a question as to whether parasitism is a clear species characteristic, or whether it may be facultative in some cases (Beamish and Withler 1986, Beamish 1987). *Lampetra tridentata* has been demonstrated to be unable to persist exclusively in freshwater after access to the ocean is blocked (Wallace 1978, Beamish and Northcote 1989) while in other references, freshwater resident *L. tridentata* are described in basins with no access to the ocean (Pletcher 1963, Lorion et al. 2000). Molecular genetics data and some morphological variation suggests that species within some complexes may interbreed occasionally, or have done so in the recent past, or that some species are polyphyletic (Kan 1975, Lorion et al. 2000). One of ODFW's management actions is to describe conservation groups for management. This is difficult to do when taxonomists cannot even agree on basic species identity.

Life history data that applies specifically to Oregon lamprey, or indeed to the genera and species in the Pacific Northwest, is scant. Most basic life history studies have been of the Sea Lamprey, *Petromyzon marinus,* in the Great Lakes. The following species and life history discussions, based on the literature plus observations by ODFW staff, take a conservative approach with the understanding that further investigations to clarify species identity, population structure within species, basic life history, and basic ecology are warranted.

Early Life History

Ammocoetes from different species are difficult to distinguish. Therefore life history descriptions tend to be generalized across all species (Potter 1980, Moore and Mallatt 1980). An exception is the detailed observations of Western Brook Lamprey (*L. richardsoni*), and to a lesser extent Pacific Lamprey, made by Pletcher (1963). The major difference noted between species is the duration of the ammocoete stage. A general description of ammocoete behavior and habitat use is provided here with specifics by species, to the extent they are known, presented below. The following descriptions largely follow Pletcher (1963) and Potter (1980).

Lamprey eggs are sticky and dense and are deposited in redds by spawning adults. Upon completion of a redd, the eggs are buried beneath sand and gravel. The length of egg incubation appears to be influenced by temperature, and perhaps varies by species, and lasts between ten and twenty days. Upon hatching early larva spend another week to a month in the redd. They eventually emerge from the natal redd at night and move downstream to areas with fine silt deposits and a mild current where they burrow into the silt. At this age they are about 10 mm long. Successful spawning grounds appear to be those located in riffle/gravel areas close to pools or other silt deposits so that the initial movement into burrows by the tiny larva is successful. The burrow is U-shaped, with the lamprey's mouth at the surface of one end from where it filter feeds.

For the next three to seven years (depending on species and regional variation) lamprey ammocoetes will remain in burrows filter feeding on algae, mostly diatoms. They will move gradually down stream, moving primarily at night, seeking courser sand/silt substrates and deeper water as they grow. Older ammocoetes tend to accumulate in lower basins and flood plains. Growth rate may vary seasonally, influenced by water temperature and food supply. The most rapid increase in length occurs in the first years during which ammocoetes of most species reach about 10 cm in length. Lipid accumulation begins at about that size, and growth rate in length declines, in preparation for the non-feeding period of metamorphism. The age of ammocoetes is very difficult to determine because the species lack bony structures. Statoliths have been used to determine ages by some authors who found no significant differences in the length frequencies of several older age classes of ammocoetes (Beamish and Medland 1988, Beamish and Levings 1991).

Courtship and Spawning

Courtship and spawning behaviors of northwest lampreys have been described for only a few species and in some cases only in captivity. Pletcher (1963) described these behaviors for Western Brook Lamprey, *L. richardsoni*, in both captivity and the wild, and for Pacific Lamprey (*L. tridentata*) mostly in captivity. Beamish (1980) described the behaviors for captive River Lamprey (*L. ayresi*). There is enough similarity between these descriptions that a single discussion is provided here.

Courtship occurs on spawning gravels and involves nest-building and mutual displays that are tactile and probably chemical. Solitary males, and perhaps some females, may begin by preparing multiple rudimentary nests. Either gender may initiate courtship by way of a “courtship glide”, where one lamprey slithers along the body of a prospective mate. A receptive mate will accompany the initiator to the rudimentary nest. Initial nests may be communal, occupied by as many as a dozen individuals of both genders. Pletcher (1963) believed that receptive females emitted a chemical stimulus that attracted other lamprey. Communal courtship generally breaks into pairs or smaller groups and disperses to separate nests before actual spawning begins. The female lays in the rudimentary nest and undulates while the male performs most of the nest building. Lamprey will carry smaller rocks to the edge of the nest in their oral disks. Larger rocks may be pushed and finer substrates may be moved by rapid swimming motions.

When the lampreys are ready to spawn the male grasps the female by the back of her head and twists his tail around her. They vibrate together depositing eggs and burying them. Spawning is mostly done by pairs, but may include additional lamprey. Both polygamous and polyandrous group matings have been observed. A female will deposit about 100 to 500 eggs in each spawning bout. Between bouts, the female rests while the male departs briefly. He resumes nest building upon return, enlarging the nest upstream so that previous egg deposits are undisturbed. Another spawning bout will be followed by another rest. A female probably deposits all her eggs in about 12 hours.

Most authors believe that all lamprey die soon after spawning. The extreme physiological changes, in particular the atrophy of the gut and the filling of the body cavity with gonadal materials, seems to make life after spawning unlikely. Females have been described as living only a few hours to a week after spawning; males perhaps for a few weeks. However one author observed out-migration of several hundred apparently robust lamprey kelts on the Olympic Peninsula and detected a repeat spawning run by two marked individuals the following year (Michael 1980). ODFW staff and volunteers on the south Oregon coast believe they have seen out-migration after spawning by some lamprey.

Pacific Lamprey *Lampetra tridentata*

Pacific Lamprey is a member of the subgenus *Entosphenus*. It has the widest world distribution of any lamprey species in Oregon, ranging around the Pacific Rim from Japan and Korea to southern California, and inland in the Columbia Basin to parts of the Snake River Basin (Lee et al. 1980) (Figures 1 and 3). It is the largest lamprey, as adults, in Oregon and it is the only species that is harvested. Fisheries target fresh, migrating adults.

Pacific Lamprey is an anadromous, parasitic species with the period of parasitism occurring in the ocean. Ammocoetes live in fresh water where they are burrowing filter feeders. Lampreys undergoing metamorphism and spawning adults do not feed.

A general growth pattern for Pacific Lamprey is shown in Figure 4. They emerge from spawning gravels at about 1 cm length. Ammocoetes will grow to 17 or 18 cm, based on measurements taken by ODFW staff in a coastal (Rogue) and a Columbia basin (Umatilla) river (Figure 5). The upper range of ammocoete sizes published in the literature include 17 cm (Beamish and Levings 1991), 16.5 cm (Hammond 1979), and 15.8 cm (Kan 1975). Beamish and Levings (1991) reported that the length of older ammocoetes, aged as 5 or 6 years old by statoliths, did not differ significantly. The age of ammocoetes in Oregon is unknown and may vary regionally with older individuals in colder water or in more inland basins. Hammond (1979) believed that lamprey ammocoetes in Idaho (Clearwater River, Snake Basin) were up to 7 years old.

Metamorphism of Pacific Lamprey is reported in the literature as occurring in July through November with out-migration to the ocean occurring November through June, peaking in the spring (Richards 1980, Beamish 1980, all observations in Canada). However, lampreys in apparently early stages of metamorphism have been observed by this author in the lower Columbia River (Scappoose Creek) in early June (enlargement of the oral disc but incomplete eye development). Pletcher (1963) and Kan (1975) were ambiguous about the time of metamorphism in Pacific Lamprey, with occurrence of it observed nearly year-round. Possibly the period of metamorphism is long, or it may vary regionally. Lampreys do not feed during metamorphism since extensive changes in the gut are occurring. Rather they live on lipid reserves, and some individuals may shrink in size. Figure 5 demonstrates the large overlap in size between ammocoetes and eye lamprey. Eyed lamprey on the Rogue ranged from 11 to 17 cm, while on the Umatilla they ranged from 8 to 22 cm. Reports in the literature include ranges of 10 to 12 cm (Beamish and Levings 1991), 10 to 13 cm (Beamish 1980), 8 to 14 cm (Richards 1980), and 10 to 17 cm (Hammond 1979, van de Wetering 1998).

According to the literature, most down-stream movement by lampreys occurs at night (Potter 1980, Beamish and Levings 1991). Timing of migration may be sensitive to temperature cues. Both eyed lamprey and ammocoetes will migrate. Ammocoetes move progressively down stream, eventually accumulating in the lower parts of basins while eyed lampreys are going to the ocean (Richards 1980, Beamish and Levings 1991). Dates of out-migration of both ammocoetes and eyed lamprey, as observed by ODFW staff, are provided in Figure 6. The data is compromised in most examples because

trapping did not occur in the fall or winter. The exception is the Umatilla, where monitoring occurred year-round. Out-migration on the Umatilla clearly occurs in winter to early spring, with no observations of eyed lamprey after the end of March (Figure 6a.). Out-migrating juvenile lamprey have been monitored at the John Day Dam juvenile by-pass since 1988. Time of passage is largely in the spring (Figure 6b); however, again no monitoring occurred at John Day in the winter. The Umatilla and John Day Dam monitoring sites are very near each other, since the Umatilla River enters John Day Pool. A comparison of the John Day Dam and Umatilla passage times suggests that perhaps more lamprey are passing John Day earlier in the winter but are undetected (Figure 6c).
Lower in the Columbia at Fifteenmile Creek, out-migration, likely of a mix of ammocoetes and eyed lamprey, occurred March through June (Figure 6d.), while on the lower Willamette outmigration peaked in May (Figure 6e), although again in both cases there was no winter monitoring. All of these observations are probably of Pacific Lamprey.

On the Oregon coast, ammocoetes and eyed lamprey were captured well into the summer, as late as August (Figures 6f-g). These samples were likely a mix of lamprey species. One cannot dismiss the possibility that out-migration is also occurring in these basins in the winter or fall. According to van der Wetering (1998) metamorphosed Pacific Lampreys in Tenmile Creek were captured primarily in the fall and winter, peaking in November. Lampreys captured in the upper Rogue were primarily ammocoetes. Some numbers of them were moving downstream throughout the monitoring period, with two big peaks in the spring (Figure 6h.). A small historic data set from the early 1960s is available from the same area in the upper Rogue. Lampreys were present in those years in more substantial numbers well into summer (Figure 6i). The historic traps were not monitored from late fall through early spring and one cannot dismiss the possibility that lamprey were also present during those months. However the recent traps were monitored through the summer but detected few lampreys.

Another interesting piece of information from the out-migration timing is the extreme episodic nature of the data. On both the Rogue and on the Umatilla, massive peaks of out-migration of both eyed and ammocoete lamprey occurred over just a few days in particular years. Such striking peaks were not seen every year. The two data sets are quite large and yet are dominated by these few episodes. These events corresponded to years with very high peaks in abundance (see discussion in the status section, below).

Pacific Lamprey enter salt water and become parasitic, feeding on a wide variety of fish and also on whales. In turn marine mammals and larger fish eat them. They move quickly off-shore, into waters up to 70 m deep (Beamish 1980). Specimens have been caught in high seas sampling. The length of time spent in the ocean is not known. Authors have estimated ocean residence could be as short as 6 months and as long as 40 months (Kan 1975, Richards 1980, Beamish 1980). Several authors speculate that Pacific Lamprey adults vary in size as distinct phenotypes and that the larger individuals are ones that move further off shore and spend more time in the ocean (Pletcher 1963, Beamish 1980). Samples of Pacific Lamprey collected in the ocean ranged from 13 to 72 cm (Beamish 1980).

Pacific Lamprey are reported to return to fresh water between April and June in Canada and on the Oregon coast (Kan 1975, Beamish 1980, Richards 1980), but are reported to enter the lower Columbia River as early as February (Kan 1975). Observations by ODFW staff indicate that lamprey peak in numbers at Willamette Falls and at Fifteenmile Creek (Figure 6d) in May and June, while coastal lamprey are present from February into August (Figure 6e-f). Long migrations, such as up the Columbia and into the Snake, can continue as late as September. After entering fresh water and completing part of their migration, Pacific Lamprey are thought to over-winter before spawning. Bayer (et al. 2000) observed that adult lampreys in the John Day River, tagged upon their arrival in August, hid under boulders and were sedentary until the following March, when they moved onto spawning grounds.

Pacific Lamprey do not feed after entering fresh water and persist through the winter until spawning by using lipid reserves. Over this period they may shrink up to 20% (Beamish 1980). Therefore measurements of adult size can be variable, depending on when the sample was taken. Measurements of adults in the literature include 39.3 to 62.0 cm (migration) and 33.2 to 54.2 cm (spawning) (Kan 1975), 16.7 to 36.0 cm (Richards 1980), 61.0 to 72.5 cm (migration) (Bayer et al. 2000), 13 to 72 cm (Beamish 1980), and 19.3 to 45.0 cm (Pletcher 1963). ODFW staff have measured sizes of adult Pacific Lamprey during spawning on the South Fork Coquille, south Oregon Coast (Figure 7a-b.) and at Willamette Falls during migration (Figure 7c-d.). The spawning Coquille lampreys are somewhat smaller than the migrating Willamette lampreys. Later spawning Coquille lampreys tend to be the smallest in the sample. The sex ratio at Willamette Falls was similar for males and females, and the length/weight distribution of the adults indicated the genders are of about equal size at migration.

Several authors have reported the occurrence of “dwarf races” of Pacific Lamprey in coastal streams in Canada (Pletcher 1963, Beamish 1980). ODFW staff and volunteers have also reported seeing “dwarf” tridentata-like lamprey on the south Oregon coast. These are discussed further in this section under enigmatic species.

Lampreys are observed to spawn in the spring between April and July in Canada (Richards 1980, Beamish 1980), and March through May on the Oregon coast (Kan 1975). ODFW staff on the Oregon coast and in the Willamette Basin note that Pacific Lampreys are spawning at the same time as winter steelhead, from February through May. Lamprey select spawning gravels just upstream of riffles and often near ammocoete habitats (silty pools and banks). They may be attracted to chemical stimuli produced by ammocoetes. Pacific Lamprey can be quite fecund, but highly variable. Estimates of fecundities reported in the literature range from 15,500 eggs/female to 240,000 eggs per female (Pletcher 1963, Kan 1975). ODFW staff have not measured lamprey fecundities.

Studies of sea lamprey (*Petromyzon marinus*) in the Great Lakes have indicated that lampreys have essentially no homing behavior (Bergstedt and Seelye 1995). In this study, marked out-migrating lampreys did not favor their own natal streams. Instead, the adults may have been attracted to concentrations of ammocoetes, detected by chemical stimuli. This has led to speculation that Pacific Lamprey also have no homing behavior and therefore essentially no population structure. However, several authors have noted patterns of geographic differences in Pacific Lamprey. Kan (1975) detected morphological differences between coastal and inland Columbia Basin lampreys. Both Pletcher (1963) and Beamish (1980) speak of "regional differences" among lamprey. Hammond (1979) noted that lamprey in the Snake River, an extreme inland population, may have a longer freshwater residence as juveniles than what is reported for other populations. Certainly there are behavioral differences between lamprey that migrate only a few kilometers up a coastal stream, and one that migrates a considerable distance to the Snake River. Some of the variation may be environmental. Growth patterns and many behaviors are reported to be sensitive to temperature (Pletcher 1963, Potter 1980). The lampreys that were studied by Bergstedt and Seelye (1995) were exotic to the study area, and lived entirely in freshwater, and of course it was a different genus. It is not clear how the results extrapolate to Oregon lamprey species in their native Pacific northwest habitats.

Western Brook Lamprey *Lampetra richardsoni*

The non-parasitic Western Brook Lamprey is in the subgenus *Lampetra*. It is recognized as the second most common and widely distributed lamprey in Oregon (Figures 2 and 8). Coast-wide, it's distribution ranges from California to British Columbia (Lee et al. 1980), and it is reported inland in the Columbia basin as far as the Yakima. ODFW staff has no information about this species, although some brook lamprey are likely included in samples of ammocoetes and eyed lamprey collected in the lower Columbia River and on the coast. Fortunately, very detailed life histories and behavior observations of Western Brook Lamprey were made by Pletcher (1963) on a small tributary of the lower Fraser River in Canada. The following information is entirely based on this work. Many of the behaviors noted are temperature sensitive and dates of occurrence may be somewhat different in Oregon.

Western Brook Lamprey spawn in the spring, producing redds in small gravels upstream of riffles. The hatching of eggs is temperature-sensitive, taking longer in colder temperatures. Hatching under the conditions observed in Canada took 15 to 20 days. Larva remain in the redds an additional 30 days until they are about 7 to 10 mm long. Emergent lampreys are eyeless, but they are very light sensitive due to a well-developed pineal gland. They emerge at night and then promptly moving to silty areas to burrow. After they enter their first burrows they develop a protective mucus layer over their skin and their skin becomes very distasteful. These characteristics, plus their tendencies to move at night, provide considerable protection against predators.

Brook lampreys distribute themselves within a creek system according to size. Smaller ammocoetes are further upstream and are in finer silt deposits and in shallower waters. They require gentle currents, but not stagnate water. Larger ones migrated gradually down stream, choose substrates that are more sandy and rich in organic litter, and tend to be in deeper waters. Like all known lamprey ammocoetes, they are filter feeders with a diet that is largely diatoms. Growth is most rapid in the first 1 to 3 years. Older ammocoetes grow much slower. In the year before metamorphous, some may not grow at all or may shrink in length (Figure 9). This growth pattern makes aging ammocoetes very difficult. They likely undergo metamorphism after four to six years.

Western Brook Lampreys in Canada undergo metamorphism between August and November. During this stage they are in burrows in water that is deeper than 1 meter and they do not feed. During this several months of rapid change the lampreys develop their eyes, there is enlargement of the oral disc, changes in the gills, and enlargement of the naso-pineal gland which is used for light and chemical detection. Internally there is a reduction of the gut. Development of the gonads occurs later, closer to spawning.

After this few months of rapid change the Western Brook Lampreys apparently enter deep burrows and become dormant. They remain in these burrows from December to March, or until they are ready to spawn. Readiness to spawn is temperature sensitive and they will remain burrowed until water temperatures rise above 10 degrees C. When they emerge they are sexually mature and range in size from 8 to 17 cm. They may migrate short distances to spawning gravels then promptly begin courtship, nest building and spawning. Spawning occurs from April to July in Canada. Fecundity, measured in the Willamette Basin, ranged from about 2,500 to 5,500 eggs per female (Kan 1975). After spawning the lampreys die. Females die about a week after all their eggs are deposited. Males may live a month after spawning.

Western Brook Lampreys appear to move about very little during their lives. The most notable movement is passive downstream movement when they leave their burrows. Brook lampreys have not been tested for saltwater tolerance, but the anadromous lampreys are only tolerant at the end of their metamorphism when they actually enter the ocean. At the end of metamorphism brook lampreys are ready to spawn and it is likely they are never saltwater tolerant. This combination of low vagility and probable saltwater intolerance is likely to have produced significant population structure among Western Brook Lampreys, especially along coastal areas. Many populations are likely in complete isolation and have been so for thousands of years.

River Lamprey *Lampetra ayresi*

The small parasitic River Lamprey is in the subgenus *Lampetra*, and is the sister-species of the Western Brook Lamprey. The distribution of River Lamprey extends from the Sacramento River to SE Alaska, and inland in the Columbia River to the Columbia Gorge (Figure 10) (Kan 1975, Lee et al. 1980). ODFW staff do not believe they have observed this species in many years and have no information about it. This lack of observations may be because the species is very rare, but another possible factor is that the species is very difficult to find in fresh water (Beamish 1980, Beamish and Youson 1987). River Lampreys spend most of their life in fresh water. However, except for the changes that occur during the last six months to one year of life, *ayresi* and *richardsoni* are indistinguishable. This similarity holds even through most of the period of metamorphism. In the spring following metamorphism, Western Brook Lamprey emerge from burrows ready to spawn while the River Lamprey finally complete development of their feeding oral discs and enter the ocean to feed. During the brief periods that River Lamprey are distinctive in fresh water they are not seen, probably because they are in deep water habitats in the mainstems of larger rivers (Beamish and Youson 1987).

The little information that is available about River Lamprey is from observations in the Fraser River and Georgia Straight in Canada (Beamish 1980, Beamish and Youson 1987). No information is available about their early life history, nor is the duration of this period or the habitats in which it occurs known.

Metamorphism occurs over a very long period, from July to April. Their distinctive oral disc is the last feature to develop and is completed just before the lampreys enter the ocean. By that time the lampreys have apparently entered main river channels and are in deep waters, three to six meters deep, just upstream of saltwater influence. At this time they may be caught in freshwater trawls low in river mainstems (Beamish 1980). They are about 12 cm long. They have also been found in samples of dredge spoils from the Fraser River. They are only found in spoils that were taken from sandy substrates high in organic material from the mainstem of the river.

River Lamprey enter salt water between May and July and promptly begin feeding. In the ocean, they are strictly surface-feeders and are not caught in mid-water or deep-water sampling. They remain very close to shore; in Canada they never leave the Georgia Straight and are found mainly near the mouths of the rivers that produced them. Their main diet is of smelt and herring. They may be more predatory than parasitic, consuming large parts of their prey. They also may be scavengers since they readily feed on dead fish. River Lamprey remain in the ocean for only about ten weeks. They leave salt water in September when they are about 25 cm long (Beamish and Youson 1987). It is assumed they spawn the following spring, although adults are almost never seen in freshwater. Kan (1975) reported spring spawning in Oregon and California and provided fecundity measurements ranging from 11,400 to 174,000 eggs per female, taken from the Columbia and the Sacramento.

Beamish (1980) noted that River Lamprey production appears to be concentrated only in particular rivers. They appear to prefer larger rivers, including the Fraser, Columbia, and Sacramento (Kan 1975), although samples have also been taken from smaller Oregon coastal streams (Figure 10). Since they do not move far from the estuaries of their natal rivers when they are in the ocean they probably return to those rivers to spawn so that the River Lamprey likely has a considerable degree of population structure.

Enigmatic Lamprey Species on the Oregon Coast and Lower Columbia

A third lamprey species in the subgenus *Lampetra* has been described by Vladkov (1973), as the Pacific Brook Lamprey (*Lampetra pacifica*). This species has a described distribution that includes Oregon and northern California (Vladkov 1973, Lee et al. 1980). The species was described based on morphological differences between *pacifica* and *richardsoni*, with particular emphasis on a difference in the number of trunk myomeres between the species (fewer in *pacifica*). Adult Pacific Brook Lamprey were described as ranging in size from 9 to 17 cm (pre-spawning), shrinking to 9 to 14 cm at spawning.

Samples of this species are in the Oregon State University (OSU) fish collection (Figure 11), collected from the Willamette River and Oregon coast. Kan (1975) disagreed with Vladkov (1973) and did not believe *pacifica* was distinctive from *richardsoni*. The American Fisheries Society believes the two species are synonymous based on Kan's argument. However the amount of actual information on this subject in Kan (1975) is very scant and is apparently based on his re-examination of some of the OSU collections. In particular, he did not re-examine any of Vladkov's original collections.

Two other enigmatic lampreys are present on the south Oregon coast. One is an apparently very small non-parasitic lamprey. It has been observed by this author and by other ODFW staff in coastal streams from about the Coquille River south. Observations have been of tight balls of perhaps 15 to 20 small adults less than 10 cm long. These have been disturbed during electroshocking from under stream banks and logs in steep gradient streams – which are not expected brook lamprey spawning habitats. There is no mention of such a small lamprey in such habitats or in such large aggregations in the literature.

The second enigmatic "species" is a small parasitic *tridentata*-like lamprey that has been closely observed in the Coquille River. Siletz tribal members also described a second small lamprey on the Oregon coast (Downey et al. 1993). The oral discs and dentition of these smaller lamprey are similar to those of Pacific Lamprey. Initially these smaller adults were dismissed as shrunken spawning or post-spawning Pacific Lamprey that appeared "small" in comparison with fresh migrating adults. However, closer observations by ODFW staff and volunteers indicate that both the larger and smaller parasitic adults are spawning in the same season. In these observations, the larger lamprey spawns first and then dies while the smaller one spawns a bit later and then migrates back downstream. A photograph of the two lampreys, both spawners, taken by an ODFW volunteer on the Coquille, is shown in Figure 12. The larger specimen is about 55 cm long while the smaller one is about 37 cm long.

"Dwarf" Pacific Lampreys have been described in Canada as being in the lower portions of coastal streams by both Pletcher (1963) and Beamish (1980). These included even smaller adults, as small as 13 to 20 cm (Pletcher 1963, Richards 1980, Beamish 1980). Beamish further speculated that some of these may spawn the same spring they enter freshwater, which would be a very unique life history. The observation by ODFW staff that the smaller lamprey migrate back to the estuary echoes the observations of Pacific Lamprey kelts described on the Olympic Peninsula by Michael (1980). Different sizes of spawning adults have been identified as a reproductive isolating mechanism between otherwise very similar species (Beamish and Neville 1992, Lorion et al. 2000). The rational is that the spawning behavior, where the male lamprey adheres to the head of the female and wraps his tail around her body, is effective at achieving fertilization only when the male and female are of similar size. Most measurements within a population of *tridentata* have demonstrated similar sizes of males and females (for example, Figure 7d).

This author believes that each of these enigmatic coastal lampreys merit further taxonomic investigation.

Pit-Klamath Brook Lamprey *Lampetra lethophaga*

The nonparasitic Pit-Klamath Brook Lamprey is a member of the subgenus *Entosphenus* and is considered to be the nonparasitic sister species of the Pacific Lamprey. The described distribution of this species is the upper Klamath Basin above Klamath Falls in SE Oregon and the upper Sacramento Basin, including the Pit River in northern California and Goose Lake Basin in SE Oregon (Lee et al. 1980). Collection locations from Oregon are shown in Figure 13. Kan (1975) stated that this species might have a polyphyletic origin, although specific reasons for this were not given. Genetics investigations conducted by ODFW, in cooperation with Dr. Margaret Docker, indicate that the populations in Goose Lake Basin and Klamath Basin are likely different species. The Goose Lake lampreys are discussed separately below.

The life history of this species is unknown, beyond being nonparasitic, apparently resident, and with filter feeding ammocoetes. Kan recorded ammocoetes up to 20 cm. This species appears to have a long period of metamorphism (Kan 1975). It likely spawns in the spring, although Kan described reproductive individuals as being present into October. Fecundity measurements ranged from 900 to 1,100 eggs per female. Adults are described as being 10 to 20 cm in length (Kan 1975).

Klamath River Lamprey *Lampetra similis*

The parasitic Klamath River Lamprey is a member of the subgenus *Entosphenus* and is a sister species of the Pacific Lamprey. The described distribution of this species is the upper Klamath Basin, down river to Copco Dam (Lee et al. 1980). Collection locations from Oregon are shown in Figure 14.

Details about the life history of this species are largely unknown. It is parasitic and non-anadromous. It may include resident, riverine individuals as well as those that are adfluvial into lakes, reservoirs, and marshes. Kan (1975) (who believed this was a subspecies of *tridentata*) described the ammocoetes and metamorphosing life stages to be very much like *tridentata*. However adults are much smaller, ranging in size from about 16 to 20 cm (Kan 1975, Lorion et al. 2000). Kan (1975) believed they metamorphosed in the fall, were parasitic in Klamath Lake for about 12 to 15 months, and spawned in the spring. He measured fecundities ranging from 8,000 to 18,000 eggs per female.

Miller Lake lamprey *Lampetra minima*

The infamous little Miller Lake Lamprey is a member of the subgenus *Entosphenus*. It appears to be most closely related to the nonparasitic *lethophaga.* This species was originally believed to be endemic to the Miller Lake subbasin, a lake/creek system that was isolated from the rest of upper Klamath Basin about 6,600 years ago by the Mount Mazama eruption (Figure 15). The only other fish naturally present in Miller Lake was the Tui chub (*Gila bicolor*), which was the natural host for this small parasitic lamprey (Kan 1975, Lee et al. 1980). The species, and its tui chub host, were intentionally extirpated from Miller Lake by Oregon Department of Fish and Wildlife in 1958 through chemical treatment of Miller Lake with Toxaphene. The reason for the treatment was that the lampreys were scaring hatchery trout that had been planted in the lake, leading to complaints from sports fishers. The species was formally described in 1973 using old collection samples and was declared extinct (Bond and Kan 1973).

The Miller Lake Lamprey in Miller Lake is considered to have been one of the most unique lamprey in the genus. Unlike any other parasitic lamprey, adults were smaller than late-stage larva. At metamorphism the lamprey were about 14 to 15 cm, but by the time they reached spawning they were only about 9 to 11 cm (Bond and Kan 1973, Kan 1975, Lorion et al. 2000). This shrinkage during the parasitic phase, a time of extensive growth in all other parasitic lamprey, was thought to occur because the tough, scaly tui chub was difficult prey for the little lamprey. Miller Lake Lampreys were thought to also be scavengers and cannibalistic; basically eating whatever was available. Possibly they were also able to spawn without ever feeding, although they were always capable of feeding unlike a true nonparasitic lamprey. The parasitic phase was very brief, lasting only three or four winter months between a fall metamorphism and spring spawning. Migration either did not occur, or was over a very short distance. Fecundities were low because of their small size, ranging from 500 to 725 eggs per female. They were largely lacustrine, with lentic spawning and ammocoetes rearing in the lake, although adfluvial members also used Miller Creek (Kan 1975).

The Miller Lake Lamprey was rediscovered in the 1990s in several separate incidences by US Forest Service and Oregon State University (OSU) staff. The species was redescribed and declared to be extant with an expanded distribution that includes Miller Lake basin, upper Klamath Marsh and the Klamath River above the marsh, and Sycan Marsh and the Sycan River above the marsh (Lorion et al. 2000). It is not known whether all the unique life history characteristics described as occurring in Miller Lake by Kan (1975) are present when the species resides in marshes or riverine habitats.

Enigmatic Lamprey Species in Klamath Basin

There are two other species recognized in the upper Klamath Basin, in addition to *lethophaga, similis,* and *minima.* Both are in the subgenus *Entosphenus.*

The first of these is the nonparasitic lamprey *Lampetra folletti*, described by Vladykov and Knott (1976) but not otherwise known. The distribution of this species is described as Lost River and the Klamath Basin around lower Klamath Marsh near Klamath Falls.

The interesting morphological features of this species is its large size and an oral disc and dentition that is more highly developed than in most other nonparasitic species. Adult sizes range from about 18 to 23 cm, which is larger than *lethophaga* (Figure 16).
Kan (1975) was unaware of this species but did describe several specimens that he thought were deviant from other Klamath lampreys. These were larger than *lethophaga* and because of their more highly developed dentition he thought they might be parasitic, although he was not sure. One of these was collected from Goose Lake Basin.

It is currently not known whether *folletti* is present, or ever was present. OSU does not have any specimens of these in their collections; Vladykov's collections are at the University of Ottawa, Canada. Lost River, an isolated subbasin of Klamath Basin, has been known to have other endemic species such as the Lost River Sucker (*Deltistes luxatus*). It is a highly developed and impacted basin due to agricultural and irrigation development. An investigation into the existence of this species is warranted.

The second enigmatic species is a relatively large parasitic species currently called *Lampetra tridentata* (Lorion et al. 2000) but likely a separate species. It is entirely freshwater while true *tridentata* typically will not persist when it is blocked from saltwater migrations (Wallace 1978, Beamish and Northcote 1989, and observations by ODFW staff). This species is the largest lamprey in Klamath Basin, although it is much smaller than the *tridentata* on the Oregon coast or in the Columbia Basin, with adults ranging in size from about 15 to 25 cm. It is parasitic and adfluvial, migrating into Klamath Lake. It seems to be primarily in the lower Sprague River. Other details of its life history are not known.

Genetics evidence from Dr. Margaret Docker indicates that the entire complex of Klamath lampreys is capable of occasional interbreeding, or that hybrid events occurred in the past. The morphological and life history characters of the various species appear to be stable for the most part. However, Kan (1975) thought he detected intermediate forms that suggested to him a polyphyletic origin for at least some of the species and he thought they might be capable of hybridizing. Docker's work discovered that variation at highly conserved gene regions that are typically good species markers were shared across some species and were variable within some populations (also Lorion 2000). In some cases, local populations were remarkably polymorphic at gene region et al. that otherwise do not vary across entire species.

The Klamath Basin is the most species-diverse basin in Oregon for lamprey, and the species are largely endemics. Further monitoring and investigation of these species is warranted.

Enigmatic Lampreys in Goose Lake Basin

Goose Lake Basin is a land-locked Great Basin in southeastern Oregon that was historically affiliated with the upper Sacramento Basin in California. It is known to contain both parasitic and nonparasitic lampreys in the subgenus *Entosphenus*. Nonparasitic lampreys are also known from the Pit River (where they are called *lethophaga*), which is south of Goose Lake, but the parasitic form is endemic to Goose Lake Basin. The Goose Lake lampreys have been variably identified as *lethophaga*, *similis*, *tridentata* or some combination of these. Oregon Department of Fish and Wildlife began a taxonomic study of this group in the mid-1990s, working with Dr. Margaret Docker. The results indicate that the Goose Lake lampreys comprise one or two unique species that are not yet named. The Goose Lake lampreys were listed as Oregon State sensitive species in 1993 and given further state protection in 1997 (OAR 635-044-0130).

If the Goose Lake lampreys were a single species it would uniquely include both parasitic and nonparasitic life histories. Such a condition has been proposed for a Canadian lamprey (Beamish and Withler 1986, Beamish 1987). However the large size differences between parasitic and nonparasitic breeding adults, which is observed in Goose Lake Basin, is generally thought to reproductively isolate such dissimilar groups (Beamish and Neville 1992, Lorion et al. 2000). One proposal is that the parasitic life history is facultative and is expressed only when environmental conditions permit migrations to Goose Lake or basin reservoirs where the lamprey can feed on fish; otherwise the lamprey can spawn without feeding as adults. However, unlike the Miller Lake Lamprey, which may also be able to breed without parasitic feeding, the nonparasitic Goose Lake lampreys look like and behave like true brook lampreys rather than like distressed parasitic lampreys. Actively feeding parasitic lampreys were observed in streams by ODFW staff during the severe drought of the early 1990s when all access from streams to Goose Lake was lost due to low water, although they were difficult to find and appeared to be rare. Parasitic individuals became much more abundant when Goose Lake refilled and they began accompanying the adfluvial Goose Lake redband trout, a preferred host species, back and forth to Goose Lake from Thomas Creek.

Much of the life history of this (or these) species is largely unknown. Some information has started to become available during investigations in the 1990s to current. Ammocoetes are filter-feeders in the upper tributaries of Goose Lake. Specimens between 1 cm and 15 cm have been collected by this author from burrows in fine silt lenses along low gradient stream meanders, most often through meadows, in upper Thomas Creek. Lampreys in early stages of metamorphism have been observed in October. Migrations, when they occur, appear to occur in the spring (Figure 19), including both downstream migrations to Goose Lake and upstream migrations of adults. Parasitic adults are able to feed while in streams. Eyed individuals, which may be out-migrating lamprey or adults, are as small as 8 cm. Obviously parasitic adults are about 19 to 21cm (Figure 20). This author has observed spawning by nonparasitic adults in May. Spawning occurred in clean shallow water over small gravels near areas where ammocoetes were rearing.

Completion of the taxonomic investigations and further studies of the life history and ecology of these unique lampreys is warranted.

Other Records of Lamprey in Oregon

Lamprey have been collected in two other locations in Oregon that are outside of the ranges of the species discussed in this report. A nonparasitic lamprey was collected in the 1930s from Chickahominy Reservoir in Silver Creek subbasin in the Malheur Lakes Basin. The collectors considered this lamprey to be a *richardsoni*. The Malheur Lakes Basin is a closed Great Basin with historic connections to the Malheur River in the Snake Basin. The second collection occurred in the 1990s from Thompson Reservoir in the Fort Rock Basin. This lamprey was thought to be a *tridentata*. Fort Rock Basin is a closed Great Basin with unknown historic connections to other basins.

ODFW staff determined that the Thompson Reservoir specimen was likely planted along with a batch of hatchery trout. Lampreys can occasionally enter hatchery raceways through the water intakes. It is likely that the Chickahominy sample came from a similar event. Both reservoirs are artificial water bodies with a history of substantial annual trout stocking. No other lampreys have ever been seen in either basin.

Chapter 2

Status of Oregon Lampreys

Introduction:

The status of Oregon lampreys is very difficult to assess for several reasons. The first reason is that the field identification of lampreys has been difficult so that abundance or distribution data that has been collected is most often generically attributed to "lamprey" and species-specific information is not available. The second reason is that there has been little effort directed at collecting lamprey data. Most data is collected incidental to monitoring salmonids. Therefore the monitoring stations and methods are not designed for the efficient sampling of lamprey, especially of lamprey adults. Also, the locations and timing of monitoring activities are appropriate for salmonids, but not necessarily for lampreys. And finally, there is very little historic data about lamprey. ODFW staff began collecting more data on lamprey in the late 1990s after the state sensitive species listing of Pacific Lamprey, but it is generally impossible to place the current data into any context of an historic trend.

Anecdotal historic observations indicate that lamprey were very abundant, at least periodically. The first observation of lamprey abundance in Oregon was at Willamette Falls in the 1800s. An observer from the United States Fish Commission recorded: "At the falls of the Willamette River, near Oregon City, Oregon, on June 23, the rocks at the particular part of the falls where salmon ascend were at times completely covered with lampreys. In places where the force of the current was least, they were several layers deep, and at a short distance the rocks appeared to be covered with a profuse growth of kelp or other water plants," (McDonald 1894). Likewise on the Fraser River in Canada: "In 1948 it was reported that masses of lampreys formed mats along the walls of Hell's Gate Canyon and Lillooet Rapids to a depth of at least a foot of entangled bodies," (Pletcher 1963). Similar "masses of lampreys" have not been reported anywhere in many decades indicating significant abundance declines.

Most Oregonian's first experience with lamprey occurred in the fish ladder observation window at Bonneville Dam. As recently as the early 1980s, "a lot" of adult Pacific Lamprey, if not "masses" of them, could be seen clinging by their sucker mouths to the windows. Devises were installed in the Columbia River dam fish ladders to keep them away from the counting windows because they were at times thick enough to interfere with counting salmon (Ocker et al. 2001). Lampreys are rarely seen at these windows these days, again indicating abundance declines.

The first alarm that something was seriously amiss with lampreys came from tribal members on the Oregon coast and the inland Columbia Basin. Lampreys have been harvested for food by Northwest tribes. Tribal elders recall that lampreys were abundant and easy to catch when they were younger but by the 1990s they had become very rare (Downey et al. 1993, Close 1995).

The only attempt at a quantitative estimate of "historic" lamprey abundance was made in Canada in the 1970s. Both Pacific Lampreys and River Lampreys were called "abundant", with an estimate of over half a million feeding adults of each species being produced in Canadian rivers, primarily in the Fraser River (Beamish 1980, Beamish and Youson 1987). Pletcher (1963) found Western Brook Lampreys to be very abundant and easy to find and observe in his study stream, a tributary of the lower Fraser, in the early 1960s. ODFW has a few historic data sets on lamprey abundance, mostly associated with dam counts, harvests, other trapping or fish kills. These sets are discussed below, along with data from the 1990s by region of the state.

One interesting attribute of the scant quantitative data is that it indicates that lamprey abundance can fluctuate wildly from year to year. One study in Canada monitored lamprey abundance in a tributary of the Thompson River in the Fraser Basin and noted that abundance in one of three consecutive years of measurement was over 9 times that seen in other years (Beamish and Levings 1991). ODFW has also noted large variations in abundance, both from year to year and from one location to another. For example, a few tens or hundreds of lampreys may be regularly observed in a network of smolt traps, until suddenly over a couple of days in one year, or in some particular location, several thousands will be observed. The dynamics of lamprey populations, and the distribution of lamprey production appears to be somewhat mysterious, making interpretation of the little quantitative data that is available difficult, especially since most of it has not been systematically collected.

Status of Lampreys in the Inland Columbia Basin (Oregon Subbasins)

SPECIES: PACIFIC LAMPREY (*LAMPETRA TRIDENTATA*) AND WESTERN BROOK LAMPREY (*L. RICHARDSONI*)

Pacific Lampreys were historically present in the inland Columbia Basin well into the Snake River basin while Western Brook Lampreys were historically present up to the confluence with the Snake River. The range of both species in this area appears to have declined.

Lampreys are entirely absent above several major artificial blockages in the inland Columbia Basin. These blockages include the Hells Canyon dam complex on the mainstem Snake, the Pelton/Round Butte dam complex on the Deschutes, and Powerdale Dam on the Hood River, even though there is a fish ladder at Powerdale that successfully passes other fish species. There are no records of historic lamprey in some of these basins but they were likely present since they are known to occur up to the dams. Pacific Lampreys were definitely collected from the Crooked River in the upper Deschutes Basin (Figure 3).

The distribution of lampreys in unblocked basins in the inland Columbia Basin also appears to have decreased since they are apparently absent in many basins. In 1999, staff from the Umatilla tribes conducted a detailed presence/absence survey of lamprey in the John Day, Umatilla, Walla Walla, Tucannon, and Grande Ronde basins (Close and Bronson 2001). They found Pacific Lampreys throughout the John Day basin, except for several survey stations in the upper South Fork and the very upper North Fork. But Pacific Lampreys were observed only in the lowest reaches surveyed in the Umatilla, Tucannon and Grande Ronde basins, and they were rare in these areas. No Pacific Lampreys were seen in the Walla Walla basin. Western Brook Lampreys were found only in one area in the South Fork Walla Walla, but were not seen in any of the other basins.

Fish inventory surveys by ODFW staff during the 1990s have detected only a few lampreys (species not identified) in the John Day, South Fork Walla Walla, and Grande Ronde basins (Figure 21). Lampreys have been regularly observed in smolt traps in the lower Umatilla River and Fifteenmile Creek. However on the Grande Ronde, where smolt traps have been operational since 1997, the only capture of lampreys occurred in 2001 when 13 were observed. Pacific Lamprey adults are observed, and occasionally harvested, at Sherars Falls on the mainstem Deschutes but no lampreys have been captured in smolt traps on Trout Creek in the Deschutes basin. A summary of the apparent remaining distribution of lampreys in the inland Columbia Basin is presented in (Figure 22).

Abundance of adult Pacific Lampreys has been incidentally monitored at Columbia and Snake River mainstem dams, although not throughout the history of fish counts at these sites (Figure 23 a-c). Counts at dams are thought to be an inefficient way to estimate absolute lamprey abundance for several reasons. First, the counts occur during the day while lampreys migrate more often at night. Recently fish counts have included night videotaping, but this requires the use of lights in the counting- area which seems to disturb the lampreys (Ocker 2001). Second, lampreys seem to struggle in the currents of most fish ladders and are often seen floating downstream. Such individuals may be counted multiple times introducing errors. And third, the counting stations were designed for salmon and lamprey can pass them without being detected (Starke and Dalen 1995). However, it is likely that these errors are fairly constant from year to year so that the dam counts can provide a reasonable index of abundance trends, if not a good measure of absolute abundance. The counts at Bonneville include one of the best historic data sets available for Oregon lamprey, extending back to 1938.

At Bonneville and The Dalles dams lamprey counts prior to 1970 were regularly at least 50,000 adults, with occasional very high peaks of several hundred thousands (Figure 23a). At McNary Dam, counts prior to 1970 were only in the few tens of thousands (Figure 23b), while the only "historic" count on the Snake was in 1969 at Lower Monumental where about 8,000 lampreys were counted. Thus even prior to 1970, lampreys were less abundant by orders of magnitude at upriver dams than they were at Bonneville or The Dalles dams, which is reasonable given that lamprey move into various subbasins along the way. The historic counts at Bonneville and The Dalles dams also demonstrate the order of magnitude variations in abundance that can occur in lamprey as numbers swung between tens of thousands and hundreds of thousands over just a few years.

Since monitoring resumed in the mid-1990s, lamprey abundance has been lower at all dams compared to the period before 1970, with numbers particularly low at the furthest upstream dams. Only about 25,000 adults are now passing Bonneville Dam annually while less than two hundred lampreys have been observed annually at the upper Snake River dams. These few Snake River lampreys are distributed into potential spawning areas over a large area that includes the Clearwater and Salmon rivers, as well as Oregon subbasins of the Snake. A study in the Clearwater River in the late 1970s indicated that lampreys were already becoming rare in the Snake River basin by that time (Hammond 1979).

Juvenile lampreys have been incidentally caught in the juvenile bypasses at the mainstem dams, and the trend for the John Day by-pass since 1988 is shown in Figure 24. The remarkable increase in juvenile abundance in 1998-2000 may be partly due to improvements in capturing and handling juvenile lamprey at the facility. However, a similar magnitude jump in juvenile abundance occurred on the Umatilla in 2001 (Figure 25). These data may also reflect the episodic nature of lamprey abundance.

Smolt traps are useful tools for capturing juvenile lampreys in smaller basins. Lampreys have been monitored at smolt traps in the lower Umatilla below Threemile Dam since 1995 (Figure 25), and since 1998 in Fifteenmile Creek (Figure 26). The figures show raw counts from the traps because the efficiencies of the traps for capturing lamprey are unknown. An effort to estimate trap efficiency was made for the first time on the Umatilla in 2000 and spring of 2001 by marking the lamprey with a small notch in a fin, then releasing them back upstream with a recovery period along with the salmonid smolts. Trap efficiencies for lampreys in the lower Umatilla ranged from about 0.5% to 5%. This approach is promising and needs to be expanded to other Oregon smolt traps that catch lampreys. Eventually some estimates of juvenile lamprey production by basin may be possible.

Another question is whether the smolt traps, which are installed to monitor salmonids, are operated during the peak of the lamprey out-migration. Monitoring in the Umatilla occurred year-round, and is the only basin in Oregon where this was so. Juvenile lampreys were observed moving out of the Umatilla in their peak numbers during the winter (Figure 6a). On Fifteenmile Creek, and at all other Oregon monitoring stations, the traps are not installed until spring. Heavy winter and early spring freshets in lower Columbia and coastal basins preclude much trapping in the winter and this fact may pose some monitoring complications.

Currently from the available data we can only conclude that similar numbers of juvenile lampreys are typically being caught in the traps in the lower Umatilla River and Fifteenmile Creek, except that the number caught in the lower Umatilla took an apparent magnitude leap in 2001. Lampreys are likely produced throughout the small but generally low-gradient Fifteenmile Creek. Lamprey production in the Umatilla appears to be restricted to the lower few miles of the basin.

The smolt traps also occasionally capture adult lampreys (i.e. Figure 26), but are very inefficient at it. Most adult salmon traps typically cannot retain adult lampreys, which manage to escape through the picket openings in the traps. Lampreys are not seen at the extremely efficient adult salmon traps at Threemile Dam (Umatilla) or Powerdale Dam (Hood); possibly passage up the fish ladders leading to these facilities is not possible for lampreys. Therefore counts of adult lampreys into individual subbasins in the inland Columbia Basin are not available.

Another source of lamprey abundance information over time is provided as snap-shots by reports of fish kills in basins. Some of the historic fish kills in the John Day and Umatilla basins were part of intentional fish eradication programs implemented by Oregon Department of Fish and Wildlife. These programs targeted “rough fish” which basically included everything that was not a salmonid, including native species like lamprey. ODFW records of the impact of these treatment projects on fish are often incomplete or unspecific. However, one report of a 1969 rotenone treatment of the North Fork John Day River stated that 33,000 adult Pacific Lampreys were killed. This is a substantial number of adult lampreys compared to contemporary mainstem dam counts. While over 50,000 lampreys were seen at The Dalles Dam in 1969, fewer than 5,000 adult lamprey were counted at McNary Dam, which is the next mainstem dam upstream of the John Day confluence (Figure 23a and b). These comparisons suggest that the John Day Basin may have been an important production area for lampreys in the inland Columbia Basin at this time – and that a substantial amount of the 1969 breeding population was destroyed in this single rotenone treatment. Another rotenone event on the John Day in 1982 killed thousands of lamprey ammocoetes. Other fish kills have been caused by accidental chemical spills. One such accident in 1999 on the lower Fifteenmile Creek killed thousands of lampreys, mostly ammocoetes.

At this time, conclusions about the status of inland Columbia Basin and Snake River lampreys are best made from the adult counts at the mainstem dams and from the distribution data. It appears that Pacific Lamprey are at dangerously low numbers in the Snake Basin, with fewer than 200 adults seen annually at Lower Monumental, Little Goose, and Lower Granite dams during the 1990s. They are absent above the Hells Canyon dam complex. Pacific Lamprey may be gone from the upper Grande Ronde, Walla Walla, and upper Umatilla basins and they are absent from the upper Deschutes and Hood basins. Lamprey distribution seems to be intact in the John Day Basin, but abundance is not known. Abundance monitoring and distribution data is needed in the Deschutes Basin below Pelton/Round Butte dams. It appears that basins and reaches not usually considered good habitat for salmonids, such as Fifteenmile Creek and the lower Umatilla and John Day are providing habitat for lampreys and further investigations into similar lower-gradient areas are warranted.

It also appears that the situation for Western Brook Lamprey in the inland Columbia Basin is precarious. They were completely absent from all areas inventoried, except for a pocket of them in the South Fork Walla Walla. Their historical abundance in these basins is not known; perhaps they were naturally rare and irregularly distributed. There were historic collections made of them from the upper John Day and from Willow Creek, a small subbasin between the John Day and Umatilla rivers (Figure 8). Their occurrence in the Deschutes and Fifteenmile Creek is unknown.

Status of Lampreys in the Lower Columbia Basin and Willamette

SPECIES: PACIFIC LAMPREY (*LAMPETRA TRIDENTATA*),
WESTERN BROOK LAMPREY (*L. RICHARDSONI*),
RIVER LAMPREY (*L. AYRESI*),
OTHER SPECIES?

Lampreys are more species diverse in the Columbia Basin west of the Columbia Gorge. Most observations of lampreys available from this area are of ammocoetes or of lampreys undergoing metamorphism and could include a mixture of species. However, River Lamprey, if they are still present, are likely in deeper rivers such as the mainstem Columbia and Willamette where they are not encountered in the incidental surveys currently being conducted. It is highly likely that brook lampreys, at least *richardsoni*, are present in this area along with the Pacific Lampreys. Lampreys have not often been encountered by ODFW inventory crews in the lower Columbia and Willamette (Figure 27) however they are incidentally observed or captured during winter steelhead spawning surveys, and during other trapping, and they have been collected after fish kills. Incidental observations suggest that lampreys are still well distributed through the Willamette Coast Range subbasins, in the Molalla/Pudding system, in the lower Santiam and in the Calapooia. They are also still seen in small numbers passing Leaburg Dam on the McKenzie River.

The distribution of lampreys in the lower Columbia is likely reduced due to passage barriers on the Sandy and Clackamas, and in the North and South Santiam, McKenzie and Middle Fork Willamette (Figure 28). No systematic survey of lamprey distribution has been conducted in this area, nor is the historic distribution known. However, a network of smolt traps in the Clackamas Basin in 2001 demonstrated how lampreys are now restricted to streams below North Fork Dam (Figure 29) in that subbasin. North Fork Dam has a functional fish ladder, unlike the Willamette Basin dams on the Santiam, McKenzie, and Middle Fork. The presence of lampreys in the small direct tributaries of the lower Columbia is generally not known, but many of these streams have small passage barriers like culverts and weirs that may be blockages for lamprey.

The Willamette Basin is probably the most important production area for Pacific Lamprey in the Columbia Basin. This was probably true historically as well as currently, as indicated by a comparison of the number of lamprey taken in the Willamette Falls fishery and the counts of adult lamprey at Bonneville Dam (Figure 30). The Bonneville Dam counts represent essentially the entire population of Pacific Lampreys in the Columbia Basin upstream of that location. During the 1940s the harvest at Willamette Falls was substantially more than the counts at Bonneville Dam in the same years. In the 1990s, the harvest has remained almost equal to the dam counts.

In spite of its importance as a production area and as a location of harvest, the status of Willamette Basin lampreys is poorly understood. The primary data set available to indicate abundance trends is that provided by the harvest itself (Figure 31). Harvest is a poor index of abundance because it is strongly influenced by regulations and harvest effort, which were not constant over the time period observed. The large harvests in the 1940s occurred at a time when the harvest effort was intense. Subsequent harvest methods changed and effort declined. It is difficult to determine how much the change in the fishing regulations and effort influenced the differences in numbers seen in the 1940s compared to those since 1969. However it is highly unlikely that hundreds of thousands of adult lamprey, the numbers taken in the 1940s harvests, currently pass Willamette Falls.

The only other systematic data set available for Willamette Basin lampreys is a count of adult Pacific Lampreys at Leaburg Dam on the McKenzie River in the upper basin (Figure 32). The numbers are very low; typically less than 50 adults have been counted annually since the early 1980s. Additional incidental observations of lamprey in the Willamette have also been made, mostly in the 1990s (Figure 33). The observations on Pringle Creek were likely a complete count of the lampreys present in the area at that time because these came from an accidental fish kill. The other data are incidental observations made during electroshocking surveys or smolt trapping.

The most interesting observation is the extremely high numbers of juvenile lampreys observed in Clear Creek on the lower Clackamas in 2001, particularly when compared to other lower Clackamas observations using the same sampling method in the same year. This observation suggests that lampreys concentrate in particular areas. Knowledge of where such areas are, and whether abundance in these areas is stable from year to year would be very important for protecting lampreys. If most lampreys are concentrated in only a few areas, a fish kill or other habitat impact in one of those areas could cause a substantial impact on the whole population even if the physical area affected is small.

An historic data set from the lower Columbia collected during the late 1950s-early 60s is available from the Gnat Creek Weir study conducted by ODFW (Willis 1962). Gnat Creek is a relatively small basin in the lower Columbia. Nevertheless, several hundreds to thousands of adult Pacific Lampreys were caught annually, along with thousands of juveniles (Figure 34). The trap at Gnat Creek collected both upstream and downstream migrating lampreys, although the author noted that additional adults were passing upstream around the facility. It is interesting to note that adults also moved downstream; Willis does not report the condition of these. Gnat Creek is now blocked by a hatchery weir.

The Gnat Creek data set can be compared to recent observations at trap facility on Scappoose Creek, another lower Columbia Basin tributary. Scappoose Creek is a larger basin than Gnat Creek. A comparison of the numbers of lampreys captured in the two basins suggests a substantial decline in lamprey abundance in the lower Columbia since the early 1960s (Figure 35).

The scant data from the lower Columbia and Willamette indicate that lamprey abundance has declined in this area, yet it remains the most important production area for Pacific Lampreys in the Columbia Basin. The presence and status of the other two major species (Western Brook and River lampreys) is completely unknown. Systematic abundance monitoring needs to be institutionalized on the Willamette, especially if harvest of Pacific Lampreys is going to continue. At this time we are not able to estimate how much of the Willamette Basin lamprey population is being taken in annual harvests.

The issue of homing behavior or lack of homing behavior by Pacific Lampreys is important when assessing the status of Columbia Basin lampreys as a whole. If homing to natal areas does not occur, several factors may work together within a basin like the Columbia to cause major shifts in distribution that interfere with the detection of population declines. Lampreys may be attracted to ammocoete rearing areas by chemical attractants released by the larva. If this is so, a decrease in the juvenile population in a basin, caused for example by a fish kill, may trigger a total extinction in the basin as progressively fewer adults are attracted to it. Difficulties of passage at artificial barriers, even at dams that have fish ladders, may discourage upstream movement and there-by shift population concentrations into other areas below the blockages. The scant data that is available for the Columbia Basin indicates that abundances have seriously declined everywhere, but especially in the upper basin. It is possible that some of the lampreys produced in the upper basin are now electing to return to spawning areas below most of the mainstem dams. If so, the lower basin is an important refuge for the entire system.

The issue of species identity is also a critical one in the Columbia Basin. We cannot differentiate juveniles and the only adults we regularly see are Pacific Lampreys. We currently have no way of knowing for certain whether Western Brook Lampreys and River Lampreys are even still present, although they probably are. Surveys of the lower mainstem Willamette and the mainstem Columbia are likely needed if we want to find River Lamprey. Spring spawning ground surveys in gentle-gradient basins may detect Western Brook Lampreys.

Status of Lampreys on the Oregon Coast

SPECIES: PACIFIC LAMPREY (*LAMPETRA TRIDENTATA*),
WESTERN BROOK LAMPREY (*L. RICHARDSONI*),
RIVER LAMPREY (*L. AYRESI*),
OTHER SPECIES?

Lamprey species diversity on the Oregon coast is likely similar to that in the lower Columbia, although it is possible that some undescribed species or variants are present on the south coast. Again, most observations of lampreys available from this area are of ammocoetes or of lampreys undergoing metamorphism, and could include a mixture of species. Most of the adult lampreys we see are Pacific Lampreys. Juvenile River Lampreys, if they are present, are likely to be mixed among, and confused with, Western Brook Lampreys in the lower portions of coastal basins.

Although systematic presence/absence surveys targeting lampreys have not been done on most of the Oregon coast they appear to be currently present throughout most Oregon coastal streams. ODFW stream inventory crews have encountered lampreys in most of the areas they have surveyed (Figure 36). Lampreys are also seen in many of the salmonid smolt traps currently operated in coastal basins and during winter steelhead spawning ground surveys. Lampreys were likely never present in some areas such as above Toketee Falls on the North Umpqua River or above Coquille Falls on the South Fork Coquille, and Pacific Lampreys, at least, are likely extinct above Lost Creek and Applegate dams on the upper Rogue River.

A systematic survey for both Pacific and Western Brook Lamprey conducted in the Alsea Basin demonstrated that both species were present and that Pacific Lampreys appeared to be the most common. Lampreys were not found in the most upstream reaches of the basin and both species were often absent above road culverts, which tend to be passage barriers for lampreys. Pacific Lampreys were more often seen in high densities than Western Brook Lampreys; this suggests the brook lampreys could be either more dispersed or more rare (Stan van de Wetering, Siletz Tribes, personal communication).

ODFW counts adult Pacific Lampreys at two dams on the Oregon coast. The count at Winchester Dam on the North Umpqua dates back to 1968. It shows a severe decline in lamprey abundance in the early 1970s and very low numbers since that time (Figure 37a). Only a few tens of lampreys have been seen in some years during the 1990s. The count at Gold Ray Dam on the upper mainstem Rogue River only dates back to 1993. Lampreys at this location have varied from just over 100 to nearly 2,500 annually (Figure 37b).

During the 1990s, lampreys have also been incidentally captured in smolt and adult traps operated on the Oregon coast. Adult lampreys are not commonly captured because the traps, designed to catch either smolts or adult salmonids, are not very efficient for adult lampreys. An historical data set from the early 1960s is available for comparison from several irrigation diversion trap boxes in the upper Rogue Basin. Data from Tenmile and Cummins creeks date back to 1993; otherwise all observations are only from the last several years. The data shown in the following figures are absolute counts; the efficiencies of these traps for lampreys have not been measured. Smolt trap efficiencies were measured in an independent study in Tenmile Creek on the Oregon Coast, where efficiencies ranged from 3% to 25%. These efficiencies were used to calculate abundances of out-migrating lampreys of 6,569 and 3,592 in 1994 and 1995 from Tenmile Creek (van der Wetering 1998).

Data from ODFW coastal smolt traps again suggest lampreys may concentrate in particular areas, being very abundant in some areas while rare or absent in adjacent areas. An example is provided from the upper Rogue Basin, where several smolt traps have been operated since 1998. Typically a few tens to hundreds of lampreys were seen in the various traps, except for the only year that a trap operated on Bear Creek, where over 6,000 were collected (Figure 38 and 39). Bear Creek, similar to Clear Creek on the Clackamas, appears to be an area of exceptional lamprey concentration, and is also a low gradient stream that is not particularly a high-use tributary for salmonids. The Rogue data indicates that lampreys are being captured in recent smolt traps at similar numbers to what was captured in irrigation diversion trap boxes in the early 1960s (Figure 39).

Cummins and Tenmile creeks on the south Oregon coast have a better record of catching adult lampreys than other traps, perhaps because trapping is more intense in these basins (Figure 40a). More lampreys are consistently seen in Tenmile Creek, including both adults and juveniles (Figure 40a-b), than in Cummins Creek, although both appear to be good locations for lamprey production. Both of these creeks are very small coastal basins; other similarly sized coastal basins are not monitored.

The Cummins and Tenmile creeks data are included with data from other Oregon coastal basins, arranged from the north coast to the south (Figure 41a-c). Although it is difficult to compare the basins from the raw data, production appears to be lower in the Tillamook Bay, Nestucca, and Yaquina basins, and highest in parts of the Alsea and in Cummins and Tenmile creeks. The network of traps is operated to monitor salmonids, and possibly the time of operation is late for lamprey, and the locations of the traps are not optimal for lamprey monitoring. However if trap efficiencies are measured, this trap network might, over time, provide a reasonable index of lamprey abundance along the Oregon coast.

Additional information about coastal Pacific Lamprey has been collected incidental to winter steelhead spawning ground surveys (Susac and Jacobs 1999, Jacobs et al. 2000). Adult lamprey and redds are observed and have been counted in several basins along the Oregon coast in 1998 and 1999 (Figure 42a-c). Spawning ground counts of redds are probably not a good measure of abundance because lampreys will produce many false redds during courtship. However, the observations are a good indication of the time and location of lamprey spawning behavior and may be used to locate concentrations of spawning activity.

The Winchester Dam counts on the Umpqua demonstrate that Pacific Lampreys in this basin have experienced severe declines since the late 1960s. Similar historic data is not available from elsewhere on the coast to determine whether this trend is coast-wide or unique to the North Fork Umpqua. Lampreys are still observed almost everywhere coast-wide, but generally not in remarkable numbers anywhere. More adult data would be useful and perhaps some of the adult traps used for monitoring salmon could be modified to retain adult lampreys without compromising their primary purpose. However, improvements in our current information will not compensate for our lack of historic data and we are likely required to depend on anecdotal recollections from coastal tribal elders, other members of the public and ODFW staff to tell us that coastal lampreys have declined over the last few decades. Better information is also needed on Western Brook Lamprey; we need to determine whether River Lamprey are still present in any basins; and we need to determine whether our observations of enigmatic lampreys really are of unique varieties or species.

Status of Lampreys in Southeastern Oregon

SPECIES: FIVE KLAMATH LAMPREYS
TWO GOOSE LAKE LAMPREYS

The lampreys in Goose Lake and Klamath basins are endemic species or variants that are highly unique with a very limited world distribution. Status of, and protection of, the populations in these basins constitute the condition of entire species. The multiple species are very similar to each other as juveniles, and adults are rarely observed. Therefore, monitoring status of any one species is quite difficult. We are certain that there are four species in the upper Klamath Basin. We do not know whether *L. folletti* is actually present. We know that we have both parasitic and non-parasitic lampreys in Goose Lake Basin and are still investigating whether these are one or two species.

At this time, we are only able to observe that lampreys, generically, appear to be well distributed in their two basins (Figure 45), and anecdotal observations by both ODFW staff and U.S. Fish and Wildlife Service (USFWS) staff suggest that they tend to be at fairly good densities wherever they are present. However, we have started only one systematic data set in Thomas Creek, Goose Lake Basin, incidental to monitoring migratory redband trout (Figure 46). Neither the redband trout nor the lampreys migrated past the location of this trap during the drought of the early 1990s so the current observations, in spite of low numbers, may be taken as a sign of improved status.

ODFW needs to invest significantly more resources into monitoring the lampreys, and other endemic species, in these basins. The Klamath Basin, along with other SE Oregon Great Basins, has the highest number of unique and endemic fishes in Oregon, and the highest number of state sensitive species and state and federal ESA-listed species, yet monitoring in these areas remains severely under-invested by the state and is under-staffed. More work is needed to determine the specific distribution of the various lamprey species, to answer the remaining taxonomic questions, and to establish monitoring that can shed some light on the status of individual species.

Because of their endemic nature, the Klamath Basin species likely warrant addition to the state Sensitive Species List as naturally rare species (Puchy and Marshall 1993). The Goose Lake species are already included on the list as *Lampetra tridentata*; they need to be recognized as separate species on the list.

Chapter 3

Management Issues

Information Needs

It is not possible to assess the status of a species or to take action to correct status problems unless we know something about the species. At a minimum we need to be able to identify individual species and know about their abundance and spatial distribution over time. Knowledge of their basic ecology, life history, and habitat needs would let us better address status problems. It is evident that we could potentially allow species to go to extinction through ignorance and negligence, never even knowing what they were. Lamprey species are susceptible to this problem. The Miller Lake Lamprey is an interesting case study of this: it was finally recognized as a unique species nearly twenty years after it allegedly became extinct, then persisted unknown to everyone for another twenty years before it was rediscovered and declared "extant" and even perhaps locally abundant. The legislature has established a statute that says: "It is the policy of the State of Oregon that wildlife shall be managed to prevent serious depletion of any indigenous species and to provide the optimum recreational and aesthetic benefits for present and future generations of the citizens of this state" (ORS 496.012 Wildlife policy) with several co-equal goals including "To maintain all species of wildlife at optimum levels" (ORS 496.012 (1) (3)). It is important to more diligently collect basic taxonomic, life history, distribution, and abundance data on species such as lamprey in order to better meet the obligations of our mission statement and to avoid management mistakes of the past. Further, information about status problems for species like lampreys may shed light on some of the reasons for status problems of species that are more popular, like salmon.

ODFW staff began collecting some data about lamprey incidental to salmonid monitoring in the late 1990s. These current efforts, while a considerable improvement over a total lack of information, are not designed for lamprey, are inefficient and are of limited scope. Co-Manager staffs, especially tribal staff in the upper Columbia and mid-Oregon coast, have implemented projects specifically focused on lamprey with much better results. The following actions are recommended for improving ODFW information about lamprey:

1) Minimum Activities:

The following information and monitoring activities are the minimum necessary to assess the status of Oregon lampreys:

a) Species Identification.

i) We need to know what species are present in Oregon.

It is currently understood that we have Pacific Lamprey (*Lampetra tridentata*) and Western Brook Lamprey (*L. richardsoni*) in the Columbia River and on the Oregon Coast. But it is likely that we have other species in these two regions. Some of these are classified, but we do not know if they are still present, like the River Lamprey (*L. ayresi*). Other enigmatic varieties may be present but their taxonomic identity is uncertain. We also know that the lamprey in the Klamath and Goose Lake basins are different species but for many of them taxonomic identity has not been determined. ODFW has identified a taxonomic survey of Oregon lampreys as an initial priority under new funding for non-game species available through the US Fish and Wildlife Service.

ii) Department staffs need to be able to reliably identify various species in the field.

This problem is extremely difficult for lampreys because field staff most often encounter them as ammocoetes, which appear nearly identical across all species. Staff with the US Geological Survey is currently working on an improved key to ammocoetes in the Columbia Basin (Bayer et al, 2001) and ODFW needs to cooperate with their effort.

Some clarity of species identity may be possible based on knowing their spatial distributions and habitat preferences. For example, it is likely that only Pacific Lampreys are present in most of the upper Columbia and Snake basins. Some species, such as the River Lamprey, may occupy unique fresh water habitats, such as lower mainstem channels. Some species may be restricted to specific basins, such as Western Brook Lamprey in the South Fork Walla Walla, or some of the endemic Klamath basin species.

b) Species Distribution.

i) We need to know the distribution of various species of lamprey in Oregon.

Presence/absence surveys that use sampling methods that are efficient for capturing lampreys are needed. Close and Bronson (2001) conducted a good example in Northeastern Oregon basins in 1999. These surveys need to extend into habitats that may be unique to some lamprey species, including low-gradient flood plain habitats and lower mainstem river channels, including the Columbia

River. These surveys need to be coupled with accurate species identification. The surveys need to be repeated periodically (but not annually) so that changes in species distribution can be detected.

c) Species Abundance and/or Densities.

i) We need abundance information collected systematically over time.

In order to detect population declines abundance data needs to be collected systematically each year. One of our big problems for assessing lamprey status currently is that we do not have very much historic abundance data for these species: we cannot tell if they have declined since we do not know how many we had in the past. We will never be able to correct this historic problem, but we can initiate abundance monitoring into the future. Several monitoring stations that detect lamprey are already in place in the Columbia Basin, on the Oregon coast, and in Goose Lake basin, although the efficiencies of most of these for lamprey are uncertain. ODFW needs to continue, or support the continuation, of the existing efforts to monitor lamprey abundance, make some improvements, and expand them in some cases.

ii) We need to measure observation and/or capture efficiencies at existing monitoring stations.

The existing network of smolt traps and counting stations at dams successfully capture or observe lampreys in many cases, but we do not know the efficiencies of the sampling. ODFW staff on the Umatilla River have successfully measured smolt trap efficiencies for lampreys using fin mark and release methods similar to what is used for salmon smolts. Smolt trap efficiencies have also been measured in Tenmile Creek (van de Wetering 1998). This effort should be tried in other basins.

We are aware that many dam counts are likely inefficient for lampreys (Starke and Dalen 1995). Some of these inefficiencies might be correctable, for example by including some night counts. It may also be valuable to expand the interval of monitoring, especially for some juvenile facilities, to include winter months (November through March). In other cases we may be able to make efficiency estimates using mark-recapture methods. Even if errors exist, if they are reasonably constant from year to year the dam counts could provide a reasonable index of abundance over time.

iii) We need to modify some existing monitoring facilities to more efficiently capture or observe adult lampreys.

The adult traps that we currently use for salmonids on the Oregon coast and in the Columbia Basin do not efficiently capture adult lampreys because the animals are able to escape thorough pickets in the trap boxes. Slight modifications of some of these traps may permit good, systematic monitoring of adult lampreys.

Moderate improvements of some counting stations in dam ladders may facilitate or improve observations of adult lampreys. Some counting stations at some Columbia basin dams were specifically equipped with devises to preclude lampreys from the counting windows because they were considered to be a nuisance. Night video counts are now occurring at some mainstem dams but the lights that are necessary to effectively operate the cameras seem to repel the light-sensitive lampreys (Ocker et al 2001). The nature and feasibility of improvements at these facilities will need to be evaluated on a case-by-case basis.

In a few cases, such as at Threemile Dam on the Umatilla and Powerdale Dam on the Hood, access to the traps is difficult or not feasible for adult lampreys and correction of the problem would require a more extensive effort.

iv) We need to add some monitoring stations where none currently exist.

The following three locations should be considered a priority for new monitoring stations:

(1) *The Willamette Basin*. This basin is likely the major production area for Pacific Lamprey in the Columbia Basin, and is also the location of the primary harvest of the species in Oregon. However no systematic monitoring of lamprey occurs currently except for a count at Leaburg Dam on the McKenzie River in the upper basin and the measure of the annual harvest. An adult monitoring station at Willamette Falls is highly recommended. One or more juvenile monitoring stations in the basin would also be useful. ODFW staff is currently pursuing Bonneville Power Administration (BPA) funding to initiate some monitoring in this basin.

(2) *The Deschutes Basin***.** This basin is also likely an important production area for Pacific Lamprey in the Columbia Basin. There is also some tribal interest in a harvest in this basin. An adult monitoring station at Sherars Falls is highly recommended.

(3) *Klamath Basin.* Klamath basin is home to four or five endemic species of lampreys, but currently we have no abundance monitoring for any of them. Systematic monitoring of lampreys in this basin will be difficult, particularly since some species are likely not migratory. However at least two species, the Klamath River Lamprey (*Lampetra similis*) and the unnamed *L. tridentata*-like species, are adfluvial between Klamath Lake and its tributaries. Adult monitoring stations for these species should be feasible.

v) **We need to add some new monitoring methods that are effective for resident species and species in unusual habitats.**

Adfluvial or anadromous species are relatively easy targets of abundance monitoring because they conveniently swim past specific locations during their downstream and/or upstream migrations where they can be intercepted and counted. However resident lampreys may never move very much and we cannot expect to catch them in migrant traps. The most common monitoring method for resident species is a periodic density measurement at selected locations through the species' distribution. This method is relatively labor-intensive, compared to operating a trap, making annual monitoring difficult. Once the spatial distribution of the various resident brook lamprey species is better understood, periodic density measures should be conducted for these species, even if they only occur once every several years.

Monitoring of the anadromous River Lamprey (*L. ayresi*), if indeed it is still present in Oregon, is made difficult because the species, is rarely seen in freshwater apparently due to the habitats it uses even though it is in freshwater for all but a few months of its life. Biologists in Canada located River Lamprey and estimated abundance in the Fraser River using several sampling techniques. These included spring freshwater trawls low in the river basins, sampling of dredge spoils from mainstem Fraser River sources, and surface seining in the ocean during the summer near the mouths of the rivers that produce the species (Beamish 1980, Beamish and Youson 1987).

2) Useful Additional Information:

If we wish to understand lampreys better, especially if we need to take actions to improve the status of a particular species, additional information about their ecology, life histories, vulnerabilities, and habitat use is valuable. The following actions would be beneficial to address basic ecology and life history questions. Some additional actions to address some specific harvest and habitat issues are included in later sections.

a) Marking of lampreys.

Marking lampreys as ammocoetes and recapturing them through their life up to adult spawners would provide valuable life history information, such as timing of migrations, durations of various life stages, and adult homing behavior. Lampreys have been successfully marked with coded- wire tags (Bergstedt and Seelye 1995). Tags in Oregon lampreys would need to be detectable in live lampreys, for example by using a coded- wire- tag wand, so that only tagged individuals are affected by reading the tags. Passive Integrated Transponders (PIT tagging) would be a viable and non-lethal, although more expensive, alternative. Experimentation is needed to refine marking technology before it can be applied efficiently to lampreys (C. Mallette ODFW, personal communication).

b) Basic lamprey ecology and habitat use.

Most of the information on the ecology of the lamprey species that are in Oregon is from graduate theses (e.g. Pletcher 1963, Kan 1975, Hammond 1979, and Richards 1980, van der Wetering 1998). The Bonneville Power Administration (BPA) is currently funding several studies that will improve understanding of lamprey ecology and habitat use in the Columbia Basin. These include studies in the John Day River of Pacific Lamprey (Bayer et al. 2000, Thorgersen and Close 2001), in the Lewis River in Washington of both Pacific Lamprey and Western Brook Lamprey (Stone et al. 2001) and in the Clearwater River in Idaho of Pacific Lamprey (Cochnauer and Claire 2001).

c) Within species biodiversity.

Within species population sub-division may differ greatly from one Oregon lamprey species to another. The anadromous Pacific Lamprey may show little population sub-division if it does not home to natal areas, or sub-division may occur over large areas such as between the coast and the Columbia basin. However, homing behavior and population sub-division in Pacific Lamprey remains to be tested. River Lamprey likely home to natal basins based on the observations made in Canada (Beamish 1980, Beamish and Youson 1987). According to those studies, River Lampreys were found in the ocean only near the mouths of the rivers that produced them; therefore they were unlikely to travel to different rivers to spawn. The resident Western Brook Lampreys are likely not saltwater tolerant, therefore they would have significant population sub-division along the Oregon coast. They apparently move very little over their lives and therefore they may be quite sub-divided in the Columbia Basin also. Population sub-division influences species status. The various semi or totally isolated populations in a highly sub-divided species have to be treated as different management units in order to effectively achieve the conservation of the biodiversity contained within the species (Rojas 1992).

Harvest

The only lamprey species that is harvested in Oregon is the Pacific Lamprey. In recent years Pacific Lampreys have been harvested at Savage Rapids Dam on the Rogue River, at Winchester Dam on the Umpqua River, at Willamette Falls on the Willamette River, in Fifteenmile Creek, at Sherars Falls on the Deschutes River, and in the John Day River. Most of the harvest outside of the Willamette Basin has been for personal use by Native Americans. The Willamette Falls harvest includes treaty Indian and non-Indian commercial and personal use.

In 2001, the Oregon Fish and Wildlife Commission implemented OAR 635-044-0130, which requires that permits be issued by the Commission before certain native non-game species, including Pacific Lamprey, can be harvested. Permits were issued for Willamette Falls and a season and regulations were set. The harvest was regulated by setting a season, limiting the area around the falls that was open for harvest, limiting harvest to daylight hours, and requiring harvest be by hand or hand-operated tools. About 15,500 lampreys were harvested, about half of the past ten-year's average harvest. Details about the 2001 harvest are available in Ward (2001).

At this time we are not able to assess the impact of this harvest because we do not have a measure of lamprey abundance in the Willamette Basin. We are able to compare this harvest to the 2001 Bonneville Dam counts, which represents the entire population of lamprey above the dam (with caveats about potential count error at the dam). The 2001 Bonneville count was 27,947 Pacific Lampreys; therefore, the harvest was about 55% of the dam count. But in order to assess the proportion of the Willamette Basin lamprey population that was taken by the harvest, an independent measure of adult lamprey abundance at Willamette Falls is needed.

It is strongly recommended that an adult abundance monitoring station be installed at Willamette Falls. Then if the Commission elects to issue permits for harvest, the proportion of the Willamette Basin population that is taken in the harvest can be measured. ODFW staff is currently seeking BPA funding for this action.

This effort will still not tell us whether the harvest rate is sustainable since we have no information about lamprey population dynamics or lamprey productivity. It may be very difficult to assess whether a particular lamprey harvest is sustainable for several reasons. First, we have reason to expect, based on the scant data we have on lamprey abundance, that population abundance can be highly variable, varying by orders of magnitude from one year to the next. We do not know why this occurs. Therefore we cannot currently predict a particular year's abundance at the time harvest is set prior to the run. Second, there are information gaps that must be filled before we might be able to develop a method of predicting adult abundance. Monitoring of juvenile lamprey production out of the Willamette Basin may help us predict future abundance and scale harvest to follow fluctuations in abundance. However, at this time we do not know the duration of salt-water residence by Pacific Lamprey. Based on the literature, lampreys leaving the Willamette in any year may return to the basin anywhere from one to four years later. There may be variation in time to return, *if* they return to the basin at all. And, so, third, if there is no homing by the lamprey there may be no relationship between juvenile production in the Willamette Basin and future adult returns to the basin. The only way to determine whether the lamprey produced in the Willamette return as adults would be to mark out-migrants with coded wire tags or PIT tags and then recapture them as adults. This study is possible, but some preliminary technology development and testing will be required before it can be developed (C. Mallette ODFW, personal communication). ODFW hopes to start some of this testing in 2002.

Sherars Falls on the Deschutes River is within the usual and accustomed harvest area for the Warm Springs Tribes. If harvest is going to occur there, an adult abundance monitoring station should be installed at the falls as soon as possible and we should request annual harvest data from the Warm Springs Tribes.

The only basin in Oregon with a recent lamprey harvest that also currently has an independent measure of adult Pacific Lamprey abundance is the upper Rogue Basin. Lampreys have been harvested at Savage Rapids Dam and adult abundance is counted just upriver at Gold Ray Dam (Figure 38b). Counts at Gold Ray Dam are not very high indicating that very little or no harvest should occur in this system.

We also have an independent measure of lamprey abundance at Winchester Dam on the Umpqua River, another location where lampreys were harvested in the past. However, fewer than 100 lampreys are seen there annually so harvest is not currently possible there.

Habitat Issues: Provisions for Upstream Passage

Lampreys have a remarkable ability to use their sucker mouths to climb natural barriers and penetrate headwater areas that are not available to other anadromous fish. Therefore it seems surprising that upstream passage barriers would be a problem for lamprey. But lampreys are unable to cope with many artificial barriers. Lampreys are weak swimmers since they lack paired fins, and they have no jumping ability. In order to climb they must find rough surfaces that they can cling to in areas with low or moderate currents so they will not be washed backwards.

The following is a brief description of the types of artificial barriers that impede upstream passage by lampreys:

1) **Dams:** Lampreys are excluded, along with other migratory fish, from passing dams that were not intended to pass fish. This list of dams includes Lost Creek and Applegate dams on the Rogue, the complex of Willamette Basin dams on the Santiam, McKenzie and Middle Fork Willamette, Pelton/Round Butte dams on the Deschutes and Hells Canyon Dam on the Snake.

   Other dams are designed to pass fish upstream and are equipped with fish ladders. However, lampreys are apparently unable to use many of these. Lampreys pass some low-head dams such as Gold Ray and Savage Rapids dams on the Rogue, Winchester Dam on the Umpqua, and Leaburg Dam on the McKenzie in the upper Willamette. They also use the fish ladders at Willamette Falls, although they also cross the falls itself as they did historically (Normandeau Associates 2001). They have not been found above some other small, but higher head dams in Oregon, such as North Fork Dam on the Clackamas, Powerdale Dam on the Hood, or Threemile Dam on the Umatilla.

   Lampreys are seen using the fish ladders in the mainstem Columbia and Snake dams, although with apparent difficulty. They are able to use the fishways, regardless of their length and slope (Slatick and Basham 1985), but some features of the structures seem to pose problems. Studies tracking radio-tagged lampreys through Bonneville, The Dalles and John Day dams have demonstrated that passage efficiency is poor – typically less than half of the lampreys that approached the dams successfully passed above them (Ocker et al. 2001). Areas of the fish ladders that seemed most difficult to the lampreys included those areas where lips or gratings had to be crossed, areas where water velocity is higher such as at entryways and over diffuser gratings, and areas that were lighted at night. These difficult areas correspond to lamprey biological characters including weak swimming, the need to cling to surfaces to rest and climb, and strong phototaxic behavior expressed as light avoidance. Lampreys, with their slim, snaky bodies, are also able to gain access through small holes into nooks and crannies along fishways that may entrap them (Starke and Dalen 1995).

One modification of fish ladders that may significantly improve lamprey passage without interfering with salmonid passage would be to provide roughened surfaces through the ladders that provide lampreys with areas that they can easily cling to, rest, and climb along.

2) **Road Culverts:** A presence/absence survey conducted by Stan van der Wetering in the Alsea Basin on the Oregon coast demonstrated that lampreys, including both Pacific and Western Brook lampreys, were not found above many road culverts. Most road culverts likely pose severe passage barriers to lamprey caused by at least the following:

   a) Smooth surfaces within the culverts that provide no surfaces for lamprey to cling to;
   b) Velocity barriers within the culverts; and
   c) Hanging culvert entrances. Even an entrance that hangs just a couple of inches cannot be entered by lamprey since they have no ability to jump.

   The provision of rough surfaces through culverts, including ramps for climbing into the entrances may assist lamprey passage.

3) **Other Barriers to Upstream Passage?** Other artificial features may also be passage barriers to lamprey, such as tide gates, hatchery weirs, or other small barriers and diversion structures. The flashboards installed at the top of Willamette Falls in the summer appear to form a passage barrier (Normandeau Associates 2001). Any barrier that has a sharp lip, a high velocity current, and/or a smooth downstream surface, or a hanging downstream drop more than a few inches high will be a passage problem. These problems should be easily correctable by providing the means for lampreys to climb around these features – it may be as simple as a pile of rocks to one side with a gentle overflow of water.

Habitat Issues: Screening for Downstream Passage

Downstream passage around dams and diversion structures may be the greater hazard for lampreys. Lampreys migrate downstream when they are very small-diameter ammocoetes or recently metamorphosed lampreys. They are not strong swimmers so their movement is at the mercy of the flow velocity. They may pass under fish screens on dams (Long 1985) or go through some bypass screens that have larger openings, making the effort to divert them out of turbines or irrigation canals ineffective. But perhaps the bigger problem is high mortality caused by the fish screens themselves. Anecdotal observations by biologists working on mainstem dams on the Columbia and Snake rivers during the 1970s and 1980s indicate that juvenile lampreys impinged on the perforated plates that blocked various openings across the forebay faces of the dams and on juvenile bypass screens in huge, but undocumented, numbers. These observations have been documented and tested more recently (Starke and Dalen 1995, Jackson et al. 1996, BioAnalysis Inc 2000, Moursund et al. 2000, Dauble and Moursund 2000).

The problem of lampreys and fish screens is caused by the small diameter of the juvenile lamprey and their weak or passive movement through the water. The design of the screen mesh is important, but the operation of the screen is also a factor. If flows approaching the screens are high, the lampreys are pressed against the screens eventually impinging from their tailend as they attempt to swim free. If the flows approaching the screens are too low, the lampreys tend to adhere to the screens with their sucker mouths then rotate with the screens until they are crushed by the gatewells or cleaners (Moursund et al. 2001). Research is continuing at the Pacific Northwest National Laboratory in Richland Washington, studying both large bypass screens on mainstem Columbia River dams and smaller screens on irrigation diversions, attempting to discover a screen design and operation that is lamprey-friendly (D. Dauble, personal communication). The ODFW screening program is also interested in supporting or participating in similar studies in an effort to make screens installed on lamprey-bearing streams under ODFW authority adequate to protect lamprey.

Diverting lamprey along with irrigation water into fields is very undesirable. Ironically, however, passing lampreys through turbines may be less harmful to them than the current screens. The shape of lamprey ammocoetes, their lack of a swim bladder, and their cartilaginous skeletons make them less susceptible than salmon to injury due to the changes in pressure and shear conditions during turbine passage (Moursund et al. 2001). Earlier studies on mainstem dams indicate that juvenile lampreys tend to be deep in the water column below the reach of many fish screens (Long 1985), although lampreys are certainly being caught in the juvenile bypasses. Also as they travel through the dams, they are able to slither into any little orifice they encounter that is large enough to let them pass, which means any opening larger than about: **O** , and they become entrapped.

Other Habitat Issues:

Our understanding of lampreys is not sufficient to determine all the habitat factors that influence them. We know they need habitats with interspersed small gravel beds (for spawning) and silt lenses (for burrowing). They need organic debris that will produce algae for their food. They need flows that are gentle to moderate. They need passages they can maneuver. Beyond this basic knowledge, our understanding of their needs is poor. The following list includes issues that may pose concerns:

1) Pollution, chemical spills, and other water quality problems

There is some speculation that lampreys are relatively tolerant of poor water quality. Kan (1975) noted that Western Brook Lampreys were present in Willamette Basin streams that were polluted by pulp mills. He speculated they may be attracted to algae that may flourish near the mills under some conditions. They may be able to acclimate to somewhat elevated water temperatures (van de Wetering and Ewing 1999). Researchers in the Great Lakes found the sea lamprey, *Petromyzon marinus*, to be remarkably tolerant of toxins when they were trying to use them to eradicate the species (J. Seelye, personal communication). In Oregon, however, lamprey are common victims of chemical spills into streams. A 1999 spill in the lower Fifteenmile Creek killed thousands of them – too many to enumerate. They have been found after chemical spills in the Willamette Basin. ODFW demonstrated that Oregon lampreys, including both adults and juveniles, are easily killed using rotenone and toxaphene.

Lamprey juveniles spend their lives buried in silt along stream banks and bottoms. These habitats also are notorious for accumulating toxins. For example, the lower Willamette/Columbia confluence and some of the adjacent sloughs are a federal superfund site due to heavy metals and other toxins built-up to lethal levels in the mud and silt. This same area is lamprey habitat and may house a substantial proportion of the lampreys in the Columbia Basin. The Environmental Protection Agency (EPA) recently detected high levels of polychlorinated biphenyls (PCBs) in lampreys collected from the Columbia River. Upper Columbia sites used by lampreys, such as the lower Umatilla, have agricultural water pollution. Bear Creek on the Rogue is evidentially important for lamprey production but is heavily polluted. Lampreys may be relatively tolerant to water pollution, in comparison with a cutthroat trout, for example. But high pollution levels, especially when toxins accumulate in the silt that houses lamprey larva, is likely not good for them.

3) Reservoir hydrographs

Anadromous lampreys, like other anadromous fish, undergo extensive physiological changes as they migrate from fresh water to the ocean. Similar to other anadromous fish, they have a specific physiological window during which their transformation occurs. Flows stimulate migratory behavior. The altered hydrograph of the Columbia and Snake rivers, caused by changing the rivers from free flowing into a series of reservoirs, has been shown to impact salmonids by substantially slowing their migrations during their out-migration. Lampreys are weak swimmers and juveniles in an unaltered river tend to be carried passively to the ocean during winter and spring freshets. In a series of reservoirs, lampreys may be impacted by delayed out-migrations similarly to salmonids.

3) Dredging

Lampreys, possibly especially the River Lamprey, likely burrow in river bottom sediments all the way down the rivers to the ocean. Beamish and Youson (1987) discovered that one way to find River Lamprey was to sift through dredge spoils from the lower Fraser River. They also discovered that only 3% to 26% of the lampreys passed through a dredge survived the experience. Dredging goes on continuously in the lower Willamette and Columbia, including up some side-channels and sloughs. It also occurs in some coastal estuary areas. It would be useful to sample dredge spoils to see if lampreys are being taken.

4) Basin scouring

Interspersion of small gravel beds for spawning and fine silt lenses for juvenile rearing in lower rivers where natural flows are gentler are important habitat characteristics for lampreys. Oregon coastal streams were subjected to extensive scouring, especially in lower basin areas, due to the effects of splash-dam logging. Many rivers were scoured to bedrock and lamprey habitat was likely lost. This activity no longer occurs and many impacted areas are recovering.

5) Rapid Water Draw-downs

Water behind some dams and diversions may be subjected to periodic rapid water draw-downs. Lamprey ammocoetes are sensitive to changes in water pressure and light and can emerge from their burrows and follow a gradual water draw-down, such as what might occur after a natural flood. However, ODFW staff has seen evidence of lampreys being stranded in their burrows by rapid artificial draw-downs. Such observations have been particularly noted at Savage Rapids Dam on the Rogue River and during dewatering of irrigation screens.

6) Vulnerability of high density areas

Our preliminary observations suggest that lampreys may concentrate at extremely high densities in particular locations. In 2001 alone, remarkable concentrations of them were found in Bear Creek in the upper Rogue Basin and Clear Creek in the lower Clackamas, compared to what was observed using similar sampling methods in adjacent tributaries in the same year. It is not yet clear what this distribution pattern is about. However, if substantial portions of the lamprey being produced by a particular basin tend to concentrate in only a few locations a single event, such as a chemical spill, that impacts that location may destroy a substantial amount of the population, even if the event affects only a small area. The extremely high kills of lampreys in Fifteenmile Creek due to a chemical spill in 1999, and due to the rotenone events on the John Day in 1969 and 1982 may have occurred because the lampreys were concentrated in the areas impacted.

7) Development in floodplains and low gradient reaches

Lampreys appear to favor lower basin low gradient reaches. Pletcher (1963) commented on how lampreys particularly occupied the river reaches in the lower river flood plains. In Oregon, low gradient flood plains tend to be highly developed areas, with primarily industrial, urban, and agricultural development. The Willamette Valley, with the state's largest urban area and port at its mouth, is the most notable example. The lower rivers and estuaries of most coastal rivers are also highly developed, as is the low gradient, mid-valley areas of the Rogue and Umpqua and the lower tributaries into Klamath Lake, especially the Sprague River. It is not possible to speculate about the potential impacts to lamprey caused by this complex development and habitat alteration but it is likely to have depressed habitat availability and productivity for lampreys.

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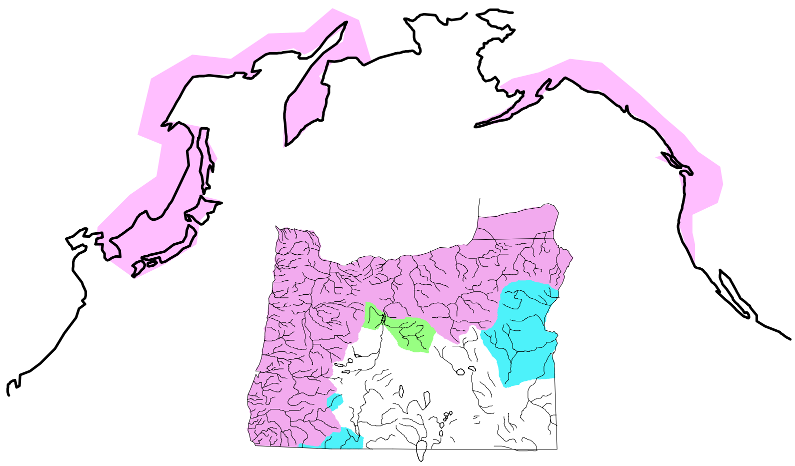

Figure 1. Present and historic distribution of the anadromous Pacific Lamprey (*Lampetra tridentata*) in Oregon and around the Pacific Rim. Present distribution ( ); area of known historic distribution ( ) and areas of suspected historic distribution ( ).

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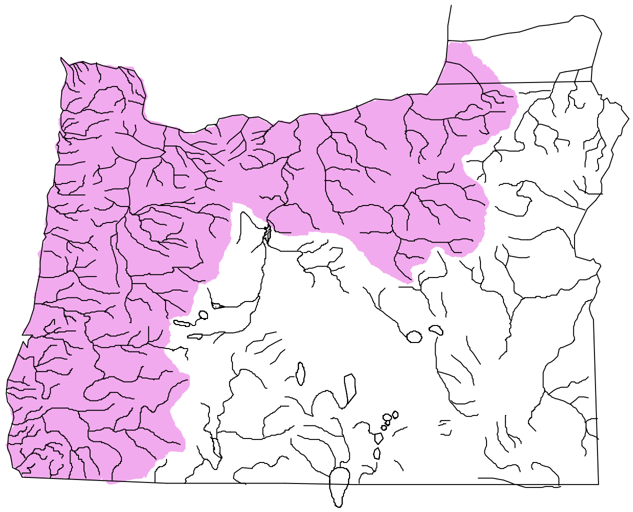

Figure 2. Distribution of the resident Western Brook Lamprey (*Lampetra richardsoni*) in Oregon.

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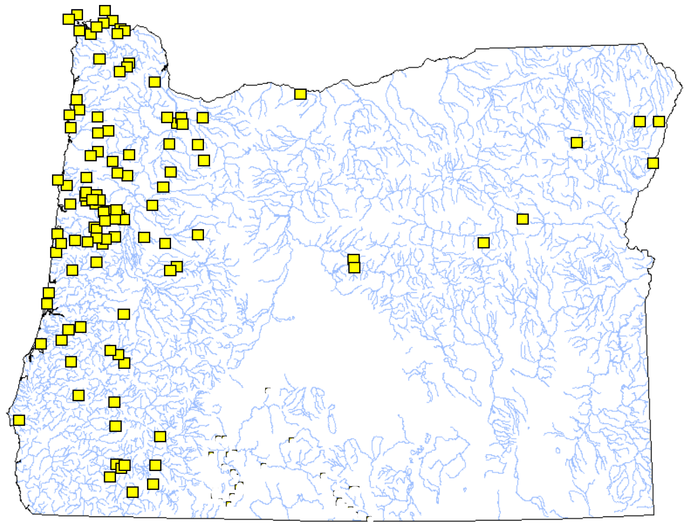

Figure 3. Collection records of anadromous Pacific Lamprey (*Lampetra tridentata*) in Oregon from the Oregon State University museum GIS data base.

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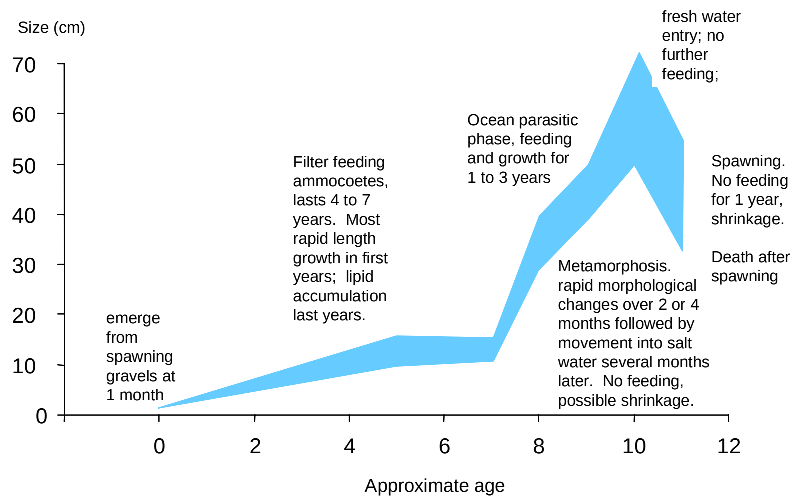


Figure 4. A generalized growth pattern (length) for Pacific Lamprey. Periods of arrested length growth and shrinkage will occur, particularly associated with bouts of no feeding.

52

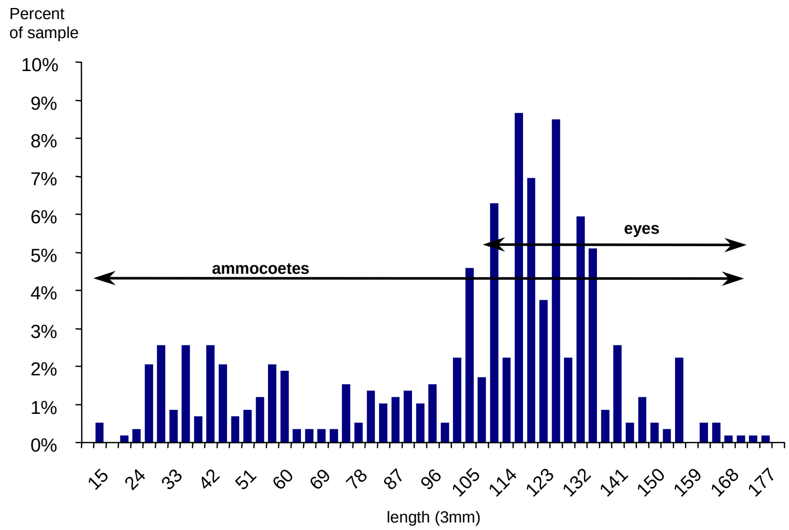


Figure 5a. Size distribution of lamprey captured in smolt traps on the upper Rogue Basin 1998-2001, all traps and years combined. Potentially multiple species present. Eyed individuals are likely undergoing metamorphism although some adult brook lamprey may be included.

53

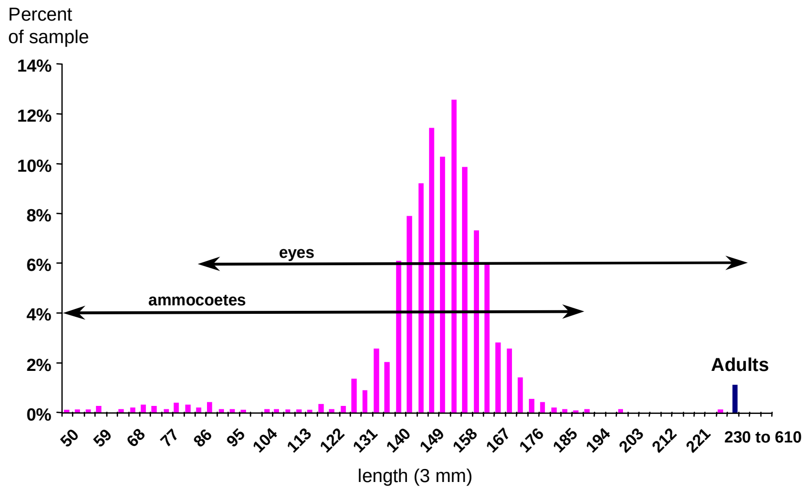


Figure 5b. Size distribution of lamprey captured in smolt traps on the lower Umatilla (RM 1.2 and 3.7), Columbia Basin 1998-2001, all traps and years combined. Only Pacific lamprey are present. Most eyed individuals are undergoing metamorphism although a few larger adults were also observed. 54

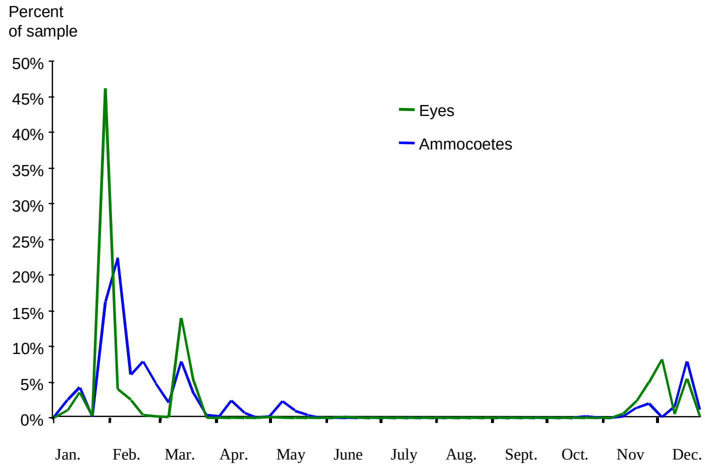


Figure 6a. Date of capture of lamprey in smolt traps in the lower Umatilla, Columbia Basin; weekly counts 1998 - 2001. All years and traps combined. N = 1,162 ammocoetes and N = 914 eyed lamprey. All lamprey observed were likely Pacific Lamprey.

55

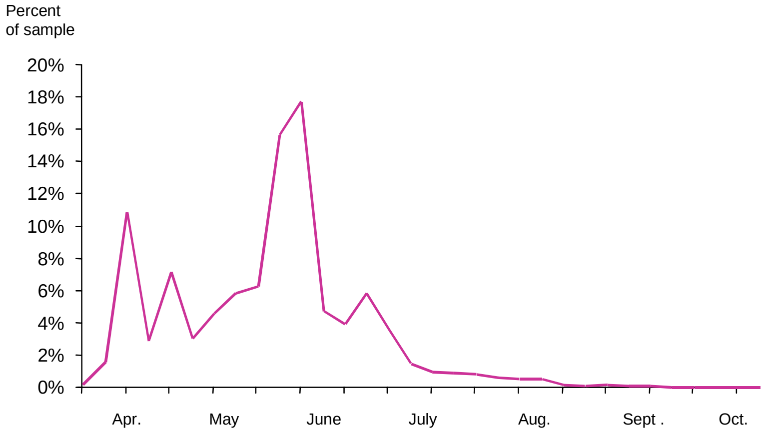


Figure 6b. Date of capture of juvenile lamprey at John Day Dam, mainstem Columbia River, 1988 - 2000 all years combined. N = 479,160. Sampling did not occur from November through mid-March.

56

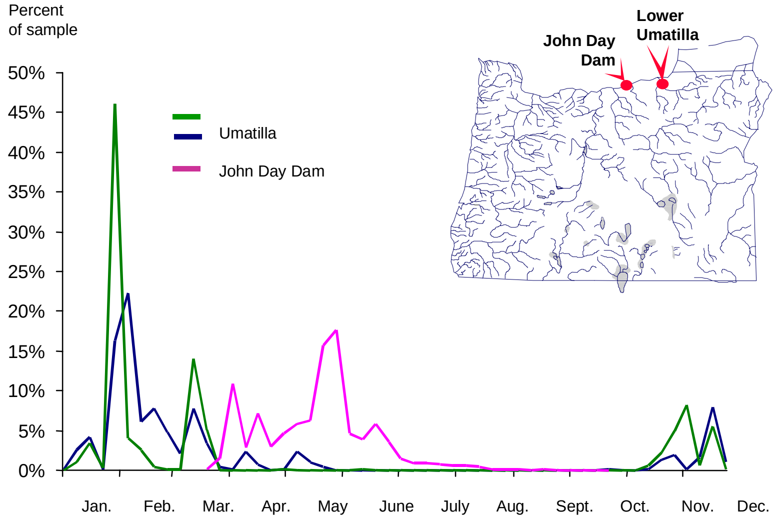


Figure 6c. Comparison of run time measured at John Day Dam (1988 - 2000) and in traps on the lower Umatilla (1998 - 2001). The two monitoring sites are very proximate to each other. Some of the differences in apparent run-time is probably caused by a lack of monitoring during the winter at John Day Dam.

57

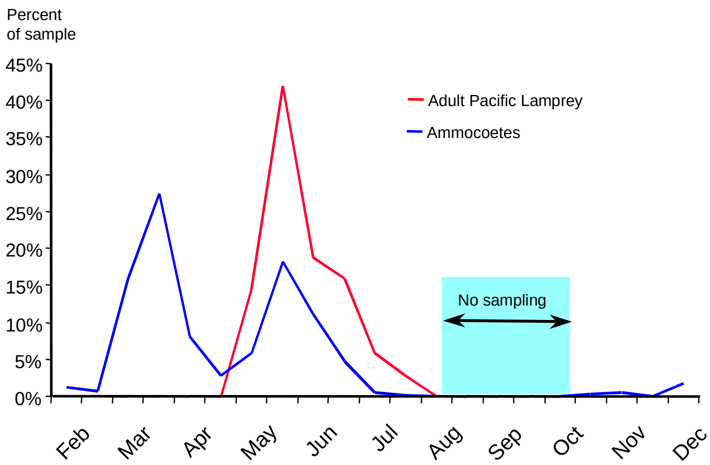


Figure 6d. Date of capture of lamprey in smolt traps on Fifteenmile Creek in the Columbia Basin, weekly counts 1998 - 2000. All years combined. Possibly western brook lamprey are among the ammocoetes. Eyed individuals not specified; uncertain whether any were observed. No sampling occurred between mid-August and mid-October, or between mid-Dec. through January.

58

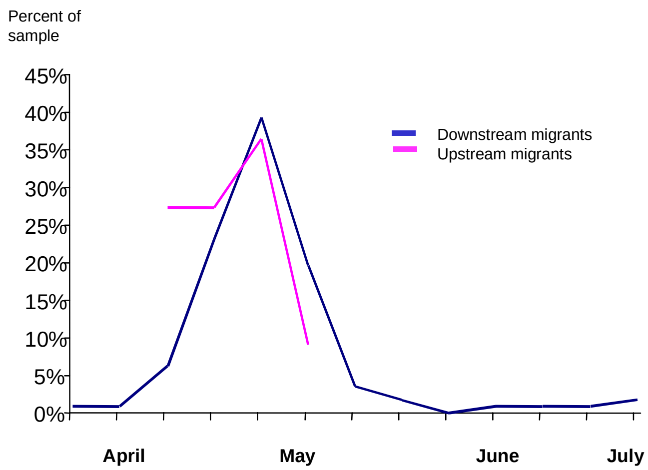


Figure 6e. Date of capture of lamprey at a trap on Mill Creek on the Yamhill River in the Willamette Basin, weekly counts during the spring made in 1976.

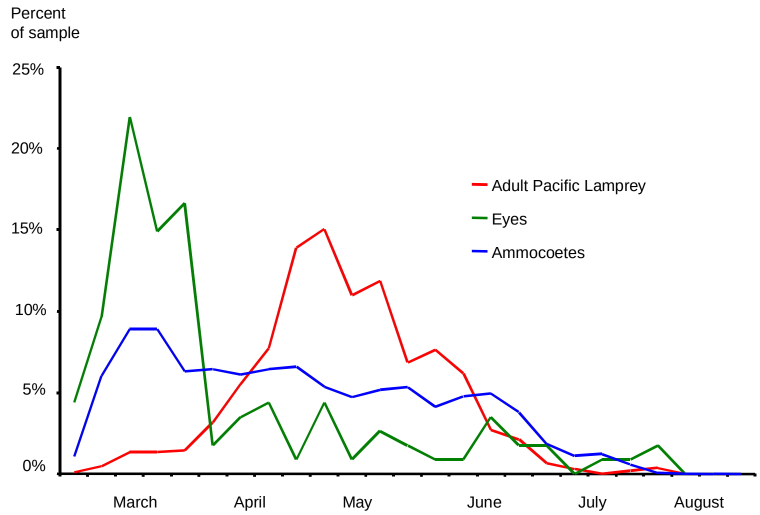


Figure 6f. Date of capture of lamprey in traps in Tenmile and Cummins creeks on the south Oregon coast, weekly counts 1993 - 2001. All traps and years combined. Eyed individuals and ammocoetes may be a mix of species. No monitoring occurred in fall or winter.

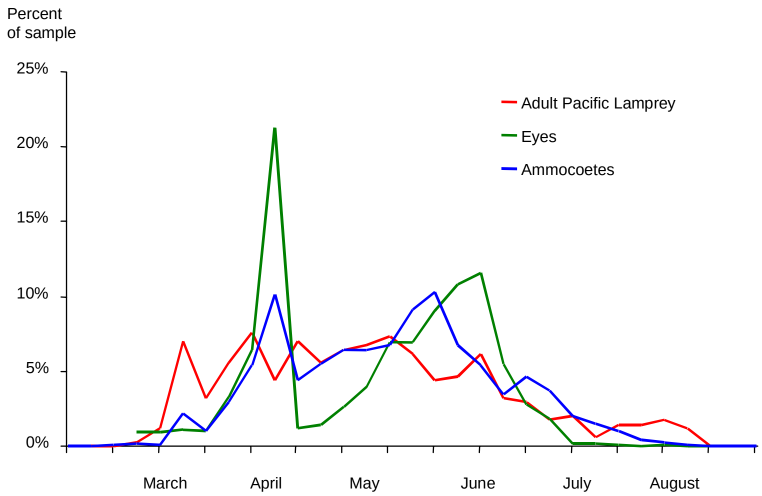


Figure 6g. Date of capture of lamprey in Oregon coastal smolt traps, weekly counts 1998 - 2001. All traps and years combined. Eyed individuals and ammocoetes may be a mix of species. No monitoring occurred in fall or winter.

61

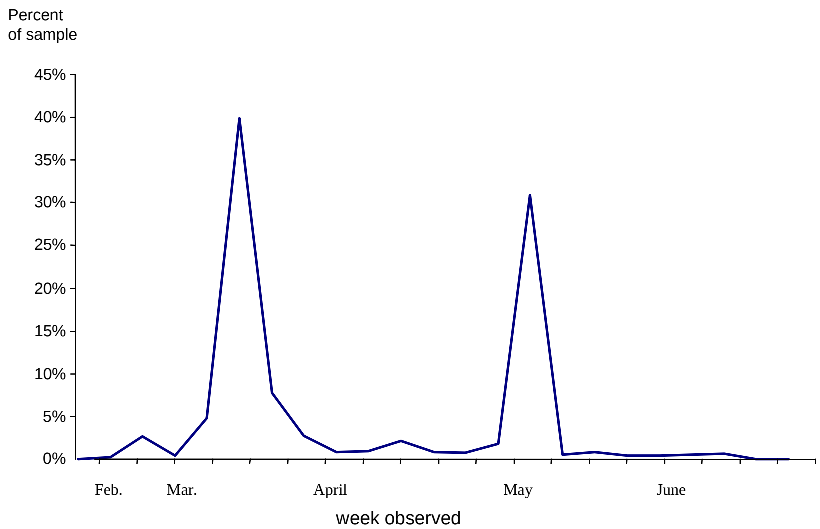


Figure 6h. Time of capture of lamprey in smolt traps in the upper Rogue River Basin; weekly data, 1998-2001. All years and traps combined. N = 7,458. Mostly ammocoetes, possibly a mix of species. A few eyed individuals were seen from late February through April. No monitoring occurred in fall or winter.

62

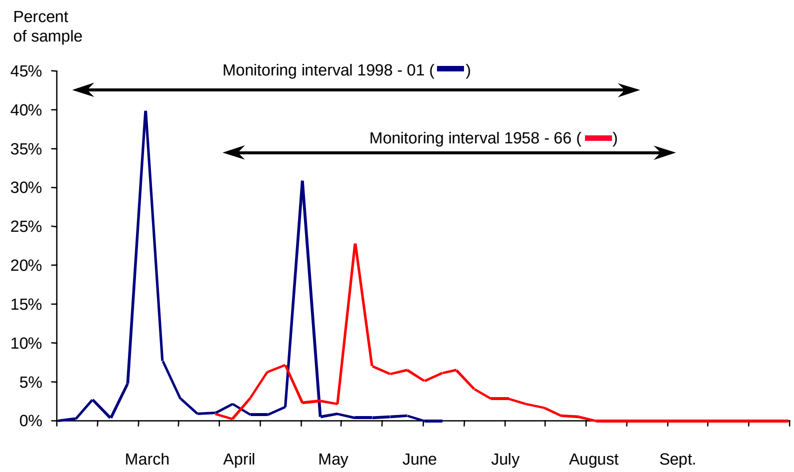


Figure 6i. A comparison of recent (1998 - 2001) and historic (1958- 1966) time of capture of lamprey in traps in the upper Rogue River Basin. All monitoring stations and years combined. The monitoring intervals in the two time periods are shown by arrows. No monitoring occurred in fall or winter.

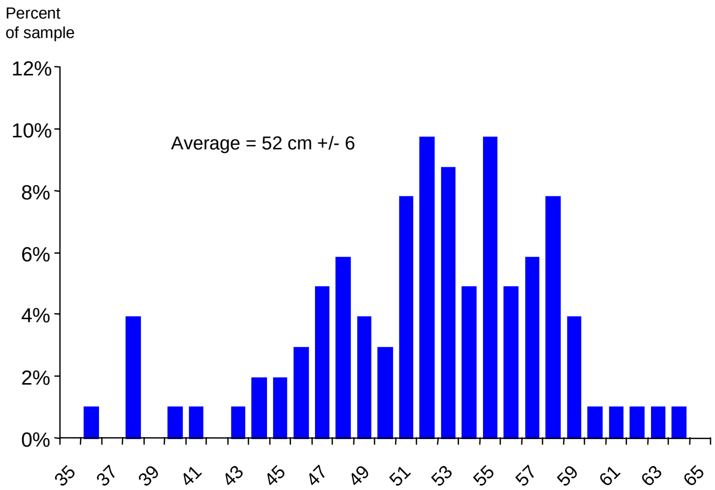


Figure 7a. Sizes of adult Pacific Lamprey collected from spawning grounds on the Coquille, in the spring of 2000; N = 103.

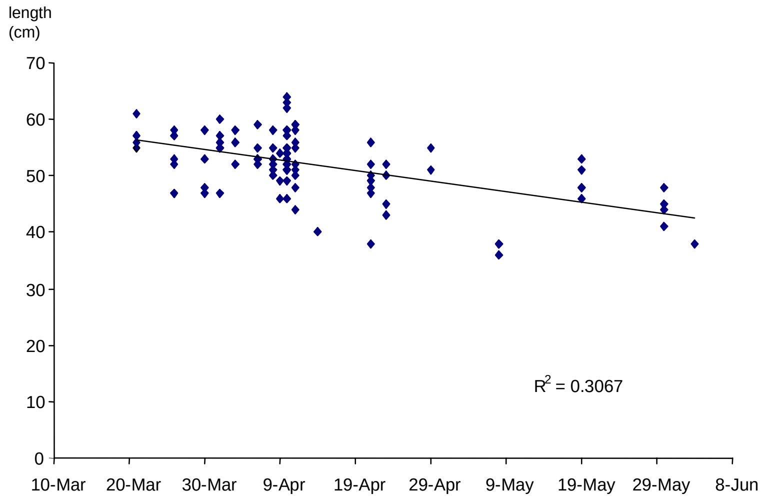


Figure 7b. Relationship between the size of spawning adult lamprey and the date of spawning on the South Fork Coquille, 2000; N = 103. Later spawning individuals tend to be smaller.

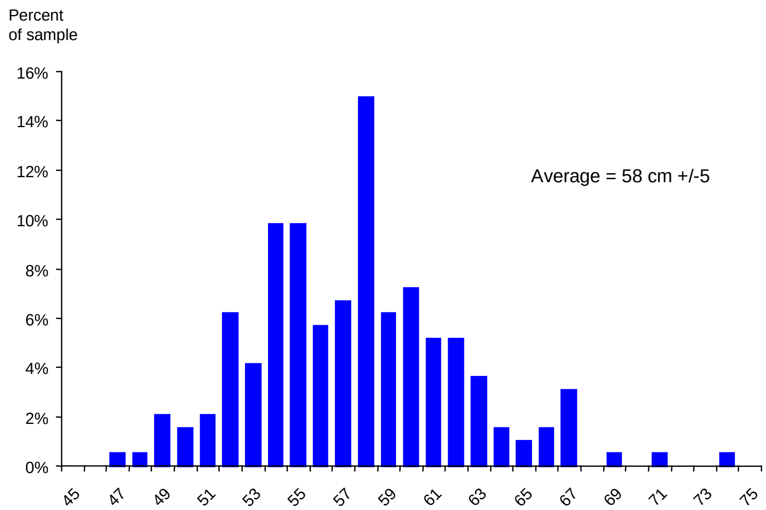


Figure 7c. Length distribution of adult Pacific Lamprey collected on one day in April 1994 at Willamette Falls; N = 194.

66

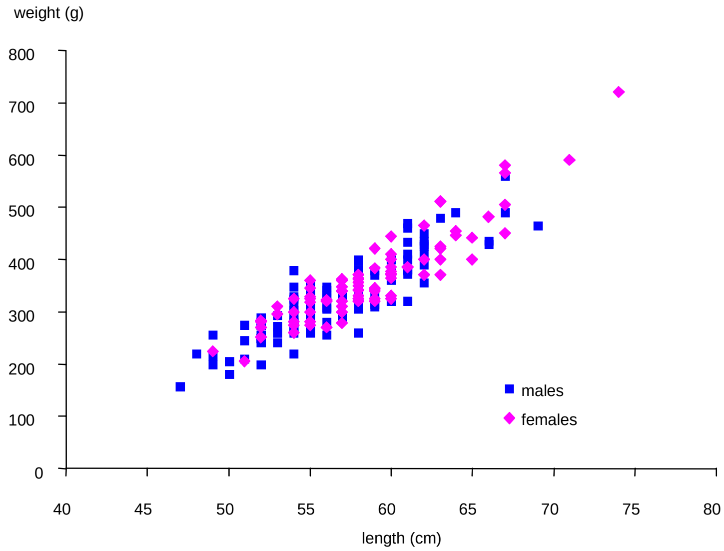


Figure 7d. Weight/length distribution by gender of Pacific Lamprey measured at Willamette Falls.

67

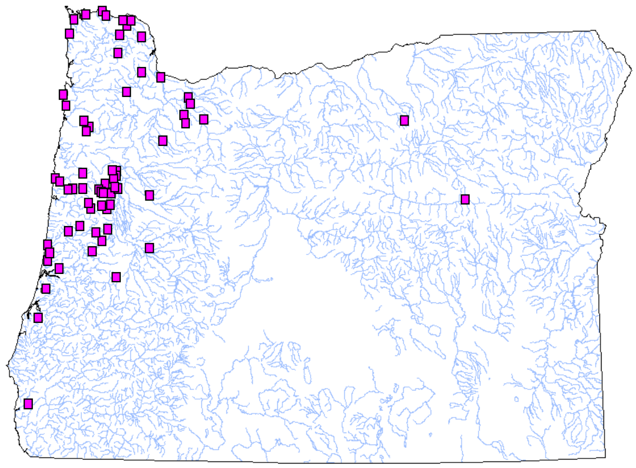


Figure 8. Collection records of the Western Brook Lamprey (*Lampetra richardsoni*) in Oregon from the Oregon State University museum GIS data base.

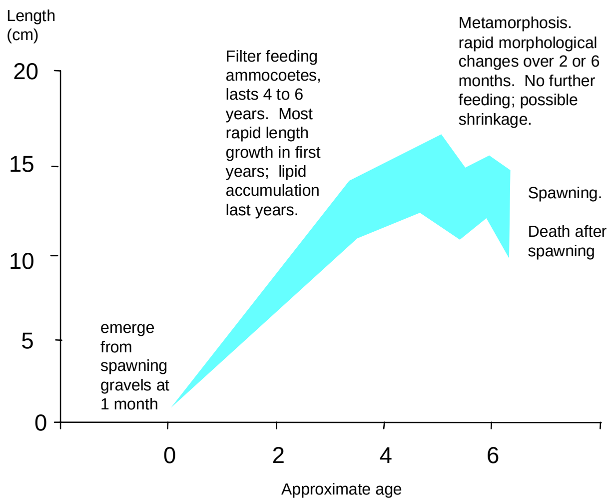


Figure 9. A generalized growth pattern (length) for brook lamprey. Feeding stops at the onset of metamorphism and the lamprey may shrink in size before spawning.

69

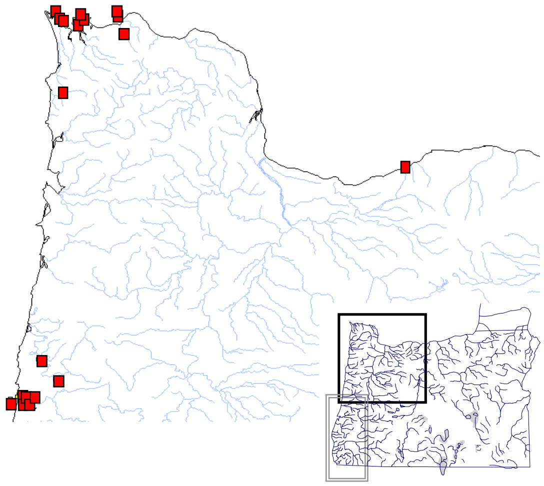


Figure 10. Collection records of the River Lamprey (*Lampetra ayresi*) in Oregon from the Oregon State University museum GIS data base.

70

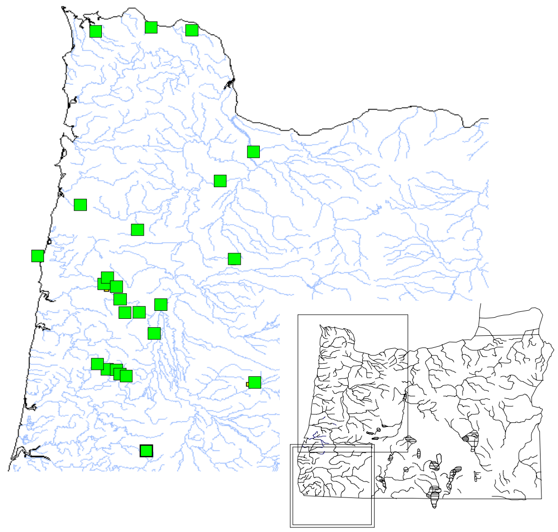


Figure 11. Collection records of the Pacific Brook Lamprey (*Lampetra pacifica*) in Oregon from the Oregon State University museum GIS data base.

71

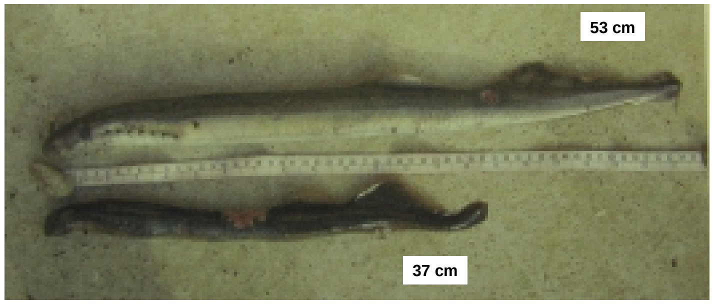


Figure 12. Photograph of Pacific Lamprey and "dwarf" Pacific Lamprey, both taken from spawning grounds, on the Coquille River. Photograph by L. Grandmontagne.

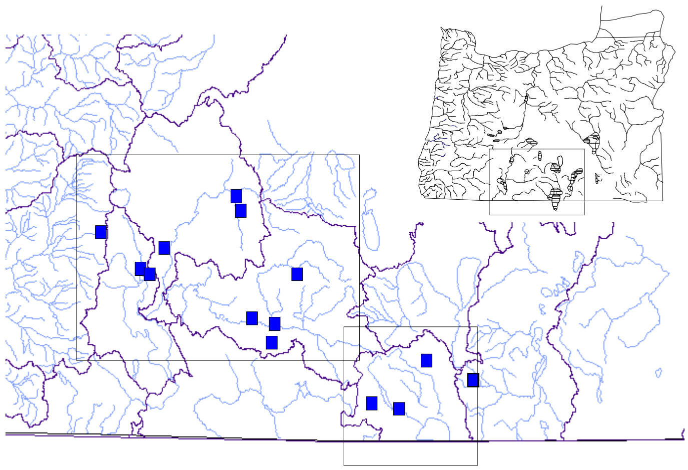


Figure 13. Collection records of the Pit-Klamath Brook Lamprey (*Lampetra lethophaga*) in Oregon from the Oregon State University museum GIS data base. Recent genetics work suggests the Klamath and Goose Lake populations may be different species.

73

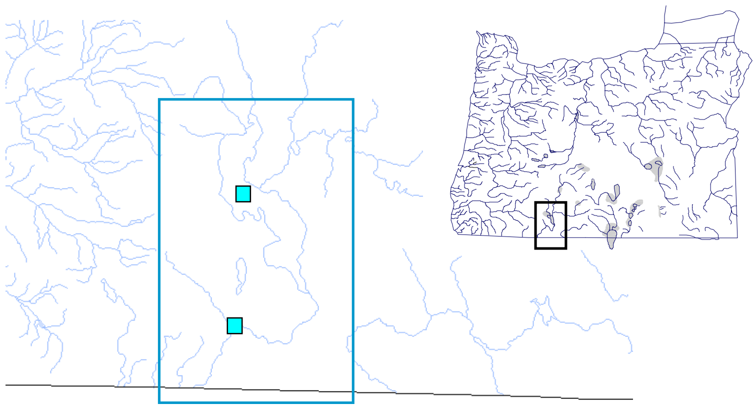


Figure 14. Collection records of the Klamath River Lamprey (*Lampetra similis*) in Oregon from the Oregon State University museum GIS data base.

74

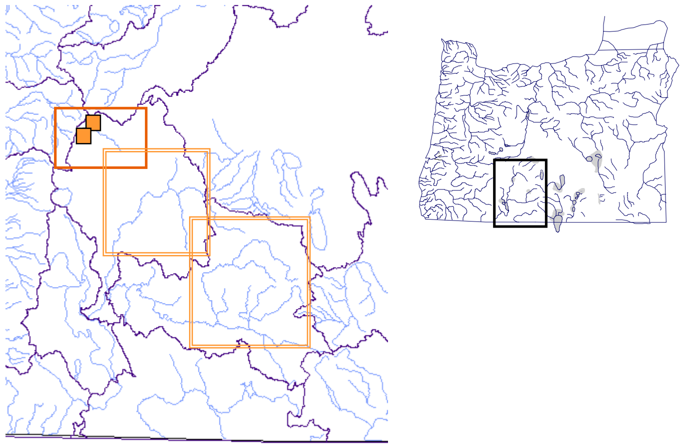


Figure 15. Collection records of the Miller Lake Lamprey (*Lampetra minima*) in Oregon from the Oregon State University museum GIS data base.

75

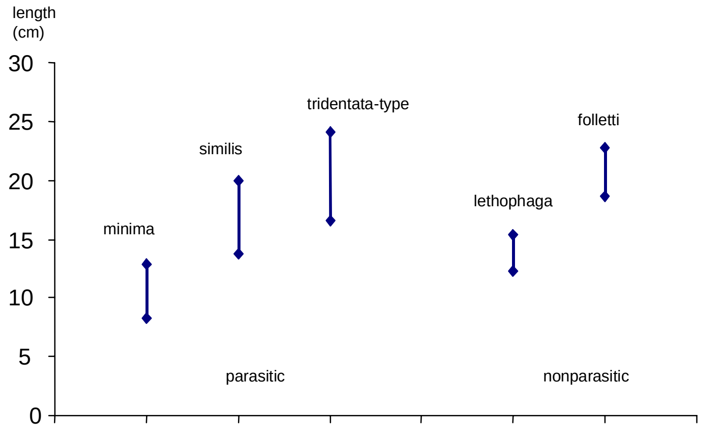


Figure 16. Adult sizes and parasitic/nonparasitic life histories of the Klamath Basin lampreys (data from Lorion et al 2000, Kan 1975, and Vladykov and Knott 1976)..

76

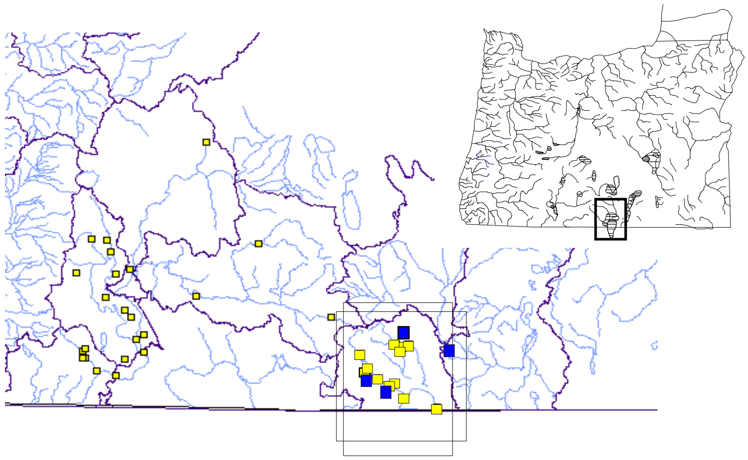


Figure 17. Collection of the Goose Lake Lampreys (*Lampetra sps.*) in Oregon from the Oregon State University museum GIS data base. Specimens include parasitic lamprey [yellow square] and nonparasitic lamprey [blue square].

77

Figure 18. Photographs of Goose Lake Lampreys collected during migrations across Thomas Creek weir. The lamprey in the lower photograph is ready to spawn.

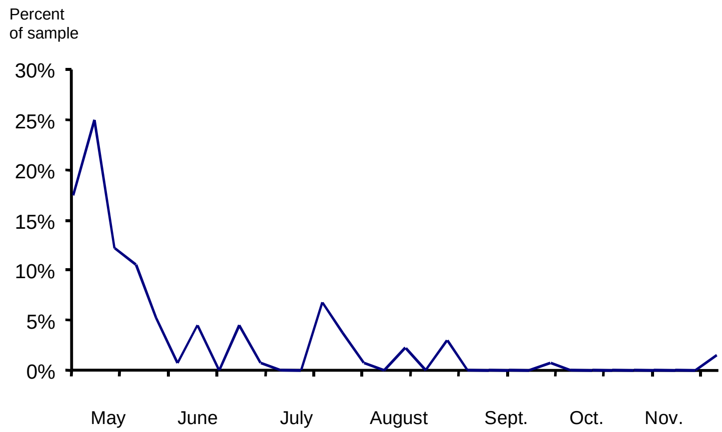


Figure 19. Date of capture of lamprey in the Thomas Creek Trap, Goose Lake Basin. Weekly captures, all data combined from 1999 to 2001 collections. Sampling did not occur between December and March.

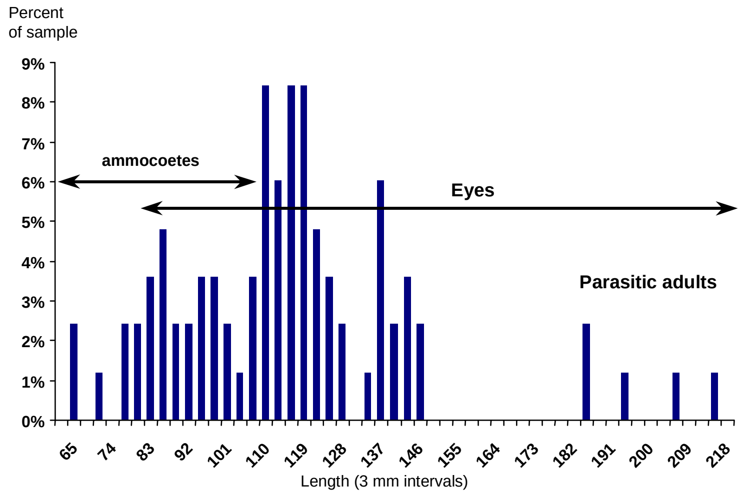


Figure 20. Length frequencies of lampreys caught in the Thomas Creek trap, Goose Lake Basin, 1999 - 2001. The larger specimens were clearly parasitic; the smaller eyed specimens may have included smaller parasitic adults, nonparasitic adults or recently metamorphosed lampreys migrating to Goose Lake.

80

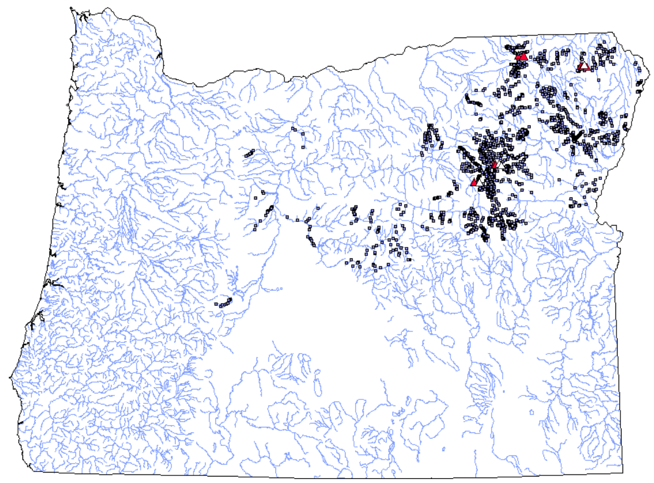


Figure 21. Observation records of lamprey in Northeast Oregon made during ODFW fish inventory surveys. Locations where lampreys were observed △ . Other locations that were sampled but no lampreys were observed ∎ .

81

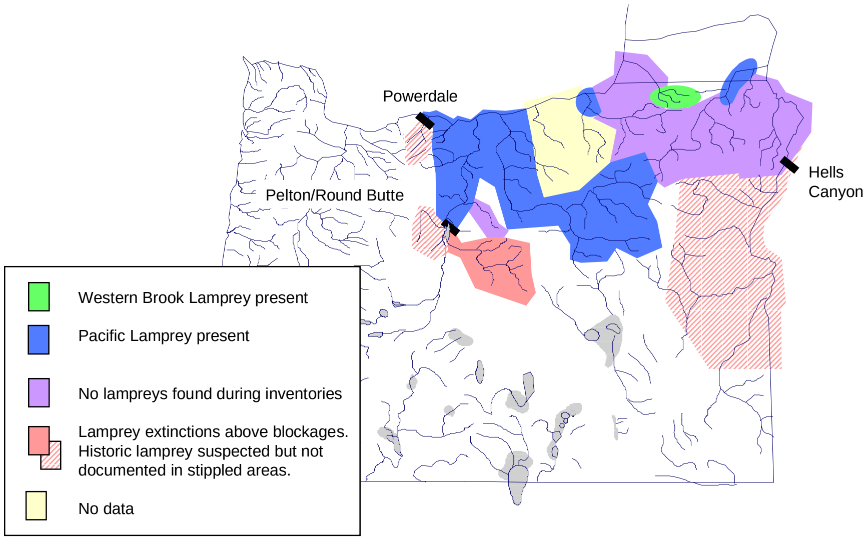


Figure 22. Lamprey distribution information for the Inland Columbia Basin area based on Close and Bronson (2001) and on observations by ODFW staff.

82

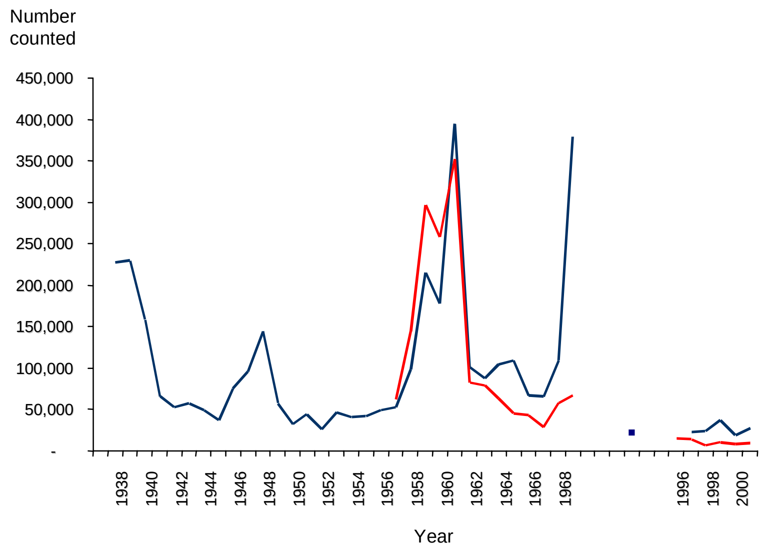


Figure 23a. Annual counts of adult Pacific Lamprey at Bonneville ( ) and The Dalles ( ) dams. Lamprey were not counted from 1970 through the mid-1990s.

83

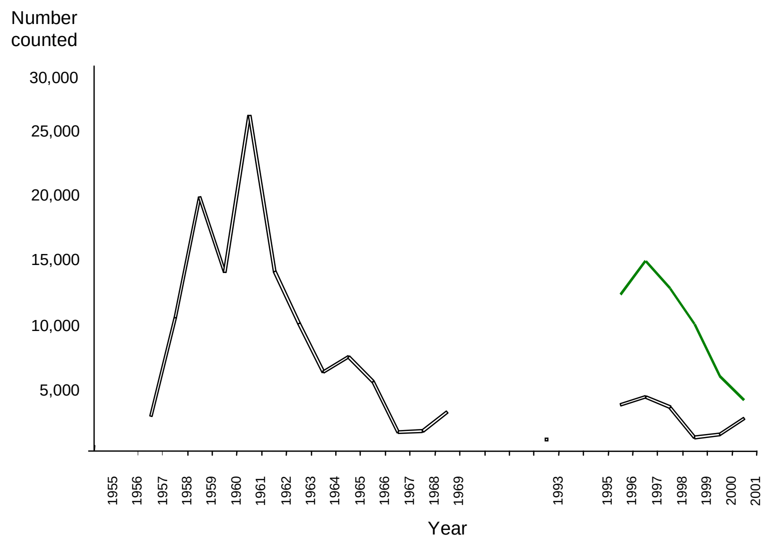


Figure 23b. Annual counts of adult Pacific Lamprey at John Day ( ) and McNary ( )dams. Lamprey were not counted from 1970 through the mid-1990s.

84

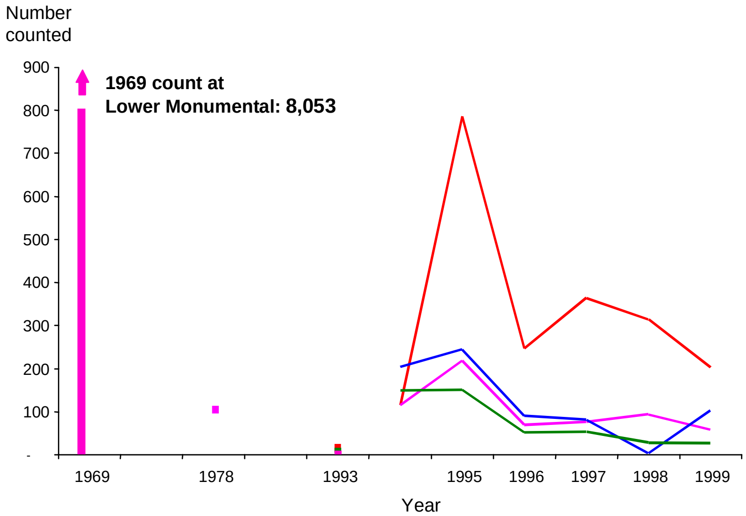


Figure 23c. Annual counts of adult Pacific Lamprey at Ice Harbor (▬), Lower Monumental (▬), Little Goose (▬) and Lower Granite (▬) dams. Lamprey were not counted from 1970 through the mid-1990s.

85

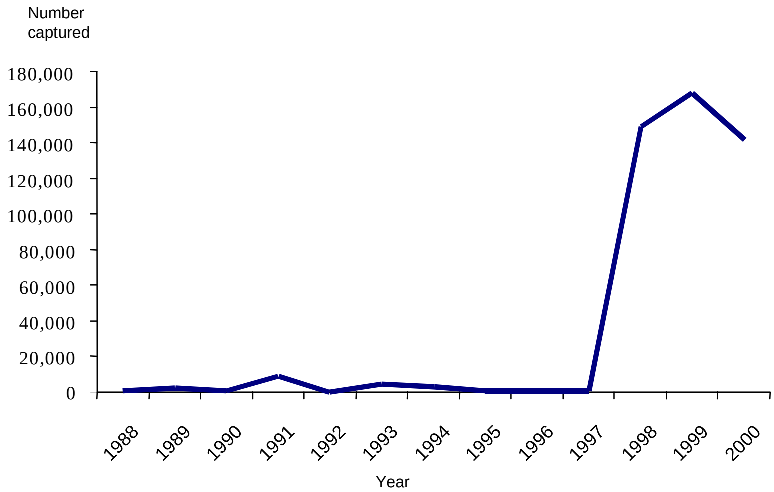


Figure 24. Numbers of juvenile Pacific Lampreys caught in the juvenile by-pass at John Day Dam, 1988 - 2000.

86

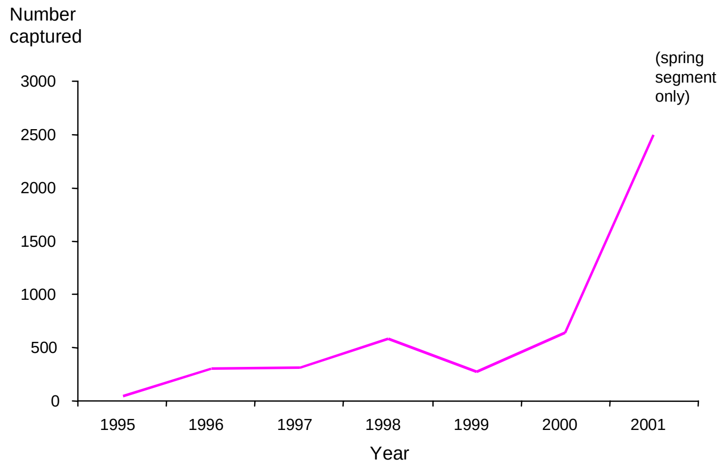


Figure 25. Numbers of juvenile Pacific Lampreys caught in smolt traps on the lower Umatilla, 1995 through spring of 2001.

87

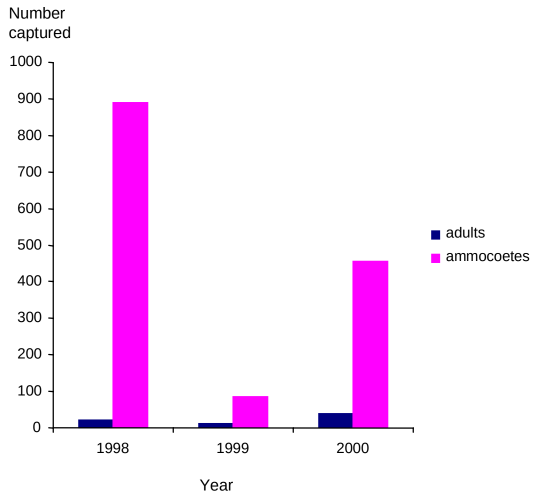


Figure 26. Number of adult and juvenile lampreys captured in a screw trap on Fifteenmile Creek, 1998 - 2000. Some of the ammocoetes may be brook lamprey.

88

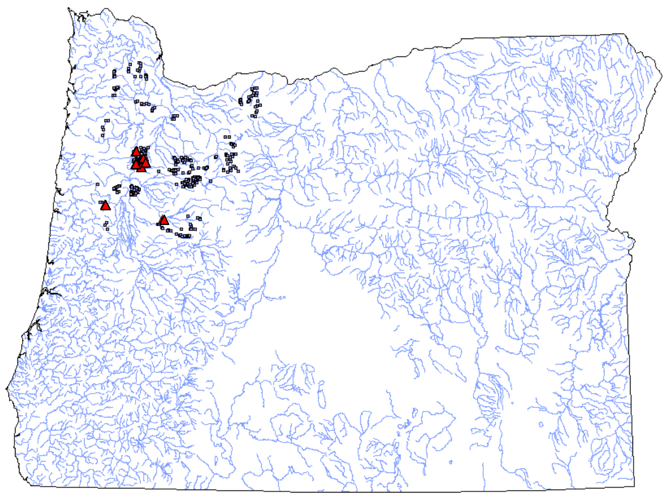


Figure 27. Observation records of lamprey in the lower Columbia and Willamette made during ODFW fish inventory surveys. Locations where lampreys were observed ▲ . Other locations that were sampled but no lampreys were observed ▪ .

89

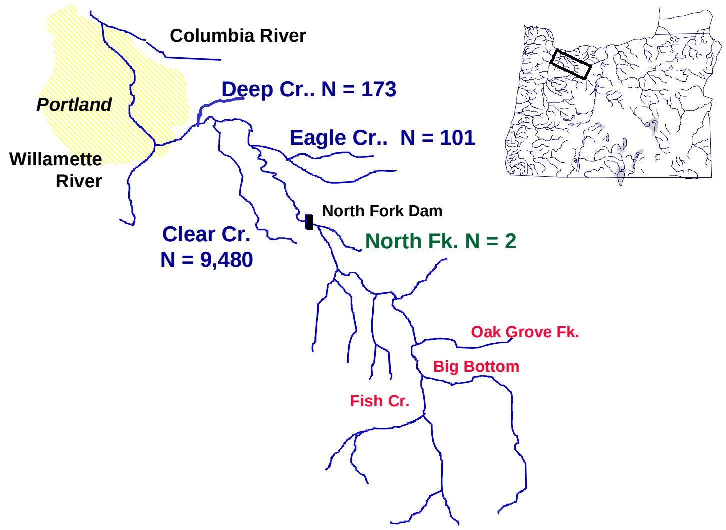
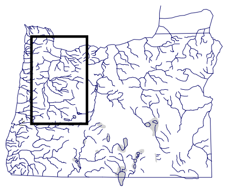


Figure 28. Distribution of lamprey collections in smolt traps on the Clackamas River in 2001. No lamprey were observed in upper basin (red traps). Only brook lamprey were observed in the North Fork trap (green trap). Likely a mix of species was seen in the lower basin (blue traps).

90



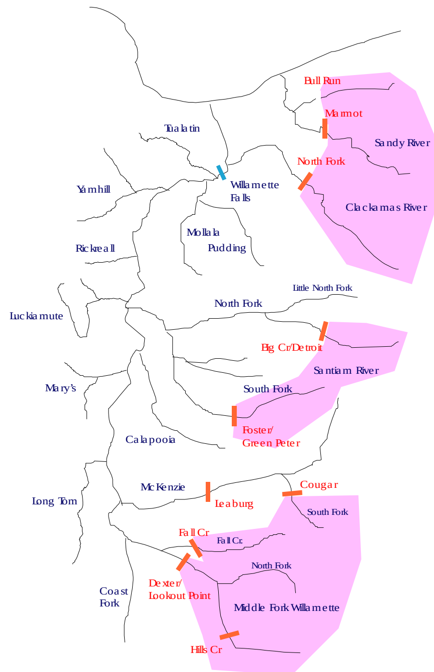


Figure 29. Willamette and Sandy rivers showing areas blocked by dams with no apparent lamprey passage.

91

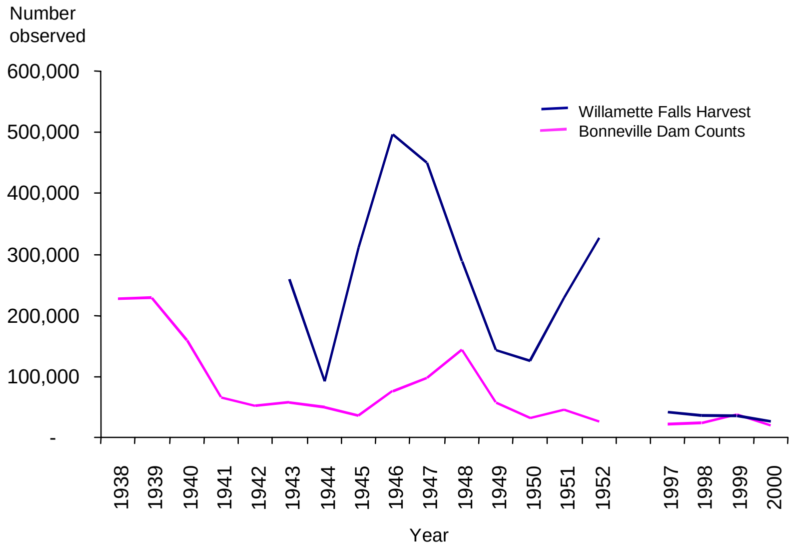


Figure 30. A comparison of the counts of Pacific Lamprey adults at Bonneville Dam to the number of lamprey harvested at Willamette Falls in an historic period (1943-52) and recently (1997-00).

92

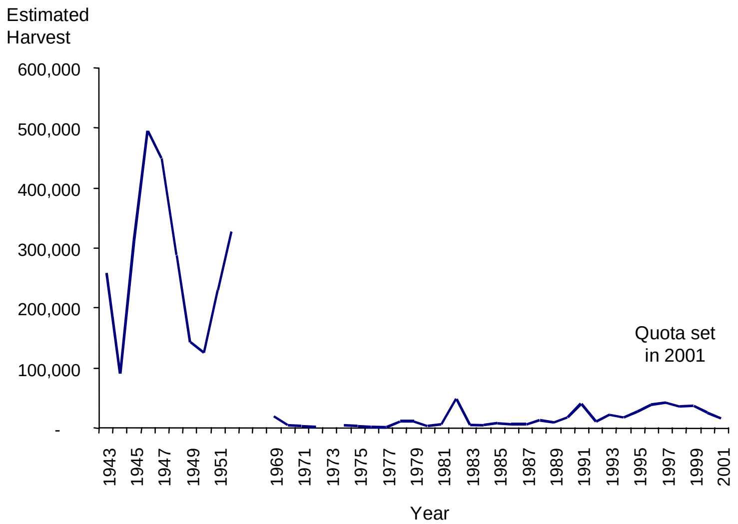


Figure 31. Estimated number of adult Pacific Lamprey harvested at Willamette Falls, 1945 - 01.

93

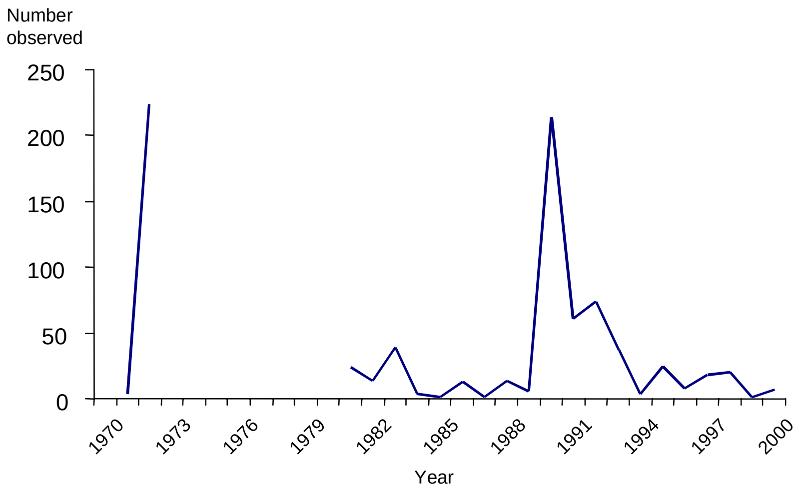


Figure 32. Counts of adult Pacific Lamprey at Leaburg Dam on the McKenzie River, upper Willamette Basin.

94

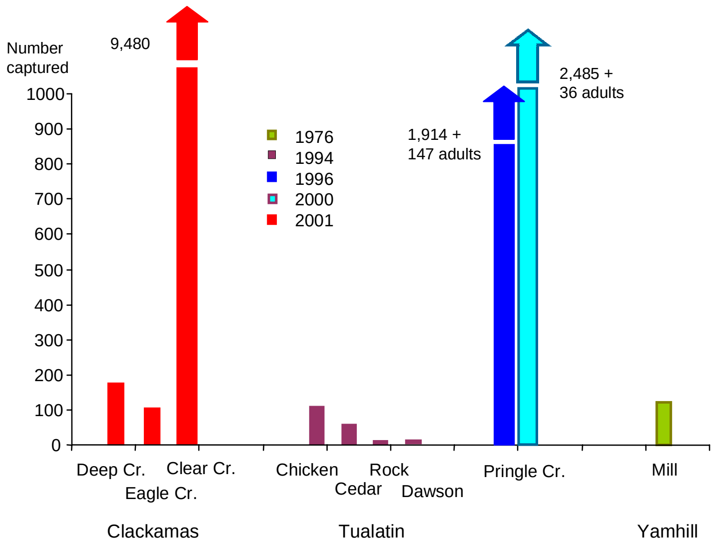


Figure 33. Incidental observations of lamprey, mostly ammocoetes, in the lower Willamette, by various sampling methods (smolt traps, electroshocking, fish kills).

95

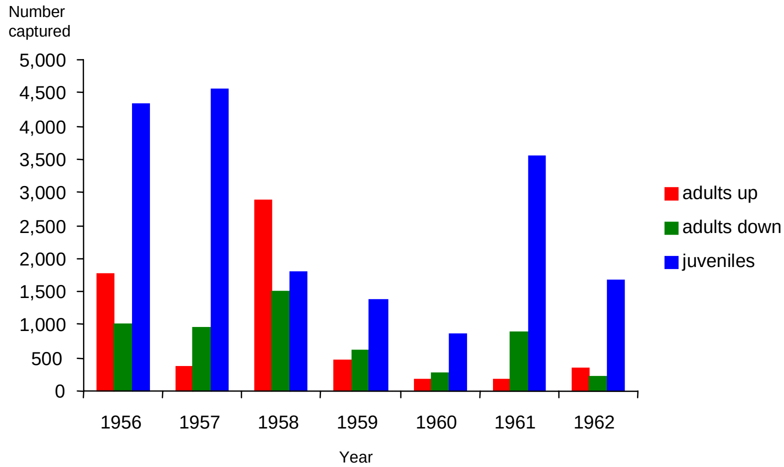


Figure 34. Numbers of lamprey captured during the Gnat Creek weir study, 1956 - 62, (from Willis 1962). All lamprey were identified as Pacific Lamprey. Additional adults were observed passing upstream without entering the trap.

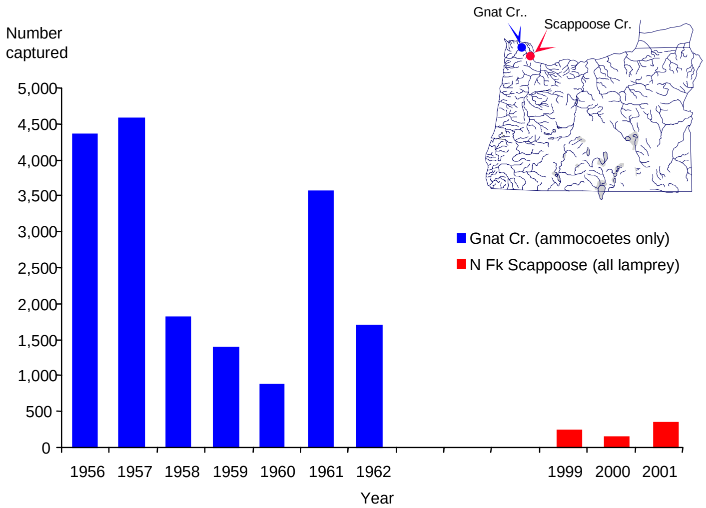


Figure 35. A comparison of the counts of lamprey at traps on Lower Columbia River tributaries, historically (Gnat Cr..) and currently (Scappoose Cr..).

97

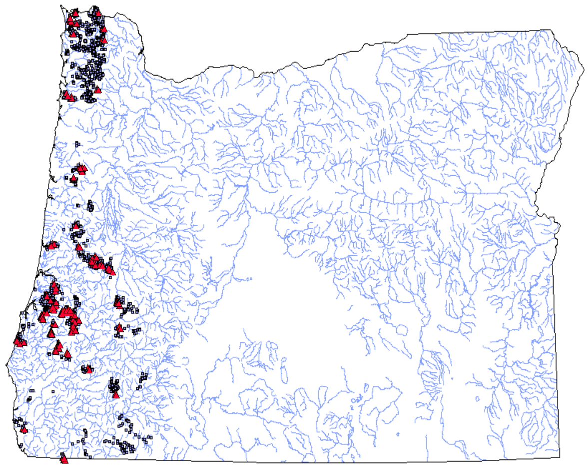


Figure 36. Observation records of lamprey on the Oregon coast made during ODFW fish inventory surveys. Locations where lampreys were observed ▲ . Other locations that were sampled but no lampreys were observed ▪ .

98

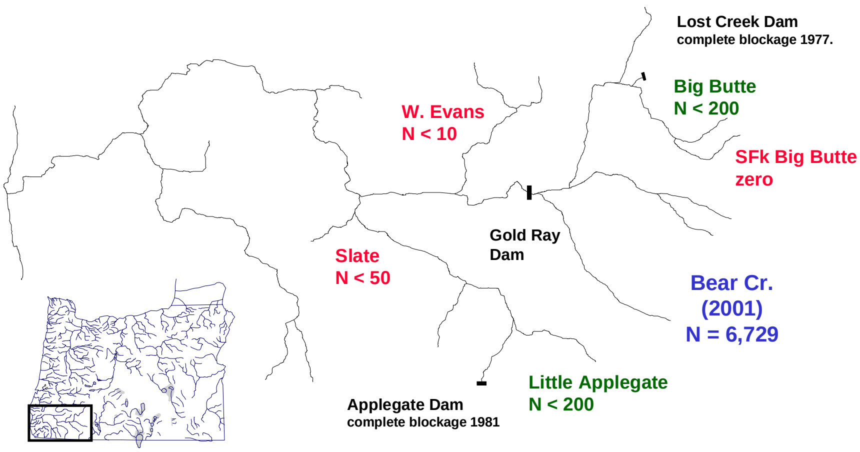


Figure 37. Distribution of recent lamprey observations in smolt traps in the upper Rogue Basin, 1998 - 2001. Counts at the red traps ranged from zero to 100; at the green traps ranged from 100 to 200, and at the blue trap, over 6,000. There is no data from the lower Rogue below the Rogue River Canyon.

99

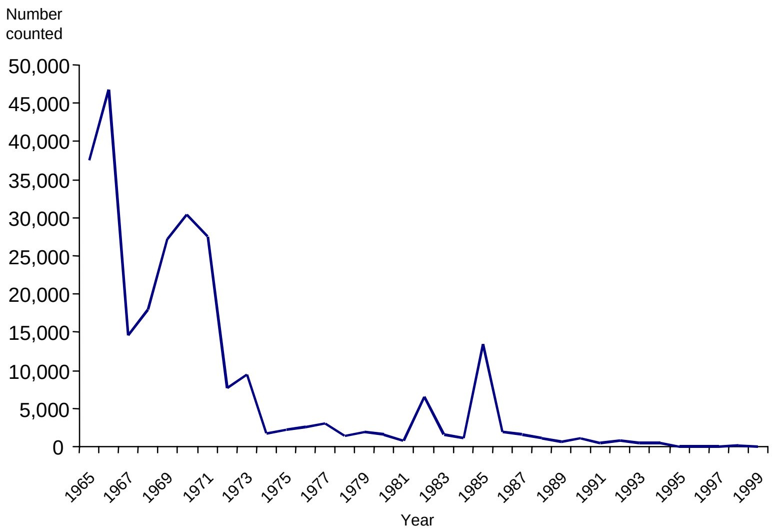


Figure 38a. Annual counts of adult Pacific Lampreys at Winchester Dam on the Umpqua River, Oregon coast, 1965 - 1999.

100

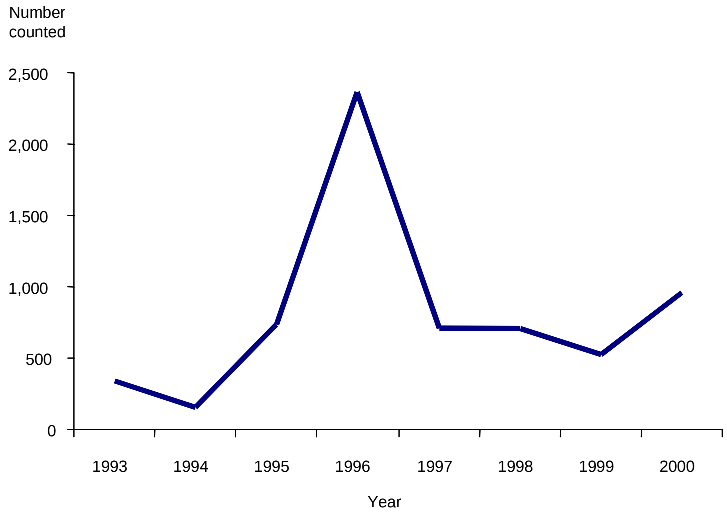


Figure 38b. Annual counts of adult Pacific Lampreys at Gold Ray Dam on the Rogue River, Oregon coast, 1993 - 2000.

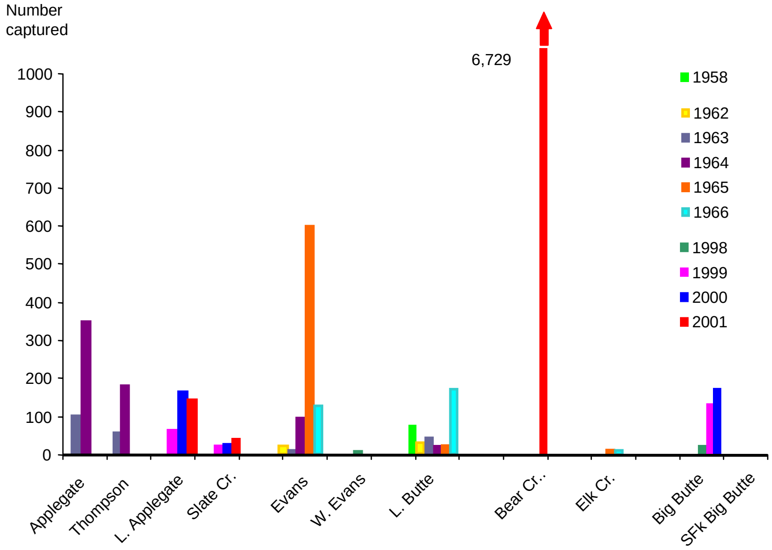


Figure 39. Counts of lampreys captured in traps in the upper Rogue River basin, including some historical observations. Mostly ammocoetes, likely a mix of species.

102

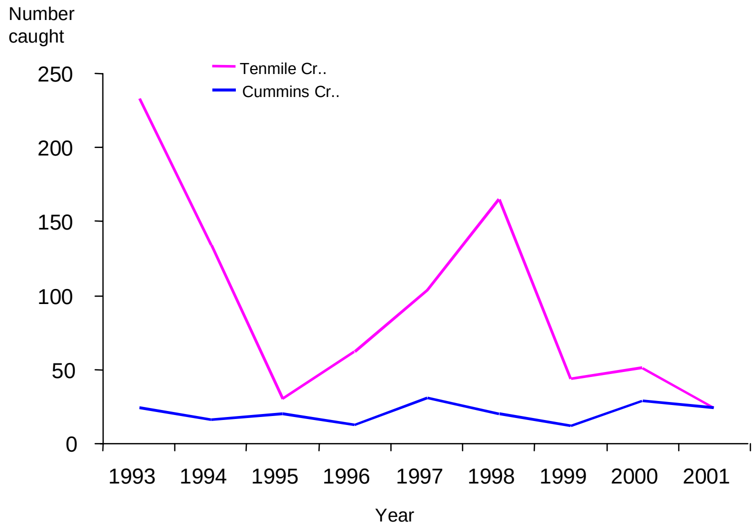


Figure 40a. Number of adult Pacific Lampreys caught annually in smolt traps on Cummins and Tenmile creeks, two small creeks on the south Oregon coast 1993 - 2001.

103

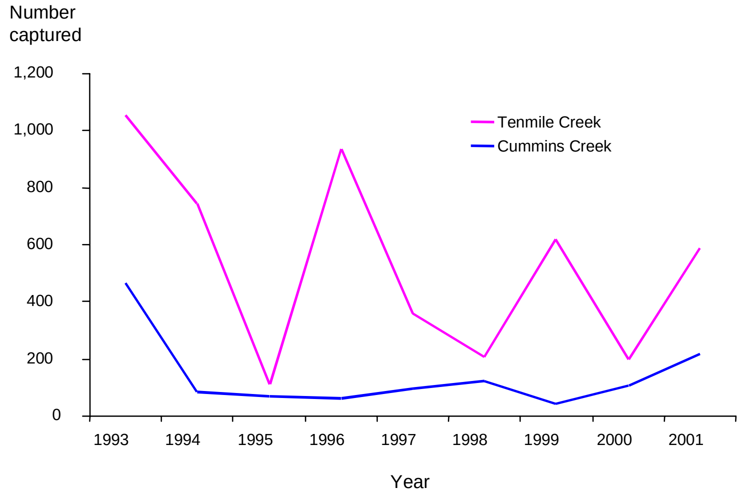


Figure 40b. Number of lamprey ammocoetes caught annually in smolt traps on Cummins and Tenmile creeks, two small creeks on the south Oregon coast 1993 - 2001. A few eyed lampreys were also caught; these may have been brook lampreys or lampreys undergoing metamorphism.

104

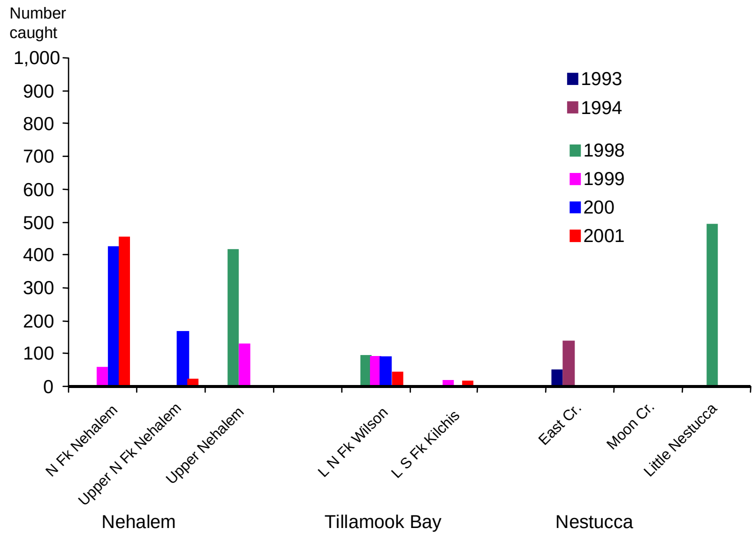


Figure 41a. Lampreys captured in smolt traps on the North Oregon coast. Most lampreys were ammocoetes. Sampling from 1993 - 2001, but not all locations were monitored in all years.

105

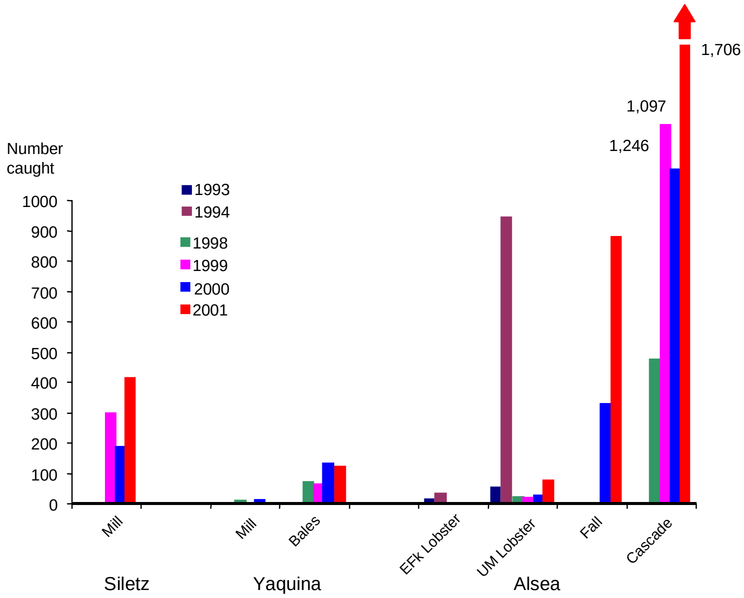


Figure 41b. Lampreys captured in smolt traps on the Mid-Oregon coast. Most lampreys were ammocoetes. Sampling from 1993 - 2001, but not all locations were monitored in all years.

106

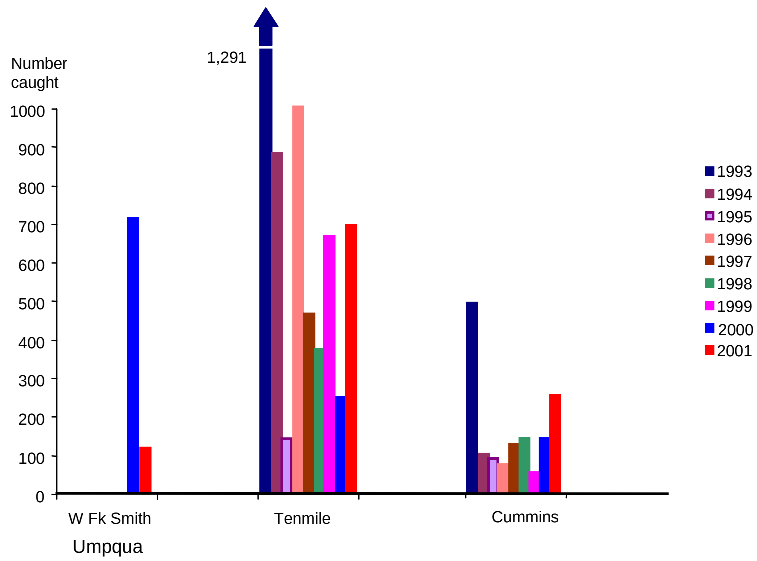


Figure 41c. Lampreys captured in smolt traps on the South Oregon coast. Most lampreys were ammocoetes. Sampling from 1993 - 2001, but not all locations were monitored in all years. 107

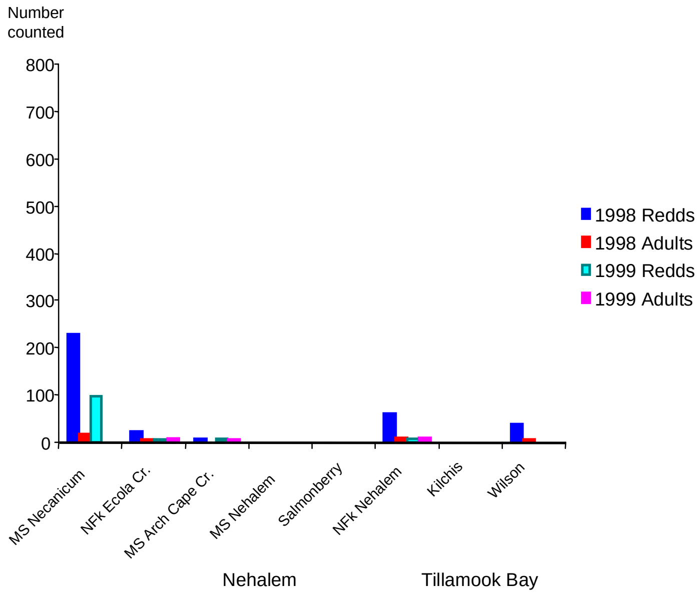


Figure 42a. Pacific Lamprey adults and redds observed during steelhead spawning ground surveys, on the north Oregon coast, 1998 - 1999.

108

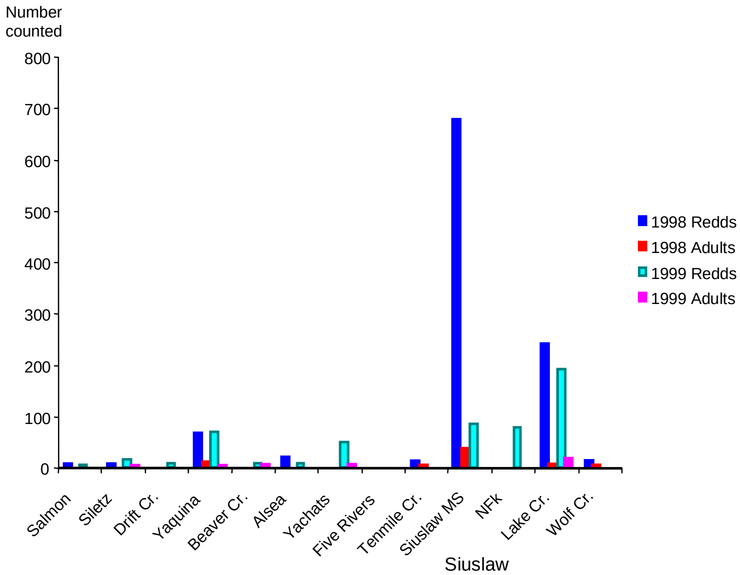


Figure 42b. Pacific Lamprey adults and redds observed during steelhead spawning ground surveys, on the mid-Oregon coast, 1998 - 1999.

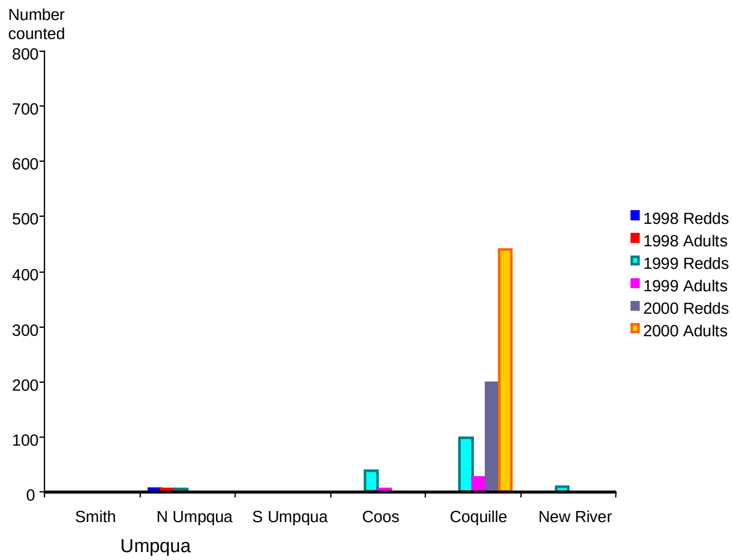


Figure 42c. Pacific Lamprey adults and redds observed during steelhead spawning ground surveys, on the south Oregon coast, 1998 - 2000.

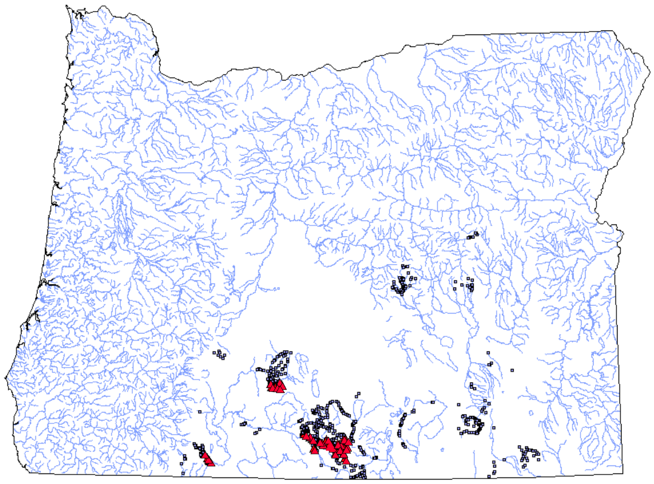


Figure 43. Observation records of lamprey in southeastern Oregon made during ODFW fish inventory surveys. Locations where lampreys were observed ▲ . Other locations that were sampled but no lampreys were observed ▪ .

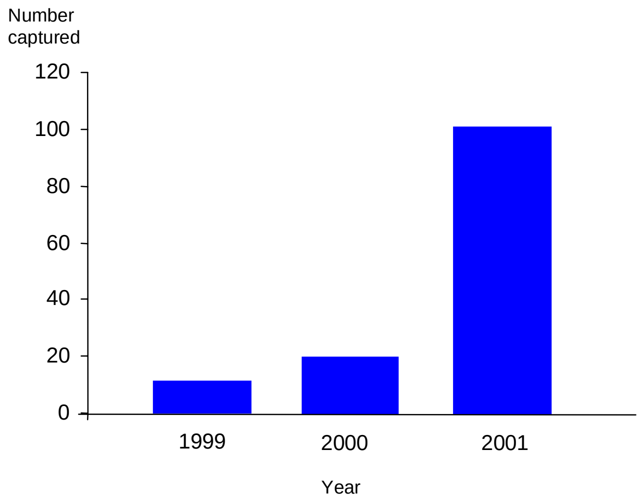


Figure 44. Counts of lampreys at the Thomas Creek trap, tributary of Goose Lake, 1999-2001. Both adults returning from Goose Lake on spawning runs and out-migrants are included.