2007-2009 Diamond Lake Amphibian Assessment

By

Chris Rombough

31 December 2009
Summary

Amphibian surveys of Diamond Lake and surrounding areas were conducted from 2007-2009, following a 2006 rotenone treatment of the lake. Data collected during this study indicates that populations of all amphibian species (except for rough-skinned newt) have increased since 2007. The effects of rotenone in establishing 2007 amphibian population sizes are not completely known, but were probably greatest on the northwestern salamanders and rough-skinned newts inhabiting the lake. Population sizes of the remaining amphibian species (Cascades frog, Pacific tree frog, western toad, and long-toed salamander) are probably less affected by rotenone treatment of the lake than the two aforementioned salamanders. Survey data indicate that aquatic areas away from Diamond Lake are more important to these species than the lake itself, and that physical factors such as annual precipitation may play a greater role in structuring their populations than any treatment of the lake.
Part 1. 2009 Amphibian Sampling

Introduction

The 2009 amphibian sampling results for both spring and fall surveys are reported here. The format follows that of previous reports (e.g., Hayes and Price 2007, Hayes and Rombough 2008), with the exception that the number and distribution of amphibian captures are summarized for each area surveyed, rather than simply reporting catch per unit effort. There are two reasons for this. First, catch or observation of amphibians during visual surveys varies tremendously as a function of many factors, including time, weather, and surveyor capacity. In the case of this report, where data from multiple surveyors with varying degrees of skill are combined, a more informative metric than catch per unit effort are changes in the patterns of distribution, relative abundance, and life stages of amphibians observed across the survey areas. Therefore, it was decided that a more effective means of communicating survey results here was by using a narrative format which provided pertinent background information on the area being surveyed. Second, because the distribution of many species observed was notably different than had been seen in previous surveys, more explanation was required to accurately describe the current situation. Species richness between survey areas is still represented in tabular format.

Spring Sampling

Methods

The spring amphibian sampling was conducted from 28 May to 03 June 2009. Weather conditions during this interval were generally poor for surveying, and consisted of overcast skies, with frequent thundershowers and daytime highs in the mid- 60s (°F). Surveys were conducted in the same areas (Diamond, Horse, and Teal Lakes, and Silent Creek) and using the same general methods (visual encounter surveys) as in the 2007 and 2008 sampling (Hayes and Price 2007, Hayes and Rombough 2008).

Results

Horse Lake

As a result of snowmelt and recent rains, the water level in Horse Lake was the highest observed during the three years of sampling, and the margins of the lake extended well back into the trees. Water clarity was very high, and limited only by pollen drifts in the shallow margins and overcast weather. As in 2007 and 2008, Horse Lake supported breeding by four amphibian species: western toad (Bufo boreas), Cascades frog (Rana cascadae), long-toed salamander (Ambystoma macrodactylum), and Pacific tree frog (Hyla regilla).
Western toad:

Spawning of western toads had just concluded when the lake was surveyed, on 30 May 2009. Though 32 adult toads (31 males and one female) were found in breeding areas around the lake, the developmental stage of toad eggs in the lake (close to hatching) indicated that breeding was coming to an end. Breeding in Horse Lake in 2009 was conducted in the same areas as in 2008: the northwest and southeast corners of the east lobe. A total of 101 egg masses were observed in Horse Lake during 2009 sampling, in contrast to 94 masses found in 2008.

In addition to breeding in Horse Lake proper, western toad larvae (ca. 4mm SVL average), representing spawning several weeks’ previous, were found in the small pond above (south of) Horse Lake. The number of larvae observed indicated at least two egg masses had been laid in this pond. The number of egg masses observed indicates that at least 103 female western toads spawned in Horse Lake during the 2009 breeding season.

Cascades frog:

Like western toads, Cascades frogs in Horse Lake had just finished spawning when the lake was surveyed (on 30 May 2009). Breeding by Cascades frogs was conducted at the same locations used by western toads: the northwest and southeast corners. Five adult Cascades frogs, four males in breeding condition and one spawned-out female, were found in the southeast corner, near egg masses. A total of 49 Cascades frog egg masses were observed in Horse Lake, and 20 Cascades frog egg masses were observed in the small pond above Horse Lake. The number of egg masses observed indicates that at least 69 female Cascades frogs spawned in Horse Lake during the 2009 breeding season. This is an increase from 2008, in which 20 egg masses were found in Horse Lake, and 12 egg masses were found in the small pond (representing 32 females).

Pacific tree frog and long-toed salamander:

Though egg masses of both species were observed in Horse Lake, no attempt was made to quantify breeding effort. Breeding by both these species was also observed in Horse Lake in 2007 and 2008.

Other animals

As per the sampling protocol for this survey (Hayes and Price 2007), potential amphibian predators were noted when encountered. During the Horse Lake survey, a single adult common garter snake (Thamnophis sirtalis fitchi), two pairs of bufflehead (Bucephala albeola), a pair of mallards (Anas platyrhynchos), and a nesting green-winged teal (Anas carolinensis) were observed.
Teal Lake

Teal Lake was sampled on 02 June 2009, under weather conditions not particularly favorable for detecting amphibians (100% cloud cover, light breeze, 55°F air temperature). Nonetheless, four species of amphibians were observed in Teal Lake: Cascades frog, Pacific tree frog, long-toed salamander, and Northwestern salamander (*Ambystoma gracile*). Water in Teal Lake was very high (well over the top of the gauge staff), and quite clear during surveys.

**Cascades frog**

One dead male Cascades frog (approximately 58mm SVL) was found in the shallow southwest corner of Teal Lake. This frog had been in breeding condition prior to death, but the reason for its presence in the lake, as well as its cause of death, is unknown. Given the number of juvenile Cascades frogs observed during fall sampling in 2008, this dead frog provides additional evidence of breeding by this species in Teal Lake. However, no additional Cascades frogs or their egg masses were observed during this survey, though it is possible that egg masses had already hatched by the time this survey was conducted, or were missed.

**Pacific tree frog**

Male tree frogs called from around Teal Lake during surveys, and larger (>40 males) choruses were observed in this lake on 30 and 31 May, and 01, 02, and 03 June.

**Long-toed salamander**

As in 2008, Teal Lake supported breeding by long-toed salamander. During the survey, 10 large egg masses of this species were observed, attached to sedges in 40-90 cm of water around the edge of the lake. Most were close to hatching, with embryos elongated and showing muscular response (movement).

**Northwestern salamander**

Two northwestern salamander (*Ambystoma gracile*) egg masses, both with well-developed embryos, were observed in Teal Lake.

**Other animals**

A pair of mallard ducks were observed feeding in the north end of Teal Lake during surveys.
Diamond Lake

Diamond Lake proper was sampled over three separate days: 28 May, 29 May, and 03 June 2009. Weather during surveys was variable, and ranged from clear skies and air temperatures in the mid-70s F, to completely overcast skies and air temperatures in the low 50s F. Five species of amphibians were found in Diamond Lake: Cascades frog, western toad, long-toed salamander, Pacific tree frog, and northwestern salamander.

Western toad:

Western toads were found breeding at two places in Diamond Lake. The first was in the mouth of a shallow (ca. 50 cm deep) ditch running into the lake from the large marsh on the south side of the lake, near the south shore boat ramp. Breeding was observed at this site on 28 and 29 May, with male toads calling and in amplexus with gravid females. That breeding had been initiated at least two weeks previously was indicated by the presence of hatching egg masses. A total of 21 adult male toads and three female toads were observed at this site on 28 May, 2009. A total of six western toad egg masses, in stages of embryonic development ranging from just laid (single-cell, egg jelly still expanding) to hatching, were found in the mouth of this ditch. 60 juvenile toads, ranging from 29-37mm SVL, were found along the edge of Diamond Lake near the south shore boat ramp. In addition, three juvenile toads of similar size were found at the mouth of Short Creek on 29 May 2009. Due to their proximity, these juvenile toads probably represent 2008 reproduction occurring at the site mentioned above. Western toads were also found breeding in the shallow marsh in the northwest corner of Diamond Lake, near the Thielsen View Campground. A single western toad egg mass, with embryos close to hatching, and 29 juvenile toads (members of the 2008 cohort) were found in this marsh on 03 June 2009.

In addition to these observations, Miss Holly Truemper, ODFW Fish Biologist, twice observed adult toads swimming in the lake during the course of electrofishing operations. On 29 June, she reported a large adult toad in the water near the northwest corner marsh, and on 20 July, she saw two adult toads in the water near Rocky Point.

Cascades frog

Cascades frogs were found at three places along the shore of Diamond Lake: the mouth of Short Creek, the mouth of Silent Creek, and the toad breeding ditch along the south shore (mentioned above). Nine frogs were found at the mouth of Short Creek: one juvenile and eight adults (three males and five females). All were healthy, though their size and condition indicated that they probably did not breed in 2009. Four frogs were observed in small overflow pools at the edge of Diamond Lake near the mouth of Silent Creek: two juveniles (ca. 26mm SVL) and two adults (ca. 44 and 75mm SVL, respectively). Five frogs were found in the toad ditch and adjacent marsh: five were adult frogs (ca. 52-58mm SVL), and two were juveniles (25 and 29mm SVL, respectively).

In addition to the survey results described here, Holly Truemper made two very interesting observations of Cascades frogs in Diamond Lake during the summer of 2009. The first of these occurred when Holly and Jordan Hazen, an intern from OSU, electrofished Short Creek on 21 July 2009. During this survey, they shocked three juvenile and two adult Cascades frogs in the portion of Short Creek above the culvert. The second observation of interest was Holly’s finding of a juvenile Cascades frog on the
edge of the weir on Lake Creek, on 10 June 2009. The significance of these results is explained below.

*Pacific tree frog*

Pacific tree frogs were observed breeding throughout the marsh on the south side of Diamond Lake, from the south shore boat ramp to west of Silent Creek. They were also found breeding in the marsh at the northwestern corner of Diamond Lake. Interestingly, no tree frog egg masses were observed in the spillway pool, adjacent to the Lake Creek outflow. This may have been due to the survey timing, as it is possible tree frogs had not started breeding in this area by the date on which surveys were conducted.

*Long-toed salamander*

Long-toed salamanders were found breeding in the marsh along the south side of Diamond Lake, both east and west of Silent Creek. No attempt was made to quantify breeding effort.

*Northwestern salamander*

Northwestern salamanders were found breeding in two places within Diamond Lake. The first of these was a shallow ditch at the south edge of the lake, approximately a hundred meters west of the south shore boat ramp, where water from the south shore marsh was slowly flowing into the lake. Two freshly laid egg masses were found at this location, attached to sticks in 40 cm of water. The second place was in the spillway pool, where two freshly laid egg masses were found attached to submerged *Elodea* in 40 cm of water near the gauge.

*Other animals*

During this survey, a single lesser scaup (*Aythya affinis*) drake and a pair of mallards were observed feeding off the mouth of Short Creek, and an adult common garter snake was found foraging in the south shore marsh next to the toad breeding ditch.

*Silent Creek*

Silent Creek was surveyed over portions of 01 and 02 June 2009, under conditions not particularly good for detecting amphibians: 100% cloud cover, daytime air temperatures in the low 50s F, and intermittent thundershowers with heavy rain and hail.

*Western toad:*

109 western toads, all juveniles, were encountered along Silent Creek during this survey. Western toads were found breeding in one place along Silent Creek: the large, open marsh just west of the creek mouth. Within this marsh, free-swimming larvae averaging ca. 4 mm SVL were observed. To minimize disturbance to these young larvae, no attempt was made to count them, or to estimate the number of egg masses they represented. Though toad breeding has not been previously reported at this location, it is likely that the juvenile toads observed along lower Silent Creek in 2007 and 2008 were spawned in this area.

*Cascades frog*
151 Cascades frogs (100 juveniles, 32 adult males, 8 females, and 11 adults for which sex was not identified) were observed along Silent Creek during this survey. By the time the survey was conducted (01 June), breeding of Cascades frogs along Silent Creek appeared to have concluded. Cascades frogs spawned in the same location as in previous years: a small pond on the west side of Silent Creek, just upstream of the footbridge. Two egg masses, about to hatch, were found in the same place where eggs had been laid in 2008. However, by the time the survey was conducted, only three male frogs were found in this breeding pond. Another 29 male frogs in breeding condition, along with 3 recently spawned female frogs, were found along Silent Creek in close proximity of each other, and within 400 m of the breeding pond, indicating a recent move away from the spawning area.

Interestingly, three female frogs (45.0, 49.5, and 69.5mm SVL, respectively) were found along the edge of the large marsh west of the mouth of Silent Creek, well away (ca. 800 m) from the closest known breeding area, the pond mentioned above.

**Pacific tree frog**

Pacific tree frogs, both juveniles and adults, were found along the length of the Silent Creek survey reach. Adult tree frogs were observed breeding in the same location as the Cascades frogs (mentioned above), as well as in the large marshes at the south end of Diamond Lake, both east and west of the Silent Creek channel. Interestingly, adult tree frogs observed along Silent Creek were consistently large (>50mm SVL), for this species, something also noted in 2008.

**Long-toed salamander**

Long-toed salamanders were found breeding in the marsh on the south side of Diamond Lake, both east and west of Silent Creek. In the marsh west of Silent Creek, an adult male long-toed salamander, in breeding condition, was found dead of unknown causes, though given the state of the animal and the location in which it was found, freeze-related mortality is suspect.

**Northwestern salamander**

Northwestern salamanders were not detected along Silent Creek during this survey.

**Other animals**

An adult female common garter snake (664.0mm SVL) was found in the large, open marsh just west of the mouth of Silent Creek (the same marsh where the toad larvae were observed). When discovered, this snake was actively feeding on juvenile toads and tree frogs. Two hen mallard ducks were observed sitting on nests in marshy areas just west of the Silent Creek channel. Nests contained six eggs apiece.
Fall Sampling

Methods
The fall amphibian sampling was conducted from 21-28 August, 2009. Weather conditions during this interval were generally good for surveying, and consisted of predominantly clear skies, with low wind and most daytime highs between 75 and 85 F. Surveys were conducted in the same areas (Diamond, Horse, and Teal Lakes, and Silent Creek) and using the same general methods (visual encounter surveys) as in the 2007 and 2008 sampling (Hayes and Price 2007, Hayes and Rombough 2008). On 22-23 August, we conducted snorkel surveys for aquatic northwestern salamanders. These surveys were conducted in the same locations around Diamond Lake and using the same methods as previously described (Hayes and Price 2007).

Results

Horse Lake
During fall surveys, the water in the west lobe of Horse Lake was still quite high; maximum depth in this part of the lake was ≥ 3 m. A dense fringe of sedges surrounded the water’s margins, and yellow pond lily (*Nuphar polysepalum*) patches were present around the western and southern edges of the lake, to a depth of about 2 m. The east lobe of Horse Lake had largely dried up, though an approximately 10 m wide pool of water was left in the north part of this lobe. The small pond above (east of) the east lobe was also mostly dry, save for an approximately 8 m wide pool (7 cm max. depth) in dense, 1.5 m high sedges in the north part of the pond.

Horse Lake was sampled on 22 August (0940-1410), under conditions good for amphibian detection: still air, 0% cloud cover, and a mean air temperature of 75 F during the survey interval. Water temperature at the west edge of the west lobe of Horse Lake measured 67.8 F at 0940 on 22 August. This west lobe of the lake was briefly examined after dark on 23 August 2009 (2135-2245) for the purpose of finding larger frogs and salamanders which may not have been visible during daylight surveys. No attempt was made to count juvenile frogs during this nocturnal survey.

Western toad:
970 recently transformed western toads were observed around Horse Lake during this survey. About half of these (488 toads) were found in the drier portions of the east lobe; in the west lobe and the small upper pond, we observed 282 and 200 juvenile toads, respectively. Like with Cascades frogs, a representative sample of juvenile toads (24 toads) was measured for comparison with those from other sites. As was observed in 2008, recently transformed toads observed at Horse Lake were smaller, on average, than those found at other sites (e.g., Silent Creek and Diamond Lake). A single adult male toad was found at the edge of Horse Lake during our 23 August nighttime check for adult frogs.
Cascades frog:

651 recently transformed Cascades frogs were observed during this survey, mostly in shallow water or among damp sedges around the larger west lobe of Horse Lake. Interestingly, no Cascades frogs were found in the upper pond, even though spawning had been observed there. As in 2008, a representative sample (21 frogs) of these recently transformed juveniles were measured, and, also as in 2008, were found to be slightly larger, on average, than those from the Silent Creek survey reach (see below). An interesting observation we made was that, during the morning hours (<1100), these juvenile Cascades frogs were found up to 2.5 m from the water’s edge, in dew-soaked grass, but as the day got warmer and the grass dried out, all frogs moved back to the immediate edge of the lake.

Our brief nighttime survey on 23 October turned up only two adult Cascades frogs, a large adult female (70.5mm SVL) and an adult male (56.0mm SVL).

Pacific tree frog:

653 juvenile Pacific tree frogs were observed around Horse Lake, distributed relatively evenly between the east and west lobes and small upper pond. Tree frogs were found from pond edges out into the forest edge, and across the open meadow of the mostly dry east lobe.

Long-toed salamander:

A single adult female (ca. 50 mm SVL) long-toed salamander was found inside a rotten log near the small pond above Horse Lake. Because these salamanders transform much more rapidly than do the northwestern salamander, no aquatic larvae were present at the time of the fall survey. Given the relatively dry conditions at the time of survey, it is not surprising that no other long-toed salamanders were found, as this species spends most of its time underground, save for brief periods of travel to and from aquatic breeding sites, and during dispersal of juveniles right after metamorphosis.

Northwestern salamander:

Our observations of this species at Horse Lake were rather interesting. All northwestern salamanders found were in the more permanent west lobe of the lake. During daytime surveys, we observed two aquatic (gilled) larvae, of approximately 45 and 65mm SVL, respectively. We observed four more larvae (SVL = ca. 45, 45, 40, and 25mm, respectively) during our nighttime check. We also found eight northwestern salamander egg masses attached to sticks around the south and east sides of the lake. These egg masses had very recently hatched, and the jelly portion of the masses was still quite intact. We also found a dead northwestern salamander floating in the water at the southeast corner of the lake. This animal was an adult female, of the terrestrial (non-gilled) form, approximately 85mm SVL. It had been partly scavenged by an unknown predator, and egg jelly which had contacted the water had begun to swell and expanded through the animal’s sides. Field dissection revealed the presence of well-developed ova, almost ready for deposition.
**Other animals:**

The shed skin of a ca. 300mm (total length) common garter snake was found under a log near the small upper pond, and a hen green-winged teal (*Anas carolinensis*) and four almost-fledged young were observed in the water-filled west lobe of Horse Lake during surveys. Interestingly, a young common garter snake (335.0mm SVL) was found foraging in water at the west edge of the lake at 2130 during our nighttime surveys. Despite an air temperature of 50.9 F, this snake was actively chasing juvenile Cascades frogs through the water.

**Teal Lake**

Teal Lake was surveyed on 22 August 2009 (1420-1600), under conditions good for detecting amphibians: 0% cloud cover, a light breeze (wind = Beaufort 0-2 from west), and an air temperature of 79.7 F. Water temperature at the east edge during the survey was 76.4 F. Teal Lake was briefly examined again, on the night of 24 August (2225-2255), in order to find adult frogs. During surveys, the staff gauge in Teal Lake read 2.0, indicating water levels similar to those of 2008 (the gauge reading on 30 August 2008 was 1.98). A few patches of pond lily growing along the south side of Teal Lake provided the only aquatic vegetative cover. As with 2008, adult and late-instar nymph water bugs (*Lethocerus* spp.) were extremely abundant around the shallow edges of the lake.

**Western toad**

No western toads were observed during the fall survey of Teal Lake.

**Cascades frog**

79 recently metamorphosed Cascades frogs, of the same size range as those observed at Horse Lake, were found during the Teal Lake survey. In addition to these juveniles, we found three adult male Cascades frogs (48.5, 49.0, and 63.5 mm SVL, respectively). The 24 August nighttime check revealed four adult Cascades frogs: three males (49.0, 59.0, and 65.0mm SVL, respectively) and one female (62.5mm SVL).

**Pacific tree frog**

Over 100 recently metamorphosed Pacific tree frogs, most between 24 and 29mm SVL, were observed around the shore of Teal Lake.

**Long-toed salamander**

No long-toed salamanders were observed during the fall survey of Teal Lake. This is not too surprising, as larvae of this species are likely to have transformed and left the water by the date of this survey.

**Northwestern salamander**

No northwestern salamanders were observed during the fall survey of Teal Lake, even during the nighttime check. This is interesting, as spawning by this species was observed in Teal Lake during the spring survey, and water clarity was excellent.
**Other animals**

The recently (> 1 week old) shed skin of an approximately 800mm (total length) common garter snake was found along the west edge of the lake. No other snakes were seen during the survey.

**Diamond Lake**

Diamond Lake was surveyed over portions of 27-28 August, 2009. Weather conditions were ideal on 27 August: 0% cloud cover, and no wind, with an air temperature of 71.7 F. Weather conditions on 28 August were less than ideal, with 100% cloud cover, strong breeze, and an air temperature of 60.9 F. In addition to the standard visual survey performed as in previous visits, we walked portions of the lakeshore in the evening to find adult toads, and set several crawdad traps, baited with cat food, in the shallow marsh along the northwest corner of Diamond Lake.

**Western toad**

39 western toads were observed around Diamond Lake proper during fall surveys. 13 of these were recently metamorphosed juveniles: seven were found in the marsh at the northwest corner of the lake, and six were found at the ditch along the south shore where toads had been observed spawning during spring surveys. Extremely dense sedges hampered surveys for toadlets in both of these areas. The remaining toads observed were larger juveniles or adults, found around the east shore in the vicinity of the campgrounds. The size distribution of the toads in our sample permitted an estimation of growth for this species at Diamond Lake, which will be discussed below.

**Cascades frog**

Cascades frogs were observed in three places along the shore of Diamond Lake: Short Creek, Silent Creek, and the marsh along the lake’s south edge. At Short Creek, a young male (42.5mm SVL) and an adult female (60.0mm SVL) frog were found, both upstream of the culvert. Both were in good condition, and the female appeared to be gravid, with eggs yolked sufficiently to permit deposition the following spring. At the mouth of Silent Creek, eleven Cascades frogs (eight adult, one large juvenile, and two recently metamorphosed juveniles) were found in bog holes at the lake’s edge. In the south shore marsh, a recently metamorphosed Cascades frog was found in the ditch west of the boat ramp (where western toads had been breeding during spring surveys). The presence of this tiny juvenile, coupled with those observed during spring surveys, suggests at least a small amount of breeding may be occurring nearby, perhaps within the marsh at this location.

**Pacific tree frog**

30 recently metamorphosed tree frog juveniles were encountered around the edges of this pool, indicating that breeding had indeed occurred, but was missed (see Spring Sampling).
**Long-toed salamander**

Although this species was not detected during daytime visual surveys, 22 long-toed salamanders were captured in the crawdad traps left overnight in the northwest corner marsh. Interestingly, these salamanders were all gilled larvae, ranging from 19-43mm SVL. The presence of non-transformed larvae in this marsh may indicate cooler water temperatures (i.e., from shading and from connection to Diamond Lake proper) than in other areas where spawning was observed (e.g., Horse Lake). This hypothesis is supported by the fact that twelve small (10-18mm SVL), metamorphosing tree frogs were also found in the marsh.

**Northwestern salamander**

Six larvae of this species were found around the shoreline of Diamond Lake, as the result of snorkel surveys (see below).

**Other animals**

A ca. 300mm SVL female common garter snake was found near the cabin at the Lake Creek outflow. This snake was resting under a warm, flat rock when captured, digesting an unidentified prey item. A second common garter snake, another adult female (623.0mm SVL), was found in grass at the base of a pine tree near the south shore boat ramp.

**Snorkel Surveys**

We snorkel-surveyed the five previously described reference points around the shore of Diamond Lake, and turned 562 rocks. We found 6 northwestern salamander larvae and 73 signal crayfish (*Pacifastacus leniusculus)*.

**Trout Stomachs**

Stomach contents of 133 rainbow trout (*Oncorhynchus mykiss*), ranging from 10 to 25 inches (25.4-63.5 cm) in fork length, were collected and examined by ODFW staff (Ryan Dippel, Holly Truemper, and intern Jordan Hazen). Dates of collection ranged from 27 April – 22 October, 2009. No fish or amphibian prey were found in any of the stomachs.

An additional small sample of 12 trout, ranging from 15 to 24 inches (38.1-61.0 cm) fork length, were collected by amphibian surveyor Chris Rombough (under a valid Oregon fishing license, and in accordance with Diamond Lake fishing regulations) during the spring amphibian sampling period. A second small sample of five trout, ranging from 12 to 26 inches (30.5-66.0 cm) fork length, were collected in the same manner during the fall amphibian sampling period. Both samples were made along the south shore, less than a hundred meters from the bank. The stomach contents of the spring trout consisted primarily of caddisfly (Trichoptera) and overwintered dragonfly (Odonata) larvae; the stomach contents of the trout collected in fall consisted almost exclusively of dragonfly larvae. None of the trout collected contained evidence of amphibian or fish prey.
Silent Creek

Silent Creek was searched over portions of 24 and 26 August, 2009, under conditions good for detecting amphibians: 0% cloud cover, little or no wind, and air temperatures of 70-75 F.

Western toad

321 western toads were found during the fall survey of Silent Creek. 302 of these were recently metamorphosed juveniles, and most of these were found near the mouth of Silent Creek, near the outflow from the large, open marsh (west of the creek channel) in which toad larvae were observed during the spring sampling. The location of these juvenile toads indicates that they represent recruitment from the spring spawning in this marsh. The marsh was now completely dry, and no amphibians were observed there. As the highest toad densities observed along Silent Creek in 2008 also occurred along the portion of the creek bordering this marsh, it seems a reasonable assumption that toads also spawned in this marsh in 2008.

Cascades frog

396 Cascades frogs were found during the fall survey of Silent Creek. The majority of these were either recently metamorphosed juveniles or frogs which had transformed in 2009. Most of the recently metamorphosed juveniles were encountered within 200m of the pond in which breeding occurred. A sample of 78 adult frogs (frogs old enough to determine sex based on secondary sexual characters) were measured; at least three of these (60.5-65.0mm SVL) were gravid, with eggs yolked sufficiently to permit deposition the following spring. These females were all found in the marsh on the east side of the channel, ca. 180m upstream of the creek mouth.

Pacific tree frog

170 individuals of this species were found during the fall survey of Silent Creek. Most tree frogs encountered (166) were recently transformed juveniles. Although these juveniles were found along the entire reach, they were most abundant near sites where breeding had taken place (e.g., the spawning pool used by Cascades frogs and the marshes near the creek’s mouth). Interestingly, we also found two larvae (ca. 15mm SVL) of this species during the survey. Both of these larvae were in a small channel at the east edge of Silent Creek, ca. 180m upstream of the creek mouth. A metamorphosing tree frog (ca. 20mm SVL) was found at the edge of the same channel. Exactly why these larvae had not yet transformed is unknown, but prolonged contact with the cold water of Silent Creek (43 F at this location) may have slowed their growth.

Long-toed salamander

This species was not detected along Silent Creek during fall sampling.

Northwestern salamander

This species was not detected along Silent Creek during fall sampling.
Other animals

12 mallards, two bufflehead (*Bucephala albeola*), and six Canada geese (*Branta canadensis*) were observed at the mouth of Silent Creek. Between two and six (51-59 cm fork length) large trout were observed near the mouth of Silent Creek, but these trout spent much of the day resting quietly at the bottom of the channel, and were not seen feeding. A single common garter snake was found during this survey, a ca. 400mm SVL individual foraging in a bog hole (which also contained two Cascades frogs) along the east side of the Silent Creek channel, ca. 80m upstream of the creek mouth.

Other Locations

On 22 August, we briefly walked through the dump and past the sewage treatment ponds. At the dump, we found juvenile toads quite abundant beneath trash. We counted 200 juvenile toads and one adult toad, as well as 32 juvenile and 7 adult tree frogs in the space of about 15 minutes. Around the sewage treatment ponds, we found juvenile toads, representing recent metamorphosis, quite abundant: we counted approximately 1,000 of these toads in about 25 minutes. Along with the newly metamorphosed toads, we found 215 toads of other age/size classes, including 200 which appeared to belong to the 2008 cohort. Although we made no attempt to seriously quantify toad size or abundance, it was our subjective impression that the sewage treatment ponds appeared to be an excellent breeding and rearing site for western toads.

It is noteworthy that we also found an adult male northwestern garter snake, *Thamnophis ordinoides*, just east of the sewage treatment ponds. This represents, to our knowledge, the first recorded observation of this reptile in the immediate vicinity of Diamond Lake, though this species was found along Lake Creek below Highway 138 during 1997 surveys (Hayes 1998).
Table 1. Occurrence of target species in Diamond Lake survey areas.

<table>
<thead>
<tr>
<th>Species</th>
<th>Diamond Lake</th>
<th>Spillway Pond/Lake Creek</th>
<th>Silent Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ambystoma gracile</strong></td>
<td>+  –  +  +   +  +  +  +  +  –  –  –  –</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ambystoma macrodactylum</strong></td>
<td>–  –  –  +   –  –  –  –  –  –  +  –</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bufo (Anaxyrus) boreas</strong></td>
<td>+  +  +  +   –  +  +  +  +  –  +  +  +</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hyla (Pseudacris) regilla</strong></td>
<td>+  +  +  +   +  +  –  +  +  +  +  +  +</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rana cascadae</strong></td>
<td>+  –  +  +   –  –  –  –  –  +  +  +  +</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Taricha granulosa</strong></td>
<td>+  +  –  –   –  –  –  –  –  –  –  –</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Thamnophis sirtalis</strong></td>
<td>+  +  +  +   +  –  +  +  +  –  –  –  +</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Species Richness</strong></td>
<td>6  4  5  6   3  3  2  4  4  2  3  5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>Horse Lake</th>
<th>Teal Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ambystoma gracile</strong></td>
<td>–  –  –  +   –  –  –  +  –</td>
<td></td>
</tr>
<tr>
<td><strong>Ambystoma macrodactylum</strong></td>
<td>+  +  +  +   +  –  +  +  +</td>
<td></td>
</tr>
<tr>
<td><strong>Bufo (Anaxyrus) boreas</strong></td>
<td>+  +  +  +   –  +  +  +  –</td>
<td></td>
</tr>
<tr>
<td><strong>Hyla (Pseudacris) regilla</strong></td>
<td>+  +  +  +   +  +  +  +  +</td>
<td></td>
</tr>
<tr>
<td><strong>Rana cascadae</strong></td>
<td>+  +  +  +   +  +  +  +  +</td>
<td></td>
</tr>
<tr>
<td><strong>Taricha granulosa</strong></td>
<td>–  –  –  –   –  –  –  –  –</td>
<td></td>
</tr>
<tr>
<td><strong>Thamnophis sirtalis</strong></td>
<td>+  –  +  +   +  –  –  –  +</td>
<td></td>
</tr>
<tr>
<td><strong>Species Richness</strong></td>
<td>5  4  5  6   4  2  4  5</td>
<td></td>
</tr>
</tbody>
</table>
Part 2. Results of Amphibian Sampling

General Results

The results of this study indicate that populations of five of the six amphibian species (all but rough-skinned newt, *Taricha granulosa*) present at Diamond Lake have increased since spring of 2007. Each of these species experienced an increase in both total abundance and distribution, based on total numbers of individuals observed, number of individuals per unit of search time, and location of observations within the study area. However, without recent data on the abundance and distribution of amphibians at Diamond Lake, it is impossible to say definitively how much of an effect the rotenone treatment had. Hayes’ 1997 data, while good, were collected almost 10 years before the lake was treated, and so do not reflect the status of amphibian populations immediately prior to treatment. Amphibian populations are notoriously variable, and those at Diamond Lake in 2006 may have been the result of such factors as recent annual precipitation, fish predation, poor water quality, etc. Therefore, while it is without question that amphibian populations at Diamond Lake experienced an increase during the survey interval, how much this represents recovery from rotenone treatment is unknown.

The data from this survey suggest that, with the exception of the northwestern salamander and the rough-skinned newt, current amphibian populations within the study area reflect recent annual weather patterns (specifically, timing and amount of annual precipitation) more than any recent rotenone treatment of Diamond Lake. In the case of the terrestrial long-toed salamander, western toad, and Pacific tree frog (as well as the semiaquatic Cascades frog), the breeding areas most important to sustaining these species’ respective populations are located outside of the lake proper. Although the actual sites used for breeding will vary between years, based on annual rainfall, the best sites will have enough water to support breeding in even low water years, thus maintaining a local population. In years with high annual precipitation, more sites will become suitable for sustaining reproduction, and ultimately, will result in a surplus of individuals which can emigrate to colonize new habitats, such as Diamond Lake itself. Within the Diamond Lake study area, the importance of breeding habitat to maintaining local populations of amphibians, especially Cascades frog and western toad, cannot be overstated. Among all other factors, it is the presence of protected breeding areas away from the main lake which allow these two species to persist. The best of these breeding areas is unquestionably Horse Lake. Across all years studied, Horse Lake supported breeding by the most species, in the highest numbers, of any site within the study area. In dry years, it may be the only site in which reproduction of western toad and Cascades frog is successful.

The northwestern salamander and the rough-skinned newt are a different case. Unlike the four species discussed above, these two amphibians, at least within the Diamond Lake study area, are highly aquatic. Though both species are typically terrestrial as adults, they may exhibit an altered life history at higher elevations (Farner and Kezer 1953; Snyder 1956; Nussbaum et al. 1983; Jones et al. 2005). In these montane populations, the majority of individuals in a given population are often neotenic: they remain a gilled, aquatic larval form for their entire life, rather than transforming into a
terrestrial adult. These aquatic larval forms develop functional gonads and successfully reproduce without ever leaving water. While this trait helps them survive in areas with a harsh terrestrial environment (e.g., cold, dry, etc.), it also makes them dependent on permanent water. Diamond Lake is the only consistently permanent body of still water within the study area, and so represents the best habitat for both species. Indeed, although the northwestern salamander was found at two other sites (Horse and Teal Lakes) throughout the study, Diamond Lake had the highest densities pre-treatment. Northwestern salamander densities in Diamond Lake were significantly lower following the 2006 treatment. Although, as mentioned, it cannot be definitively proved based on available data, the patterns of abundance observed during this and the 1997 surveys suggest that rotenone was responsible for the decrease in this population. The increasing numbers of northwestern salamander observed during this study demonstrate that some individuals did survive treatment, and appear to be re-populating the lake.

**Results by Species**

**Cascades frog (Rana cascadae)**

Across survey sites, a net increase in both the degree of breeding effort and the number of Cascades frogs found was observed over the sampling interval. Between 2007 and 2009, Cascades frogs were found at Horse and Teal Lakes, along Silent Creek, and around the south shore of Diamond Lake to as far north and east as Short Creek. Within this area, breeding was observed each year in Horse Lake and in a seasonal pool along Silent Creek. While no appreciable increase in breeding effort was observed in the single known site along Silent Creek, the number of frogs encountered along the survey reach increased dramatically from 2007 to 2009. This increase in the number of individuals observed presumably reflected conditions favorable for recruitment, a hypothesis supported by the size distribution of captured frogs in the 2008 and 2009 samples. At Horse Lake, the number of Cascades frog egg masses found increased from 31 masses in 2007 to 69 masses in 2009, demonstrating an increase in the size of the breeding population. However, unlike the situation along Silent Creek, we failed to detect increased numbers of postmetamorphic Cascades frogs older than six months. Exactly where Horse Lake frogs go following metamorphosis is a mystery which may be critical to the survival of this population.

The presence of recently metamorphosed juvenile frogs around Teal Lake during each of the fall 2008 and 2009 sampling sessions suggests that breeding (at least on the order of a single egg mass) occurred there in both years, even though no egg masses were observed. The repeated presence of adult and recently metamorphosed frogs in the south shore marsh just west of the boat ramp during 2009 surveys (see above) suggests that at least a small amount of breeding may have also occurred in that area.

The combined observations of Cascades frogs at Short Creek (beginning in 2007; see Truemper 2008; Turnstone 2007) are somewhat puzzling. Short Creek may serve as a refuge for juvenile frogs dispersing from a breeding site, though it is unknown (aside from Silent Creek and the marshes on the south side of Diamond Lake) exactly where such a site might be. Because most frogs observed in and around Short Creek during
2009 surveys were maturing adults, spawning may occur at this site in 2010. Since Short Creek upstream of the culvert is not very suitable habitat for Cascades frog reproduction, it seems most likely that spawning will occur near the sedge flat at the creek mouth, and egg masses should be looked for there. Because Cascades frogs were not found along the north and east sides of Diamond Lake in any of the post-treatment survey years, the presence of the juvenile frog observed by Holly Truemper on the Lake Creek weir is also a puzzle. This frog may have originated somewhere around the lake, or perhaps been carried in by a child. It may be instructive to periodically examine this area for additional specimens.

Western toad (*Bufo boreas*)

2007 surveys found western toad reproduction at two sites: Horse Lake and the marsh in the northwest corner of Diamond Lake. 2009 surveys found western toad reproduction at four sites: Horse Lake, the marsh in the northwest corner of Diamond Lake, a spot along the south shore of Diamond Lake, and the marsh west of the mouth of Silent Creek. Discovery of juvenile toads near the latter two sites in fall 2008 indicates that reproduction occurred at each of these in 2008, as well as in 2009. In addition to an increase in the number of sites used for spawning, the number of toads breeding in at least one of the sites, Horse Lake, increased from 94 females in 2008 to >103 females in 2009 (2007 surveys were not conducted until after egg masses had hatched). Coincident with increases in reproduction, the number of post-metamorphic toads observed in survey units also increased. This increase was most noticeable around Diamond Lake. In 2007, the only toad found along the east shore of Diamond Lake was a single juvenile, seen at the mouth of Lake Creek. In 2009, 76 juvenile and 63 adult toads were found across the same area.

Pacific tree frog (*Hyla regilla*)

During the course of this survey, Pacific tree frogs were found breeding in almost every body of still water around Diamond Lake, with the exception of the lake itself. Observed breeding areas included Horse and Teal Lakes, the marshes on the south side and in the northwest corner of Diamond Lake, the seasonal pond just south of the footbridge on Silent Creek, and the sewage treatment ponds northwest of the Diamond Lake resort.

Survey data, including number of animals observed per unit of search time, counts of total animals observed, and observations of individual distribution, all indicate an increase in the numbers of this species within the survey area. However, making more than a general statement regarding the disposition of the Diamond Lake tree frog population is beyond the scope of this survey. There are several reasons for this: besides the fact that the tree frog’s physiology allows it greater mobility and hiding capacity than the strictly terrestrial forms, female tree frogs lay multiple small egg packets, making it much more difficult to estimate the size of the breeding population than for species in which females deposit a single mass.

In addition to this finding, an interesting observation deserves mention, as it may prove useful to the Department with respect to future work. Pacific tree frogs across the
Diamond Lake survey area generally transformed at sizes between 18 and 25mm SVL. The mean size of a sample of 44 newly transformed frogs from Horse and Teal Lakes was 21.5mm SVL and 0.6g. Although the rate of growth is unknown, adult tree frogs from the vicinity of Diamond Lake are consistently quite large for this species: individual frogs commonly measure between 40 and 50mm SVL, and a large number of the adult frogs found are between 50 and 60mm SVL. Examination of the sizes of captured frogs reveals a curious lack of frogs between 30 and 40mm SVL. This finding, coupled with the timing of surveys (at the beginning and end of the annual growth period), suggests that tree frogs in the vicinity of Diamond Lake may grow quite fast, reaching sizes of 40mm SVL or more within one year after they transform.

Northwestern salamander (*Ambystoma gracile*)

The northwestern salamander is the species which Hayes (1997) predicted would suffer most heavily from rotenone treatment of Diamond Lake, as the local population prior to treatment appeared to consist mostly of aquatic adults (neotenes) and larvae. As expected, the number of northwestern salamander egg masses and larvae observed in Diamond Lake (as compared to the pre-treatment surveys) decreased dramatically following treatment. That the species did not disappear entirely from the lake indicates one of two (or even both) possibilities. The first is that some aquatic individuals managed to survive poisoning of the lake, either because they were in an area that did not receive rotenone in lethal concentrations, or because they simply tolerated rotenone levels which killed fish. The second possibility is that terrestrial adults, living underground around the lake, simply returned to the lake to spawn in the spring of 2007. Because most northwestern salamander populations are known to contain both life history types (Farner and Kezer 1953; Snyder 1956; Nussbaum et al. 1983; Jones et al. 2005), this scenario seems fairly likely.

Although it may take many years for the population to reach pre-treatment levels, two facts seem encouraging. The first is that the lake was treated before (in 1954), so some parallel for this type of action exists. The 1997 population itself was probably the progeny of salamanders surviving this earlier treatment of the lake. The second encouraging fact is that the current post-treatment surveys indicate that the salamander population, as both the number of larvae observed, as well as the number of breeding adults, is increasing (see above). One interesting observation is the discovery of a 95mm SVL neotenic adult in a trout stomach in 2008. Assuming all salamanders were, in fact, successfully eradicated from the lake via rotenone, this animal must have been the result of spawning in 2007, and thus reached maturity in less than a year and a half after being laid as an egg.

The issue of northwestern salamander occurrence as an item of trout diet is somewhat interesting. Prior to the 2006 rotenone treatment, Hayes (1997) found northwestern salamanders in the stomachs of 12 of 134 fish sampled. In 2007, none of a sample of 98 fish contained salamander larvae, a finding attributed to the apparent extirpation of northwestern salamanders from the lake via treatment. In 2008, two of 193 trout examined contained northwestern salamanders, but in 2009, none of 150 trout did. In addition to the post-rotenone scarcity of salamanders mentioned previously, one possible explanation of this pattern is an increase in preferred insect prey. Hayes noted a
distinct lack of insects in the stomachs of pre-treatment fish, whereas the stomachs of the 17 fish collected during 2009 amphibian sampling (see above) were quite full. Of the 133 fish examined by ODFW staff in 2009, only one had an empty stomach, whereas Hayes noted that over 50% of 1997 trout stomachs contained little or no digestible food.

Outside of Diamond Lake proper, the northwestern salamander occurs in both Teal and Horse Lakes. In each of these lakes, the number of individuals encountered, as well as the number of animals found per unit of survey time, suggests an increase in the number of northwestern salamanders present (over the 2007-2009 period). However, these data should be interpreted with caution. Northwestern salamander larvae are secretive and nocturnal, traits which often result in their being missed during standard daytime visual encounter surveys, a fact Hayes pointed out in 1997, and the reason snorkel surveys were included as part of the survey effort. They are also highly cannibalistic, a trait which may cause marked variation in the number of individuals present, particularly if water level or the amount of cover present in a system decreases during the season. For these reasons, and because each female salamander is presumed to lay only one egg mass per year, egg mass surveys are the most efficient means of determining changes in long-term population size. That said, it should also be noted that the timing of oviposition may vary markedly between sites. This variation in spawning time may be the result of physical characteristics of the habitat (e.g., elevation, water temperature) or even the life history type of the salamander (e.g., neotenic vs. terrestrial forms). As a result of 2009 surveys, Horse Lake is known to harbor at least the terrestrial (metamorphosing) life history type. Variation in spawning time between Horse and Teal Lakes was also observed during the 2009 survey, with northwestern salamanders in Teal Lake spawning in May, and those in Horse Lake spawning in late July (see above).

Regardless of the size of Horse and Teal Lake northwestern salamander populations, the most important finding of this survey is that, outside of Diamond Lake, these lakes currently represent the sole known habitat of this species, and are therefore the source from which individuals would re-colonize the area should the Diamond Lake population ever be successfully terminated.

Long-toed salamander (*Ambystoma macrodactylum*)

During the course of the post-rotenone surveys, the number of sites at which this salamander was observed increased markedly. During the most recent (2009) survey, it was found in all of the survey areas examined. Eggs, larvae, or reproductive adults of this species were found in each of Horse and Teal Lakes, in the marshes on the east and west sides of lower Silent Creek (along the south shore of Diamond Lake), and in the marsh at the northwest corner of Diamond Lake.

Because this is a secretive species which spends most of the year under cover objects (rocks, logs, etc.) or below the soil surface in the vicinity of water, surveys of potential breeding areas for eggs or larvae are the best means of detecting it. Long-toed salamanders have a relatively short larval period compared to northwestern salamanders, and are capable of using ephemeral ponds for breeding. Because of their activity patterns, larvae of long-toed salamanders are more susceptible to fish predation, and so are typically found in highest densities in ephemeral or fish-free ponds. The occurrence of
this species across the survey area is expected to remain restricted to these types of habitats, and to sheltered areas of Diamond Lake which contain heavy vegetative cover.

Larvae of long-toed salamanders breeding in Horse and Teal Lakes appeared to have completed metamorphosis and left the water by the time the fall surveys were conducted each year. Therefore, it was a surprise to find aquatic larvae still present in the Diamond Lake marsh during the 2009 fall surveys (see above). Long-toed salamanders in the vicinity of Crater Lake are apparently capable of overwintering as larvae (Kezer and Farner 1955), and the proximity and elevation of Diamond Lake indicates that a similar situation would be possible here, though whether or not this actually occurs is unknown.

Rough-skinned newt (*Taricha granulosa*)

The status of this amphibian at Diamond Lake remains somewhat of a puzzle. Apparently not abundant prior to the 2006 rotenone treatment (Hayes 1997), this species has only been found once following the treatment, in 2007. Newts, like northwestern salamanders, are capable of transformation into terrestrial adults. Therefore, while it seems unlikely that the Diamond Lake population of rough-skinned newts has been extirpated, it may have been reduced to such low levels as to make detectability difficult. Given the reported palatability and relative ease of capture of larvae and neotenes of this species when compared to the northwestern salamander (larvae of the latter spend much of their time hiding under objects on the lake bottom during daylight hours), it is likely that this species will never become abundant in Diamond Lake under current management practices. Rather, rough-skinned newts, if present, will probably remain restricted to heavily vegetated habitats around the lake margin which are difficult for fish to access, such as the marsh in Diamond Lake’s northwest corner.

Common garter snake (*Thamnophis sirtalis*)

Though not an amphibian, the rate at which this snake was encountered during surveys, as well as the condition of individual serpents, were interpreted as indicators of overall amphibian abundance (Hayes 1997). In 2009, this snake was encountered in all of the survey areas at Diamond Lake, for a net increase of three sites over 2008. Though the number of garter snakes found along Diamond Lake proper is less than for 2008, this is probably due to poor sampling conditions for this species (cool and cloudy) during the period in which the most heavily occupied part of the lake (the north shore) was surveyed. All garter snakes found in 2009 were in good condition, consistent with that of healthy individuals of this species. (Condition was assessed as the relationship between snake mass and length, as well as the location, behavior, and outward appearance of individuals.) The overall condition of snakes encountered improved slightly across the post-rotenone survey interval, though the relatively small sample size makes it difficult to interpret these data. Hayes noted that two-thirds of the snakes found in 1997 were thin or underweight, suggesting that the condition of individual snakes has since improved. However, this is a qualitative assessment, as the measurement data for 1997 snakes was not available for comparison. Nevertheless, our observations indicate that common garter snakes in the vicinity of Diamond Lake have increased in both number and condition since 2007, presumably as a result of an increase in amphibian populations.
Acknowledgements

Laura Trunk was awesome. She tirelessly assisted with every one of the surveys, performing valuable fieldwork and providing a sharp eye, particularly for toads. The 2009 project would not have been a success without her. Drs. Josh “Jack” Wallace and Sean “Windshield” Lundy assisted with the fall sampling, Josh impressing us all with his snorkeling ability. These two terrors of the marsh left no stone, log, or old tire unturned in their quest for reptilian life. It is to them that I give the credit for the dump and sewage pond surveys. Thanks guys! You three ROCK!!!

In addition to these three amigos, Holly Truemper kindly provided advice, data, and valuable observations of fishes and amphibians at Diamond Lake, as well as reminders of important deadlines. Thank you Holly!

References


Hayes, M.P. 1998. Assessment of the aquatic amphibian and reptile fauna of Lake Creek between Diamond Lake and Lemolo Reservoir. Report to the Oregon Department of Fish and Wildlife, Southwest Region.

Hayes, M.P., and R.F. Price. 2007. Aquatic amphibian and reptile surveys during the first year after the fall 2006 rotenone treatment of Diamond Lake. Report to the Oregon Department of Fish and Wildlife, Southwest Region.


