Assessment of Tiger Salamander Habitat at Four Lakes in the South Okanagan, British Columbia

(in alphabetical order)

Elizabeth Fairhurst, Yongshu Fan, Elaine Fitzpatrick, Nicole Gervan, David Hebert, Zayed Mohamed, and Colleen Phung

Prepared for EVSC 491
Instructor: Alton Harestad
Environmental Science Program
Simon Fraser University

October 6, 2005
Introduction

The tiger salamander (*Ambystoma tigrinum*) is an endangered species in British Columbia (Government of Canada 2005) and was red-listed in 1996 by the BC Ministry of Environment (Richardson et al. 2000). Its population in the southern Okanagan is small and declining, and less than 100 aquatic breeding sites are thought to exist (Cannings et al. 1999). In light of this situation, the Environmental Science 491 class at Simon Fraser University set out to assess the habitat characteristics at four lakes (i.e., small lakes and ponds) near Oliver, B.C., known to be occupied by tiger salamanders (Orville Dyer, BC Ministry of Environment, personal communication). In this report, we use results of our surveys to evaluate breeding habitat quality in terms of water and vegetation characteristics, along with impacts from humans, cattle and wildlife. Our findings may be useful in guiding future research and monitoring of breeding habitat, as well as supporting management for this species. The goal of this study is to identify potential management strategies for the conservation of tiger salamander metapopulations.

Objectives: Water Quality, Vegetation, and Impacts

1. Water quality

Tiger salamanders depend on ponds and small lakes for reproduction. Eggs are laid in shallow water, larvae depend on water for food and cover until they undergo metamorphosis and move to terrestrial habitat, whereas paedomorphic populations depend entirely on water throughout their lives. When breeding or as eggs and larvae, tiger salamanders are usually found in warm ponds with abundant aquatic plants, aquatic insects, and other invertebrates. However, the quality of water preferred by tiger
salamanders has not yet been fully described. Our objectives are to describe the features and characteristics of lakes and ponds used by tiger salamanders and to take measurements of water quality so that lake conditions can be monitored.

2. Vegetation

Tiger salamanders are vulnerable to desiccation and predation while migrating between aquatic and upland terrestrial habitat. The presence of suitable cover in the form of vegetation or coarse woody debris (CWD) on and near the lakeshore might reduce mortality during these seasonal migrations. Likewise, mortality might be lower when the distance traversed is shorter (i.e., when the lakeshore is narrow).

We have two objectives for our vegetation and CWD survey. First, we aim to estimate the distance required for migration across the lakeshore at known or potential tiger salamander breeding sites, and use this distance as an index of relative duration of exposed travel. Second, we assess the amount of cover provided by vegetation and CWD in the area surrounding each lake, and thus estimate the hazard faced by migrating salamanders. Together, these data will help rank the suitability of each site as tiger salamander breeding habitat.

3. Human, cattle, and wildlife impacts

Tiger salamanders are sensitive to impacts by humans, cattle and wildlife, especially because their complex life history depends upon two or more habitats (Richardson, 1999, p.407). Cattle congregate around water sources, including small ponds and lakes used by tiger salamanders for breeding and larval development, thus there is potential for interaction between the two species through use of these habitats. As reviewed by Accounts and Measures for Managing Identified Wildlife – Accounts V. (Sarell 2004),
cattle can affect salamander habitat by trampling wetland banks, collapsing burrows, eroding edges, reducing riparian vegetation, causing soil compaction and influencing water quality. As well, small puddles formed by tracks may be attractive microsites in which to lay eggs, but larvae and eggs within them die when these microsites dry as shoreline recedes (Ministry of Environment 2005). As well, human and wildlife activities around ponds and lakes inhabited by salamanders could have further negative effects. These land use activities may potentially increase mortality and reduce productivity of tiger salamanders. Although these effects could occur, there have been no studies that quantify use of existing tiger salamander habitat by humans, cattle and wildlife and their influence on tiger salamander mortality.

Our objective is to describe and quantify the use of lakes and surrounding areas by cattle, humans and wildlife so comparisons can be made among the lakes. Our intent is to use techniques developed in this study to monitor changes in land use and allow comparisons among years.

**Methods**

During August 21-26 2005, we sampled water quality, surrounding vegetation, and habitat use by humans, wildlife and cattle at three four lakes in the South Okanagan Valley of British Columbia. These lakes (Burnell Lake, Deadman’s Lake (south from the road to Burnell Lake), and the two small lakes (i.e., ponds) near Madden Lake) are all located within a short distance from Oliver, B.C. Deadman’s Lake is the name on a sign posted on a tree along a road leading to a small pond. We use this name in the report but it may be incorrect.
1. Water quality and lake characteristics

At each lake, we inspected the shoreline to determine if it could be stratified based on physical characteristics. If there was a clear stratification of the shoreline, we randomly sampled from each shore type, otherwise we randomly sampled throughout the entire shoreline. At each sample site along the shoreline, we obtained a sample of surface water 3 m towards the centre of the lake from the first visible water. For each water sample, we measured total dissolved solids (TDS), pH and water temperature. Jars were submersed, filled with water, and then, if possible, sealed underwater to ensure that samples were airtight. The samples were then analyzed for copper, iron, nitrates, phosphates, and dissolved oxygen content. If possible, we also sampled surface water from the middle of the lake and performed the same water quality measurements.

We used a weighted line to determine lake depth and turbidity. The amount of algae and other aquatic plants along the shore was classified as relatively low, medium or high density. We also measured the diameter and depth of each lake and used these data to estimate water volume. Diameter was measured using a hip chain except for at Burnell Lake where we calculated diameter from its circumference. Depth was measured using various methods described below. In most cases, a ring of unvegetated dried and drying mud surrounded the lakes. Upslope, past this zone was an area of patchy, sparse vegetation that we assumed revealed the seasonal reach of high water. By measuring the diameter and depth (i.e., vertical height) of these zones, we calculated volumes of seasonal fill and flood for each pond.
1a. Burnell Lake (UTM 309800 5453800)

Burnell Lake had two bodies of water, a large section and a small pond separated by a strip of dried mud. We divided the lake into 4 strata for sampling, shallow shoreline, deep shoreline, pond, and mid-lake. The shallow shoreline had a gentle slope and shallow water, and the deep shoreline had a steeper slope and increased in depth quickly. Within each zone, a sample point was chosen at random and two other points were selected at 150-m intervals from the original point. Samples were taken from the middle of the larger lake at two points on its long axis. Three samples were also taken from the pond portion of Burnell Lake.

The height of an old dock was measured from the current water level to estimate the change in lake depth over years. To provide a basis for future comparison we noted relative depth against a permanent benchmark (an upright broken pipe on the west side of the lake).

1b. Deadman’s Lake (UTM 310700 5452550)

Deadman’s Lake was nearly dry containing mostly mud crusted with white precipitates and small highly saline puddles. Three samples were taken from the puddles using a tin can attached to a long stick because soft mud prevented safe access to the puddles. Dissolved oxygen could not be measured because high salinity was thought to have interfered with operation of the instrument. Due to high concentrations of dissolved solids, water samples had to be diluted to obtain readings within the ranges of our meters.

We estimated approximate annual maximum water depth from deposits of precipitates on an upright post within the lakebed. This post could serve as a benchmark for monitoring depth. To estimate possible lake volumes, we assumed that the area within
the “aquatic plant” zone diameter was approximately flat and the slope of the zones composed of mud and grass increased at a constant rate.

1c. Madden Lake Pond 1 (UTM 309200 5455850)

Sampling was done with a tin can nailed to an 8-foot stick because the shoreline was saturated and had very soft mud. Three samples were taken along the edge of the pond and two were taken from the middle on the pond’s long axis. The middle samples were taken with a tin can attached to cord strung across the lake and held by two people. When the cord was slackened, the can could be lowered and filled with water to obtain the sample from anywhere within the small pond. When the cord was pulled taut, the can was raised. Then while one person stood still, the other person walked in an arc to transport the sample to a firm location on the shore. Dissolved oxygen and temperature were measured immediately after sampling and the remaining chemical tests were performed shortly afterwards.

Water depth was measured with a weighted string hung from a cord stretched across the lake. Flagging tape was secured to the string at measured intervals so when the string was submerged the depth of the pond could be measured by counting the tape markers.

The zone of flood was not delineated by patchy grass as at other lakes, instead an almost vertical bank seemed to contain the lake at flood level. The height of this bank was measured.

1d. Madden Lake Pond 2 (UTM 309300 5456250)

This pond was sampled in the same manner as Madden Lake Pond 1 with the exception that we could not reach the shore with our stick. Instead the three shoreline
samples were taken by the tin can and cord method described above. The flood zone was characterized by patchy grass. The width and depth of this zone were measured.

2. Vegetation

We divided the shoreline of each lake into four sampling zones based on natural vegetation patterns radiating out from the water: Zone 1 (mud flats), Zone 2 (short grass), Zone 3 (longer grass/forbs), and Zone 4 (riparian trees and shrubs). Zone boundaries were generally distinct; the boundaries of the lakeshore sampling area as a whole were marked by the water’s edge at the beginning of Zone 1 and the end of dense shrubs and trees (or the start of the coniferous forest) at the far margin of Zone 4.

We measured zone widths at sites spaced every 200 paces (180-200 m), for a total of 11 replicates around the shore of Burnell Lake. Because the other 3 ponds (Deadman’s Lake, Madden Lake Pond 1 and Madden Lake Pond 2) were considerably smaller, sampling locations were chosen at four sites roughly equidistant from each other around the water’s edge. At each site, zones were sampled along a transect radiating from the lake. We visually estimated percentage vegetation cover both overall and by species using a 1x1-m quadrat randomly placed along the transect in each zone. Within each quadrat, we also measured maximum vegetation height using a meter stick. We qualitatively estimated the slope of the ground for the zone in the general vicinity of the quadrat, classifying it as flat, very to medium-gentle, or medium to high. Each piece of Coarse Woody Debris (CWD) was counted within the first three zones and the diameter at their midpoint was measured using a meter stick. CWD was then classified into three categories based on diameter (6-10 cm, 11-30 cm and >30 cm).
3. Human, cattle, and wildlife impacts

3a. Sampling

Burnell (Sawmill) Lake, Deadman’s Lake, Madden Lake Pond 1 and Madden Lake Pond 2 were assessed for intensity of cattle, human and wildlife use and their potential impacts on tiger salamander habitat. Sightings and evidence of wildlife and human activities were documented for each lake. Cattle use was measured in 4-m² quadrats randomly placed within 3 strata around the perimeter of each lake. Based on our initial observations and the presence of cattle fences, we ascertained that intensity of use differed around Burnell Lake. Therefore, we stratified our samples into low, moderate and high use sections. Track intensity was sampled in the mud along the lakeshore, but grazing intensity was sampled in the zones of vegetation consisting of grasses and riparian species. Track intensity was measured by counting the number of tracks and also estimating the percentage of the ground covered by tracks; where discernible, tracks were identified to species. The tracks included: cattle, horse, dog (other canids), bear, and deer. The intensity of grazing was assessed by visually estimating the percentage cover of vegetation that was grazed.

At Burnell Lake, we identified three levels (low, moderate, high) of track and grazing intensity and a total of 23 pairs of quadrats were sampled beginning at the dock, located on the south side, and then moving counterclockwise around the lake. Each quadrat pair consisted of a quadrat to sample track intensity, as well as, a quadrat to sample grazing intensity, located along the same horizontal distance of lakeshore at intervals of 10-100 m (Figure 3.1).
At Deadman’s Lake, we identified two levels of grazing intensity that were associated with the presence of fences. Five quadrats of grazing intensity were sampled for each predetermined level. In total, 10 quadrats for grazing were sampled beginning at Fence 1 and 5 quadrats were sampled for trampling beginning at Fence 2 (Figure 3.2).

At Madden Pond 1, 12 pairs of quadrats were sampled beginning at the rock outcrop on the north side (Figure 3.3). Unlike Madden Pond 1, our initial observations of Madden Pond 2 indicated that there was minor grazing and few tracks in the mud zone (Figure 3.4). Therefore, we restricted our sampling to grazing intensity of two zones surrounding the lake. Only three quadrats were sampled at the typical grass zone, because the area was typically free from cattle grazing. Another five quadrats were sampled at higher elevations (i.e., heights above the lake shore) than at other lakes.

3b. Data analyses

Line graphs of grazing and track intensities versus quadrat location were created for Burnell, Deadman’s and Madden Lake 1, to reveal the variability around the lake.

Grazing and track intensities were placed in 3 categories. Low intensity was defined as 0-33% track or grazing percentage cover. Moderate intensity was defined as 34-66% track or grazing percentage cover. High intensity was defined as 67-100% track or grazing percentage cover. We used intervals of approximately 8% to create frequency distributions for grazing and track intensity for all data collected, to compare frequency distributions between grazing and tracks at low, moderate and high categories.

Bar graphs were created to show the percentage of the total lake perimeter that is represented by each intensity category. These percentages were used to compare the magnitude of each intensity category that exists at individual lakes. However, Madden
Lake Pond 2 was excluded because there were no cattle tracks and only minor grazing at higher elevations than measured at other lakes. Besides frequency of categories, a sample mean and standard error were calculated for each predetermined intensity category (low, moderate and high) at each lake.

Results

1. Water Quality

1a. Burnell Lake

Burnell Lake is relatively large and unevenly shaped which made it difficult to estimate its seasonal depth. However, areas of dried aquatic vegetation and algae on the shore suggest the lake had recently extended to these areas. We reasoned that the region of unvegetated mud represented the highest recent water level. A local resident stated that the dock at Burnell Lake was floating horizontally nine years ago. Using the angle from the current water level to the top of the dock, we calculated that the water level has dropped 2.52 m in nine years. Diameter, depth and volume are described in Figs. 1.1, 1.2, and 1.3.

There was a lot of aquatic vegetation (vascular plants and algae) floating along the shore in the shallow portions of the lake. The greatest amounts of aquatic vegetation were in the separated pond and along its shallow shoreline. There was aquatic vegetation along the deep shore portions of the lake, but it was not as dense as that in the shallow areas. The width of the deep shore aquatic vegetation zone was also much narrower than those in the other two strata. Samples taken in the pond and the shallow shore of the main lake had abundant invertebrates, with the pond having the greatest density. Fewer
organisms were in the water samples from the deep shore, and none were in the samples taken from the centre of the lake.

The surficial strata of Burnell Lake were similar in water characteristics with the exception of pH which seemed to vary (Fig. 1.4). Areas with dense mats of aquatic vegetation had a higher pH compared to areas with less aquatic vegetation. The pond portion of Burnell Lake had a pH of 9.5, whereas the middle of the main lake had a pH of 8.8. Dissolved oxygen content exceeded the 200% maximum of our oxygen detector in all samples tested.

1b. Deadman’s Lake

Due to the high “salinity” of the lake, many water characteristics were beyond the range of our instruments. The high concentration of ions in solution was thought to make readings unreliable, thus in situ measurements were impossible. Samples were transported back to camp, diluted, and analyzed.

The mean total dissolved solids (TDS) was 437500 ppm after accounting for a 500x dilution (Fig. 1.5). Precipitates formed between sampling and analysis so the value obtained for TDS in Deadman’s Lake is likely an underestimate. Dissolved oxygen could not be measured because of the high salinity of the water.

Phosphates were in relatively high concentrations; however they comprised a small proportion of the total dissolved solids (Table 1.1). Nitrates, copper and iron compounds were in small quantities (Table 1.1). We visually estimated a total of approximately 40 liters of water distributed among small puddles, and we found no living organisms in Deadman’s Lake.
Initially we measured a mean pH of 7.6; however, the mean pH of the dilutions we made to determine TDS was 8.6. These differences in pH lead us to question the accuracy of our initial pH reading. Given the effect of high salinity on our other instruments and that we expect such concentrated lake water to be alkaline; it seems likely that the pH reading was inaccurate.

A permanent fence post at the west side of the pond can serve as a reference post to determine seasonal fill or change in water depth at a particular time of year. The post had a thick deposit of precipitates at 42 cm above the lakebed, and we assumed this was the height of the lake when it was full (i.e., filled to the top edge of the mud zone). The precipitates on the post reached a maximum height about 3 cm above the thickest deposit of precipitates and we assumed this was the flood depth (i.e., depth when the lake is filled to the top edge of the short grass zone). Volumes at each of these depths were calculated (Figs. 1.1, 1.2, and 1.3).

1c. Madden Pond 1

The shoreline of this pond was characterized by a steep bank. The diameter, depth, and volume at the time of sampling and the estimated seasonal fill are summarized in Figs. 1.1, 1.2, and 1.3. We determined that flooding would be contained within the walls of the steep bank.

This was the first site at which we think dissolved oxygen could be reliably measured. The mean value for dissolved oxygen was 64.3% but it varied by location in the pond. The samples taken near the middle of the pond had lower dissolved oxygen than those taken near the shore.
Phosphorous was measured in moderate concentrations, and pH was relatively low for a pond of its size (Table 1.1, Fig. 1.4). Total dissolved solids were high but within the range of our instruments (Table 1.1). There was abundant aquatic vegetation along the shore of Madden Pond 1.

**1d. Madden Lake Pond 2**

Madden Lake Pond 2 had high salinity and water samples had to be diluted to bring the concentrations within the ranges of our instruments. It had the highest mean value for pH of the 4 ponds that we sampled (Fig. 1.4) but was not significantly different from the readings obtained from the shore of Burnell Lake shore. There was no variation between any of the pH readings taken within Madden Lake Pond 2.

There were no traces of copper, nitrates, or iron (Table 1.1). Phosphate was relatively low considering the high concentrations of total dissolved solids in the lake (Table 1.1 and Fig. 1.5).

The mean dissolved oxygen along the shore was approximately 122%, and the two samples from the middle of the lake were similar (125% and 121%). There was little aquatic vegetation visible in Madden Lake Pond 2 but when we were retrieving the depth cord, we snagged a large wad of vegetation and dragged it onto the soft mud near the water. A small painted turtle, caught in the vegetation, scampered back to the water.

**2. Vegetation**

The width and percentage cover of each zone varied among lakes, but several patterns emerged. Zone 1 was characterized by a flat to very gentle slope and an almost
complete lack of vegetation (Fig. 2.1). It varied in width from 0 m at Madden Lake Pond 1 to a maximum of 50.8 m at portions of Burnell Lake.

Zone 2 had a gentle slope and was dominated by grass grazed short by cattle. Its width ranged from 1.8 m to 131.9 m, both at Burnell Lake. Percentage cover of vegetation ranged from 1.5% at Burnell Lake to 100% at Madden Lake Pond 2.

Zone 3 exhibited large variation in plant species, including tall grasses, forbs (e.g., thistle and great mullein), small shrubs, and seedlings of trembling aspen, paper birch and willow. Its slope was gentle to medium-gentle. Its maximum and minimum widths (90 m and 2 m, respectively) were both found at Burnell Lake. Percentage cover ranged from 7% at Burnell Lake to 100% at Madden Lake Pond 2.

Zone 4 was characterized by riparian trees and shrubs, particularly trembling aspen, willow, Saskatoon, and rose. Its slope was generally moderate to steep, but was occasionally more gentle. Its width ranged from 3 m at Burnell Lake to 57.5 m at Deadman’s Lake. The range of tall riparian vegetation often extended at low densities past our zone limits and into ponderosa pine and bunchgrass areas.

Large variation in average zone widths occurs among the lakes (Fig. 2.2), with a smaller amount of variation in the percentage of the lakeshore comprised of each zone (Fig. 2.3). Coarse woody debris also varied, with Madden 1 having both the highest density (Table 2.1) and absolute number of logs (Fig. 2.4). CWD was almost absent at Burnell, where the density and absolute number of logs were lowest of the four lakes.

We did not analyze percentage cover by individual plant species, but a list of species encountered in our quadrats is in Appendix 2.1.

3. Human, cattle, and wildlife impacts
The sample mean and its standard error associated with each predetermined intensity category (low, moderate and high) were calculated for each lake (Table 3.1). The intensity of grazing and tracks varied along the perimeter of each lake and varied among lakes (Fig. 3.5a-d). Grazing and tracks intensities varied at each lake. Contrary to our expectations, grazing and trampling intensities were not correlated significantly ($r^2 = -0.0034$, $P>0.05$).

The majority of land at Deadman’s Lake was classed as low intensity tracks whereas the perimeters of Madden Lake Pond 1 and Burnell Lake had greater densities of tracks (Fig. 3.6a, b). The perimeters of Burnell Lake and Deadman’s Lake exhibited either low or high grazing intensities, with few sites moderately grazed. But at Madden Lake Pond 1, grazing intensity was either moderate or high. Based on our observations, grazing at Madden Lake Pond 2 only occurred at elevations (height above the lakebed) beyond our normal sample sites and no tracks were seen along the lake edge. Overall, the amount and extent of grazing and tracks varied among lakes.

For all three lakes, in terms of grazing, low intensities skewed to the left and high intensities were normally distributed (Fig. 3.7a). Whereas for tracks, low intensities skewed to the left and high intensities were evenly distributed (Fig. 3.7b). Moderate intensities did not occur frequently enough to provide sufficient data to determine a pattern for both moderate grazing and tracks. Grazing intensities were mostly low or high, but track intensities were more normally distributed across low, moderate and high categories.

Wildlife species that may negatively influence salamander habitat were observed at each lake, including mule deer and black bears. Table 3.2 is a list of wildlife species
sighted during our field work at the lakes. Human activities that may negatively affect salamander habitat were observed, including evidence of off-roading, camping, hiking, horseback riding, dirt biking, water control systems, and pets (Table 3.3).

Discussion

1. Water quality

In general, we observed the lakes to be small, warm, and alkaline, which is similar to findings of other researchers (Green and Campbell 1984, Richardson et al. 2000). All sites showed some evidence of seasonal variability in pond diameter and water depth. Deadman’s Lake was almost completely evaporated, however we estimated that when full, it will hold 357 m$^3$ of water. Therefore, Deadman’s Lake showed the most relative seasonal variability in water depth of all sites. Madden Lake Pond 2 showed the next highest amount of relative seasonal variability, and we estimated that the water level rises to hold twice the volume it did when we conducted our measurements. Madden Lake Pond 1 and Burnell Lake showed the least variability by shrinking to only 80% of our estimated recent fill volume. The percentage change in depth seems related to the pond’s width depth ratio. Madden Lake Pond 2 and Deadman’s Lake are relatively shallow in comparison to their diameters and hence perhaps more prone to evaporation and loss to seepage. Burnell lake and Madden Lake Pond 1 are each relatively deep for their size.

The variable nature of some of these ponds has a direct consequence for the success of tiger salamander breeding. A dry or hot year may cause drying of the pond before larvae are able to metamorphose and move to land. If a pond dries to a depth that it is no longer suitable as a breeding site, tiger salamanders must find another pond to breed or forego breeding that year. There have been no studies to show how far a tiger
salamander will travel to find a breeding site. However, Richardson et al. (2000) tracked tiger salamander movement around breeding sites and dispersal from breeding sites, and found they moved < 150 m or < 500 m, respectively. Conversely, Sarell (2000, reviewed in Sarell 2004) observed adults more than 1 km from a possible breeding site.

Ephemeral ponds also prevent the establishment of paedomorphic populations; thus we expect such populations to be confined to lakes where there is no risk of losing their habitat due to evaporation (e.g., Burnell Lake and perhaps Madden Lake Pond 1). Lakes with high concentrations of dissolved solids may become toxic before they dry completely because salinity increases during progressive evaporation. Hence, less saline ponds may be able to support larvae for longer than more saline ponds of the same size.

Total dissolved solids varied considerably among ponds. However, there was little variation within each pond. Deadman’s Lake had the highest amount of dissolved solids at 437500 ppm which, while extreme, would be diluted when the pond floods in spring. Madden Lake Pond 2 was the next highest; whereas Madden Lake Pond 1 and Burnell Lake had the least dissolved solids. Lakes with the highest dissolved solids appeared to be those that where relatively shallow and had the greatest relative change in water depth.

All lakes that we sampled appeared to be relatively alkaline. Changes in alkalinity within a lake seemed to be related to local changes in the amount of aquatic vegetation. Within Burnell Lake and Madden Lake Pond 1, pH seemed to increase in areas where there was abundant aquatic vegetation. In Madden Lake Pond 2 and Deadman’s Lake (sites with little or no aquatic vegetation) there was little variation among samples.

It is difficult, based on our measurements, to compare phosphate concentrations among lakes because most of our results were at the low end of an imprecise scale.
However, Madden Lake Pond 1 is thought to be most heavily used by cattle for its size (see Section 3: Human, Cattle, and Wildlife Impacts), and also has the highest concentrations of phosphate of the two Madden Lake ponds. It is possible that cattle feces contributed to the increase in available phosphates.

Madden Lake Pond 2 had the lowest concentrations of phosphates despite having the second highest concentration of dissolved solids. This may have affected the overall productivity of the pond which had the least evidence of aquatic vegetation growth of all the sites measured. Even Deadman’s Lake showed evidence of aquatic vegetation established in a ring around the highly saline centre.

Iron, copper and nitrates were in negligible quantities. In most cases, the colouring of the testing solution suggested a trace presence; however, all test samples were below the lowest values on our comparison chart. In many cases, the natural colouring of the sample water made it difficult to compare between the sample and the comparison chart.

Although there were some challenges to sampling and measuring water quality, we were able to describe water quality and characteristics of lakes and ponds used by tiger salamanders. As well, our findings provide baselines to compare monitoring of these lakes over time.

2. Vegetation

When terrestrial factors are considered, Madden Lake Pond 1 appears to be the most suitable breeding habitat for tiger salamanders in terms of densities of vegetation and coarse woody debris. Although its Zone 2 is wider than the same zone at the other ponds, and has relatively little plant cover, its superior CWD density should provide
better cover for migrating salamanders. Madden Lake Pond 1’s complete lack of a mud zone can also be seen in a positive light; salamanders can travel directly from the water to the cover of Zone 2.

The worst site for the terrestrial portion of the tiger salamander’s life history appears to be Burnell Lake. Its mud zone is substantially wider than that of the other ponds, exposing emerging salamanders to predators and the elements (sun and desiccation) for a greater period during migratory movements. Although many migratory movements occur at night (Richardson et al. 2000), we found one metamorph (with small bumps where its gills were receding) at the Zone 2 – Zone 1 boundary moving towards Burnell Lake during the mid-afternoon on August 22. This problem of a wide mud zone at Burnell Lake is compounded by the near total lack of CWD in Zones 1 to 3; and thus, any cover must be derived from vegetation. We hypothesize that lack of CWD at Burnell is linked to heavy use of the area for recreation whereby CWD would be collected for campfires. Compounding the problem of insufficient cover, Burnell Lake has been stocked with fish and is aerated to prevent anoxia. Thus, even if salamanders survive the journey to the lake, their probability of reproductive success is probably low due to predation on eggs and larvae by fish.

3. Human, cattle, and wildlife impacts

Variation in grazing and track intensities at each lake may show that use by cattle is not evenly distributed and could be the result of selective grazing by cattle, following an “all or nothing” approach. For example, unpalatable vegetation would inhibit grazing at a particular site and thus these areas would retain more vegetation and may provide better habitat for tiger salamanders. At Madden Lake Pond 2, the normal grass zone was
covered primarily by unpalatable vegetation, thus there was very little grazing in this area. However, grazing was more extensive at higher elevation quadrats (i.e., in high zones), in part due to their proximity to cattle paths. Therefore, areas with unpalatable vegetation may be suitable areas to exclude cattle because such areas already have vegetation and it would not reduce availability of palatable food to cattle. There were some fences that isolated sections of the grass zone, and within the ungrazed fenced areas grasses and forbs were denser and taller than in adjacent grazed areas. These fences explain why some areas had low grazing intensities while others were extensively grazed.

Because there is no significant correlation between tracks and grazing intensities, these factors likely represent different aspects of cattle activity. We think that cattle grazing provides a better index of impact than do tracks (Fig. 3.7a, b), because cattle grazing patterns matched our visual observations of effects on vegetation better than did track patterns. Grazing intensity was also a more distinctive measurement of total cattle activity than tracks because cattle selectively graze. From a perspective of tiger salamander habitat, grazing is an indicator of both vegetation loss and perhaps even collapse of small mammal burrows.

The statistical distribution of grazing (i.e., low intensity skewed to the left) may be due to the following reasons: unpalatable vegetation, positions of fences, and seasonal grazing. Unfavourable water access, such as in the case of Madden Lake Pond 2, may explain a left skewed distribution for low track intensity.

Portions of Deadman’s Lake are potentially more suitable for tiger salamanders because the majority of grazing and tracks were at low intensity. These results could be due to seasonal grazing because at the time of our study, there was little water in the lake
and what was there was highly saline. However, Deadman’s Lake could be suitable salamander breeding habitat earlier in the year because it likely does not dry until July, after the critical metamorphosis period.

Wildlife species, such as mule deer, also likely graze on vegetation surrounding the lakes. However based on tracks and other signs, wildlife grazing appears to be a small fraction of the total grazing. Large wildlife species, including black bear, can leave footprints and thus create depressions in the ground surrounding the lake. These depressions could form microsites in which mortality of salamander eggs and larvae would be high if the pockets of water dried. Nevertheless, it appears wildlife tracks have minor effects compared to cattle, due to their small quantity.

Human activities, such as off-roading, may cause similar impacts to salamander habitat as cattle grazing and trampling. For example, ATV tracks could cause small depressions that could fill with water and subsequently dry out and kill eggs and larvae. Other activities, such as camping and campfires, may decrease the amount of riparian vegetation and CWD available to salamanders.

Sources of error

1. Water quality

Reliability of our data may be compromised by the salinity of the water. In Deadman’s Lake, high concentrations of dissolved solids may have caused erroneous pH readings. Tests at the other lakes seemed to produce reasonable values, but it is possible that salinity had an effect on those readings as well. At Deadman’s Lake, tests for nitrates and iron could only be done on greatly diluted samples because the reducing agents used could not be dissolved in the already super saturated solution. Although unavoidable, it is
possible that the dilution reduced the concentrations of nitrates and iron below our detection threshold.

Seasonal fill and seasonal flood water levels are estimates that, in part, are based on assumptions about the lateral extent of water reasoned from white deposits and zones of vegetation. Hence errors in our assumptions may have biased our results. Our estimates of lake volume were calculated with simple geometry and using very rough estimates of lakebed shape and shoreline slope. Our methods were consistent between lakes and thus valid for comparisons, but the actual morphology of the lakes was probably more complex and our estimates of lake volumes and changes to depths should be considered very rough.

2. Vegetation

Several factors may have contributed to our sampling error. Most importantly, our choice of sampling locations within each zone was not always random and was influenced by difficult terrain, evidence of potentially dangerous wildlife (e.g., rattlesnakes, black widow spiders), and dense shrubs. We also tried to choose sampling locations based on the presence of vegetation that appeared to be representative of the whole zone in a given area.

Error could also have arisen in our calculation of the area over which we counted CWD. This area was calculated indirectly using the circumference of one zone and average zone width, and for simplicity, we assumed that all lakes were circular. Other error related to CWD may have arisen through diminished detection of the CWD due to dense vegetation, and by thistle covered with hornets around the Madden Lake ponds and dense grass at Deadman’s Lake.
Some uncertainty is associated with our estimates of tree or shrub heights > 2 m, because these were not direct measurements and may have been subject to observer bias and individual judgment.

Finally, due to the time of year at which our surveys were conducted (i.e., dry season of late August), habitat characteristics may differ from those present during the breeding season during spring and early summer. Vegetation patterns and lake size may differ during the breeding season, and the amount of cover available to migrating salamanders could be superior or inferior at that critical period.

3. Human, cattle, and wildlife impacts

Our samples may have potential biases because we stratified intensity of use (both for grazing and for tracks) around the lake. Additionally, our standard error is high, because we used visual estimates of percentage cover. Tracks and grazing by wildlife were included on our quadrats; thus, we cannot quantitatively distinguish cattle and wildlife use. However because of our qualitative observations, for data analyses, we assumed that cattle were responsible for the majority of grazing and tracks because wildlife use appeared to be minor. Because of time constraints, our sample sizes were small and this could increase our standard errors.

Future Research

1. Water quality

Future research should include determining water quality and lake characteristics of ponds and lakes that are not occupied by tiger salamanders to identify water conditions in which they are not present. The lakes and ponds sampled in this study should be
revisited at the beginning of breeding season in the early spring to measure water quality and lake characteristics such as depth and lateral extent of water.

Low iodine concentrations are thought to be one factor that leads to the development of neotenic individuals. Measurements of iodine concentrations in lakes where tiger salamanders inhabit and lakes that do not contain tiger salamanders may reveal iodine concentrations necessary for neoteny.

2. Vegetation

Future studies of CWD could focus on salamander preference for particular cover, such as size of debris, zone in which CWD is located, and soil moisture beneath pieces of CWD. This could help determine what kind of CWD should be retained at sites earmarked for tiger salamander conservation.

Another question of potential interest is whether or not the vegetation community is an indicator of habitat disturbance. If plant species surrounding a given lake are generally known to be invasive or characteristic of disturbed sites, will tiger salamanders be less likely to use that site for breeding, and will their survival rates be affected? Is plant community composition a good indicator of general habitat quality?

3. Human, cattle, and wildlife impacts

We recommend further research to determine the effectiveness of cattle fencing for maintaining salamander habitat. Variations in grazing and track intensities can identify locations where resource sharing between cattle and salamanders may be successfully applied. As well, a complete inventory of all plant species grazed by cattle would be beneficial in identifying possible vegetation cover for tiger salamander habitat enhancement. Future studies to monitor the preferential migration routes of the tiger
salamander should be performed simultaneously with habitat enhancement projects. Ideally, the migration routes of tiger salamanders should overlap with areas of cattle exclusion.

**Literature Cited**

Cannings, S.G., L.R. Ramsay, D.F. Fraser, and M.A. Fraker. 1999. Rare amphibians, reptiles, and mammals of British Columbia. BC Ministry of Environment: Victoria, BC.


1. Water Quality

Table 1.1. Mean lake characteristics. August 21-26, 2005.

<table>
<thead>
<tr>
<th>Lake</th>
<th>Site</th>
<th>T (°C)</th>
<th>NO3 (ppm)</th>
<th>Cu (ppm)</th>
<th>PO4 (ppm)</th>
<th>Fe (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burnell</td>
<td>Shallow shoreline</td>
<td>27.5</td>
<td>&lt;0.25</td>
<td>&lt;0.1</td>
<td>0.02</td>
<td>&lt;0.15</td>
</tr>
<tr>
<td></td>
<td>Deep shoreline</td>
<td>25.2</td>
<td>&lt;0.25</td>
<td>&lt;0.1</td>
<td>0.03</td>
<td>&lt;0.15</td>
</tr>
<tr>
<td></td>
<td>Mid-lake</td>
<td>23.0</td>
<td>&lt;0.25</td>
<td>&lt;0.1</td>
<td>0.02</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Side Pond</td>
<td>26.3</td>
<td>&lt;0.25</td>
<td>&lt;0.1</td>
<td>0.03</td>
<td>&lt;0.15</td>
</tr>
<tr>
<td>Deadman’s</td>
<td></td>
<td>22.0</td>
<td>0</td>
<td>0</td>
<td>14.0</td>
<td>&lt;0.15</td>
</tr>
<tr>
<td>Madden Pond 1</td>
<td>Shoreline</td>
<td>18.7</td>
<td>0</td>
<td>&lt;0.2</td>
<td>0.03</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mid-lake</td>
<td>23.9</td>
<td>&lt;0.25</td>
<td>&lt;0.1</td>
<td>0.04</td>
<td>&lt;0.15</td>
</tr>
<tr>
<td>Madden Pond 2</td>
<td>Shoreline</td>
<td>30.6</td>
<td>0</td>
<td>0</td>
<td>0.03</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mid-lake</td>
<td>25.5</td>
<td>&lt;0.25</td>
<td>0</td>
<td>&lt;0.02</td>
<td>0</td>
</tr>
</tbody>
</table>
Fig. 1.1. Average diameter of the four lakes when sampling occurred (black) and the estimated diameter at seasonal fill (white) and at flooding (gray). Flood diameter was not estimated for Burnell Lake or Madden Lake Pond 1. Madden Lake Pond 1 had a steep mud bank which we reasoned would contain the flood water.

Fig. 1.2 The average depth of the four lakes when sampling occurred (black), and the estimated depth at seasonal fill (white) and at flooding (gray), based on two measurements at each lake. There was not enough water in Deadman’s Lake to calculate a depth.
Fig. 1.3 The approximate volumes of the four lakes when sampling occurred (black) and at seasonal fill (white) and at flooding (gray), based on two measurements at each lake. We estimated the current volume of water in Deadman’s Lake to be 0.04 m$^3$ Burnell Lake volumes were much greater than all others. Volumes were approximately 471000 m$^3$ and 579000 m$^3$ when sampling occurred and at seasonal fill, respectively.

Fig. 1.4 The pH of each sample site is shown. Letters show a significant difference among sites (P<0.05). * The pH measured for Deadman’s Lake is probably inaccurate due to interference of high salinity.
Fig. 1.5 Total Dissolved Solids from 3 of the 4 lakes sampled, including 3 strata from Burnell Lake are shown. Deadman’s Lake is excluded because we obtained measurements for only two of the three samples because there was not enough water available to dilute the third. The two samples from Deadman’s Lake were much higher than the other samples (435000 and 440000 ppm). Different letters indicate significant differences among lakes (P<0.05).
2. Vegetation

Figure 2.1. Average percentage cover of vegetation in each zone at Burnell Lake, Deadman’s Lake, and Madden Lake Ponds 1 and 2. Zones were defined by the principal substrate and vegetation cover: Zone 1 (mud flats), Zone 2 (short grass), Zone 3 (longer grass/forbs), and Zone 4 (riparian trees and shrubs).
Figure 2.2. Average widths (± SE) for each vegetation zone at Burnell Lake, Deadman’s Lake, and Madden Lake Ponds 1 and 2.

Figure 2.3. Zones as a percentage of the distance from water edge to the far edge of Zone 4 at Burnell Lake, Deadman’s Lake, and Madden Lake Ponds 1 and 2.
Figure 2.4. Total number of pieces of coarse woody debris (CWD) in three diameter classes in vegetation zones 1-3 at Burnell Lake, Deadman’s Lake, and Madden Lake Ponds 1 and 2.

Table 2.1. Density of coarse woody debris (pieces/ha) for 3 size classes in Zones 1-3 at Burnell Lake, Deadman’s Lake, and Madden Lake Ponds 1 and 2.
Appendix 2.1. Plant Species Encountered in Vegetation Surveys.

Native Species Indicative of Clearings/Grasslands/Lakeshores
Aster, various species (Aster spp.)
Douglas maple (Acer glabrum)
Red-osier dogwood (Cornus stolonifera/sericea)
Rose (Rosa spp.)
Silverweed (Potentilla anserine)
Rough fescue (Festuca campestris)
Small yellow water-buttercup (Ranunculus gmelinii)
Tall Oregon-grape (Mahonia aquifolium)
Trembling aspen (Populus tremuloides)
Willow, various (Salix spp.)

Native Species Indicative of Disturbed Areas
Purple-leaved willowherb (Epilobium ciliatum/watsonii)
Foxtail barley (Hordeum jubatum)
Saskatoon (Amelanchier alnifolia)
Yarrow (Achillea millefolium)

Native Species, General
Cinquefoil, unknown species (Potentilla sp.)
Common plantain (Plantago major)
Common snowberry (Symphoricarpos albus)
Desert-parsley, unknown species (Lomatium sp.)
Paper birch (Betula papyrifera)
Ponderosa pine (Pinus ponderosa)
Stonecrop (Sedum sp.)

Introduced/Invasive Species
Black medic (Medicago lupulina)
Bull thistle (Cirsium vulgare)
Canada thistle (Cirsium arvense)
Common dandelion (Taraxacum officinale)
Diffuse knapweed (Centaurea diffusa)
Great mullein (Verbascum thapsus)
Red clover (Trifolium pratense)
White sweet-clover (Melilotus alba)

Other Groups
Grass
Moss, various species
3. Human, wildlife, and cattle impacts

![Diagram of Stratification of sampling site at Burnell Lake (Sawmill Lake) with labels for Moderate, Low, High, and Starting Point.]

![Diagram of Stratification of sampling site at Deadman’s Lake with labels for Gate 1 and Gate 2.]

![Diagram of Stratification of sampling site at Madden Lake 1 with labels for Moderate, Low, High, and Initial.]

![Diagram of Stratification of sampling site at Madden Lake 2 with labels for Low and High.]

---

35
Figure 3.5a. Percentage cover of grazing and tracks at locations along the perimeter of Burnell Lake.

Figure 3.5b. Percentage cover of grazing at locations along the perimeter of Deadman’s Lake.
Figure 3.5c. Percentage cover of tracks locations along the perimeter of Deadman’s Lake.

Figure 3.5d. Percentage cover of tracks and grazing at locations along the perimeter of Madden Lake 1.
Figure 3.6a. Distribution of percentage of total perimeter for each track intensity class for Burnell, Deadman’s and Madden Lake Pond 1.

Figure 3.6b. Distribution of percentage of total perimeter for each grazing intensity class for Burnell, Deadman’s and Madden Lake Pond 1.
Figure 3.7a. Frequency distribution of grazing intensities for all lakes.

Figure 3.7b. Frequency distribution of track intensities for all lakes.
Table 3.1. Mean (± SE) percentage cover of tracks and grazing for each intensity class.
* No data available for this intensity level and lake
** Only one datum collected, standard error is not applicable.

<table>
<thead>
<tr>
<th>Lake</th>
<th>Tracks Low</th>
<th>Tracks Moderate</th>
<th>Tracks High</th>
<th>Grazing Low</th>
<th>Grazing Moderate</th>
<th>Grazing High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burnell</td>
<td>7.5±1.2</td>
<td>39.3±0.7</td>
<td>68.8±10.6</td>
<td>10.3±1.2</td>
<td>45.0±0.7</td>
<td>81.8±10.6</td>
</tr>
<tr>
<td>Deadman’s</td>
<td>21.7±5.2</td>
<td>40.0±7.1</td>
<td>*</td>
<td>10.0±0.9</td>
<td>40.0**</td>
<td>76.7±2.9</td>
</tr>
<tr>
<td>Madden 1</td>
<td>30±0</td>
<td>42.5±1.7</td>
<td>73±2.1</td>
<td>*</td>
<td>47.9±1.3</td>
<td>81.0±2</td>
</tr>
<tr>
<td>Madden 2</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>0.7±0.3</td>
<td>*</td>
<td>76.0±2.1</td>
</tr>
</tbody>
</table>

Table 3.2. Wildlife observed at Burnell, Deadman’s and Madden Lake Ponds, August 21-26, 2005.

<table>
<thead>
<tr>
<th>Wildlife Observed</th>
<th>Burnell Lake</th>
<th>Deadman’s Lake</th>
<th>Madden Pond 1</th>
<th>Madden Pond 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Bear (Ursus americanus)</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mule Deer (Odocoileus hemionus)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Duck</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Painted Turtle (Chrysemys picta)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Garter Snake (Thamnophis sirtalis)</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Rattlesnake (Crotalus viridis)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow-bellied Marmot</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ruffed Grouse (Bonasa umbellus)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pacific Tree Frog (Hyla regilla)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cedar Waxwing (Bonbycilla cedrorum)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red–breasted Nuthatch (Sitta canadensis)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mountain Chickadee (Parus gambeli)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rufous-Sided Towhee (Pipilo erythrophthalmus)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharp-shinned Hawk (Accipiter striatus)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tiger salamander (Ambystoma trigrinum)</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>California Quail (Lophortys californicus)</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Red Crossbill (Loxia crurvirostra)</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.3. Human activities observed at Burnell, Deadman’s and Madden Lake Ponds.

<table>
<thead>
<tr>
<th>Human Activities Observed</th>
<th>Burnell Lake</th>
<th>Deadman’s Lake</th>
<th>Madden Pond 1</th>
<th>Madden Pond 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off-riding</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camping</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partying</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fishing</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horseback riding</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Dirt biking</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dogs swimming</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water control system</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>