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UNEXPLAINED DIE-OFF OF LARVAL BARRED TIGER SALAMANDERS (*AMBYSTOMA MAVORTIUM*) IN AN AGRICULTURAL POND IN THE SOUTH OKANAGAN VALLEY, BRITISH COLUMBIA, CANADA

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Key words: *Ambystoma mavortium*, Barred Tiger Salamander, Canada, die-off, Okanagan Valley

The Southern Mountain population of the Barred Tiger Salamander (*Ambystoma mavortium*) is federally listed in Canada as endangered (Southern Interior Reptile and Amphibian Recovery Team 2008; Species at Risk Public Registry http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=697; listed as *Ambystoma tigrinum* prior to name change in 2010). This population is restricted to the South Okanagan, Lower Similkameen, and Kettle River watersheds in British Columbia (Sarell 1996, 2004; Southern Interior Reptile and Amphibian Recovery Team 2008). A decline in the geographic range of the Barred Tiger Salamander in the interior of British Columbia during the past 30 y is inferred from apparent extirpations at historic breeding sites, combined with extensive habitat loss (Lea 2008). As of August 2005, only 57 occupied breeding sites were known in British Columbia (BCMOE 2005; Southern Interior Reptile and Amphibian Recovery Team 2008). We report here on the incidence of a die-off of Barred Tiger Salamanders and the consequences that multiple stressors and isolation have on the potential for population recovery at this site.

We conducted a survey of amphibians from 2003 to 2006 to determine amphibian use of ponds within the lowland valley and intensive agricultural zone of the south Okanagan Valley. Wetlands from Okanagan Falls to Osoyoos were surveyed for occupancy by amphibians. Barred Tiger Salamanders were found at only 8 of the 96 ponds surveyed.

A pond (Pond #1) near Osoyoos, within an orchard and vineyard farm, was first surveyed in 2003. The pond holds water permanently and is approximately 5 m deep, 95 m long, and 73 m wide. Between 9 and 25 June, we surveyed the pond on 3 occasions using floating minnow traps set overnight, and on 5 occasions using daytime time-constrained dip-net searches (Table 1). Barred Tiger Salamanders observed 9 to 12 June were alive (n = 28 larvae), and none showed signs of ill health. On 19 June, however, 4 living and 4 dead larvae were observed in traps. On 23 and 24 June, only dead and floating Barred Tiger Salamander larvae were observed in the pond (n_{total} = 13 larvae). Due to extreme decomposition at the time of collection, samples of the larvae were not collected or examined to determine cause(s) of death.

We next sampled Pond #1 thirteen times between 28 April and 25 June 2004 (Table 1). We used similar methods as in 2003, and no salamanders were found. The pond was also surveyed annually in the same way from April to June, 2005 through 2009 (Table 1), and no evidence of salamanders was found in any of these years. Adult and larval Pacific Treefrogs (*Pseudacris regilla*), however, were observed in all years, and none were found dead or moribund.

The reason for the observed larval Barred Tiger Salamander deaths in 2003 and the corresponding absence of Barred Tiger Salamanders in Pond #1 from 2004 to 2009 is unknown. We do know that Pond #1 is located within a farm that uses conventional pesticide and fertilizer spray applications. These types of chemicals can be toxic to amphibians and other aquatic organisms and can negatively affect their immune systems (Erickson and others 1996; Chen and Lin 2001; Sparling and others 2010). Unfortunately, details regarding pond water chemistry and spray events at the farm were unavailable before or during the incidence of larval mortality.

Ranaviruses and *Batrachocytrium dendrobatridis* (*Bd*) fungus also can infect and negatively

TABLE 1. Pond sampling effort from Pond #1(Barred Tiger Salamander unknown die-off in 2003), Pond #2 (Barred Tiger Salamander breeding site in 2003, goldfish introduced in 2004), Pond #3 (historic Barred Tiger Salamander site, goldfish removed in 2009), and Pond #4 (sustained Barred Tiger Salamander breeding site) from 2003 through 2009. FMT = floating minnow trap; Trap-night = number of traps x number of nights.

Pond	Sampling period	Sampling device	Sampling occasions	No. of trap-nights	Total trap or search hours
1	9–25 June 2003	FMT	3	14	42.2
		Dip-net	5	—	6.4
1	28 April–25 June 2004	FMT	8	15	41.5
		Dip-net	5	—	3.5
1	April–June, 2005–2009[a]	FMT	—	10–15	24.1–48.4
		Dip-net	3–5	—	1.3–4.5
2	2003–2009[a]	FMT	—	16	145.6–161.3
		Dip-net	3–5	—	2.2–3.0
3	2003–2009[a]	FMT	—	15–25	167.3–215.2
		Dip-net	3–5	—	1.5–8.5
4	2003–2009[a]	FMT	—	12–16	42.4–137.2
		Dip-net	3–5	—	1.5–5.5

[a] data represent range/category over annual survey periods

affect Tiger Salamanders (Collins and Storfer 2003; Davidson and others 2003). Ranaviruses can cause mortality in wild Tiger Salamanders (Collins and Storfer, 2003), and larval salamanders are particularly likely to carry ranavirus (Brunner and others 2004). Exposure to *Ambystoma tigrinumvirus* (ATV) is generally lethal, and the virus is known to occur in Canadian Tiger Salamander populations, although it has only been reported in the Prairie Provinces (Bollinger and others 1999). Field data corroborate the persistence of ATV between epidemics in sublethally infected Tiger Salamander metamorphs (Brunner and others 2004), and salamander populations typically recover 1 to 2 y after a die-off, suggesting evolved resistance (Brunner and others 2004). In contrast, the cause of the die-off at the farm in the Okanagan Valley appears to have either killed all individuals in the population or substantially reduced the population size to a point that the population, as of 2009, has not recovered.

The impact of this die-off and apparent lack of recovery of the population in Pond #1 has broader implications for the survival of Barred Tiger Salamanders south of Okanagan Falls within the lowland valley (<500m elevation) and core agricultural zone (approximately 1000 km^2) of the Okanagan Valley. Based on surveys conducted by SLA, there are only 3 ponds (Pond #2, Pond #3, and Pond #4) within a 1.5 km radius of Pond #1. Only Pond #4 (1.3.km from Pond #1) contained Barred Tiger Salamanders during the entire survey period (2003 through 2009). In 2003, however, the closest known Barred Tiger Salamander breeding site was Pond #2, approximately 500 m distant from Pond #1. Goldfish (*Carassius auratus*), who have been documented as preying on the eggs and larvae of amphibians (Monello and Wright 1999, 2001), were known by the authors to have been introduced at this permanent pond in 2004; and no larval Barred Tiger Salamanders were detected in Pond #2 during annual surveys from 2004 through 2009 (Table 1).

In the 1990s, Goldfish also had been introduced into Pond #3, which is 250 m from Pond #1. The landowner of the pond provided photo-documentation of adult Barred Tiger Salamanders near Pond #3 prior to the introduction of the Goldfish. This suggests that the pond also may have been a Barred Tiger Salamander breeding site prior to the eradication of the salamander population, due in part we suspect, to the presence of the Goldfish. In 2008 and 2009, SLA used seines to remove Goldfish from the pond (2008: 8 seining occasions, 15.25 h total; 2009: 4 seining occasions, 10.35 h total), completely eradicating Goldfish by spring 2009. Complete removal of the Goldfish resulted in rapid colonization and metamorphic success at the site by Great Basin Spadefoots (*Spea intermontana*) and Pacific Treefrogs in the same year; however, no larval Barred Tiger Salamanders were found at the site.

We also surveyed for Barred Tiger Salamanders in Pond #4 in each year from 2003 through 2009 (Table 1), and a population was confirmed to persist at this site during the entire period. We suspect that any recolonization of Pond #1 by Barred Tiger Salamanders would be primarily dependent on the dispersal of individuals from Pond #4. These individuals, however, would need to travel across an arid landscape fragmented by a 4-lane highway, several secondary roads, and agricultural and urban development to re-colonize historically populated ponds. In arid locations, such as the Grand Canyon in Arizona, radio-tagged Tiger Salamander metamorphs return to their home pond only in the spring when climatic conditions are favorable for migration (Greer and others 2009). Therefore, the limited seasonal migrations of Tiger Salamanders to breeding ponds, even in relatively pristine environments (Greer and others 2009), coupled with mass migration and mortality of Tiger Salamanders across highways (Clevenger and others 2003) reduces the probability of successful recolonization and dispersal in the south Okanagan Valley.

Based on our 7 y of surveys, we conclude that a combination of factors may account for the lack of recovery of the Barred Tiger Salamander population in Pond #1 after the die-off. These factors include: (1) the use of pesticides and fertilizers at the farm where the pond is located; (2) the possible persistence of ranavirus or other diseases in this small, localized salamander population prior to extirpation; (3) the presence of an introduced exotic predator (Goldfish) in neighboring ponds; and (4) the low potential for immigration of colonizing individuals from Pond #4, the only nearby pond with a persistent population of Barred Tiger Salamanders. Persistence and recovery of populations of Barred Tiger Salamanders will depend on management of these stressors to ensure the long-term quantity and quality of habitat for this species and to allow for immigration among discrete pond sites throughout this species' range.

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CHANGES IN POPULATION SIZE OF BATS AT A HIBERNACULUM IN ALBERTA, CANADA, IN RELATION TO CAVE DISTURBANCE AND ACCESS RESTRICTIONS

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Key words: Alberta, bats, Cadomin, cave, census, disturbance, hibernaculum, *Myotis*, population change, Rocky Mountains

Long-term data for bat populations are absent for much of North America, resulting in a generally poor understanding of bat population trends for the majority of species. Inventory of sedentary individuals at cave hibernacula offers one opportunity for long-term monitoring of bat populations. However, the Canadian Rockies have few known caves with large bat populations; thus, opportunities for assessing populations in these regions are limited. Where the majority of bats in Alberta, and most other areas in western North America, hibernate currently is unknown, but it is clear that known bat hibernacula in north-western North America account for a very small proportion of the total bat population (Schowalter 1979; Nagorsen and others 1993). Nonetheless, census data at cave hibernacula could provide a useful indicator of the general stability of bat populations, and are important for assessing the efficacy of cave management practices. With the rapid spread of white nose syndrome, a fungal pathogen spreading across North America that is associated with widespread mortality in populations of cave-hibernating bats (Blehert and others 2009), it is increasingly important to establish baseline population data prior to contact of bats with this pathogen or other unforeseen threats. In this note, we present 25 y of census data from Cadomin Cave, the largest known bat hibernaculum in Alberta, Canada.

Cadomin Cave (length 2791 m, depth 220 m; UTM: Zone 11, 477630E, 5872323N, NAD83) is among the largest caves in the Canadian Rockies (Rollins 2004). The cave is set in relatively soft sandstone and consists of a labyrinth series of expanded 'rooms' and connecting corridors resulting from ancient flowing waters and subsequent seepage and erosion. It is located near the hamlet of Cadomin, 262 km west of Edmonton, Alberta in the foothills along the eastern slopes of the