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UNUSUAL SUBTERRANEAN AGGREGATIONS OF THE CALIFORNIA GIANT SALAMANDER, *DICAMPTODON ENSATUS*

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***Abstract*.—Larval *Dicamptodon* are one of the most abundant vertebrates in headwater streams in the Pacific Northwest. Their numbers and biomass can exceed those of all other amphibians, and of salmonid fishes. By contrast, metamorphosed *Dicamptodon* are only found infrequently, usually during formal surveys using pitfall traps, cover boards, or time constrained surveys However, we found two aggregations (23 and 27 individuals) of metamorphosed *Dicamptodon ensatus* during a culvert removal project at Point Reyes National Seashore, California. Furthermore, we found an additional 23 terrestrial *D. ensatus* in terrestrial habitat adjacent to the culverts. We did not expect these aggregations because metamorphosed individuals are so rarely encountered, and aggregations are likely to increase competition and predation in a species known to feed regularly on vertebrate prey. Deteriorating culverts might provide an unusually high-quality habitat that leads to aggregations such as we describe. Our observations may provide insight into the natural haunts of *D. ensatus*—underground burrows or caverns—and if so, then aggregations may be normal, but rarely seen.**

Key Words.—aggregation; California Giant Salamander; culverts; *Dicamptodon ensatus*; habitat; subterranean

INTRODUCTION

The use of heavy equipment (e.g., pry bars, jackhammers, bulldozers, excavators) to move large cover objects or entire stream banks in search of amphibians is impractical and environmentally unfriendly. Such equipment, however, is regularly used during construction and stream renovation projects. Traditionally, biologists have not been present at construction sites, both for safety reasons and out of general concern that their discoveries would interfere with completion of a project. More recently, the requirements of the U.S. Endangered Species Act have resulted in the increased involvement of biologists in the planning and implementation of construction projects so these projects do not impact listed species, and animals can be relocated as necessary.

In the fall of 2007, Point Reyes National Seashore (Marin County, CA) replaced four culverts with short bridges as part of a stream restoration project designed to improve salmonid fish habitat. The work involved the removal of culverts and associated boulders, and the recontouring of the adjacent stream bank. The project required the removal or rearrangement of a significant amount of soil, boulders, and logs. Because the federally protected California Red-legged Frog (*Rana draytonii*) inhabited the streams, at least one of the authors was present during all phases of the construction. Close cooperation between the construction crew and biologists allowed us to carefully examine potential amphibian habitats during the removal of cover items. This was an unusual opportunity because the number, size, and weight of the cover items removed far exceeded that which could be examined by hand during standard amphibian surveys (Welsh et al. 2007).

Herein, we report the discovery during the construction period of two large aggregations of metamorphosed California Giant Salamanders (*Dicamptodon ensatus*), a life history stage rarely detected during standard amphibian surveys. *Dicamptodon ensatus* occurs only along the central coastal California, where it inhabits wet, shaded forests near permanent or semi-permanent streams (Stebbins 2003; Bury 2005). Biologists occasionally find metamorphosed *D. ensatus* hiding under logs and rocks, walking in the woods or across roads during fall and winter rains, or looking out of burrows along stream banks or road cuts. In one case, a pipe drilled 6.1 m into a spring immediately produced two dismembered and one intact adult *D. ensatus*, and three weeks later produced another five adults (Dethlefsen 1948). We are not aware of any other reports of > 3 metamorphosed *Dicamptodon* sp. in close proximity to each other; hence, our discovery of aggregations of over 20 salamanders at each of two culverts is unusual and raises questions about competition and predation in this species.

FIGURE 1. Estero road culvert at Point Reyes National Seashore. Though partially obscured by shadows, an eroded, drippy, wet cavern is visible on the underside of the culvert. The cavern appeared to be ideal salamander habitat. When the culvert was lifted, 27 *Dicamptodon ensatus* were exposed, along with other amphibians and reptiles (Table 1).

FIGURE 2. Removal of a culvert at Mt. Vision Road, Point Reyes National Seashore, California. We found no *Dicamptodon ensatus* under this culvert even though the cavern on the underside of the culvert was similar to those at both the Estero and Glenbrook sites. However, the Estero and Glenbrook culverts were much wetter and provided better amphibian habitat. At the time of this photograph, rock and soil had been removed from the top and sides of the culvert, but nothing had been disturbed below the lower lip of the culvert.

METHODS AND MATERIALS

The steel culverts scheduled for replacement had been in place at road crossings within Point Reyes National Seashore since about 1982. The Estero Road culvert was 2.1 m wide x 1.4 m high x 12.2 m long (Fig. 1), and the Glenbrook culvert was circular in cross section with a diameter of 1.2 m and a length of 12.2 m. Over time, water had flowed around both culverts from the upstream side (Fig. 2), creating numerous small tunnels. Furthermore, during the winter of 2006-07, a sinkhole developed in the trail above the Glenbrook culvert and allowed more water to flow around the culvert. Both culverts had rusted to such an extent that water dripped through them onto the underlying substrate. Water passing alongside and through the rusted culvert had eroded the soils underneath, leaving a drippy, wet cavern. Riprap (large, irregular rocks), placed at the culvert outflows to prevent erosion, formed stable entrances to these caverns. At the Estero culvert, we estimated that a cavern approximately 0.3 m high x 1 m wide x 1.5 m deep had developed. The cavern appeared to be ideal salamander habitat.

Two additional culverts similar to the one at Estero Road were also removed, but these were either nearly dry underneath (Mt Vision Road) or embedded in the bottom of the stream channel and covered by a 0.5–1.0 m deep layer of sediment that protected the structure of the culvert (Home Ranch). Neither of these culverts provided significant habitat for adult salamanders, and we do not discuss them further.

The Estero culvert was in a 30–60 m-wide riparian corridor where the dominant vegetation was Red Alder (*Alnus rubra*), willow (*Salix* sp.), Himalayan Blackberry (*Rubus discolor*), Western Swordfern (*Polystichum munitum*), and nettle (*Stachys* sp.). The Glenbrook culvert (4.7 km to the southwest) was in a 25–50 m-wide riparian zone with Red Alder, California Bay (*Umbellularia californica*), willow, Himalayan Blackberry, Western Swordfern, nettle, and Salmonberry (*Rubus spectabilis*). At both sites, the adjacent habitat was dry grassland with European grasses, Coyote Brush (*Baccharis pilularis*), Himalayan Blackberry, Poison Oak (*Toxicodendron diversilobum*), and scattered Bishop Pine (*Pinus muricata*). Although Point Reyes generally has warm dry summers and cool, rainy winters, there is often a dense summer fog that moderates temperatures. September is typically the warmest and driest month. Mean high temperatures range from 11.7°C (January) to 18.3°C (September), with 17.8°C the mean temperature high for both July and August. Mean precipitation is 94 cm, with 70% of that falling between December and March (National Park Service weather records, Bear Valley Visitor Center, Olema, California).

Prior to construction, we conducted nocturnal visual encounter surveys for amphibians (Crump and Scott 2001). These surveys included the stream and stream banks 50 m upstream and downstream of each culvert. We conducted surveys at each construction site on 11 and 15 August 2007. The weather on both nights was clear and calm, with an air temperature of 14°C. We used spotlights and binoculars to detect eyeshine of

Table 1. Amphibians and reptiles found during surveys conducted before, during, and after culvert removal at two construction sites at Point Reyes National Seashore, California. We detected no larval amphibians; hence all counts are for metamorphosed adults.

Species	Estero Road			Glenbrook Creek			Total
	Before	During	After	Before	During	After	
Dicamptodon ensatus California Giant Salamander	1	27	0	1	23	21	73
Ensatina eschscholtzii Ensatina salamander	0	0	0	0	1	0	1
Taricha granulosa Rough-skinned Newt	0	8	2	3	10	7	30
Rana draytonii California Red-legged Frog	14	1	4	18	4	23	64
Pseudacris regilla Pacific Treefrog	5	1	2	3	0	8	19
Thamnophis spp. Garter snake	12	1	0	8	0	4	25

amphibians in the water, on the adjacent bank, or in burrow entrances (Corben and Fellers 2001).

Site preparation, culvert removal, and new culvert placement took place between 13 August and 7 September 2007. Workmen used an excavator to clear vegetation, move earth and rock, and lift culverts (Fig. 1). They removed the Estero culvert 27 August 2007 and the Glenbrook Creek culvert on 4 September 2007. Throughout all construction work, at least one of the authors was at the work site to capture and move amphibians approximately 150 m downstream of the construction site. Equipment operators alerted us to exposed animals and stopped work when we requested access to the site. Temporary silt fencing was erected around each site to prevent return of the translocated amphibians.

Results

We found only one metamorphosed *Dicamptodon ensatus* at each site during surveys prior to culvert removal. Furthermore, we found only three other species of amphibians and one reptile during these surveys (Table 1). When the culverts were lifted, 27 metamorphosed *D. ensatus* were exposed at Estero Road and 23 metamorphosed *D. ensatus* at Glenbrook Creek (Table 1). We found additional amphibians and reptiles during the final phase of construction. During the project, we found 187 adult and juvenile amphibians, and 25 *Thamnophis* spp. (Table 1). Adult and juvenile *D. ensatus* accounted for 40% (73 individuals) of all amphibians.

Discussion

Dicamptodon larvae are common inhabitants of cold, headwater streams. Their density is similar to or exceeds that of salmonid fishes in many coastal streams (Bury et al. 1991). *Dicamptodon* are not just numerically abundant; their biomass is often equal to or greater than that of any other species of aquatic vertebrate, including salmonid fish. Bury et al. (1991) reported that *D. tenebrosus*, a species closely related to *D. ensatus*, was ten times more abundant than salmonids and had four times their biomass in headwater streams in the Pacific region.

It is rare to find metamorphosed *Dicamptodon* during systematic amphibian surveys. Larvae accounted for 99% of the 1,868 *Dicamptodon tenebrosus* detected by Ashton et al. (2006) during nocturnal visual encounter surveys in northwestern California. At Point Reyes National Seashore, we accumulated 18,032 trap nights from 1998-201 using 196 pitfall traps associated with 840 m of drift fence (G. Fellers and D. Pratt, unpublished data). Only 12 *D. ensatus* were captured in the four habitats suitable for this species [Coast Redwood (*Sequoia sempervirens*), Douglas Fir (*Pseudotsuga menziesii*), Bishop Pine (*Pinus muricata*), and riparian], resulting in a rate of 0.067 *Dicamptodon* per 100 trap nights (Table 2). These findings are similar to those of Corn and Bury (1991) who used 36 pitfall traps in each of 45 forest stands to capture 61 *D. tenebrosus* at a rate of 0.045 per 100 trap nights. We have also deployed 84 plywood cover boards in the same four habitat types and found no *D. ensatus* with 1,932 cover board checks over a four year period (1998-2001)

TABLE 2. Results from pitfall trapping and artificial cover board checks for *Dicamptodon ensatus* at Point Reyes National Seashore, California (1998-2001) within four habitats with suitable *Dicamptodon* habitat (G. Fellers and D. Pratt, unpublished data). TD = Trap day.

Habitat	Pitfall TD	Pitfall Captures	Captures per 100 TD	Board TD	Board Captures	Captures per 100 TD
Douglas fir	6,580	2	0.030	705	0	0.000
Bishop pine	6,552	10	0.153	702	0	0.000
Riparian	4,116	0	0.000	441	0	0.000
Redwood	784	0	0.000	84	0	0.000
Totals	18,032	12	0.067	1,932	0	0.000

(G. Fellers and D. Pratt, unpublished data). This level of detection suggests that metamorphosed *Dicamptodon* are not common in the habitats sampled at Point Reyes.

Similarly, metamorphosed *Dicamptodon* are only rarely captured with time constrained surveys (TCS). Welsh et al. (2007) conducted six years of TCS in the Pacific Northwest and captured 5,923 individual amphibians in 288 hours of search time. They found only 25 *D. tenebrosus* representing 0.4% of total captures. Corn and Bury (1991) spent 160.8 hours searching under 536 logs and found one *D. tenebrosus*, representing 3.8% of the amphibians captured.

We did not expect to find adult *Dicamptodon* aggregations. *Dicamptodon* sp. are large salamanders (6–17 cm SVL; Stebbins 2003) that feed on a variety of prey, including vertebrates (Bury 2005). Although little information is available, the diet of larval and metamorphosed *D. ensatus* is likely similar to that of congenerics. Bury (1972) found the remains of nine mammals, one lizard, two salamanders, large-sized land invertebrates, and much debris in the guts of 12 adult *D. ensatus*. Anderson (1960) reported cannibalism in a captive *D. ensatus* held in a quart jar, and in another individual captured under a large redwood log. Thus, D. *ensatus* are not only capable of subduing vertebrate prey, but apparently do so regularly. There must also be competition for food and possible cannibalism when there are as many *Dicamptodon* as we observed under the two culverts. One would not expect *D. ensatus* to form aggregations unless there was an abundance of prey or limited suitable habitat.

If aggregations are common, we would expect adult and subadult salamanders to travel away from daytime retreats in search of food, at least on occasion. On rainy nights, terrestrial adults should be found much more often than is reported, and adults should be captured in pitfall traps much more often than our data (Table 1) and the literature suggest. Adult *D. tenebrosus* accounted for only 1% of the individuals detected by Ashton et al. (2006) during nocturnal visual encounter surveys along streams. Pitfall trapping in suitable habitat does not result in significant numbers of *Dicamptodon*, suggesting that adults do not stray far from their diurnal retreats. Additionally, Bury (2005) reported that breeding migrations for *D. ensatus* were unknown.

With an increased risk of predation and competition, there must be a compensating advantage for these large, predatory salamanders to form aggregations. In the Point Reyes area, one benefit is shelter in an area with limited or patchy suitable habitat. In this region, areas outside the narrow riparian zones are too dry to support *D. ensatus* throughout most of the year. Habitats similar to the drippy, wet caverns that formed under the Estero and Glenbrook culverts are uncommon at Point Reyes, even along stream corridors. Other possible reasons for aggregations might include recent disturbance and displacement from nearby habitats, and breeding assemblages. Both of the culvert sites are within a national park and there was no habitat disturbance prior to culvert removal; therefore, we doubt that recent alteration or loss of habitat caused the aggregations. Eggs of *D. ensatus* have been found in the field in June (attached to a log in a fast flowing stream; Henry and Twitty 1940), and *D. tenebrosus* eggs have been found in July (attached to a log in a riffle at the edge of the stream; Nussbaum 1969, Jones et al. 1990). It is not likely that breeding was the motivation for the aggregations we observed during late August and early September.

With the current practice of removing culverts as part of salmon restoration projects, biologists might locate additional *Dicamptodon* aggregations. Culverts may prove to be an unusually good, albeit unnatural, habitat for *Dicamptodon*. Both the Estero and Glenbrook culverts were "perched" with the downstream end > 1 m above the stream channel. At the outflow, wet areas formed as falling water splashed on the substrate. Both culverts had modest amounts of rock riprap at the outfall, no doubt creating wet crevices and small caves for amphibians.

The process of culvert degradation probably enhances habitat for amphibians. Typically, degradation begins with perforations forming in the bottom of the culvert. As gravel moves through the culvert during storms, the metal erodes leading to the development of holes in the culvert bottom. After this happens, water drains through the holes, erodes the underlying soils, and thus increases the amount of suitable amphibian habitat. Another measure of culvert failure is piping, or the process of water from the upstream side establishing flow paths down the outside of the culvert, through the fill. Both of these processes can combine to develop an extensive network of amphibian habitat (Brannon Ketchum, pers. comm.). Rock layers found beneath riparian soils might also allow for formation of similar, but natural, cavities.

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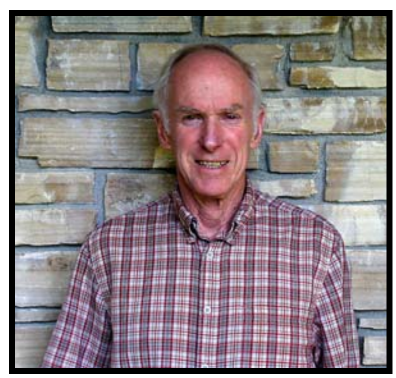
Leslie Long Wood is an independent consultant who works primarily on projects with California Red-legged Frogs and Mountain Yellow-legged Frogs. She received a B.S. in zoology from the University of California at Davis and an M.S. in marine science from the University of California at Santa Cruz. She has conducted research on the effects of pH and UV-B on amphibians, and has participated in research projects involving Spotted Frogs in Nevada, Foothill Yellow-legged Frogs in the sierra foothills, California Red-legged Frogs at Point Reyes, Guadalupe Fur Seals on Guadalupe Island, Baja California, Mexico, and oceanographic research in the Weddell Sea, Antarctica.

Sarah Carlisle graduated from Princeton University with a degree in Ecology and Evolutionary Biology. After brief periods of working with large ungulates and migratory waterfowl, she finally settled on fish. She is currently working as the crew leader for the Coho and Steelhead Monitoring Program at Point Reyes National Seashore, with occasional stints as a biological monitor for construction projects within the park that impact threatened and endangered fish or amphibians.



David Pratt is a retired biologist. Initially, he retired from a career as a microbiologist at the University of Wisconsin and the University of California at Davis. He subsequently worked as a Wildlife Biologist for the U.S. Forest Service, National Park Service, and U.S. Geological Survey before retiring a second time. In the Tahoe National Forest, in the Sierra Nevada of California, he participated in research on the effects of timber harvest practices in coniferous and Black Oak forests on populations of Pine Martens, other small mammals, Spotted Owls, and other birds. At Point Reyes National Seashore, he carried out inventories of terrestrial mammals, amphibians, and reptiles. He also took part in translocations and surveys of Mountain Yellow-legged Frogs in Sequoia and Kings Canyon National Park.