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An ectoparasitic snail (*Evalea tenuisculpta*) infects red abalone (*Haliotis rufescens*) in northern California

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We document the presence of the ectoparasitic fine-sculptured odostome snail (*Evalea tenuisculpta*) on red abalone (*Haliotis rufescens*) in northern California. Red abalone form the basis for an important recreational fishery north of San Francisco. We found that 82% of the red abalone examined from three sites (n=73) in Sonoma County had these small snail parasites. We document that the parasitic snails also infects northern abalone (*H. kamtschatkana*). Infected red abalone had an average of 12 parasitic snails, averaging 4.8mm in length (range 1.0 to 8.8 mm) on their shell. In the laboratory, starved parasitic snails presented with live abalone elongated their proboscis to feed. Over three days, parasitic snails (85%) laid at least one egg mass, with larger snails laying more egg masses (containing more eggs) than smaller snails. Egg masses averaged 360 eggs per mass. More work is needed on the biology of this parasitic snail to determine its impacts on abalone, abalone populations, and the abalone fishery.

Key words: California, ectoparasite, *Evalea tenuisculpta*, *Haliotis rufescens*, *Haliotis kamtschatkana,* Odostomidae, Pyramidellidae

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There is growing evidence that parasitic gastropods in the family Pyramidellidae can have significant effects on mollusk fisheries (Wilson et al. 1988) and aquaculture (Cumming 1988), but little is known about the prevalence of pyramidellids on their hosts. These snails are small marine ectoparasites that feed on mollusc and polychaete hosts (McLean 2007). Economically important bivalves such as the American oyster (*Crassostrea virginica*) and the giant clam (*Tridacna gigas*) have experienced shell malformation, lower growth rates, increased mortality, and increased transmission of bacterial disease in response to pyramidellid infestation (Boglio and Lucas 1997, Wilson et al. 1988). Pyramidellids derive nutrients from their host by piercing the body wall with an acrembolic proboscis and sucking blood or tissue by means of a buccal pump (radula is lacking) (Fretter and Graham 1949). These small snails (commonly <5 mm in length) are cross-fertilizing, simultaneous hermaphrodites (Mclean 2007, Robertson 2012). This method of reproduction eliminates the necessity of finding a mate of the opposite sex for fertilization and can increase the reproductive potential of the parasites. While a few species of pyramidellids from California have been identified, literature on their biology and host associations is scarce.

The fine-sculptured odostome snail (*Evalea tenuisculpta*; Carpenter 1864) in the subfamily Odostomiinae has been observed in intertidal and shallow subtidal habitats from Alaska to Baja California (Abbott 1974). It has been described as a parasite on scallops, chitons, clams, mussels, and abalone (Harbo et al. 2012), but little is known about its distribution, behavior, or life history. The systematics of the fine sculptured odostome snail is poorly understood. Formerly known as *Odostomia tenuisculpita,* this snail has had more than 15 different synonyms (Abbott 1974). More study is needed on living pyramidellid snails to understand their relationship with host mollusks.

The red abalone (*Haliotis rufescen*s) forms the basis for an important recreational fishery in northern California. On average 260,000 red abalone are fished each year by 36,000 fishermen, who support the local coastal economy (Kalvass and Geibel 2006). Little work has been done examining parasites of red abalone, but some information exists on shell-boring organisms. Common shell parasites include boring bivalves, polydorid worms, and boring sponges (Cox 1962, Stefaniak et al. 2005). Shell-boring organisms create crevices and reduce shell strength of the host. These weaknesses facilitate predation and mortality of abalone, causing shell breakage during heavy wave action or human harvest (Shepherd 1973, Pedren-Caballero et. al. 2010). A single host abalone may support a diverse assemblage of parasites, and multiple parasite loads may work in concert to influence host growth, shell bio-erosion, and health and survival of the host.

We observed parasitic snails on red abalone taken by recreational fishermen in northern California during summer 2012. We identified the snails as the fine sculptured odostome (*E. tenuisculpta*) belonging to the family Pyramidellidae. Here we examine populations of the fine-sculptured odostome and their relationship with abalone at three sites in northern California. Using field surveys and laboratory observations, we examined: (1) prevalence of the snail on red abalone at three sites in Sonoma County; (2) infestation characteristics of the parasites; (3) feeding behavior; and (4) reproductive capacity of the snails.

Materials and Methods

Field sites.—Our study sites were located at Sea Ranch (38° 42' N, 123° 26' W), Jenner (38° 45' N, 123° 11' W), and Horseshoe Cove (38°18' N 123° 04' W) along the coast of Sonoma County, California. All sites are dominated by rocky reef ecosystems. These sites support diverse kelp forest ecosystems with abundant red abalone and sparse Northern abalone populations. One of the sites, Horseshoe Cove, is located within the Bodega State Marine Reserve where no fishing is permitted.

We sampled abalone in Sea Ranch for the presence of the fine sculptured odostome in October 2012. We performed four dive surveys for the snails to depths of 18 m. Based on a visual assessment, red and northern abalone were categorized as infested (with snails) or not infested (without snails). A subsample of eight red abalone was brought to the surface to confirm the identity of the snails and examine characteristics of the infestations. In Jenner, we examined nine red abalone caught by recreational fishermen in November 2012.

Abalone were taken from depths of 3–9 m. A total of 18 red abalone were collected from Horseshoe Cove in November 2012 and maintained in the Bodega Marine Lab (BML) until examination during March 2013. At all three sites we quantified the number of the snails on each abalone, the location of the parasites, and egg mass cover on the abalone shell. Parasitic snail surveys were not conducted on other mollusk species or on rocky substrates during our field surveys.

Laboratory.—Live parasitic snails (*n*=254) were transported to BML for measurements and to observe feeding and reproductive behaviors during fall, 2012. Length was determined by measuring the shell of the snail from the longest leading edge of the anterior (siphonal) canal to the apex of the shell spire. Parasitic snails (*n*=15) were separated from their host and starved for 10 days to facilitate examination of feeding preferences. The snails were then allowed to feed on live adult red abalone, live juveniles (>15 mm shell length), or freshly dissected red abalone tissue. Red abalone used in these trials were collected from Sea Ranch.

The reproductive characteristics of the snails were examined using 20 pairs of snails during December 2012. We placed two snails in 50 ml conical vials filled with sea water and floated the vials in an ambient temperature seawater bath (12–13 °C). The number of egg masses laid was recorded daily, and the water in the vials was changed regularly.

All statistical analyses were performed using JMP software (Version 10). A linear model was used to describe the relationship between the number of snails on the abalone and the snail egg mass coverage on the shell. Similarly, we used a linear model to describe the relationship between snail length and the number of egg masses laid and eggs per mass. We used one-way ANOVA to determine if there were differences in shell size of parasitic snails among sites, and Tukey's multiple comparisons test to determine if snail sizes differed between sites. A distribution of infection densities was used to identify aggregation characteristics.

Results

Parasite prevalence.—We sampled 73 adult red abalone (100–250 mm in length) at Sea Ranch, Jenner, and Horseshoe cove. We found 46 red abalone and 1 northern abalone during 4 swim surveys at Sea Ranch in October 2012 (Table 1). On swim survey number four (Table 1) we sampled a northern abalone, 95 mm in shell length, which was infested with 16 parasitic snails.

Table 1.—Number of red abalone, *Haliotis rufescens*, infested with the fine sculptured odostome snail (*Evalea tenuisculpta*). Sea Ranch, Sonoma County, California, November 2012.

Swim Survey	Depth (m)	Abalone with parasitic snail present	Percent
1	3-5	11/13	84
2	4-6	9/11	81
3	4-5	12/21	57
4	15-18	1/1	100
Total		33/46	72

Table 2.—Quantitative descriptions of the fine sculptured odostome snail (*Evalea tenuisculpta*) infecting red abalone (*Haliotis rufescens*). Sonoma County, California, October 2012 – March 2013.

	Location			
	Sea Ranch	Jenner	Horseshoe Cove	Summary
Infection Rate (*n*)	72% (46)	100% (9)	83% (18)	82% (73)
Snails per abalone	0 to 32	2 to 57	0 to 31	0 to 57
Avg per abalone (*n*)	13 (8)	18 (9)	6 (18)	12 (35)
Snail size (mm)	2.4-8.8	1.0-5.0	2.0-8.2	1.0-8.8
Avg snail size (*n*)	6 (70)	2.9 (74)	5.4 (110)	4.8 (254)

The prevalence of the snails infecting red abalone was high (>50%) at all three sites though infection rates varied at each site (Table 2). The number of snails per abalone ranged from 0 to 57 (Table 2). The majority of abalone (70%) were lightly infected (<10 parasitic snails) while 30% percent of abalone had >10 parasitic snails (Figure 1). The number of snails per abalone may be an underestimate as snails could have been lost during collection and transport.

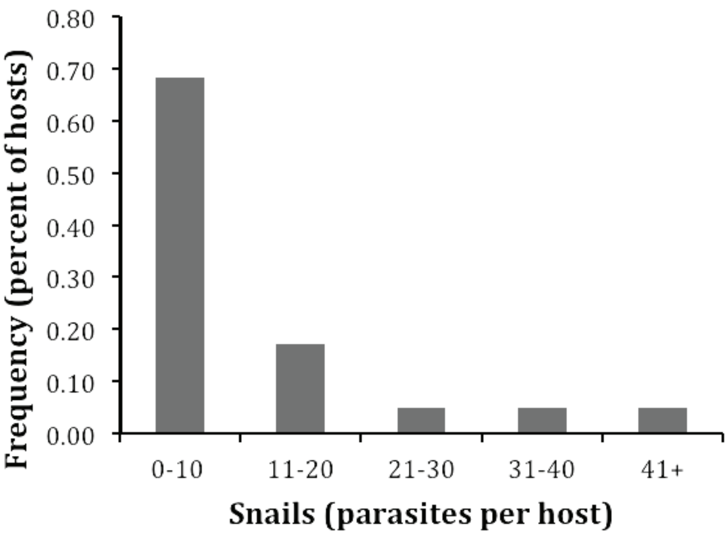

Figure 1.—Distribution of the fine sculptured odostome snail (*Evalea tenuisculpta*) on red abalone (*Haliotis rufescens*) October 2012 – March 2013 in Sonoma County, California.

Parasite size.— Snail sizes were significantly different between all sites, with the largest snails at Sea Ranch and smallest at Jenner (Figure 2). The largest snail found was 8.8 mm. Snail sizes at two sites were normally distributed, while at Jenner they had a bimodal distribution. Snail shell length was significantly different between sites ($F_{2, 254}$ =127.2, P<0.001). Model residuals were distributed normally.

Figure 2. —Shells of eight fine sculptured odostome snails (*Evalea tenuisculpta*) ranging in size from 1.6 to 8.8 mm. Top row: snails collected from red abalone at Sea Ranch, Sonoma County, California in October 2012 (LACM 178561). Bottom row: snails collected from red abalone at Jenner, Sonoma County, California on 11 November 2012 (LACM 178560). Photo credit P. Lafollette.

Infestation characteristics.—Parasitic snails were found on the abalone shell, but not the foot tissue. Snails were mostly located near the respiratory pores of the abalone, tucked within pits bored out by bivalves, or in eroded areas near the ventral margin of the shell. Groups of snails were often surrounded by or coated in a gelatinous matrix. This matrix contained snail eggs and acted as an attachment to the abalone shell. This gelatinous matrix and egg mass also captured extraneous particles of bio-debris making the parasitic snails hard to detect. We observed four abalone with parasitic snails that had completely merged the respiratory pores at Sea Ranch.

Behavior.—All the snails (n=5) presented with a live, intact adult abalone, elongated their proboscis when they came in contact with the abalone and prodded the abalone foot tissue, indicative of feeding (Figure 3). Of the snails (n=5) presented with a juvenile abalone, four of the five elongated their proboscis and prodded the foot tissue, again indicative of feeding. Snails fed near crevices in the ventral margin of the shell, through the reparatory pores, or from the base of the abalone foot. The elongated proboscis of the parasites often exceeded the length of the snail. Snails (n=5) presented with freshly dissected abalone tentacle tissue did not show any interest in feeding or extending their proboscis.

Figure 3.—Fine sculptured odostome snail (*Evalea tenuisculpta*; length 7mm) collected at Sea Ranch, Sonoma County, California in October 2012, probing adult abalone (182 mm) foot tissue, under laboratory conditions, with its proboscis.

Reproduction.—Egg masses were present on all abalone with >1 parasitic snail, at all sites, from October 2012–March 2013; egg masses were not seen on abalone that lacked the parasites. Masses were irregular in shape and appeared as a thin, opaque, gelatinous layer. One abalone (with over 50 snails) had 65% of its shell covered in eggs. Percent cover of parasitic snail egg masses on the host abalone shell increased with an increase in the number of fine sculptured odostome snails on the red abalone, (r^2= 0.91 n=33, P<0.001; Figure 4). A goodness of fit test suggested the residuals from this linear model were not distributed normally. Egg laying was common in the snail, with 85% of the snail pairs laying egg masses within 3 days of isolation. On average, each snail pair laid two egg masses per vial (i.e., one egg mass per snail), and each egg mass (n=24) contained an average of 360 eggs (SD=230; range 105–840). There was a positive correlation (r^2= 0.59, n=20, P<0.001) between snail size and number of egg masses laid (Figure 5). Furthermore, the larger snails produced egg masses with more than the average number of eggs per mass (r^2= 0.29, n=24, P<0.001; m=93, b=0).

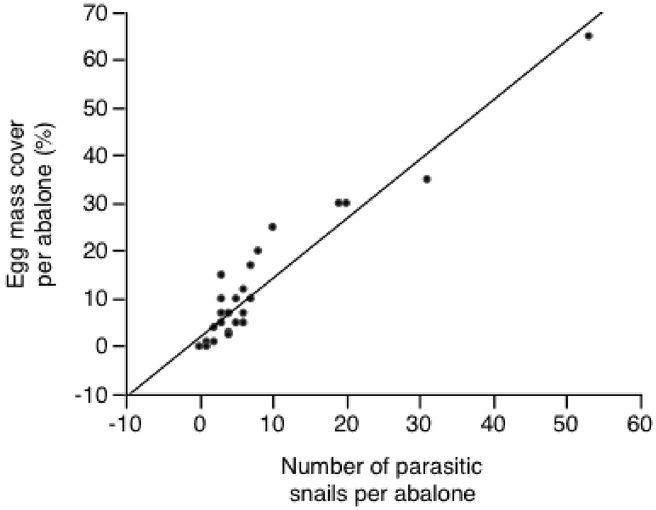

Figure 4.—Relationship between the number of fine sculptured odostome snails (*Evalea tenuisculpta*) and the percent cover of parasitic snail egg masses on the host red abalone shell. The linear relationship is percent cover of parasitic snail egg masses = 1.25 × number of parasitic snails per abalone. Sonoma County, California, December 2012.

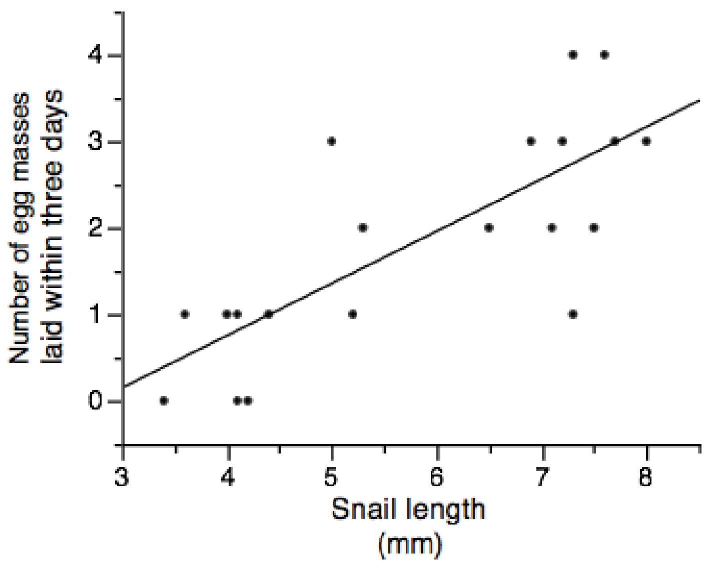

Figure 5.—Relationship between shell length of the fine sculptured odostome snail (*Evalea tenuisculpta*) and the number of egg masses laid. The linear relationship is egg mass number = (0.6 × shell length) + 1.7. Snails were collected from Sea Ranch, California and observed egg laying in the laboratory during December 2012.

Discussion

Snail abundance.—Red abalone are known to be parasitized by snails in the family Pyramidellidae; however, until now the prevalence of these snails has not been quantified. Our study demonstrated that the fine-sculptured odostome snail commonly (82%) infests red abalone at Sea Ranch, Jenner, and Horseshoe Cove, Sonoma County, California (Table 2). Furthermore, our research documents the first known account of the fine sculptured odostome snail infecting northern abalone, a species of concern. We suggest other sites in Sonoma County may also have high infection rates, and that more study is needed to better understand this parasite-host relationship.

Parasitic snails occurred in aggregations on their hosts. We found that many abalone were lightly infested with snails, while a few abalone were heavily infested. Aggregated distributions such as this are typical of macroparasites, and tend to be most harmful to heavily infested hosts (Crofton 1971). As many as 57 snails and as few as 0 snails were found on a single abalone (Table 2). Other investigators have documented up to 100 pyramidellid snails (*Boonea impressa*) on a single oyster (*Crassostrea virginica*) (White et al. 1985). It is likely that higher densities of parasites could be found on red abalone with more sampling. Heavy infestations of snails may have negative consequences for the health of red abalone. The impact of large aggregations on red abalone warrants further investigation.

It was remarkable that egg masses were found on most abalone with more than one parasitic snail and that reproduction did not taper off with high densities of snails (at the densities observed; Figure 4). This relationship was not influenced by the size of the abalone shell. Up to 65% of an abalone's shell was covered by snail egg masses. We have portrayed the relationship between snail number and egg mass coverage as linear, but with a larger sample size this relationship may not hold. The reproductive output of these snails may be enhanced in aquaculture facilities, where abalone are often kept at high densities in recirculating sea water systems.

Snail size.—The fine sculptured odostome snail ranged in size from 1 to 8.8 mm. Prior to our study, the maximum recorded length of this snail was 6 mm (Abbott 1974). We found the largest snails at Sea Ranch (Figure 2). Site differences may be a result of variation in host population, habitat, or lack of synchrony in parasite reproduction. White et. al (1985) reported that the size of preferred hosts changes with pyramidellid size. Additional investigations, such as underwater surveys or sampling of recreational catch, should be undertaken to better understand the relationship between host and snail characteristics.

Knowing that the fine sculptured odostome snail is a relatively large pyramidellid, it is important to understand how the size of a parasite might influence reproduction. In the laboratory, larger snails produced more egg masses (Figure 5). The larger snails not only produced more egg masses, but the masses they produced had more than the average (360) number of eggs. We suggest the fine sculptured odostome may have the highest reproductive output at sites with large snails and large aggregations. Although we know of no literature defining the larval production of the fine sculptured odostome, other species of pyramidellid populations can grow quickly, and may have enhanced reproduction. For example, Cumming (1988) reported that an initial population of six adults can give rise to an average of more than 1,700 individuals in just 4 months. In order to quantify fecundity in this parasite more research on its larval biology and development is needed.

Snail behavior.—Snails were distributed in groups on the shell and were observed feeding on abalone in the lab. Vacant pits and areas of shell damage appeared to act as a place of refuge for the fine sculptured odostome. Snails were found feeding along the respiratory pores and near the edge of the shell of the host. The parasitic snail fed on adult and juvenile abalone in the lab, indicating that abalone not only provide habitat, but also act as a food source. It is important to note, however, that snails did not feed on dissected tissue. We suggest that snails prefer live abalone and may feed exclusively on abalone hemolymph, rather than tissue (Figure 3). The impact of snail parasites on abalone reproduction, growth or health is unknown, although heavy infestation rates could have negative impacts.

In conclusion, we have determined that the fine sculptured odostome snail is commonly found on red abalone in Sonoma County, California. We have learned more about the abundance, behavior, and reproductive capacity of the snail. Many questions remain about the development, distribution, and transmissibility of this parasite, and additional work is needed on the ecology and biology of the parasitic snail to assess its impact on red abalone and other potential hosts.

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