Reproduction and Population Dynamics in the Calcareous Sponge, *Leucetta losangelensis*

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Abstract

Leucetta losangelensis is a common intertidal calcareous sponge inhabiting the northern Gulf of California whose basic biology is poorly known. To investigate this species' annual cycles in biomass and reproductive behavior, we censused sponges inhabiting a mid-intertidal boulder field near Puerto Peñasco, Sonora, Mexico. Each month for 1 year we collected sea temperature data, as well as the number and size of sponges growing on randomly selected boulders. From 5 sponges within each census, we preserved and lipid-stained a 1cm³ tissue sample, which we examined for the presence of gametes and larvae using light microscopy. We found oocytes and/or larvae in all months, indicating year-round reproduction. There was no correlation between water temperature and the number of reproducing sponges, and no correlation between sponge size and reproductive capacity. However, consistent with the hypothesis that this species is a "winter sponge" with seasonally – rather than reproductively – mediated annual cycles, the correlation between sea temperature and sponge size was significant and negative. Our results are the first to document the reproductive behavior of this species, and provide the first explanation for its cycles of abundance in the Gulf of California.

Introduction

The classification of sponges has endured a long and at times acrimonious debate between "lumpers" and "splitters." Lumpers suggest that single sponge species can display high phenotypic and behavioral plasticity, whereas differences in life history are used by some splitters as evidence of separate species. Indeed, investigators of sponge life history have successfully used reproductive cycles to distinguish morphologically similar species (Johnson, 1978). Here, we examine the reproductive biology of a calcareous sponge, *Leucetta losangelensis* (de Laubenfels), as it applies to population dynamics in Puerto Peñasco, Sonora, Mexico.

Leucetta losangelensis is a calcareous sponge in the subclass Calcinea and order Clathrinida. Shuster (1986; 1991) recorded annual population fluctuations of *L. losangelensis* on Station Beach in 1983–85. To understand why this sponge is so common in late winter and spring but scarce during the summer and into the fall, we conducted a year long survey to verify annual population fluctuations as well as to identify their cause. Sea temperature has been linked to sponge death (Gaino 1996; Fell, 1983) as well as the timing of reproduction (Mariani 2000; Witte 1994; Lepore 2000; Johnson 1978). Mariani's 2000 study shows a positive correlation between sponge biomass and abundance of larvae. However, a 1996 study in Italy by Gaino et al. credits high water temperatures during the summer for the population fluctuations of a similar species, *Clathrina cerebrum*. We posed two hypotheses regarding *L. losangelensis* population dynamics. (1) If population dynamics depend on reproductive cycles, we expected total sponge biomass to correlate with the appearance of gametes and larvae in tissue samples. (2) If population dynamics depend on temperature, we expected no relationship between biomass and reproductive activity, but rather that sponge biomass would correlate with thermal highs or lows.

Methods

To examine seasonal biomass fluctuations over a one-year period, we identified a 3m by 7m plot in the mid-intertidal zone on Station Beach in Puerto Peñasco, Sonora, Mexico. In this area, during periods of extreme low tide, we conducted monthly censuses for sponges growing on and under boulders. In each census, we recorded the number and size of each sponge growing on 15 randomly selected boulders. The sea surface temperature was also recorded at this time.

To examine seasonal reproductive changes we collected a 1cm3 tissue sample from at least one sponge each month. Each tissue sample was preserved immediately in 2.5% glutaraldehyde and seawater and stored. In the laboratory, the preserved tissue samples were decalcified in 0.12% EDTA in 5.5% hydrogen chloride for eight hours. Each sample was stained using Red Oil O for Lipids (Presnell, 1997). Primary investigation occurred using a dissecting microscope and then a light microscope at 1450x magnification. A digital camera connected to the microscope enabled pictures to be taken of oocytes and larvae. Since unfertilized oocytes and mature larvae were the easiest to see and identify (Figures 3A–D), we classified sponges possessing these structures as reproductive, and those lacking them as non-reproductive.

Statistical analysis included a one way analysis of variance (ANOVA) to show the within month and among month variation of biomass of all samples collected. Using linear regression, we examined the relationships between total sponge biomass and sea surface temperature. Using ANOVA, we compared the volumes of sponges containing and lacking reproductive cells. All variables were log-transformed before analysis.

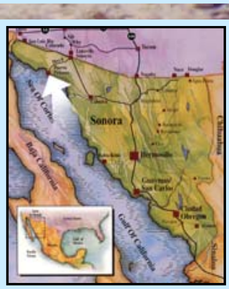


Figure 1: Map of the Northern Sea of Cortez and Puerto Penasco, Sonora, Mexico.

Figure 2: *Leucetta losangelensis* (the cream colored sponge) among other local sponges and coraline algae

Photo taken March 2004 by A. Shows

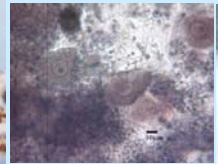


Figure 3A: Unfertilized oocytes in sponge mesohyl

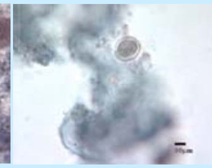


Figure 3B: Possible spermatocyst

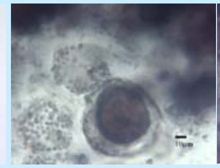


Figure 3C: Mature larva encased in maternal follicle

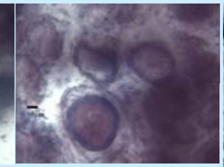


Figure 3D: Mature larva encased in maternal follicle

Results

Population dynamics

The population of *L. losangelensis* fluctuated in 2003–04 in a pattern similar to that shown in 1983–1985 (Shuster 1986; 1991). The greatest abundance of adult sponges was observed in April and May (57 and 39 individuals respectively) and the peak in individual mean sponge volume occurred between January and April (averaging 30,000 mm³ – 40,000 mm³). Mean sponge volume varied significantly throughout the year ($F_{[11,691]}$=5.51, P<0.001; Fig. 4).

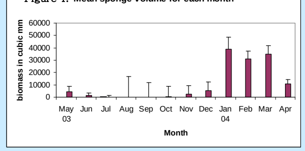
Sea temperatures were the highest (31.6C) in August and biomass was the lowest in August (274 mm³). Sea temperatures were lowest in January (14.5C) and biomass was highest in April (859,549 mm³) when the average temperature for that month was 20.4C (taken from the previous year's data) (CEDO, unpublished; Figure 5). The relationship between sea temperature and sponge volume was significant and negative ($F_{[1,11]}$=9.27, R2=.48, P<.012; Fig. 6).

Reproduction

Reproductive structures were categorized as either unfertilized oocytes (Figure 3A) or mature larvae (Figure 3C, 3D). The hollow spheres in Figures 3C and 3D may be young larvae or empty maternal follicles left behind after the expulsion of the mature larva (Fell, 1974). Figure 3B shows a structure that may be a spermatocyst, although further analysis is needed to confirm this.

We found oocytes and larvae throughout the year, thus reproduction was not confined to a specific season. Also, reproduction was not found to be simultaneous; it was possible to see larvae, oocytes or no reproductive cells in any month (Fig.7). Sponges not containing reproductive cells were investigated to see if this state correlated with the time of year or with the size of the sponge. We found no correlation with either of these two variables. Neither was there a correlation between sponges containing oocytes or larvae and their size. Reproductive cells were found in sponges as small as 64 mm³ and as large as 159,732 mm³. Contrary to our first hypothesis, there was no difference in the volume of reproductive and non-reproductive sponges ($F_{[1,39]}$=.080, P=0.778).

Figure 4. Mean sponge volume for each month



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Month	11	4.88251e10	4.43864e9	5.5098	<.0001
Error	680	5.47806e11	805597585		
C. Total	691	5.96631e11			

Figure 5. Monthly sponge (L. losangelensis) biomass compared to sea temperatures in Puerto Penasco, Mexico

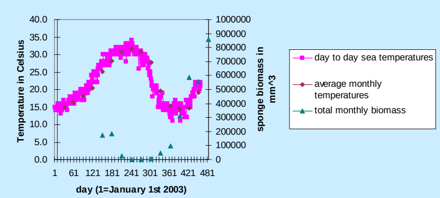
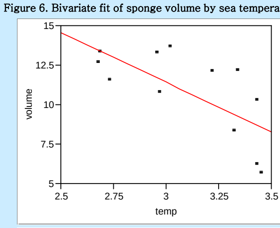


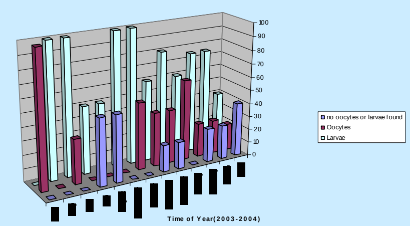
Figure 6. Bivariate fit of sponge volume by sea temperature



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	1	39.467920	39.4679	9.2734	0.0124
Error	10	42.560442	4.2560		
C. Total	11	82.028362			

Figure 7. Percent of samples that contain either ooctyes, larvae, or no reproductive cells at all



Discussion and Conclusions

Our study of the reproductive biology of *Leucetta losangelensis* demonstrates the utility of such analyses in explaining sponge population dynamics. We have shown that reproduction does not occur in an isolated period in *Leucetta losangelensis*, but rather occurs year-round in sponges of every size. We conclude that the annual fluctuation in biomass is not caused, as stated in our first hypothesis, by a reproductive cycle. Moreover, gametogenesis does not appear to be caused by fluctuations in sea temperatures. Instead, our second hypothesis is confirmed; biomass fluctuation is evidently caused by an unfavorable environment associated with high sea temperatures.

In addressing this hypothesis, we can only show the negative correlation between monthly sponge biomass and sea temperature. Our study has not shown that it is water temperature alone that causes sponges to die or degenerate. However, a similar study on another clathrinidan sponge, *Clathrina cerebrum*, states that littoral calcareous sponges generally tend to be common in winter and rare in summer, categorizing these as "winter sponges" (Gaino, 1996). It seems safe to categorize *L. losangelensis*, also, as a "winter sponge." This study also explains their survival through summer by the presence of minute forms of the sponge; we found few large forms of *L. losangelensis* and many small undeveloped (very tiny) forms in June and July. Gaino et al. state that these minute forms have a "successful strategy for withstanding the summer heat crisis" but fail to describe this strategy that is apparently absent in adult sponges.

In summary, our study has successfully eliminated the possibility that reproduction is the cause of annual population fluctuations in *L. losangelensis*. It has also allowed this species to be categorized as a "winter sponge" because it is rare in the summer and common during the winter months. A more detailed qualification of the term "winter sponge" which included the mechanisms for survival during hot summer months would strengthen this grouping.

Future Research

Studies of *Leucetta* population dynamics in other locations could determine whether this sponge consistently degrades in warmer temperatures. Previous work suggests that *Leucetta* is the most common intertidal calcareous sponge in the Gulf (Brusca, 1980), but recent observations suggest that this species is now less abundant, even during cooler months. Recent rises in sea surface temperature, possibly due to climate change, could be responsible for changes in the distribution and life history of species like as *Leucetta losangelensis* that normally inhabit coastlines with fluctuating temperatures. Further studies could also determine whether populations found on the Pacific coast, where temperatures are cooler and less variable, still behave as "winter sponges."

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