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Journal of Experimental Marine Biology and Ecology 348 (2007) 121–132

Journal of EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY

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# Spatial patchiness in the sea cucumber *Pachythyone rubra* in the California Channel Islands

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Received 14 December 2006; received in revised form 17 April 2007; accepted 20 April 2007

**Abstract**

*Pachythyone rubra* is a small, direct-developing sea cucumber, with a limited geographic range in central and southern California. Surveys from 1996 to 1998 in the Santa Barbara Channel revealed spatial patchiness, with high densities immediately adjacent to low or zero densities in similar habitat. To investigate causes of this patchiness, I transplanted and followed survival and recruitment of *P. rubra* in sites that had high and low densities of *P. rubra*. This transplant experiment revealed that survival and recruitment of *P. rubra* vary spatially, along a gradient in environmental conditions, and that these differences may be caused by predation, sedimentation, and food supply. Laboratory predation experiments identified two predators: the lobster *Panulirus interruptus* and the sea star *Pycnopodia helianthoides*. Field observations and trials with freeze-dried *P. rubra* pellets suggested that fish do not eat *P. rubra*. Population growth of *P. rubra* was highest in the western region of the Channel Islands that receives cool, nutrient and phytoplankton-rich water suitable for *P. rubra* feeding and reproduction. Patchiness of *P. rubra* in this area may result from spatially variable, but intense, predation by *P. helianthoides*. The eastern region of the Channel Islands has warmer water with less nutrients and phytoplankton, which may be less suitable for *P. rubra* feeding and reproduction but lacks *P. helianthoides*, resulting in lower population growth but potentially more stable patches over space and time.


*Keywords:* Marine invertebrate; *Pachythyone rubra*; Predation; Sea cucumber; Spatial variability; California Channel Islands

## 1. Introduction

Spatial variability is common in marine populations and has been found to be highest in species with limited or no larval dispersal (Bingham, 1992; Reed et al., 2000; Johnson et al., 2001). For example, Bingham (1992) found patchy distributions in species with short-lived larvae and more even distributions in species with long-lived larvae in mangrove epifaunal communities. Reed et al. (2000) found, for a group of 27 species of marine plants and animals at 16 kelp forest sites monitored from 1986 to 1994, that spatial variability in abundance was greater for species with limited larval dispersal. Johnson et al. (2001) compared spatial variability in molluscs on the Isle of Man and found relatively more variability in abundance within shores for species having direct development (no larval dispersal) compared with species having larval dispersal. High spatial variability was also attributed to limited dispersal in a bryozoan (Keough and Chernoff, 1987). These observational

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doi:10.1016/j.jembe.2007.04.004

studies do not directly test the mechanism or mechanisms that cause increased spatial or temporal variability in abundance or density in species with limited dispersal. Here, I document spatial variability in abundance in a marine species with limited dispersal and explore the processes that may be responsible. I conducted surveys, predation experiments and transplant experiments to document the distribution and abundance of *Pachythyone rubra* and examine the role of abiotic and biotic factors in affecting its distribution and abundance.

### 1.1. Background on the focal species

The aggregating red sea cucumber, *P. rubra*, is a small (maximum length 2.5 cm) filter-feeder with a limited geographic range in central and southern California in shallow waters from 0 to 30 m (Morris et al., 1980). Its reproduction is hermaphroditic with some evidence of self fertilization (J. Pearse, University of California Santa Cruz, personal communication; Chaffee, 1987). Young are brooded in the coelom and released through the anus as juveniles, approximately one to five mm long (Chaffee, 1982). Little is known about seasonality of reproduction in the field. Adults and juveniles are largely sedentary and must be attached to the substrate to feed, although they can crawl short distances. Substrate preference has not been investigated. Within its limited geographic range *P. rubra* populations are patchy, and dense patches occur sporadically at the Channel Islands where *P. rubra* can cover up to 50% of the substrate in kelp forest and urchin barren habitats (S. Holbrook, University of California Santa Barbara, personal communication). High density ($>1000$ m$^{-2}$) patches have been observed in the same locations for more than 10 years at Santa Cruz Island (S. Holbrook, University of California Santa Barbara, personal communication), for over 20 years at San Nicolas Island (J. Estes, University of California, Santa Cruz, personal communication), and have fluctuated greatly over time at both islands. High density patches have not been observed on the nearby mainland nor on any of the eastern Channel Islands (Anacapa Island, Santa Barbara Island, San Clemente Island, Catalina Island) (J. Engle and S. Anderson, University of California, Santa Barbara, personal communication). Repeated surveys over several seasons at Santa Cruz Island indicated that densities generally increase during the summer and decrease during the winter (Eckert, 1999). The restricted geographic range and locally large populations of *P. rubra* during the 1990s are intriguing and are the focus of this study.

### 1.2. Study area

This study was conducted in the Santa Barbara Channel, which extends from Point Conception to Point Mugu and is bounded by offshore islands (Fig. 1). Spatially and temporally variable oceanographic conditions occur in this region (Hendershott and Winant, 1996; Harms and Winant, 1998; Hickey et al., 2003; Blanchette et al., 2006). From May through October, the western portion of the channel is much colder than the eastern portion, with the greatest temperature difference (6°C) occurring in August (Harms and Winant, 1998). During this period, cold, upwelled water from Point Conception flows equatorward into the western portion of the channel and bifurcates near Santa Rosa Island, either flowing offshore or flowing inshore and mixing with warm water from the Southern California Bight. Phytoplankton productivity is higher in the upwelled water (Barber and Smith, 1981) and high chlorophyll concentrations can be viewed on SeaWIFS satellite images during upwelling conditions (Nezlin and Li, 2003). The boundary between these distinct oceanographic conditions occurs near Santa Cruz Island and is associated with relatively abrupt changes in the dominant species that inhabit the islands (Hewatt, 1946; Neushul, 1967; Seapy and Littler, 1980; Engle, 1994; Blanchette et al., 2006). As a result, the western end of Santa Cruz Island has a different composition of species than the eastern end (Hewatt, 1946).

## 2. Materials and methods

### 2.1. Surveys

*Pachythyone rubra* density was surveyed to assess broad-scale patterns of distribution and abundance at 46 sites throughout the California Channel Islands from June 1996 to August 1998 (Fig. 1). The island archipelago extends 258 km from San Miguel in the north to San Clemente in the south, and both edges of this range were sampled. Santa Cruz Island was sampled more intensively than other areas, and the minimum distance between survey sites was approximately 0.5 km. Sampling was opportunistic and occurred in conjunction with ongoing research projects throughout the region (e.g. Channel Islands Research Program). Surveys were conducted at sites where others (Channel Islands Research Program; Channel Islands National Park Kelp Forest Monitoring Program) had noted *P. rubra* populations, particularly dense ones. Therefore, surveyed areas were more likely to have *P. rubra* populations than unsurveyed areas. At each site, a 30–