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LOCALIZED MASS MORTALITY OF RED SEA URCHIN, *STRONGYLOCENTROTUS FRANCISCANUS*, NEAR SANTA CRUZ, CALIFORNIA

Johnson (1971) reported on the occurrence of a mass mortality of red sea urchin, *Strongylocentrotus franciscanus* (Stimpson 1857) off Point Loma, San Diego, in the summer of 1970, and she detailed the symptoms of the diseased sea urchins. Large areas of the test, particularly of the interambulacra, were denuded of spines and epidermis. These denuded areas were chalky white with green blotches and often were bordered by a ring of swollen tissue. The test plates of the denuded area were layered and a middle "red-friable" layer with disorganized cellular structure replaced the normal plate tissue and ossicle. In some cases, lesions broke through the denuded tests and these apparently led to the animals' death. The internal organs appeared to be normal. Johnson (1971) was unable to determine the cause of these symptoms, but she suggested that a microorganism, perhaps a fungus, might be responsible.

The area affected in the 1970 mass mortality off Point Loma was limited to a few hectares (Johnson 1971). It was first noted in May 1970, when the center of the area was littered with dying sea urchins while the perimeter had fewer diseased animals with only small patches of denuded tests. The affected area did not spread, and by the middle of summer, many of the surviving urchins were regenerating spines. Diseased animals with partially denuded tests were difficult to find in November 1970.

We report here two other localized mass mortalities of *S. franciscanus* in central California, which seem to be similar to the one documented by Johnson (1971). One was found in 3–5 m of water off the southeast side of Año Nuevo Island (lat. 37°06′25″N, long. 122°19′30″W). It was first observed on 18 July 1976, and revisited on 31 July 1976. Diseased animals with drooping spines and partially denuded tests were found scattered among healthy-appearing individuals. They did not seem to be clumped or segregated, although most diseased animals were in the open while healthy-appearing animals tended to be under ledges or in crevices. Diseased animals did not hold onto the rocks as normal animals usually do, and they were picked up easily by divers. Empty tests of recently dead animals littered portions of the bottom. Red sea urchins were the only animals noted to be affected at the Año Nuevo Island site. Other areas of similar depth to the south and northwest of Año Nuevo Island supported numerous healthy-appearing red sea urchins and none with denuded tests.

The diseased animals collected from Año Nuevo Island were very similar to those described by Johnson (1971) (Figure 1). Portions of the test were denuded of spines while the remainder of the test was covered with normal-appearing spines. The affected test plates were layered with a thin greenish surface layer, a red-friable middle layer

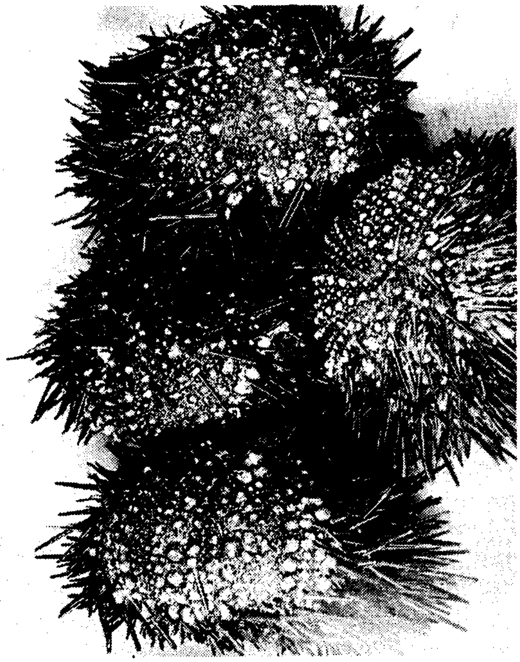

FIGURE 1.—Four diseased *Strongylocentrotus franciscanus* collected on 31 July 1976 from 3–5 m depth off Año Nuevo Island, Calif. Each animal is about 10 cm in diameter. Note the large portion of test denuded of spines in each animal.

and a nearly normal white inner layer (the "callus" layer, see Pearse and Pearse (1975) for description of the layers of the test plates and methods for examining them). Portions of the inner layer of the affected area were discolored reddish brown, however, often with a rather blotchy appearance. Clorox[1] cleaned and thin-ground preparations of the plates showed that middle layer of the diseased plates had lost much of its trabecular structure and there were large spaces between the middle layer and the inner layer. In the most diseased plates, the inner layer could be separated easily from the middle layer of the plates. The ambulacral system with the water vascular canals, ampullae, and radial nerve were all discolored reddish brown under the diseased portions of the test and much of these tissues were speckled with dark reddish-brown flakes, probably clumped coelomocytes. The internal organs in other portions of the diseased animals appeared normal.

The symptoms noted in the diseased animals at Año Nuevo Island in 1976 seemed identical to those described for diseased animals found at Point Loma in 1970 by Johnson (1971). Such similarity suggests that the same disease organism may be involved in these mass mortalities. Alternatively, the symptoms could reflect a general response to localized infections or disruptions of the test from a variety of physical, chemical, or biological agents. As Johnson (1971) cautioned, careful microbiological work needs to be done before the causative agent(s) of these mass mortalities can be identified.

The Año Nuevo Island site of the mass mortality was revisited on 24 September 1976. Sea urchins were scarce compared with the earlier visit and most were nestled in crevices. Only one animal was found with symptoms of the disease; it had a narrow strip down one interambulacrum which was denuded of spines. However, when this animal was examined in the laboratory, it was found that a large portion of the diseased interambulacrum and adjacent ambulacrum was covered with short regenerating spines, and the ambulacrum was concave and grossly deformed. Six other normal-appearing animals were brought into the laboratory and two of these had small areas on the test with regenerating spines. From these observations, it appeared that the mass mortality had ceased and some of the animals survived and regenerated their lost spines.

The second mass mortality of *S. franciscanus* we found in 1976 occurred at 4–6 m depth off the east side of Point Santa Cruz (lat. 36°57′05″N, long. 122°01′30″W); this area was described by Mattison et al. (1977). Animals looking "sick" and losing spines were seen in the area in early June (A. L. Shanks, J. D. Trent pers. commun.). We did quantitative studies at fixed stations off Point Santa Cruz on 28–30 June 1976 and again on 10–11 September 1976. Although we found no animals with denuded tests at our study stations, there was a notable decrease in the number of animals present compared with the counts made in the previous two summers (Figure 2). The number of animals at the seaward edge of the kelp forest maintained densities of about 55–65/10 m^2 during the summers of 1974 and 1975. Fifty and one hundred meters seaward of the kelp forest, lower densities of 20–30 animals/10 m^2 occurred on the barren-appearing rocks. In the summer of 1976, we found only about 20 animals/10 m^2 at the edge of the kelp forest and about 1–2/10 m^2 50 and 100 m

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

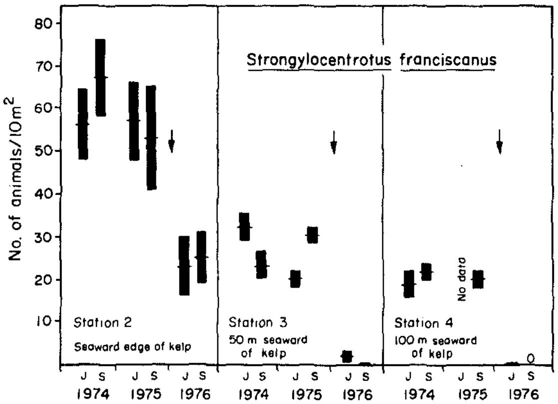

FIGURE 2.—Densities of *Strongylocentrotus franciscanus* at three fixed stations off Point Santa Cruz as estimated in June and September 1974, 1975, and 1976. Each station encompassed an area of 2,500 m^2 and the density estimates are based on counts from 12 randomly selected 10 m^2 quadrats. Station 1 was located 50 m inshore from Station 2 within the kelp forest and always contained very low densities of sea urchins, <1/10 m^2. Figure shows mean number of animals per 10 m^2 and the standard error of the mean. The arrows indicate the period of the mass mortality.

offshore. This represents a decrease of about 60% of the dense population of animals at the kelp forest edge and about 95% of the animals farther offshore. The area of each study station was about 2,500 m^2. In absolute terms, the decrease in number of animals within the study station at the edge of the kelp forest was about 9,000 animals, while in each of the two study stations 50 and 100 m farther offshore, about 5,500 animals were lost.

About 10% of the animals remaining in our Point Santa Cruz study site in June 1976 had large conspicuous portions of the test covered with regenerating spines only 1–5 mm long, contrasting noticeably with the surrounding normal-appearing areas. Since we did not detect any abnormalities in January 1976, the mass mortality probably followed its full course in less than 6 mo, as did the one described by Johnson (1971), and probably the one we observed at Año Nuevo Island.

During August–October 1976 we (M. B. Y. and C. R. A.) surveyed the 35-km coastline between Point Santa Cruz and Año Nuevo Island at 2-km intervals. Most of the kelp forests along this coastline have dense populations of *S. franciscanus* along their seaward edge, similar to conditions found at Point Santa Cruz before 1976. No evidence of mass mortality of these populations of sea urchins was found, either as large numbers of dying animals or unusually low numbers of animals. However, diseased animals with partially denuded tests were found occasionally all along the coastline with estimated incidences of 1 in 1,000 animals. These observations suggest that potential outbreaks of localized mass mortalities could occur in many places under suitable conditions.

The mass mortality of *S. fransicanus* at Point Loma in 1970 and those at Año Nuevo Island and Point Santa Cruz in 1976 were all relatively small and localized in both space and time. Moreover, all the animals in the populations were not killed. Rather, within less than 6 mo low numbers of normal and healthy-appearing animals were present and there was little trace of the mass mortalities—no piles of empty tests remained. Small localized mass mortalities might occur in other areas and not be noticed or reported. If they do, such mass mortalities could be important in regulating the distributions and densities of sea urchin populations. Moreover, since a major portion of the recruitment of juveniles of *S. franciscanus* occurs under adult animals (Tegner and Dayton 1977), near complete mass mortalities, such as that in our study stations 50 and 100 m seaward of the kelp forest off Point Santa Cruz, could have long lasting effects. Such a source of mortality could have practical importance both as means of minimizing overgrazing of kelp by sea urchins (North and Pearse 1971) and as a threat to the developing sea urchin fishery in California (Kato 1972).

Acknowledgments

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FIRST RECORD OF A SECOND MATING AND SPAWNING OF THE SPOT PRAWN, *PANDALUS PLATYCEROS*, IN CAPTIVITY

The spot prawn, *Pandalus platyceros* Brandt, is the largest species of the family Pandalidae. It supports a minor fishery within its range of San Diego to the Bering Strait, Korea, and Japan in depths to 532 m (Butler 1964). The prawn is being studied at the National Marine Fisheries Service (NMFS) Aquaculture Research Station, Manchester, Wash., as a possible companion crop to Pacific salmon reared in floating net pens (Mahnken 1975; Prentice 1975). One phase of this work is to investigate the reproductive potential of the prawn in captivity.

The prawn is a protandric hermaphrodite, i.e., an individual matures first as a male (at age 1.5 yr), breeds one or more times as a male, passes through a transitional phase (at age 2.5 yr), and becomes a functional female (at age 3.5 yr) (Butler 1964). In studies of natural populations in southern British Columbia, Butler (1964) found that few if any females breed more than once and suggested that the females die soon after spawning.

At the Aquaculture Research Station, prawn culture and breeding experiments have been carried out since 1973. The matings reported in this study were made with laboratory-cultured males and captured, wild females. The females were captured in ovigerous condition in 1974 from Hood Canal, Wash., and their eggs hatched in the laboratory during February and March 1975. Therefore, we know these females have spawned at least once, and since their prior history is unknown, there is the possibility that some or all may have spawned more than once.

The spawned females (103) were held from March to August at the Aquaculture Research Station in floating net pens or in benthic cages 10 m beneath floating net pens containing salmon. The postspawning survival was 100% through August 1975 for both groups. All prawns in the net pens were maintained on a diet of frozen clam meat, *Panope generosa*, and salmon mortalities. The benthic cage group did not receive any supplemental food.

In August varying densities of spawned females and cultured males (Table 1) were placed either in three net pens, eight laboratory tanks, or in a benthic cage. The net pens were constructed of 18-mm mesh (stretch measure) knotless nylon with 6.8 m² of substrate per pen available to the prawns. The top of each pen was covered with black plastic sheeting. Each laboratory tank had 0.24 m² of available substrate. All water entering the tanks was sand filtered and not recycled. The single benthic cage was constructed of vinyl-coated wire mesh (9.0-mm stretched measure) and had 2.6 m² of substrate available to the prawns. All test groups were fed the clam–salmon diet with the exception of those in the benthic cage which received no supplemental food. A continuous low-level mortality was observed among the females from August to early October 1975 which reduced their survival to 39.8%.

Survival of the female prawns was not dependent upon stocking density; however, survival was significantly greater in the benthic cage and laboratory tanks than in the net pens (Table 1).

TABLE 1.—Survival (percent in parentheses) and second spawning of female *Pandalus platyceros* in three seawater systems.

Container type	No. of prawns per container		Density of prawns[1]	Survival of previously spawned females	Survivors spawning a second time
	Female	Male			
Benthic cage (9 m deep)	5	5	3.8	4 (80.0)	3 (75.0)
Net pen 1	29	56	12.5	12 (44.8)	10 (84.6)
Net pen 2	24	43	9.9	6 (25.0)	4 (66.7)
Net pen 3	29	89	17.4	6 (20.7)	5 (83.3)
Laboratory tanks[2]	2	2	16.7	12 (75.0)	12 (100.0)

[1]Prawns per square meter of available substrate.
[2]A total of eight laboratory tanks.