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Black Abalone at San Nicolas Island: Patterns of Abundance and Movement

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Black abalone (Haliotis cracherodii Leach, 1817) are locally abundant in rocky intertidal habitats at San Nicolas Island. The dense populations of abalone are probably maintained by at least two factors, the absence of significant predation and the abundance of food. Two potentially important predators, sea otters and aboriginal man, were exterminated from San Nicolas Island by fur hunters and traders during the 19th century (Ogden 1941, Meighan and Eberhart 1953). Security requirements of the Pacific Missile Test Center restrict commercial and sport harvests of black abalone by contemporary man. However, limited sport harvests are made by U.S. Navy personnel on the Island, and illegal and excessive harvests by persons unknown probably occur on occasion. Black abalone feed by entrapping detached fragments of macroalgae (Bergen 1971); the vast kelp forests of the nearshore waters at San Nicolas Island produce large quantities of algal material, much of which is cast ashore by wind-driven waves and currents.

Here I report on the progress of field studies of black abalone at San Nicolas Island. Three issues are under examination: (1) In areas of locally high abalone abundance, how do abalone densities vary over time and microhabitat type? (2) In the same areas, how do movement patterns vary over time and microhabitat type? (3) How do black abalone populations interact with populations of other species to provide biological structure in rocky intertidal communities?

These are of interest to the Fish and Wildlife Service for two reasons, both related to the California population of the sea otter (Enhydra lutris nereis {Merriam}). An understanding of the effects of sea otters on nearshore marine communities in mainland central California will be improved by studies of similar communities in areas beyond the effects of foraging sea otters. Secondly, it has been suggested that San Nicolas Island is an appropriate site for establishment, through translocation, of a second California colony of sea otters. Such action is contemplated as a means of improving the threatened status of California's sea otters, as defined by the Endangered Species Act of 1973 (Benz and Kobetich 1981). Should sea otters be translocated to San Nicolas Island (the decision to do so has not been made), measurement of the biological impact of sea otters requires extensive "pre-otter" documentation of abundance, variability, and interaction in populations of interest, such as black abalone, (see also Harrold, this symposium).

Field work to date has focused primarily on documentation of abundance patterns of black abalone. Preliminary data have been gathered on movement rates of individual abalone. No field work has been done to date on impacts of abalone on other species.

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Patterns of Abundance

Forty-two permanent transect lines have been established in nine rocky intertidal study areas at San Nicolas Island (Figure 1 and Table 1). Transects range in length from 7 m to 40 m; most are 30 m in length. All transect lines pass through dense

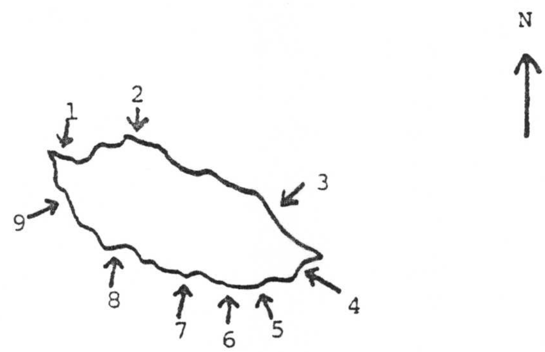

Figure 1. Location of black abalone sampling stations, San Nicolas Island (see also Table 1.).

patches of black abalone. Lines are defined by small stainless steel eyebolts placed in holes drilled in rock and held by marine epoxy compound ("Splash zone", Koppers Co., Inc., Los Angeles). Transects are sampled by attaching a temporary line to the eyebolts. Quadrats of 1 m^2 area are placed in contiguous fashion along each side of the line. All abalone within each quadrat are counted. Thus, a 30 m transect provides a sample of sixty quadrat counts of abalone. Because the substratum surface is often irregular, individual quadrat counts frequently represent areas greater than 1 m^2. However, all quadrats are permanently fixed in space. Thus, substratum irregularity does not bias conclusions regarding changes in abalone densities over time. At this writing all transects have been sampled once. Mean densities per transect range from 1 to 33 abalone per quadrat; the maximum recorded single-quadrat density is 135 abalone. Mean density of all transects combined is 12 abalone per quadrat. Data are summarized in Table 1. I plan to sample transects once per year in order to measure the relative effects of predation on black abalone

Table 1. Summary of data on black abalone densities collected at San Nicolas Island during 1981. Additional details in text.

Station Number	Unofficial Name	Number of transects	Number of Quadrats (1 m^2)	Mean density per quadrat	Maximum Single-quadrat density	Sampling dates
1	Bomber Cove	6	360	8	78	14,15 Feb 81
2	Thousand Springs	6	274	8	62	9,10 May 81
3	Northeast Wall	6	294	6*	39*	10,12 Nov 81
4	East End Reef	2	54	8	45	5 Jun 81
5	Swordfish Reef	3	70	15	91	7 May,5 Jun 81
6	East Dutch Harbor	4	252	7	41	7,8 May 81
7	Fug Point	5	259	27*	123*	17 Mar,12 Nov 81
8	Mussel Shoals	5	280	18*	135*	11 Nov 81*
9	808 Beach	5	194	12	84	5,6 Jun 81
-	Totals	42	2037	12	135*	

* Heavy surf prevented sampling of all quadrats.

contemporary man and, should they be moved to the island, sea otters. All sampled quadrats will be classified according to microhabitat type (e.g., vertical vs. horizontal substratum, exposed vs. crevice or cave habitat, etc.). With use of the appropriate analytical methods, I can determine vulnerability of black abalone to predation as a function of microhabitat type.

Patterns of Movement

Fifty-nine black abalone were permanently tagged at station 1 (see Figure 1 and Table 1) in February 1980. All tagged animals were within a single 1 m^2 quadrat on open horizontal rock substratum. The quadrat also contains a stainless steel bolt embedded in the substratum. The bolt is used as a reference point for measurement of movements. Tags are numbered yellow plastic discs 19 mm in diameter (Floy Tag Company, Seattle). The discs are attached to the backs of shells with marine epoxy compound. The principal purpose of this first tagging effort was to evaluate the tagging technique. Searches of station 1 for the tagged abalone were made in March 1980 and February, March, and June 1981. The position of each relocated, tagged abalone was determined (i.e., distance and bearing from reference bolt) for each search effort. These preliminary observations are summarized in Table 2. The tagging method appears to be satisfactory; about 40% of the tagged animals were relocated 16 months after tags were attached. Tagged abalone are capable of substantial movement. The largest net movement over 16 months is 16 m. Movements as great as 13 m have been recorded for 1-month periods. Some individuals alternate periods of extensive movement with periods of virtually no movement. Seven of the 59 tagged abalone have made no

Table 2. Summary of preliminary data on movement of black abalone at station 1, San Nicolas Island (see Figure 1).

	March 1980	Feb 1981	March 1981	June 1981
Number of abalone relocated (59 abalone tagged, Feb. 1980)	53	27	17	23
Distribution of tagged abalone by total net movement from reference bolt since tagging (by percentage of total):				
less than 1 m:	51%	30%	41%	30%
1-5 m:	34%	48%	53%	39%
5-10 m:	11%	11%	6%	13%
greater than 10 m:	4%	11%	0%	18%

significant net movement over 16 months.

Discussion

The principal achievement to date has been the establishment of permanent study areas and the development of techniques for censusing locally dense abalone populations and for tagging and observing movements of individual abalone. These necessary and time-consuming steps completed, efforts can now be devoted to pursuit of the long-term goals of evaluating effects of time and microhabitat type on density and behavior.

The emphasis on microhabitat effects results from the known foraging habits of sea otters. Following the return of sea otters to kelp forests near the Monterey Penninsula, dense groups of subtidal red abalone (*Haliotis rufescens*) could be found only in cryptic habitats such as crevices, where sea otters cannot forage effectively (Lowry and Pearse 1973). If sea otters become established at San Nicolas Island, it is likely that foraging on intertidal abalone will follow a similar pattern. One interpretation of the preliminary data on abalone movement is that individual abalone may constantly seek and possibly compete for microhabitat sites which provide refuge from sea otters, which were abundant historically, and provide an adequate supply of food. Many of the abalone tagged at station 1 have moved to crevices or other cryptic sites. Expanded study of tagged individuals will permit evaluation of various models of movement behavior.

There is evidence to suggest that abalone densities have declined sharply at station 1 in recent years. Photographs of dense patches of black abalone were taken at station 1 in 1975 by the California Department of Fish and Game (published in Woolfenden 1979). I photographed the same areas in June 1981. Counts of abalones in photographs indicate a five-fold decline in abalone numbers over the six-year interval. Harvesting by man is the likely cause for the decline but sample size is insufficient for any conclusion. Detailed censusing of all nine permanent stations in future years will reveal whether or not such declines are occurring, and if so are episodic or continuous, localized or island-wide. Such data will also permit clarification of relative rates of predation by man and sea otters if and when sea otters are moved to the island.

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