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Chapter 34
Brood-stock transplants as an approach to abalone stock enhancement

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ABSTRACT: When local abalone populations are eliminated by disturbance or over-exploitation, natural recovery will depend on recolonization by dispersing larvae. Recolonization by larvae depends upon the distance from brood stock, current patterns, and the length of the planktonic phase. Green abalone, *Haliotis fulgens*, populations on the Palos Verdes Peninsula in Southern California showed little evidence of recovery despite adequate food and a fishing closure. The short free-swimming period of the larvae and a drift-tube experiment suggested that dispersal between isolated populations is rare and stressed the importance of local brood stock. To provide local sources of larvae, 4453 sexually-mature green abalone were transplanted between November 1981 and September 1982 to two locations at Palos Verdes, where the drift-tube data indicated that the probability of larval retention on the peninsula was high. Abalone were tagged, measured and graded visually for gonadal condition before planting. Predator control efforts were associated with reductions in the short-term mortality associated with planting: total mortality observed by September 1983 was less than 10%. The abalone grew and gonadal changes suggested reproduction. Surveys at Palos Verdes in 1985 found a large number of animals within size categories expected from the brood-stock transplants; there was no comparable pulse of recruitment at sites distant from Palos Verdes. As in recent results from Australia, the recruitment apparently resulting from these transplants is local, but the scale observed ranges from hundreds of metres to a few kilometres. The results indicate that fishing closures will be an effective means of rehabilitating stocks only when there is an adequate source of larvae. Brood-stock transplants are expensive, but until the survival rates of cultured larval or seed releases improve, this may be the only approach for the recovery of badly depleted and isolated stocks.

RESUMEN: Cuando las poblaciones locales de abulón son elinimadas por disturbios o por sobre-explotación, la recuperación natural dependerá de la recolonización por larvas provenientes de otros lados. Esta recolonización depende de la distancia a donde se originaron las larvas, la duración de la fase planctónica y los patrones de corrientes. Las poblaciones de abulón verde *Haliotis fulgens*, en la Península de Palos Verdes, al sur de California, mostraron pocas evidencias de recuperación, a pesar de tener alimento adecuado y haberse vedado la pesquería. El período natatorio tan corto de la larva y un experimento con tubos a la deriva, sugieren que la dispersión entre poblaciones aisladas es rara, y resalta la importancia que las poblaciones locales tienen como stock reproductor. Para proporcionar fuentes locales de larvas se transplantaron 4453 abulones maduros entre Noviembre de 1981 y Septiembre de 1982 a dos localidades en la Península de Palos Verdes, donde los datos de deriva indicaron que la probabilidad de retención de larvas era alta. Antes del transplante éstos se marcaron, midieron, y se les valoró visualmente su condición gonadal. El control de depredadores estuvo asociado con una disminución a corto plazo de la mortalidad asociada al transplante; la mortalidad observada hasta Septiembre de 1983 fué menor al 10%. Los abulones crecieron y los cambios gonádicos sugieren que hubo reproducción. Evaluaciones realizadas en Palos Verdes en 1985 mostraron que un gran número de animales encontrados estuvieron dentro de los intervalos de tallas esperados del stock de reproductores provenientes del transplante; además, no hubo pulsos de reclutamiento comparables en sitios lejanos a Palos Verdes. Al igual que en resultados recientes de Australia, el reclutamiento aparentemente producido por los transplantes es

local; sin embargo, la escala aquí observada va de los cientos de metros a algunos kilómetros. Los resultados indican que el cierre de la pesquería sería una medida efectiva en la rehabilitación de poblaciones sólo cuando exista una fuente adecuada de larvas. Los transplantes de stocks de reproductores son caros, pero hasta que las tasas de sobrevivencia de larvas o de semillas liberadas no mejoren, este podría ser el único medio para la recuperación de poblaciones muy mermadas y aisladas.

INTRODUCTION

The California Legislature closed the coastline from Palos Verdes Point to Dana Point (Figs 34.1 and 34.2), an area adjacent to densely-populated urban areas of Los Angeles and Orange Counties, to all abalone fishing in 1977 to allow recovery of badly depleted stocks. The Palos Verdes Peninsula, which once supported a productive fishery for several species of abalone (unpublished California Department of Fish and Game (CDFG) block landing records), suffered major environmental degradation due to sewage pollution; there was little or no giant kelp (*Macrocystis pyrifera*), the major source of abalone food, for almost two decades.

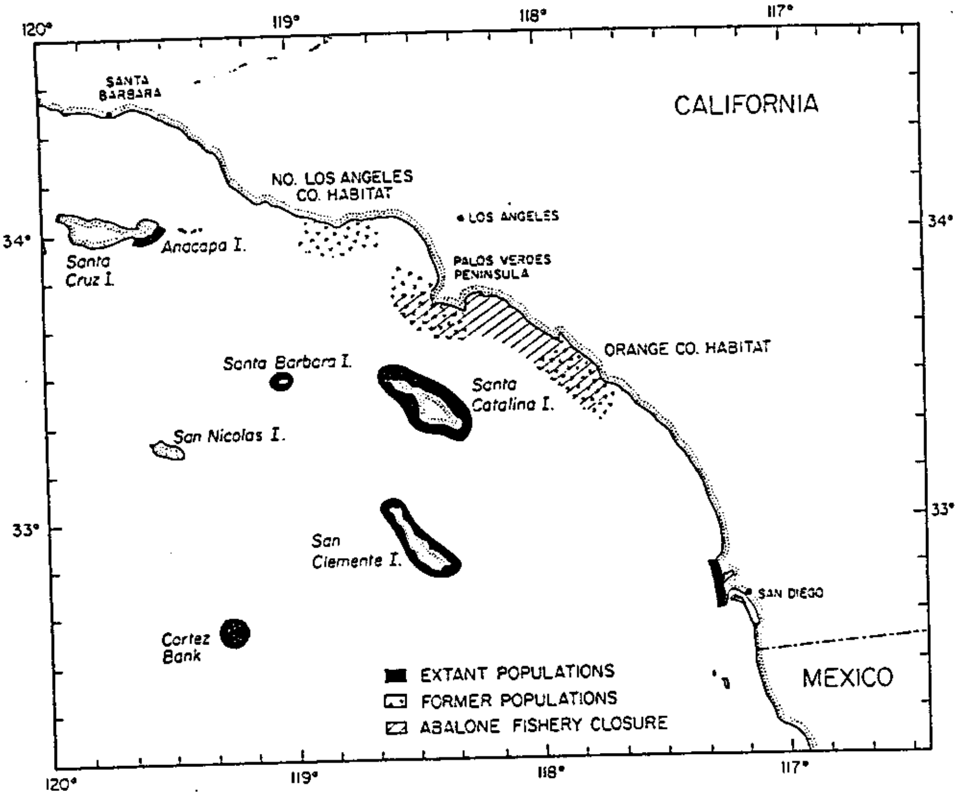

Fig. 34.1 Map illustrating green abalone (*Haliotis fulgens*) habitat in southern California. With the exception of Santa Cruz Island, green abalone populations remain relatively abundant at Channel Island locations but are depleted in former mainland habitats north of San Diego. The Palos Verdes Peninsula is isolated from other mainland kelp forest habitats by long stretches of soft bottom.

Pollution controls and kelp restoration efforts began to show results in 1974 and, by the early 1980s, the *Macrocystis* canopy was in the same size range as during the major years of the abalone fishery (Wilson *et al.*, 1977, unpublished data). Despite protection from fishing and abundant food, the green abalone (*Haliotis fulgens*) population of Palos Verdes showed no signs of recovery. The low number of recruits in apparently suitable habitat and the relatively short larval life of this species (Leighton *et al.*, 1981) suggested that recolonization of Palos Verdes by larvae originating elsewhere is a rare event. A drift-tube experiment (Tegner & Butler, 1985a) indicated that the probability of larval transport from offshore islands, where this species remains relatively abundant, to the depleted mainland within an appropriate time frame is low. However, a high proportion of the drift tubes deployed along the mainland were transported a few kilometres and recovered in suitable habitat within reasonable time frames. The results of the drift-tube experiment suggested that, in the virtual absence of local brood stock, the fishing closure would not promote recovery of mainland populations of green abalone in the near future. The objectives of this study were to test the hypothesis that local brood stock is required for the recovery of an isolated green abalone population and to consider the feasibility of adult transplants as a management tool.

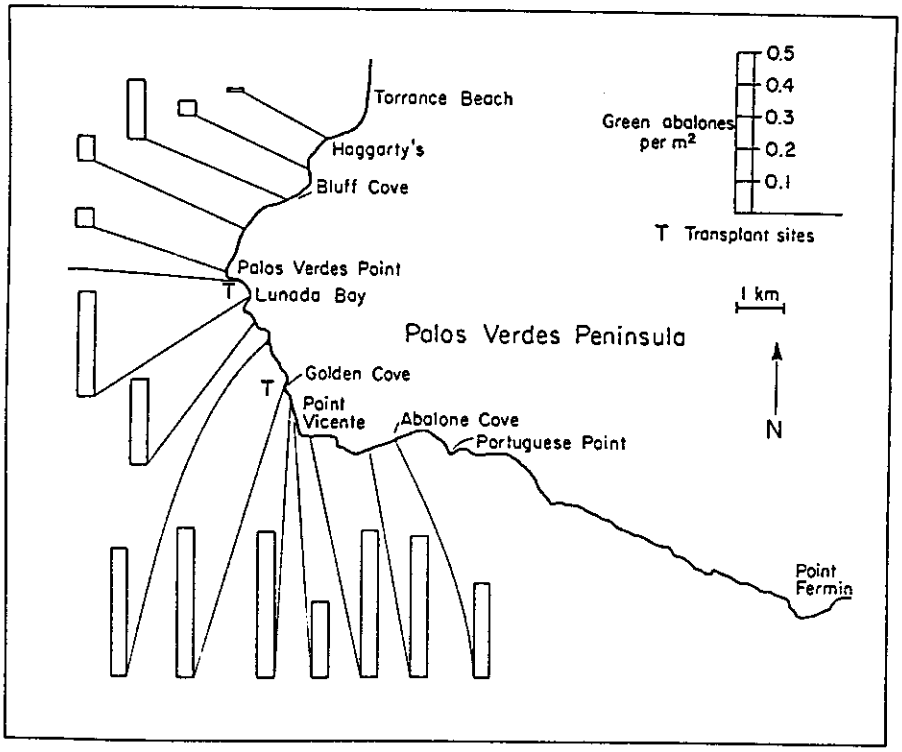

Fig. 34.2 Density of green abalone (*Haliotis fulgens*) in 1985 as a function of distance from the brood-stock transplant sites. The fishing closure extends south from Palos Verdes Point; the second brood-stock site was about 0.3 km east of this point. Torrance Beach and Portuegese Point represent the present boundaries of unsuitable habitat.

The Japanese began transplanting abalone as early as 1929 to improve growth rates (Saito, 1979), and moving slow-growing animals to better areas remains fairly common practice in that country (Mottet, 1978). Emmett & Jamieson (1989) concluded that transplantation of 50–100 mm *H. kamtschatkana* from exposed, food-poor habitat to sheltered, productive habitat was feasible to enhance growth, but that economic feasibility would be dependent on site-specific recovery rates and transplantation costs. Saito (1979) showed that spawning of transplants in a bay previously unoccupied by abalone led to susbstantial recruitment and development of fishable stocks. However, the rapid loss of a small brood-stock transplant at Santa Catalina Island (Henderson *et al.*, 1988) suggests that illegal take may be a critical problem in southern California.

MATERIALS AND METHODS

To provide local sources of larvae, the author, in conjunction with the CDFG, collected 4453 reproductively-mature (>100 mm, Tutschulte, 1976) green abalone from inside the shallow water (6 m) commercial fishing closure on the windward side of Santa Barbara Island between November 1981 and September 1982. The animals were transported in the flooded stern well, which had been lined with a thick net to prevent attachment directly to the deck, of the *RV Kelp Bass*; seawater was pumped continuously at a vigorous rate. The abalone were tagged with numbered, stainless-steel washers twisted on to stainless-steel wire threaded through the anterior respiratory pores, and they went measured, sexed and graded for gonadal bulk before transplantation. A simple visual index of gonadal bulk (G. Lockwood, pers. comm.), with 1 representing a depleted state and 6 a full gonad protruding from the mantle cavity, was used to estimate the stage of the spawning cycle. For consistency, a single observer made all gonadal bulk measurements. Three criteria were used to select the transplant sites at Palos Verdes:

(1) locations within the fishing closure (see Fig. 34.2),
(2) locations where the drift bottle data suggested a high probability of larval retention on the peninsula (Tegner & Butler, 1985a),
(3) good habitat for green abalone (e.g. Tegner & Butler, 1989).

The abalone were transplanted individually into appropriate habitat and clustered to facilitate fertilization (e.g. Pennington, 1985). Weather permitting, mortality (based on shell and tag collections), gonadal state and general condition of the animals were evaluated monthly through September 1983.

Evaluation was conducted in spring 1985. Because the physical habitat at Palos Verdes is quite variable and the type of habitat favoured by green abalone is known (Tegner & Butler, 1989), we sampled non-randomly to maximize areal coverage in the time available to us. Experienced abalone biologists placed 1 m^2 frames over suitable habitat, typically piles of turnable rocks within channels in the appropriate depth stratum, searched all possible surfaces and measured all abalone found.

RESULTS AND DISCUSSION

Survival and growth of the transplants

Short-term mortality associated with the stresses of transplantation was reduced considerably as we instituted and expanded predator and scavenger controls (Table 34.1). Live but stressed abalone attract attacks by scavengers, notably a whelk (*Kellettia kellettii*) and two asteroids of the genus *Pisaster*. No predators were collected during a small trial transplant to Golden Cove in November 1981, and the mortality rate by December 1982 was 42% based on the collection of tagged shells. We collected all predators in the immediate region of transplanted

Table 34.1 Short-term mortality experienced by adult green abalone (*Haliotis fulgens*) transplants as a function of increasing predator control; while the time periods for the mortality calculations differ, the results are comparable because most of the mortality took place within three months of transplantation (see text).

(a) Transplant record

Transplant date	Number transplanted	% Mortalities (through Dec. 1982)	Predator control?
Golden Cove			
Nov 1981	57	42	no
Feb 1982	679	21	yes
Apr 1982	1036	12	yes
Jun 1982	608	7	yes
Totals	2380	14	
Palos Verdes Point			
Aug 1982	1042	3	yes
Sep 1982	1031	4	yes
Totals	2073	4	

(b) Predator removal record; small numbers (4–10) of *Astrometis sertulifera*, *Loxorhynchus grandis*, *Panulirus interruptus* and *Scorpaenichthys marmoratus* were also removed.

Transplant date	*Octopus* spp.	*Kelletia kelleti*	*Pisaster* spp.
Golden Cove			
Nov 1981		No predators were removed	
Feb 1982	7	936	396
Apr 1982	16	3076	656
Jun 1982	7	1093	266
Totals	30	5105	1318
Palos Verdes Point			
Aug 1982	11	609	81
Sep 1982	4	605	44
Totals	15	1214	125

animals in a large-scale experiment in February 1982 and the mortality was reduced to 21%. A concerted effort was made to remove as many predators as possible in April, and mortality as of December 1982 was 12%. By the final Golden Cove transplant in June, reductions in the catch per unit effort indicated that our collections were clearly having an impact. Fewer predators were found and the mortality rate of these animals was 7%. The total mortality rate observed through December 1982 for the 2380 green abalone transplanted into Golden Cove was 14%.

Predator control was instituted from the beginning of the transplants to the Palos Verdes Point site. In August and September 1982 2073 animals were transplanted and the observed mortality through December 1982 was 4% (Table 34.1). Although this site did not have as large a scavenger population, intensive control combined with our greater experience in handling the abalone apparently resulted in many fewer deaths.

Most deaths probably occurred within the first few days after transplantation. Once abalone overcome the stress of handling and heal minor cuts or abrasions, they become immune to attacks by scavenging whelks and seastars. However, *Octopus* spp., batrays (*Myliobatis californica*), possibly spiny lobsters (*Panulirus interruptus*) and sheep crabs (*Loxorhynchus grandis*) prey on healthy adult abalone. We thus expected and observed a continuing low mortality rate of presumably adapted animals. The shell collections of the April transplant are typical. Fifty-seven shells (6% of the number planted and 45% of the mortalities as of December 1982) were found the week they were put down and are considered transplant mortalities. Sixteen shells which showed no growth were found in May, 14 in June, 1 in August, 3 in September, 4 in October, 3 in November and 4 in December. Some of these are doubtlessly transplant mortalities which were not found in April; others probably survived longer but did not grow. Starting in October, we began finding an equal number of shells which had increased in size since transplantation. A 152 mm animal grew 15 mm before its shell was found in December; a growth rate of almost 2 mm per month is outstanding for a large animal.

The extraordinary El Niño storms of 1982–3 (Tegner & Dayton, 1987) had dramatic effects in shallow green abalone habitat. *Macrocystis* was eliminated from both transplant sites; we assume that the animals had virtually no food from January until kelp recruited in late April. The large waves caused considerable sand movement at Golden Cove and rock rolling at Palos Verdes Point; both are potential sources of abalone mortality (Cox, 1962). Based on collections of shells or tags, 63 mortalities or 3.1% of the animals alive at the end of 1982 were found at Golden Cove and 22 mortalities or 1.1% of the remaining transplants were found at Palos Verdes Point. (Assuming that all abalone had adapted to their new habitat by December 1982, animals from the different transplant dates were subsequently lumped.) While some mortalities may have been buried or transported out of the area, extensive searches suggest that this number is low. The total mortality observed through September 1983, 9.1% of the 4453 animals transplanted, would appear to be an acceptable level for resource management considerations, especially considering the severity of the storms.

In September 1983, 356 animals were brought to the surface to be measured. Growth, which varied with abalone size, transplant date and location, ranged from 0 to 33 mm over the 12 to 23 months since transplantation. Forty per cent showed no growth or were actually slightly decreased in size due to shell abrasion. On a per-year basis, average growth of animals from the different transplant groups ranged from 1.8 to 2.9 mm/year. These low rates are not surprising given transplantation stress, low food availability during early 1983 and the size of the animals. The tagging data of Burge *et al.* (1975) indicate that green abalone of 156 mm, the average size of the transplants, are 8 to 9 years old and growing at a slow rate. In spring 1985, remeasurement of 206 animals yielded an average net growth of 7 mm at Golden Cove and 12 mm at Palos Verdes Point. Sea urchin grazing was having a major impact on kelp availability at Golden Cove in 1985.

Evidence for reproduction

While survival and growth are indications that the transplants have adapted to a new environment, an important criterion for the success of this experiment is evidence of reproduction. Leighton *et al.* (1981) report that the natural spawning period of *H. fulgens* extends from late spring to mid-summer and again from early to mid-autumn. The gonads of a haphazard sample of abalone from each transplant group were graded about monthly through September 1983. The initial and final gradings were done on board ship and the intervening assessments underwater. Some degree of spawning always took place on board ship before the gonads were graded prior to transplantation. The average gonad grade of the April group dropped one month after transplantation (Fig. 34.3). This may have been caused by additional spawning during planting (as was observed at Palos Verdes Point) or more likely because the animals mobilized energy reserves stored in the gonads to heal the inevitable abrasion or small cuts suffered during handling. By two months after planting, average gonad grades for each set of animals increased to well over their initial grade. The hypothesis that gonad grades dropped the first month after transplantation to deal with associated stress is supported by the February group's gonads developing in size before the April animals, which in turn developed before the June animals for an August spawning, whereas all three groups developed synchronously for a November spawning.

The evidence for a 1982 summer spawning of the Golden Cove animals was the increase in average gonad grade up to August followed by a sharp decline (Fig. 34.3). The average August grade for abalone transplanted in February and April was 3.5. We have observed spontaneous spawning when animals of grade 3.5 and above are handled, so we believe that a large proportion of the abalone spawned during the summer. The November 1982 peak was about 2.6, so fewer animals were ripe. Nevertheless, some reproduction probably did take place. Samples of both sexes from both transplant sites brought on board ship in November spawned spontaneously in flowing seawater aquaria.

While the winter of 1982–3 apparently did not have much effect on the survival of transplants, there was a striking effect on the gonad cycle. Gonad development was depressed and delayed in comparison with 1982 (Tegner & Dayton, 1987, Fig. 9). Uki & Kikuchi (1982) have shown in the laboratory that abalone given insufficient food show slower gonad growth and a lower rate of spawning success than satiated controls. As the transplanted animals were essentially without food

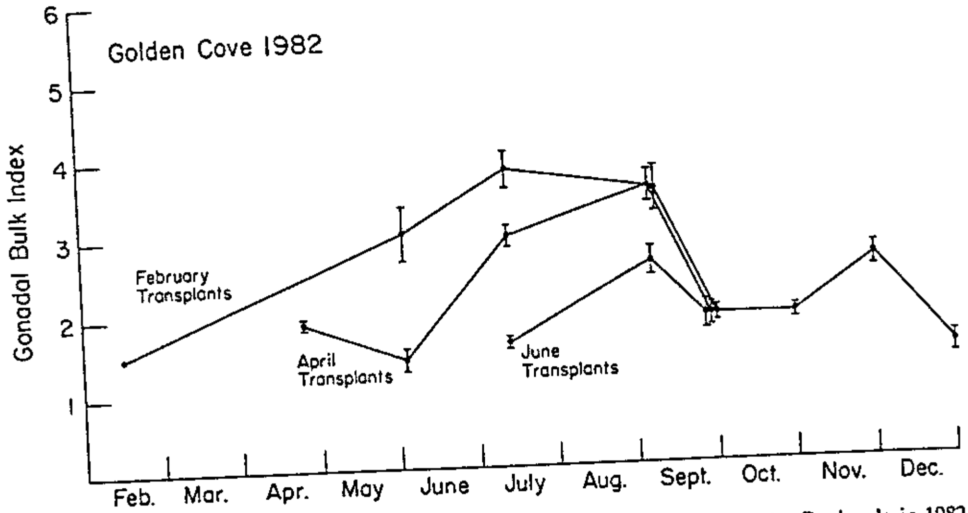

Fig. 34.3 Change in gonadal bulk index after transplantation to the Palos Verdes Peninsula in 1982. The scale varies from 1, a spawned-out condition, to 6; spontaneous spawning has been observed at ≥3.5. Variability is expressed as ± one standard error with the exception of February, which was estimated only. There was no difference between groups after September.

for three months, we assume that this was the explanation for the delayed onset and lower average gonad grade. Despite the low averages, some abalone at each transplant site were in spawning condition during summer 1983 (Fig. 34.4). Kelp

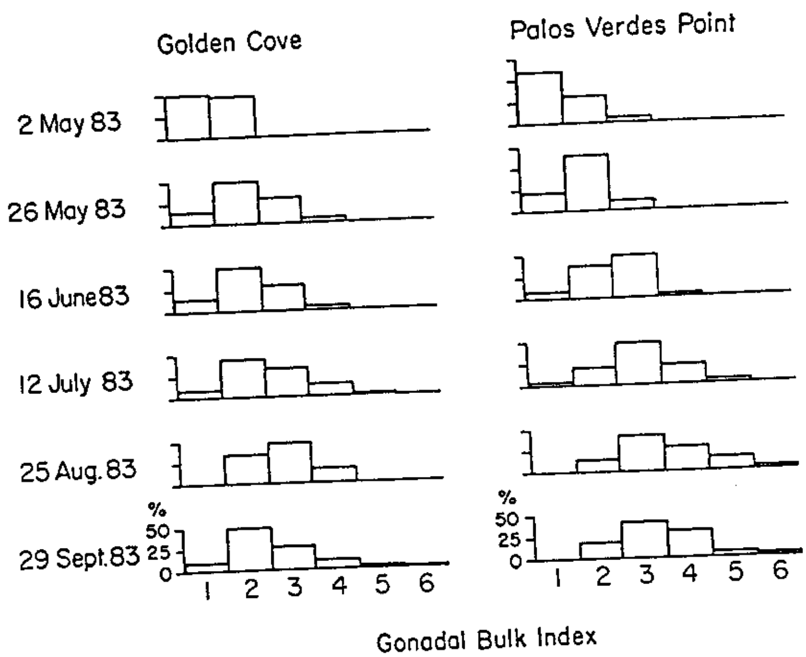

Fig. 34.4 Proportion of the sampled population in each gonad grade from May through September 1983 at the Golden Cove and Palos Verdes Point transplant sites.

canopies were luxuriant by midsummer and remained abundant through the rest of the study; there should have been much spawning from autumn 1983 onwards.

Evidence for recruitment resulting from the transplants

In spring 1985, Palos Verdes was surveyed for recruits to the green abalone population. On the basis of the drift-tube data (Tegner & Butler, 1985a), we believed that juveniles resulting from the brood-stock transplants were likely to be spread over several kilometres; sites examined are shown in Fig. 34.2. With insufficient resources to conduct proper density estimations in many locations, we chose to maximize the number of abalone sampled by selecting optimal habitat. The size–frequency distribution of the 348 green abalone found in 1985 is shown in Fig. 34.5. In the laboratory, green abalone may grow up to 39 mm in their first year (Leighton, 1974). Thus animals spawned in August 1982 could have been up to 100 mm, but most of the spawning undoubtedly took place after that. It is

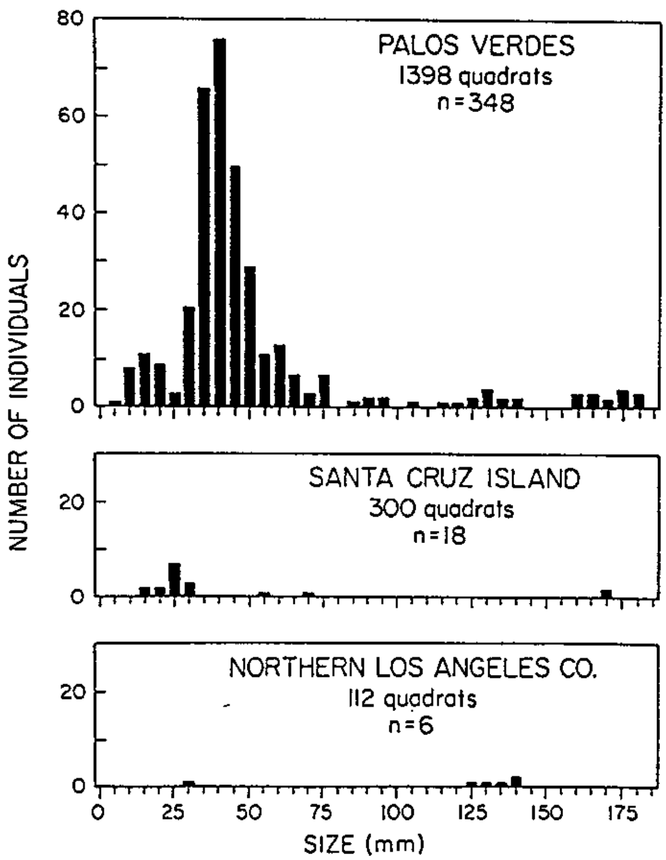

Fig. 34.5 Size–frequency distribution of all green abalone (*Haliotis fulgens*) found at Palos Verdes, Santa Cruz Island and northern Los Angeles County in spring 1985, 2.3 years after the completion of the brood-stock transplants.

apparent that virtually all of the abalone were in size categories which could have resulted from the brood-stock transplants. The abalone were spread around the suitable habitat of the peninsula (Fig. 34.4). Torrance Beach in the north marks the beginning of a long stretch of sandy coastline and landslides from Portugese Point east make that area unsuitable. The average size of the animals found from Point Vicente east was significantly larger than that of green abalone found in the central and northern areas of the peninsula (Kolmogorov-Smirnov test, $p < 0.05$). As food supplies appeared to be equally abundant, this observation suggests the possibility of variation among spawning seasons in the net current direction.

The relationship between the density in diver-selected quadrats and absolute density is strongly habitat dependent and thus site specific. The absolute density was determined at Lunada Bay with the use of randomly chosen quadrats on transects laid perpendicular to the shoreline. The density in the diver-selected quadrats was 32% higher than in the randomly chosen quadrats ($N = 68$ and 45, respectively). At a site between Golden Cove and Point Vicente, every third square metre was searched on three transects perpendicular to shore. Here the density in the diver-selected quadrats was almost twice the density in the regularly spaced quadrats ($N = 31$ and 75, respectively). Given the habitat variability characteristic of Palos Verdes, these relationships between density in selected habitat and absolute density should be considered as representative only.

During the course of various green, red (*H. rufescens*), and pink (*H. corrugata*) abalone seeding experiments at Palos Verdes during 1978–82 (see Tegner & Butler, 1989), several sites within an appropriate depth range for green abalone were surveyed; only two had supported *H. fulgens*. These sites were reexamined with random sampling techniques in 1985. Haggarty's at the north end of the peninsula (Fig. 34.2), had had a larger expanse of relatively uniform appropriate habitat and the largest green abalone population we had found (Table 34.2). However, this site was devastated by the storms of 1983; the waves apparently

Table 34.2 Changes in green abalone (*Haliotis fulgens*) densities at two locations on the Palos Verdes Peninsula which had supported populations of this species before the brood stock transplants.

Year	Number of m^2 sampled	Number of live abalones <100 mm	Density
(a) Haggarty's			
1980	145	4	0.028
1981	287	26	0.091
1982	399	31	0.078
1985	229	2	0.009
(b) Lunada Bay			
1978	38	0	0
1979	39	1	0.026
1980	35	0	0
1985	45	12	0.267

dispersed the boulder habitat, creating a sandy to silty environment with virtually no kelp. Not surprisingly, the abalone population had declined from previous observations. The results from the other site, a small kelp forest on an energetic point off Lunada Bay, suggested that there had been an increase in green abalone populations after the brood-stock transplants (Table 34.2). While the data in Fig. 34.4 are not absolute densities, a comparison with the 1980–82 data from Haggarty's, the densest green population observed prior to this experiment, supports order of magnitude or greater increases in density.

To control for potential large-scale changes in recruitment patterns which might have been caused by the 1982–4 El Niño (Tegner & Dayton, 1987), for example, similar searches were conducted in green abalone habitat on Santa Cruz Island and northern Los Angeles County, regions which the drift-bottle data suggested would not be influenced by the brood-stock transplants at Palos Verdes. Both regions had supported green abalone populations in the past (CDFG, unpublished block landing data); information about specific sites within each region had been synthesized for the drift-bottle study (Tegner & Butler, 1985a). Using the same method of sampling optimal habitat at a number of sites, one juvenile green was found at northern Los Angeles County and 16 at Santa Cruz Island (Table 34.3). We had no previous data for any of the northern Los Angeles County sites and eight of the nine Santa Cruz Island sites. No juvenile green abalone were found at Middle Anchorage on southeastern Santa Cruz Island in 1981 ($180\,m^2$, density of adults $>100\,mm = 0.15$) and none in 1985 ($49\,m^2$). While the size–frequency data at the two control sites suggest that 1985 may have represented increases over past recruitment, these sites clearly did not experience the scale of recruitment observed at Palos Verdes (Fig. 34.5).

Prince *et al.* (1987, 1988) observed a strong relationship between adult and recruit density for *H. rubra* in Australia, and suggested that recruitment is local, on a spatial scale of tens of metres. There was no relationship between adult and recruit density for *H. fulgens* at Palos Verdes; while there was evidence of reproduction at both sites, the Golden Cove adult transplant site had the highest and the Palos Verdes Point site the lowest recruit densities of the 15 sites surveyed (Fig. 34.4). The green abalone data support the hypothesis of primarily local recruitment, but on a scale of hundreds of metres to several kilometres. Thus it is likely that these larvae dispersed pelagically. Over longer time scales, pelagic dispersal would have been required to account for the distribution of this species among the islands of the Southern California Bight.

Table 34.3 Green abalone (*Haliotis fulgens*) selected quadrat data, 1985.

Site	Number of m^2 sampled	Number of live abalones <100 mm	Density
Palos Verdes Peninsula	1398	330	0.236
Northern Los Angeles Co.	112	1	0.009
Santa Cruz Island	300	16	0.053

Management considerations

These results support the hypotheses generated by the drift-tube study that green abalone recruitment is relatively local and that, in the absence of local brood stock, a fishing closure will not support recovery of depleted stocks on short time scales. The size–frequency data and the apparent increases in density suggest that brood-stock transplants may be an effective approach to stock enhancement. Natural production of recruits by transplants eliminates the behavioural problems which apparently limit the survival of hatchery-reared juveniles, an approach to stock enhancement which has not been effective at Palos Verdes and in southern California generally (Tegner & Butler, 1985b, 1989; Schiel & Welden, 1987). While brood-stock transplants may be effective in depleted areas, the approach is expensive and limited by the availability of animals for transplantation. Nevertheless, until the survival rates of cultured larvae (Tong *et al.*, 1987) or seed (Tegner & Butler, 1985b, 1989) improve, this may be the only approach for the recovery of isolated stocks.

The effectiveness of the brood-stock approach is dependent upon the longevity of the transplants. Poaching appears to be a serious problem; Henderson *et al.* (1988) were able to locate fewer than 5% of the animals one year after a small transplant of pink abalone to Santa Catalina Island, a case where known mortalities were 18%. At Palos Verdes Point, migration of tagged animals into and out of a 400 m^2 marked square during the first year demonstrated that the green transplants were moving, but the extent of their dispersal over the period of the study is unknown. Using the number of abalone recovered per dive on the first day of a survey as an indication of abundance, the abundance declined by 63% at Golden Cove and by 36% at Palos Verdes Point between September 1983 and spring 1985. About 9% of the number originally planted in 1981–2 at each site were observed alive in 1985 in 27 dives at Golden Cove and 18 at Palos Verdes Point; these search efforts were too low to account for much dispersal. The natural mortality rate of sexually mature green abalone is not known, but it is likely to be low (Tutschulte, 1976). Despite less sport diver activity than at Santa Catalina Island, poaching was probably an issue at Palos Verdes as well. Future transplant efforts should involve increased public education and enforcement activity.

These results have general implications for fishery managers beyond the narrower issue of rehabilitation of depleted stocks. Local recruitment underscores the importance of maintaining local brood stocks at concentrations high enough to promote successful fertilization and an adequate larval supply as a basic management goal (see also Prince *et al.*, 1987). Fishery closures, a traditional management tool, will only work if adequate brood stock remains nearby, as isolated stocks cannot depend upon long-distance larval dispersal for replenishment. Thus managers are faced with the need for very fine-scale assessment of stocks, a difficult proposition in the financial climate of the 1990s in California.

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