

Part II

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REBUILDING CALIFORNIA'S ABALONE STOCKS

The red abalone extend in such an abundant quantity along the coast . . . that it would be impossible to materially reduce their number, as they live in water beyond the depth to which a hunter can go; and their habits and methods of propagation are such that the spawn would immediately repopulate a district if it could be fished out, which, however, is impossible.

—Dr. Harold Heath, Stanford University, 1925¹

Abalone stocks in southern California have been severely depleted since the peak of the fishery in the 1960s and 1970s (Karpov et al. 2000), culminating in the closure of the recreational and commercial fisheries in southern California in 1997 (CDFG Code 5521). Since then, abalone populations have not recovered, indicating the need for a comprehensive restoration program. Population assessments have been hampered by a lack of both current and historic population surveys for fished species, including red abalone (*Haliotis rufescens*), pink abalone (*H. corrugata*), black abalone (*H. cracherodii*), and green abalone (*H. fulgens*), as well as three minor species in the abalone fishery complex. In 2000 a status review of the white abalone (*H. sorenseni*) (Hobday and Tegner 2000) resulted in the listing of this species as the first federally endangered marine invertebrate. The black abalone (*H. cracherodii*) has been proposed for listing, and the threaded abalone (a subspecies of the pinto abalone, *H. k. kamtschatkana*) may now be even more rare than the white abalone.

The reproductive potential of abalones was once thought to render them extinction proof (Heath 1925); however, we now have evidence that this is not the case for abalone (Campbell 2000; Shepherd et al. 2001) or for other marine organisms (Carlton et al. 1999;

Roberts and Hawkins 1999). Reproductive failure may occur at any stage during the recruitment process, including fertilization (Babcock and Keesing 1999), larval development, settlement, and postsettlement. Measures of recruitment success suggest that abalones may go for years, sometimes decades, without a major recruitment event (Tegner et al. 1989). A comprehensive understanding of the factors affecting recruitment remains elusive, despite significant interest for nearly a century in the recruitment of marine organisms (Hjort 1914; Houde 1987). We know that survival of juvenile abalone is highly spatially variable, suggesting that site-specific conditions such as predators and food availability are important (Schiel 1993). Spatial patterns in abalone productivity have been quantified using fishery data in an effort to identify prime restoration sites in southern California (Rogers-Bennett et al. 2002). Nearshore sites, however, have been dramatically altered by anthropogenic impacts such as pollution and fishing operations, which may have both direct and indirect effects (Dayton et al. 1998). Indirect effects such as the removal of red sea urchins has been shown to reduce the survival of juvenile abalone (Rogers-Bennett and Pearse 2001; Day and Branch 2002).

In drafting a recovery plan for California's abalone stocks, choices will have to be made from among enhancement options that include aggregation of adults, captive rearing and seeding, and no human intervention. Key information gaps will need to be filled in order to implement an effective restoration program. The white abalone, for example, now exists on deep offshore reefs, but are these remnant populations reproducing successfully or should some of these individuals be collected for captive rearing, and are there enough individuals for aggregation? We have filled one gap through our extensive knowledge of spawning and rearing methods developed by the abalone aquaculture industry (Hahn 1989; McCormick et al. 1994; Leighton 2000). This

¹Heath 1925.

may make captive rearing a plausible option for most species of abalone in California (except perhaps black abalone). Yet, many challenges remain for broodstock aggregation and captive rearing, including protecting aggregations from illegal fishing and tracking reproduction (Henderson et al. 1988; Tegner 1992) and maximizing the survival of captive-reared abalone in the wild (Tegner and Butler 1989; Davis 1995; Rogers-Bennett and Pearse 1998; Tegner 2000). Restoration programs will need to address a suite of factors, such as (1) quantifying the success of enhancement programs, (2) investigating the genetic structure of wild and seeded populations, (3) restoring populations within the range of the lethal disease withering syndrome, (4) knowledge of range expansions of sea otter populations, (5) preventing the introduction of diseases and parasites into the wild (such as sabellid polychaetes), and (6) protecting wild and seeded abalone from illegal fishing. While these tasks will be challenging, some populations are at such drastically low levels that what we do or do not do now may dictate the success of our efforts to save California's abalone from extinction.

The articles in this section are based on presentations given at CalCOFI's 2001 symposium, "Rebuilding California's Abalone Stocks."² Laura Rogers-Bennett et al. estimate baseline abundances of abalone in the past to help set goals for restoration. Population surveys are rarely conducted prior to the start of a fishery, and perceptions of what baseline abundances were tend to shift downward over time (Pauly 1995; Dayton et al. 1998; Jackson et al. 2001). Abalones are particularly sensitive to ocean temperature and storm conditions, which impact growth, reproduction, and food availability. Alistair Hobday and Mia Tegner report on the results of an individual-based model exploring the effects of sea surface temperature, fishing pressure, and reserve size on two populations of red abalone in the northern Channel Islands. The two model populations decreased during the warm-water conditions of the last 20 years, and fishing intensified this decline. Fishery reserves and larval connectivity, however, ameliorated the decline. Warm-water conditions also enhanced the expression of the lethal disease withering syndrome, which has decimated black abalone populations in southern California. Moore et al. review the current state of knowledge regarding withering syndrome and the implications of this disease for abalone recovery programs. Plans for abalone restoration must take into account the susceptibility of abalone to this disease as well as the distribution of the causative agent (a prokaryote), which is now enzootic in the ocean south of San Francisco. Finally, the information from this symposium, sharing abalone restoration experiences

from around the world, coupled with the continued cooperation among multiple agencies, universities, and foundations, will be critical to establishing a comprehensive abalone restoration strategy for California.

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Laura Rogers-Bennett

John Butler

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²Several of the presentations were not submitted as articles for publication.

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