Artificial Reefs as a Resource Management Option for Siting Coastal Power Stations in Southern California

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Introduction

The Pendleton Artificial Reef was constructed in nearshore southern California waters (Fig. 1) in 1980. This artificial reef is a joint research project of the Southern California Edison Company (SCE) and the California Department of Fish and Game (CDFG) to assess the viability of man-made reefs as a compensation measure for the use of public resources in the form of cooling water for coastal power stations.

The CDFG, through a cooperative agreement with SCE, directed the design and construction of the Pendleton Artificial Reef and is conducting a resource management study on the reef. Specific reef management objectives are:

1) Determine whether a stable kelp bed can be established on a man-made reef in nearshore southern California waters;

2) Investigate the long-term stability and fisheries' (shellfish and finfish) standing crop on such a reef; and

3) Determine the appropriate size and design criteria of structural habitat modifications that will optimally enhance the selected fisheries' resources.

The concept of the Pendleton Artificial Reef project originated from specific marine studies associated with the operation of the San Onofre Nuclear Generating Station (SONGS) and general studies of coastal natural resources being conducted by SCE. This reef project was initiated to find a cost-effective, solution-oriented, marine resource enhancement scheme that would be applicable to SONGS and potentially any future coastal power plant.

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Background

An understanding of the history of the SONGS project and the evolving regulatory climate is necessary to appreciate the specific origins of the Pendleton Artificial Reef.

San Onofre Unit 1 began operation in 1968. Marine studies have been conducted in the San Onofre area since 1963. The San Onofre site is presently being expanded from a single 450 MW unit to 2,650 MW with two additional units and separate once-through cooling

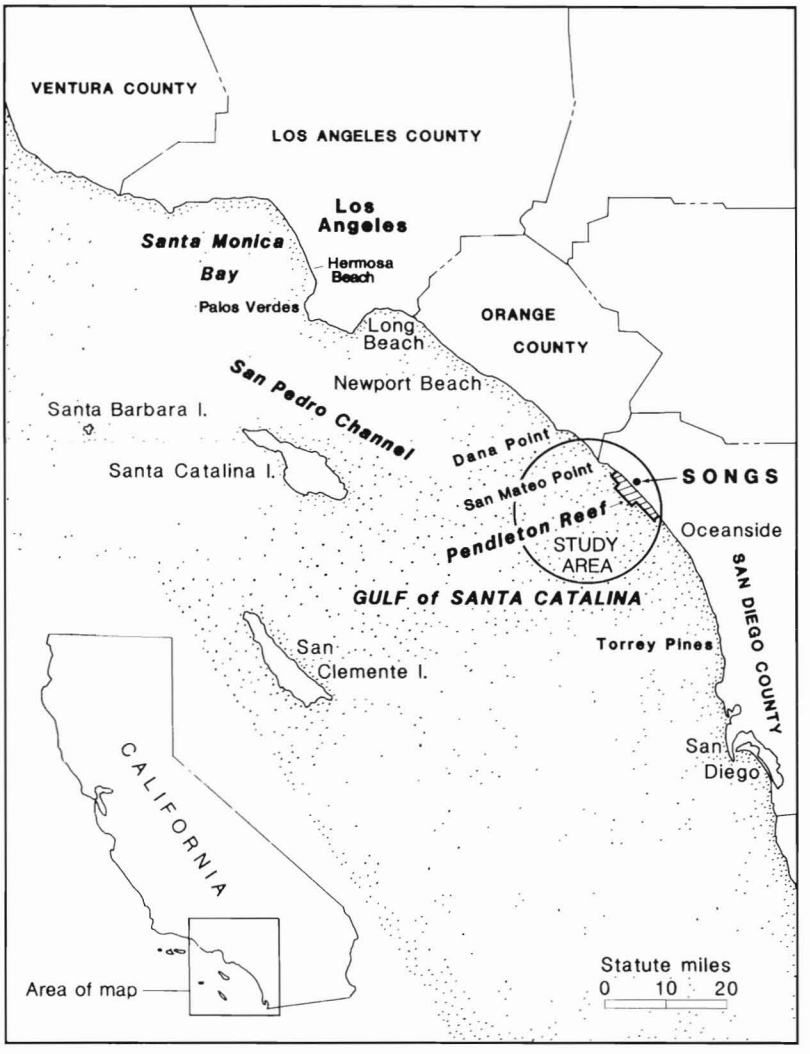

Figure 1.—Location of the San Onofre Nuclear Generating Station (SONGS) and the Pendleton Artificial Reef.

systems. The new units are due to begin operations in 1982 and 1983, respectively. Design and permit application work for Units 2 and 3 began in the late 1960's

By 1973 the environmental licensing process had progressed to the stage of obtaining a construction permit from the California Coastal Zone Conservation Commission (now the California Coastal Commission). In sequential order this was the 20th environmental protection-related permit in a series of 33 environmental permits connected with the licensing of Units 2 and 3 (SCE, 1976). The Coastal Commission approved a conditional permit which required the establishment of an independent scientific investigative group called the Marine Review Committee (MRC).

The MRC was charged to carry out "a comprehensive and continuing study of the marine environment offshore from San Onofre . . . to predict, and later to measure the effects of San Onofre 2 & 3 on the marine environment . . . in a manner that will result in the broadest possible consideration of the effects of Units 1, 2 & 3 on the entire marine environment in the vicinity of San Onofre" (Murdock, 1981). Further, the MRC must make recommendations to the Coastal Commission in the area of remedying any predicted adverse marine impact through cooling system design changes.

The MRC (1980) report to the Coastal Commission gave the predictions and recommendations of the MRC. It was recommended to not move the intake or discharge pipes or change the cooling system design, or to convert to cooling towers. The recommendation was to continue to monitor the marine environment and to initiate the examination of the feasibility of mitigating some or all of the predicted effects of the power plant on the environment. The option of recommending any actual power plant changes has been left open.

This has been a costly study: To date, SCE funding of these independent MRC studies has exceeded $17 million. The MRC is continuing its plankton, kelp, fish, and oceanographic studies with a 1981 budget of $3.29 million. As the MRC (1980) report to the Coastal Commission states: "Although we can and will obtain some more information on the major parts of the ecosystem near San Onofre Nuclear Generating Station before Units 2 & 3 begin operation, we have obtained most of the information it is possible to obtain with a feasible expenditure of effort. Where major uncertainties remain, further study will not, in general, resolve them. . . ."

It is this framework of events and costs that led SCE to develop the concept of compensatory resource enhancement through establishment of an artificial reef project. This represents a major departure from the standard practice of amassing an extensive marine data base which will most likely not succeed in resolving all present environmental uncertainties. Ultimately, reef management projects could at lease minimize investment in marine data collecting that cannot yield any possible significant return.

Pendleton Artificial Reef Planning

Active planning of an artificial reef began in 1979 at SCE. Initially, two possibilities for mitigating possible effects of coastal power plant circulating water systems were investigated for a site such as San Onofre:

1) The deployment of additional structures as part of, or adjacent to, a San Onofre-type cooling system to contain and utilize the waste heat output to enhance a general set of marine biotic resources at the site; and

2) The construction of structures away from the power plant site to enhance a specified set of marine biota resources of high social value that would compensate for "loss of like value" at the power plant.

The first alternative was suggested as a result of research being carried out by SCE on coastal power plants and possible marine habitat enhancement through specified design and operations modes of once-through cooling systems. For example, at SCE's Redondo Generating Station, the configuration of the King Harbor breakwater and adjacent power plant cooling system structures at the head of the Redondo Submarine Canyon, has led to enrichment of the fish fauna (Stephens, 1982). This biotic richness is apparently dependent on both the static and dynamic characteristics of the habitat created by the combination harbor/submarine canyon/cooling system configuration. Application to future power plant siting and cooling system design shows promise (Stephens and Palmer, 1979). Yet, whereas this option would provide the maximum direct association of the generating station with resource enhancement, the ability to manipulate the environment and biotic populations at an open ocean site such as San Onofre in a manner similar to the way it was done at King Harbor was not feasible as a demonstrative project because a new harbor or series of breakwaters would have to be built.

The second option, derived from past demonstrations in southern California, is that the productivity of a fishery can be enhanced by structural modification of the habitat, particularly in areas of low biological productivity. Artificial reefs have been employed successfully by the CDFG to enhance sport fisheries off the southern California coast (Turner et al., 1969). This option is viewed as most feasible and a straightforward trade-off: Where the influence of a generating station is viewed as negative, an equal or greater resource enhancement could be implemented in an adjacent location. The marine resources having greatest importance or value in terms of predicted losses due to the operation of coastal power plants are fish and kelp (MRC, 1980; Stephens, 1982). Both of these resources may be enhanced with artificial reefs as an offset to power plant impacts.

Pendleton Reef Preconstruction Activities

A site for the reef was chosen by SCE and the CDFG in proximity to San Onofre but away from any possible power plant influence, and in a relatively barren (with respect to fish and kelp), flat sandy bottom area. The reef location is approximately lat. 33°20′N, long. 117°31′W (Fig. 1). The CDFG made general reconnaissance surveys of the area and found it acceptable. Also, a control site for biological studies was concurrently selected nearby: Las Pulgas Reef (the inshore Barn Kelp Bed area), where

Figure 2.—Schematic of the Pendleton Artificial Reef.

substrate type and relief similar to the proposed artificial reef were found. Also, the Pendleton site, being adjacent to the marine biological and oceanographic surveillance zones of San Onofre, allows studies at the Pendleton Artificial Reef to draw upon 18 years of marine data for siting assessment and future comparative work. Another factor that was crucial in reef siting was proximity to natural kelp beds. The Pendleton Artificial Reef site is near natural kelp beds, both a few miles north and a few miles south, and the area has historically been recorded as a kelp area according to 1911 surveys.

The reef design and orientation took into consideration water currents and nutrient dynamics, criteria developed from previous CDFG reef building experiences, and comments received from expert reviewers from around the country. Reef configuration is shown in Figure 2. The reef was designed to incorporate basic ecological principles which should increase diversity and productivity. For example, the archipelagos arrangement was determined to be better than a single large mound, rugosity to be better than simplicity, relief was an important consideration, and heterogeneity over homogeneity was sought.

Reef Construction

Actual construction of the reef began in August 1980 and took less than 2 weeks. The reef was constructed of 10,000 tons of rock from the Connolly-Pacific[1] quarry on Santa Catalina Island. Total cost of the Connolly-Pacific operation, including barging and placement, was $250,000.

Eight reef units were constructed. Each unit measures about 100 feet by 40 feet with at least a 10-foot relief. The units are spread about 60 feet apart. All reef units are made up of rock mixture that has an approximate size range of 2-5 feet in cross section. Four reef units received a topping of relatively fine (1 foot cross section) quarry rock. The purpose of the "topping" is to provide shelter for small invertebrates and small fish[2,3].

Reef Management

Besides, the necessary reconnaissance of the area before reef placement, the CDFG, in its role of resource manage-

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[2]Letter from Al Ebeling, University of California, Santa Barbara, to T. C. Sciarrotta, Southern California Edison. "Re: Review of March 3, 1980 Proposal on the Artificial Reef." 7 March 1980.

[3]Tegner, M., 1980. Scripps Oceanographic Institution, La Jolla, Calif., pers. commun. to B. Mechalas, South. Calif. Edison.

ment, performed surveys of the newly constructed reef, and is now involved in the manipulation of the reef with the purpose of maximizing resource yields for key fish and invertebrate species. For example, substrate is being altered to meet minimum design criteria established for life stages of certain taxa such as abalone. Also, kelp is being transplanted on the reef from surrounding areas to achieve a standing crop of parent *Macrocystis* plants. Natural kelp recruitment is an objective of this work. Kelp will increase the relief of the structure without making the reef a possible hazard to navigation, and fish seem to be attracted to higher vertical relief[4]. Kelp will also increase algal biomass sufficiently to allow a stable food web which includes invertebrates and fish.

SCE is providing 20,000 juvenile red abalone from its marine research laboratory at King Harbor to be transplanted on the Pendleton Reef (Kelly et al., 1982). The first transplant of 825 young abalone took place in July 1981. Follow-up observations through the summer of 1981 revealed that these abalone were showing new growth, and a transplant of 18,000 was performed in December 1981 (Fig. 3).

The CDFG is predicting that the reef will take about 6 years to reach a "natural" point of successional development, that is, to achieve an appearance similar to reefs of natural origin in the area. Even so, within weeks of reef construction sportsmen found the reef to be a desirable fishing point and commercial lobster fishermen now successfully set their pots on the reef. Through the rest of 1980 and the summer of 1981 the long-term ecological study program of the reef was being established. Reef physical parameters were measured and documented, and 5-year biological transects were set up. Observational dives and transplanting work were the main thrusts of the biological study activities during this time. The documentation of the reef's succession and further reef biomanipulation are the primary activities of the continuing CDFG work on the reef for the future.

Figure 3.—A CDFG biologist places juvenile abalone on the Pendleton Artificial Reef.

Conclusion

The Pendleton Artificial Reef project has demonstrated in its 1 year of existence that biological activity has followed an orderly succession to an apparently stable system that directly supports an enhanced fishery. The objectives of the Pendleton Artificial Reef and the continuing reef management study remain to establish a stable kelp bed on a man-made reef, to document the environmental stability and standing fisheries crop of the reef, and to determine the size and design criteria of structural habitat modifications that will selectively enhance desired marine resources in southern California. It is further hoped that this effort will lead to advances in artificial reef technology and marine resource management in coastal waters.

[4]Sheehy, D. 1980. Artificial reefs as a means of marine mitigation and habitat improvement in Southern California. Report for the Marine Review Committee, 23 September 1980. Aquabio, Inc., Columbia, Md., 53 p.

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