CALIFORNIA DEPARTMENT OF FISH AND GAME
NEARSHORE SPORT FISH HABITAT ENHANCEMENT PROGRAM

ARTIFICIAL REEF PLAN FOR SPORT FISH ENHANCEMENT

Prepared by

K.C. WILSON, R.D. LEWIS, AND H.A. TOGSTAD

NOVEMBER 1990

Administrative Report No. 90-15

California Department of Fish and Game
Nearshore Sport Fish Habitat Enhancement Program

ARTIFICIAL REEF PLAN FOR SPORT FISH ENHANCEMENT

by
Kenneth C. Wilson
Robin D. Lewis
Heidi A. Togstad

EXECUTIVE SUMMARY

Hard bottom substrate provides habitat for a multitude of marine fishes, invertebrates, and plants -- particularly giant kelp -- which are of direct and indirect importance to sport and commercial fisheries. These reefs also enhance esthetic uses of the marine environment. This document sets forth the plan of the California Department of Fish and Game (CDFG) for the construction of artificial reefs.

The plan includes an outline for defining the purpose of reef construction, gathering information pertinent to reef placement and design, selecting a reef site, preparing a project narrative, obtaining permits and approvals for reef construction, developing a general permit for reef construction, and establishing a system of fisheries habitat enhancement areas. Procedures for constructing and mapping reefs are discussed and an outline for conducting short- and long-term biological studies of reef communities is presented.

Since 1958, CDFG has constructed 31 reefs off southern California. Thirteen of the largest and most frequently used reefs were mapped using hydroacoustic and radio-locating techniques. Maps of these reefs were published in a 1989 CDFG booklet entitled "A Guide to the Artificial Reefs of Southern California".

Since 1978, seven developmental reefs have been constructed: 1) Pendleton Artificial Reef (1980) - San Diego County; 2) Pitas Point Artificial Reef (1984) - Ventura County; 3) Marina Del Rey Artificial Reef (1985) - Los Angeles County; 4) Oceanside Artificial Reef (1987) - San Diego County; 5) Pacific Beach Artificial Reef (1987) - San Diego County; 6) Santa Monica Artificial Reef (1987) - Los Angeles County; and 7) Topanga Artificial Reef (1987) - Los Angeles County. These reefs were built to improve habitat for sport fishes and associated fauna and to evaluate the enhancement characteristics of reefs related to geographic location, depth, height, rock size, and reef spacing.

Short-term studies revealed that all reefs have provided shelter, food, nesting, and nursery areas for important fish species and have increased sport fishing opportunities. Furthermore, giant kelp has been observed on all reefs built at suitable depths. More extensive long-term studies are planned in 1998 when reef communities will be at successional equilibrium. These studies will provide additional information concerning the long-term potential of artificial reefs as habitat for sport fish, invertebrates, and plants.

The plan discusses different types of man-made reefs, including developmental, production, and fishing access reefs, and provides examples of each. It documents CDFG policy regarding the use of reefs as mitigation for impacts on rocky habitat and kelp. It also documents the laws authorizing CDFG to administer reef construction and studies in California. The activities involved in designing, permitting, constructing, and evaluating Pendleton Artificial Reef are provided as an example of the reef building and study process.

A list of reefs is provided to document the location, depth, area, materials, and funding sources for all reefs constructed and/or augmented in California.

Marine Resources Administrative Report No. 90-15. (rev. 1/26/91)

Marine Resources Division, 330 Golden Shores Dr. Suite 50, Long Beach, CA 90802

ACKNOWLEDGEMENTS

We wish to thank John Carlisle, Charles Turner (deceased), Earl Ebert, and Robert Given for their pioneer work on the artificial reefs in California. Their work provided a sound base of knowledge upon which today's reef studies and development program was built.

Our thanks to Southern California Edison Company for their ideas, cooperation, and support for the California Department of Fish and Game reef study program.

We also wish to thank Harold Clemens, John Duffy, and Kenneth Miller for their editorial review. Their work contributed much to the readability of the plan. Our thanks to John Carter and Richard Ambrose for their critical review of the draft report. We also want to acknowledge John Grant for his input in preparing the text. Our thanks also to Kimberly McKee, Melodie Palmer-Zwahlen, John Tarpley, Mickey Wolfe, and Eileen Price for their help in typing the text and preparing the graphics.

Our appreciation to Richard Stone for allowing us to review a draft of the National Artificial Reef Plan. It provided a broad perspective and is a valuable complement to the California Artificial Reef Plan.

Last, but not least, the Nearshore Sport Fish Habitat Enhancement Program (California Project F-27-D) wishes to acknowledge the support of the Federal Aid in Sport Fish Restoration Program and the California Federal Aid coordinator, Chuck Knutson. Without the support of these individuals and agencies, this valuable work would not have been possible.

TABLE OF CONTENTS

page

EXECUTIVE SUMMARY i

AKNOWLEDGEMENTS iii

TABLE OF CONTENTS iv

LIST OF FIGURES, TABLES AND APPENDICES vi

FOREWORD viii

INTRODUCTION 1

ARTIFICIAL REEF PLAN 8
- Preconstruction Activities 8
  - Defining the Purpose 8
  - Information Gathering 10
  - Site Selection 13
  - Reef Plans 13
  - Project Narrative 15
  - Permits and Approvals 15
- Construction 17
  - Funding 17
  - Contractor Selection 17
  - Plan Confirmation 17
  - Scheduling 18
  - Reef Placement and Verification of Reef Structure 18
  - Reef Mapping 18
  - Reef Studies 19
    - Observations on New Developmental Reefs (short term) 21
    - Studies of Fish Production and Behavior 22
    - Studies of Developmental Reefs at Successional Equilibrium 22

ARTIFICIAL REEF LOCATION AND MAPPING 23

DEVELOPMENTAL FISHING REEFS 24
- PAR - The First in a Series 24
  - Pendleton Artificial Reef (PAR) 24
- Subsequent Developmental Reefs 26
  - Pitas Point Artificial Reef (PPAR) 26
  - Marina Del Rey Artificial Reef (MDRAR) 26
  - Santa Barbara, Oceanside, and Pacific Beach Artificial Reefs 28
  - Santa Monica Bay Artificial Reef (SMBAR) 31
  - Topanga Artificial Reef (TPAR) 31

FUTURE REEFS.. 34
Developmental Reefs.. 34
Improved Production Reefs.. 35
Fishing Access Reefs 35

MITIGATION.. 36

CONCLUSION.. 36

LITERATURE CITED.. 37

LIST OF FIGURES, TABLES, AND APPENDICES

		page
Figure 1.	Multiple component replication reef (from Turner, Ebert, and Given 1969)	3
Figure 2.	Locations of the recreational artificial fishing reefs in southern California	4
Figure 3.	Locations of the developmental artificial fishing reefs in southern California	6
Figure 4.	Artificial Reef Construction and Studies Flow Chart	9
Figure 5.	Pendleton Artificial Reef - diagram	25
Figure 6.	Design of Pitas Point Artificial Reef	27
Figure 7.	Design of Marina Del Rey Artificial Reef #2	29
Figure 8.	Design of artificial reefs at Santa Barbara, Oceanside, and Pacific Beach	30
Figure 9.	Design of Santa Monica Bay Artificial Reef	32
Figure 10.	Design of Topanga Artificial Reef	33
Figure A4-1.	Proposed Santa Barbara Artificial Reef Fisheries Habitat Enhancement Area	55
Figure A4-2.	Proposed Santa Monica Artificial Reef Fisheries Habitat Enhancement Area	56
Figure A4-3.	Proposed Marina del Rey Artificial Reef Fisheries Habitat Enhancement Area	57
Figure A4-4.	Proposed Redondo-Hermosa Artificial Reef Fisheries Habitat Enhancement Area	58
Figure A4-5.	Proposed Bolsa Chica Artificial Reef Fisheries Habitat Enhancement Area	59
Figure A4-6.	Proposed Newport Beach Artificial Reef Fisheries Habitat Enhancement Area	60
Figure A4-7.	Proposed Oceanside Artificial Reef Fisheries Habitat Enhancement Area	61
Figure A4-8.	Proposed Mission Bay Park Artificial Reef Fisheries Habitat Enhancement Area	62

Figure A5-1. Planned location of Carlsbad Artificial Reef.......................... 64

Figure A5-2. Scaled drawing of planned Carlsbad Artificial Reef in relation to kelp beds and Batiquitos lagoon (kelp bed information based on 1988 aerial survey)................................ 65

Figure A5-3. Plan view of Carlsbad Artificial Reef.................................... 66

Figure A5-4. Planned location of Palos Verdes Wreck Reef......................... 67

Figure A6-1. Locations of Pendleton Artificial Reef (PAR), Las Pulgas Reef (LPR), and Torrey Pines Artificial Reef (TPAR)............. 71

Table 1. Proposed Artificial Reef Fisheries Habitat Enhancement Areas (FHEA)... 14

Appendix 1. Fish and Game Code, Sections 1700-1701 - Conservation of Aquatic Resources.. 40

Appendix 2. Fish and Game Code, Article 2, Sections 6420-6425 - Artificial Reefs..................................... 42

Appendix 3. Artificial Reefs Along the California Coast- November 1990 (listed by county from north to south)........... 45

Appendix 4. Proposed Locations and Configurations of Artificial Reef Fisheries Enhancement Reserves in Southern California... 54

Appendix 5. Planned and Proposed Artificial Reefs Along the Southern California Coast.. 63

Appendix 6. PAR - A Pilot Developmental Reef.. 68

Appendix 7. List of Common and Scientific Names................................... 74

FOREWORD

Hard-bottom (reef) substrate provides habitat for a multitude of nearshore fishes, invertebrates, and plants. Included are many species of direct and indirect importance to sport and/or commercial fisheries and to esthetic uses of the nearshore environment.

This report sets forth a plan for enhancing stocks of marine sport fishes, using artificial reefs. It presents the procedures used by the California Department of Fish and Game (CDFG) for designing, siting, and constructing, reefs. It also presents plans for future artificial reef studies and presents the laws which authorize CDFG to engage in habitat enhancement.

The Artificial Reef Plan was written primarily for resource managers who wish to develop a comprehensive long-term reef program for fisheries enhancement. Consequently, common names of organisms were used whenever possible, English measurements were emphasized, and literature citations and statistical data were kept to a minimum. A list of the common and scientific names of organisms discussed in the text is included.

A detailed report of scientific studies conducted at Pendleton Artificial Reef (PAR) from 1980-1986 provides much of the basis for this report.

INTRODUCTION

Artificial reefs have long been recognized as valuable for attracting fishes. Such reefs have been used to improve the fish catch in Japan for over 500 years and in the United States for over 140 years (Ino 1974; Elliott 1846). Nevertheless, the characteristics of reefs which attract fishes and those which contribute to fish reproduction and growth (fish production) are not clearly understood. Knowledge of the relationship of reef structure and placement to the life history of associated biota is necessary for improving habitat enhancement techniques and fisheries management strategies.

The California Department of Fish and Game (CDFG) is authorized by State law "....to encourage the conservation, maintenance, and utilization of the living marine resources of the ocean...for the benefit of all the citizens of the state...." (Fish and Game Code, Sections 1700-1701 [Appendix 1]). This paper discusses the development and implementation of the Department's Nearshore Sport Fish Habitat Enhancement Program (NSHEP) plan to: 1) rehabilitate and enhance stocks of certain living marine resources, 2) improve recreational fishing opportunities, and 3) evaluate the potential of using artificial reefs as mitigation/compensation for the loss of certain habitat and associated living resources.

Reefs provide critical habitat for sheltering, foraging, or nesting of many fishes and for growth of a multitude of motile and sessile invertebrates. Reefs placed in appropriate locations and depths can also furnish habitat for growth of giant kelp which, in turn, provides habitat for nearly 800 species of fishes and invertebrates (McPeak *et al.* 1988). Included among the important sport fishes occurring on man-made reefs in southern California are kelp bass, barred sand bass, sheephead, surfperches, cabezon, sculpin, and various species of rockfish. Blacksmith, garibaldi, plainfin midshipman, and other fishes nest directly on man-made reefs such as Pendleton Artificial Reef (PAR); the young use the reef as a nursery area, and the adults spend much of their lives associated with reefs. Important invertebrate species including lobster, sea urchins, crabs, and scallops often occur in substantial numbers on man-made reefs, depending upon reef placement, configuration, and season.

Many of the fishes inhabiting man-made and natural reefs feed, to a large extent, upon reef-associated invertebrates, fishes, and plants. For example, barred sand bass, a common inhabitant of reefs, often feed upon shrimp, crab, octopus, squid, and brittlestars, as well as reef-associated fishes such as plainfin midshipman, and non reef-associated fishes such as anchovy and jack mackerel Black perch, another common inhabitant of reefs, forage primarily upon reef-dwelling invertebrates such as barnacles, bryozoans, worms, amphipods, and other small invertebrates common on quarry rock reefs (North and Hubbs 1968; Turner *et al.* 1969; Feder *et al.* 1974).

Kelp on man-made reefs provides additional habitat and forage for sport fishes such as opaleye and halfmoon, and for many invertebrates. In fact, natural reefs of low-to-moderate relief, with kelp, will support two to three times the standing crop of fishes than will similar reefs without kelp (Quast 1968b). CDFG observations suggest that biotic communities relate to natural reefs and to quarry rock reefs (of like configuration, location, and depth) in a similar manner, and an objective of the Artificial Reef Plan is to investigate the relationship of sport fishes to associated reef communities.

Intensive human use of nearshore waters and associated resources, particularly off southern California, has contributed to the widespread deterioration and/or loss of reef and kelp forest habitat, to the disruption of certain trophic relationships, and to the decline of many living marine resources. Such changes first became evident in the mid-1940's and were related to coastal development, ocean sewage discharges, and intensive fishing pressure and related increases in numbers of herbivorous sea urchins. Since that time, the impact of human use on the marine environment has increased significantly. (California State Water Quality Control Board 1964; Grigg and Kiwala 1970; Grigg 1978; Peterson 1974; Devinney and Volse 1978; Tegner 1980; Wilson and North 1983; Wilson and McPeak 1983).

In 1958, CDFG began a pilot study to determine the feasibility of improving the nearshore marine habitat and increasing sport fishing opportunity by constructing artificial reefs. Work began with the construction and study of three experimental reefs: two in Los Angeles County (off Paradise Cove and off Redondo Beach) and one in Santa Barbara County (off Rincon Pt.). Built from materials of "opportunity", such as automobile bodies and streetcars, these reefs attracted substantial numbers of fishes; one reef provided habitat, at least temporarily, for giant kelp (Carlisle *et al.* 1964).

Based on information from this study, three reef complexes were designed and constructed in 1960 to test the suitability of various materials as habitat for fishes, invertebrates, and plants (Turner *et al.* 1969). These "multiple component replication reefs" were placed in Santa Monica Bay near the cities of Malibu, Santa Monica, and Hermosa Beach. Each reef complex consisted of four sub-reefs (modules) of equal volume. Each module was constructed of a different material: quarry rock, specially designed concrete fish shelters, automobile bodies, and streetcars (Figure 1). It was found that quarry rock had the least effect on surrounding sediments and was the most cost effective material for attracting fishes. The concrete fish shelters worked well, at first, but sedimentation eventually reduced their effectiveness. Automobile bodies and street cars proved unsatisfactory for long-term habitat enhancement because they deteriorated rapidly. Tires were tested in 1960 and again in 1975, but were unsuitable because many were moved about by large sea swells and ended up on adjacent beaches (despite attempts to anchor them) and because toxic materials such as polybutadienes and zinc may be released from tires into the environment.

These investigations also provided insight into the early stages of biotic succession on man-made habitats and information on the natural history of fishes, invertebrates, and plants associated with reefs. Because of the success of these early reefs, CDFG constructed 15 additional recreational fishing reefs and augmented 13 existing reefs in southern California between 1962 and 1979 (Figure 2). Most of these reefs consisted of four to six low relief modules that were 2-4 ft (0.6 m to 1.2 m) high, spaced approximately 60 ft (18 m) apart, and located at depths of 60-72 ft (18 m to 22 m) mean lower low water (MLLW). The primary materials used were, in order of preference, quarry rock, concrete rubble, and heavy iron objects such as barges and ship hulls. Quarry rock reefs were also constructed adjacent to seven heavily used fishing piers from Venice (Los Angeles County) to Oceanside (San Diego County).

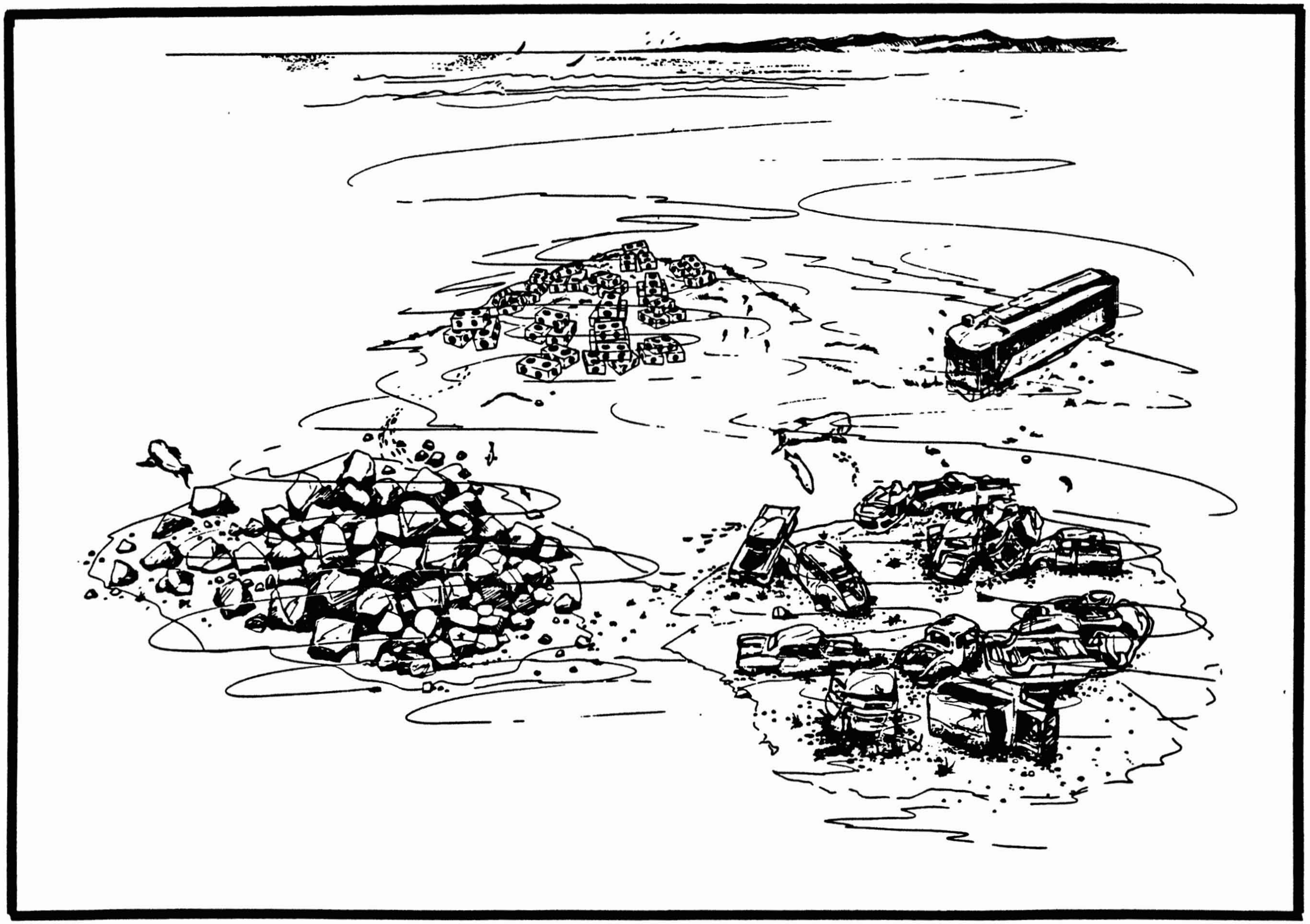

Figure 1. Multiple component replication reef (from Turner, Ebert, and Given 1969)

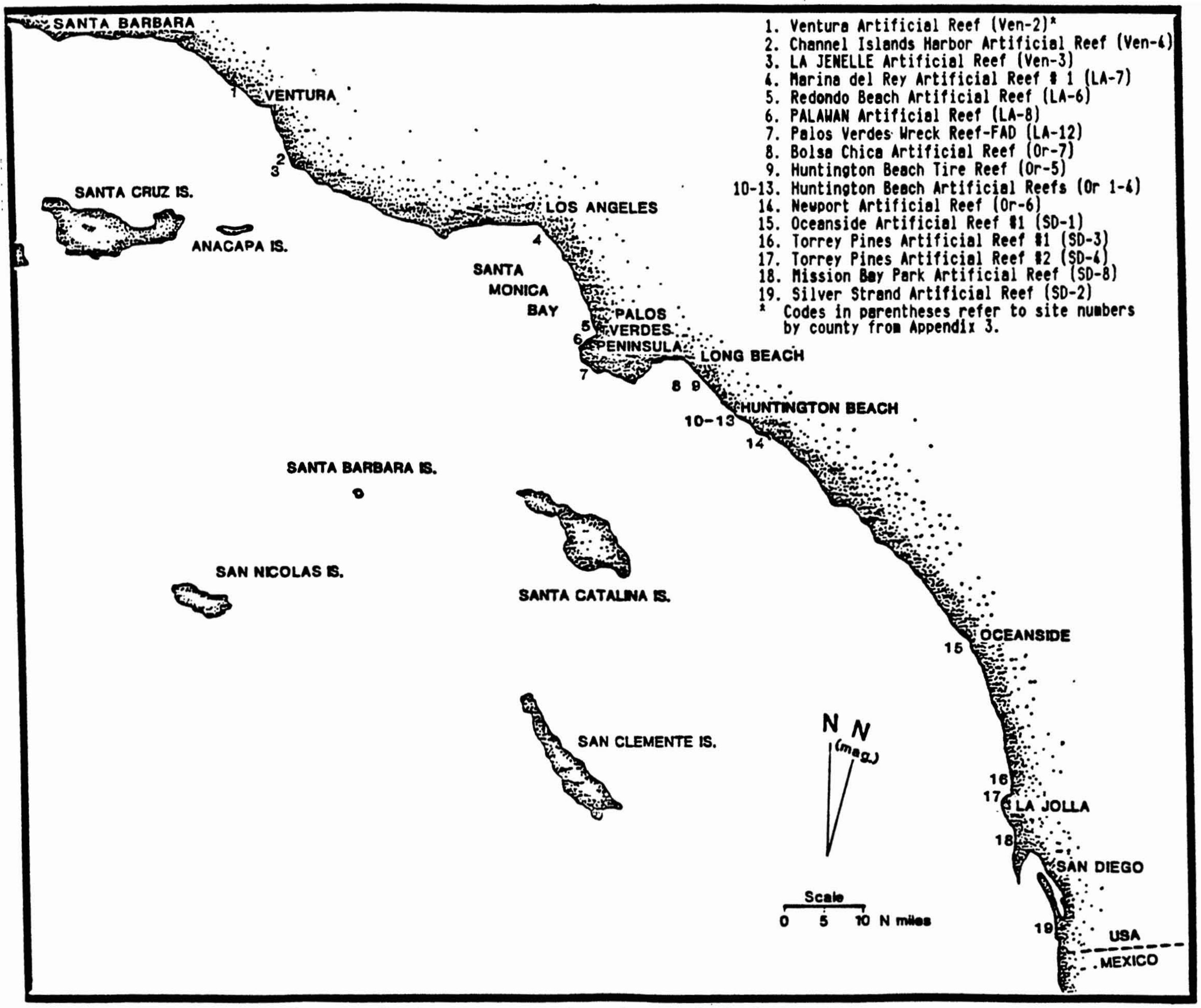

Figure 2. Locations of the recreational artificial fishing reefs in southern California.

Deterioration of kelp forests in Los Angeles and San Diego Counties became a serious problem in the mid 1960's; in 1970, CDFG redirected its habitat enhancement efforts to emphasize kelp restoration along Palos Verdes Peninsula (L.A. County). This work continued until 1979, when the Palos Verdes kelp forests were well on their way to recovery.

In 1979, Southern California Edison (SCE), an electric utility company, became interested in developing techniques for addressing possible effects of the San Onofre Nuclear Generating Station (SONGS) on the local kelp forest community. Aware of the marine habitat enhancement work of CDFG, SCE offered to pay for constructing and studying an artificial reef to test the acceptability of using such reefs to replace kelp forest communities damaged by power plant operation and to improve reef design for enhancing sport fish habitat. Several conditions were placed on the proposed project by SCE: 1) the reef must be located between Dana Point (Orange County) and Oceanside (San Diego County); 2) it must be outside the projected influence of SONGS; 3) it must cost no more than $250,000; and 4) it must be "state of the art" and designed to provide habitat for giant kelp.

In 1980, CDFG and SCE entered into a formal agreement to design, construct, and study Pendleton Artificial Reef (PAR) in northern San Diego County (Figure 3-#12, and Appendix 1). To carry out this agreement, CDFG formed the Nearshore Sport Fish Habitat Enhancement Program (NSHEP) and shifted emphasis from kelp restoration back to artificial reefs. PAR was constructed in the fall of 1980.

The quest for new information on artificial reefs also led to a joint sponsorship, by CDFG and SCE, of the Third International Artificial Reef Conference in Newport Beach, California during November 1983. Conference participants acknowledged the potential of artificial reefs for habitat enhancement and emphasized the importance of identifying and elucidating the mechanisms by which enhancement occurs (Buckley *et al.* 1985; Bohnsack and Sutherland 1985).

In 1983, the NSHEP staff began developing a plan to improve nearshore recreational fishing opportunity by constructing "state of the art" fishing reefs. For purposes of discussion, these are designated as "developmental" reefs, "production" reefs, and "fish attracting devices" (FADs). While both developmental and production reefs were designed primarily to increase production (change of biomass over time) of living marine resources and to increase fishing opportunity, developmental reefs are often more complex in structure and have a secondary purpose--to answer questions concerning the interactions of biotic communities with man-made reefs. The fundamental designs for developmental and production reefs were based on over 86 "biologist-years" of studies and observations of biota associated with both natural and man-made habitats in the southern California bight.

Developmental reefs are intended to develop better techniques for increasing production of living marine resources through scientific investigations of reef design and function. The Pitas Point Artificial Reef and the Marina del Rey Artificial Reef #2 were constructed in 1984 and 1985, respectively, as developmental reefs (Figure 3-#3 and #9).

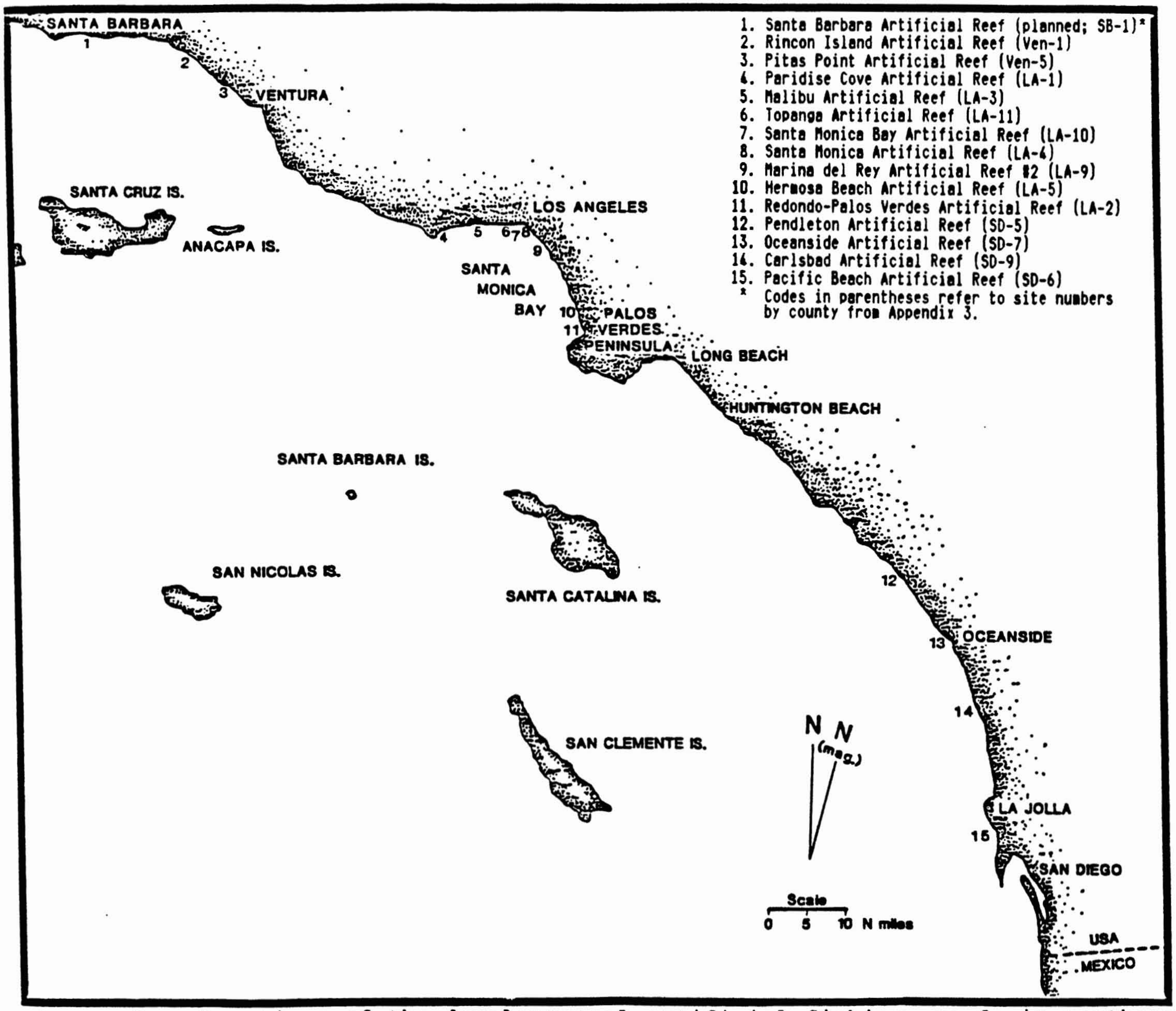

Figure 3. Locations of the developmental artificial fishing reefs in southern California.

Production reefs are primarily intended to enhance the production of living marine resources and fishing opportunity. Such reefs are generally built from "materials of opportunity" such as high quality concrete rubble or quarry rocks, often at little or no cost to the state. The designs, locations, and depths of production reefs are "state of the art" and based, in part, upon information obtained from CDFG studies and observations, literature review, and upon human use criteria discussed, in the section entitled "Artificial Reef Plan".

Fish Attracting Devices, in contrast, are constructed to attract sport fishes and increase the catch without necessarily contributing to an increase in standing crop.

Recognizing the potential of artificial reefs for enhancing sport fish habitat and catch, California Legislature enacted Assembly Bill 706 (Fish and Game Code, Article 2, Section 6420-6425) in 1985 (Appendix 2). This legislation formalized CDFG's status as the lead agency in California's reef building process. It authorized CDFG to construct additional reefs and administer reef studies with cooperation and assistance from the California university systems and other appropriate academic institutions and organizations. It also required that information from reef studies be used to formulate long-term plans for improving nearshore fisheries production, and specified several potential sources for funding reef construction and studies.

With legislative authorization CDFG was able to obtain additional funding, and progress on NSHEP's reef plan accelerated. In fiscal years 1985-86 and 1986-87, CDFG allocated 1.3 million dollars of legislative special appropriation funds to build five developmental fishing reefs of quarry rock; two in San Diego County, two in Los Angeles County, and one in Santa Barbara County (Figure 3 - reef #13, #15, #6, #7, and #1, respectively).

ARTIFICIAL REEF PLAN

The following section provides an outline for defining the purposes of reef construction; gathering information pertinent to reef placement and design; selecting a reef site; designing a reef; preparing a project narrative; obtaining permits and approvals to build a reef; developing a general artificial reef permit and a system of fisheries habitat enhancement areas. The plan also outlines procedures for implementing reef construction, mapping reefs, and conducting short and long-term studies of reef biota (Figure 4).

I. Preconstruction Activities

A. Defining the Purpose.

The purpose for constructing an artificial reef will, to a great extent, determine its placement and structure. If, for example, the purpose is to enhance habitat for kelp-associated sport fishes and invertebrates, a reef should be built in a location and a depth, comprised of materials and configured to encourage development of a stable stand of giant kelp, and to provide habitat for other reef-associated species. Reef placement and configuration should also be compatible with local biota and human activities.

The following purposes have been identified for constructing reefs:

1. Sport Fish Habitat Enhancement - Augment standing stocks of sport fishes and associated fishes, invertebrates, and/or plants (particularly giant kelp) by increasing reef habitat.

2. Sport Fish Catch Enhancement - Increase catch of sport fishes without necessarily increasing their standing stocks, as in the case of Fish Aggregating Devices (FADs).

3. Reef Study - Increase the opportunity for scientific evaluation of reef structure, placement, and biota to improve the structure and placement of future reefs.

4. Multi-Purpose - Reefs constructed for combinations of the purposes listed above.

5. Mitigation - Includes reefs built to mitigate for impacts on reef/kelp habitat and associated species due to development projects in the nearshore area.

Reef planning, construction, and evaluation activities described in this plan will be primarily directed toward multi-purpose reefs. Construction of FADs or reefs for mitigating impacts of human activities could entail the use of different materials, reef placement, and/or evaluation procedures.

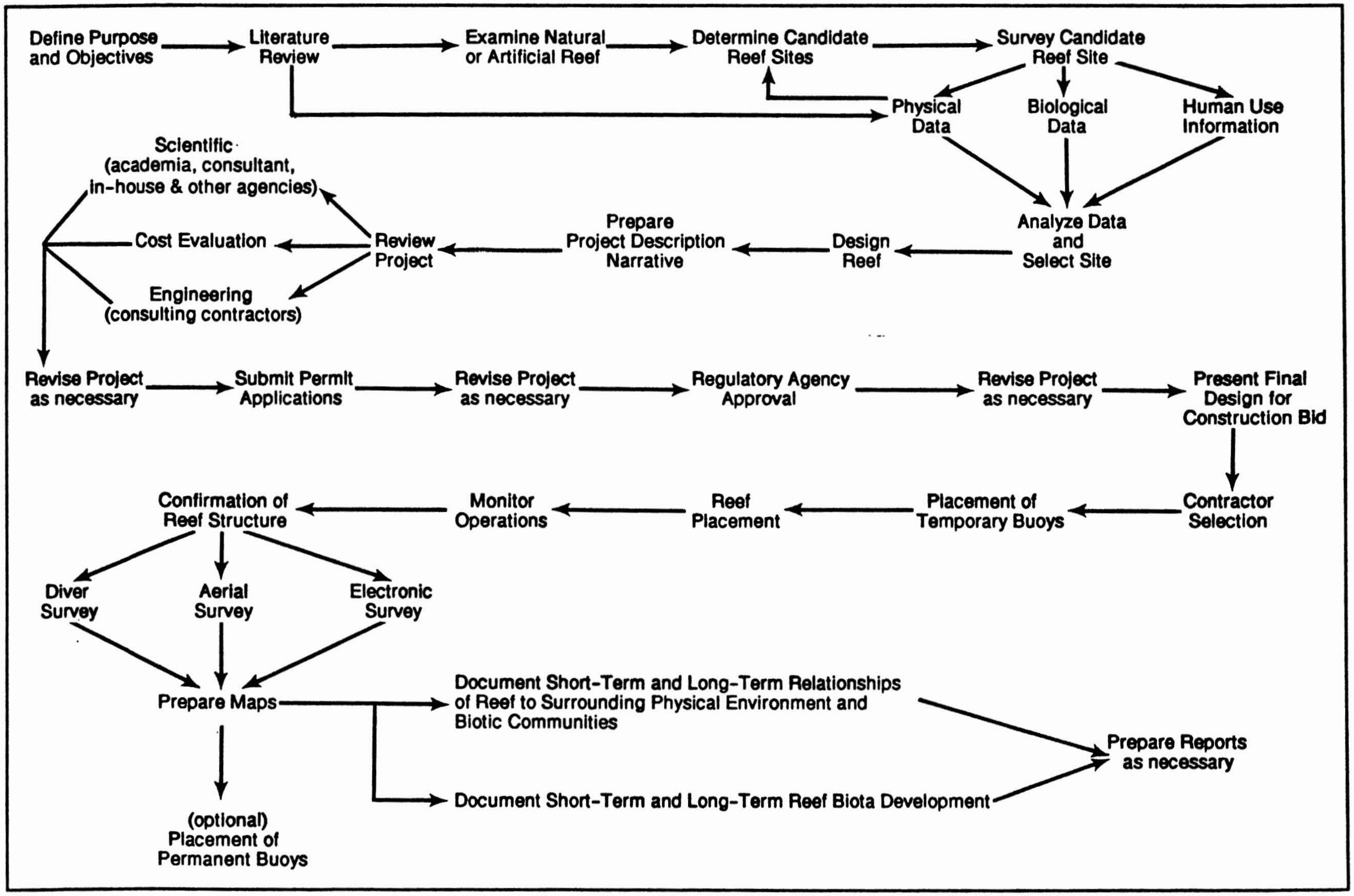

Figure 4. Artificial reef construction and studies flow chart.

B. Information Gathering

Obtain physical, biological, and human use data for designing and placing reefs and for determining the effects of such reefs on local biotic communities. This information should be obtained for target areas (potential reef sites and reference reefs). Knowledge of the physical and biological conditions that exist at potential reef sites and at reference reefs1/ is useful for predicting interactions between a proposed reef and the surrounding environment, the nature of reef biota at successional equilibrium, and the long-term contribution of the reef and associated biota to sport fisheries.

Much of the physical and biological information pertaining to target areas may be obtained from existing sources such as scientific journals and government reports. Environmental impact reports (EIRs), environmental impact statements (EISs), and other studies required by regulatory agencies from waste dischargers, utility companies, and developers often provide useful information. Consultation with scientists from government agencies, universities, and private enterprise is also useful.

Information not obtained during the literature search and from consultations should be obtained through diving surveys or other field operations.

The following information has proven useful for selecting reef sites and for preparing reef designs, project narratives, and permit applications:

1. Physical Information - Compile information describing the physical characteristics of target areas. Data should include the following:

    a. Location - Determine the latitude and longitude of the proposed artificial reef site and/or the boundaries of the Fishery Habitat Enhancement Area (FHEA), and the distance and direction from shore and from local ports or marinas, headlands, cities, or other conspicuous reference points.

    b. Water depth - Determine the depth of the potential reef site and/or of the boundaries of the FHEA.

    c. Substrate Description - Obtain data describing substrate characteristics in target areas. Such information is useful for determining if a potential site is suitable for reef construction and or projecting the possible effects of a reef on surrounding substrate.

1/ A reference reef should be a natural reef or a man-made reef at successional equilibrium (at least 10 years old). This reef should be in the general vicinity of a potential reef site and should support a biotic community which includes fishery-targeted species. The developmental reefs were designed to provide reference information by affording investigators opportunity to evaluate the nature of effects of reef placement and configuration on the reef biota (particularly sport fishes).

c. Substrate Description (cont).

1). Potential reef sites - Note sediment type. Estimate sediment sand grain size, ripple marks, load-bearing capacity, depth of sediment overburden, proximity and description of nearby reefs, and sources of sedimentation. Additional information, useful for selecting a reef site in depths less than 40 ft (12m), includes the local rates of sediment deposition and erosion and the depth of the closure zone (area in which the major portion of longshore sand transport occurs).

2). Reference reefs (if pertinent) - Estimate the area, relief, rugosity, substrate type, and rock versus sand cover on such a reef; provide a description of sediments and sand scour adjacent to the reef; and provide a simple description of and the approximate distance to local reefs.

d. Oceanic conditions - Investigate sea conditions (swells, wind waves, and currents) and upwelling characteristics in potential reef sites to assure placement of the reef in a safe and productive area.

2. Biological Information - Compile information describing the biotic communities occurring in target areas, with special emphasis on sport fishes. The data should include the following:

a. Epibenthic and/or Benthic Communities - Determine species composition, percent cover, and/or density of conspicuous invertebrates and plants (as needed) by diver surveys, video recordings, and photography.

b. Fishes - Determine species composition, size composition, and make relative abundance estimates of fishes using the above methods. Fathometer surveys can augment relative abundance information.

c. Natural History Observations - Note sheltering, foraging, and nesting activities of selected reef fishes and invertebrates, where applicable.

3. Human activities - Compile information describing activities within and near potential reef sites so that the reef can be designed to interact minimally with such uses.

a. Vessel traffic and anchorages - Document movement and anchoring of vessels in potential reef sites. Information may be obtained from the National Oceanic and Atmospheric Administration (NOAA) navigation charts and from the U.S. Coast Guard and other branches of the military, port and harbor districts, harbor pilots, yacht clubs, utility companies, oil companies, etc.

b. Recreational use - Document recreational activities (such as sport fishing, scuba diving, sailing, etc.) occurring in or near potential reef sites. Review CDFG landing records and logs to obtain general information on sport fish catch and effort. Contact local angler organizations, diver councils, commercial passenger sport fishing vessel operators, sport fish landing operators, local county Fish and Game Commissions, lifeguards, and Parks and Recreation department personnel to obtain pertinent information.

c. Commercial fishing and mariculture - Document the location and intensity of commercial fisheries which occur in potential reef sites. Of particular interest are gill net, drift net, trammel net, purse seine, and trawl fisheries; lobster and crab trapping; and mariculture operations. Review CDFG landing records, logs, and mariculture permits. Contact local commercial fishing associations and the University of California - Sea Grant advisor if further information is necessary.

d. Areas of Special Biological Significance (ASBS), Marine Reserves or Refuges, or areas of importance to scientific studies - Determine if any ASBS exist, or if any ongoing scientific studies are underway in or near potential reef sites, and assess impacts of interactions. Information may be obtained from CDFG Wildlife Protection Division (Sacramento), universities, private consulting firms, and/or regulatory agencies such as the regional water quality control boards and the California Coastal Commission (CCC). Refer also to The Marine Life Refuges and Reserves of California (Smith *et al.* 1989).

e. Discharge of domestic and industrial wastes, power plant effluents, and dredge spoils -

   1). Determine the location of outfalls, nature of discharges and level of treatment, discharge rates, depths, zones of initial dilution, and direction of movement of effluents. Information may be obtained from NOAA navigation charts, Southern California Coastal Water Research Project personnel and reports, regional water quality control boards, sanitation districts, and CDFG Environmental Services Division (ESD) personnel.

   2). Determine the location of dredge spoil disposal sites, nature of materials, amount and frequency of disposal, direction of movement, and area of influence. Information may be obtained from NOAA navigation charts, port and harbor districts, U.S. Army Corps of Engineers, and ESD.

f. Extraction of mineral resources (e.g., oil) - Determine the location of mineral leases and oil platforms, pipelines, and power and communication cables. Information may be obtained from NOAA navigation charts, State Lands Commission (SLC), Minerals Management Service, and oil companies.

g. Areas of historical or cultural significance (e.g., shipwrecks and archaeological sites) - Information may be obtained from the SLC, the CCC, local museums of natural history, and historical societies.

C. Site Selection

Among the most critical steps in the reef-building process is selecting a reef site. Of particular importance are geographic location and depth. For example, if the reef is to provide habitat for kelp-associated sport fishes, the site selected should be located near a stable kelp forest and at a depth in which giant kelp will grow. Other physical, biological, and human factors must also be considered. See the General Artificial Reef Permit section (page 15).

To facilitate selection of the most suitable reef site, an evaluation matrix should be devised so potential sites can be ranked according to their suitability for accomplishing desired fishery enhancement objectives. Using this system, physical, biological, and human use factors can be evaluated. Variables should be weighted numerically according to their projected contribution to and impacts on the proposed reef, the local environment, and human activities (Table 1). Sites with the highest total scores would be the primary candidates for reef construction.

D. Reef Plans

The physical structure of a reef is an important factor contributing to its usefulness as a sport fish habitat enhancement tool. A reef should be designed to provide shelter, forage, nesting, and nursery areas for reef associated sport fishes. It should also provide habitat for other fishes, invertebrates, and (if the depth is appropriate) plants, which are the basis of a food web which supports stocks of reef associated sport fishes. Important variables in reef structure include the number and spacing of sub-reefs (modules), module height and area, and type and size of component materials. In the case of a quarry rock reef for kelp and associated sport fishes, CDFG reef studies suggest that reef modules should range from 2.5 to 5 ft (0.8 to 1.5 m) in height and should have an area of approximately 1.24 acres (0.5 hectare) - minimum 0.68 acre (0.28 hectare). Nominal rock diameter should be approximately 1.5 ft. (0.4 m) - minimum 1.0 ft (0.3 m). Specifications for reef structure and placement may vary in relation to purpose and to local conditions.

Plans for reefs should include information about the potential reef site such as geographic location, area, depth, and substrate characteristics and about the reef structure, including type and size of materials, module configuration, and module spacing. Plans should be discussed with a marine construction engineer to determine if the proposed reef is technologically and economically feasible to build. The following figures should be included in the reef plan:

1. Map showing the <u>regional</u> location of the reef site in reference to major geographical features (i.e. the southern California Bight, Los Angeles, San Diego etc.).

Table 1. Proposed Artificial Reef Fisheries Habitat Enhancement Areas (FHEA).

Area Name	Reef Nos.	Site Designation*	Proposed Area (Nmi²/Acres)	Corner and Center Coordinates
Santa Barbara	SB-1	A	0.61/515	34°23'30"N; 119°35'11"W 34°24'06"N; 119°34'36"W 34°23'39"N; 119°33'41"W 34°23'16"N; 119°34'07"W
				34°23'16"N; 119°34'17"W
Santa Monica	LA-4 LA-4a LA-10	B	1.60/1,370	34°00'17"N; 118°33'22"W 33°59'42"N; 118°32'09"W 34°01'25"N; 118°32'48"W 34°00'52"N; 118°31'28"W
				34°00'33"N; 118°32'28"W
Marina del Rey	LA-7 LA-7a LA-7b LA-9	C	1.40/1,200	33°57'48"N; 118°30'14"W 33°58'32"N; 118°28'57"W 33°57'41"N; 118°28'14"W 33°56'57"N; 118°29'32"W
				33°57'44"N; 118°29'14"W
Redondo/Hermosa	LA-5 LA-5a LA-6 LA-6a-e	D	1.20/1,025	33°51'24"N; 118°25'21"W 33°51'38"N; 118°24'28"W 33°50'09"N; 118°23'55"W 33°49'54"N; 118°24'48"W
				33°50'47"N; 118°24'38"W
Bolsa Chica	Or-7	E	0.26/220	33°39'39"N; 118°06'04"W 33°39'34"N; 118°05'42"W 33°38'42"N; 118°06'25"W 33°38'35"N; 118°06'02"W
				33°39'02"N; 118°06'05"W
Newport Beach	Or-6 Or-6a-c	F	0.14/120	33°35'55"N; 117°58'22"W 33°36'41"N; 117°57'50"W 33°36'26"N; 117°57'16"W 33°35'38"N; 117°57'47"W
				33°36'10"N; 117°57'50"W
Oceanside 1	SD-1 SD-1a	G	0.17/145	33°11'01"N; 117°25'10"W 33°11'17"N; 117°24'39"W 33°10'50"N; 117°24'58"W 33°10'06"N; 117°24'30"W
				33°11'04"N; 117°24'48"W
Oceanside 2	SD-7	H	0.68/575	33°11'43"N; 117°26'05"W 33°11'18"N; 117°25'12"W 33°12'07"N; 117°26'25"W 33°12"42"N; 117°25'31"W
				33°12'15"N; 117°25'48"W
Pacific Beach	SD-6	I	0.40/340	32°47'29"N; 117°17'19"W 32°47'05"N; 117°17'07"W 32°47'48"N; 117°16'18"W 32°47'26"N; 117°16'08"W
				32°47'29"N; 117°16'42"W
Mission Bay Park	SD-8	J	0.80/512	32°46'37"N; 117°17'00"W 32°46'30"N; 117°15'51"W 32°45'44"N; 117°15'54"W 32°45'50"N; 117°17'06"W
				32°46'10"N; 117°16'30"W

* - Site designation used in Appendix 4.

2. Map showing the specific location, depth, and scale of the reef site and modules in reference to local geographical features (7.5 min. U.S. Geological Survey maps are useful).

3. Drawings depicting plan, side, and oblique views of the reef and component modules with size and space measurements indicated.

E. Project Narrative

1. New Reefs - A project narrative should be prepared for any new reef project. Such a document should state the long-term and short-term objectives of the project and should address the impacts (positive and negative) of the reef on its environment and on the human activities in the proposed site, as outlined in Sections A and B. This document should also provide details on the geographic location, area, depth, structure, and total amount of materials required for the proposed reef, as outlined in Sections C and D.

2. Reef Augmentations - A new project narrative should not be required if reef augmentations are carried out within the parameters specified in the original document. The narrative should, however, be amended if significant changes occur in reef plans or in local human activities since the original document was prepared. Such changes include augmentations that exceed the amount of reef materials planned and/or involve increases in the original area delineated for reef construction. Significant changes in local human activities such as major modifications in waste discharges, vessel traffic, etc. would also provide a basis for amendments to a project narrative.

F. Permits and Approvals

The "California Artificial Reef Program" of CDFG (also known as the Nearshore Sport Fish Habitat Enhancement Program) is responsible for administering placement and studies of artificial reefs in State waters as authorized by Fish and Game Code Article 2, Sections 6420-6425 and Sections 1700-1701 (Appendix 2). Consequently, CDFG is the lead agency involved in the process of obtaining permits and approvals for reef construction. This is a complex process and often requires six months to complete.

1. Permit Application and Approval process - Once a suitable site has been selected, a reef plan formulated, and a project narrative prepared, the permit application and approval process should be initiated. Permits must be obtained from the U.S. Army Corps of Engineers, the CCC, and the SLC. Approvals must be obtained from the appropriate regional water quality control board, adjacent cities (in the case of granted lands), and the U.S. Coast Guard. Reefs must also conform to requirements of the California Environmental Quality Act.

   To obtain permits, completed application forms and a copy of the project narrative are sent to appropriate regulatory agencies. To obtain approvals for reef construction, project narratives and a cover letter requesting project approval are sent to appropriate agencies.

2. General Artificial Reef Permit (GARP) - The prolonged time interval between the notice of availability of "free" reef materials and the receipt of all permits and approvals for reef construction, frequently results in the loss of materials which could, otherwise, have been used to build excellent fishing reefs. To solve this problem, CDFG has prepared a GARP. This document will provide guidelines for placement and construction of reefs and will form the basis for a cooperative agreement among the various agencies for pre-approved reef augmentations in specific locations known as fishery habitat enhancement areas (FHEAs). These will be sections of ocean bottom designated especially for the enhancement of living marine resources (particularly sport fishes) through artificial reef construction. The locations and configurations of FHEAs are based on the presence of existing man-made reefs, proximity to user groups, and anticipated need for habitat enhancement (Table 2, and Appendix 4). All reefs constructed within these enhancement areas must comply with guidelines stated above. New FHEAs may be created, boundaries of existing areas modified, and new reefs constructed, with approval of regulatory agencies, when future needs arise.

   The objectives of GARP are to: 1) expedite and facilitate the process of obtaining reef permits; 2) minimize potential controversial interactions between artificial reefs and other uses of the marine environment; and 3) set standards to ensure long-lasting and productive reefs.

   The GARP assures that the environmental characteristics and important human uses of potential reef sites are considered prior to reef construction (discussed in Section B). These include the potential interactions between the reefs and:

   nearby natural habitats and associated biotic communities, ASBS, (e.g. marine reserves or refuges);

   physical oceanographic phenomena, e.g. sand transport, reef subsidence or burial, etc.;

   vessel traffic and anchorages for recreational, commercial, and military vessels;

   sport fishing, scuba diving, and other recreational uses;

   commercial fishing and mariculture;

   extraction of mineral resources, such as oil;

   discharge of domestic and industrial wastes, or dredge spoils;

   areas of historical or cultural significance, e.g. shipwrecks, archaeological sites, etc.

To facilitate access, reefs will be located, whenever possible, within 7 nautical miles (13 km) of ports or marinas, as a convenience for sport fishing. Reefs constructed for mitigation or for study purposes (rather than solely for recreational fishing) may be built in more distant locations if necessary to accommodate mitigation requirements or scientific objectives.

To ensure longevity and to avoid possible negative environmental impacts, reef materials must:

persist in the marine environment for a minimum of twenty years (automobiles, aluminum, wood structures, etc. are prohibited);

have at least twice the specific gravity of sea water or be intrinsically and permanently weighted to prevent movement; and

be clean and free of contaminants (asphalt, pavement, and vehicle tires are prohibited).

Rock used for constructing artificial reefs should be quarried, not river-run materials. The angularity of quarried rocks helps to increase the stability of a reef's structure.

Permanent marker buoys should be installed and maintained at reefs. CDFG encourages local government agencies or user groups to purchase and maintain such markers.

II. Construction

Once all permits and approvals have been obtained, final preparation for reef construction can begin. Proper planning and implementation of construction operations are crucial to the success of any reef development project.

A. Funding

The funding sources for reef construction in California have included: Wildlife Conservation Board, Federal Aid to Sport Fish Restoration, state legislative special appropriations, state ballot propositions, county fish and game commissions, power companies, port and harbor districts, oil companies, etc (Appendix 3). Other sources can also be used (Appendix 2).

B. Contractor Selection

The contractor should be selected after examining qualifications and experience with similar projects, as well as the competitive bid. This will help to ensure that reefs are constructed according to plan and that the most materials are obtained for the money.

C. Plan Confirmation

The reef building contractor should be provided with a copy of the project narrative and reef plans. Information on the design, location, and construction of the reef should be thoroughly detailed in the contract.

Procedures for verification and correction of reef structure should also be specified. All designs, procedures, and conditions of the contract should be discussed with the contractor prior to reef construction.

Any changes in reef design or placement required by regulatory agencies, should be discussed with the contractor, prior to beginning construction, to confirm what impact the changes could have on the reef building process.

D. Scheduling

The optimum time to construct quarry rock reefs in southern California extends from August to November, when oceanic and weather conditions are relatively mild. During this period, builders can better control deployment of reef materials to meet contract specifications. Verifying that reefs, "as built," meet plan specifications and correcting deficiencies in reef structure, should they be found, are also more easily accomplished during this period.

E. Reef Placement and Verification of Reef Structure

To facilitate precise placement and configuration of reef modules, the contractor should be required to place temporary buoys demarcating the planned positions of modules. As construction proceeds, modules should be examined to confirm that they meet design specifications. To facilitate corrective work, if required, modules should be surveyed as soon as possible after reef construction, preferably while the temporary marking buoys are still in place. The marking buoys on modules simplify the confirmation survey process, by making the modules easier to find, and they simplify the process of obtaining accurate Loran positions of modules for future reference.

On smaller reefs, within the 80 ft (24 m) depth contour, size measurements obtained by diving surveys should be adequate for confirming the reef configuration. Aerial surveys conducted from August to November, when water transparency is generally high, also provide useful information on placement, orientation, and configuration of reefs in water depths less than 50 ft (15 m). Verification surveys form the basis for reef mapping procedures.

F. Reef Mapping

If funding allows, or if the reef is constructed for purposes of mitigation, it is recommended that the reef be mapped. Ideally, this process should involve a variety of data gathering methods including diving surveys, aerial photographs, sonar observations, echo sounding surveys, sub-bottom profiling, and radio-locating techniques. Information from these surveys should be used to generate a topographic map of the reef for future reference. This information could also be used to document changes in distribution of surrounding sediments, should additional surveys be conducted.

G. Reef Studies

Early development of biotic communities on artificial reefs in Santa Monica Bay was documented by CDFG biologists between 1960 and 1964 (Turner *et al.* 1969). They found that encrusting (turf) communities changed after reef construction and "felt that true animal succession" occurred among the encrusting species. They reported that fishes were attracted to the reefs within hours of construction and that the structure of the fish community changed between the first and third years "as resident species (i.e. gobies, sculpins, and rockfishes) increased in numbers and the reefs approached a natural equilibrium." These studies provided evidence that biotic communities on new reefs change with time until, "Ultimately (in about 5 years) a natural situation is attained and the plant and animal populations on man-made reefs exhibit fluctuations typical of 'natural' reef ecosystems".

Many parallels between the development of biotic communities at reefs in Santa Monica Bay were seen in CDFG studies at PAR from 1980-1986. For example, fishes were attracted to PAR within hours of construction as they were to reefs in Santa Monica Bay. In both locations, fish communities were similar during the first year and dominated by semi-resident fishes such as barred sand bass, black perch, and white seaperch. Resident fishes (which rely primarily on a reef for shelter and subsistence) appeared in the second and third years of PAR's existence as they did on reefs in Santa Monica Bay. Parallel development of turf communities, small attached invertebrates and plants, was also noted.

Some minor qualitative differences in structure of fish, invertebrate, and plant communities were noted on reefs in Santa Monica Bay and at PAR, however, such differences were attributable to location and depth factors. Thus, the overall similarity in development of biotic communities among the four reefs constructed in 1960 and 1980, in two different locations (approximately 70 nautical miles [130 km] apart), provides evidence that succession of biota on man-made reefs not only occurs in encrusting species but also occurs in fish communities. However, unlike the studies in Santa Monica Bay, which suggested that reef communities mature in about 5 years, studies at PAR suggested that communities on some southern California artificial reefs may require at least 10 years to attain successional equilibrium, depending upon reef location, depth, structure, and upon the character of local biota, etc. (CDFG 1983, 1984, 1985; Buckley and Hueckel 1985; Carter *et al.* 1985a, 1985b; Jessee *et al.* 1985; and Wilson and Lewis 1990).

Most studies of biota on artificial reefs have been conducted within 5 years of construction, when biotic communities are changing and are likely to be influenced as much by successional development as by seasonal or oceanic changes. (Carlisle *et al.* 1964; Turner *et al.* 1969; Carter *et al.* 1985a; Matthews 1985; Solonsky 1985; Ambrose and Swarbrick 1989; Anderson *et al.* 1989; Hueckel and Buckley 1989). Consequently, quantitative and qualitative estimates of the standing crop of reef communities and of the trophic relationships within these communities may not be representative of those occurring at successional equilibrium.

Food habits of reef fishes and of other consumers often reflect the availability of preferred food items on and near reefs with which they are associated (Turner *et al.* 1969; and Feder *et al.* 1974). Thus, the standing crop and productivity of reef fishes (to the extent they depend upon reef biota for sustenance) should vary in response to corresponding changes in the standing crop and productivity of the associated reef species. Such biota will, of course, vary relative to reef location, depth, material, configuration, area, and complexity of substrate. Water quality, seasonal changes in temperatures, light and nutrients, as well as meteorological and oceanic conditions are other important factors which will influence the standing crop and production of reef biota. Reef age is also an important factor.

Recognizing that major components of the biota associated with man-made reefs undergo successional change for approximately 5 to 10 years following reef construction, NSHEP biologists hypothesize that the estimates of the standing crop and the production/ aggregation characteristics of reef-associated sport fishes (and those of other fishes), may be affected by the state of successional development of a reef's biotic communities. Consequently, to obtain the best estimate of long-term reef productivity, CDFG recommends that resource managers direct their principal efforts toward quantifying the <u>long-term</u> biotic potential of artificial reefs for enhancing sport fish populations and less effort toward measuring the transient relationships of sport fishes to reefs during successional development.

Thus, studies of fishes and invertebrates associated with new reefs (within the first 3 to 5 years of construction) should be primarily qualitative in nature. Quantitative studies should be undertaken on reefs at or near successional equilibrium. The optimum time to begin such studies could vary from 5 to 10 years following reef construction and should be determined by comparing biota at man-made and reference reefs. Ideally, evaluation of biotic communities on man-made reefs should be undertaken on specially designed "developmental" reefs to facilitate the investigation of the effects of reef structure and placement on reef biota.

Since reefs constructed by CDFG are designed to function for many decades, the <u>major</u> emphasis of future biological studies will be directed toward evaluating reef communities which are at, or near, successional equilibrium. This approach will help to assure that reliable estimates are obtained of the long-term bioenhancement characteristics of man-made reefs.

The CDFG Artificial Reef Plan, therefore, includes (in chronological order):

periodic (short-term) qualitative observations of biota on new reefs to monitor the development of successional equilibrium of biotic communities - 1988 to 1997;

fish production and behavior studies (short-term) at selected artificial and natural reefs 1990 to 1997; and

quantitative studies (long-term) of biota on developmental reefs at successional equilibrium - 1998 to 2005.

The following study methods are suggested for short-term and long-term studies to determine the relationship of reef structure and biotic communities:

1. Observations on New Developmental Reefs (short-term)

   a. Physical surveys will be conducted to determine the reef configuration and the characteristics of surrounding sediments. Observations will include, but not be limited to, the following:

      1). Reefs - Depth, description of materials, length, width, height, and angle of slope of reef modules.

      2). Sediments - If present, type and depth of sediments upon which the reef was built, magnitude of scouring and/or subsidence of reef materials into sedimentary substrate, and other alterations of sediments adjacent to reefs.

   b. Biological Surveys - Since information gathered during the early stages of reef community development provides insight into the successional pathways leading to mature communities, CDFG plans to conduct qualitative (short-term) biological surveys periodically on new developmental reefs. Biological surveys will include the following:

      1). Turf Communities - Species composition and percent cover estimates will be made of conspicuous biota, using diver observations, video recordings, and photography, as needed.

      2). Macroinvertebrates and macroalgae - Species composition and relative abundance estimates will be made using methods similar to those described for turf communities.

      3). Fishes - Species composition, size structure, and relative abundance estimates will be made using the above methods. Hydroacoustic surveys may be undertaken to augment relative abundance information.

      4). Natural History Observations - Sheltering, foraging, and nesting behavior of selected fishes will be observed and related to reef structure, depth, materials, and associated biota.

These surveys will be conducted on developmental reefs, annually, from 1988 to 1997 as time, funding, and manpower permit. Other artificial and/or natural reefs may be examined for reference purposes. Reports of observations will be prepared as needed. When reefs attain successional equilibrium, CDFG will initiate quantitative studies to document the mature reef communities (section 3). These studies will be administered by the CDFG and will be designed and conducted with the cooperation and assistance of appropriate academic institutions such as the University of California and the California State University, and other organizations with expertise in the field (Appendix 2).

2. Studies of Fish Production and Behavior

Estimating fish production (increase in biomass over time) on artificial and natural reefs is difficult due to the migratory and foraging behavior of many species. However, production of some fishes, such as kelp bass, barred sand bass, and sheephead, could be estimated by censusing the juveniles that rely on reefs and associated biota for shelter and nutrition. In addition, CDFG plans to investigate food habits, behavior, and movements of select species to ascertain how artificial and natural reefs compare in providing fishes with food and habitat. Investigation of these aspects of fish production and behavior are to be implemented on natural habitats, such as Las Pulgas Reef, and on man-made reefs, such as PAR and Torrey Pines Artificial Reef 2 between 1991 and 1997.

Studies of selected developmental reefs are planned from 1990 to 1997 to obtain information on how specific physical characteristics of reef structure and placement influence fish production and behavior.

3. Studies of Developmental Reefs at Successional Equilibrium (long-term)

Quantitative Surveys will begin at these reefs about 1998. Studies will be conducted by CDFG and others, semi-annually, for four years. Detailed physical measurements of reefs and quantitative information on standing crops of reef biota will be obtained to determine what combinations of reef location, rugosity, boulder size, module depth, height, and spacing will optimally enhance target species. Studies will emphasize species which are important to fishermen, ecologically significant, conspicuous, abundant, or unusual.

Survey methods may vary depending upon funding, personnel, available technology, and local conditions (e.g. depth), but will be similar in scope to methods used at PAR:

a. Turf community - Percent cover will be estimated using random point contact methods and/or video and photographic techniques.

b. Macroinvertebrates - Density estimates will be made using randomly placed permanent band transects. Particularly abundant sessile species will be subsampled using quadrat counts and/or percent cover estimates. Size measurements will be made of selected species including gorgonians, scallops, abalone, sea urchins, etc.

c. Macroalgae - Density estimates will be made using randomly placed permanent band transects. Plant size and condition will also be noted. Particular emphasis will be placed on giant kelp due to its importance to other marine resources.

d. Fishes - Density and size estimates will be made for adult, sub adult, and juvenile fishes by means of band and/or video transects.

e. Natural History Studies - A quantitative assessment of sheltering, foraging, and nesting behavior of selected reef fishes will be made and related to reef structure, depth, and materials.

ARTIFICIAL REEF LOCATION AND MAPPING

Since 1958, thirty one reefs have been built in southern California nearshore waters. The last reef, Topanga Artificial Reef, was constructed in November 1987 (Appendix 3). Nine were partially or completely lost due to: 1) deterioration of experimental components, such as wooden streetcars and automobile bodies; 2) burial in sediments; 3) movement of materials, such as tires, due to vandalism or deterioration of the binding and ballast systems; and 4) loss of surface marking buoys and/or changes in onshore landmarks.

To update information on location and structure of the remaining reefs, CDFG located and mapped thirteen of the largest and most frequently fished reefs from Santa Monica Bay to San Diego.

Date were collected for each reef, using down-looking and sidescan sonar and recording echosounder equipment installed on a small boat (less than 30 ft [9 m] in length). Position data were collected simultaneously by microwave transceivers and onshore transponders. Topographic contour and three dimensional maps were created from this information. Loran-C positions were recorded for all reef sites. To facilitate the use of these reefs, an informational booklet describing the location and configuration of important reefs was published (Lewis and McKee 1989).

Appropriate equipment and techniques are crucial for accurate mapping and the following procedures are recommended:

1. To obtain accurate data on the relative position of the survey vessel and the target reef, at least three onshore radio location transponders are recommended. A primary transponder should be placed at each of two benchmarks which are (to the extent possible) located at right angles from the survey site. The third unit should be positioned at a benchmark near the mid-point, between the two primary transponders, for use as a backup in case a primary unit fails. If the site is large or if terrain blocks signal transmission, the additional transponder will also help to maintain right angle positioning and/or allowing uninterrupted signals.

2. When using sonar, high frequency (150 to 200 Khz) transducers will provide the necessary precision. At least two scanning passes (tracks) should be made over the target reef. Additional track lines will be required if the survey site is large. Tracks should be straight and oriented at right angles to one another to minimize angular distortions and shadow effects of high relief substrate. Temporary surface buoys can help to position the survey vessel.

3. When using echo-sounding equipment, narrowly spaced parallel track lines should be run in a cross-tied pattern to insure accurate recording of topographic features of the target reef. For small reefs, the maximum distance between track lines should not exceed 25 ft (8 m). The spacing distances between track lines can be further reduced and/or the tracking pattern modified to increase resolution of relief contours. Closer spacing of lines will provide more accurate results but will, of course, increase survey time.

4. Aerial photography is effective in documenting spatial relationships of artificial reefs and basement substrate when water depth and transparency are adequate. Vertical photographs of the study areas are taken through an observation port in the floor of the aircraft. A hand-held 35 mm camera with a 50 mm f1.4 lens and color slide film produces good results. The camera should be panned slightly to compensate for forward movement of the plane. To minimize glare, photographs should be taken before 10:00 A.M. or after 2:00 P.M. (Pacific Standard Time) when the sun angle is low. A polarizing filter may also be used to further reduce glare. Photographs may be printed, digitized, and computer enhanced to improve the images.

"Ground truth" diving surveys should be conducted (if practical) to verify information generated by remote sensing. The length and bearing of major and minor axes and angle of slope of modules should be noted. Maximum relief, depth of water, and depth and type of bottom substrate should also be recorded.

When using Loran-C coordinates, variation in readings among receivers may make reefs difficult to locate. To help alleviate this problem, it is advisable not only to record the coordinates of the reef, but also to record the precise Loran and latitude/longitude coordinates of a convenient and conspicuous fixed landmark, near each reef, such as a harbor entrance, a breakwater, or an oil platform. These additional coordinates may be used to calculate correction factors for different Loran receivers, which will facilitate the locating of reefs.

DEVELOPMENTAL FISHING REEFS

Since 1980, seven developmental reefs have been constructed from quarried rock to improve sport fishing and to evaluate the biotic enhancement characteristics of man-made reefs. A description of developmental reefs constructed between 1980 and 1987 follows:

PAR - The First of a Series

Pendleton Artificial Reef (PAR) -- This reef was constructed off the south end of San Onofre State Beach near Camp Pendleton Marine Base in fall 1980 to determine if man-made reefs could be used to address a possible loss of kelp forest communities due to power plant operations (Figure 3 - #12).

PAR was constructed on sand bottom in 43 ft (13 m) of water approximately one nautical mile from shore. It is composed of 10,000 short tons (9,078 metric tons) of quarry rock, ranging in size from 1 ft to 6 ft (0.3 to 2.0 m) in diameter, and consists of eight modules spaced about 60 ft (18 m) apart (Figure 5). Modules are somewhat irregular in shape, averaging 118 ft long, 66 ft wide, and 15 ft high (36 m X 20 m X 4.5 m). The modules and sandy interspaces encompass an area of approximately 3.5 acres (1.4 hectares).

In July 1989, nearly 9 years after reef construction, the biota on PAR were similar in most respects to natural reefs in the area.

The turf community was similar to that recorded in fall 1986 when quantitative studies were completed. Erect ectoprocts, algal turf, ornate jewel boxes, and hydroids were still major components of the turf community. However, percent cover of foliose red algae and colonies of scaled-worm mollusks had increased.

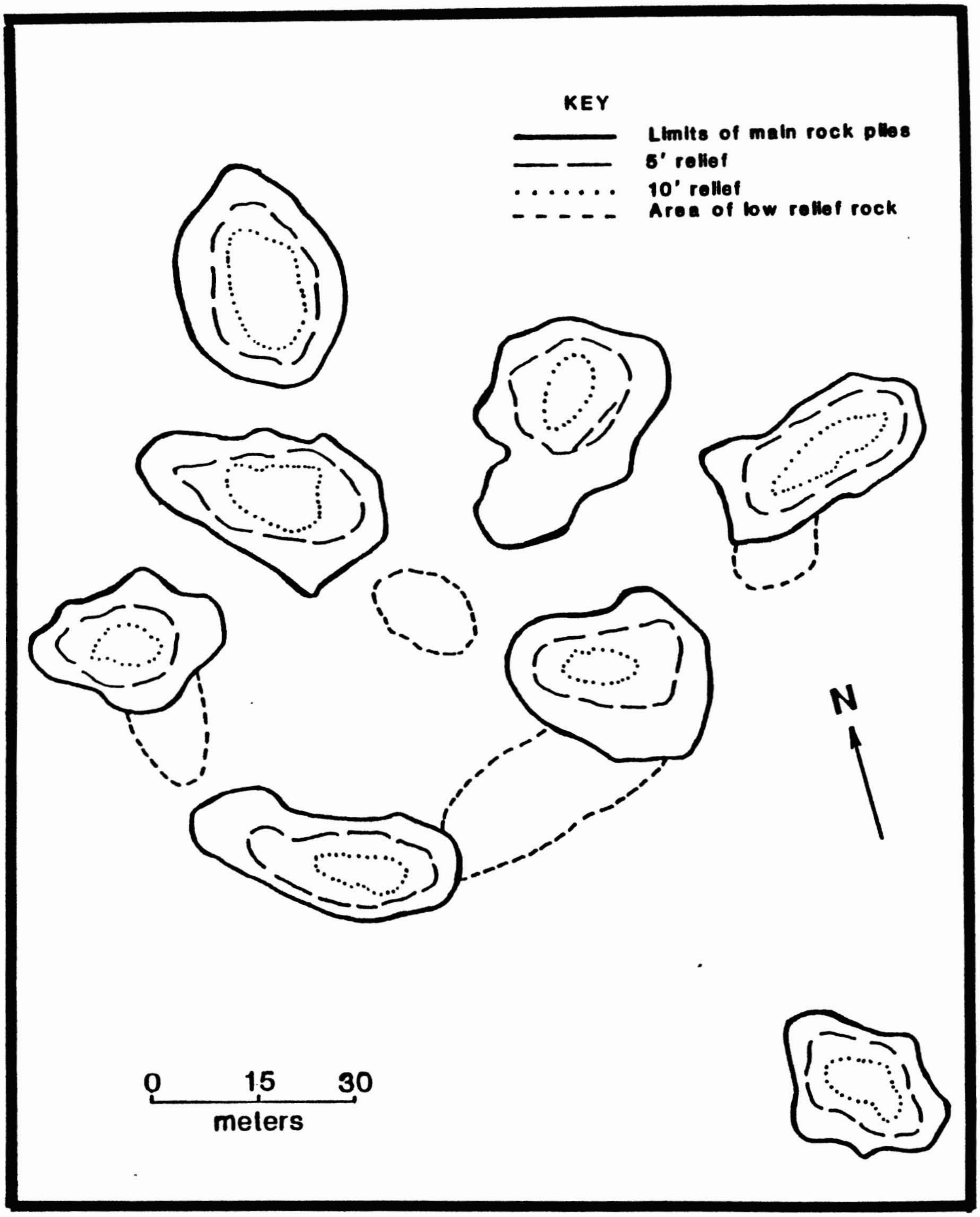

Figure 5. Pendleton Artificial Reef - diagram.

The macroinvertebrate community had changed. Three species of snails (Kellet's whelk, festive whelk, and Poulson's dwarf triton), keyhole limpets, and sea cucumbers were more abundant in 1989 than in 1986. The wavy turban snail was seen for the first time. As in earlier years, sea urchins were rare and abalone were not observed.

The macroalgae community had also changed. The size and number of giant kelp plants had increased over earlier surveys. Brown macroalgae (pea kelp, *Laminaria* sp., and *Pterygophora* sp.), primarily drift plants in earlier years, had reproduced and their offspring had become established directly on the reef substrate by 1989.

Although poor water conditions limited diver observations, species composition and relative abundance estimates suggested that fish communities at PAR showed little change since 1986.

Subsequent Developmental Reefs

Studies of natural and man-made reefs and other structures; experience with kelp restoration work in Los Angeles, Orange, and Santa Barbara counties; review of literature; and consultation with outside biologists, engineers, and oceanographers provided information for use in constructing six new "developmental" quarry rock reefs since 1984. These reefs have provided increased habitat for fishes, invertebrates, and plants. They have also permitted CDFG personnel and other researchers to accumulate information for constructing new reefs which will be even more effective for enhancing nearshore habitat.

Nearly all of the developmental reefs support giant kelp. Growth of giant kelp plants was particularly encouraging on Pitas Point Artificial Reef (constructed in 1984), Santa Monica Bay Artificial Reef (constructed in 1987), and Topanga Artificial Reef (constructed in 1987). At least two generations of giant kelp were observed on these reefs and many plants had survived long enough to form surface canopies. These ranged from small, on the shallower modules of the Santa Monica Bay Artificial Reef, to large, on the Topanga Artificial Reef (Wilson *et al.* 1990; Lewis *et al.* 1990). Dense stands of giant kelp were observed on Topanga Artificial Reef as late as April 1990.

Pitas Point Artificial Reef (PPAR) -- This reef was constructed off Ventura County, in spring 1984 (Figure 3-#3 and Appendix 3). It was designed to improve sport fishing opportunities and to provide substrate for the establishment of giant kelp and associated biotic communities. PPAR was built from 7200 short tons (6,536 metric tons) of class A* and B** quarry rock on sand substrate at a depth of 28 ft (8.5 m) MLLW.

The reef is comprised of four modules (Figure 6), each measuring 120 ft long, 50 ft wide, and 10 ft high (36 m X 15 m X 3 m). It was placed 100 ft (30 m) offshore of a stand of giant kelp to encourage natural kelp recruitment. To

---

* Class A = 2.5 ft to 4.0 ft (0.8 m to 1.2 m) in diameter
** Class B = 1.0 ft to 3.0 ft (0.3 m to 1.0 m) in diameter

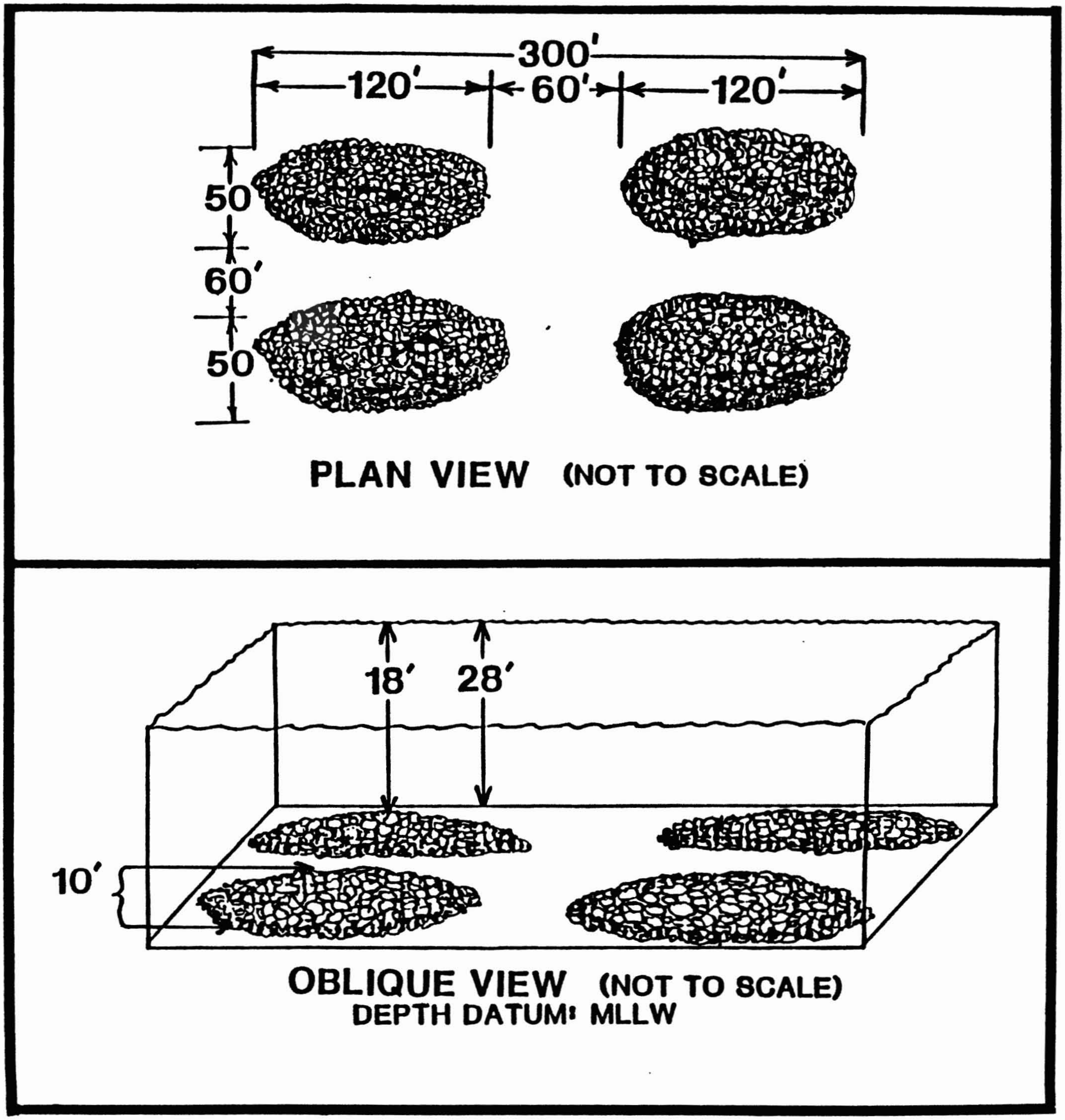

Figure 6. Design of Pitas Point Artificial Reef.

further increase the likelihood of establishing giant kelp on the reef, a kelp spore culture was sprayed on the quarry rocks immediately prior to placing them in the water; later, adult plants were also transplanted onto the reef.

In April 1987, three years after construction, the reef supported a substantial stand of giant kelp and associated biota (Wilson and Togstad 1987). Many of the kelp plants were at least two years old, and had an average of 16 ± 14 fronds per plant. Whether the kelp stand at PPAR arose because of natural recruitment from the nearby kelp bed, kelp spore cultures, or kelp transplanting, it is clear that giant kelp can germinate, mature, and reproduce on artificial reefs.

At PPAR, fishes were more abundant near the kelp/water and rock/water interfaces of the modules than within the perimeter of the kelp stands themselves. Macroinvertebrates, such as sea urchins, characteristic of more mature reef communities with algal cover, were scarce, as expected. Successful growth of the kelp bed at PPAR provided the impetus for constructing the Topanga Artificial Reef.

Marina del Rey Artificial Reef (MDRAR) -- Constructed in Santa Monica Bay during spring 1985, this reef was designed to test the effect of module spacing on development of reef communities (Figure 3-#9 and Appendix 3). It was built from 11,000 short tons (9,986 metric tons) of class B quarry rock, arranged in two rectangular complexes of eight modules each on sand/cobble bottom at a depth of 65 ft (20 m) MLLW. In one complex, eight modules are spaced approximately 60 ft (18 m) apart; in the other, which lies 300 ft (91 m) to the north, the eight modules are spaced approximately 200 ft (61 m) apart. Modules averaged 50 ft (15 m) in diameter by 10 ft (3.1 m) high (Figure 7).

The eight closely spaced modules were inspected in fall 1987. The algal community was not well developed, probably because water depth was too great and light levels too low to encourage plant growth. Macroinvertebrates were also scarce, as would be expected in a reef community in such an early stage of successional development.

Santa Barbara, Oceanside, and Pacific Beach Artificial Reefs -- These three reef complexes, one in Santa Barbara County and two in San Diego County (Figure 3-#1, #13, #15 and Appendix 3), were designed to investigate the effects of reef location, depth, and relief on biotic community structure. Each reef complex is identical in design. All are to be built on sand bottom from 10,000 short tons (9,078 metric tons) of class B quarry rock. Each complex will consist of 24 modules - four pairs at each of three depths: 42 ft, 57 ft, and 72 ft MLLW (12.8 m, 17.4 m, and 21.9 m), respectively. Two pairs of modules at each depth contour are to be high relief, 12 ± 2 ft (3.7 ± 0.6 m), and two pairs are to be low relief, 5 ± 2 ft (1.5 ± 0.6 m). All modules will be approximately 50 ft (15 m) in diameter (Figure 8).

The Oceanside and Pacific Beach reefs were built in spring 1987. Construction of the Santa Barbara Artificial Reef has been postponed until a suitable site can be located.

Surveys of Oceanside and Pacific Beach Artificial Reefs, conducted in October 1990, revealed that a giant kelp community had developed on a number of reef modules.

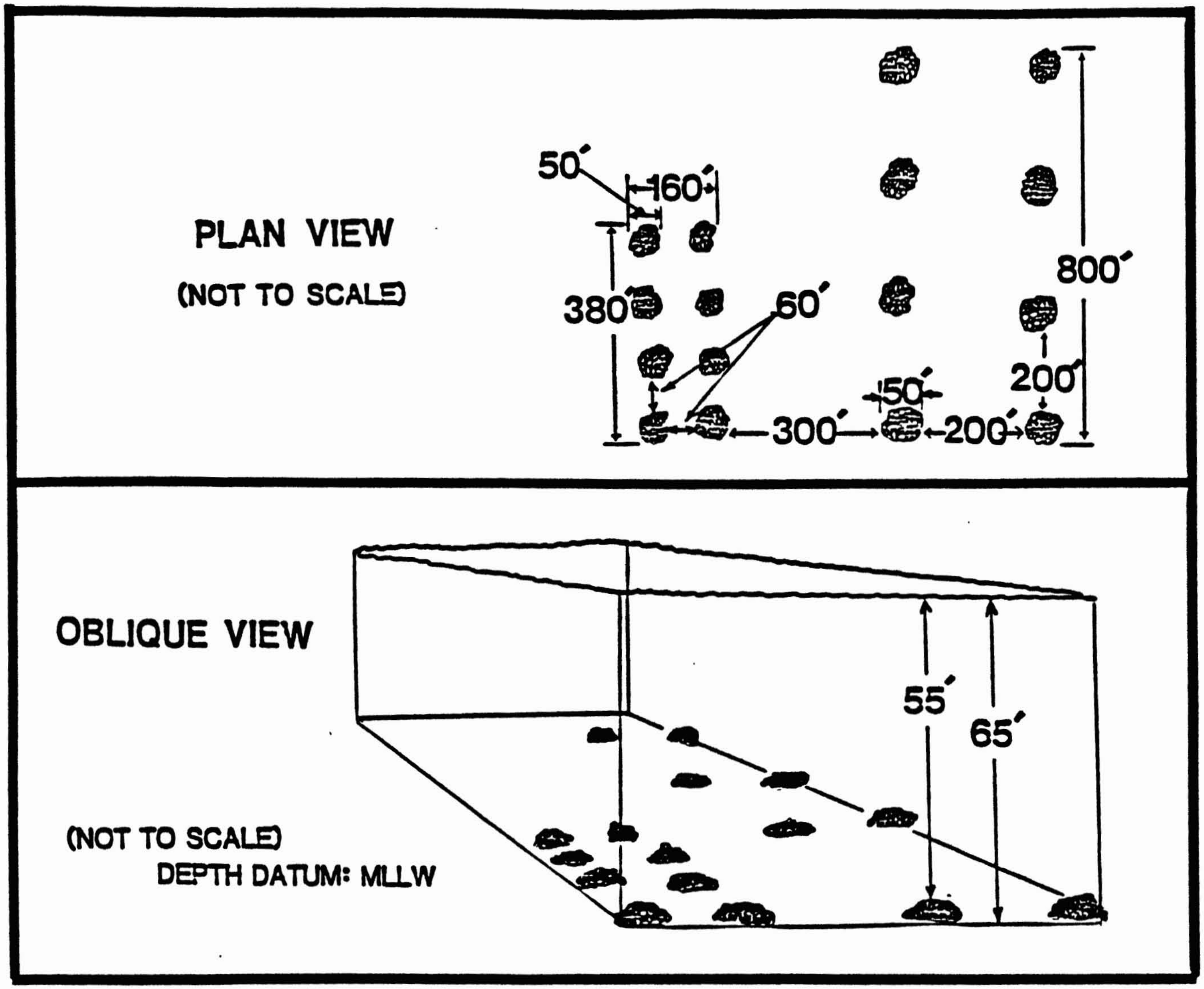

Figure 7. Design of Marina Del Rey Artificial Reef.

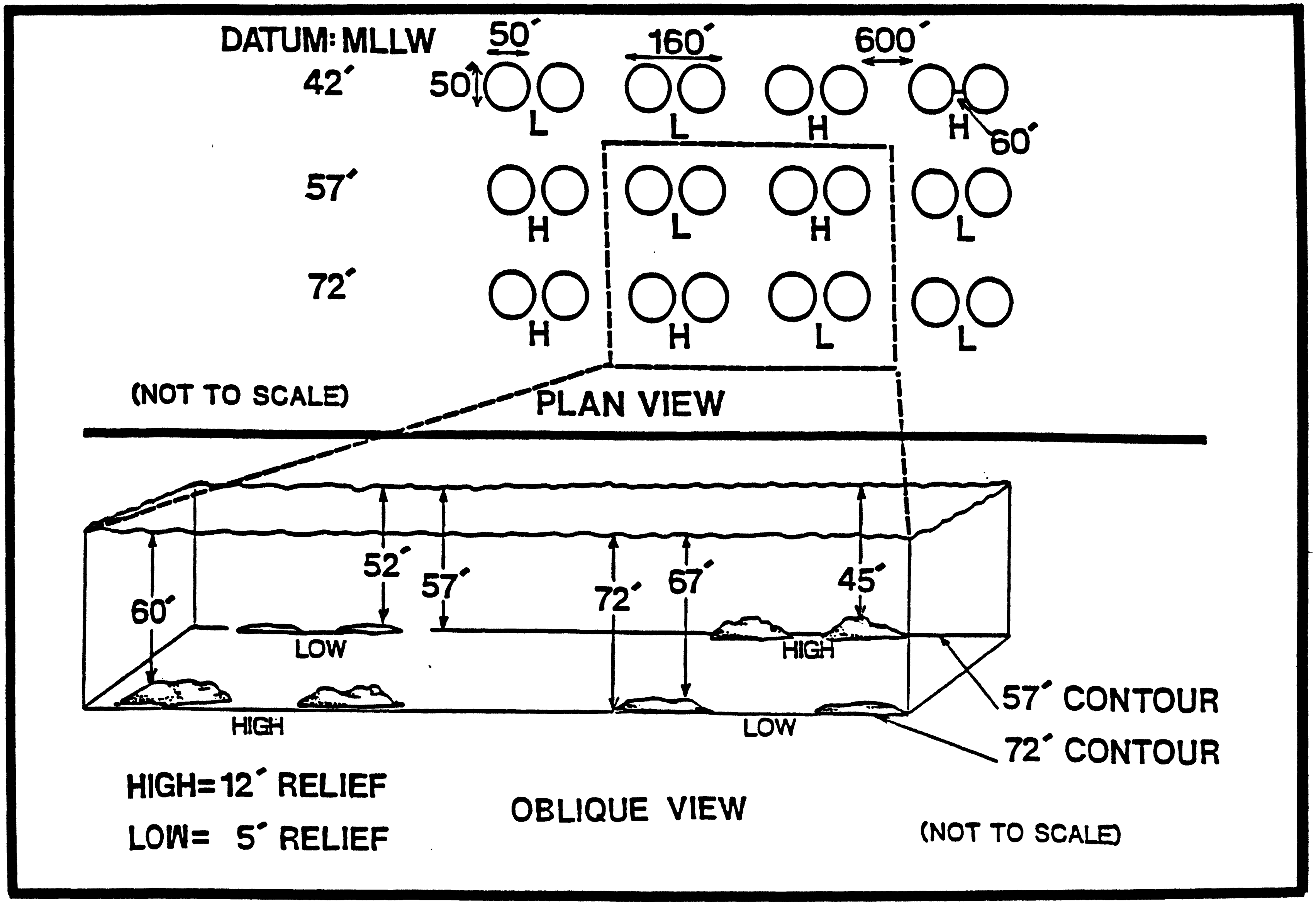

Figure 8. Design of artificial reefs at Santa Barbara, Oceanside, and Pacific Beach.

Santa Monica Bay Artificial Reef (SMBAR) -- This reef complex, located in Los Angeles County (Figure 3-#7 and Appendix 3), was constructed in October 1987 to investigate the effects of location, depth, relief, and rock size on the structure of biotic communities. It was built from 20,000 short tons (18,156 metric tons) of quarry rock. The complex consists of 48 modules, one row of 16 modules at each of the three depth contours as specified for the 24-module reefs. Each row is comprised of four pairs of high relief modules and four pairs of low relief modules. To test the effects of rock size, four pairs of the modules in each depth were constructed from class A rock and four pairs were constructed from class B rock, as used in the 24-module reefs (Figure 9).

An examination of this reef in 1989 revealed that some giant kelp had become established on modules along the 42 ft (13 m) depth contour MLLW. Numerous sport fish were observed on modules at all reef depths. The most frequently encountered species were barred sand bass, California scorpionfish, white seaperch and kelp bass (Wilson *et al.* 1990).

Topanga Artificial Reef (TAR) -- This reef, located in northern Santa Monica Bay, was constructed in October 1987 (Figure 3-#6 and Appendix 3). It was designed to enhance sport fish habitat and to encourage reestablishment of a productive kelp bed which existed there in the 1930's. TAR was built from 10,000 short tons (9,078 metric tons) of quarry rock on sand bottom at a depth of 28 ft (8.5 m) MLLW. It is arranged in three large, low profile modules, each measuring 300 ft long, 100 ft wide, and 3 ft high (91 m x 30 m x 1 m) (Figure 10).

Stands of giant kelp have persisted on Topanga Artificial Reef, more or less consistently, since 1988 (Lewis *et al.* 1990). CDFG hypothesizes that the success of this reef, as habitat for giant kelp and associated sport fish species, is related to three factors. First, the large reef area allows development of a large kelp stand in which the ratio of stand volume to kelp/sand perimeter is high. This reduces the impact of damage to the main body of kelp caused by excessive grazing of herbivorous fishes and invertebrates, which tend to concentrate in the vulnerable kelp perimeter ecotone (Leighton *et al.* 1965; Bernstein and Jung 1979). Second, the proximity of the reef to natural kelp beds, 0.9 km (0.5 nautical mile), could have facilitated the germination and growth of kelp plants on the reef. Third, the relatively shallow water depth 28 ft (9.5 m) of this site apparently encourages growth of kelp and other algae due to increased light transmittance.

In March 1989, an examination of this reef revealed fourteen species of fishes, nine of which were sport species. The most frequently observed (in descending order of abundance) were white seaperch, barred sand bass, pile perch, and kelp bass (Lewis *et al.* 1990).

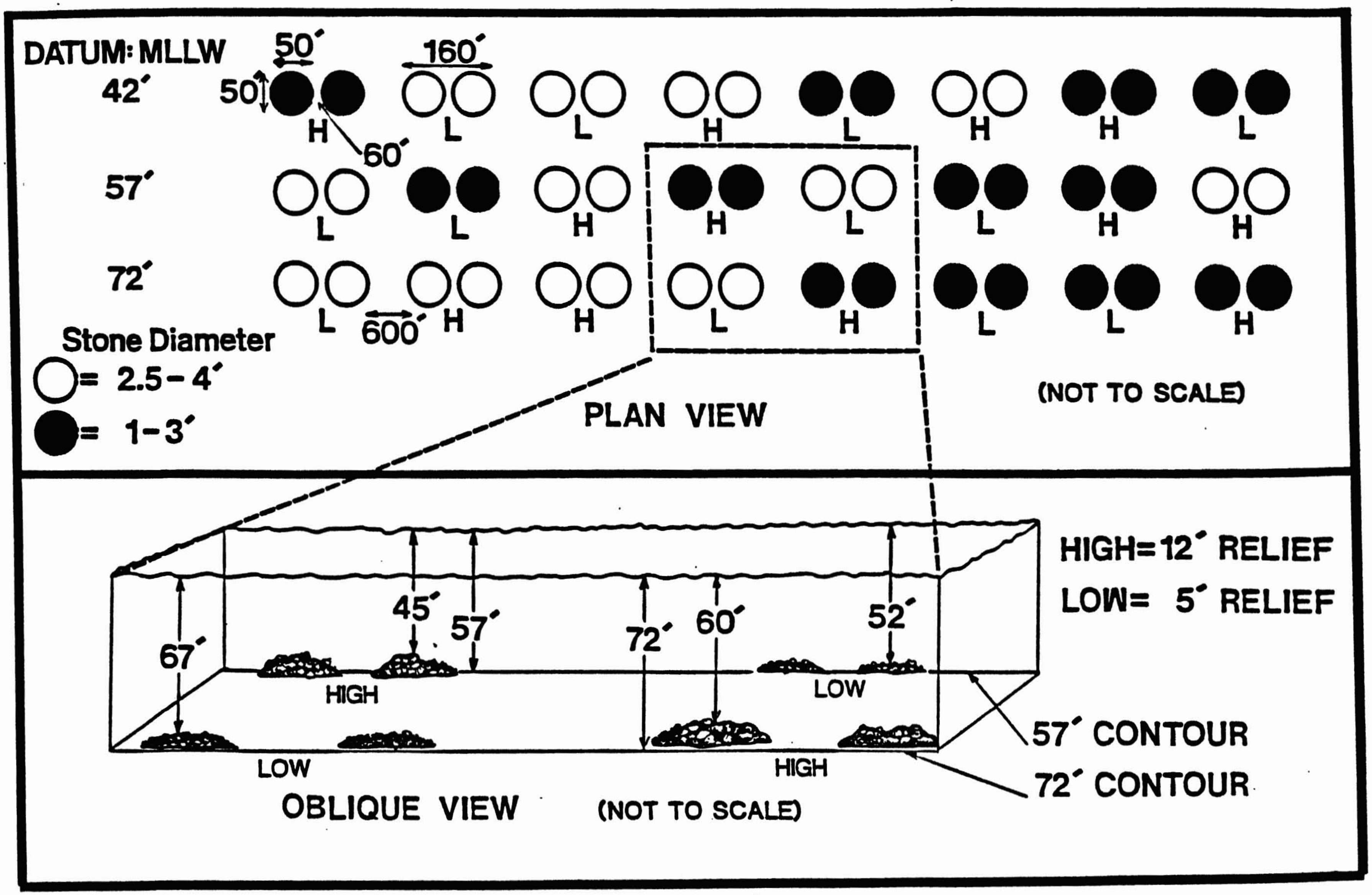

Figure 9. Design of Santa Monica Bay Artificial Reef.

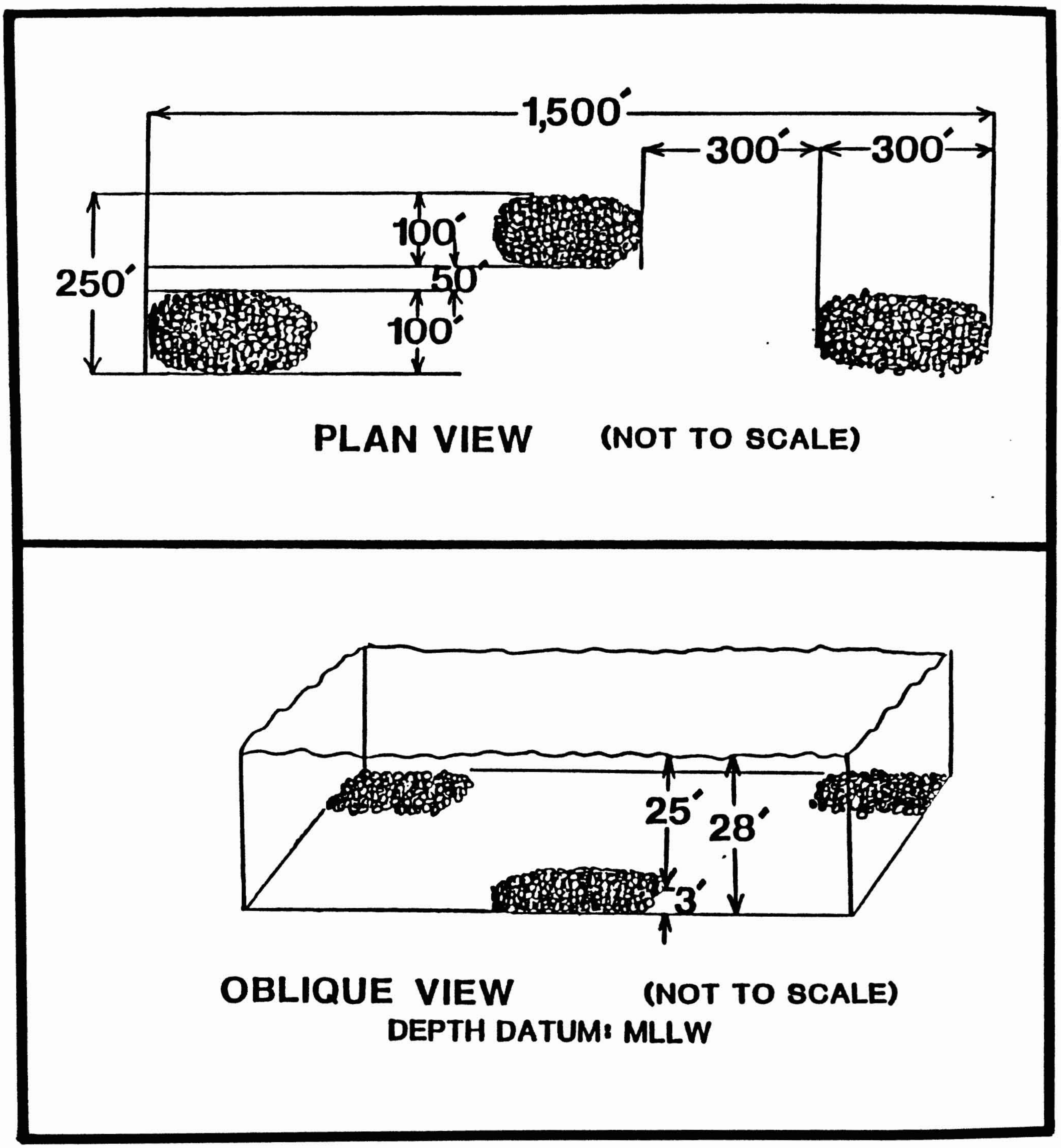

Figure 10. Design of Topanga Artificial Reef.

FUTURE REEFS

To meet the goals of the reef program, CDFG plans to continue the reef studies through 2005 and reef building through 2011. Three types of reefs may be constructed during this period: developmental reefs, improved production reefs, and fishing access reefs. All will contribute to sport fishing success but each reef type will have a different secondary purpose.

Should funding become available, CDFG plans to construct and augment existing artificial reefs in nearshore waters within the following counties (listed from north to south): Humboldt, San Francisco, San Mateo, Santa Cruz, Monterey, San Luis Obispo, Santa Barbara, Los Angeles, Orange, and San Diego. Fishing reefs also may be built adjacent to public piers should need and opportunities arise and local conditions permit.

The precise location and structure of future reefs, statewide, will be prioritized by local sport fishing needs and by biological and physical conditions.

Developmental Reefs

Developmental reefs will be studied to evaluate the effects of reef placement and structure on reef biota. Information obtained from studies of developmental reefs and from parallel studies of natural reefs will be used to improve future reef designs in order to build improved production reefs. Several concepts for new developmental reefs are outlined below.

A 12-module reef complex will be constructed offshore of Batiquitos Lagoon, an estuary in San Diego County. This reef, to be named Carlsbad Artificial Reef (CAR), will provide habitat for typical reef associated fishes, invertebrates, and plants and should complement the planned rehabilitation of the lagoon (Figure 3-#14, and Appendix 5).

CAR could enhance the survival of nearshore fishes which utilize the lagoon and/or the surf zone, offering them shelter and/or forage during onshore/offshore migrations. Such species include California halibut, white seabass, and various surfperches, all of which are of direct importance to southern California fisheries. Prey species such as midshipman and blennies should also benefit from food and habitat afforded by CAR.

Six modules of CAR will be constructed from large boulders, 4-6 ft (1.2 to 1.8 m) diameter and six modules will be constructed from smaller boulders, 1-3 ft (0.3 to 0.9 m) diameter. Four modules will be constructed along each of three depth contours: 37 ft, 42 ft, and 57 ft (11 m, 13 m, and 17 m) MLLW. Modules comprised of large boulders will be located away from those built with smaller rock. These variations of structure and location should increase habitat for a diverse reef biota, including giant kelp, and provide spatial partitioning for adult and subadult fishes.

Another concept is to construct quarry rock reefs on natural pavement substrate to control grazing damage to kelp forests caused by sea urchins. Such reefs should help to protect kelp forests in two ways: (1) reefs would provide cryptic habitat for sea urchins on, otherwise, flat pavement substrate (thus decreasing sea urchin movement), and (2) reefs would tend to accumulate drift algae which would, otherwise, be swept offshore unutilized (Tegner and Dayton 1980; Wilson, pers. observation). Such reefs should not only help to increase the stability of nearby kelp forests and associated sport fishes, but should also contribute to production of sea urchin, lobster, and abalone by increasing the availability of critical shelter and forage.

Another concept would test the effect of module size on associated biotic communities.

Improved Production Reefs

Improved production (IP) reefs would be constructed by varying factors of reef location, depth, relief, rock size, module spacing, and module area to suit specific habitat requirements of preferred biotic communities or target species as indicated by the reef study program. Using these concepts, IP reefs could be constructed, in fisheries habitat enhancement areas (FHEAs), to provide ideal habitat for shelter, nesting space, nursery areas, and food resources for critical life stages of important nearshore marine organisms. Our studies suggest that IP reefs could be even more effective than today's reefs for increasing standing crops of specific living marine resources.

Fishing Access Reefs

Fishing access reefs, like the PALAWAN Artificial Reef which includes a retired liberty ship (Figure 2-#6), and the Mission Bay Park Artificial Reef which includes retired vessels EL REY and RUBY E. (Figure 2-#18), may also be built. These reefs, including the planned Palos Verdes Wreck Reef which will include another retired ship (Figure 2-#7 and Appendix 6), will be constructed to increase the take of fishes without, contributing significantly to their standing crop. Such reefs are termed fish aggregating devices (FADs). Additional FADs may be installed if CDFG determines the need is appropriate. Under some circumstances, CDFG may build IP reefs in conjunction with FADs to compensate for increased fish take.

MITIGATION

California Department of Fish and Game believes that artificial reefs, when properly constructed, can be used as mitigation for impacts on rocky habitat, and, in certain cases, for damage to giant kelp. Artificial reef construction can be used in these cases because the constructed reefs may be inhabited by essentially the same species and populations impacted by the damage to rocky habitat or kelp bed areas. However, the extent to which artificial reefs benefit fishery stocks, has not yet been fully investigated. Until this question is satisfactorily addressed, the usefulness of artificial reefs as mitigation must be carefully considered on a case-by-case basis.

CONCLUSION

The success of habitat enhancement operations and, particularly, reef construction and study program depends upon the cooperation and support of governmental agencies, the legislature, academic institutions, industry, fishermen, and general public.

Through team effort, CDFG can undertake a program of sufficient magnitude to contribute, meaningfully, to the maintenance and replenishment of California's nearshore living marine resources.

LITERATURE CITED

Ambrose, R. F. and S.L. Swarbrick. 1989. Composition of fish assemblages on artificial and natural reefs off the coast of southern California. Bull. Mar. Sci. 44(2):718-733.

Anderson, T.W., E.E. DeMartini, and D.A. Roberts. 1989. Relationship between habitat structure, body size, and distribution of fishes at a temperate artificial reef. Bull. Mar. Sci. 44(2):681-697.

Bernstein, B.B. and N. Jung. 1989. Selective pressures and coevolution in a kelp canopy community in Southern California. Ecol. Mono. 49(3):335-355.

Bohnsack, J.A., and D.L. Sutherland. 1985. Artificial reef research: A review with recommendations for future priorities. Bull. Mar. Sci. 37(1):11-39.

Buckley, R.M., and G.J. Hueckel. 1985. Biological processes and ecological development on an artificial reef in Puget Sound, Washington. Bull. Mar. Sci. 37(1):50-69.

Buckley, R.M., J.J. Grant, and J. Stephens, Jr. 1985. Foreword-Third International Artificial Reef Conference 3-5 November 1983, Newport Beach, CA. Bull. Mar. Sci. 37(1):1-2.

California Department of Fish and Game. 1983. Pendleton Artificial Reef. Annual Report. 1981-82. Prepared by the Nearshore Sport Fish Habitat Enhancement Program, Calif. Dept. Fish & Game, MRD, Long Beach, CA 90802.

California Department of Fish and Game. 1984. Pendleton Artificial Reef. An overview of progress 1984. Prepared by the Nearshore Sport Fish Habitat Enhancement Program, Calif. Dept. Fish & Game, MRD, Long Beach, CA 90802.

California Department of Fish and Game. 1985. Pendleton Artificial Reef. An overview of progress 1985. Prepared by the Nearshore Sport Fish Habitat Enhancement Program, Calif. Dept. Fish & Game, MRD, Long Beach, CA 90802.

California State Water Quality Control Board. 1964. An investigation of the effects of discharged wastes on kelp. Publication 26. Calif. Water Quality Control Board. Sacto.

Carlisle, J.G., Jr., C.H. Turner, and E.E. Ebert. 1964. Artificial habitat in the marine environment. Calif. Dept. Fish & Game, MRR. Fish Bull. 124. 93 p.

Carter, J.W., A.L. Carpenter, M.S. Foster, and W.N. Jessee. 1985a. Benthic succession on an artificial reef designed to support a kelp-reef community. Bull. Mar. Sci. 37(1):86-113.

Carter, J.W., W.N. Jessee, M.S. Foster, and A.L. Carpenter. 1985b. Management of artificial reefs designed to support natural communities. Bull. Mar. Sci. 37(1):114-128.

CDFG. see California Department of Fish and Game.

Devinney, J. and L. Volse. 1978. Effects of sediments on the development of *Macrocystis pyrifera* gametophytes. Mar. Biol. 48:343-348.

Elliott, W. 1846. Carolina sports by land and water. Burges and James Printers, Charleston, S.C. 172 p.

Feder, H.M., C.H. Turner, and C. Limbaugh. 1974. Observations on fishes associated with kelp beds in southern California. Calif. Dept. Fish & Game, MRR. Fish Bull. 160. 144 p.

Grigg, R.W. 1978. Long term changes in rocky bottom communities off Palos Verdes. In: Coastal Water Research Project Annual Rept. 1978. pp. 157-184. El Segundo, CA.

Grigg, R.W. and R. Kiwala. 1970. Some ecological effects of discharged wastes on marine life. Calif. Fish & Game 56:145-155.

Hueckel, G.J. and R.M. Buckley. 1989. Predicting fish species on artificial reefs using indicator biota from natural reefs. 44(2):873-880.

Ino, T. 1974. Historical review of artificial reef activities in Japan. Proc. of Internatl Conf. on artificial reefs. Sea Grant Publication TAMU-56-74-103.

Jessee, W.N., A.L. Carpenter, and J.W. Carter. 1985. Distribution patterns and density estimates of fishes on a southern California artificial reef with comparisons to natural kelp- reef habitats. Bull. Mar. Sci. 37(1):214-226.

Leighton, D.L., L.G. Jones, and W.J. North. 1965. Ecological relationships between giant kelp and sea urchins in southern California. In: E.G. Young and J.L. McLachlan (eds.). Proceedings of the Fifth International Seaweed Symposium- Halifax Aug. 25-28, 1965. Pergamon Press, New York:141-153.

Lewis, R.D. and K.K. McKee. 1989. A guide to the artificial reefs of southern California. Calif. Dept. Fish & Game, Sacramento, CA. 73 p.

Lewis, R.D., K.C. Wilson, and K.K. McKee. 1989. A report of biological observations at Topanga Artificial Reef. Calif. Dept. of Fish and Game, MRD, Long Beach, CA 10 p.

Matthews, K.R. 1985. Species similarity and movement of fishes on natural and artificial reefs in Monterey Bay, California. Bull. Mar. Sci. 37(1):252-270.

McPeak, R.H., D.A. Glantz, and C.R. Shaw. 1988. The amber forest: beauty and biology of California's submarine forests. Watersport Publishing, Inc., P.O. Box 83727, San Diego, 92138. 143 p.

Peterson, L.L. 1974. The propagation of sunlight and the size distribution of suspended particles in a municipally polluted ocean water, doctoral dissertation, Calif. Inst. Technol. Pasadena, CA. 174 p.

Quast, J.C. 1968a. Observations on the food and biology of the kelp bass, *Paralabrax clathratus*, with notes on its sport fishery at San Diego, California. In: W.J. North and C.L. Hubbs (eds.). Utilization of kelp-bed resources in southern California. Calif. Dept. Fish & Game. Fish Bull. 139. pp. 81-108.

______. 1968b. Observations on the food of kelp-bed fishes. In: W.J. North and C.L. Hubbs (eds.). Utilization of kelp-bed resources in southern California. Calif. Dept. Fish & Game, MRR. Fish Bull. 139. pp. 109-141.

Smith, E.J., T.H. Johnson, and D. Zeiner. 1989. The marine life refuges and reserves of California. Calif. Dept. of Fish and Game. Mar. Res. Info. Bull. No. 1, 63 p.

Solonsky, A. C. 1985. Fish colonization and the effects of fishing activities on two artificial reefs in Monterey Bay, California. Bull. Mar. Sci. 37(1):336-347.

Southern California Edison Company (SCE). 1979. Annual Operating Report, San Onofre Nuclear Generating Station, Volume IV, Biological, Sedimentological, and Oceanographic Data Analysis - 1978, Environmental Technical Specifications - Unit 1, Construction Monitoring Program - Units 2 and 3, Prepared by Lockheed Center for Marine Research, Carlsbad, CA 79-RD-54.

______. 1980. Annual Operating Report, San Onofre Nuclear Generating Station, Volume V, Biological, and Oceanographic Data Analysis - 1979, Environmental Technical Specifications - Unit 1, Preoperational Monitoring Program - Units 2 and 3. Prepared by Brown and Caldwell, Lockheed Center for Marine Research, and Marine Biological Consultants, Inc. 90-RD-100.

Tegner, M.J. 1980. Multispecies considerations of resource management in southern California kelp beds. Canadian Technical Report of Fish and Aquatic Sciences. 954: pp. 125-143.

Turner, C.H., E.E. Ebert, and R.R. Given. 1969. Man-made reef ecology. Calif. Dept. Fish & Game, MRR Fish Bull. 146. 221 p.

Wilson, K.C. and R.A. McPeak. 1983. Kelp restoration. In: Proc. Symp. on the Effects of Waste Disposal on Kelp Commnities, W. Bascom (ed.), La Jolla, CA. Jan. 1983. pp. 199-216.

Wilson, K.C. and W.J. North. 1983. A review of kelp bed management in southern California. J. World Maricul. Soc. 14:347-359.

Wilson, K.C. and H.A. Togstad. 1987. Report of diving observations at Pitas Point Artificial Reef. Calif. Dept. of Fish and Game, MRD, Long Beach, CA 90802. m.s., 11 p.

Wilson, K.C. and R.D. Lewis. 1990. Report of Pendleton Artificial Reef studies with recommendations for constructing a kelp reef. Final Report to Southern California Edison, Contract 6C-1347, August 1990. Calif. Dept. of Fish and Game, MRD, Long Beach, CA 90802, 57 p.

Wilson, K.C., R.D. Lewis, and K.K. McKee. 1990. A report of biological observations at Santa Monica Bay Artificial Reef. Calif. Dept. of Fish and Game, MRD, Long Beach, CA 90802, m.s. 10 p.

APPENDIX 1.

Fish and Game Code, Sections 1700-1701.

APPENDIX 1. Fish and Game Code, Sections 1700-1701.

§1700. State policy.

It is hereby declared to be the policy of the state to encourage the conservation, maintenance, and utilization of the living resources of the ocean and other waters under the jurisdiction and influence of the state for the benefit of all the citizens of the state and to promote the development of local fisheries and distant-water fisheries based in California in harmony with international law respecting fishing and the conservation of the living resources of the oceans and other waters under the jurisdiction and influence of the state. This policy shall include all of the following objectives:

(a) The maintenance of sufficient populations of all species of aquatic organisms to insure their continued existence.

(b) The recognition of the importance of the aesthetic, educational, scientific, and nonextractive recreational uses of the living resources of the California Current.

(c) the maintenance of a sufficient resource to support a reasonable sport use, where a species is the object of sport fishing, taking into consideration the necessity of regulating individual sport fishery bag limits to the quantity that is sufficient to provide a satisfying sport.

(d) The growth of local commerical fisheries, consistent with aesthetic, educational, scientific, and recreational uses of such living resources, the utilization of unused resources, taking into consideration the necessity of regulating the catch within the limits of maximum sustainable yields, and the development of distant-water and overseas fishery enterprises.

(e) The management, on a basis of adequate scientific information promptly promulgated for public scrutiny, of the fisheries under the state's jurisdiction, and the participation in the management of other fisheries in which California fishermen are engaged, with the objective of maximizing the sustained harvest.

(f) The development of commercial aquaculture. *(Amended by Stats 1982 ch 1486.)*

§1701. Marine fishery resources; research and mangement studies, etc.

(a) The department shall conduct research and management studies of marine fishery resources.

(b) Consistent with the policies established in Section 1700, the department shall closely monitor changes in the status of any marine fishery resource.

(c) When the department determines, based on the best available scientific information, that a marine fishery resource cannot be maintained at levels necessary to meet the policies and objectives established in Section 1700, the department shall report that determination to the Legislature.

(d) Determinations made by the department pursuant to subdivision (c) shall be based on, but not limited to, an analysis of catch and effort data, the age and size composition of the catch, information of the relative contribution of individual year classes to the fishery, and estimates of maximum sustainable yield when that information is available or when other fishery dependent or fishery independent information, which can describe changes in the fishery resource, is available.

(e) Any report to the Legislature pursuant to subdivision (c) shall include, but not be limited to, recommendations on measures necessary to rehabilitate the resource to levels necessary to meet the policies and objectives established in Section 1700. *(Added by Stats 1986 ch 586.)*

APPENDIX 2.

Fish and Game Code, Article 2, Sections 6420-6425.

APPENDIX 2. Fish and Game Code, Article 2, Sections 6420-6425.

*Article 2. Artificial Reefs

(Added by Stats 1985 ch 1103.)

§6420. Findings & declarations.

The Legislature finds and declares all of the following:

(a) Declines in various southern California marine species of fish have adversely affected the sport and commercial fishing industry.

(b) Efforts to enhance these species through the placement of artificial reefs need to be investigated.

(c) A program of artificial reef research and development, including reef design, placement, and monitoring, is in the public interest and can best be accomplished under the administration of the department with the cooperation and assistance of the University of California, the California State University, other established, appropriate academic institutions, and other organizations with demonstrated expertise in the field.

(d) A state artificial reef research and construction program under the administration of the department is necessary to coordinate ongoing studies and construction of artificial reefs in waters of the state. *(Added by Stats 1985 ch 1103.)*

§6421. Definitions.

For purposes of this article, the following terms have the following meaning:

(a) "Artificial reef" means manmade or natural objects intentionally placed in selected areas of the marine environment to duplicate those conditions that induce production of fish and invertebrates on natural reefs and rough bottoms, and that stimulate the growth of kelp or other midwater plant life which creates natural habitat for those species.

(b) "Production" means increases in the biomass of a species or number of species.

(c) "Program" means the California Artificial Reef Program. *(Added by Stats 1985 ch 1103.)*

§6422. Program administration.

The department shall administer the California Artificial Reef Program. *(Added by Stats 1985 ch 1103.)*

§6423. Program elements.

The program shall include all of the following:

(a) The placement of artificial reefs in state waters.

(b) A study of existing successful reefs and all new reefs placed by the program to determine the design criteria needed to construct artificial reefs capable of increasing fish and invertebrate production in waters of the state.

(c) A determination of the requirements for reef siting and placement. *(Added by Stats 1985 ch 1103.)*

*Former Article 2 repealed by Stats 1982 ch 1486.

§6424. Limitation on allocations for administration.
The amount allocated for the administration of the program in any fiscal year may not exceed the amount authorized by applicable state and federal policy guidelines. *(Added by Stats 1985 ch 1103.)*

§6425. Allocation; future funding sources.
(a) It is the intent of the Legislature that not more than five hundred thousand dollars ($500,000) shall be allocated to the program for the 1985-86 fiscal year.
(b) It is the intent of the Legislature that future sources of funding for the program may include, but are not limited to, the Fish and Game Preservation Fund, the California Environmental License Plate Fund, the Wildlife Restoration Fund, recreational bond act funds, federal grants-in-aid, county fish and game propagation funds, and private donations. *(Added by Stats 1985 ch 1103.)*

APPENDIX 3.

Artificial Reefs Along the California Coast - November 1990
(listed by county from north to south)

Appendix 3. Artificial Reefs along the California Coast - November 1990 (listed from north to south)

County	# by County	Year Constr.	Name and Location	Depth MLLW(1)	Area	Materials and Configuration	Remarks
Santa Cruz	SC-1	1981	***Soquel Cove Artificial Reef*** (SCAR) aka Capitola Fishing Reef; 36°57'00" N; 121°57'18" W (2)	45'	0.6 ac.	480 concrete culvert pipes; 2 modules, 1.5 to 16'(H), 0.25 Nmi. apart	Recreational fishing reef.
San Luis Obispo	SLO-2	1985	***Estero Bay Artificial Reef*** (EBAR) aka Texaco Reef and Atascadero Artificial Reef; 1.9 Nmi N of Morro Bay entrance, 0.5 Nmi offshore of Atascadero State Beach; 35°23'36" N; 120°52'32" W	55'	0.4 ac.	3,500 tons quarry rock; 2 modules, each 100'(L) x 60'(W) x 8'(H), 100' apart	Recreational fishing reef created to cover terminus of two abandoned Texaco oil pipe lines. Funding: Texaco Oil Co. - NCS(3).
	SLO-1	1984-1985	***San Luis Obispo County Artificial Reef*** (SLOCAR) 0.54 Nmi offshore, 4.5 Nmi NW of Port San Luis; 35°11'25" N; 120°49'55" W	42'-52'	13 ac.	27,000 tons concrete "tribar" and rubble; 4 modules, each 262'(L) x 131'(W) x 10-13'(H)	Production reef for rockfish. Materials from damaged Diablo Canyon breakwater. Funding: PG&E - NCS.
Ventura	Ven-1	1958	***Rincon Island Artificial Reef*** (RIAR); 34°20'50" N; 119°26'41" W	40'+	ND (4)	120 car bodies	Early developmental reef. Funding: Richfield Oil Co.-NCS. Deteriorated.
	Ven-1a	1976	Augmentation(5)	40'	ND	10,000 tires	Recreational fishing reef. Moorpark College project - NCS. Deteriorated.
	Ven-5	1984 Apr.	***Pitas Point Artificial Reef*** (PPAR); 0.7 Nmi downcoast of Pitas Point; offshore of Solimar; 6 Nmi @ 291°(mag) from Ventura Harbor; 34°18'08" N; 119°22'06" W	28'	1.1 ac.	7,200 tons quarry rock; 4 modules, each 120'(L) x 50'(W) x 10'(H), 60' apart	Developmental fishing reef. Designed for kelp growth. Funding: Wildlife Conservation Board - $187,200.
	Ven-2	1965	***Ventura Artificial Reef*** (VAR) aka Ventura Fish Haven; 34°14'37" N; 119°17'56" W	60'	8.8 ac. site (6)	2,000 tons quarry rock; 8 modules, each 100' diameter x 5-6'(H)	Recreational fishing reef. Funding: Wildlife Conservation Board - $11,000. Buried in 1969 flood.
	Ven-2a	1976	Augmentation	60'	ND	9,600 tires; 1,600 modules of 6 tires each	Built to replace VAR - NCS. Location unknown.
	Ven-4	1976-1979	***Channel Islands Harbor Artificial Reef*** (CIHAR); 34°09'19" N; 119°16'02" W	60'	ND	60,000 tires	Recreational fishing reef. Funding: Ventura County F&G Commission - NCS.

	Ven-3	1975	***LA JENELLE Artificial Reef*** (LJAR); 34°07'30" N; 119°17'40" W	90'-100'	ND	Vessel superstructure of LA JENELLE; cut into approximately 8 pieces	Recreational fishing reef. Funding: Ventura County F&G Commission - NCS.
Los Angeles	LA-1	1958	***Paradise Cove Artificial Reef*** (PCAR); northern Santa Monica Bay; 34°01'00" N; 118°46'00" W	50'	0.5 ac.	20 car bodies; one module	First developmental reef in California. Deteriorated. Results in Fish Bull. 124 (1964).
	LA-3	1960 Aug.	***Malibu Artificial Reef*** (MAR); 0.5 Nmi offshore; 1.5 Nmi east of Malibu Pt.; 10.5 Nmi @ 293° (mag) from Marina del Rey Harbor entrance; 34°01'49" N; 118°39'02" W	60'	0.5 ac.	333 tons quarry rock, 44 concrete shelters, 14 car bodies, 1 streetcar; in 4 discrete piles, 150' apart	Developmental "replication reef" (1 of 3). Funding: Wildlife Conservation Board. Car bodies and street car deteriorated. DFG studies-Results in FB 146 (1969)
	LA-11	1987 Nov.	***Topanga Artificial Reef*** (TAR) aka Topanga Kelp Reef; 0.25 Nmi offshore of Santa Monica harbor office - in vicinity of old Santa Monica harbor pier; 5.25 Nmi @ 302° (mag) from Marina del Rey Harbor entrance; 34°01'38" N; 118°31'57" W	28'	13 ac. site (7)	10,000 tons quarry rock; 3 modules, each 300' (L) x 100' (W) x 2.5' (H), 100' apart	Developmental fishing reef designed for kelp growth. Funding: SB 400 (8) - $240,000.
	LA-10	1987 Oct.	***Santa Monica Bay Artificial Reef*** (SMBAR) aka Santa Monica Bay Experimental Artificial Reef; 5 Nmi @ 290° (mag) from Marina del Rey Harbor entrance; 34°00'47" N; 118°32'33" W	42'-72'	256 ac. (9)	20,000 tons quarry rock; 48 modules (24 pairs), each 50' (L) x 50' (W); 8 pairs at each of 3 depths: 42', 57', and 72'. At each depth: 4 pairs are high relief (12'), 4 pairs low relief (5'); 4 pairs are constructed of large rock, 4 pairs of small rock. Module pairs in same depth contour are 600' apart (as designed).	Developmental fishing reef investigating location, rock size, module depth, and relief. Funding: SB 400 - $360,000.
	LA-4	1960 Aug.	***Santa Monica Artificial Reef*** (SMAR); 4.5 Nmi @ 295° (mag) from Marina del Rey Harbor entrance; 34°00'34" N; 118°31'47" W	60'	0.5 ac.	same as LA-3	Developmental "replication reef" (2 of 3); same as LA-3.

(1) MLLW - Mean Lower Low Water
(2) Center coordinates of reef
(3) NCS - No cost to the state
(4) ND - Not Determined
(5) Augmentation materials added to same reef location
(6) Reef materials cover 3.2 acres
(7) Reef materials cover 2.0 acres
(8) SB 400 - Senate Bill 400 (Keene) Fisheries Restoration Account
(9) Area indicated represents total area approved for reef construction Actual area occupied by reef material is 1.4% or less of total area
(10) Reef materials cover 6.4 acres

Appendix 3 continued.

County	# by County	Year Constr.	Name and Location	Depth MLLW(1)	Area	Materials and Configuration	Remarks
Los Angeles	LA-4a	1971	Augmentation(5)	60'	ND	100 tons pier pilings; one module	Materials from demolition of Standard Oil facility at El Segundo pier. Funding: Standard Oil Co. - NCS(3).
	LA-9	1985 Apr/ May	***Marina del Rey Artificial Reef #2*** (MDRAR2); 1.25 Nmi @ 270°(mag) from Marina del Rey Harbor entrance; 33°58'06" N; 118°29'11" W (2)	65'	6.9 ac.	10,000 tons quarry rock; 16 modules, each 50'(L) x 50'(W) x 10'(H); 8 modules are 60' apart, 8 are 200' apart (as designed).	Developmental fishing reef investigating module spacing. Funding: Wildlife Conservation Board - $245,000.
	LA-7	1965	***Marina del Rey Artificial Reef #1*** (MDRAR1); 1.25 Nmi @ 252° (mag) from Marina del Rey Harbor entrance; 33°57'54" N; 118°29'10" W	65'	3.2 ac.	2,000 tons quarry rock; 8 modules, 100' diameter x 5-6'(H)	Recreational fishing reef. Funding: LA County F&G Commission - NCS.
	LA-7a	1976	Augmentation 33°57'50" N; 118°29'05"	60'	0.2 ac.	120 concrete dock floats, each 5'x 8' x 2'	Materials from Marina del Rey harbor - NCS.
	LA-7b	1978	Augmentation (same as LA-7a)	60'	ND(4)	4,000 tons concrete rubble	Partial funding: Wildlife Conservation Board.
	LA-5	1960	***Hermosa Beach Artificial Reef*** (HBAR); 0.7 Nmi offshore of Hermosa Beach; 1 Nmi @ 302°(mag) from King Harbor entrance; 33°51'13" N; 118°24'48" W	60'	0.5 ac.	same as LA-3	Developmental "replication reef" (3 of 3); same as LA-3.
	LA-5a	1975	Augmentation	55'-60'	ND	461 tires	Funding: Wildlife Conservation Board.
	LA-6	1962	***Redondo Beach Artificial Reef*** (RBAR); 0.75 Nmi @ 242°(mag) from King Harbor entrance; 33°50'14" N; 118°24'32" W	72'	1.6 ac.	1,000 tons quarry rock; 4 modules, each 100' diameter x 2-4'(H), 100' apart.	Recreational fishing reef. Funding: LA County F&G Commission - NCS.
	LA-6a	1974	Augmentation	72'	0.1 ac.	Barge, 100'(L) x 40'(W) x 10'(H)	Barge donated by U.S. Navy - NCS.
	LA-6b	1975	Augmentation	72'	0.1 ac.	350 tons of asbestos/ concrete pipe	Materials from John's-Manville Co. Funding: J-M Co. and Wildlife Conservation Board.
	LA-6c	1976	Augmentation	72'	ND	700 tons concrete pilings	Materials from Harbor Precast of San Pedro - NCS.

Los Angeles	LA-6d	1978	Augmentation	72'	ND	200 concrete dock floats, each 6-8' x 3' x 3'	Materials from King Harbor marina - NCS.
	LA-6e	1979	Augmentation	72'	ND	1,500 concrete dock floats, each 8'x 4'x 2'	Materials from King Harbor marina - NCS.
	LA-8	1977	***PALAWAN Artificial Reef*** (PWAR); 1.45 Nmi @ 209° (mag) from King Harbor entrance; 33°49'25" N; 118°24'53" W	120'	0.6 ac.	Liberty ship PALAWAN, lies with long axis @ 150° x 330° (mag)	Recreational fishing reef. Ship provided by Maritime Administration - NCS.
	LA-8a	1978	Augmentation	120'	ND	6,000 cu.yds concrete rubble	Materials from Port of LA pier demolition - NCS.
	LA-2	1958	***Redondo-Palos Verdes Artificial Reef*** (RPVAR); 33°48'48" N; 118°24'18" W	60'	0.1 ac.	6 streetcars	Second developmental reef in California; same as LA-1.
Orange	Or-7	1986	***Bolsa Chica Artificial Reef*** (BCAR) aka Huntington Beach Artificial Reef, aka Izor Reef; 5.25 Nmi @ 56° (mag) from Alamitos Bay entrance; 33°39'02" N; 118°06'05" W	85'-100'	220 ac. (9)	6,600 tons concrete rubble; 8 modules, each 100'(L) x 50'(W) x 6'(H), approx. 0.3 Nmi apart; 8 steel/concrete barges placed on reef, one per module (30,000 tons permitted)	Recreational fishing reef. Materials from San Pedro 22nd St. viaduct. Funding: Wildlife Conservation Board & SB 400(8) - $142,055; U.S. Navy donated and placed barges - NCS.
	Or-5	1975	***Huntington Beach Tire Reef*** (HBTR); Directly inshore of platform EVA, approx. 1 Nmi offshore; 33°40'00" N; 118°03'00" W	40'	35 ac. site (10)	25,000 tires	Recreational fishing reef. Funding: Los Angeles Rod & Reel Foundation - NCS. Partially deteriorated; tires washed onshore during 1977 storms.
	Or-1	1963	***Huntington Beach Artificial Reef #4*** (HUNBAR4) aka Huntington Beach A; 6 Nmi @ 261°(mag) from end of Newport Jetty; 33°37'27" N; 118°00'04" W	60'	ND	1,000 tons quarry rock; one module, 100' diameter x 2-5'(H)	Recreational fishing reef. Funding: Wildlife Conservation Board.
	Or-2	1963	***Huntington Beach Artificial Reef #3*** (HUNBAR3) aka Huntington Beach B; 33°37'17" N; 117°59'51" W	60'	ND	1,000 tons quarry rock; one module, 100' diameter x 2-5'(H)	Recreational fishing reef. Funding: Wildlife Conservation Board.

(1) MLLW - Mean Lower Low Water
(2) Center coordinates of reef
(3) NCS - No cost to the state
(4) ND - Not Determined
(5) Augmentation materials added to same reef location
(6) Reef materials cover 3.2 acres
(7) Reef materials cover 2.0 acres
(8) SB 400 - Senate Bill 400 (Keene) Fisheries Restoration Account
(9) Area indicated represents total area approved for reef construction Actual area occupied by reef material is 1.4% or less of total area
(10) Reef materials cover 6.4 acres

Appendix 3 continued.

County	# by County	Year Constr.	Name and Location	Depth MLLW(1)	Area	Materials and Configuration	Remarks
Orange	Or-3	1963	***Huntington Beach Artificial Reef #2*** (HUNBAR2) aka Huntington Beach C; 33°37'09" N; 117°59'17" W(2)	60'	ND(4)	1,000 tons quarry rock; one module, 100' diameter x 2-5'(H)	Recreational fishing reef. Funding: Wildlife Conservation Board.
	Or-4	1963	***Huntington Beach Artificial Reef #1*** (HUNBAR1) aka Huntington Beach D; 33°36'51" N; 117°58'49" W	60'	ND	1,000 tons quarry rock; one module, 100' diameter x 2-5'(H)	Recreational fishing reef. Funding: Wildlife Conservation Board.
	Or-6	1979	***Newport Beach Artificial Reef*** (NBAR); 4.5 Nmi @ 267° (mag) from end of Newport Jetty; 33°36'13" N; 117°57'49" W	72'	4.0 ac.	1,200 tons concrete rubble and pilings	Recreational fishing reef. Funding: Wildlife Conservation Board.
	Or-6a	1981	Augmentation(5)	72'	ND	2,700 tons concrete rubble	No information available.
	Or-6b	1982	Augmentation	72'	0.1 ac.	375 tons concrete blocks; one module, 50'(L) x 50'(W) x 10'(H)	Materials donated by THUMS (oil consortium) - NCS(3).
	Or-6c	1984	Augmentation	72'	2.0 ac.	6,400 tons concrete rubble and pilings; 5 modules, each 100'(L) x 50'(W) x 10'(H)	Materials from Port of LA (Berth 44-46) - NCS.
San Diego	SD-5	1980 Aug-Sept	***Pendleton Artificial Reef*** (PAR); 3 Nmi SSE of San Onofre power plant, approx. 1 Nmi offshore; 12 Nmi @ 118°(mag) from Dana Pt. Harbor and 10 Nmi from Oceanside Harbor entrance; 33°19'30" N; 117°31'42" W	43'	3.5 ac.	10,000 tons quarry rock; 8 modules, each 100'(L) x 30'(W) x 12'(H), 30 to 150' apart	Pilot developmental reef. Funding: Southern California Edison Co., $250,000 - NCS.
	SD-7	1987 Oct.	***Oceanside Artificial Reef #2*** (OAR2) aka Oceanside Experimental Reef; 2 Nmi @ 248°(mag) from Oceanside Harbor entrance; 33°12'35" N; 117°25'38" W	42'-72'	256 ac. (9)	same as LA-10	Developmental fishing reef investigating location, module depth, and relief. Funding: SB 400(8) and Wallop-Breaux - $223,000.
	SD-1	1964	***Oceanside Artificial Reef #1*** (OAR1); 1.75 Nmi @ 202°(mag) from Oceanside breakwater entrance; 33°10'57" N; 117°25'00" W	82'-120'	4.0 ac.	2,000 tons quarry rock; 4 modules, each 100' diameter x 5-6'(H); arranged in 2 rows	Recreational fishing reef. Funding: Wildlife Conservation Board.

San Diego	SD-1a	1987	Augmentation	45'-90'	64 ac. (9)	concrete dock floats; 12 modules, each 100' dia. x 5'(H), 100'apart	Funding: Oceanside Harbor District - NCS.
	SD-4	1975	***Torrey Pines Artificial Reef #2*** (TPAR2) aka Bureaucrat Reef; 3 Nmi @ 359°(mag) from Pt. La Jolla tower; 32°53'35" N; 117°15'35" W	44'	0.4 ac.	3,000 tons quarry rock; one module, 225'(L) x 70'(W) x 12'(H)	Recreational fishing reef. Funding: City of San Diego - NCS.
	SD-4a	1979	Augmentation 60' seaward of SD-4	45'	0.6 ac.	One barge load of steel reinforced concrete dock floats	Funding: Wildlife Conservation Board.
	SD-3	1964	***Torrey Pines Artificial Reef #1*** (TPAR1) aka Fish & Game Reef; offshore of TPAR2; 2.5 Nmi @ 352°(mag) from Point La Jolla tower; 32°53'12" N; 117°15'50" W	67'	ND	1,000 tons quarry rock	Recreational fishing reef. Funding: Wildlife Conservation Board.
	SD-6	1987 Sept /Oct	***Pacific Beach Artificial Reef*** (PBAR) aka Mission Bay Park Experimental Artificial Reef; 2.5 Nmi @ 324°(mag) from Mission Bay entrance; 32°47'35" N; 117°16'35" W	42'-72'	109 ac. (9)	same as LA-10	Developmental fishing reef investigating location, module depth, and relief. Funding: SB 400 - $223,000.
	SD-8	1987 Apr.	***Mission Bay Park Artificial Reef*** (MBPAR); 1 Nmi @ 300° (mag) from Mission Bay entr.; 32°46'10" N; 117°16'30" W	80'-90'	512 ac. (9)	Kelp harvester EL REY (100' L), 3 smaller fishing boats	Recreational fishing reef. Funding: Kelco Co. and Department of Fish and Game.
	SD-8a	1984 July	Augmentation	80'-90'	same	Retired Coast Guard Cutter RUBY E (165'L)	Recreational fishing reef - Prepared by San Diego Council of Divers; purchased by CDFG for $1.00.
	SD-8b	1989 Aug.	Augmentation	80'-90'	same	2,700 tons concrete rubble; arranged in 6 piles (1 @ 1200 tons and 5 @ 300 tons)	Recreational fishing reef - Materials from demolition of Ingraham Street Bridge (North) - NCS.
	SD-8c	1990 June	Augmentation	80'-90'	same	4,200 tons concrete rubble and pilings; arranged in 3 piles	Recreational fishing reef - Materials from demolition of the Broadway Street pier - NCS.

(1) MLLW - Mean Lower Low Water
(2) Center coordinates of reef
(3) NCS - No cost to the state
(4) ND - Not Determined
(5) Augmentation materials added to same reef location
(6) Reef materials cover 3.2 acres
(7) Reef materials cover 2.0 acres
(8) SB 400 - Senate Bill 400 (Keene) Fisheries Restoration Account
(9) Area indicated represents total area approved for reef construction Actual area occupied by reef material is 1.4% or less of total area
(10) Reef materials cover 6.4 acres

Appendix 3 continued.

County	# by County	Year Constr.	Name and Location	Depth MLLW(1)	Area	Materials and Configuration	Remarks
	SD-2	1964	***Silver Strand Artificial Reef*** (SSAR) aka Lost & Found Reef; off Silver Strand State Beach, south San Diego County	50'	0.3 ac.	2,000 tons quarry rock; one module, 148'(L) x 75'(W) x 10'(H)	Recreational fishing reef. Accidently created when rock laden barge overturned - NCS(3).

PLANNED ARTIFICIAL REEFS ALONG THE CALIFORNIA COAST
(updated November 1990)

County	# by County	Year Constr.	Name and Location	Depth MLLW(1)	Area	Materials and Configuration	Remarks
Santa Barbara	SB-2	Proposed Date ND	Unnamed; pending site selection; proposed for Vandenburg area	90'-300'	ND(4)	200,000+ tons concrete rubble, 190 steel tanks; design not finalized	Production reef for rockfish. Funding: Vandenburg Air Force Base - NCS.
	SB-1	Planned Date ND	***Santa Barbara Artificial Reef*** (SBAR); location unknown (Pending Evaluation)	42'-72'	256 ac. (9)	10,000 tons quarry rock; 24 modules (12 pairs) each 50'(L) x 50'(W); 4 pairs at each of 3 depths: 42', 57', and 72'. At each depth 2 pairs are high relief (12') and 2 pairs are low relief (5')	Developmental fishing reef investigating reef location, module depth, and relief. Funding: source ND.
Los Angeles		Proposed Date ND	Unnamed; pending site selection; proposed for Santa Catalina Island	ND	ND	Quarry rock; design ND	Developmental fishery reef investigating effects of depth and reef size on reef biota. Funding: source ND
	LA-12	Proposed Date ND	***Palos Verdes Wreck Reef-Fish Aggregating Device*** (PAVFAD); 12.5 Nmi @ 270° (mag) from L.A. Harbor entrance; 33°45'03" N;118°25'18" W(2)	100'	ND	Retired vessel - specific vessel ND	Recreational fishing reef; Funding: source ND.
San Diego	SD-9	Planned 1990-91	***Carlsbad Artificial Reef*** (CAR); 8.2 Nmi @ 138°(mag) from Oceanside Harbor Jetty; 33°05'08" N;117°19'10" W	37'-57'	ND	10,000 tons quarry rock; 12 modules each 50'(L)x 50'(W); 4 modules at each of 3 depths: 37,42,& 52ft; 3 pairs of modules with rock 1-3 ft dia.; 3 pairs with rock 4-6 ft dia.	Recreational fishing and habitat enhancement reef. Funding: source ND.
San Diego	SD-10	Proposed	Unnamed; vicinity of Pt. Loma 32°36'03" N; 117°13'41"W	ND	ND	Quarry rock; design ND	Recreational fishing reef; details ND.

(1) MLLW - Mean Lower Low Water
(2) Center coordinates of reef
(3) NCS - No cost to the state
(4) ND - Not Determined
(5) Augmentation materials added to same reef location
(6) Reef materials cover 3.2 acres
(7) Reef materials cover 2.0 acres
(8) SB 400 - Senate Bill 400 (Keene) Fisheries Restoration Account
(9) Area indicated represents total area approved for reef construction Actual area occupied by reef material is 1.4% or less of total area
(10) Reef materials cover 6.4 acres

APPENDIX 4

Proposed Locations and Configurations of Artificial Reef Fisheries Habitat Enhancement Areas in Southern California

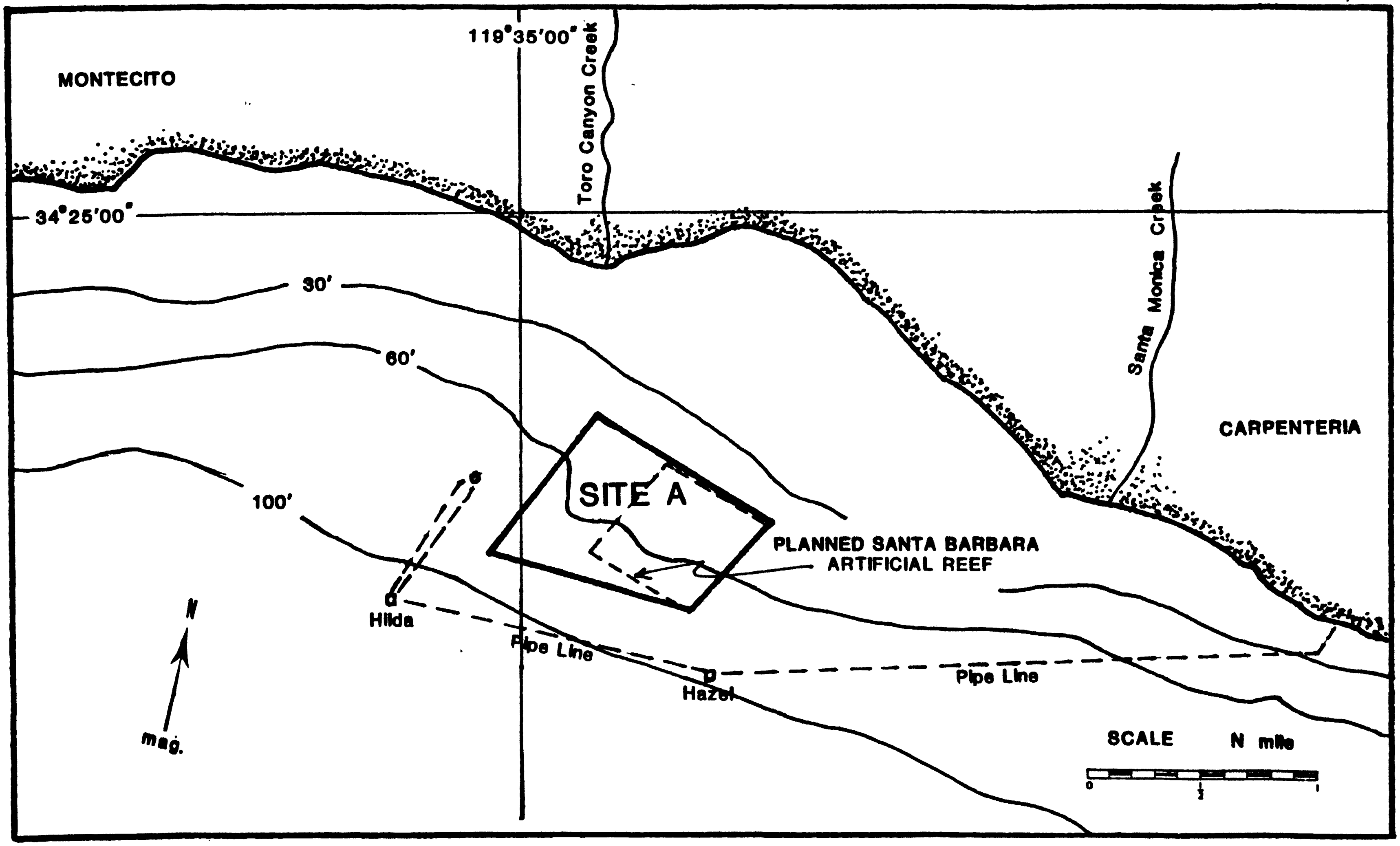

Figure A4-1. Proposed Santa Barbara Artificial Reef Fisheries Habitat Enhancement Area.

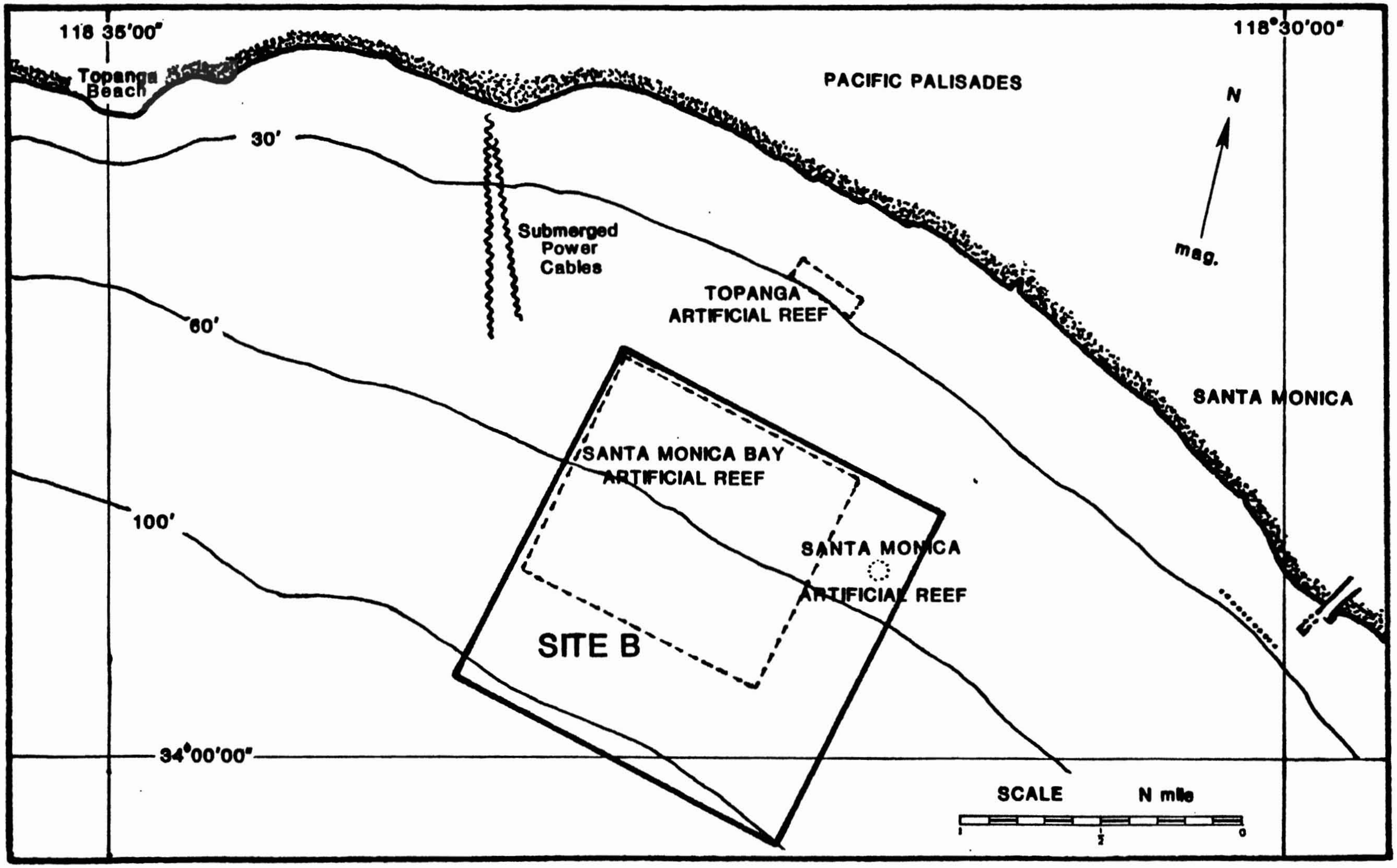

Figure A4-2. Proposed Santa Monica Artificial Reef Fisheries Habitat Enhancement Area.

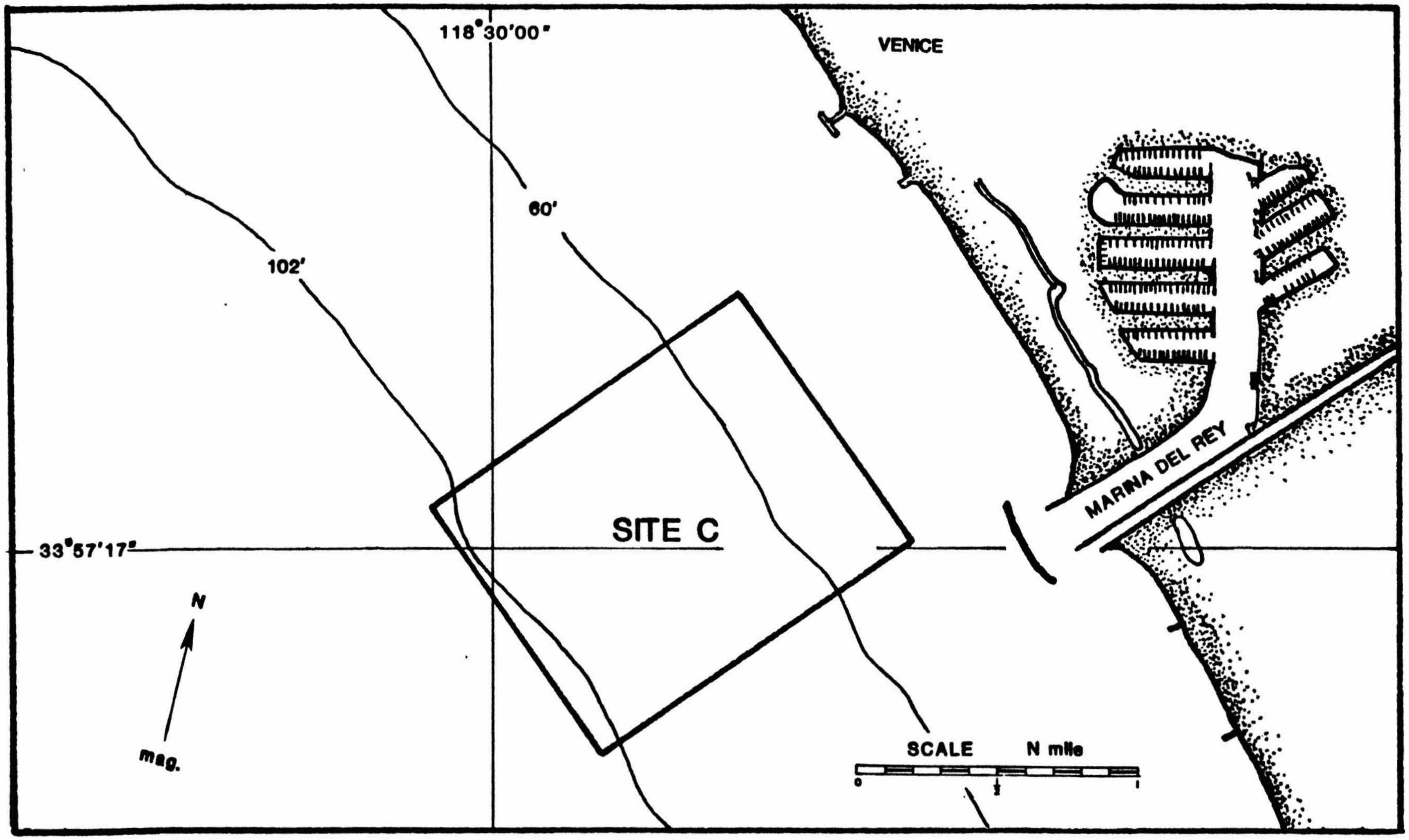

Figure A4-3. Proposed Marina del Rey Artificial Reef Fisheries Habitat Enhancement Area.

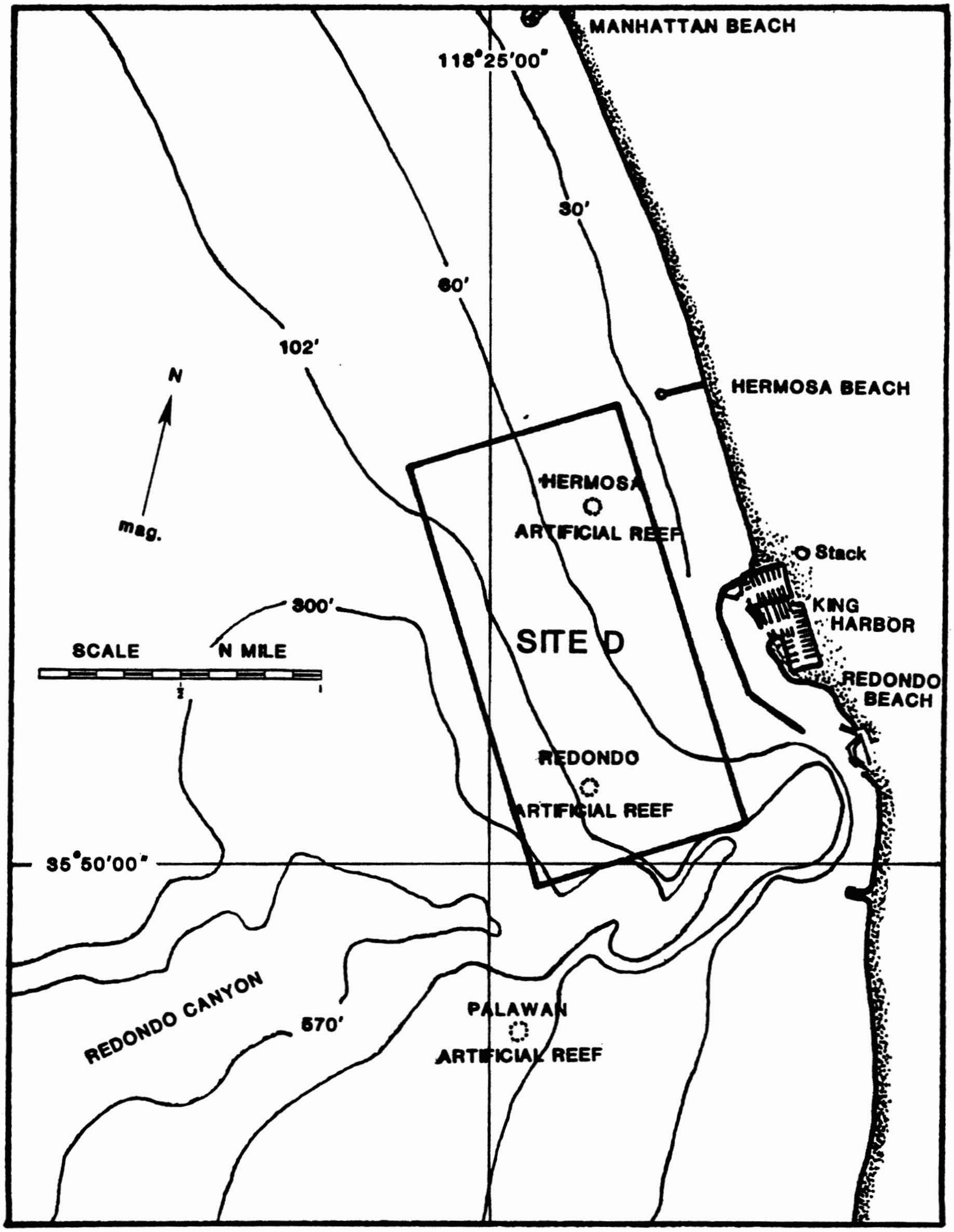

Figure A4-4. Proposed Redondo-Hermosa Artificial Reef Fisheries Habitat Enhancement Area.

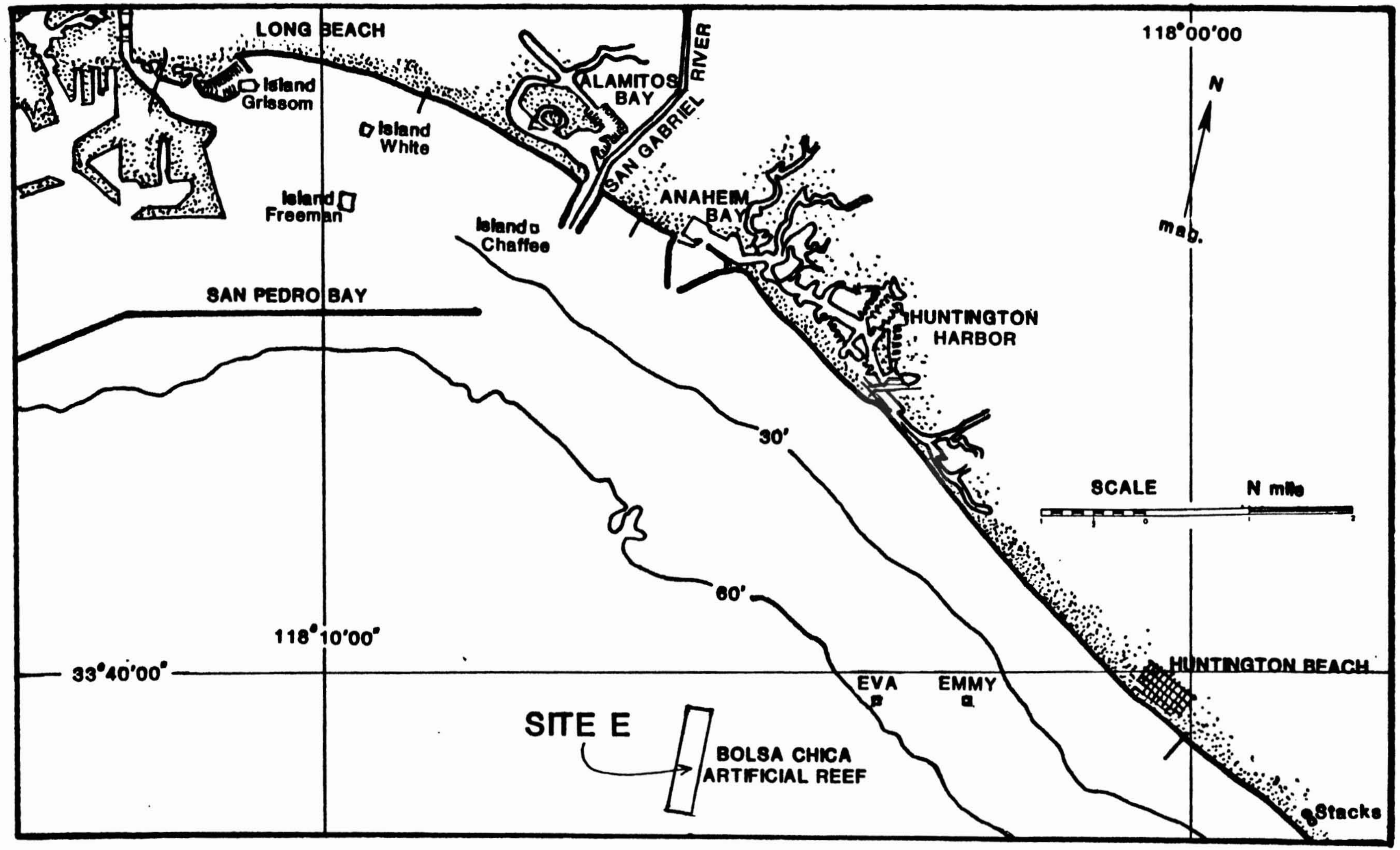

Figure A4-5. Proposed Bolsa Chica Artificial Reef Fisheries Habitat Enhancement Area.

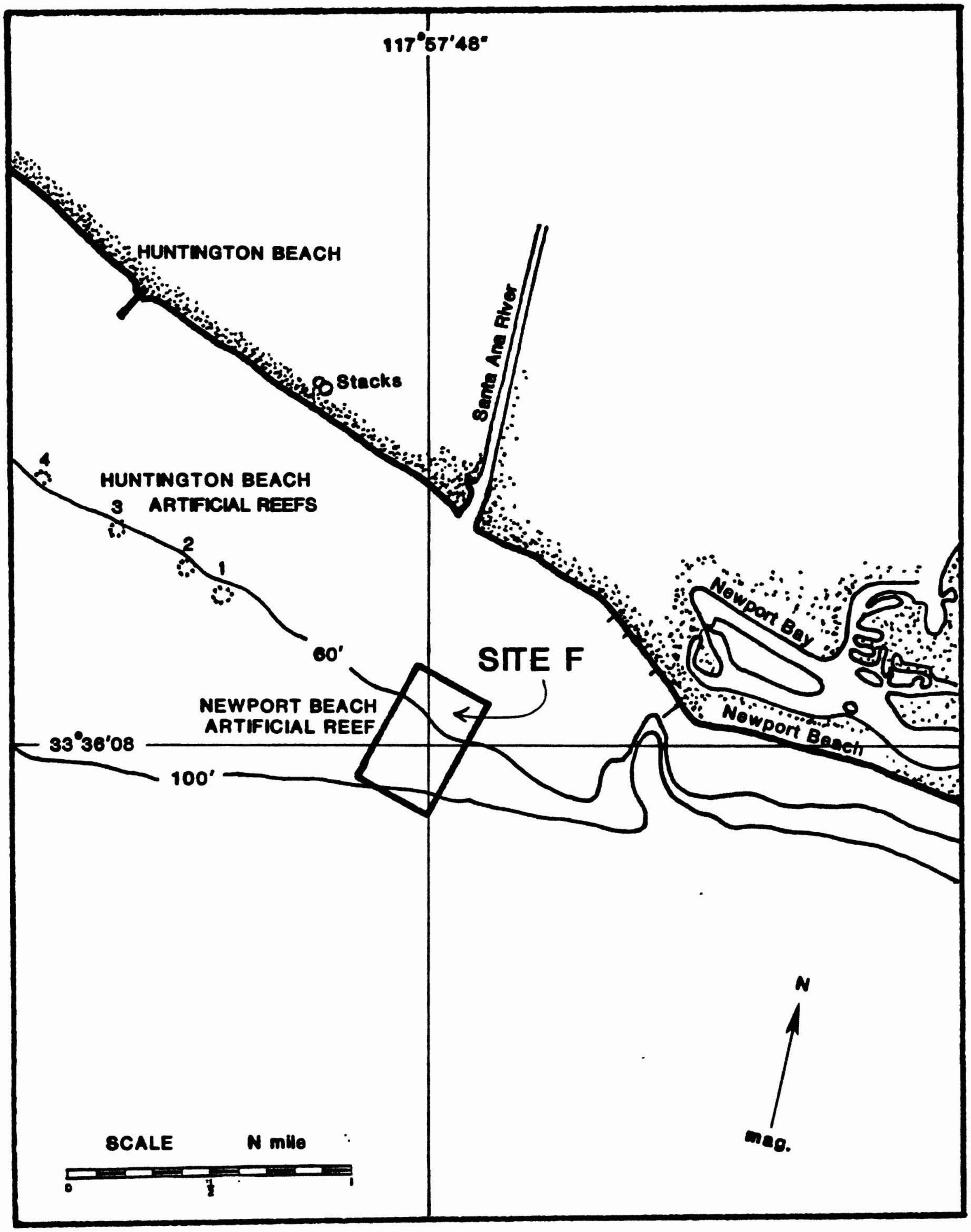

Figure A4-6. Proposed Newport Beach Artificial Reef Fisheries Habitat Enhancement Area.

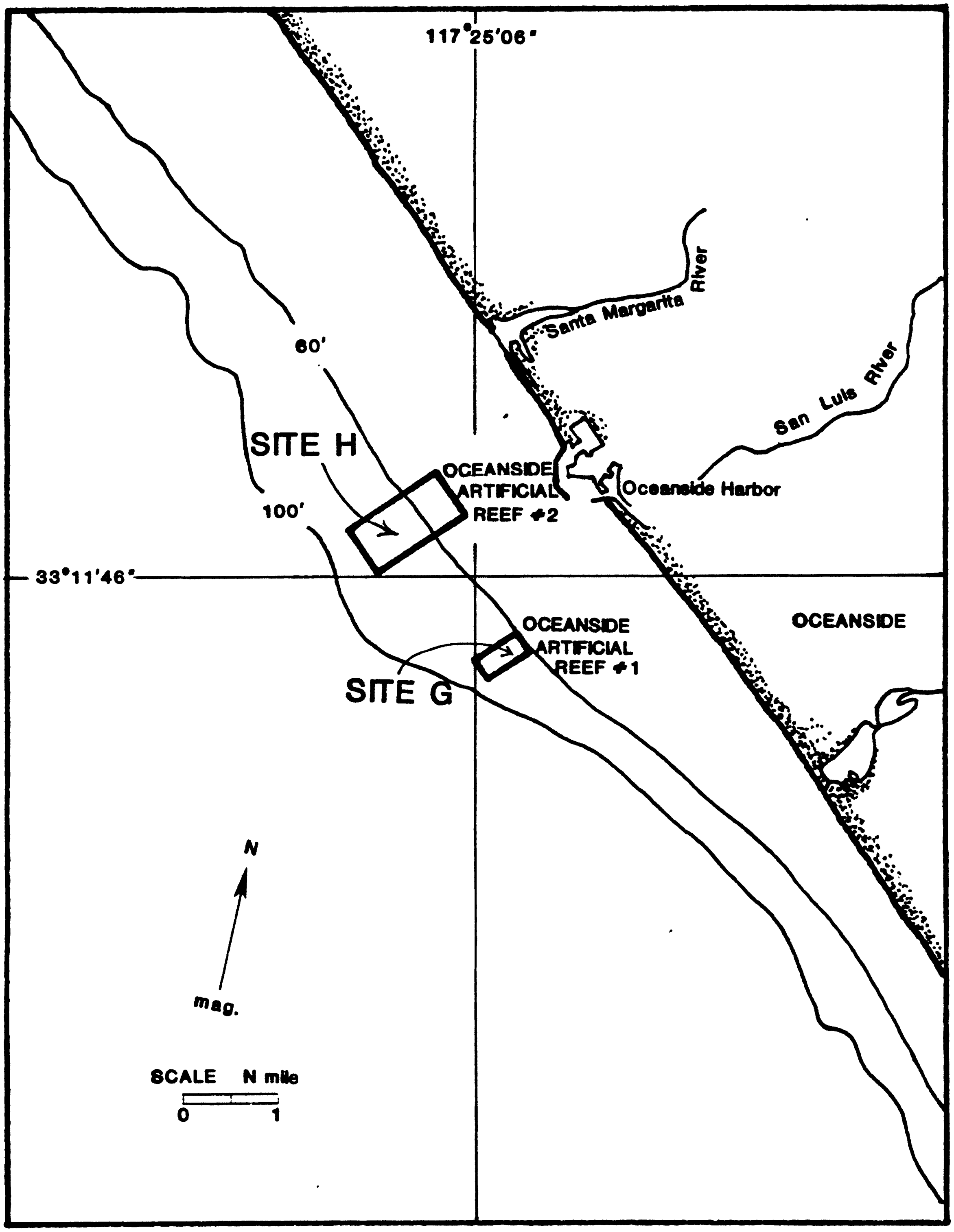

Figure A4-7. Proposed Oceanside Artificial Reef Fisheries Habitat Enhancement Area.

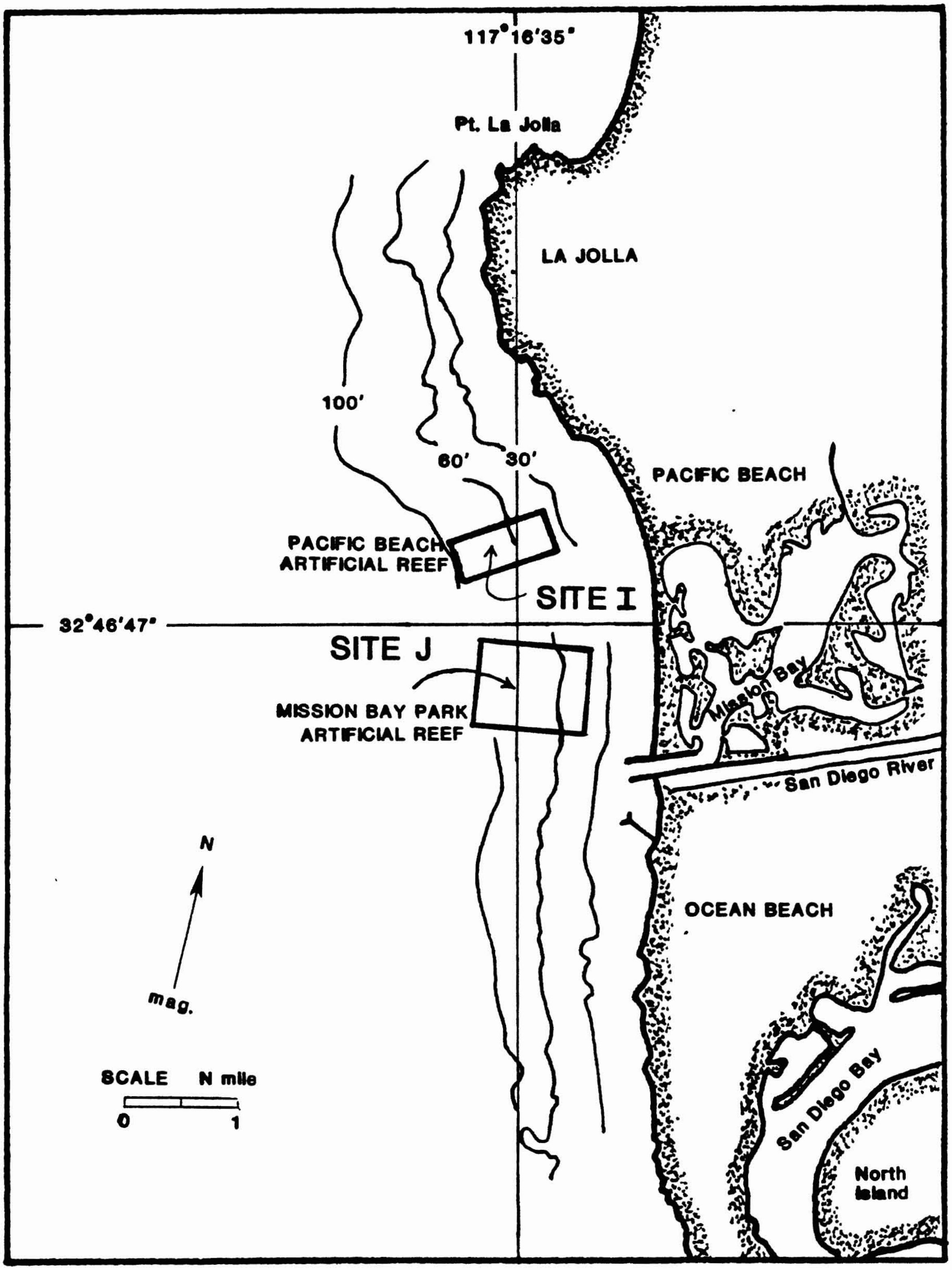

Figure A4-8. Proposed Mission Bay Park Artificial Reef Fisheries Habitat Enhancement Area.

APPENDIX 5

Planned and Proposed Artificial Reefs Along the Southern California Coast

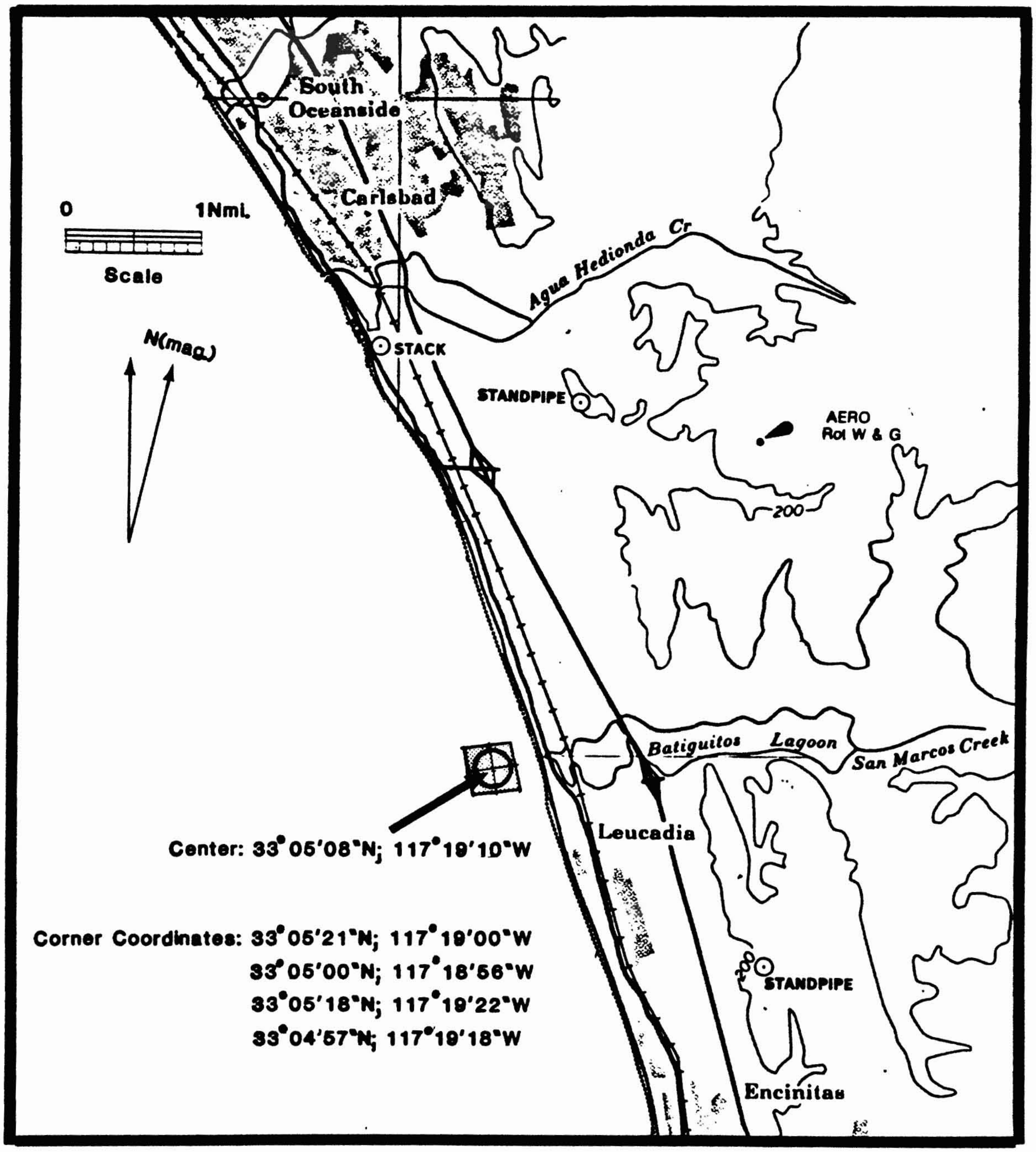

Figure A5-1. Planned location of Carlsbad Artificial Reef.

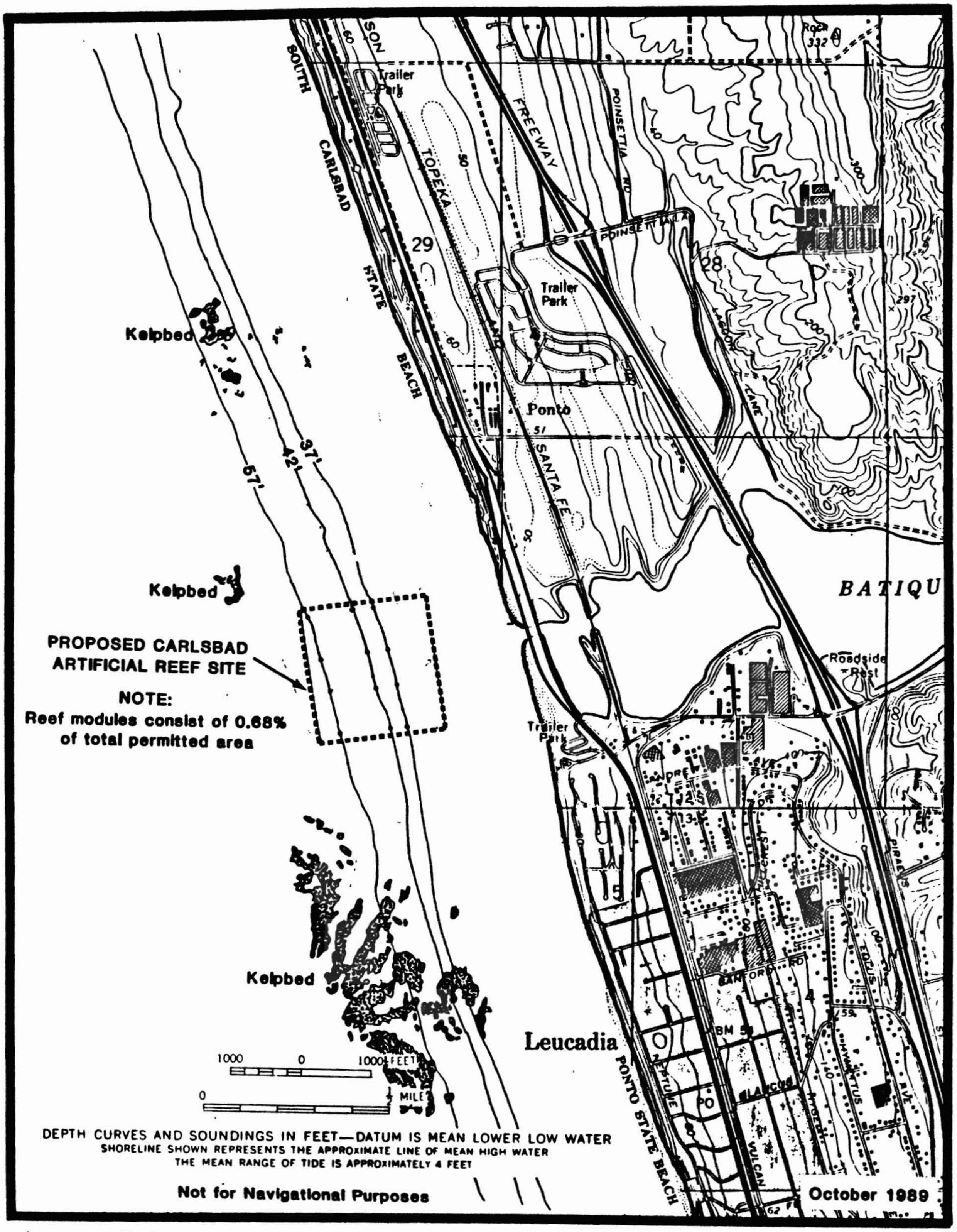

Figure A5-2. Scale drawing of the planned Carlsbad Artificial Reef in relation to kelp beds and Batiquitos Lagoon (kelp bed information based on 1988 aerial survey).

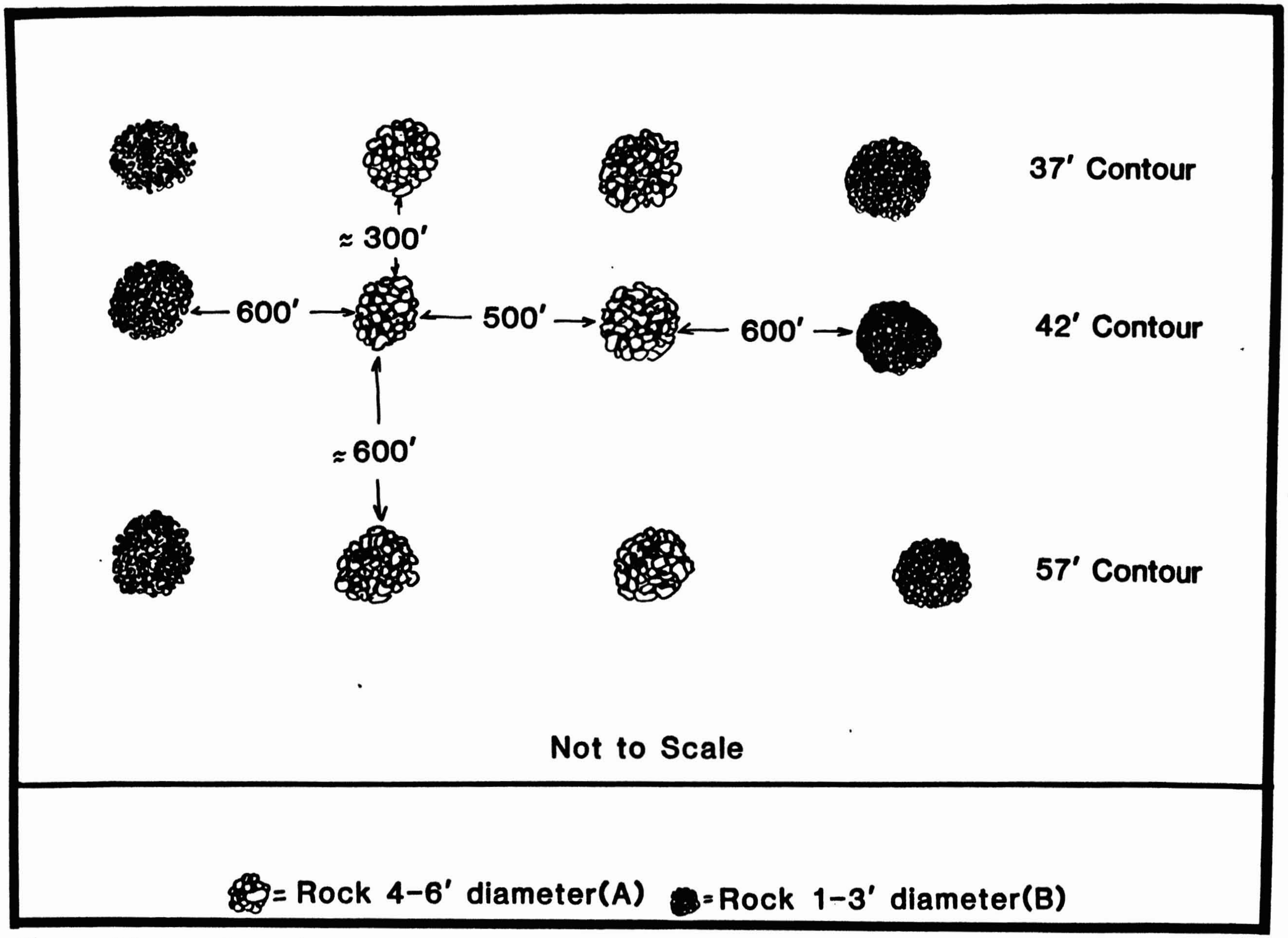

Figure A5-3. Plan view of Carlsbad Artificial Reef.

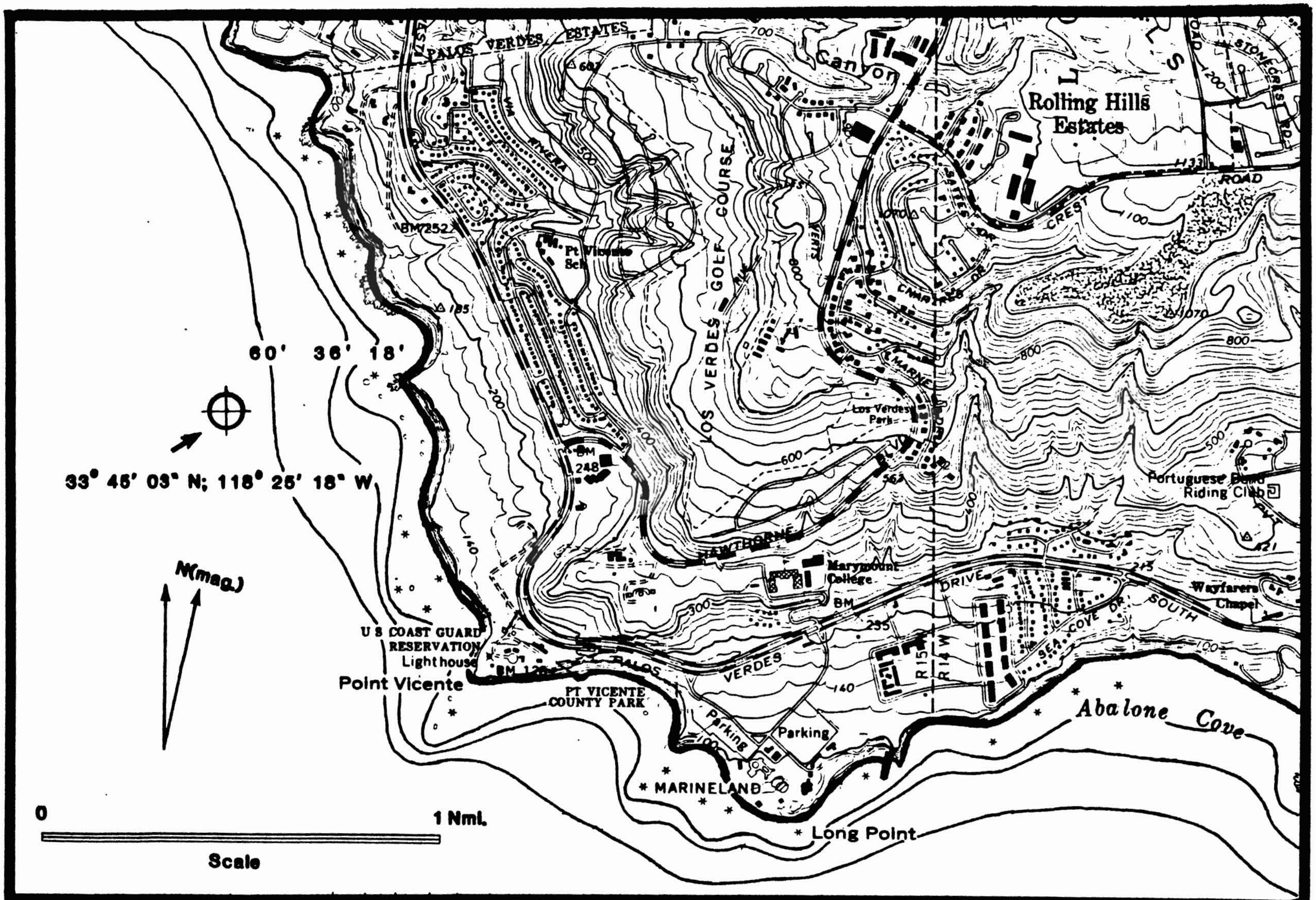

Figure A5-4. Planned location of Palos Verdes Wreck Reef.

APPENDIX 6

PAR - A Pilot Developmental Reef

APPENDIX 6. PAR - A Pilot Developmental Reef

The following overview of work on Pendleton Artificial Reef, illustrates reef construction and study processes.

PRECONSTRUCTION, PLANNING, AND SITING

Preconstruction activities began in 1979 and included literature searches, field surveys, preparation of a reef design, formulation of a biological study plan, and obtaining reef construction permits.

A literature search provided helpful information on reef design and placement, and reports of SCE studies, off San Onofre, provided information on the physical and biological characteristics of specific nearshore areas (SCE Company 1979, 1980). Historical records of kelp forest distribution and data from CDFG survey flights provided information on kelp forests near San Onofre. CDFG records (Dana Point to San Onofre) also provided information on local fisheries.

Field surveys characterized the biotic communities associated with a number of artificial and natural reefs from Laguna to La Jolla, such as Torrey Pines Artificial Reef 2 (TPAR 2) and the natural reefs at Las Pulgas and San Onofre. The information obtained was used to predict, qualitatively, the general nature of successionally mature biotic communities associated with man-made reefs and their long-term biotic potential.

Field surveys were conducted in several locations, from Dana Point to Oceanside, to gather information on the physical and biological characteristics of potential reef sites. At each location, bottom sediments were described and their load bearing characteristics and thickness estimated using probes. Biotic communities on the soft bottom were characterized to estimate the extent of changes expected following reef construction. The location and description of nearby natural reefs were also noted.

Mia Tegner of Scripps Institution of Oceanography and David Parker of CDFG, both abalone experts, were consulted regarding substrate requirements for abalone. John G. Carlisle, marine habitat development coordinator for CDFG (1965 to 1978), was consulted regarding artificial reef habitat for fishes.

Information was analyzed and a design formulated for use in constructing a multiple purpose "state of the art" reef. It was to consist of eight uniformly spaced modules to maximize the availability (perimeter:area ratio) of sand/rock ecotones for fishes. It was to have high relief to increase vertical diversity of habitats and associated biota and to provide substrate for growth of giant kelp and other algae above sediments disturbed by wave surge. It was to be built from both large and small boulders to provide a complex of crevices and exposed surfaces for use by fishes and invertebrates as sheltering, foraging, nesting, and nursery habitats. Cobble topping was to be placed on several modules to provide small crevice habitat to increase the survival of juvenile abalone and other invertebrates. It was to be placed within the depth range of kelp forests at San Onofre and Barn Kelp (Figure A6-1). Finally, the reef was to be located beyond the influence of major sources of sedimentation and seaward of the primary region of longshore sand transport to minimize the probability of reef burial and of impacts on sand movement.

The reef design was reviewed by Michael Neushul and Al Ebling of U.C. Santa Barbara, Wheeler North of California Institute of Technology, and Raymond Buckley of Washington State Department of Fisheries.

Oceanographers from SCE were consulted to estimate the maximum area of influence of the power plant, in full operation, and to ensure that a reef would not affect SCE`S ongoing studies. Plans for the reef were also discussed with personnel of the Pendleton Marine Base Command and with personnel of the State Beach at San Onofre for their input regarding location and possible interactions with onshore operations. A site, two nautical miles south of SONGS, was selected for reef construction, and reef building permits were obtained from the regulatory agencies (Figure 4).

The plan was then presented to scientists employed by the Marine Review Committee (MRC), a research group appointed by the California Coastal Commission to investigate the effects of SONGS operation on the marine environment. They felt that a reef, at the proposed location, might influence their plankton studies and suggested locating the reef an additional nautical mile south of SONGS.

Permits were then amended and in August-September 1980, after eleven months of research, design, and permitting efforts, the Pendleton Artificial Reef was constructed.

Reef Description

PAR was built on sand bottom in 43 ft (13 m) of water approximately one nautical mile from shore. It is composed of 9,078 metric tons of quarry rock, ranging in size from 1 to 6 ft (0.3 m to 2.0 m) in diameter, and consists of eight modules spaced about 60 ft (18 m) apart. Modules are somewhat irregular in shape, averaging 118 ft x 66 ft x 15 ft (36 m long, 20 m wide, and 4.5 m high). The reef and sandy interspaces encompass an area of approximately 3.5 acres (1.4 hectares) (Figure 5).

POST-CONSTRUCTION STUDIES

Physical Surveys

Following construction, diving surveys and aerial photographic surveys were conducted to document the reef structure and to help create a topographic map.

Biological Surveys

Background - Early studies of successional development of biotic communities on artificial reefs in Santa Monica Bay have been well documented (Carlisle *et al.* 1964; Turner *et al.* 1969). These studies suggest that the biota on reefs continued to change for at least 5 years following reef construction. Since CDFG was interested principally in the long-term biotic potential of artificial reefs for enhancing sport fish populations and not transient stages of biotic development, studies of fishes, macroinvertebrates, and macroalgae at PAR were primarily qualitative for the first 3 years following reef construction (1980 to 1983).

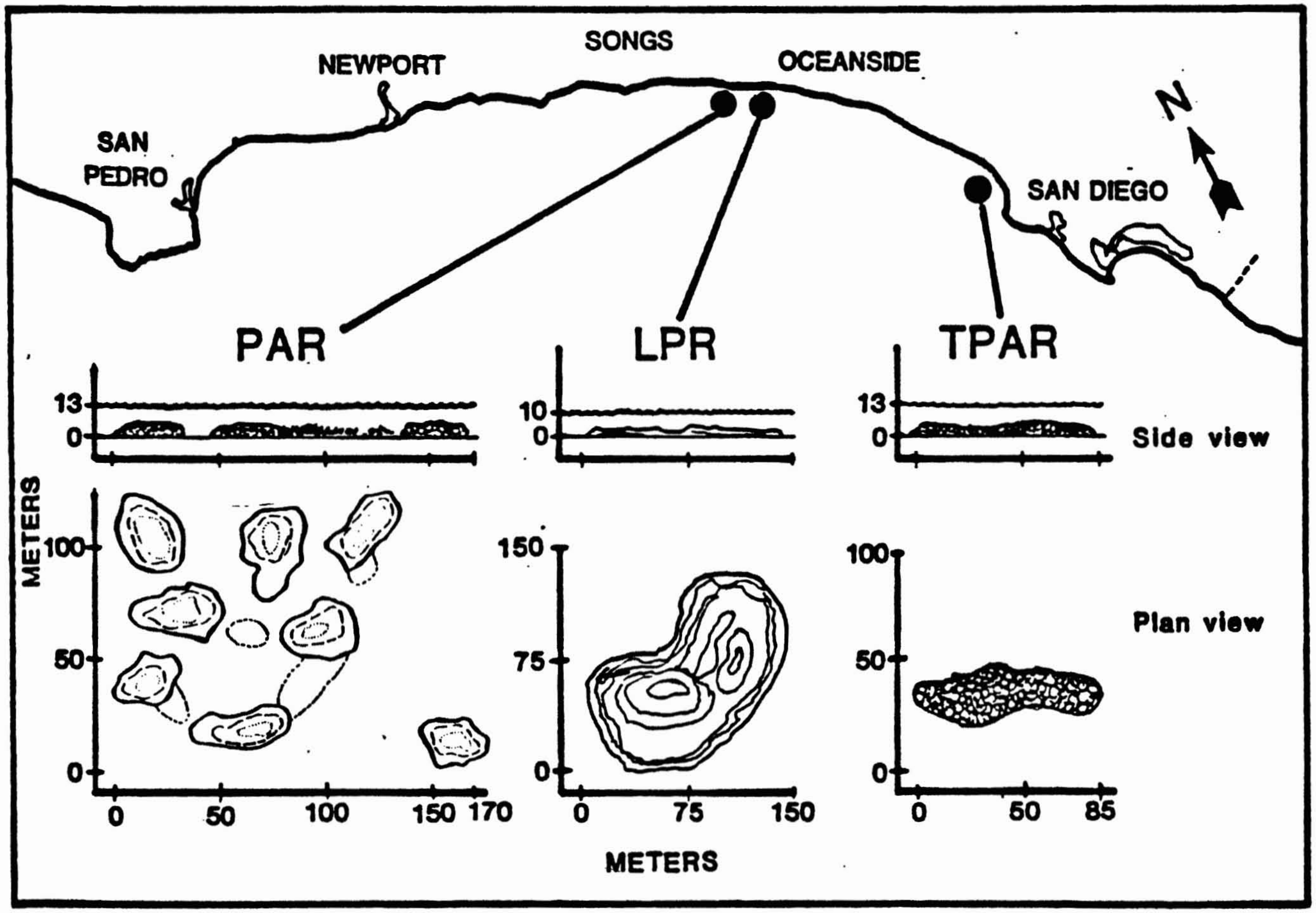

Figure A6. Locations of Pendleton Artificial Reef (PAR), Las Pulgas Reef (LPR), and Torrey Pines Artificial Reef (TPAR).

In 1981, CDFG began a quantitative study of PAR's turf community (low growing algae and small sessile epibenthic invertebrates) to determine if the biotic succession was similar to that on artificial reefs in Santa Monica Bay. Quantitative studies of fishes, macroinvertebrates, and macroalgae began in 1984, when PAR's biotic community had reached an "intermediate" stage of succession. In an effort to estimate the long term biotic potential of reefs such as PAR, CDFG undertook parallel studies at two reference reefs: Torrey Pines Artificial Reef 2 (TPAR 2) -- an older reef, presumably at or near successional equilibrium, and Las Pulgas Reef (LPR) -- a natural reef at successional equilibrium (Figure A6-1). These reference reefs were similar to PAR in relief, depth, and general location.

The development of biotic communities at PAR was also studied by MRC scientists during the first two years following reef construction and again in 1986. These efforts contributed to the knowledge of early and intermediate stages of biotic community development on man-made reefs.

Summary of CDFG Survey Methods- Turf community organisms were sampled using 1/8 square meter random point contact (RPC) quadrats, each with 30 evenly distributed points. Quadrat numbers were adjusted by reef site to accommodate for variation in reef size, relief, and configuration. During the first four years, RPC quadrat samples were taken quarterly at PAR. In the last two years of the study, sampling at PAR and reference sites was conducted in the spring (April-June) and fall (September-November). To determine the relationship between distribution of species and reef height, the data were stratified into three 5 ft (1.5 m) relief profiles: the interface, 0 to 5 ft (0 m to 1.5 m) above the bottom; slope, 5 ft to 10 ft (1.6 m to 3.1 m); and crest, 10+ ft (3.1+ m). Data were expressed in mean percent cover by species or taxonomic group within each relief profile.

Macroinvertebrates and macroalgae (sea stars, lobster, kelp species, etc.) were also sampled in spring and fall using 16 ft by 3 ft (5 m x 1 m) band transects. Transect lines were randomly placed within each relief profile along randomly selected isobaths. Care was taken to avoid overlap of transects. The number of transects differed among reefs, depending upon reef area; however, the number of transects within each reef location remained constant. Areas surveyed ranged from 4 percent of the total on the largest reef to 25 percent on the smallest reefs or modules. Only conspicuous organisms were counted. If the number of organisms was exceptionally high, as in the case of gorgonian colonies (often in excess of 30 individuals/m^2), subsamples were taken by counting all colonies within two randomly selected square meter plots within each transect. Data were expressed as mean number of individuals per square meter. Sizes of gorgonians and scallops were also measured.

Fish communities were surveyed at PAR and reference sites each year, between September and October, when underwater visibility was likely to exceed 10 ft (3.1 m). Permanent transect lines were placed along the crests and along the 5 ft (1.5 m) relief contour of each reef. Divers swam slowly along the lines and counted non-cryptic adult and sub-adult fishes within a transect, 10 ft (3.1 m) wide by 5 ft (1.5 m) high, which varied from 46 ft to 98 ft (14 m to 30 m) in length, depending upon reef size. Eight replicate counts were made along each line. A 2-minute pause was taken between replicate counts to minimize effects of redistribution of fishes caused by the movement of divers during the previous count. Data were expressed as mean number of fishes/3531 cu. ft (100 m^3).

Summary of Survey Results- The results indicated that PAR's plant and animal communities were still undergoing successional change in fall 1986, six years following reef construction. Qualitative observations, in September 1987 and July 1988, revealed minor successional changes since 1986.

Studies at PAR and reference sites have also helped us to identify individual species and "suites" of organisms that indicate the approach of successional equilibrium in artificial reef biota in the SONGS/Camp Pendleton area. The principal organisms are listed with notes on their relationship to successional development:

> Encrusting ectoprocts, primarily *Cryptoarachnidium argilla*, hydroids, and barnacles are often major components of epibenthic communities on new reefs. These decreased in abundance, with time, to levels similar to those on reference reefs.
>
> Erect ectoprocts, such as *Bugula* sp., increased in percent cover the first four years. Cover stabilized after four years.
>
> Scaled-worm molluscs increased in percent cover, with time. The cover stabilized somewhat after five years.
>
> Gorgonian colonies were smaller and occurred in higher densities on new reefs than on older ones.
>
> Motile epibenthic macroinvertebrates such as sea urchins, snails, and starfishes were more diverse and abundant on the reference reefs than on PAR.
>
> Foliose and articulated coralline algae cover was greater on the reference reefs than on PAR.

Observations in other areas of southern California suggest that these organisms may also be useful as indicators of advanced successional development on other artificial reefs. The predictability of the progression of successional development on any reef will vary with geographic location, water depth, water quality, presence of surface or sub-canopy forming vegetation, etc.

The fish community at PAR began to develop within hours of construction. Observed at this time were kelp bass, barred sand bass, surfperches, California scorpionfish, and sheephead. By February 1984, a cumulative total of 41 fish species had been observed.

Twenty-four species of fishes were observed at PAR from 1984 to 1986. The ten most abundant and consistently observed fishes during this period were (in order of decreasing 3-year weight mean density) blacksmith, senorita, sheephead, rock wrasse, black perch, kelp bass, garibaldi, halfmoon, opaleye, and barred sand bass. Annual mean densities (AMD) of these ten species fluctuated widely between 1984 and 1986. The AMDs of eight species decreased, while those of only two species, sheephead and rock wrasse, increased through the period (Wilson and Lewis 1990).

Appendix 7.

List of Common and Scientific Names

Appendix 7. List of Common and Scientific Names 1/

INVERTEBRATES

CNIDARIA	
hydroids	primarily *Obelia* sp.
gorgonians	*Muricea californica, M. fruticosa,* and *Lophogorgia chilensis*
ECTOPROCTA	
bryozoans	encrusting and erect ectoprocts
encrusting ectoprocts	*Cryptoarachnidium argilla*,others
erect ectoprocts	*Bugula* sp., others
POLYCHAETA	
worms	*Chaetopterus* sp., *Diopatra ornata, Eudistylia polymorpha*, others
CRUSTACEA	
amphipods	gammarids
barnacles	*Megabalanus* sp.
crabs	primarily *Cancer* sp., others
lobsters	*Panulirua interruptus*
shrimp	*Hippolysmata Californica*
MOLLUSCA	
abalone	*Haliotis* spp.
jewel box, ornate	*Chama pellucida*
limpet, keyhole	*Megathura crenulata*
octopus	*Octupus* sp.
scallop, giant	*Hinnites giganteus*
scaled-worm mollusc	*Serpulorbis squamigerus*
squid	*Loligo opalescens*
wavy ruban	*Astraea undosa*
whelk, festive	*Pterapurpura festiva*
whelk, kellets	*Kelletia kelletii*
whelk, poulson's	*Ocenebra poulsoni*
ECHINODERMATA	
brittle stars	ophiuroids
sea cucumbers	*Parastichopus parvimensis, Cucumaria* sp.
sea stars	*Pisaster* spp.
sea urchins	*Strongylocentrotus purpuratus, S. franciscanus, Lytechinus anamesus*

FISHES

anchovy	*Engraulis mordax*
bass	*Paralabrax nebulifer*
bass, kelp	*P. clathratus*
blacksmith	*Chromis punctipinnis*
cabezon	*Scorpaenichthys marmoratus*
garibaldi	*Hypsypops rubicundus*
perch, pile	*Rhacochilus vacca*
perch, black	*Embiotoca jacksoni*
perch, white sea	*Phanerodon furcatus*
halfmoon	*Medialuna californiensis*
opaleye	*Girella nigricans*
mackerel, jack	*Trachurus symmetricus*
midshipman, plainfin	*Porichthys notatus*
scorpion fish, California	*Scorpaena guttata*
sculpin	cottids
sheephead	*Semicossyphus pulcher*
surfperches	embiotocids
basses	serranids
rockfishes	*Sebastes* spp.
gobies	gobiids
halibut, California	*Paralichthys californicus*
white seabass	*Atractoscion nobilis*
blennies	*Hypsoblennius* spp.
wrasse, rock	*Halichoeres semicinctus*

ALGAE

algal turf	low-growing filamentous and polysiphonous algae
articulated coralline algae	*Corallina vancouverensis*
foliose algae	*Gigartina* sp., *Rhodymenia* spp., *Gelidium/Pterocladia* spp., others
giant kelp	*Macrocystis pyrifera*
pea kelp	*Cystoseira osmundacea*
no common name	*Laininaria* sp.
no common name	*Pterygophoracalifornica*

1/ Used in the report