

INTRODUCTION

This booklet is offered as a convenient guide to illustrate and describe the location, topography and some living resources of artificial reefs along the southern California coast. It is also intended to increase public awareness, knowledge, and use of these artificial reefs built by the California Department of Fish and Game (DFG).

Artificial reef construction is one aspect of the DFG's Nearshore Sport fish Habitat Enhancement Program for restoring or enhancing sport fish habitat along the southern California coastline. The program has also made significant contributions to the improvement of sport fish habitat through kelp forest restoration on Palos Verdes Peninsula, in Los Angeles County, and along the Santa Barbara and Orange County coast. The program's objective is to maintain sportfishing success in the face of the cumulative effects of increasing fishing pressure as well as negative impacts on the nearshore ecosystem. Coastal sport fishing in California is important in providing food and recreation to a large and increasing human population. Good fishing for many of the most popular sport fish species usually exists where natural reefs, rocky headlands, and shoals are located. However, most southern California coastal subtidal areas are characterized by sand, silt, or muddy bottom, with only occasional small rocky patches. Such areas provide little support for reef associated sport fishes or for development of the marine life these fishes require for food and habitat. With this in mind, in 1958 the DFG began a program of artificial reef research and development. This booklet is one result of that program.

HOW TO USE THIS BOOKLET

The reefs are described by Latitude-Longitude coordinates, bearings from nearby access ports, and materials of construction. While maps and bearings are included, **THIS PUBLICATION IS NOT INTENDED FOR NAVIGATION PURPOSES**. Users are reminded that some of the coordinates listed for the reefs were generated from older shipboard LORAN-C units. Readings of LORAN receivers vary considerably. More recent reefs were charted utilizing differential GPS. Consequently, we recommend that when reefs vary from actual chart coordinates, users make their own GPS readings once a reef has been located. This will make the reef easier to located on subsequent trips.

While some minor physical changes may occur over time, the maps should present a reasonably accurate long-term view of the reef configurations. Several of the reefs described are marked by buoys; nevertheless, these are often lost or destroyed and, when replaced, are usually in somewhat different location on the reef complex. Consequently, bearings taken from buoys on one trip may not be reliable on subsequent trips. The reefs are discussed in the order they occur along the coast from north to south. Each reef location is indicated on its map together with Latitude - Longitude coordinates. Each location also indicates, where possible, distance and bearings from nearest port, boat launching facility, and /or landmark. Finally, each reef is diagrammed from a vertical perspective, essentially providing a "footprint" of the reef.

SPORT FISH HABITAT ENHANCEMENT

During the early days of the program, DFG marine biologists investigated the effectiveness of various reef materials for increasing sportfishing success. The first two reefs in California were constructed of donated materials, since the DFG's artificial reef project had not yet been funded. The operators of Paradise Cove Landing in northern Santa Monica Bay contributed 20 old automobile bodies to DFG. These old cars were placed in 50 feet of water at Paradise Cove in May 1958. In September 1958, six old wooden streetcars were placed in 60 feet of water near Redondo Beach. The donated streetcars were sunk at the site by the U.S. Navy, which towed them from Los Angeles Harbor.

These early artificial reefs were designed to test the effectiveness of such structures in attracting fish. They proved very successful. DFG marine biologist, using scuba, carried out extensive observations of the reefs for several years. Fishes began to aggregate around the Paradise Cove car body reef within hours of construction. Surfperches, sargos, kelp bass, and small California halibut were among the first fishes attracted to the reef, followed closely by sheephead and opaleye. Later, rockfish and sand bass appeared. The fish population on the reef increased, until a high of 24,000 semi-resident fishes was counted in September 1960. During a 30 month survey period, 49 species of fish were noted on Paradise Cove Reef.

Similar results were observed at Redondo Beach Reef. The streetcars attracted 3,000 fishes, of 47 species, within 25 months. The success of the reefs was attributed to three main factors: the schooling behavior of fish, the availability of food and shelter, and a phenomenon known as thigmotropism (the tendency of fish to orient close to a solid object).

The success of artificial reefs in attracting and concentrating fishes caused the DFG to initiate a program to investigate the cost-effectiveness and practicality of various reef building materials. An experiment was designed to determine the enhancement characteristics

resulting from the construction of reefs of similar materials in four separate locations in Santa Monica Bay. Funded by the Wildlife Conservation Board, these replication reefs were placed in 60 feet of water off Malibu, Santa Monica, and Hermosa Beach. Each reef had one streetcar, several old car bodies, quarry rock, and concrete boxes placed in equal volumes and similar configuration. These reefs were built on relatively barren sand areas remote from productive, natural rocky substrate. Observations over several years indicated that concrete boxes were the most effective in attracting fishes, with quarry rock a very close second. Quarry rock, at half the cost of the fabricated concrete boxes proved to be the most cost-effective material. While subsequent studies have further substantiated the value of quarry rock, due to its potential for colonization by, and production of, food organisms, the availability of surplus concrete from port side demolition projects has proven to provide both a cost effective and productive material as well.

Since the early days of DFG's artificial reef construction program, several other materials have been tried with varied success. In the 1970's and 80's used automobile tires were constantly being offered for use, but have not proven workable in California, as in other coastal states, because of problems in keeping tire reefs in place and because they seem to offer a poor surface area for attachment of marine organisms. There is also a potential for release of harmful chemicals from the tires over time. Several ships have been sunk as reefs. The first, retired Liberty ship, the PALAWAN, was placed off Redondo Beach in about 120 feet of water. In 1987 a retired kelp harvesting vessel, the EL REY, formed the nucleus of a three ship submerged "fleet" off Mission Beach in San Diego. Observations of the Mission Beach vessels through the early 1990's showed that vessels did not provide enough small hiding places as do quarry rock or broken concrete rubble, and so further use of ships as reefs was abandoned.

After the early investigative work from 1958 to 1964, the Department continued to augment existing reef sites with quarry rock, and donated concrete piping and rubble. Fishing reefs were also constructed around seven of southern California's fishing piers.

The reefs were occasionally observed by DFG biologists during the course of other work. However, in 1980 DFG began a major program of artificial reef construction and research.

Recent Reef Development

Southern California Edison (SCE), a major utility company, operates a number of coastal power plants. SCE biologists were aware of the potential that such power plants could negatively impact nearby kelp forests, through distribution of nearshore sediments by cooling waters. To address this concern and to develop more effective

reefs for enhancing sport fish populations, DFG and SCE began a cooperative project leading to construction of Pendleton Artificial Reef (PAR). Studies were conducted by DFG biologists to evaluate the PAR's potential for enhancing marine resources. In fall 1980, PAR, a "state-of-the-art" quarry rock reef, was constructed in northern San Diego County. Intensive studies were conducted at PAR from 1980-1986, by DFG biologists and others, to learn how to more effectively enhance stocks of marine fishes, shell fishes, and plants using artificial reefs. The information developed during these studies has been used to design new and more effective artificial reefs built since 1984. Studies on this new generation of reefs are being used to further improve designs of future reefs in the continuing search for the most effective reefs for enhancing marine resources.

Since the publication of the original booklet in 1989 two new reefs have been built, and existing reefs have been extensively augmented. In 1990 Carlsbad Artificial Reef was constructed from quarry rock, in anticipation of the re-opening of the mouth of Batiquitos Lagoon. In 1991 International Artificial Reef was constructed from quarry rock in deep water (165 ft. depth) near the international border.

Bolsa Chica Artificial Reef off Orange Co. has increased from 10,000 tons to 120,000 tons of material. During the summer of 2001 it will grow to 160,000 tons.

During 1992, 9000 tons of broken concrete rubble was scattered over 11 acres at the Mission Beach Artificial Reef. In less than one year this reef supported a large kelp bed. The kelp remains ten years later. This represents the first time a kelp bed has been sustained on a long term basis on an artificial reef in southern California.

During the fall of 1999 Southern California Edison built an experimental mitigation reef off San Clemente, covering 22 acres of bottom. Similar in construction to the Mission Beach Kelp Artificial Reef, the SCE reef is designed to support a kelp bed and associated community. While it is too soon to render a judgement on the long term success of this experiment, as of the spring of 2001 it appears to be well on its way to succeeding, as it supports kelp canopy over most of its 22 acres.

How Reefs Work (Aggregation and Production)

Artificial reefs have been used for over 200 years to enhance fishing catches. Early Japanese fishermen used mounds of stone, laboriously carried to selected locations in boats, to attract fish. Construction of rock reefs continues in Japan. Currently, Japan spends approximately \$60 million per year for fisheries enhancement projects, including artificial reef construction. Japanese reef designers have concentrated on creating reefs which attract fishes, primarily to increase harvest rather than increase production.

Early in California's reef development efforts, DFG marine biologists noted the immediate attraction of large numbers of fishes to artificial reefs, and thus considered reefs successful. Later, we began to look at the overall impact of such reefs on fish populations. If the reefs simply attracted fishes and made them easier to catch, we were doing little to maintain or increase fish populations. Although increased sport fishing success initially makes anglers happy, the long-term effects of increased local fishing pressure could result in decreased fish stocks and lower catches. Consequently, reef design and studies were directed toward developing reefs that increase fish production by augmenting shelter and forage for target species.

Japanese scientists found that fish attraction was generally greatest in those reefs with the highest profile to water depth ratio. They built tall, open, prefabricated reef structures that provided little surface area, but considerable high relief. By altering these designs and choosing specific sites, they found they could attract certain species in predictable fashion. But these structures, by nature of their openness and relative lack of surface area, provide little space for colonization by encrusting plants and animals that provide food and shelter. Furthermore, many of the fishes attracted to the Japanese high relief, low surface area-to-volume reefs are pelagic, offshore species that migrate through and aggregate around these reefs but generally feed elsewhere in the open ocean. The Japanese reefs designs are generally fish attracting devices (FADS) which allow Japanese commercial fisheries to better exploit these fishes.

The sport fishes inhabiting California's reefs are primarily rock and kelp habitat dwellers, such as kelp bass, sand bass, sheephead, surfperches, and rockfishes. Like the Japanese fishes, California species are also attracted to high volume, low surface area reefs. To overcome this potential problem, DFG biologists design reefs which will not only attract fishes, but will provide them with adequate habitat for shelter, forage, growth, and reproduction, thereby, increasing fish production. Cattlemen and ecologists use the term "carrying capacity". It is used to describe the numbers and condition of individuals of a species that can live on a specific quantity of habitat. For example, ranches with irrigated pastures have a larger carrying capacity per acre for cattle than do dry land pastures. Generally, shallow ocean areas with rock reefs have higher carrying capacities for most sport fishes than nearby sandy areas.

Our goal is to increase the fish carrying capacity of selected areas. To increase carrying capacity, we attempt to mimic those areas that naturally produce and maintain greater numbers of fish and good fishing success. DFG reefs generally consist of numerous low relief rock piles placed at various water depths. Growth of giant kelp on shallow, man-made rock reefs, like Mission Beach Artificial Reef, San Diego County, increases the abundance of food and the availability of shelter. Deeper reefs, beyond depths in which kelp will grow, also provide critical and important substrate for fish production. Various rock and crevice sizes allow fishes of diverse size to find shelter and reproduce.

Since 1980, beginning with Pendleton Artificial Reef, ten large quarry rock reefs have been built from San Luis Obispo County to San Diego at an average of cost of \$275,000. An additional five reefs have been constructed or augmented with concrete rubble.

Reef Construction

Artificial reef construction can be divided in four phases: site selection, permit process, contract bidding, and construction operations.

Site selection is crucial to the success of the reef. The location must meet a number of biological, physical, and social criteria, with the primary concern being minimal negative environmental impacts. No existing shellfish beds or other productive areas can be covered or damaged. However, the proposed site must have the potential for providing and supporting the plants and animals that eventually colonize the reef surface. Growth of giant kelp (*Macrocystis sp.*) on man-made reefs can benefit many of the more desirable sport fish species in the Southern California Bight. Consequently, sites that favor giant kelp growth are selected where possible. However, in order to provide a full range of habitats and forage for the widest diversity of nearshore species, reefs are also constructed in areas and at depths in which giant kelp cannot grow.

Physical conditions at the proposed site are equally important. The bottom must be hard enough to support the reef material. Sites with flat pavement bed rock or hard-packed, fine sand have proven very successful. The reefs cannot be placed in areas where they could impact shorelines or interfere with normal sand and water movement.

Social issues require similar consideration. The reefs must be accessible to the sportfishing public; consequently, they have to be located reasonably near boating access. At the same time, they cannot be located in navigation channels, where they might create an obstruction to vessel traffic, or where they may impact oil and gas lines, telephone cables, or other subtidal constructions. Finally, they should be placed in areas where sportfishing and commercial fishing interactions are minimized. While it is true that the increased production on and around artificial reefs is beneficial to both sport and commercial fish species, reefs may create hazards to nets and trawling gear. Site selection criteria seek to minimize negative interactions between sport and commercial fishing groups.

The artificial reef research, development, and building process is ongoing. However, new reefs can only continue to be constructed subject to the availability of funds and also can only be sited in appropriate areas. The California Department of Fish and Game is committed to supporting sport fish populations by habitat restoration and enhancement.

We hope you enjoy your visit to the reefs and that you find this publication useful in increasing your fishing success. We solicit your comments about any aspects of the reef program. The address is:

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