

M E C BIOLOGICAL PROJECT
SAN ONOFRE NUCLEAR GENERATING STATION
MONITORING STUDIES ON
MYSIDS AND SOFT BOTTOM BENTHOS
FINAL REPORT

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provide information that would enable the California Coastal Commission to evaluate the impacts of SONGS operations. The goals of the MRC studies were to detect significant changes in the marine biota, to determine the magnitude and extent of those changes, and to determine whether the operation of Units 2 and 3 caused those changes. The MRC defined a significant change as a 50 percent reduction in abundance below what would be expected to occur in the absence of SONGS. The sampling program was designed to detect such a change if it occurred over an area of several square kilometers.

Two of the communities near SONGS that the MRC decided to monitor were the mysids and soft-bottom benthos. The mysids were chosen because they are an important trophic link between the benthos and the pelagic zone (which includes fish) and they are abundant near SONGS year-round. The benthos was chosen because benthic organisms are a major food source for demersal fish, the benthos is for the most part stationary, and it is amenable to quantitative sampling. Section 1.4 of this report provides an overview of the mysid and benthic communities of the study area.

MEC's monitoring studies sought to determine whether the operation of SONGS had caused marked changes in: (1) the abundance of mysids and benthic organisms; (2) their distribution in space; (3) the structure of the mysid and benthic communities; and (4) the relationships between the organisms and their environment.

Section 2 of this report explains the rationale behind the selection of species and groups to be studied and the details of the sampling and analysis plans. Mysids were sampled at two locations: an impact location three km south of SONGS (to permit the detection of large-scale changes) and a control area 18 km south (to correspond with fish studies). Samples were collected along onshore/offshore transects

analyses of benthic community structure and pattern were applied to 48 taxonomic subsets of 19 trophic-motility (TM) groups and to approximately 250 individual taxa. BACI analyses were applied to 18 TM groups, 2 to 4 taxonomic subsets of 7 of those TM groups, and 28 individual taxa.

MEC's results are presented in Section 3. The analysis of physical and chemical data (Section 3.1) showed that there was a marked difference between 8 and 18 m in the temporal and spatial distributions of most of the variables that were studied. Sediments were coarser at 8 m than at 18 m. A large input of silt and clay which appeared in 1981 dominated the 18 m sediments within 2 km of SONGS until early 1985. Sediment chlorophyll concentrations were very low during 1982 and 1983, presumably reflecting the effects of the 1982-1984 California El Nino, but increased substantially in 1986. Values of percent silt and clay and sediment chlorophyll at 18 m, macrodetritus at 8 m, and organic carbon at both depths appeared to be higher within 2 km of SONGS during part or all of the operational period, but these gradients did not extend as far downcoast as the mysid transects or the benthic Intermediate and Control stations. There were very few correlations among the physical and chemical variables.

MEC detected few changes in the mysid community that could be attributed to the operation of SONGS (Section 3.2). The power of the BACI test was high enough to detect 50 percent changes with more than a 50 percent probability in five of the nine species and two of the three summary groups, and in nineteen of the thirty-six life stages. Two of the five species showed significant BACI changes in abundance; both were relative increases at SONGS. The analyses of the individual life stages generally supported the results from the total abundance of each species. BACI tests showed that the proportion of brooding females of

The community analyses identified the area within about 3 km downcoast from SONGS as different in the After period from the Control stations 6.7-9.4 km downcoast, primarily at 18 m. The upcoast stations were dominated in the After period by subsurface motile polychaetes, the downcoast ones by colonizing crustacea. The pattern analysis of individual TM groups and taxa tended to concur that an area extending about 1-3 km downcoast from SONGS was different from the rest of the study area in the After period.

Small changes in the trophic structure of the benthic community occurred from the Before to the After period, at both depths. At 8 m, motile subsurface deposit-feeding and surface suspension/deposit-feeding polychaetes, as well as carnivore/omnivores, declined in abundance. These declines caused motile surface deposit-feeding crustaceans to increase in relative importance, and the community to become indicative of an earlier successional stage. At 18 m, there was increased dominance near SONGS of subsurface deposit-feeding motile organisms, particularly polychaetes, and an increased importance and abundance of discretely motile crustaceans away from SONGS. The abundance of carnivore/omnivores also changed between the Before and After periods. These changes resulted in species assemblages characteristic of an earlier successional stage, and a marked longshore difference in the species composition of those assemblages.

A total of 10 of the 114 categories tested yielded BACI and pattern analysis results clearly interpretable as SONGS effects. At 8 m, combinations of primary BACI, secondary BACI, and pattern analysis results for 10 of the 53 categories tested showed possible effects. Two of them were clearly associated with SONGS (these were relative decreases for the motile surface omnivore/deposit-feeders and for Typosyllis hyalina). At 18 m, 31 of the 61 categories tested indicated

community from the El Nino event. At 8 m the recovery appeared to be similar among all sampling stations downcoast of SONGS. At 18 m, the recovery began to diverge longshore in early 1986. By the end of the study, the species assemblage at the downcoast stations was different than that at the upcoast stations. This implies that SONGS may have influenced the composition of the community. The ecological importance of the difference at 18 m cannot be fully judged with the information at hand because none of the sampling locations had fully recovered from the El Nino-related disruption by the end of the study. To make this final judgement an assessment would have to be made as to whether full recovery to a late successional stage has presently occurred further downcoast than 9400 m and/or whether the difference in species composition between the upcoast and downcoast stations will continue.

species in the cooling water results in the death of a large proportion of those animals (Barnett et al., 1982, for Unit 2 and 3 losses and review of Unit 1), thus removing them from the system and potentially reducing their populations. Their carcasses, and the carcasses of invertebrates that live in the intake conduits and feed upon the material in the withdrawn water, are discharged into the environment, and may serve as an additional food source for the surrounding animals. Discharged material and animals entrained from the nearshore zone may be transported to the faster longshore currents farther offshore, and thus be lost to the inner nearshore zone. Sediments may be altered as a result of the transport of water high in suspended matter from inshore to farther offshore by the discharge currents. Predator/prey interactions may be altered as a result of changes in the abundances of predators or their prey. Discharges of biocides, metals, or radionuclides may contribute to any net reductions in abundance; however, evaluations of such potential contributions are outside the scope of these studies.

One of the original concerns raised when Units 2 and 3 were being planned was that the use of so much cooling water, and the entrainment of water representing about eight times that volume in the discharge, could have cumulative effects that would lead to large-scale reductions in the aquatic biota, possibly extending several kilometers from SONGS. An alternative view was that the longshore currents, eddy diffusivity, and cross-shelf circulation would be sufficiently strong to dilute the effects of SONGS rapidly to below detectable levels.

In 1974, as part of the permitting process for the San Onofre Nuclear Generating Station Units 2 and 3, the California Coastal Zone Commission (now the California Coastal Commission) issued Permit No.

depending upon how important the effect is judged to be, appropriate isolating studies can be conducted to determine the specific source(s) of the observed change and the mechanism(s) by which the change is effected. Note that it is possible that the sum of the positive effects and the negative effects can result in a zero net sum. Thus, a drawback to this approach is that there could be effects, but they could not be identified or measured.

The second approach is to design each of the monitoring elements, possibly in conjunction with controlled laboratory and field experiments, in such a way as to make that element relate specifically to a particular source of, and/or mechanism for, potential effects. Negative results allow one to remove that source or mechanism from continued scrutiny. Positive results permit a more rapid determination of effects and potential mitigations. This approach is costly at a facility such as SONGS, at which a variety of mechanisms can cause changes in many different marine populations. Furthermore, it may or may not be possible to integrate the results of the various elements arithmetically, since some effects may interact synergistically to cause an impact far different from their arithmetic sum. These could include opposing effects that cancel each other. For these reasons, isolating specific hypothesized mechanisms, even with the support of laboratory experiments, is difficult, and in some cases may be impossible.

In general, the MRC has taken the first approach in designing and implementing its studies. The resultant monitoring program, called BACI (an acronym for Before/After, Control/Impact), has been the MRC's primary tool for investigating SONGS net effects. The second approach, i.e., the study of mechanisms, was the primary approach to the study of

The soft-bottom benthos consists of organisms that live on or in the substratum, and includes representatives from every major animal phylum. The benthos is of interest in part because benthic organisms are a major source of food for demersal fish. In addition, the benthos is suitable for studies of SONGS impacts because it is stationary, widely distributed in the study area, and relatively amenable to quantitative sampling. SONGS could affect the benthos by changing the nature of the sediment near SONGS, which would cause some species to decline and others to increase; by providing additional food, which would cause increases in abundance; by changing the number and type of predators; and by reducing or preventing recruitment in the vicinity of the intakes and diffusers through the removal of larvae from the water column.

1.2 The Issues Addressed by Marine Ecological Consultants Studies

Marine Ecological Consultants (MEC) has studied mysids and soft-bottom benthos in the vicinity of SONGS since 1976. Monitoring studies began in 1979. The fundamental questions that MEC's monitoring study design asked were whether power plant operations had caused marked changes in:

- 1) the abundance of mysids and benthic fauna;
- 2) their distribution in space;
- 3) the structure of the mysid and benthic communities in the study area;
- 4) the relationships between physical/chemical variables and the patterns of abundance and community structure that we detected in the study area.

We studied individual species for three reasons. First, direct effects of the plant, namely removal of individuals, can be detected as

1.3 Approach

The MRC established a monitoring plan to measure net changes in the abundance of animals that could be attributed to SONGS operations. MEC's sample collection and data analysis were designed primarily to permit the detection of such changes.

1.3.1 Synopsis of Sampling Design

The details of the station locations, sampling schemes, and sample analysis procedures are presented in Section 2 and Appendix B. This section presents an outline of the sampling schemes used in the mysid and benthos studies.

1.3.1.1 Mysid Sampling

The mysid sampling scheme was designed to assess possible effects of SONGS on the nearshore (< 37 m) species assemblage defined by Clutter (1967) and Bernstein and Gleye (1981). Preliminary analyses (e.g., Clutter, 1977; Bernstein, 1980) suggested that entrainment and mortality in the intake could result in the daily loss of as many as 10% of the mysids in the vicinity of the intake, and changes in the abundance of mysids within 6 km of the plant.

To investigate those possibilities, mysids were collected at three transects, representing the Impact area in the BACI model, located 2.5 to 3.5 km downcoast (southeast) of the discharges, and at three transects, representing the Control area of the BACI model, located 17.5 to 18.5 km downcoast. The location of the Impact sampling area was chosen for two reasons. First, we reasoned that very large-scale changes, such as had been predicted, would be detectable at a station somewhat removed from SONGS, whereas any effects in the immediate

Mysids were sampled on a total of 43 occasions: 19 times during the preoperational period (October 1979 to December 1981; 7 times during the interim period (March 1982 to October 1983), and 17 times during the operational phase (October 1983 to December 1986). Surveys were conducted at approximately two-week intervals during 1979 and 1980, and quarterly during 1981 to 1983. Note that frequent sampling during the preoperational period only took place over approximately one year (November 1979 to November 1980).

During the operational period, surveys were conducted at approximately five-week intervals. The five-week interval was chosen for two reasons. First, that interval would spread the sampling over the course of two years (August 1984 to December 1986). Second, because the generation time of the most abundant mysid is approximately five weeks, using that interval would reduce the degree of serial correlation in the data set. Close-interval sampling (approximately monthly) occupied two full years (December 1984 to December 1986).

1.3.1.2 Benthos Sampling

The benthic sampling plan was designed to assess possible effects of SONGS on the soft-bottom benthic community near SONGS. Preliminary studies of Unit 1 (e.g., Diener and Parr, 1977; Parr and Diener, 1978) showed that the benthic community within 0.2 to 0.4 km of the intake and discharge contained fewer species and fewer individuals than did the community at the Control site, possibly because of the plant-induced coarsening of the sediments near the discharge and reduced settlement of larvae due to intake losses. Outside of the zone of coarsened sediments, and extending to 0.8 to 1.6 km from the plant, there was an increase in both abundance and diversity. This was attributed to

to four weeks between November 1979 and November 1980 (preoperational) and between December 1984 and December 1986 (operational), and approximately quarterly during 1981 through 1984.

1.3.2 Analytical Design

1.3.2.1 Changes in Abundance

The difficulties inherent in attempting to determine the differences between potential SONGS effects and natural variation in an open marine system were appreciated at an early stage by the MRC, their consultants, their contractors, and others. Accordingly, in 1979 the BACI analysis scheme was developed by the MRC and its consultants. The BACI analytical procedure is described in detail in Section 2. Briefly, however, samples are collected from Control sites and from potential Impact sites near SONGS many times during both the preoperational (Before) and operational (After) periods. On each occasion the results of the Control are subtracted from the results of the Impact, yielding a set of Before differences and a set of After differences, or "Deltas." The mean of the differences between the Impact and Control samples in the Before period--the Before Deltas--is then tested against the mean of the After Deltas by a two-sample t-test to determine whether a significant change occurred. A significant change would imply an effect due to SONGS.

As a technique for analyzing monitoring measurements of marine organisms, BACI has some definite advantages. Marine populations integrate effects over time as well as effects arising from different stresses or enhancements. Using the differences between Impact and Control should eliminate, or at least minimize, the effects of natural changes in time. Therefore, BACI analyses should detect net changes in marine populations occurring over large scales.

As an aid to interpreting the results of the BACI analyses of mysid abundance, MEC calculated the intake losses of mysids. Mysids are, to some degree, planktonic at night, which makes them vulnerable to intake losses through withdrawal and entrainment. Because mysids vary in their inshore/offshore distribution, some species and life stages are more vulnerable to intake losses than others. Therefore, we estimated the losses of the various life stages of each species separately. This gave us insight into which species were more at risk to the direct effects of intake losses.

Mysid reproductive potential was also considered in these studies. The proportion of adult females in brooding condition was analyzed by an adaptation of the BACI procedure. A period-by-location analysis of covariance (ANCOVA), with the number of total females as the covariate, was used to obtain a relationship between the number of brooding females and the number of adult females at SONGS Before, SONGS After, Control before, and Control After. The slopes of these relationships represented the average proportion of brooding females within each BACI cell. We contrasted the slopes for each combination of paired cells to determine which pairs were different. A significant difference in the slope of SONGS After that did not occur at Control suggested a SONGS effect.

1.3.2.2 Changes in Distribution

MEC structured the sampling scheme to permit the examination of changes in the spatial (inshore/offshore) distribution of mysid species over time and changes in longshore patterns of abundance of benthic groups between the Before and After periods. We thought that plant-induced changes in the physical environment might cause a

differences that occurred at all the others in order to determine where, within the study area, those changes occurred. A pattern shift would be demonstrated if some stations showed different degrees of changes in abundance.

1.3.2.3 Changes in Community Structure

The structure of the mysid species assemblage was examined using analysis of the rank order of abundance of the component species. Small but persistent changes in abundance could show up as changes in the rank order of a species group, thereby suggesting a fundamental change in the dominance structure of the community. The MANOVA procedure was used to detect changes in the rank order of species between the Before and After periods at the Control and SONGS locations separately. Observed changes at each location were then tested by t-tests on each species, with the significance level adjusted to reflect multiple testing.

The structure of the benthic community was investigated by a comparison of the average percentages of each TM group at each station in the Before and After periods. We were interested to know whether the percentage of certain indicator groups changed only near SONGS. The number of species (i.e., diversity), the abundance, and the evenness of each group were also considered in the same fashion. The structures of both mysid and benthic communities were also examined by cluster analysis to describe associations of species. Cluster analysis groups entities, such as samples or species, on the basis of the similarity of some attribute. MEC used an agglomerative hierarchical clustering technique to examine the structures of both the mysid and benthic communities. For mysids, the stages of the species were first grouped on the basis of their similarity with regard to their abundances at

1.4 Mysids and Benthos of the Study Area

The mysids and benthos near San Onofre are part of a faunal assemblage characteristic of the shallow shelf zone of the Southern California Bight (Jones, 1969). The mysids of the bight have been studied in some detail (e.g., Clarke, 1971; Clutter, 1967, 1969; Bernstein and Gleye, 1981; Barnett et al., 1983b, 1984b, 1985). The taxonomy of the group has recently undergone revisions; Table 1-1 presents the old and new names of the common species of the San Onofre area. Previous reports to the MRC used the old names. In this, the final report, the current taxonomic nomenclature is used. The studies cited above have identified a nearshore species group whose distribution extends to a depth of 37 m off San Onofre. The most abundant species in that group is Metamysidopsis elongata. Within the nearshore zone, these species exhibit a distinct horizontal zonation (Table 1-1). Inshore species tend to occur in water less than 15 m deep, and offshore species tend not to be found at depths of less than 15 m. The cross-shelf species are widely distributed throughout most of the depth range studied.

Mysids are omnivores (Mauchline, 1980), feeding on small live animals, dead animals, plants, and detritus. Mysids feed by selecting larger particles and filtering suspended material. Certain species migrate up into the water column at night, where they probably feed largely by filtering. In the San Onofre area, Barnett et al. (1983b) showed that a decrease in the abundance of three mysid species in the period 1979 to 1983 reflected decreases in macrodetritus, sediment phaeopigment, and water column chlorophyll-a concentrations and an increase in temperature. The same study detected a reduction in mysid reproduction, which suggested that the increase in reproduction

Numerous studies have documented the overriding importance of grain size in determining the species composition of the benthic infauna (see the review by Gray, 1974). Grain-size determines optimal feeding modes (for example, deposit feeders tend to be favored in unstable silts and muds, whereas suspension-feeding tends to prevail in more stable, coarser-grained sediments; Flint, 1981), and influences such factors as the retention of organic matter and the concentration of oxygen.

Benthic communities are known to vary along physical gradients such as depth (Johnson, 1970), wave disturbance (Oliver et al., 1980; McLachlan et al., 1984), organic pollution (Pearson and Rosenberg, 1978) and substrate type (Johnson, 1970; Nichols, 1970; Flint and Rabalais, 1980; Jaramillo et al., 1984). On a smaller scale, infaunal assemblages have been shown to be sensitive to local patterns of food concentration (e.g., Whitlatch, 1980), predation intensity (Thistle, 1980; Van Blaricom, 1982; Ambrose, 1984), and the silt and clay content of the sediment (Nichols, 1970).

In the vicinity of SONGS, Parr and Diener (1978) attributed the observed changes in the abundance and diversity of benthic species to the changes in sediment, hydrographic, and detritus conditions caused by the intake and discharge of Unit 1. Mobile species, such as amphipods and cumaceans, were apparently attracted to the discharge by the increased supply of detritus; some species near the intake declined, possibly as a result of decreased recruitment caused by the entrainment of larvae; and changes in the grain size of sediments in the intake/outfall area apparently caused changes in the abundance of several infauna species. Barnett et al. (1983a) demonstrated a progression of species assemblages with depth in the San Onofre area during the preoperational period, and showed that differences in grain

study area comprise three more or less distinct assemblages: a nearshore (less than 10 m depth) assemblage, an offshore (10 to 35 m) assemblage, and a shelf assemblage seaward of the other two. The nearshore assemblage is dominated by the polychaetes Amastigos acutus, Owenia collaris, and Prionospio pygmaea, the bivalve Tellina modesta, and the cumacean crustacean Diastylopsis tenuis. The offshore assemblage is dominated by the polychaetes Mediomastus californiensis, Nephtys sp., Acesta catherinae, Tauberia gracilis, and Aricidea wassi, the bivalves Tellina modesta and Macoma sp., and the tanaid crustacean Leptochelia dubia. The shelf assemblage is dominated by brittle stars (Ophiuroidea) and small polychaetes. Subsequent studies (Barnett et al., 1982; 1983a,b, 1984a, 1985, 1986) have described as many as nine more or less distinct groups (Table 1-2). In the table, groups A through E are subgroups of the 15-30 m fauna, the subgroups being defined along narrower depth zones or on the basis of seasonal occurrence. Group F is associated with the kelp beds, group G is ubiquitous across the shelf, and groups H and I are characteristic of the 8-15 m fauna. The recent studies have elaborated upon the early groupings, but have not revealed material changes in species distributions and associations.

1.5 Scope of the Report

This introductory section has presented the framework within which the mysid and benthos studies were conducted, and a general overview of MEC's approach to the study design, sampling, and data analysis problems involved in attaining the goals set by the MRC. Subsequent sections will describe the sampling and analytical methods in detail, and will present the results of the analyses.

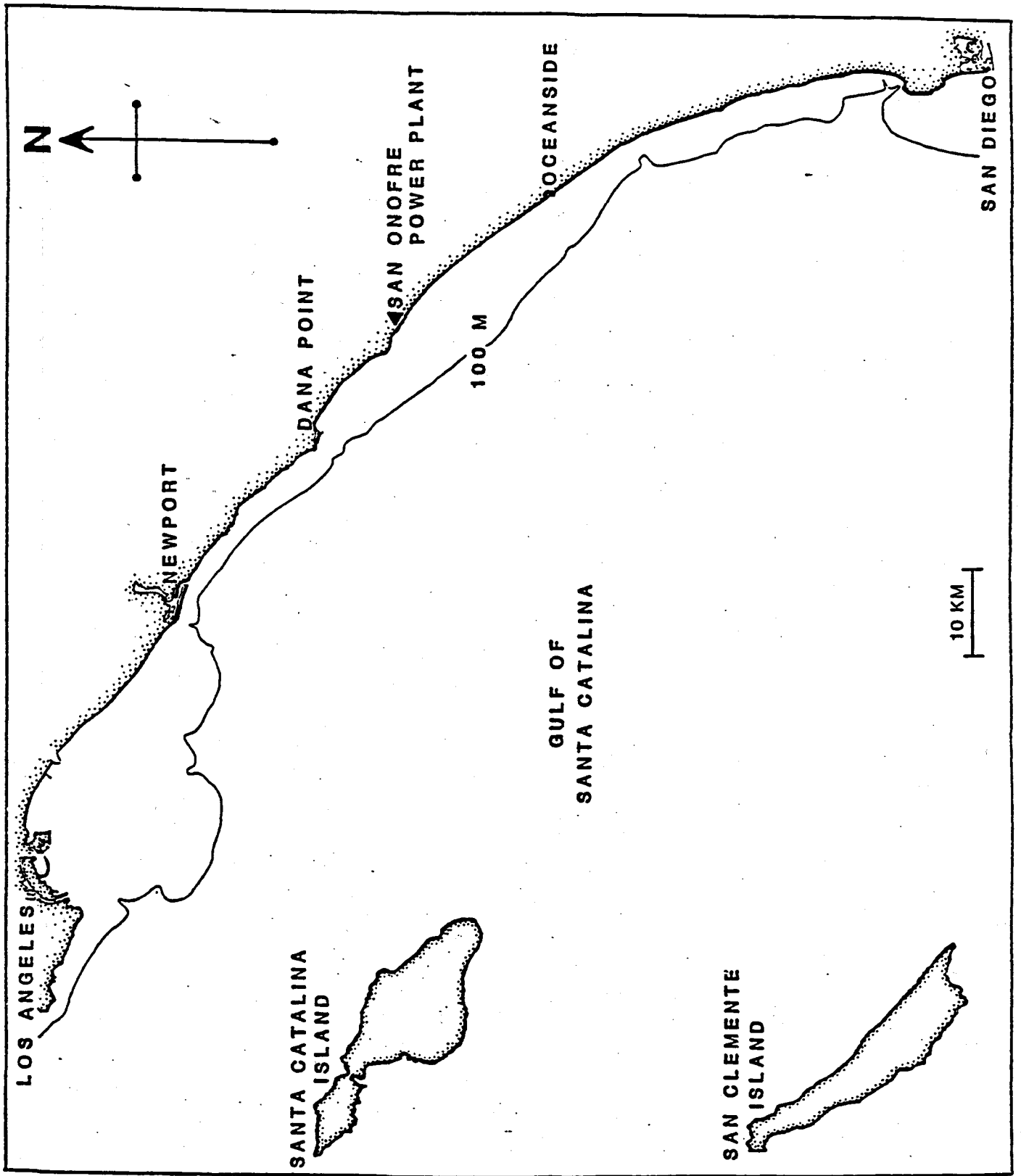


Figure 1-1. Regional setting of the SONGS site.