MARINE REVIEW COMMITTEE

FINAL REPORT OF
THE MARINE REVIEW COMMITTEE
TO THE CALIFORNIA COASTAL COMMISSION

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FINAL REPORT (DOCUMENT NO. 89-02)
OF THE MARINE REVIEW COMMITTEE
SUBMITTED TO THE
CALIFORNIA COASTAL COMMISSION
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MATERIALS SUBMITTED TO THE CCC

Final MRC Report to the CCC (this document - MRC Doc. 89-02)

MRC Technical Reports to the CCC

Final Contractors' Reports to the MRC

Reviews of Contractors' Reports and Technical Reports

MRC data bases (11 mainframe tapes)

MRC data bases (on 5.25" floppy diskettes)

Guide to MRC data bases

MRC raw data files (13 mainframe tapes)

Final computer "dump" of MRC files and programs

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GUIDE TO THIS FINAL REPORT

Section I provides a summary of the entire report. Chapter 1 presents the Results and Recommendations; in doing so it summarizes Sections III-V (Chapters 6-20) of this report. Chapter 2 is essentially a summary of Section II (Chapters 3-5).

For those with time to read beyond Section I, Section II gives a fuller account of the background to the study. The results of each component of the study, and the means by which they were obtained, are presented in Section III (Chapters 6-17). Section IV (Chapter 18) presents those MRC results that bear on water quality regulations and, in response to provision B.1.b. of Coastal Permit No. 183-73, explains how decisions were reached on SONGS' compliance with these regulations. Section V (Chapters 19-20) provides the rationale for the recommendations made in light of the Results.

Annotation

The data presented in the MRC Final Report to the California Coastal Commission (MRC Doc. 89-02) have their sources in the *Technical Reports* and the *Interim Technical Reports* to the CCC. The identity of the source information is indicated in square brackets [ ].

Technical Reports

The Technical Report that is the source of a conclusion is referred to as TR, thus Section 2.1 in Technical Report A is abbreviated as [TR A: 2.1]. Information from Technical Reports is referred to by section. The fifteen Technical Reports prepared for the CCC are:

Technical Report A.	Sand Crabs	TR A
Technical Report B.	Anomalous sediments in the San Onofre kelp bed	TR B
Technical Report C.	Entrapment of juvenile and adult fish at SONGS	TR C
Technical Report D.	Adult-Equivalent loss	TR D
Technical Report E.	Metals and Radiation	TR E
Technical Report F.	Kelp Forest Invertebrates	TR F
Technical Report G.	Mysids	TR G
Technical Report H.	Mitigation	TR H
Technical Report I.	Soft Bottom Benthos	TR I
Technical Report J.	Kelp Bed Fish	TR J
Technical Report K.	Giant Kelp	TR K
Technical Report L.	Physical and Chemical Oceanography	TR L
Technical Report M.	Bight-wide effects on fish: Compensation	TR M
Technical Report N.	Integration of local depressions and increases in fish stocks with inplant losses	TR N
Technical Report O.	Water Quality Compliance	TR O

Interim Technical Reports

The Interim Technical Report that is the source of a conclusion is referred to as ITR, thus page 17 in Interim Technical Report 3 is abbreviated as [ITR 3: 17].

Information from Technical Reports is referred to by page, not section. The five Interim Technical Reports prepared for the CCC are:

1. Plant Description and Operating History	ITR 1
2. Sampling Design and Analytical Procedures (BACIP)	ITR 2
3. Midwater and Benthic Fish	ITR 3
4. Plankton	ITR 4
5. Fish Larvae and Eggs	ITR 5

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SECTION I.

SUMMARY

Chapter 1

RESULTS AND RECOMMENDATIONS

Summary

Under the mandate of the Coastal Commission Permit 183-73, the Marine Review Committee (MRC) has studied the effects of San Onofre Nuclear Generating station (SONGS) on the marine environment since 1975. Our principal conclusions and recommendations are summarized below.

The plant kills large numbers of organisms in its intake cooling water, and sometimes moves turbid water into the San Onofre kelp bed (SOK).

The MRC has measured adverse effects on the kelp community in San Onofre kelp bed, including giant kelp, fish, and large benthic invertebrates. These effects, although local, are deemed substantial because kelp is a valuable and limited habitat.

The MRC calculates that there is a substantial impact on the standing stock of a number of midwater fish populations in the Southern California Bight. The reductions in standing stock are probably between one and ten percent. Because the effects can occur over large populations, we conclude they are substantial.

The MRC has also measured a reduction in the local abundance of some midwater fish populations. In addition, SONGS kills at least 20 tons of fish per year in its intake system.

The MRC analyzed a range of options for preventing, reducing, or mitigating these impacts, and presents two sets of options to the Commission. Option 1a is cooling towers; the majority of the MRC (Mechalas and Murdoch) recommends rejection of this option, Dr. Fay recommends its acceptance. Option 1b is moving the discharges; the MRC recommends against this option. The MRC recommends acceptance of option 2, which involves selection of one or a combination of four techniques: (1) reduction of flow of cooling water through SONGS or other SCE coastal power plants; (2) construction of a high-relief artificial reef designed to maximize fish production; and/or (3) restoration of a wetland. (4) Upgrading the existing systems at SONGS that are designed to exclude fish from the plant or to return them to the ocean. The MRC also recommends that the State Thermal Plan be amended to remove restrictions on the allowable across-the-condenser temperature rise for open coastal power plants, to facilitate reducing the flow of cooling water.

Other parts of the community that were studied and in which no substantial adverse effects were found are: the plankton, a range of animals associated with the sandy bottom, including invertebrates living in or on the soft sediments (these are called the "soft benthos"), certain mysids, bottom-dwelling fish, and intertidal sand crabs. The soft benthos, mysids and bottom-dwelling fish increased in abundance in the SONGS' area as a result of the plant's activities.[1]

The MRC concludes that SONGS is not in compliance with certain water quality regulations. The level of natural light at the bottom, downcoast from SONGS, was 6 - 16% lower than it would have been without SONGS. There were

[1] Dr. Fay disagrees with these conclusions.

significant reductions in local populations of midwater fish, and of kelp, fish and invertebrates in the San Onofre kelp bed. (Whether SONGS is in compliance with regulations for sediments will be determined by the results of an ongoing study.)

Some perspective on SONGS' effects on the marine environment may be useful. The impacts detected or inferred by the MRC, especially on the kelp community and on bight-wide fish populations, are substantial for the reasons given above. They should be prevented or mitigated. But they are not large-scale ecological disasters.[2] In particular, they are not on the scale of effects predicted during the 1973-74 Public Hearings, which were the stimulus for the creation of the Marine Review Committee. Key testimony at these hearings predicted that SONGS would create a large inshore ecological "desert." This has not occurred.

This chapter (a) summarizes the effects of San Onofre Nuclear Generating Station on the marine environment, (b) compares the MRC's results with the regulations of the National Pollutant Discharge Elimination System permits for the station, (c) explains the Committee's recommendations for prevention, reduction, and/or mitigation of effects, including monitoring of the effectiveness of mitigation measures, and (d) recommends future monitoring in relation to plant operation.

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[2] Dr. Fay disagrees with this conclusion.

RESULTS

Physical Effects

The physical effects are discussed in detail in Chapter 6. SONGS Units 1, 2 and 3 take in a volume of water equivalent to 1 mile square and 14 feet deep each day. About 10 times this volume is quickly mixed with the discharged water. This plume is further diluted to about a 1% concentration about 2 miles downstream from the plant. The plume is pushed offshore by SONGS, and about 60% of the time is carried downcoast and through and over the San Onofre kelp bed (SOK) by the prevailing currents. This plume is often more turbid (contains more particles) than the ambient water. Make-up water, mainly from offshore, flows towards SONGS' diffusers, replacing the water entrained by the discharge jets.

The major physical effects caused by SONGS' plume are as follows. (1) When the plume is turbid, it decreases the light reaching the ocean floor below it. On average, the light level at the bottom in SOK is about 16% lower than it would be in the absence of SONGS. (2) The turbid plume also increases the flow of particles close to the bottom, and increases the rate at which particles settle on the bottom. (3) The directions of currents near the plant are modified: upstream of the diffusers currents are diverted shoreward, while downstream currents are initially diverted offshore in the plume.

The turbid plume may be responsible for patches of anomalous sediment in SOK. These presently cover about 9 hectares (22 acres, 4.5%) of cobble bottom in

SOK. MRC is investigating this matter. The area covered by these patches has not increased since 1987, and has recently decreased.

The plant is a source of metals and radioactive nuclides. However, there is no evidence that SONGS releases enough metals to increase substantially their concentrations in the environment. The environment near SONGS is typically low in metals that might be released from SONGS. The activity levels of plant-related radioactive nuclides in local sediments and animal tissues are sometimes detectable, but are well below those associated with naturally-occurring radioactive nuclides. These results are presented in detail in Chapter 17.

Biological Effects

The effects reported here are based on many samples taken over at least four years; they therefore represent estimates of long-term effects.

Substantial impacts have been measured or inferred to occur in two components of the biota: fish, and organisms in San Onofre kelp bed. They arise, respectively, from two mechanisms. (1) Losses as a result of passage into or through the plant in the cooling water. (2) Changes in the physical environment in SOK as a result of the sometimes turbid plume.

SONGS' release of metals and radioactive nuclides does not lead to ecologically hazardous concentrations of these pollutants in the environment or the local biota. Metal concentrations are low and do not provide a reasonable explanation for the observed negative effects of SONGS on the biota. The same is true for radioactive nuclides; internal radiation activity levels in local organisms are raised only slightly above the background level. See Chapter 17 for details.

1. Fish stocks in the southern California Bight (see Chapter 10)

This is the only finding of an adverse effect that is not based on direct observation of reduced abundances but instead is inferred from the assumed 100% mortality of fish eggs, larvae and juveniles taken into the plant in its cooling water.

For the most vulnerable fish species, MRC measured or estimated the amount by which mortality in Units 2 and 3 increases the bight-wide death rate of the immature stages. Simple models suggest that the increased death rate leads to a reduction in the Bight's standing stock of adult fish. It is not possible to estimate the reduction with any degree of precision. An estimate that lies in the middle of those possible, points to a loss of several hundred tons of mainly "fodder" fish (i.e., species that serve mainly as food for other fish species).

2. San Onofre Kelp Bed

Substantial impacts have been measured in three components of this community: giant kelp, kelp-bed fish, and large invertebrates living on the cobble bottom. Kelp beds are a particularly valuable and limited habitat.

2a. Giant Kelp (see Chapter 7)

Giant kelp is the key species in the bed, providing food and habitat for many other species. The Permit contains a condition, Condition C, stating that the diffusers "shall not be located within 1,900 feet of the area where the kelp bed to the south of the diffusers is likely to expand." In the Findings and Declarations, the Permit states that "Condition C will insure that the effects of Units 2 and 3 on the kelp beds are not substantial."

The area covered by moderate to high density kelp in SOK has been reduced on average by about 200 acres (80 hectares), or 60% below the abundance that would have occurred in the absence of SONGS. Increased turbidity created by SONGS' discharge plume is the cause. The MRC did not study organisms, such as some species of mysid shrimps, that are closely associated with kelp canopy, but it is a reasonable expectation that these species have also declined at SOK.

The estimated reduction of kelp, 80 hectares, is MRC's best estimate. However there is uncertainty as to the exact size of the loss since estimates of kelp abundance are subject to sampling "error," factors other than SONGS influence its abundance, and the amount lost varies through time. The loss might be as small as 40 hectares and, less probably, could be as high as 100 hectares. Nevertheless, 80 hectares is our best estimate and was derived using the assumptions that are most consistent with the available information.

2b. Kelp-bed Fish (see Chapter 8)

Fish living near the bottom in SOK (e.g., sheephead, barred sandbass and black surfperch) have been reduced by about 70% (roughly 200,000 fish weighing about 28 tons) below the abundance that would have occurred in the absence of SONGS. These losses were presumably caused largely by the reduction in kelp, but other changes in the kelp-bed habitat caused by SONGS also contributed. Again, there is uncertainty concerning the exact size of this loss, but 28 tons is the MRC's best estimate.

2c. Kelp-bed Invertebrates (see Chapter 9)

The abundances of 13 species of snails, and of the white sea urchin, were reduced substantially (30%-90%) below the levels that would have occurred in the absence of SONGS. These species were chosen for study, from over one hundred species of large benthic invertebrates that live on the cobble bottom in SOK, because they are common enough to be sampled accurately. It is reasonable to infer that the abundance of other less common species in this habitat, which were not sampled, also declined. The reduction is associated with the increase in turbidity caused by SONGS' plume, and hence with an increased flow of particles near the ocean floor. The particles may interfere with the feeding or other essential activities of these organisms. Patches of fine sediments on the cobble bottom at SOK have also played a part in reducing the abundance of these organisms.

3. Local Midwater Fish Populations (see Chapter 11)

The observed reductions in local fish populations represent a substantial, but local effect.

Each year, SONGS takes in 45 tons of fish and kills at least 21 tons. This estimate was made in a period of depressed fish abundance, and over the long term the amount killed will be about 56 tons per year.

In the midwater, the local abundance of queenfish has been reduced by between 30% and 70%, depending on the location, out to a distance of 2-3 km from SONGS, relative to the abundance expected in the absence of SONGS. A similar reduction occurred in white croaker, but over a smaller area. Several other species probably have experienced smaller reductions. Over 100 species of fish have been entrapped during the study. The reduction in white croaker and some of the reduction in queenfish can be explained by the loss of fish in SONGS' intakes, but it seems that some other factor (perhaps the local increase in turbidity caused by the plume, which might cause fish to leave the area) must also be operating.

Other Biological Effects

4. Local Benthic Fish Populations

The abundance of fish living on the bottom typically increased above the levels that would have occurred in the absence of SONGS, although a few less common species decreased. White croaker and queenfish increased by more than

100% 1.5 km downcoast of SONGS. Several other less common species also increased on the bottom.

5. Soft Benthos (see Chapter 14)

The abundances of small invertebrates (worms, crustacea, clams, etc.) that live in and on the sandy bottom near SONGS were in general increased above the levels that would have prevailed in the absence of SONGS. The increases were more prevalent in deeper (roughly 60-foot [18 meter]) water than in shallower (26-foot [8 meter]) water, and in the deeper water increases were seen in some organisms as far as 2 miles (3 km) downcoast from the diffusers. The increases are themselves increasing through time. SONGS has not changed the type of community present (e.g., the increase is not in "pollution-tolerant" species). Some decreases were seen in species in shallow water, out to almost 1 mile from the plant, but these decreases are disappearing with time.

6. Mysids (see Chapter 15)

Mysids are shrimp-like crustaceans, many of which stay near the bottom during the day, and move up in the water column at night. They were chosen to represent a larger group of crustacea that share this "semi-planktonic" habit. The MRC did not detect reductions in the abundance of these mysids; indeed, some species increased significantly in abundance above the level that would have occurred in SONGS' absence, and there was a general pattern of increases in this group. The increases were in species typical of the community and do not represent a change to a different and perhaps less-desirable set of species. The MRC did not study mysids in the kelp bed. It is reasonable to infer that the other organisms in this semi-planktonic assemblage also increased in general.[3]

7. Plankton (see Chapter 12)

The abundance of plankton near SONGS was largely unaffected by SONGS' operation because the plume is very rapidly mixed with ambient water. The abundance of one (numerically minor) component, the meroplankton (which is made up of the larvae of animals living on the ocean floor), increased above the level that would have occurred in the absence of SONGS.[4]

About 1400 tons (dry weight) of zooplankton are taken in and killed each year by SONGS. There is no evidence for a local reduction in plankton, and the MRC concludes that these losses do not constitute a substantial adverse effect.

The MRC was established in large part because it was feared that the plankton, and especially the meroplankton, would be severely reduced in abundance and that a very extensive nearshore "desert" would be created as a consequence. These results show that this severe effect did not occur.

8. Fish larvae (see Chapter 13)

The most serious effect of SONGS upon fish larvae is on those species that are vulnerable to being taken into the plant because they are concentrated inshore

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[3] Dr. Fay has a reservation about this inference.

[4] Dr. Fay disagrees with the conclusions concerning this group.

at the depths of the intakes. These losses, which amount to several billion individuals per year, lead to the estimated reductions in adult fish stocks discussed above.

There is no clear pattern of decreases in the abundance of fish larvae near SONGS. Overall, more species increased than decreased, though the changes for particular species were rarely statistically significant. An exception is the northern anchovy larvae, which showed a decrease of about 30%, although anchovy eggs increased by 100%. The vast majority of the larvae of this very abundant species are offshore, and a local depression in the SONGS' area has negligible consequences for the population in the Bight.

9. Sand Crabs (see Chapter 16)

Sand crabs live for much of the year on intertidal sandy beaches. Unlike all other groups studied by the MRC, it has been suggested that substantial effects on crabs were caused by SONGS Unit 1, which began commercial operation in 1968.

Sand crabs at beaches near SONGS have often been different in some respects from those at more distant beaches (usually they have been smaller and less successful in some aspects of reproduction), though in other regards they have not been different. The evidence is most consistent with the conclusion that these spatial patterns reflect natural differences in the physical characteristics of the beaches near and far from SONGS. The evidence is strongly against the hypothesis that the patterns are related to operation of the plant.[5]

[5] Dr. Fay disagrees with this conclusion.

Consistency in SONGS' Effects

The effects detected in different components of the marine community are consistent with each other and with the mechanisms known to be operating. This internal consistency reinforces and adds to our confidence in the conclusions reached for the separate components of the marine biota.

Measurements of local currents, of the movement of the discharge plume itself, of light in the water and of particulate matter near the ocean floor, all show that the plume increases turbidity, reduces light, and increases the flow of particles near the bottom in the ocean. In addition, the plume and these effects are most prevalent in the downcoast direction and in the more offshore portions of the area studied. These physical effects occur mainly downcoast of SONGS because the natural current flow is predominantly in that direction. As would be expected, effects within the kelp bed are more severe nearest the diffusers.

The increased turbidity has adverse effects on giant kelp and on the fish and organisms living on hard bottom in the kelp bed. Increased organic material falling from the turbid plume may cause the increases in the abundance of organisms on and associated with the soft bottom.

The absence of effects in some groups is also consistent across these groups and with known mechanisms. Although many organisms living in the water column are taken in and killed by the plant, there is very rapid mixing and dilution of plume water, and local reductions that might occur in, for example, plankton and mysids, would be on the order of a few percent at most near SONGS. On the other hand, individual fish can be expected to remain in the area for some time and it is not wholly unexpected that fish losses accumulate and appear as measurable local reductions in abundance.

The "reach" of the plant is also about the range expected, i.e., one to a few miles depending on the effect (except for fish populations in the Southern California Bight). The plume alters physical conditions at least as far as the downcoast edge of the kelp bed (1.2 miles [2 km] distant) and, as implied by the changes in the soft benthos, materials still fall out of the plume in significant amounts almost 2 miles (3 km) downcoast of the diffusers. The MRC concludes that fish in the Bight as a whole are influenced by SONGS, but that is because fish and their immature stages move away from the area of impact, not because the plant has long-range physical effects.

Future Effects

SONGS operated at a higher level in the years 1987-89 than it did in the years 1983-86, the period when MRC made most of the measurements needed to estimate the plant's effects. It is therefore possible that impacts will be more severe (or less severe) than we have estimated. In addition, it is in principle possible that some conditions will gradually worsen, or that the operation of the plant will change, or that negative biological effects will accumulate. We address these two questions here.

1. Fish stocks in the California Bight

The mortality of fish larvae, which leads to inferred Bight-wide reductions in fish standing stocks, was calculated when SONGS pumped at 78% of maximum. During 1987-89 pumping averaged 85%, a 7% increase above the 1983-86 level. This is a very high level of efficiency, and it does not seem likely that the plant will exceed it over long periods in the future. If this level is maintained in the future, our estimate of fish reductions will be low by 7%. Given the large uncertainty of our present estimates, this is a small error. We know of no reason to expect that the effects on Bight-wide stocks would be cumulative. Thus our present estimate of Bight-wide reductions does not need to be modified for the long term.

2a. Giant kelp

Although we are concerned with the possibility that the effect on kelp will increase with time, we do not expect this to occur. First, our estimates of kelp losses are based on measurements of kelp made during 1986-89, when SONGS Units 2 and 3 pumped on average 85% of its maximum rate; i.e., at the maximum that is likely to be achieved over the long term. Second, during this period the bed was the largest we have seen it, so that the acreage lost is also close to maximum. Third, the size of the effect has not increased over the past two years, and there is no reason to believe that the physical conditions for kelp will become progressively or cumulatively worse as SONGS continues to operate.[6] Fourth, Unit 3 was offline during spring in two of the years (1987 and 1988) when the estimate of losses was derived. These were periods when recruitment of kelp might have occurred. It is

[6] Dr. Fay does not agree.

therefore possible that the reduction in kelp would have been larger had the Unit been on line. However, each Unit will be down for several months at least every two years, and fall and spring are the most likely times for them to be down. So the observed pattern is likely to be a common one. Finally, SONGS may have created new patches of sediment on the bottom at SOK, but the area covered by these patches is relatively small (presently 9 hectares [22 acres]) and has not increased since 1987.

2b. Kelp-bed Fish

Estimates of kelp-bed fish losses were made when the plant was pumping at less than the recent 85% average. It is possible that the increase in the pumping rate might have increased losses of kelp-bed fish by a small fraction, since some of the losses appear to be caused by changes other than loss of kelp. However, fish losses in the kelp bed were estimated in a period when kelp reduction was greater than the average reduction of 60%. Since loss of kelp is probably a major cause of loss of fish, we would not expect the percent of fish lost to increase significantly in the future. On the other hand, fish were less abundant than usual during the operational sampling period, because of the El Nino condition, and in absolute terms the long term reduction could be greater than the estimated 28 tons.

2c. Kelp-bed Invertebrates

It is possible that the effects on large invertebrates living on the cobble bottom in the kelp bed will become more severe. First, effects were estimated when pumping was 7% lower than it has been recently. Second, there is evidence that the size of the effect was increasing in some species towards the end of the sampling period. Third, some of these invertebrates live for many years, and cumulative effects are possible.

3. Local Midwater Fish Populations

The amount of adult fish killed in the plant can also be expected to be 7% higher. We would not expect the additional pumping to make a detectable change in local densities, and there is no reason to expect cumulative effects.

Effects observed on other components of the biota were not shown to be negative. Among these, it is likely that the soft benthos will show cumulative effects, since the effects detected so far are changing with time.

In summary, the MRC does not expect most impacts to become significantly worse with time. It is of course not possible to be certain on this matter and the MRC recommends a variety of monitoring programs, summarized below.

RESULTS: COMPLIANCE

A comparison of MRC results with the regulations of the National Pollutant Discharge Elimination System (NPDES) permits for SONGS leads to a set of conclusions on compliance summarized in Table 1.1. Results of MRC studies apply to regulations for temperature, natural light levels, metals, and marine organisms in the receiving water. SONGS was in compliance for temperature and metals, but

Table 1.1

Summary of SONGS' compliance with water quality regulations in the NPDES permits.

REGULATION	MRC FINDING	COMPLIANCE
D.1.a Increases in natural water temperature shall not exceed 4°F at the ocean surface 1000 ft beyond the diffusers or at the bottom.	Maximum increase in temperature was about 1°F	YES
D.1.c.3 Natural light levels shall not be reduced outside the zone of initial dilution.	Irradiance was reduced by 6 - 16%	NO
B.4.c The discharge shall not contain substances (metals) that accumulate to toxic levels in marine life. and D.1.d.4 Concentrations of metals shall not increase to levels that would adversely affect marine life	No evidence for accumulation of metals due to SONGS	YES
D.1.c.2 Changes in the rate of deposition of sediments should not adversely affect marine life.	awaits completion of sediment studies	?
D.1.e.1 SONGS shall not have adverse effects on marine organisms.	1. reductions in local populations of midwater fish 2. reductions in kelp, fish and invertebrates in SOK	NO

was not in compliance for light levels and effects on marine life. The turbiddischarge plume caused a reduction of 6% - 16% in natural light levels near the bottom, downcoast from SONGS. Significant reductions were found in local populations of midwater fish, and in kelp, invertebrates and fish in SOK. New results relating to sediments may be found.

RECOMMENDATIONS: MITIGATION AND MONITORING

The recommendations are based on the above findings. They are summarized in Tables 1.2 and 1.3. There are two type of recommendations: (1) those aimed at reducing or mitigating effects, and (2) those for future monitoring.

Mitigation

We present two options for mitigating the effects of SONGS. **Option 1: Changes to the Cooling System**, responds to the Permit's directive that the Committee be responsible for "recommending ... any changes it believes necessary in the cooling system for Units 2 and 3" (Condition B.4). **Option 2: Prevention and Mitigation** responds to the Commission's 1979 resolution requesting the MRC to study promising mitigation measures and to recommend measures "to assure there would be no net adverse effect on the marine environment" (Staff Reports 11/9/79, 4/4/80).

Option 1: Changes to cooling system

We discuss two possible changes to the cooling system at SONGS, constructing cooling towers and moving the discharge. Other alternatives are discussed in *Technical Report H.*

<u>Option 1a: Cooling towers</u>

The advantage of cooling towers is that they would reduce the flow of water through SONGS by 90% or more, thereby reducing all of SONGS' effects on the

Table 1.2
Mitigation Recommendations

OPTION	TECHNIQUE	OBJECTIVE	RECOMMENDATION
1: Changes to cooling system			
1a	Cooling towers	Reduce all losses	Reject (WM, BM) Accept (RF)
1b	Moving discharge	Reduce discharge losses	Reject
2: Prevention and mitigation			Accept
	Reschedule operations[1]	Reduce larval fish losses	
	Reduce flow[1]	(1-10% reductions in standing	
	Artificial reef (60 ha)[1]	stocks of some species)	
	Restore wetland (30 to 60 ha)[1]	"	
	Reduce impingement losses	Reduce fish intake losses (21 tons/yr)	
	Artificial reef (120 ha)	Replace kelp community losses (80 ha kelp and associated invertebrates and fish)	

[1] A combination of these techniques could be used as long as overall result was complete mitigation.

Table 1.3

Monitoring Recommendations

CATEGORY	RECOMMENDATION
A. Compliance[1]	
Irradiance	Measure irradiance and currents
Fish	Densities of midwater fish
Kelp Community	Densities of large invertebrates and kelp bed fish
B. Mitigation	
Low-relief artificial reef	Giant kelp, fish, algae & invertebrates
High-relief artificial reef	Fish production
Wetland	Depends on restoration plan
C. Effects[1]	
Soft benthos	Densities of infauna

[1] The future value of the monitoring data will be greatly increased if they are recorded and maintained in such a way that they can be analyzed in conjunction with those already collected by MRC.

marine environment that the MRC has measured. This option has the following problems and disadvantages: There would be technical problems adapting cooling tower technology to the scale needed at SONGS, particularly because the towers would have to retrofit. Cooling towers would cause (1) adverse impacts to the terrestrial environment from construction and salt drift, (2) discharge of contaminants to the ocean, (3) increased air quality impacts, (4) slight increase in risk to human safety, (5) aesthetic impacts, and (6) noise impacts. The cost of cooling towers is estimated to be about $1 billion, plus reduced efficiency of up to 20% that would add an additional $1 billion cost over the life of the plant.

<u>Recommendation</u>: **The majority of the Committee (Mechalas and Murdoch) recommends rejection of the cooling tower option because its technical, environmental and safety disadvantages and high costs outweigh its advantages at SONGS. Dr. Fay recommends acceptance of Option 1a.**

<u>Option 1b: Moving the discharge</u>

The advantage of moving the discharge is that impacts to the kelp bed community would be eliminated. The disadvantages of this option include engineering constraints, new impacts on the marine environment, and the fact that it would not reduce the adverse effects on fish populations caused by entrapment. The cost of this option would be hundreds of millions of dollars.

<u>Recommendation</u>: **The MRC recommends rejection of the option of moving the discharge because its considerable technical and**

environmental disadvantages and high costs outweigh its advantages at SONGS.

Option 2: Prevention and Mitigation

Recommendation: **The MRC recommends acceptance of Option 2, which consists of a possible combination of four different techniques for reducing or mitigating fish losses and one technique for mitigating the impacts to the San Onofre Kelp bed community.**

The recommendations in the option are organized according to two major categories of losses: fish and kelp forest community.

Fish losses

The MRC recommends a possible combination of four different techniques for mitigating the fish losses: (1) reduce the number of larvae entrained (by reducing the flow rate at SONGS or other coastal power stations or by scheduling SONGS so it does not operate during periods of maximum abundance of fish larvae), (2) construct an artificial reef, (3) restore a wetland, and (4) reduce the in-plant loss of juvenile and adult fish. Different combinations of the first three techniques could each result in complete mitigation.

(1) Larval fish entrainment could be reduced by scheduling SONGS not to operate during periods of highest larval abundances, and/or reducing the flow of water during SONGS' operations. An equivalent reduction in entrainment at other SCE coastal power stations could be an acceptable substitution for reducing entrainment at SONGS. Larval entrainment could by reduced by 15% or more by flow reduction alone, 50% by rescheduling to avoid March and April, and 60% or more by combining techniques.

Reducing the flow through SONGS and other coastal power plants is a preferred technique for reducing impacts to the marine environment but would require a variance from the State Thermal Plan. These power plants could operate more efficiently with lower flow. Their ability to do so is affected by the Thermal Plan, which restricts the rise in water temperature across the condensers to 20°F. If, instead of 20°F, the allowed increase was 30°F, the flow through the plant could be reduced by one-third, with a concomitant reduction in larval entrainment. Since the MRC has found negligible thermal effects, but adverse effects on fish that are proportional to the flow of water through SONGS, we recommend that the Plan be amended to remove restrictions on the temperature rise allowed for open coastal power plants.

(2) A high-relief artificial reef of appropriate size would increase the general production of fish, thereby mitigating fish losses caused by SONGS. We estimate that a 60-ha high-relief reef, costing about $15 million, would provide complete mitigation for the fish losses.

(3) Wetlands are valuable coastal habitats in Southern California, and wetland restoration would be an appropriate means of mitigating the loss of fish caused by SONGS. The amount of restoration needed will depend on the specific design of the restoration; we estimate that 30 to 60 hectares (1 ha = 100 meters by 100 meters) would adequately mitigate for fish losses. The cost of restoration could be between $3 million and $18 million, depending on the design and whether or not land would have to be purchased.

The above three techniques could be combined to provide complete mitigation. For example, for each 1% reduction in entrainment losses, SCE would get credit for 1% of complete mitigation; each 1 hectare of high-relief artificial reef constructed would provide 100%/60 hectare = 1.67% credit; and each 1 hectare of wetland restored would provide 100%/(30 to 60 hectare) = 1.67% to 3.33% credit, depending on the particular restoration.

(4) Impingement losses might be reduced by new techniques, and SCE should be able to choose any technique that they think will effectively reduce these losses. The MRC has identified two techniques that could potentially reduce this impact: mercury lights and sonic devices. Because the effectiveness of these techniques has not been adequately tested, we recommend that they be tested and their implementation be required if they will reduce impingement losses by 2 MT per year.

Kelp forest community impacts

The MRC recommends that the fraction of community lost at San Onofre kelp bed be replaced by constructing a low-relief artificial reef that develops and maintains a kelp bed. Complete mitigation would be achieved by constructing a 120-hectare low-relief artificial reef, at an estimated cost of $7.5 million for construction and $3 million for establishing kelp.

Future Monitoring

The MRC recommends three different types of programs for future monitoring (Table 1.3), each of which is motivated by its own set of objectives.

Compliance with water quality regulations

As a result of the comparison of differences in the results of MRC and NPDES studies, we have developed suggestions for changes in the NPDES monitoring program. We recommend that: (1) quarterly transmissivity samples be replaced with measurements of irradiance and currents taken continuously, (2) monitoring of kelp forests include regular samples of large invertebrates and fish, and (3) populations of midwater fish be monitored near SONGS. We also recommend that the density of adult, subadult and juvenile giant kelp continue to be monitored.

Mitigation

The MRC recommends that the low-relief artificial reef constructed to replace kelp forest resources be monitored to ensure that (1) it is constructed according to its design specifications, and (2) giant kelp becomes established. The physical structure of the reef should be monitored immediately after construction to verify that it meets the design standards; if it does not, additional construction should be required to bring it up to the standards. In addition, monitoring should be conducted to ensure that giant kelp becomes established according to a reasonable timetable (e.g., three years). If monitoring indicates that it has not been established on schedule, additional efforts should be required until the new kelp community is established. Fish, benthic algae and benthic invertebrates should also be monitored.

The MRC recommends that the high-relief artificial reef and/or restored wetland constructed as mitigation for fish losses be monitored. The high-relief reef should be monitored (1) to ensure that it is constructed according to its design specifications, and (2) to evaluate the amount of fish produced on the reef. The comprehensive evaluation of fish production on the reef, to be completed over a period of perhaps five years, will be extremely valuable for evaluating future proposals to use artificial reefs as mitigation. Monitoring of the wetland should ensure that (1) the restoration is conducted according to the design specifications, and (2) the best possible effort is made to establish the target community.

Effects

The monitoring proposed above for compliance also serves the purpose of keeping track of some effects. In addition, the MRC recommends that the soft benthos be monitored to determine if the spatial extent of SONGS' effects changes through time. We recommend that the soft benthos be sampled at the same stations used by the MRC, with the addition of a more distant control.

At this point, the MRC has not made a determination about the link between SONGS and the anomalous sediments in the San Onofre kelp bed. If SONGS is linked to these sediments, we recommend that their distribution and abundance be monitored using the same sites and methods we used in 1989, with permanent stakes added to measure changes in sediment depth.

Chapter 2

OVERVIEW OF THE REPORT

This overview chapter explains briefly how the MRC arrived at the Results and Recommendations; it is essentially a summary of Section II. Chapter 1 presents the Results and Recommendations; in doing so it summarizes Sections III-V of this report. Thus Chapters 1 and 2 together provide a summary of the report.

For those with time to read beyond Section I, Section II gives a fuller account of the background to the study. The results of each component of the study, and the means by which they were obtained, are presented in Section III. Section IV selects those MRC results that bear on water quality regulations and, in response to provision B.1.b. of Coastal Permit No. 183-73, explains how decisions were reached on SONGS' compliance with these regulations. Section V provides the rationale for the recommendations made in light of the Results.

MRC Mandate, Structure and Scientific Management

This report is submitted to the California Coastal Commission (CCC) in response to the conditions of Permit No. 183-73, dated February 28, 1974, of the then California Coastal Zone Conservation Commission (Appendix 1). The MRC is an advisory body to the CCC and was established in response to an application by the Southern California Edison Company (SCE) to expand the San Onofre Nuclear Generating Station (SONGS) by adding Units 2 and 3 to the already existing Unit 1. The MRC consists of three scientists, one appointed by the applicants (SCE), one appointed by the appellants (consisting of several environmental groups), and the other (the chairman) appointed by the Commission.

The MRC was charged to

> "carry out a comprehensive and continuing study of the marine environment offshore from San Onofre...to predict, and later to measure, the effects of San Onofre Units 2 and 3 on the marine environment, with emphasis on (a) the effects of the new units on zooplankton and larval organisms, and (b) compliance with the regulatory requirements of State and Federal water quality agencies...in a manner that will result in the broadest possible consideration of the effects of Units 1, 2 and 3 on the entire marine environment in the vicinity of San Onofre."

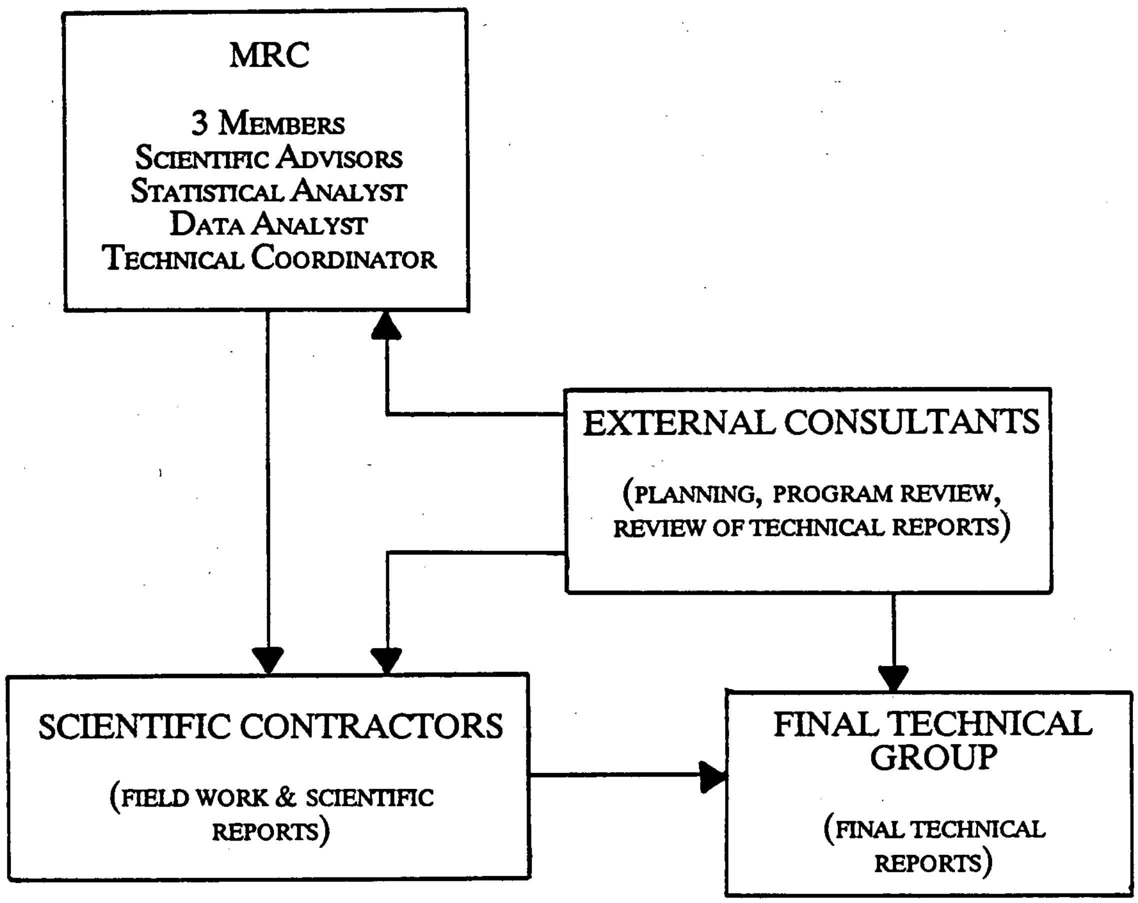
The MRC was then charged to report to the Commission any predicted or discovered substantial adverse effects on the marine environment, and any evidence the plant was not in compliance with federal or state water quality regulations, together with recommendations for changes in SONGS' cooling system that would reduce such effects.

In 1979, the CCC recognized that operational changes or mitigation measures might compensate for losses of marine life, and might substitute for changes to the cooling system. The Commission therefore directed the MRC to study mitigation and make recommendations to ensure there would be no net adverse effect of SONGS operation on the marine environment (Appendix 2).

The structure of the MRC is described in Figure 2.1. The programs to measure the effects of SONGS on the marine environment were designed by the MRC in collaboration with the scientists contracted to collect the data and with outside scientists. The data were collected and analyzed by the scientific contractors (henceforth "contractors"). Internal and external oversight and review were carried

Figure 2.1.

Structure of the Marine Review Committee



out in a variety of ways (Figure 2.2). The contractors' data quality was subjected to independent check, as was their analysis of the data, by MRC analysts hired for this purpose. Outside experts were called in as needed to consult on, and sometimes to help oversee, ongoing field programs. Contractors' reports were subjected to external as well as internal review.

After the contractors' Final Reports were in hand, further analyses of the data were carried out by the MRC technical group, who prepared the MRC Technical Reports to the CCC. The Reports were also subject to internal and external review. In all, more than 100 external scientific experts were used by the MRC, and at least 573 reviews of contractor and MRC technical reports were done in the period 1982-Technical89.

Brief History

Figure 2.3 provides a history of the construction of the marine portion of SONGS Units 2 and 3 and of their operation. The figure shows how the various MRC studies and its major reports relate to the history of the new units.

There have been five phases to the study, each of which corresponds to a task given to the MRC either by the Permit or the CCC. The phases and the associated MRC reports to the CCC are as follows.

1) Effects of the cooling system of Unit 1: "Updated Estimated Effects of SONGS Unit 1 on Marine Organisms," August 1978, MRC Document No. 78-01.

Figure 2.2.

INTERNAL AND EXTERNAL REVIEW PROCESS

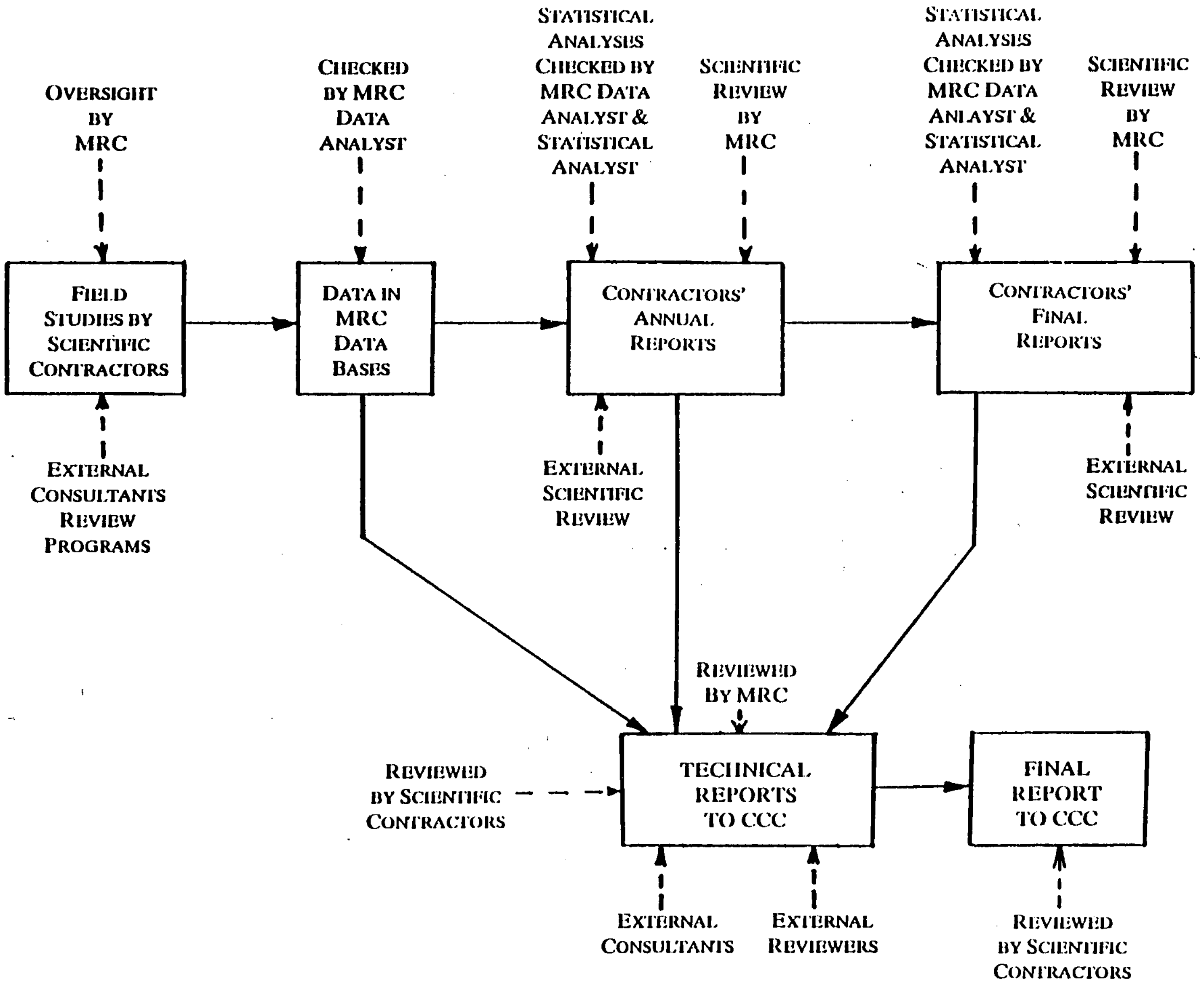
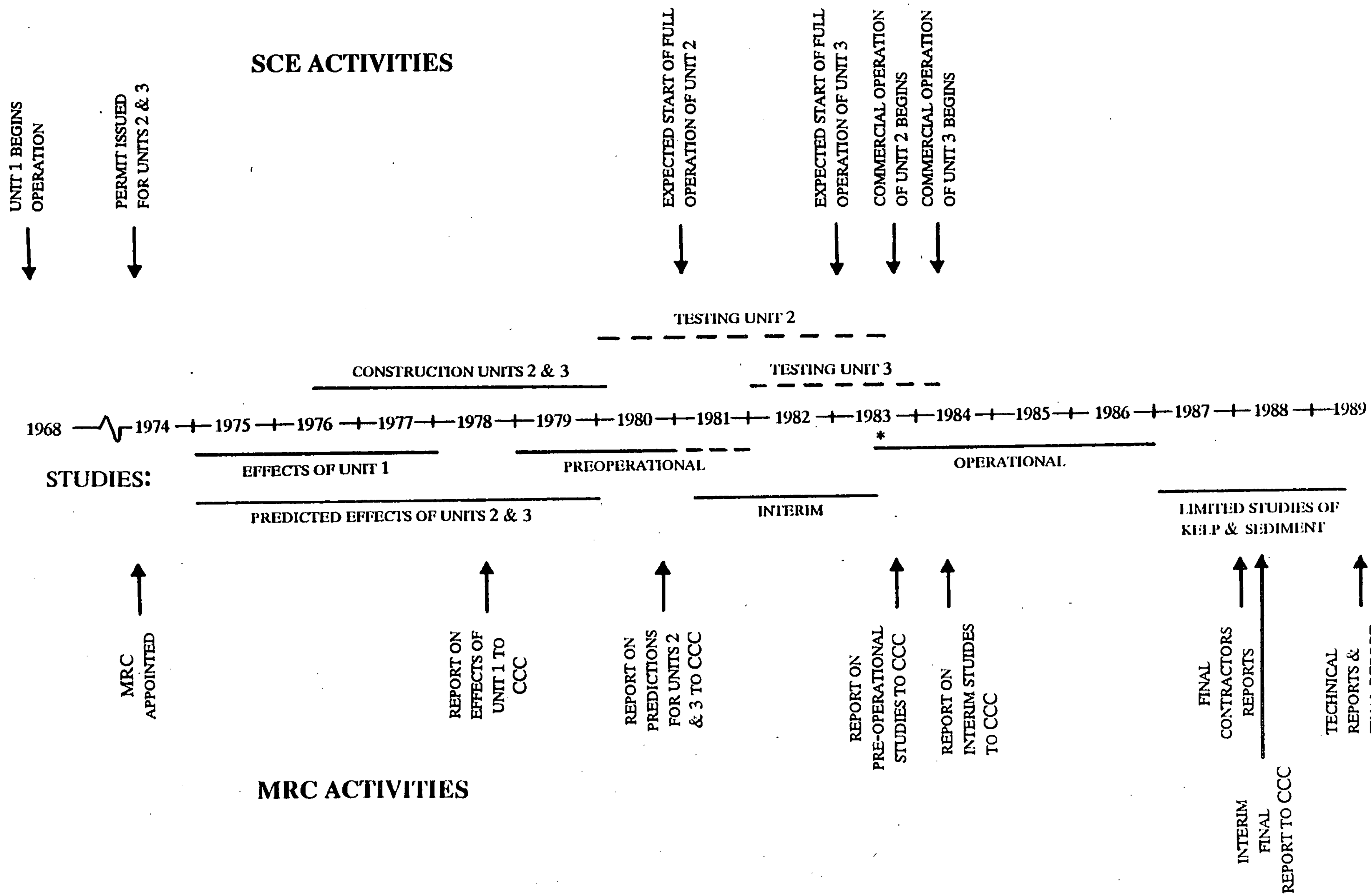


Figure 2.3

History of main events, studies, and MRC reports to CCC



* MRC RECOGNIZES FULL OPERATION STAR[illegible]AY 19[illegible]

2) Predictions of effects of Units 2 and 3: "Prediction of the Effects of the San Onofre Nuclear Generating Station and Recommendations: Recommendations, Predictions and Rationale," November 3, 1980, MRC Document No. 80-04(1).

3) Results of pre-operational monitoring of effects of Units 2 and 3 (1979-1981/2): "Pre-Operational Monitoring for Units 2 and 3 of San Onofre Nuclear Generating Station," October 13, 1983, MRC Document No. 83-01.

4) Results of interim-period monitoring (1981-83): "Report to the CCC concerning Interim Operation of San Onofre Nuclear Generating Station," April 24, 1984, MRC Document No. 84-08.

5) The final phase is monitoring in the operational period, determining the effects of SONGS, and making recommendations. Some of the results were reported to the CCC in an Interim Report (MRC Doc. 88-05, April 18 1988). These have been incorporated into the present report.

Structure and Operation of SONGS and Possible Effects

SONGS consists of three units, the first of which began operation in 1968. Each generates electrical power using a pressurized nuclear reactor that boils fresh water contained in a closed loop. The resulting steam drives the turbines and is then cooled by seawater, which does not come into contact with the steam (except for minor leakage through seals). In each of the new units (2 and 3), seawater is drawn into an intake pipe in 30 feet of water, passes through the plant where its temperature is raised about 19°F, and pumped out to the ocean 5900 feet (Unit 3) or 8200 feet (Unit 2) from shore through a "diffuser" (Figure 2.4).

Each diffuser is a 2500-foot long concrete tube with 63 openings along its length through which the cooling water is ejected. The jets of cooling water immediately draw in and carry along ("entrain") about 10 times their own volume, so the discharge water is very rapidly mixed with ambient water as it rises to the surface, where it usually forms a visible plume. This mixing rapidly dissipates the

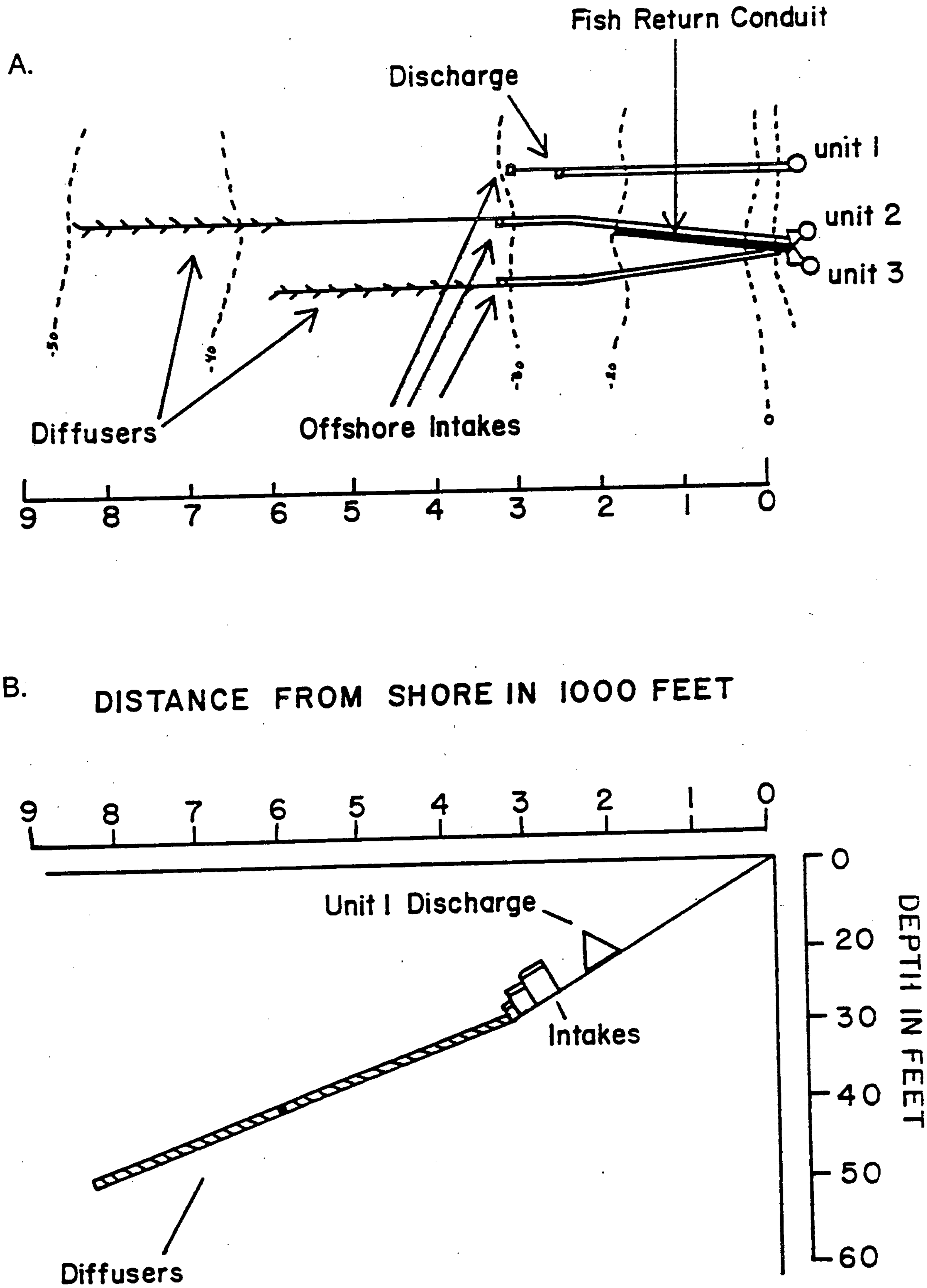


Figure 2.4. Schematic diagram of SONGS Units 1, 2 & 3 intake and discharge systems, by (A) aerial view and (B) offshore-onshore view on the cross-shelf plane.

heat in the cooling water. Each day, SONGS discharges a volume of water measuring a mile square and 14 feet deep.

The effects of SONGS on the marine environment are associated with the passage of cooling water. Most small organisms taken into the plant (including plankton and fish larvae) probably are killed. Some fish are killed by being impinged on screens that prevent large objects from entering the cooling system. Many fish are diverted to a Fish Return System that returns them to the ocean; some of these individuals also die. The cooling water taken into the plant comes from close to shore and is therefore relatively turbid. In addition, the jets emerge at just over 6 feet above the ocean floor, where the water is more turbid than it is nearer the surface. The discharge plume is pushed offshore and toward the surface by SONGS, and therefore typically moves turbid water to a zone that is naturally less turbid. The local currents move downcoast about 60% of the time (we refer to this direction as "south" though it is strictly east of south). As a result, SONGS has the potential to increase the flow of particles and reduce the penetration of light in the San Onofre kelp bed (Figure 2.5), and hence reduce its size.

At the Public Hearings on the Permit in 1973/74, the major concern was that there would be massive mortality of plankton, including immature stages, from the combined effects of intake mortality and transport of plankton offshore in the plume to an inhospitable environment where they would perish. It was predicted that this would cause massive reductions in the abundance of the nearshore fauna.

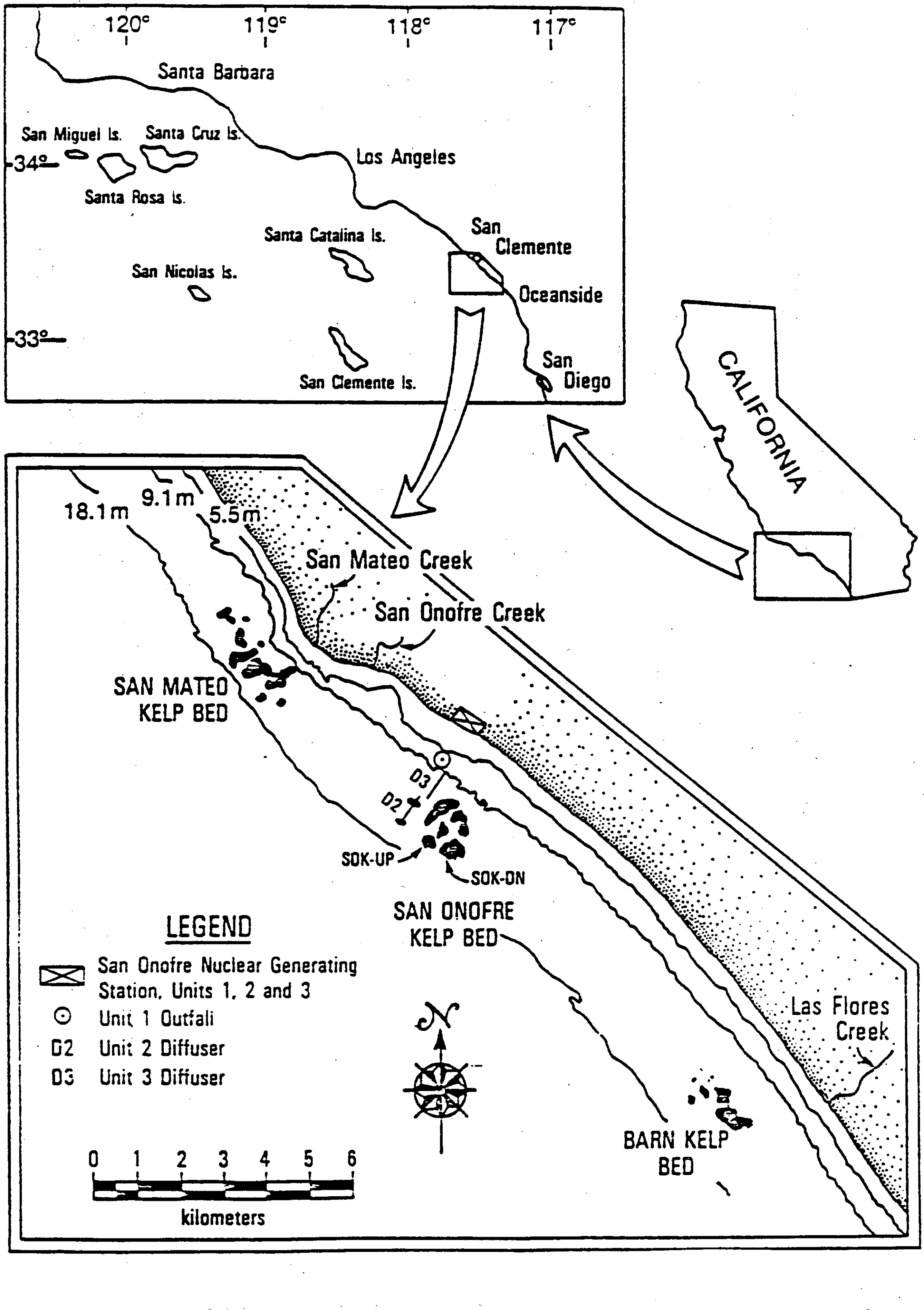


Figure 2.5. Map of San Onofre Area

MRC Approach to Determining Effects

The MRC was guided by the Permit's unambiguous emphasis on determining effects on the marine environment and its clear concern for effects on the biota. The Committee, therefore, concentrated on developing programs that would enable it to conclude whether SONGS has reduced the abundance of organisms representing a broad range of the marine communities near the plant.

To decide this question, we need to compare the abundances of the affected organisms in the presence of SONGS to the abundances they would have had if SONGS had never operated.

An obvious way to approach this problem is to compare the abundances before SONGS started up to the abundances after start-up. But this simple approach alone would not work, because marine organisms vary greatly in the short term (e.g., because of storms), the middle term (e.g., seasons) and the long term (e.g., major weather changes such as El Nino). The long-term variation could either hide a SONGS-induced reduction in abundances (by causing temporary increases that cancel it out) or mimic one; the short and middle term variation would make our data more variable, and thus make any general change harder to detect.

A second way to decide the question is to compare the area near to SONGS (the "Impact" area) with a similar area (called a "Control") that is nearby but outside the likely range of effects. However this approach is also flawed. Different parts of the coastline are likely to differ in several ways, some unknown to us; abundances of species in the community are therefore likely to vary from place to place.

The weaknesses of both approaches can be overcome by combining them. Since the Impact and Control areas are less than 20 km apart, they will be affected very similarly by the main causes of natural variation: storms, seasons and major weather changes should have about the same effects at both places. Thus, although species abundances may differ between the two areas, the amount of difference should not vary much over time.

However, if there are SONGS effects, they should be felt at the Impact area and not at the Control. Thus such effects *will* cause a change in the differences between Impact and Control. In other words, keeping track of the *differences* between the Impact area abundance and the Control area abundance should be a good guide to a SONGS effect because (a) the differences should be just as affected by SONGS as the Impact area abundances themselves, and (b) their natural variation over time should be much less than the variation in actual abundance, and so it will not cancel, mimic or obscure a SONGS effect.

Samples were taken close to SONGS at one or several *Impact* stations, and also far from SONGS at a *Control* station, both *Before* and *After* Units 2 and 3 began operation. In each time period (*Before* or *After*) samples were taken at both stations as close to simultaneously as possible (examples are in Figure 2.6). Such *paired* samples were taken on many occasions spread over the time available. For example, net samples of fish were taken at Control and Impact stations, on the same night, on 60 occasions spread evenly between 1980 and 1982 before the new units began operating, and on 32 occasions over three years after operation began. The samples are thus *paired* in time at the two stations. The design is abbreviated to BACIP (Before-After/Control-Impact Paired).

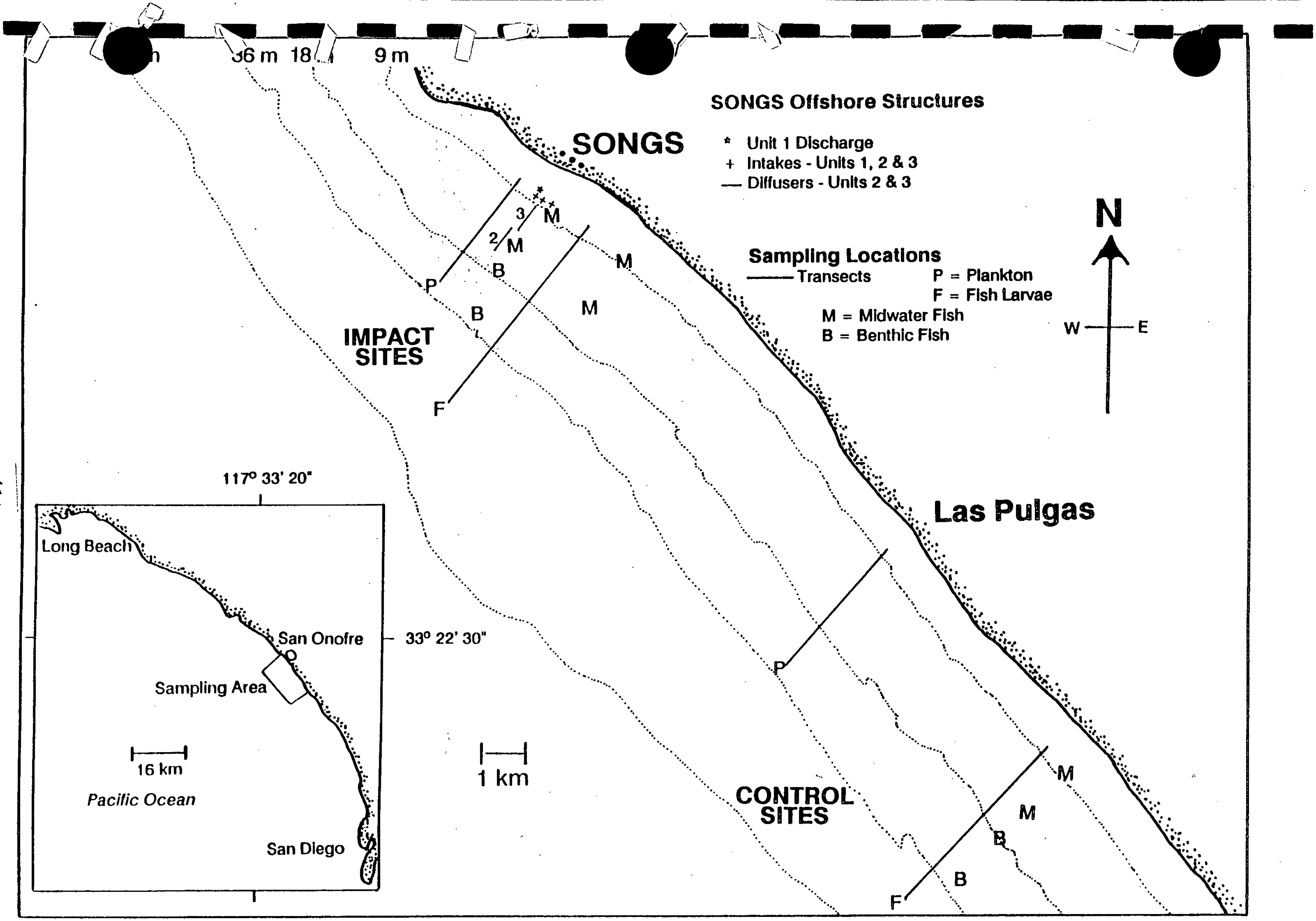


Figure 2.6. Map of sampling locations for plankton, fish larvae, midwater fish and benthic fish.

In the BACIP design, the information of interest on each sampling occasion is the *difference* in abundance between the Control and Impact samples. From these differences, we obtain an estimate of the *average difference* in abundance between the two stations before the new units began operation. Our question then is: *Did the average difference in abundance between the Control and Impact stations change between the Before and After periods*? For details see Chapter 5.

Our first aim was to decide whether a SONGS-induced change occurred. We have also estimated the size of each effect where possible. For example, a given species might show a 50% reduction in abundance at SONGS relative to the control station. This means that the abundance at SONGS in the After period is about one-half what it would have been if SONGS had not been operating. The reader should view the calculated value of the change as an estimate; variability among samples, and sometimes other factors, make the precise value unknowable. However, almost all reported changes are "statistically significant;" that is, they are not likely to be mere chance events, and the size of effect reported is our best estimate.

Firm conclusions (i.e., whether or not there has been an effect) have been reached mainly for the most abundant and the most frequently-occurring species. Although we have not been able to draw individual conclusions for the many species that are rare and infrequent, our conclusions do embrace the majority of the individuals. Furthermore, when no significant effect can be detected in many individual species, it has often been possible to detect a significant pattern of change when similar species in a particular part of the community are treated as a group.

A number of programs were designed to obtain information on the spatial pattern of effects. They were used for organisms in which it seemed likely that effects would occur, and in which the size of the effect at different distances from the plant might be detectable consistently over time. In these cases there were two or more Impact sites situated at different distances from the plant. The organisms studied under such a "gradient" design were the midwater fish, giant kelp, kelp bed fish, kelp bed invertebrates, and soft bottom benthos; physical/chemical programs also typically had a gradient of stations. It needs to be noted, however, that for a given research effort, a single Impact station has more power to detect an effect than do several stations.

In addition to sampling the abundance of many organisms, the MRC also carried out studies to help tie observed changes in abundance to the operation of the plant. For example, estimates were made of the number of organisms killed in the intake water. Measurements were made of ocean currents and other features of the environment, such as light in the kelp bed and organic matter in soft sediments, that might be affected by SONGS. Finally in a few cases experiments were done either to detect the plant's effect on organisms or to elucidate the mechanisms causing the effect.

A variety of studies of metals and radioactive elements (radionuclides) were carried out in response to suggestions that sand crabs in the SONGS area might be affected by these pollutants.

Predicted Effects and Results

Two ways in which SONGS might have a large effect on the biota were suggested during the hearings on the Permit: via (1) its intake of massive amounts of cooling water and (2) the transport offshore of roughly 10 times that intake. (Because heat is dissipated so rapidly in the discharge plume, there appear to be no significant effects of elevated temperatures once the discharge leaves the diffusers).

Some of the actual effects of SONGS are very different from those predicted initially. Virtually all of the expert testimony regarding SONGS' likely effects on the marine biota, recorded in the minutes of the 1973-1974 public hearings before the CCZCC and summarized in the Permit itself, concerned the possible effects of intake and offshore transport on zooplankton. It was feared that

> "the cooling system for Units 2 and 3 would have a massive environmental impact on the most important ecosystem, the plankton ... [which] represent a main source of food for most organisms in the nearshore environment, and of greater importance, the plankton include the immature stages of nearly all other nearshore marine animals." (Minutes of October 18, 1973, p. 13).

It was stated that vast numbers of zooplankton would be killed directly by being taken into the plant. More importantly, even larger numbers would be transported offshore in the discharge water, which would act like a massive river, carrying plankton a mile offshore to an inhospitable environment, where they would perish. The consequences would be "impoverishment of the nearshore fauna, including clams, lobsters, and mussels, [whose larvae are in the plankton], and everything that depends on plankton," and the production of a nearshore "desert" (Minutes, p. 13).

This predicted effect did not occur. The discussion in the Public Hearings did not consider carefully how much dilution there would be; in addition, water entrained along the diffusers is typically moved only 2000 to 3000 feet further offshore, so the predictions made in the Permit hearings overestimated the potential effects of offshore transport.

Although turbidity was not discussed at the Hearings, the Permit itself raises the possibility that increases in turbidity from SONGS' plume might have a negative effect on the kelp bed, but does not go into detail.

In 1980 the MRC developed a set of predictions for the CCC. As might be expected since they were based on several years of study, these were closer to the mark than those made in the Public Hearings. But they were by no means wholly accurate. Several major predictions by the MRC were borne out. Intake losses of fish larvae were expected to lead to reductions in the bight-wide populations or production of fodder fish in particular, and our calculations still suggest that this is the case. A reduction of the kelp bed, via suppression of recruitment of small plants by the turbid plume, was predicted - especially in the offshore portion - and was observed. The MRC predicted that particles from the plume would enrich the communities of organisms living on the ocean floor, and the abundances of these organisms have increased.

Among the inaccurate predictions in the 1980 MRC report were the following. We predicted that there would be no increase in benthic fish, but there was[1]. We suggested there might be sizeable decreases in some species of semi-planktonic mysids near SONGS; however the model on which this prediction was based was wrong, and there was an increase in mysids. We thought it probable that

[1] Dr. Fay does not agree with this conclusion.

there would be some (unspecified) decrease in local plankton density, and none occurred[2]. We expected SONGS to cause upwelling of nutrient-rich waters, but there is no evidence that it does. Information on the likely paths of the plume led us to predict that there would be no increased accumulation of sediments on hard substrates in the kelp bed, but there appears to have been an increase in sedimentation rate there.

The failures of prediction can be explained largely by a lack of quantitative information about crucial processes, especially the rate of oceanic mixing and the amount of offshore transport by the plume, and about the quantitative details of complex ecological processes. Our oceanographic studies eventually gave us much of the needed quantitative physical information. But the quantitative details of interactions in the biotic community remain in practical terms unknowable for most marine situations. Nevertheless, the studies reported here have provided much needed insight into the spatial scale on which ecological communities are affected by physical and chemical disturbances of the sort engendered by SONGS.

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[2] Dr. Fay does not agree with this conclusion.

SECTION II.

INTRODUCTION AND BACKGROUND

Chapter 3

THE MRC: ITS MANDATE, HISTORY, AND OPERATION

The MRC and its Mandate

This Report is submitted to the California Coastal Commission (CCC) in response to the conditions of Permit No. 183-73, dated February 28, 1974, of the then California Coastal Zone Conservation Commission (Appendix 1).

The MRC was established in response to an application by Southern California Edison Company (SCE) to expand its San Onofre Nuclear Generating Station (SONGS) by adding Units 2 and 3 to the already existing Unit 1. The MRC consists of three scientists, one appointed by Southern California Edison, one appointed by the appellants (Groups United Against Radiation Dangers, Environmental Coalition of Orange County, Friends of the Earth, *et al.*), and the other (the chairman) appointed by the Commission. From 1974 until 1980, the chairman was Dr. J. H. Connell, while Dr. J. Mihursky represented the appellants. The present membership is Dr. R. Fay (appellants), Dr. B. Mechalas (SCE), and Dr. W. Murdoch (chairman), and has been unchanged since 1980.

The MRC was charged to "carry out a comprehensive and continuing study of the marine environment offshore from San Onofre...to predict, and later to measure, the effects of San Onofre Units 2 and 3 on the marine environment, with emphasis on (a) the effects of the new units on zooplankton and larval organisms, and (b) compliance with the regulatory requirements of State and Federal water quality agencies ... in a manner that will result in the broadest possible consideration of the effects of Units 1, 2 and 3 on the entire marine environment in the vicinity of San Onofre."

The MRC was charged with "recommending to the State Commission any changes it believes necessary in the cooling system for Units 2 and 3. The State Commission shall then further condition the permit accordingly" (Condition B.4).

Finally, condition B.6 provides that:

> "Should the study at any time indicate that the project will not comply with the regulatory requirements of State or Federal water quality agencies, or that substantial adverse effects on the marine environment are likely to occur, or are occurring, through the operation of Units 1, 2, and 3, the applicants shall immediately undertake such modifications to the cooling system as may reasonably be required to reduce such effects or comply with such regulatory requirements (which can be made while construction is going on and could be as extensive as requiring cooling towers if that is the recommendation). The State Commission shall then further condition the permit accordingly."

On November 1979 the Commission expressed interest in evaluating other means of mitigating adverse effects other than changes to the cooling system and directed the MRC as follows:

> "Mitigation Alternatives to Design Changes. The Commission also recognizes that operational changes or mitigation measures might adequately compensate for any marine life damages resulting from the operation of Units 2 and 3. The Commission, therefore, requests the MRC to study the feasibility and effects of selected promising mitigation measures, including construction of an artificial reef, as suggested by Southern California Edison. The MRC should recommend what measures might be taken to assure there would be no net adverse effect on the marine environment from operation of SONGS Units 2 and 3." (Staff Reports 11/9/79, 4/4/80).

A Brief History of MRC Studies

Figure 3.1 provides a history of the construction of the marine portion of SONGS Units 2 and 3 and of their operation. The figure shows how the various MRC studies and reports relate to the history of the new units. Unit 2 was expected to become operational in early 1981, but in fact was not commercially licensed until August 1983. As a result, the pre-operational sampling could have been spread over a longer period than was the case, and there was an Interim period from early 1981 to mid-1983, during which samples were taken less frequently. In some programs it has been appropriate to use some of the interim samples as part of the pre-operational data base. The new units were both operating commercially by April 1984. The MRC determined in retrospect, however, that the new units maintained a level of operation from May 1983 till April 1984 that was similar to that in the following two years, and so designated the former date as the start of the Operational period.

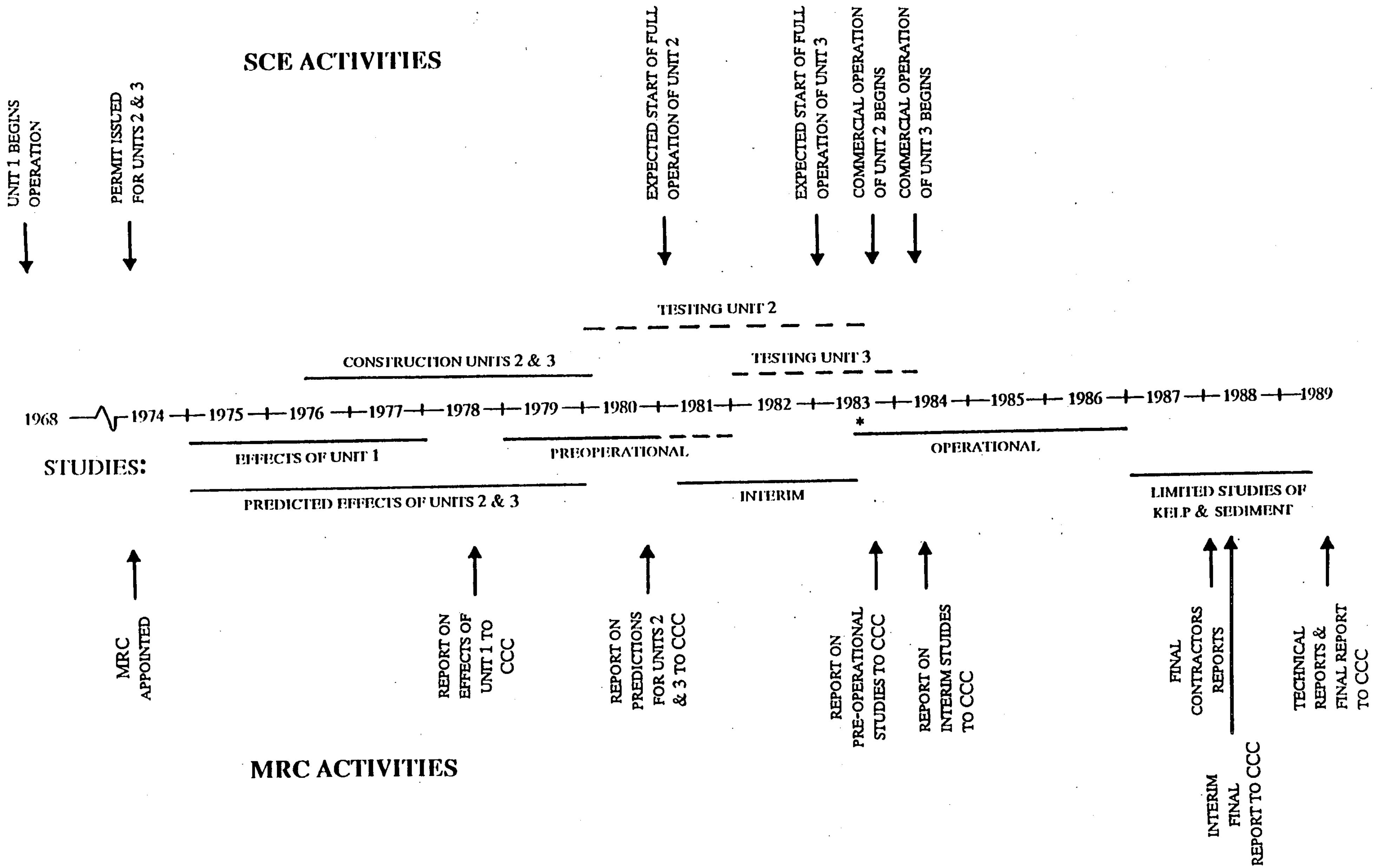
MRC studies fall into five phases corresponding to the tasks laid out in the Permit and requested at various times by the Commission. The tasks and the associated reports that have been submitted to the Commission are as follows:

1) Effects of the cooling system of Unit 1: "Updated Estimated Effects of SONGS Unit 1 on Marine Organisms," August 1978, MRC Document No. 78-01.

2) Predictions of effects of Units 2 and 3: "Prediction of the Effects of the San Onofre Nuclear Generating Station and Recommendations: Recommendations, Predictions and Rationale," November 3, 1980, MRC Document

Figure 3.1.

History of main events, studies, and MRC reports to CCC



* MRC RECOGNIZES FULL OPERATION STARTS MAY 1983

No. 80-04(1). This report recommended against changes in the cooling system at that time, because confidently-predicted effects of the plant were not sufficiently adverse, the likely environmental effects of changes to the cooling system were not known, and mitigation of at least some effects appeared to be a possibility.

3) Findings of pre-operational monitoring of effects of Units 2 and 3 (1979-1981/2): "Pre-Operational Monitoring for Units 2 and 3 of San Onofre Nuclear Generating Station," October 13, 1983, MRC Document No. 83-01.

4) Findings of interim period monitoring (1981-83): "Report to the CCC concerning Interim Operation of San Onofre Nuclear Generating Station," April 24, 1984, MRC Document No. 84-08.

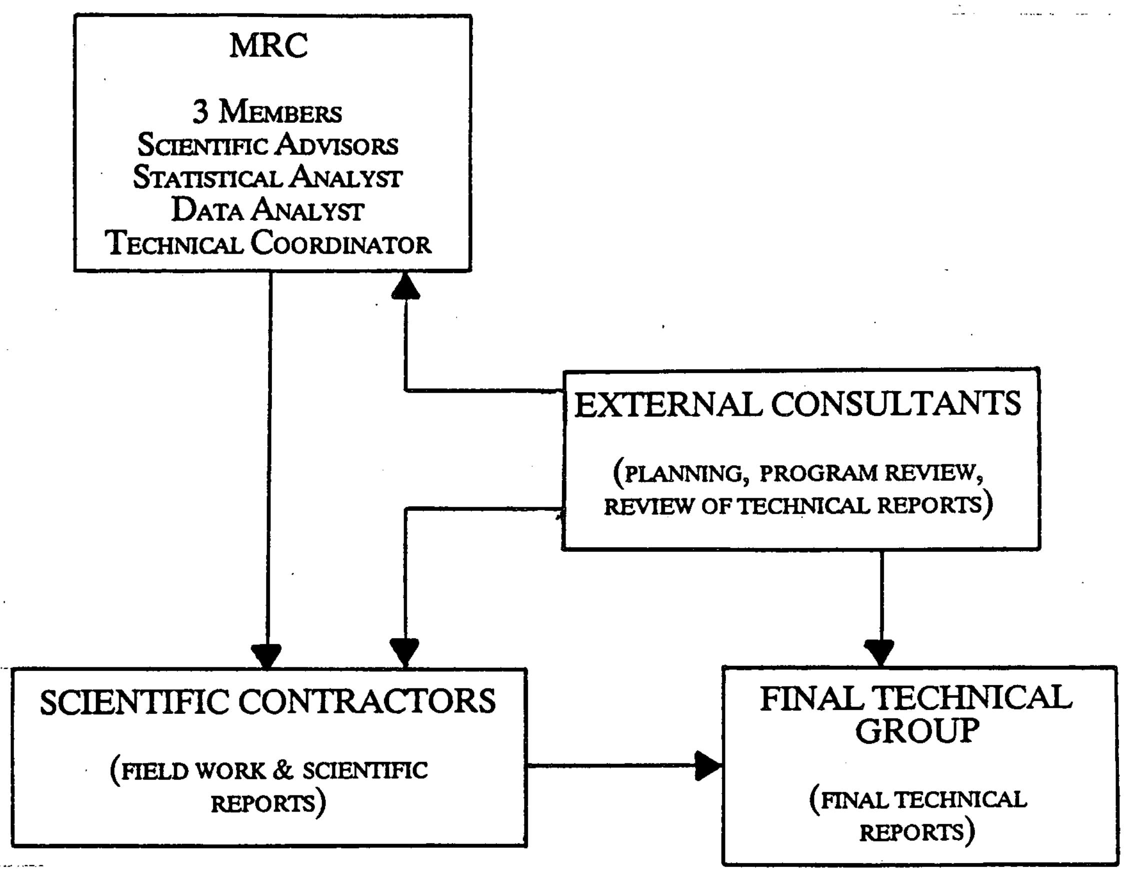
5) The final phase consists of monitoring in the operational period, determining the effects of SONGS, and making recommendations. Part of the results and findings from this phase were reported to the CCC in an Interim Report (MRC Doc. 88-05, April 18 1988). These results have been incorporated into the present report.

Scientific Management and Decision-making

The structure of the MRC is described in Figure 3.2. As noted above, the MRC has three members. Each member had access to a scientific advisor of his choice. The data were collected and analyzed by scientific contractors (henceforth "contractors"), who reported their results formally to the MRC, typically in annual reports. In 1978 an executive director, later the technical coordinator (1984), was hired to oversee the day-to-day running of the programs. In 1981 the Committee

Figure 3.2.

Structure of the Marine Review Committee



hired a statistical analyst to evaluate the analyses done by the scientific contractors and to make suggestions for improving the studies and analyses. Finally, in 1984 a data analyst was hired to ensure the integrity of the MRC data. External consultants and reviewers were hired throughout the study as needed.

The studies were designed by the MRC in collaboration with the scientists contracted to collect the data, and with the help of outside scientists (Figure 3.2). For example, the statistical design underlying many studies (BACIP - see chapter 5) was developed in collaboration with three consulting statisticians. The kelp studies, which in many ways faced the most difficult problems, were designed, and overseen throughout much of their existence, by a committee containing outside kelp experts and a statistician. Outside consultants were called in whenever particularly difficult problems of study design arose.

The implementation of the studies was done by contractors, who collected samples or did other appropriate studies, following the agreed-upon design. Members kept up to date on the progress of studies via informal reports, presentations at MRC meetings, and formal scientific reports.

It is standard in many studies of this nature that the contractors collecting the data, who in this case were primarily experts in marine biology, are not responsible for analyzing them. The latter task instead is given to more statistically-expert contractors. This approach was indeed strongly recommended by the late Dr. Tibor Polgar (the scientific advisor for the appellants), who had extensive experience in environmental impact studies. The MRC decided instead to encourage the field contractors to analyze their data, on the grounds that the contractors had been chosen for their abilities as working scientists, not merely as data collectors, and that it was better to get insight from a wide range of scientists. It was recognized from the start, of course, that the ultimate responsibility for interpreting the data lay with the three members of the MRC.

The structure of the internal and external review process is shown in Figure 3.3. This process occurred at various stages in the development of MRC studies.

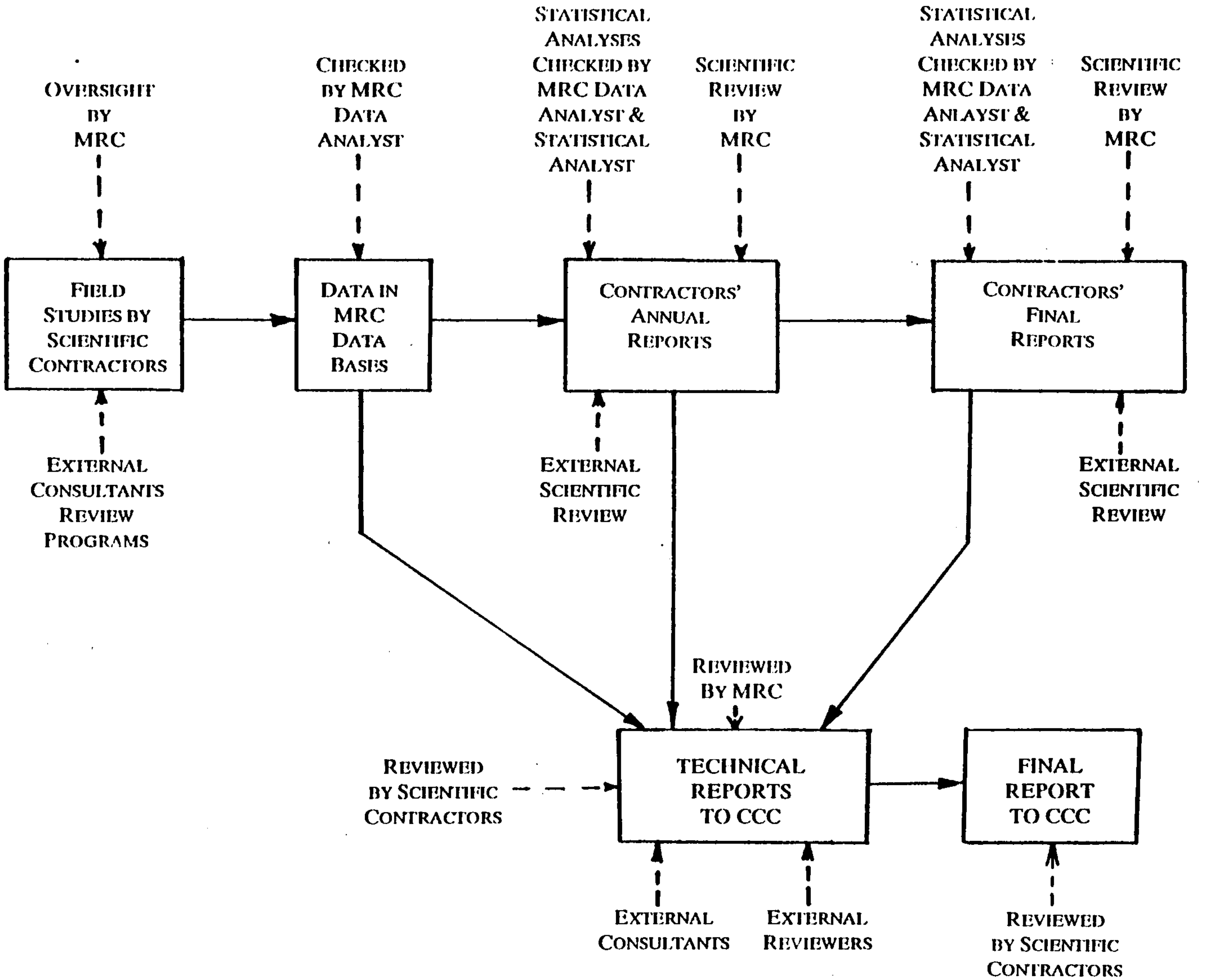
(1) As noted, external review and consulting took place at the design of studies and, in some cases, in the oversight of ongoing field studies.

(2) The *MRC data bases* have been established in the following way. The contractor transferred the results of analyzing field samples, etc. from their data note books to "raw data" files in the MRC computer. The note books, or copies thereof, have been retained by the MRC. The raw data files were transformed to (SAS) "data files," i.e., to a form suitable for statistical analysis. There are approximately 1700 such data files containing 300 megabytes of data (the equivalent of 75,000 typewritten pages). The data analyst used a variety of procedures to ensure the integrity of the MRC data files. The procedures used to create the data files, and the contents of each group of data files (a "data base"), are described in the MRC's Data Standards Document. A Guide to the Databases has also been prepared for the more complex data bases.

(3) The *contractors' statistical analyses* were checked by the data analyst to ensure that the results presented could be duplicated, by repeating the analysis using

Figure 3.3.

INTERNAL AND EXTERNAL REVIEW PROCESS



the same data base. The contractors' Final Reports contain a listing of the data bases used in the analyses presented in the reports.

(4) The *contractors' scientific reports to the MRC* were subjected to review by both the MRC and outside scientists. Within the MRC, reviews were usually provided by the members and/or their scientific advisors and by the statistical analyst. External reviews were obtained for the contractors' annual reports, though these reviews were not routinely archived until 1982. The contractors' Final Reports were also externally reviewed. Each member chose one external reviewer for each contractors' report.

(5) In 1987 the MRC began the process of preparing this Final Report to the CCC. The basis of this report is a series of Technical Reports, which were written by the MRC's technical group. That group consisted of the technical coordinator, the statistical analyst, a statistical analyst who had worked with the contractors, and some of the contractors. (They are listed at the start of the appropriate chapters in sections III-V.) External scientific advice was sought where appropriate by the technical group. There was frequent interaction between the MRC members and the technical group during this process, and the members provided suggestions for analyses.

The technical group used the contractors' Final Reports as their starting point. However, they also returned to the data bases, sometimes repeating the contractors analyses but often doing new analyses. The technical group had the advantages of building upon each contractor's analyses, of seeing the larger picture provided by all the contractor reports taken together, of some new data, and of an additional two years in which to solve outstanding problems of analysis, as well as their own fresh insight. Typically the Technical Reports confirm the conclusions reached by the contractor, but often they are able to expand and amplify them.

These *Technical Reports* have also been subject to the standard internal and external review process (Figure 3.3). This Final Report to the CCC is based on the Technical Reports.

During the process described above, 99 non-MRC scientists either reviewed various reports or consulted on various aspects of the MRC program. Between 1982 and July 1989, at least 573 written reviews were received.

Public Access to MRC Data and Reports

This report has been written for the non-scientist who nevertheless might like to know the background to the study and how the MRC arrived at its conclusions. For those with limited time, Chapter 1 contains the important conclusions.

This report does not include detailed references to the technical sources of its conclusions, which can be found in the associated series of *Technical Reports.* (In Sections III-V, the Technical Report that is the source of a conclusion is referred to as TR, thus Section 2.1 in *Technical Report A* is abbreviated to TR A: 2.1.) These Technical Reports are written for scientists, especially biologists, with a working knowledge of statistics, the use of which is central to the design and interpretation of the study.

The MRC is lodging with the CCC the following reports and materials: this Final Report, a set of the Technical Reports, a set of the contractors' Final Reports, a copy of the external reviews, and various data sets and guides to their use. The data sets include: the MRC data bases on both 9-track magnetic tapes (11) and floppy discs (approximately 300), the raw data files on magnetic tape (13) and, also on magnetic tape copies of the programs used in the analysis of the data and to create the data bases from the raw data files.

The MRC intends that interested scientists should be able to repeat and elaborate on its analyses. As noted above, this report indicates, for each result, where the supporting evidence can be found in the associated *Technical Reports.* These reports in turn list the particular MRC data bases analyzed to arrive at their conclusions, and refer the interested reader to a file containing the programs used in the analyses. The Technical Reports on occasion refer to the contractors' Final Reports.

Chapter 4

STRUCTURE AND OPERATION OF SONGS

A more detailed account of the structure and operation of SONGS than that which follows can be found in the *Interim Technical Report: 1. Plant Description and Operation*.

SONGS consists of three units. Each generates electrical power using a pressurized water nuclear reactor. The reactors boil fresh water that is contained in a closed loop. The resulting steam drives turbines, and is then cooled in the condensers by seawater (which does not come into contact with the steam except for minor leaks through the seals). The seawater for each unit is taken in through a single intake, passes through the condenser, absorbs heat in the process of cooling the freshwater steam, and then is discharged to the ocean where it dissipates its accumulated heat.

SONGS Unit 1 began commercial operation in 1968. It produces 436 megawatts (MW) of electrical power. Its intake is in water 27 feet deep and about 3000 feet from the shore (Figure 4.1). The intake is a vertical pipe with a velocity cap above it, 15.5 feet above the ocean floor. Between the pipe and the cap is a space of about 4 feet through which the water enters. The cap's intended purpose is to make the flow of water into the pipe horizontal, and hence to make it easier for fish to avoid entrapment. During normal operation seawater increases in temperature about 22°F during its passage through the plant, and is discharged through a single vertical pipe in 25 feet of water about 2500 feet from the shore

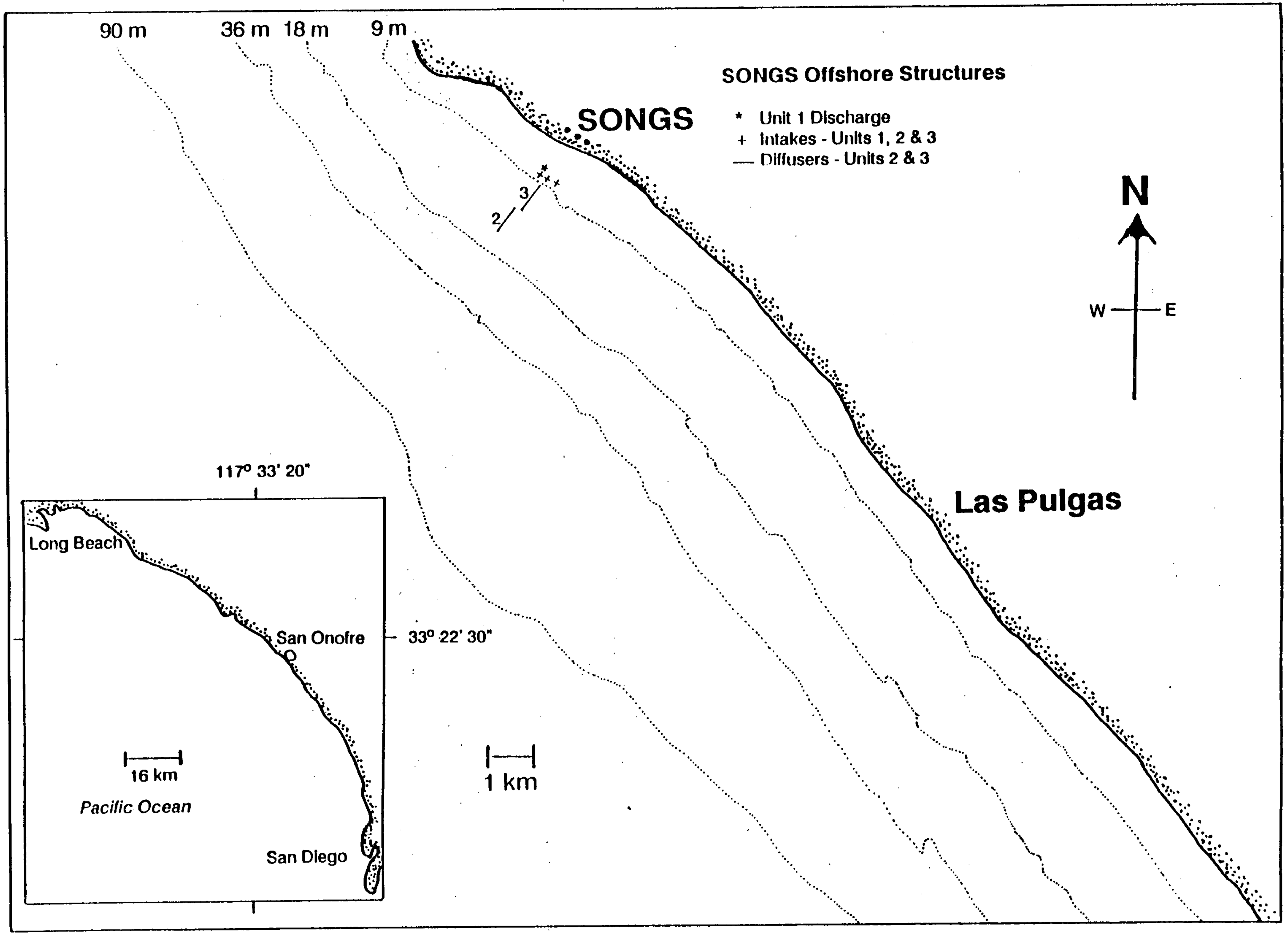


Figure 4.1. Map of SONGS area.

[ITR 1: 1-2] Units 2 and 3 are the subject of the CCC Permit. Each has an electrical power output of 1100 MW. The marine portions were built between 1974 and 1981. Each has a single intake with a velocity cap, reaching about 18 feet above the ocean floor, and situated 3200 feet from the shore in 30-foot water. Seawater in these units gains 19°F, and is discharged through a diffuser of unique design (Figure 4.2). Each diffuser is a concrete tube 2500 feet long, with 63 diffuser ports along its length. Each port is a 2-foot in diameter circular opening in a concrete block built on to the tube, facing offshore, with a tilt upwards and alternately to one side or the other. Water is discharged in a powerful jet with an initial velocity of 13 feet per second. Unit 2's diffuser ends 8200 feet offshore at a depth of 50 feet, while Unit 3's diffuser ends 5900 feet offshore at a depth of 38 feet [ITR 1: 2].

At normal full operation, Unit 1 takes in 320,000 gallons (1211 cubic meters) of seawater per minute [ITR 1: 1], while Units 2 and 3 each take in about two-and-a-half times as much water (830,000 gallons per minute) [ITR 1: 2]. Thus, all three units operating together can take in and discharge almost 2 million gallons (over 7,000 cubic meters) every minute, or a volume of water measuring a square mile, 14 feet deep, every day. The volume passing through the three units in the course of a week is thus equivalent to all the water out to the 36-foot depth contour (about 4800 feet from shore) along a six-mile stretch of coastline. Virtually all this water comes immediately from inshore of the 36-foot contour, but the currents that bring water to SONGS are highly variable, so some of the water taken in may have been a few miles offshore or a few tens of miles alongshore in the course of the preceding week.

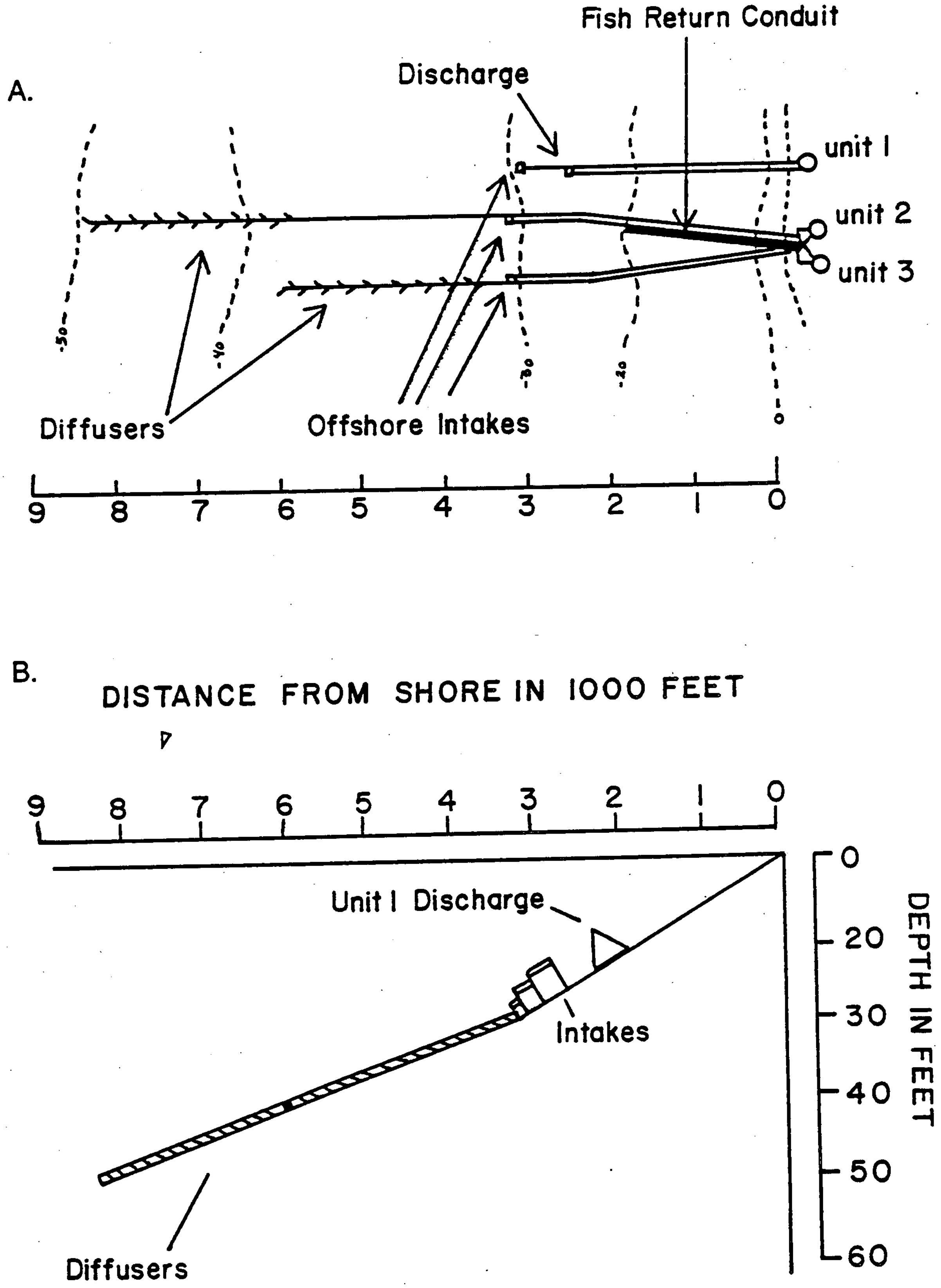


Figure 4.2. Schematic diagram of SONGS Units 1, 2 & 3 intake and discharge systems, by (A) aerial view and (B) offshore-onshore view on the cross-shelf plane.

In order to limit the local rise in water temperature around SONGS, the diffusers were designed to mix large volumes of ambient seawater with the heated discharge jets. The jets draw in and carry along ("entrain") about ten times the discharge flow. This entire body of water is initially pushed towards the surface and offshore. Its further direction is determined by the speed and direction of the prevailing ocean currents. Water along the diffuser lines that is entrained by the discharge plume is moved, on average, about 2000-3000 feet further offshore [ITR 1: 3]. Thus the bulk of this water is usually not pushed offshore of the diffusers (in contrast to expectations based on a "tank" model of the discharge made by the designers of the diffusers and noted in the predictions made by the MRC in 1980). Chapter 6 discusses the behavior of the discharge plume in some detail.

Fish and other large objects are prevented from entering the plant by screens set across the incoming water as it enters the cooling system. In Unit 1, material collected on the screens is trucked away for disposal on land. Units 2 and 3 are equipped with louvres in front of the screens, designed to guide incoming fish away from the screens and towards a holding bay. Fish that are so diverted are returned to the ocean via the Fish Return System (FRS), a 4-foot diameter conduit that extends 1900 feet from the plant back into the ocean [ITR 1: 3].

Figure 4.3 summarizes the operational history of Units 2 & 3 through early 1989. Unit 1 had a variable level of operation during this period. By October 1983 Units 2 and 3 combined reached the level of pumping that was characteristic of the operational sampling period (78%). From the end of operational sampling (December 31, 1986) until April 30, 1989, the average pumping level has been 85%,

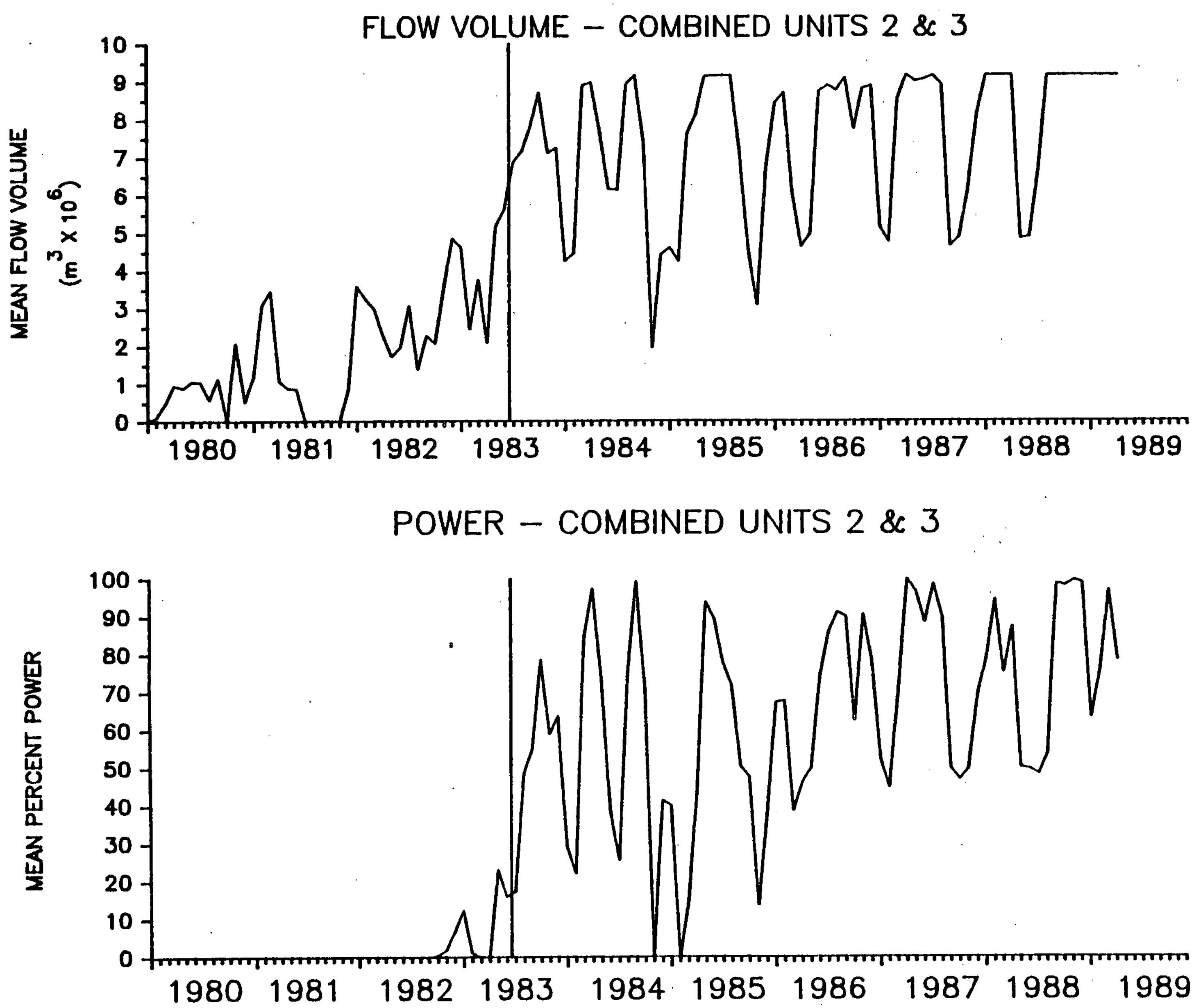


Figure 4.3. Operational history of Units 2 and 3 combined. Vertical line indicates beginning of operational period (mid-1983).

an increase of 7%. Over the operational sampling period power production averaged 56%. Between the end of sampling and April 30, 1989, power production was 75%, an increase of 19%.

Each of the new units has four pumps. When the plant is not producing power it is still typically pumping water, which may not become heated. However, the MRC takes the pumping level as the main criterion of level of operation since it believes that unheated water is as likely to affect the marine environment as is heated water.

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Chapter 5

APPROACH AND DESIGN OF THE MRC STUDIES

The Permit makes clear that the MRC's main task was the detection of SONGS' effects on the marine biota, and this directive determined the MRC's approach. Thus the Committee defined an effect of SONGS as a change in the abundance of marine organisms that could be attributed to the action of the Plant, and designed its studies to detect such changes and to distinguish them from natural variation in abundance. The MRC also designed some studies to elucidate the mechanism(s) by which SONGS caused observed effects and to evaluate some potential effects of toxic materials. The main goal, however, was to find effects. It has always been recognized that establishing mechanisms might prove impossible, and that determining that the Plant caused a given effect did not require establishing mechanisms.

Components of the biota studied

As directed by the Permit, a wide range of organisms was studied. The list is laid out in the contents to this report. It includes representatives from all the major habitats near SONGS. Zooplankton (including the larvae of animals that live on the bottom as adults) and fish larvae were studied because the Permit singled them out as a subject of concern. Fish in three different habitats were studied because they are a resource of special interest. The same is true of giant kelp and, in addition, the Permit raised the possibility that giant kelp might be affected. Many species of invertebrates in the San Onofre kelp bed were studied because they represented a major group living on hard substrate that might be affected together with giant kelp. The small invertebrates living in and on the extensive sandy bottom near SONGS represented another large component of the biota, and yet another habitat. A set of mysid species that live close to the bottom during part of the day, and join the plankton for the rest of the time, were chosen to represent a group of organisms sharing this behavior.

The MRC did not, however, study the entire biota, an endeavor that would have cost an unimaginable sum. Some groups, seabirds for example, were ignored because it was not reasonable to expect effects. Some organisms (or groups of organisms), such as starfish living on the sandy bottom habitat, are so rare and/or variable in their distribution that the cost of obtaining reliable estimates of SONGS' effect would be very high. Similarly, organisms in the canopy of the kelp bed were found to be too variable to yield reliable estimates of abundance. (On the other hand, midwater fish are also highly variable but are of special interest and warranted unusual efforts.)

Since SONGS' effects were expected to be quite unlike those associated with facilities such as sewage treatment plants, the MRC also did not direct major efforts towards sampling for "indicator" species, for example those that colonize heavily polluted areas (though such species would have been detected by a number of the programs, such as the soft benthos program, had they appeared in abundance). Very small organisms that might be important in such situations - bacteria and protozoa for example - were thus not sampled.

A few studies were done that are not reported in this volume. Interested readers can find them in the parenthetical references to follow. Organisms that settle on and "foul" kelp blades were studied because they were expected to increase after SONGS began operating. No effects were found on these organisms (Dixon, Schroeter and Dean, 1987, MRC Doc. D-087). A group of small encrusting organisms that settle and grow on boulders in local kelp beds were the subject of a study in the period before plant operation. This study did not provide an adequate data base in the period before the plant began operating and was therefore discontinued (Osman *et al.* 1981; MRC Doc. D80-458). These organisms were studied again, however, for a short time after the plant began operating, and this study is referred to in the report dealing with the "anomalous sediments" in San Onofre kelp bed (*Technical Report B*).

Sampling and analytical design

In 1977, when the MRC monitoring program was being developed, existing programs at other nuclear power plants had not produced "quantitative information necessary to detect and assess the environmental effects of power plant operation" (McKenzie *et al.* 1977, "Design and analysis of aquatic monitoring programs at nuclear power plants," a review of monitoring programs done by Batelle Corp. on behalf of the Nuclear Regulatory Commission). The approach to detecting effects used almost throughout the MRC studies was developed in response to weaknesses in these existing programs. We give a brief account of the approach here as a necessary prerequisite for understanding the results. Readers seeking more detail should refer to *Interim Technical Report 2.*

Samples were taken close to SONGS where potential effects were likely to occur (*Impact* station) and far from SONGS where they were not (*Control* station) both *Before* and *After* Units 2 and 3 began operation. In each time period (Before or After), samples were taken at both stations, as close to simultaneously as possible. Such paired samples were taken on many occasions spread over the time available. For example, net samples of fish were taken at Control and Impact stations, on the same night, on 62 occasions spread evenly between 1980 and 1982 before the new units began operating, and on 30 occasions over three years after operation began. The samples are thus *paired* in time at the two stations. The design is abbreviated to BACIP (Before-After/Control-Impact Paired).

The BACIP design was developed in response to two major problems of sampling design. First, the abundance of organisms varies naturally through time, so any change observed near SONGS between the preoperational and operational periods in, for example, fish abundance might be unrelated to the Plant. Indeed, large natural changes in abundance did occur in the region during the study period because of an intense El Nino episode. Changes in the rank abundances of species between before and after were noted at both Impact and Control sites.

Second, there are always differences in the abundance of organisms between any two areas of the ocean, so simply observing a difference between an Impact and a Control station in the After period does not mean SONGS was the cause. We could also miss a SONGS effect by such a comparison if SONGS reduced a previously higher abundance at Impact, to a lower level similar to the abundance at Control.

The BACIP design overcomes these difficulties. In the BACIP design, the information of interest on each sampling occasion is the *difference* in abundance between the Control and Impact samples. From the sequence of such differences over time, we obtain an estimate of the *average difference* in abundance between the two stations before the new units began operation. Our question then is: *Did the average difference in abundance between the stations change after the plant began operating?*

With this design, SONGS-induced changes are not obscured by natural differences between Control and Impact, or by natural changes that occur at both Control and Impact through time. Nor are such natural differences mistakenly attributed to SONGS. The design has the additional benefit that seasonal changes in abundance can usually be accounted for, because they tend to be similar at the two sites and so disappear when we take differences.

The key assumption in the BACIP design is that there is no natural change in the difference between the stations that happens to coincide with the onset of Plant operation. Such changes are of course possible; their occurrence could lead us to falsely implicate SONGS or to mistakenly exonerate it. It seems, however, that changes in natural processes that cause different effects at Control and Impact that persist for several years, and that coincide with the onset of SONGS operation, are unlikely and, if they occur, are likely to be noticeable.

An important natural change did occur during the study, and it served to emphasize the utility of the BACIP approach. The El Nino years 1982-1984 were a time of persistent massive "downwelling" that resulted in increased water temperature and severe depletion of nutrients in the nearshore zone. The effects were so drastic that El Nino could have affected the results of MRC's BACIP tests if it had different effects at the impact and control stations. However, records of bottom temperature, which were not significantly affected by SONGS, show that the physical effects of El Nino were substantially uniform in the region studied by MRC: El Nino raised the mean bottom temperature at 14 m depth by 3.1°F in the San Onofre kelp bed, and by 3.2°F in the San Mateo kelp bed 5 km upcoast [TR L: 2.1.1]. The results discussed in Chapters 8, 9 and 11-15 show that changes in the biota also changed in response to El Nino, but similarly at Control and Impact sites. Separating such changes from those induced by SONGS would not have been possible without the BACIP design.

Selection of Sampling Sites

The selection of impact and control sites needed to be based on knowledge of the local environment and expectations about the likely effect of SONGS, both of which were provided by MRC's early studies (Chapter 3). There was no way to ensure, of course, that a station was at the precise spot where the impact would be maximum, but placing most sites within a few kilometers downcoast of the plant maximized the chances of detecting ecologically important effects (for details on each program see the appropriate chapter). Within this area the choice of site reflected the mechanism by which the plant was expected to have its effect. For example, soft benthos samples were taken both at the intake depth and in deeper water where we expected the plume to be more prevalent. For the biota in the kelp bed, of course, the choice of Impact site was obvious.

The main purpose in siting the impact stations was to detect effects. Measuring the extent of effects, which would have required a grid of stations, is a much larger problem, especially since the MRC did not know what effects, if any, would occur or how far they would extend. Sampling a grid large enough to fully delineate effects would have been enormously expensive, and would not have been justifiable where there was doubt that effects would occur.

A particularly useful component of a grid of sampling stations is sites spaced at intervals downstream from the plant; such sites can be expected to lie along a "gradient" of potential effects. A number of the studies incorporated one or more intermediate sampling locations in their designs (the midwater fish, kelp bed fish, giant kelp, kelp bed invertebrates, soft bottom benthos and physical/chemical programs all had such stations), and an example is given in Figure 5.1. It needs to be remembered, however, that for a given level of effort, sampling at a single Impact site and a single Control site is a more powerful means of detecting an effect. In summary, the MRC program detects effects, measures the size of the effect at the particular impact station(s), but gives more or less incomplete information about the spatial extent of effects.

The control site need not be, indeed cannot be, exactly like the impact site; different areas in the ocean are bound to be different. The key requirement is, rather, that the abundance of the species in question at the impact station, in the absence of SONGS, should "track" that at control; i.e., it should change in a similar manner. Control sites were therefore chosen to be similar to the impact area, and not so far away that they are influenced by very different environmental factors. Second, the control site needs to be far enough from SONGS that it is influenced by the plant only a small amount at most. In principle, there is nowhere in the ocean that is uninfluenced by SONGS' discharge to some degree. In practice, at around

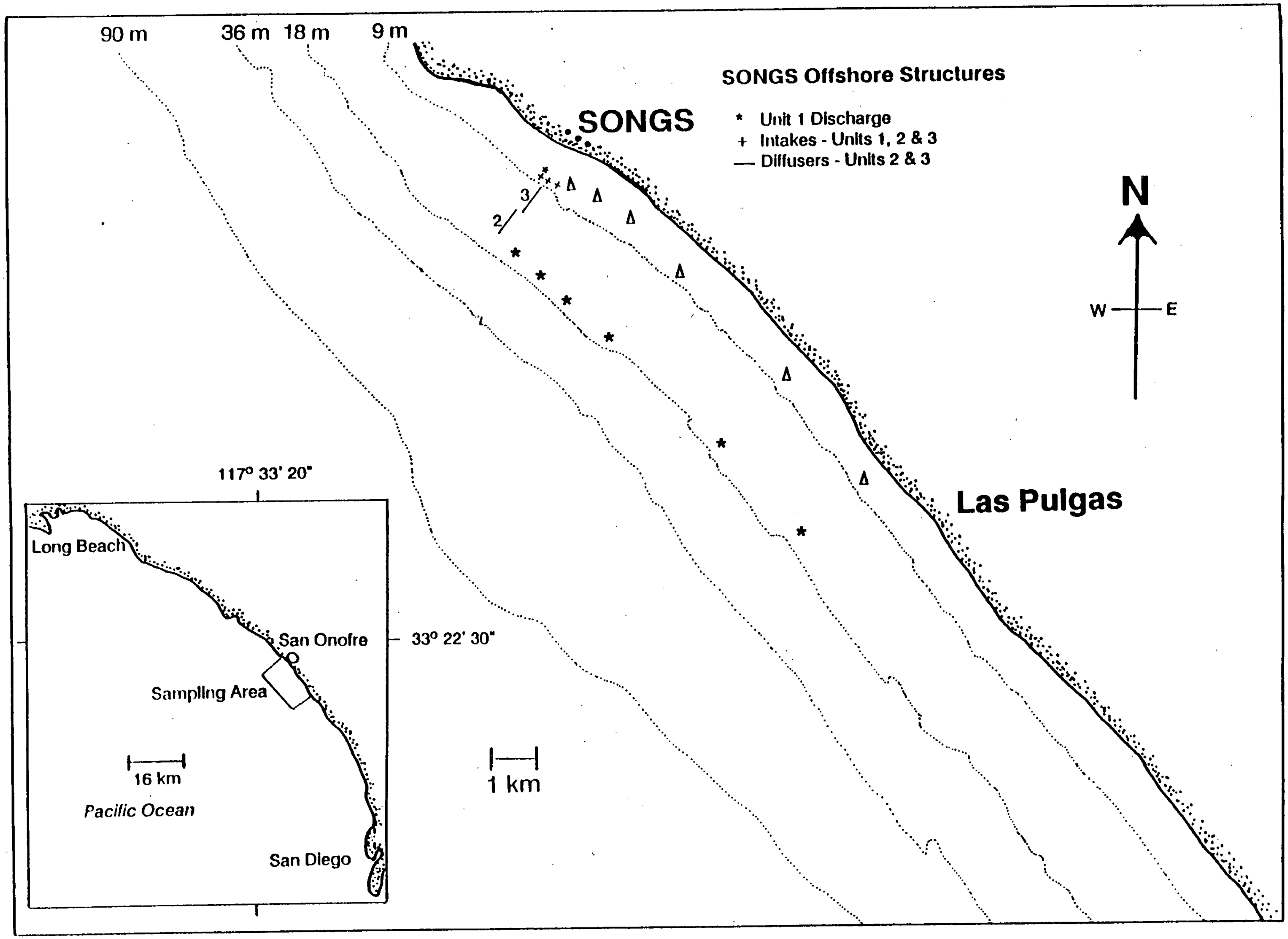

Figure 5.1. Locations of benthic sampling stations. Δ indicates a depth of 8 m. * indicates a depth of 18 m.

10 km downcoast of the plant the plume has been diluted to a concentration of less than 1%. Selection of a control site thus represents a balance between minimizing the effect of SONGS and staying in the same general area as the impact site.

Other Approaches

A variety of other approaches was used, mainly to measure SONGS-induced mortality directly and to determine the mechanisms by which the plant affects the biota. The rate of loss of plankton (Chapter 12), larval and adult fish (Chapter 10, 11, 13), and mysids (Chapter 15) in the intake waters was estimated. An oceanography program measured the direction and speed of currents in the area to provide information on SONGS effects on local water movements (Chapter 6). This program also measured various other factors, such as temperature, light level and the flux of seston near the ocean floor, to determine how they are affected by SONGS' discharge plume and, hence, how the plume might affect the biota. Physical and chemical characteristics of soft sediments were measured (Chapter 14).

The MRC has sometimes been able to carry out experiments to help determine effects and their causes. For example, kelp plants were transplanted into the discharge plume of Unit 1, before Units 2 and 3 were built, to help predict the effect of the new units on the San Onofre kelp bed (Chapter 7).

Finally, concerning toxics, in response to suggestions that sand crabs in the area might be suffering from exposure to metals or radionuclides produced by SONGS, several studies were done to investigate the levels of these pollutants in the local environment and in sand crabs and mussels, to investigate whether the concentrations of such pollutants could explain apparent anomalies in the sand crabs, and to determine whether SONGS was a likely source of these pollutants (Chapters 16 & 17). In addition, the results of water quality sampling at SONGS were analyzed.

Evaluating the Results

Conclusions about SONGS' effects in this report typically are stated in the following ways: "the relative abundance of species X decreased at SONGS;" or "there was a decrease in the abundance of species X at SONGS, compared with the Control station." The basis for such statements is the BACIP approach outlined above in "Sampling and Analytical Design."

Although statistical considerations were central to the design of the studies and are crucial to their analysis and interpretation, this summary report is not the place for such technical detail. It is, however, important to understand the meaning of (1) "statistically significant, " and (2) "an X% reduction in relative abundance."

A result that is "statistically significant" is one that we are willing to accept as real, as distinct from being a mere chance event. Given the apparent difference in relative abundance shown by our samples, the test asks whether a sampling program like ours would show such a difference by chance, if there were no SONGS effect. Statistical rules allow us to calculate the probability of such chance events occurring. A standard convention is to report as significant only those differences that would occur no more than 1 in 20 times by chance. If one wished to be more sure of catching SONGS' effects, one might wish to make the level 1 in 10. (The trade-off is that we are then more likely to attribute to SONGS an "effect" that in fact is a purely chance occurrence.) Indeed, there is no "correct" level of significance. We have followed the convention of stating as "significant" those results that a particular test shows should occur by chance in, at most, 1 time out of 20, and as "almost significant" those that should occur by chance in, at most, 1 time out of 10.

The report expresses the size of an effect as, for example, "a 50% reduction in relative abundance at SONGS." This means that the abundance at SONGS in the After period is about one-half what it would have been if, since the Before period, the population there had changed in the same way as the population at the Control station. The reader should not take the calculated value of the change (e.g., 50%) as being precise. The data are treated statistically ("transformed") before a test is run, to ensure that they pass certain statistical assumptions. The absolute size of the difference detected can vary somewhat with different transformations, several such transformations may be appropriate, and we report only one of them, usually the most significant. A reported relative decrease of, say, 50%, does mean, however, that there was a substantial relative decline in abundance of about one-half. The estimated size of relative increases can be particularly variable when they are large, and for this reason increases greater than 100% are described simply as greater than 100%.

For many species that occurred fairly frequently in samples, we are not able to apply statistical tests for one reason or another, or a test was applied but the observed change was not statistically significant. For these species we have asked whether there was a change in relative abundance at SONGS - and designated the result as a "tendency" to increase or decrease. Notice that it is extremely unlikely that the difference between Impact and Control in the After period would be precisely the same as that in the Before period; i.e., there is bound to be a change, however small. If the plant has no general effect, we would expect increases and decreases to be about equally common among such changes and, if this were the case, we would conclude that none of the changes was related to the plant. A general tendency for decreases, however, would alert us to widespread plant effects that we were failing to pick up by our other statistical analyses. (For a few species, the actual direction of change depends upon the statistical transformation used, and these species are ignored.)

Finally, a relative reduction in abundance near SONGS can occur in several ways, and does not always indicate that the absolute abundance near SONGS was actually lower than before the plant began operating. Abundance at Control can increase, decrease or stay the same from Before to After. A reduction in relative abundance at SONGS can then result from abundance there increasing less than at Control, or decreasing when Control did not, or decreasing more than at Control.

Three main factors influence our ability to detect a change in abundance. The first is how big the change was. But "big" only has meaning relative to how variable the differences between Control and Impact were within the Before and After periods: the more variable the differences, the larger the change must be to be detected. Thus, the second factor is variability. The third is how many times the species was sampled: we will more easily detect a given amount of change, at a given level of variation, if the species has been sampled more times. Three important points follow.

(1) Firm conclusions about whether or not there has been an effect have been reached mainly for the most abundant and the most frequently-occurring species. (2) Thus, although we have not been able to draw individual conclusions for the many rare and infrequent species, our conclusions do embrace the majority of the individuals. If we sampled for an indefinite period of time, and took an unlimited number of samples, we would eventually be able to draw firm conclusions for virtually every species. (3) However, once many samples have been taken, there is a rapidly diminishing return on further sampling. For example, in order to halve the size of the SONGS effects we can detect, we would need to quadruple the number of samples; eventually, even huge increases in sampling yield only small decreases in the minimum effect we could detect.

The next section (Section II) presents the results program by program.

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SECTION III.

DETAILED RESULTS

Chapter 6

EFFECTS OF SONGS UNITS 2 AND 3 ON THE PHYSICAL ENVIRONMENT*

Summary

The main effects of SONGS on the physical environment are as follows. (1) The average offshore displacement of plume water is estimated to be 2000 to 3000 feet beyond the end of the diffusers. (2) Water discharged from SONGS is quickly diluted. Dye studies at Unit 3 showed relative dye concentrations of 13% at 150 feet downcurrent from the diffuser, 10% at 1200 feet, and 4% at 3300 feet. Over the long term the plume concentration is estimated to fall to about 1.5% at a point on the shoreline 2 km downcoast, and to about 0.5% at 7 km upcoast or 11 km downcoast from SONGS. (3) The average light intensity in the San Onofre kelp bed (SOK) was reduced by about 25% on days when the current was downcoast. Overall, the reduction of light in SOK was 6% to 16%. (4) There was an increase of 48% in the accumulation rate of seston (suspended particles) that fall into open-tube traps near the bottom in SOK at 400 meters compared to 1400 meters from the diffusers.

Introduction

The biological results presented in other chapters are mostly self-standing statistical results that do not provide or depend on any physical explanations of how

* Drs. John Reitzel, Rusty Erdman and Hany Elwany, and Mr. Karel Zabloudil (Eco-Systems Management, Inc.) carried out the scientific studies of the physical environment on which this chapter is based. Drs. John Reitzel and Hany Elwany prepared the Contractor's Final Report. The Technical Report (L) to the CCC was prepared by Dr. John Reitzel.

the biological changes were brought about. The information reported here on the effects of SONGS on the physical environment is useful in providing explanations or showing the reasonableness of biological results, or conversely in drawing attention to results that are not well explained by the physical effects of SONGS.

As described in Chapter 4, SONGS Units 2 and 3 together take in about 100 cubic meters per second of seawater, heat this water by 19°F in the power plant, and discharge it through diffusers with lines of jets pointing offshore, which entrain about ten times as much ambient water and carry it offshore in the discharge plume. The high ratio of entrainment to discharge produces a high dilution of the water heated in SONGS to meet the California thermal standard, which limits temperature rise in the sea to 4°F beyond 1000 feet (305 m) from the discharge. The price of this high dilution is the large seaward flow of about 1000 cubic meters per second (23 billion gallons or 70,000 acre-feet per day) of discharged and entrained water at a speed on the order of 10 centimeters per second (about 5 miles per day). This flow carries entrained particles some distance offshore, altering their natural distribution in the waters around SONGS.

The potential environmental impacts of SONGS are of two main kinds: (1) mortality of organisms that are drawn into the intakes of SONGS, and (2) changes in underwater light, turbidity, sedimentation, and nutrients due to SONGS' alteration of natural flow patterns.

To give the background for discussing these physical effects, we begin with a more detailed description of the SONGS cooling system and its effects on water flow off San Onofre.

Water flows induced by SONGS

The operation of SONGS alters the pattern of water movement near the plant by taking in a large volume of water and discharging it through diffusers. The layout of the intakes and diffusers of SONGS, relative to the shore and the cobble beds that provide kelp habitat, is shown in Figure 6.1. Each of SONGS Units 2 and 3 draws in 52 cubic meters per second at an intake about 950 m from shore in water about 10 m deep. This water enters the intake at an average speed of 53 centimeters per second; at a distance of 30 m from the intake, in the absence of current, the speed of water toward the intake has fallen off to about 3 centimeters per second and is approximately the same at all depths in the water column [TR L: 3.0]. Each diffuser carries 63 jets with ports 0.5 m in diameter 2.2 m above the bottom, directed offshore with a tilt of 20° upward, and alternately 25° upcoast and 25° downcoast. Each jet discharges 0.8 cubic meters of water per second at an initial velocity of 4 meters per second.

The idealized plume trajectories in Figure 6.2 show how the plume moves directly offshore in very weak currents, but is increasingly turned downcurrent with increasing speed of the natural longshore current [TR L: 3.0]. These drawings are taken from dye-photographs and temperature maps for steady longshore flows in a laboratory tank model, and represent idealized plumes when the water is not stratified. Actual plumes may be distorted by fluctuations and eddies in the current, and are often partly diverted around kelp beds by the frictional drag of kelp inside the beds, but the model plumes still give a good overall representation of actual plumes observed in the field.

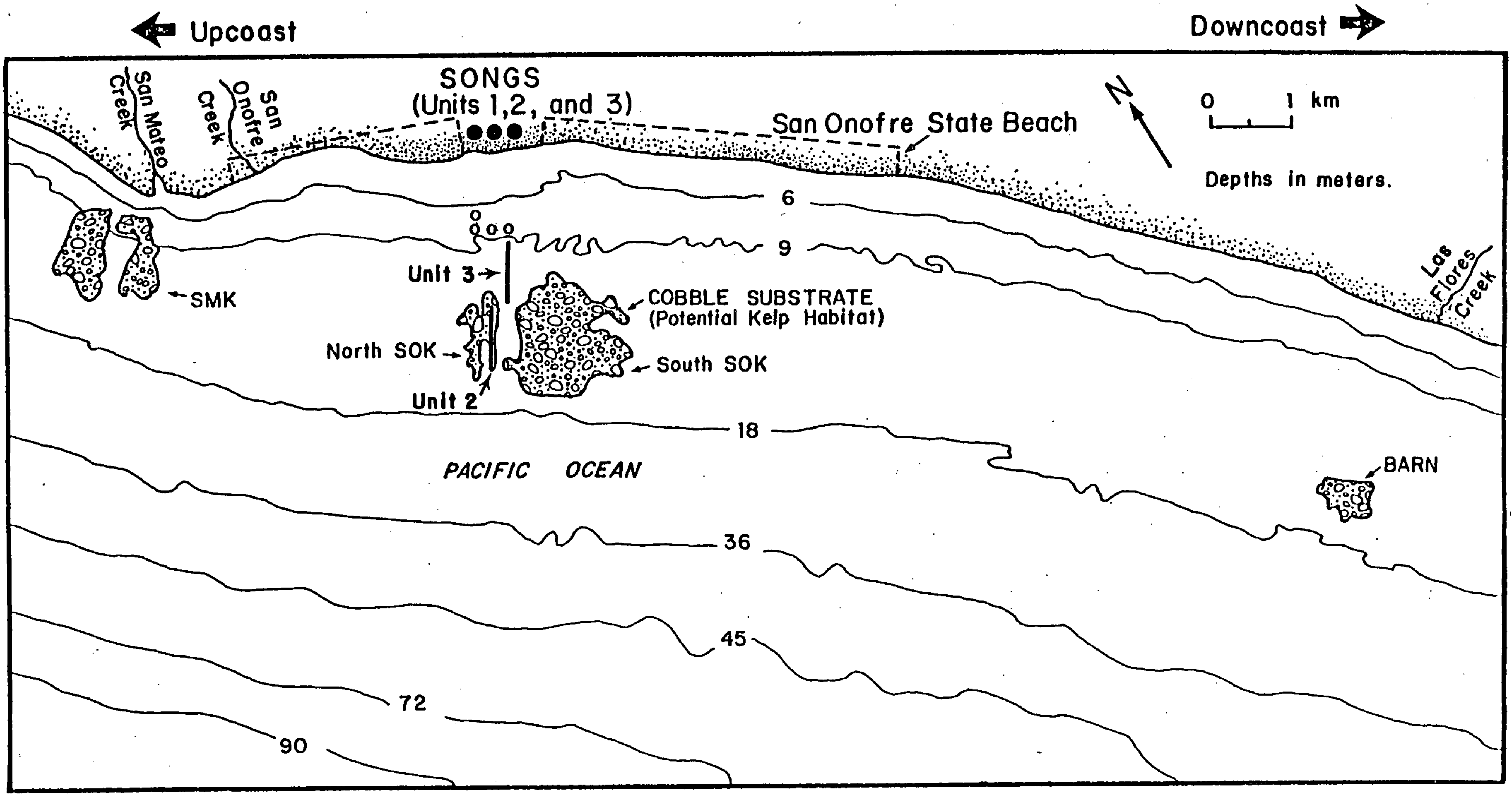


Figure 6.1. Layout of SONGS intakes and diffusers relative to the shore and the cobble beds that provide kelp habitat.

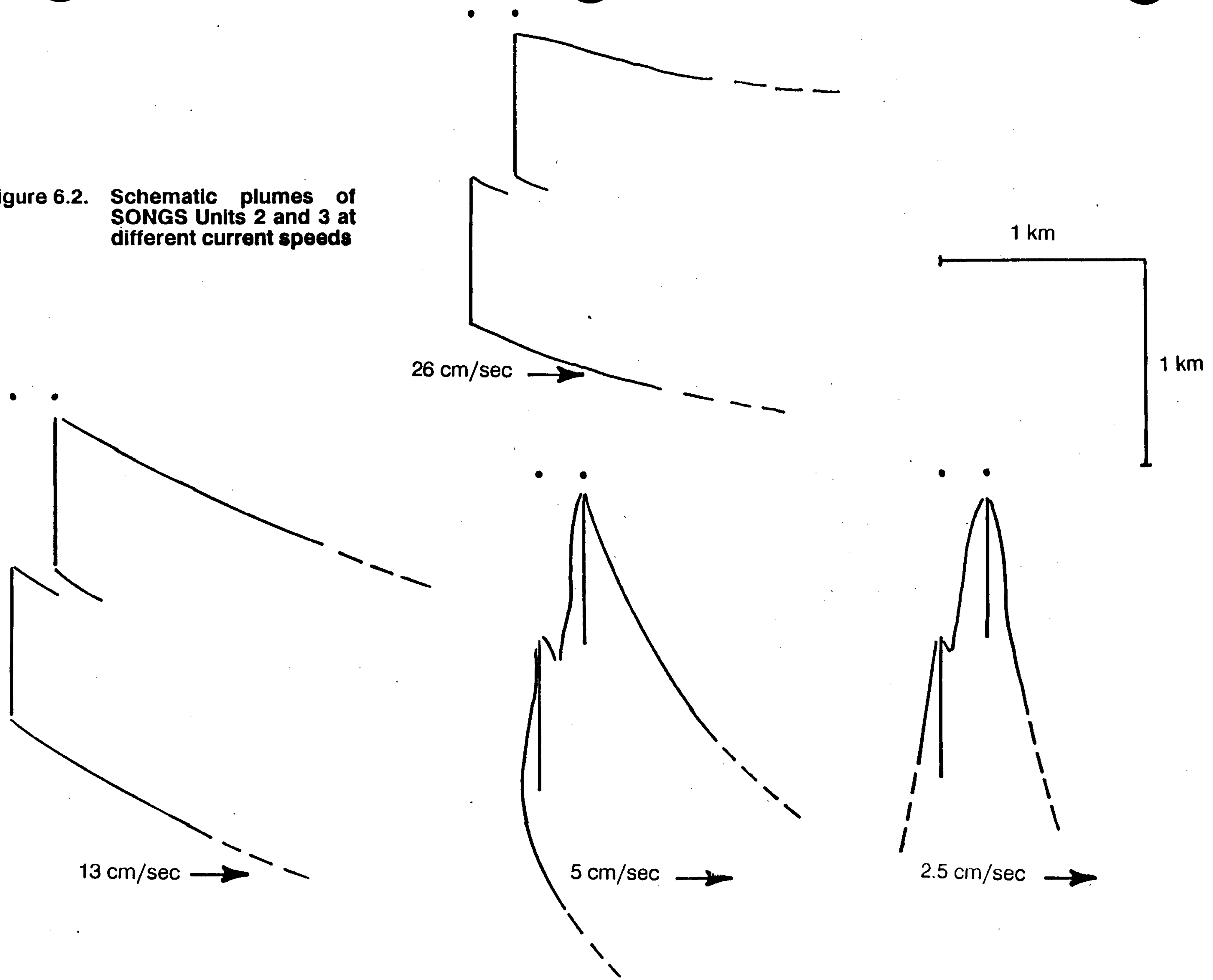


Figure 6.2. **Schematic plumes of SONGS Units 2 and 3 at different current speeds**

The motion in an actual plume crossing San Onofre kelp bed is illustrated by Figure 6.3, which shows the trajectories of a number of dye-patches released in the plume over a time when the longshore current outside the plume varied in the range 8 to 12 centimeters per second downcoast; the dots on the trajectories are at half-hour intervals. Patches #9 and #15 in particular show how the kelp diverted the flow around the upcoast end of the bed.

The idealized plume trajectory of Figure 6.2, for a current of 13 centimeters per second, moves somewhat more than 700 m offshore before the plume loses its identity by mixing into the sea. The dye-patches #14 and #15 in Figure 6.3, launched near the inshore diffuser, also moved about 700 m offshore (one through and one around the kelp bed), as did water at the plume front directly offshore from the outer diffuser. Plume water will move farther offshore in slower currents, and since the actual current is less than 13 centimeters per second for 80% of the time [TR L: 3.2.3], we can take 700 m (about 2000 feet) or so as a rough lower estimate for the average offshore displacement of plume water. A reasonable overall estimate of the average offshore displacement of plume water is 2000 to 3000 feet.

In isolated laboratory jets, the discharge velocity is diluted in about the same way as other properties of the discharged water. The real SONGS jets, however, are decelerated because they push up a hill of water on the surface and lose momentum by climbing this hill. Both in the tank and in the field, the maximum offshore velocities observed in the plume are 20 centimeters per second or less, rather than the 40 centimeters per second or so that would be expected from a tenfold dilution of the original velocity of 4 meters per second [TR L: 3.2.1].

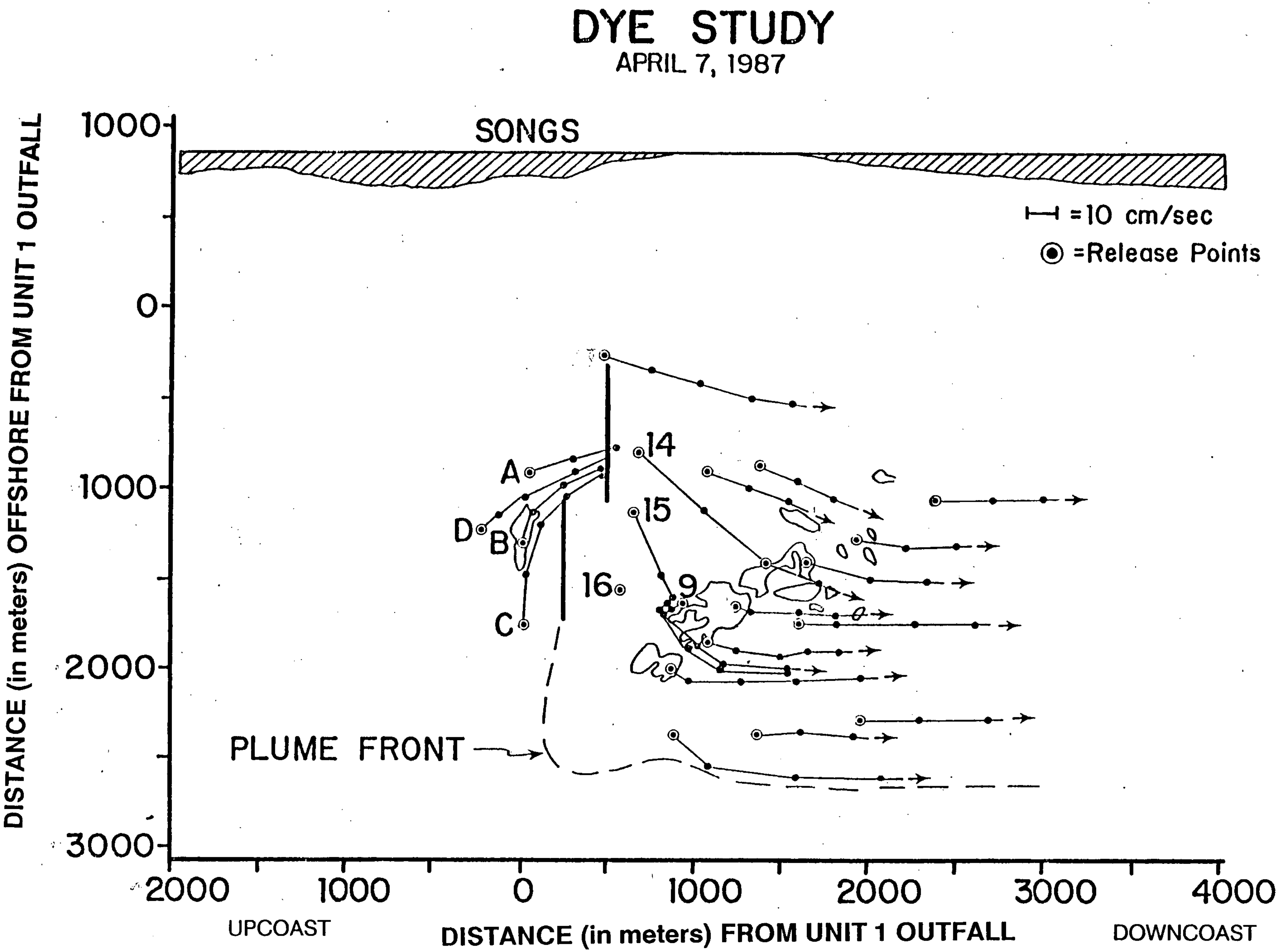


Figure 6.3. Dye Study.

This momentum loss, and further losses or gains due to buoyancy spreading, prevent any precise estimation of how much water SONGS drives beyond any given distance from the outer end of the diffusers, but we do have some useful evidence on this question. Figure 6.4 shows the joint distributions of hourly longshore and on-offshore currents (that is, "current roses") at stations around SONGS for all of 1985. Station 20, 500 m beyond the diffusers, shows a distinct lobe of offshore velocities up to 20 centimeters per second that recur at times when the longshore current reverses and the plume swings past the station (i.e., it is moving straight offshore). In contrast, Station 02, 1.7 km beyond the diffusers, shows no sign of offshore velocity due to the plume.

The seaward flow of about 1000 cubic meters per second that is carried away from SONGS in the plume has to be replaced by an equal make-up flow toward SONGS, or else the neighborhood of SONGS would soon run dry. It can be calculated that this water will flow towards the diffusers from all directions and all depths in the water column [TR L: 3.2.3]. The make-up flow will bring water from offshore to the neighborhood of SONGS, which can potentially alter the character of nearshore water off San Onofre, relative to nearshore water at other places on the coast, as discussed below.

The dye-patches A to D in Figure 6.3 clearly show the shoreward component of the make-up flow near the diffusers on the upcurrent side; patch #16, which did not move for four hours, locates a point where the inward make-up flow just matched the outward flow in a narrow region between separate plumes from Unit 2 and Unit 3. The stations 01 and 19 in Figure 6.4, on opposite sides of the diffusers, show that the shoreward component of the flow when either station is upcurrent

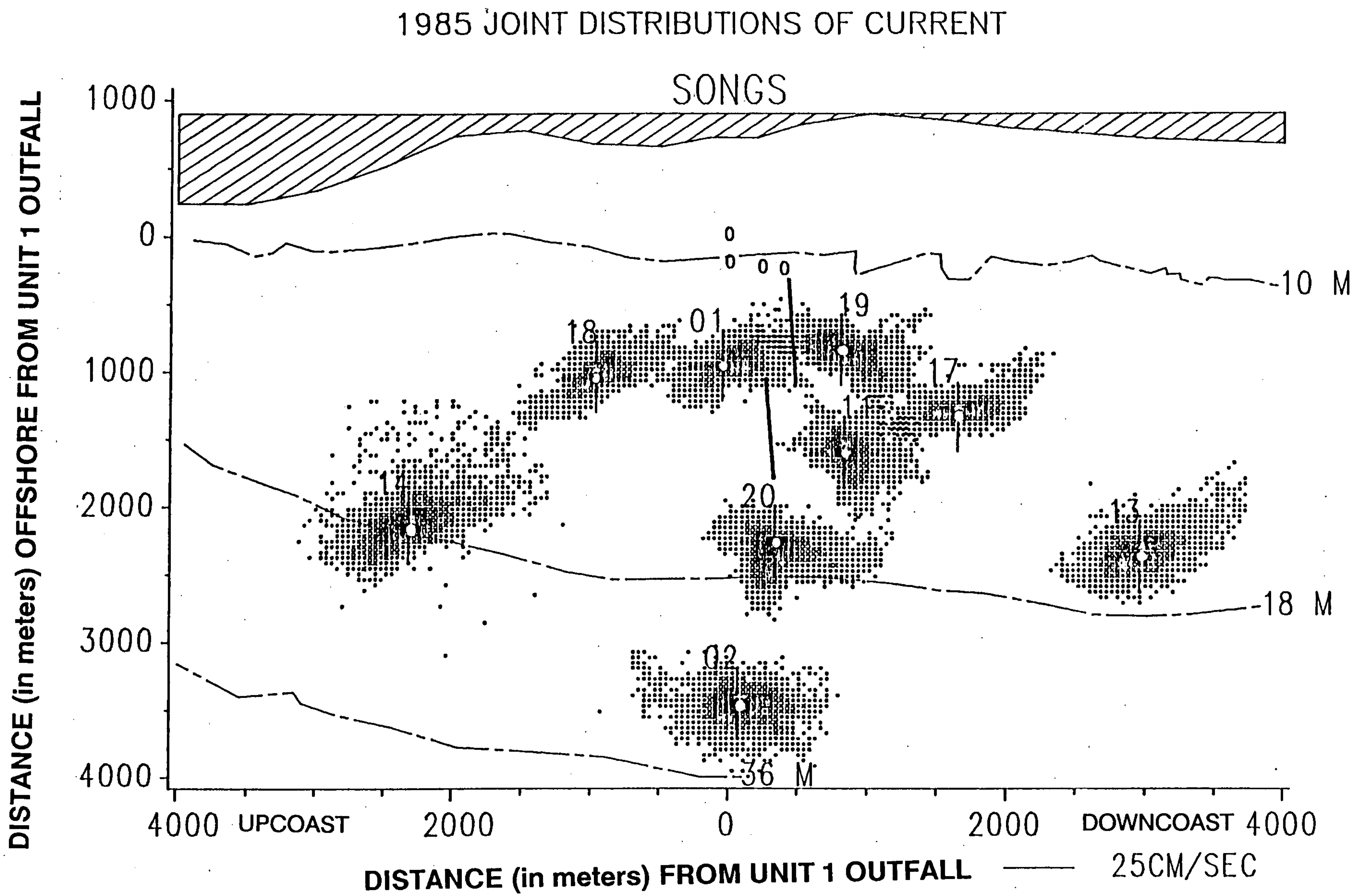


Figure 6.4. 1985 joint distribution of current.

from the diffusers is a persisting long-term effect and not simply a happenstance on the day of the dye-study.

Dilution of the plume with distance from SONGS

The concentration of plume water at various distances downstream from SONGS is relevant to a number of issues. For example, it affects the extent to which mortality of plankton and other organisms in the intake water is reflected in the density of local populations.

Dilution was studied (1) in a laboratory tank with model diffusers, (2) by measuring the dilution of dye at various distances, and (3) by calculations based on measurements of water movement by current meters. In the laboratory, a jet will entrain and mix about 10 times the discharge flow in the first 20 port diameters along its axis (i.e., within 10 m if the port opening is 0.5 meters), 20 times in the first 40 diameters, and so on. Entrainment by the SONGS jets is limited because the discharged water rises to the surface and mixes with water from other jets to form a plume, but the jets still accomplish high dilutions. A study with dye injected into the intake of Unit 3 showed relative dye concentrations of 13% at 50 meters downcurrent from the diffuser, 10% at 400 meters, 6% at 650 meters, and 4% at 1100 meters, with an ambient longshore current of about 7 centimeters per second [TR L: 3.1]; this field observation agrees well with a hydraulic tank model of the SONGS system at about the same current speed.

The tank model confirms the theoretical expectation that dilution will increase with the speed of the natural current across the diffusers. Minimum dilution near the model diffusers is 8- to 10-fold in currents of 5 centimeters per second or less, which occur 45% of the time off San Onofre, 13-fold at a current speed of 13 centimeters per second or less, occurring 80% of the time, and greater than 20-fold in currents exceeding 26 centimeters per second, which occur less than 3% of the time [TR L: 3.1].

Dilution of the plume at longer ranges depends on the capacity of the natural currents and turbulence to disperse parcels of water and suspended particles. This capacity, which is called diffusivity, is an important characteristic of the local environment that does much to determine its response to SONGS. Diffusivity can only be measured accurately by a long series of direct observations of the dispersion of drifting objects or dye-patches, but the long-term average diffusivity can be roughly estimated from the statistics of long current records [TR L: 2.4].

With very high diffusivity, the killing of plankton by SONGS might have no detectable effect on population density because the effect is rapidly diluted; with low diffusivity, it might reduce the density severely over several square miles around the diffusers. Such density changes due to SONGS will fall off with distance in about the same way as the concentration of a tracer, such as dye, discharged from the diffusers. Figure 6.5 is a map of the average long-term long-range relative concentration of a tracer released by SONGS, from approximate calculations using long-term current statistics from San Onofre [TR L: 3.2.4]. (Dilution is the reciprocal of concentration.) This map indicates that long-term average depletions of plankton and concentration of effluents will fall off to about 1.5% of their original values at a point on the shoreline about 2 km downcoast from the diffusers, and to about 0.5% of the original values at 9 km distance upcoast or downcoast from

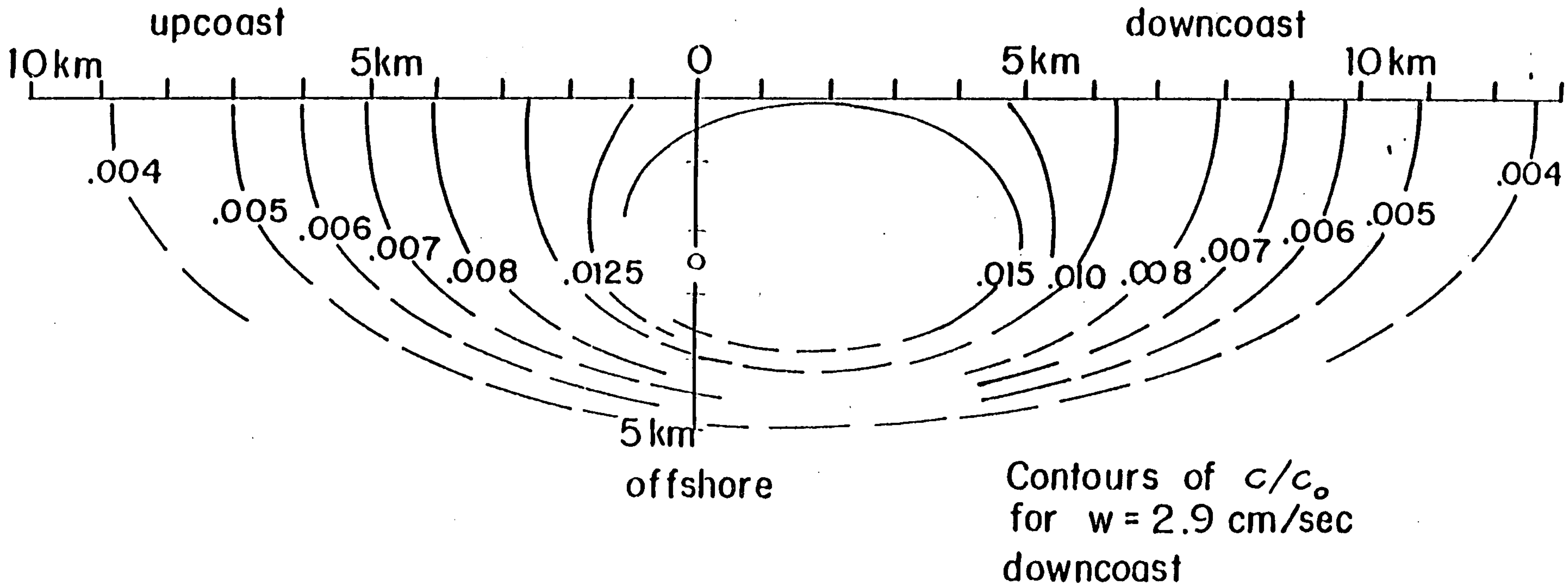


Figure 6.5. Contours of relative concentration c/c_0 for mean current 2.9 cm/sec downcoast.

this point. The pattern is shifted downcoast by the long-term average current of 3 centimeters per second downcoast.

Underwater light intensity

Light intensity or irradiance in the sea falls off by a fraction with each meter of depth. This fraction is called the extinction; the larger the extinction, the smaller the irradiance at any depth. The normal variations of extinction in the nearshore waters off San Onofre make the irradiance at the bottom in 14 m depth vary above and below 1% of the surface irradiance, so the normally available light in the San Onofre kelp bed is somewhat marginal for dependable recruitment and growth of small new kelp plants on the bottom [TR L: 2.2].

We have found by experiment that extinction in the nearshore waters off San Onofre increases in a predictable way with the total concentration of suspended particles in the water [TR L: 2.2]; other than plankton, these particles are fine mineral grains which come immediately from bottom sediments resuspended by waves, and originally from stream runoff and coastal erosion.

The average concentration of suspended particles is less in waters more distant from shore, both because these waters are further from the original source and because waves disturb the bottom less in deeper water. Since the SONGS discharge carries nearshore water seaward and over the San Onofre kelp bed some of the time, it is reasonable to expect that SONGS may increase the average extinction in the kelp beds to some extent. On the other hand, the make-up flow discussed above draws some water to the diffusers from offshore, which may decrease the local average extinction.

The overall net result of these opposite effects has been measured by two kinds of statistical studies of irradiance near the bottom at stations in the San Onofre kelp bed downcoast from the diffusers. The first kind of study was a set of BACIP tests. These estimated SONGS-induced changes by comparing the irradiance levels observed after SONGS began operating to what they would have been had SONGS never operated. The latter levels were estimated using (a) the levels observed at the same time at the control station in the San Mateo kelp bed 5 km upcoast, and (b) the historical differences between the San Mateo levels and those in the San Onofre kelp bed as measured before SONGS began operating. These BACIP studies showed that average light intensity at the bottom was significantly reduced by about 25% on days when the kelp stations were down-current from the diffusers; it may have increased by a somewhat smaller percentage on days when the current was upcoast, but this effect was not significant [TR L: 5.1].

Longshore currents move downcoast 60% of the time, so the average effect of SONGS over all days at stations in SOK (downcoast of the diffusers) was a net reduction of light. The net reduction will be about 6% if the positive effect of the make-up water is real and as large as the negative effect of the plume, and will be 16% if the effect of the make-up water is actually zero [TR L: 1.2.2, 5.2]. Because the upcurrent increase was not significant, we take an overall decrease of 16% to be the best estimate. The effect of light reduction on the kelp upcoast of the diffusers will be different from that downcoast of the diffusers because of the asymmetry of the longshore currents. Upcoast of the diffuser, the plume-induced decrease in light would happen only 40% of the time while any make-up water increase would occur 60% of the time. The average bottom irradiance upcoast would be increased by 6% if the make-up water effect were real and equal to the negative effect of the plume, and it would be decreased by 12% if the make-up water effect were zero. These results show that biological effects due to changes of irradiance or concentration of suspended particles can reasonably be expected to be different on opposite sides of the diffusers.

As noted above, the irradiance changes found by BACIP tests are relative to what irradiance would have been at the kelp stations if SONGS had never operated. We made another set of statistical tests comparing irradiance between stations in the plume of SONGS and counterpart stations in "ambient" water on the other side of the diffusers at the same time. Near-bottom irradiance at the plume stations averaged about 18% less than at the ambient stations at the same time [TR L: 5.1]. This reduction is larger than the overall reductions found by the BACIP tests, probably because the water at the ambient stations was indeed somewhat clarified by admixture of offshore water brought in by the make-up flow.

Suspended particles and sedimentation

The rate at which sediment accumulates in open-tube traps set out in the sea is roughly proportional to the concentration of suspended particles in the water times the settling-rate of the particles. Thus these traps will give a useful relative measure of particle concentrations at different places if the settling-rates of the particles are about the same. A BACIP test of accumulation-rates in traps just above the bottom, which compared stations in the San Onofre kelp bed 400 m and

1400 m downcoast from the diffusers, showed a statistically significant increase of 48% at the nearer station after SONGS began operation during 1983 [TR L: 6.3; TR B: 4.3.3]. This result establishes a physical basis for any biological effects attributable to changes in the flux of suspended particles near the bottom, such as burial, abrasion or dislodgement of small new kelp plants and other organisms.

Additional evidence of an increase in suspended particles due to SONGS comes from measurements of the extinction of light, which is largely caused by suspended particles in the water (TR L: 2.2). We compared extinction between a set of stations in SOK, downcoast from the diffusers, and another set upcoast from the diffusers. On days when the current carried the plume the same way, either upcoast or downcoast, during all the daylight hours, extinction in the bottom 2 m of the water column was significantly greater at stations downcurrent from the diffusers than it was at upcurrent stations at the same time (TR L: 6.3).

The deposition or erosion of bottom sediments at different places depends on the shifting local balance between particles settling to the bottom out of the water and the resuspension and dispersal of particles on the bottom by waves and currents. SONGS may alter this balance and produce localized deposition or erosion. This possibility is the subject of a separate study by MRC, and the evidence bearing on this question is presented in *Final Technical Report B: Anomalous sediments in the San Onofre kelp bed.*

SONGS' plume is likely to increase the rate at which organic material reaches the ocean bottom. Among the particles in SONGS' plume are the remains of plankton and other organisms taken into the intakes. Zooplankton alone contributes 1400 tons (dry weight) (Chapter 12); phytoplankton is typically more abundant than zooplankton, and the total amount might be about 10,000 tons (dry weight) each year. The smaller organic particles can go several kilometers in either direction before settling to the bottom. Calculations in *Technical Report L* show that it is reasonable to infer that organic matter falling from the plume will increase the productivity of organisms living on soft benthos in the areas near SONGS sampled by the MRC [TR L: Appendix E].

Nutrients and Upwelling

Marine plants need nutrients as well as light, and obtain them from chemicals dissolved in the sea. The most important nutrients, exemplified by nitrogen, are often in short supply in waters off San Onofre that are naturally warmer than about 57°F [TR L: 2.1]. Nearshore waters shallower than 45 feet are usually above 57°F, and the supply of nutrients to these waters depends to a large extent on events called upwellings, in which colder and richer water rises from greater depths to replace nearshore surface water that is displaced offshore.

The make-up flow toward the SONGS' diffusers brings some deeper water upward and shoreward, and is a potential source of artificial upwelling that might improve the local nutrient supply. Since nutrient concentrations are closely related to temperature in southern California, we were able to test this possibility with BACIP tests on MRC's records of bottom temperature at stations in the San Onofre and San Mateo kelp beds. The single result that was statistically reliable showed a very small increase of no statistical or physical significance, so there is no evidence that SONGS generally alters local nutrient concentrations [TR L: 6.2]. At times of natural upwelling, however, the upward transport of water by the SONGS jets may somewhat increase the nutrients directly available to the kelp canopy on the surface; since the plume water is artificially heated, this possibility cannot be tested from temperature records, but would need measurement of nutrient concentrations.

The opposite of an upwelling is a downwelling, in which the nearshore zone is filled with a thick wedge of warm nutrient-poor surface water driven onshore. The El Nino years 1982-1984 were a time of persistent massive downwelling, with large increases in water temperature and severe depletion of nutrients in the nearshore zone. The effects on marine life were so drastic that they could have affected the results of MRC's BACIP tests if they were not similar at both impact and control sites. Records of bottom temperature, which were not significantly affected by SONGS, show however that the physical effects of El Nino were substantially uniform in the region studied by MRC [TR L: 2.2]. El Nino raised the mean bottom temperature at 14 m depth by 3.1°F in the San Onofre kelp bed and by 3.2°F in the San Mateo kelp bed (5 km upcoast). The temperature fluctuations at these places and at the Barn kelp bed (10 km downcoast) were all highly correlated, having 83 to 94% of their variations in common. Temperature rise is the most evident physical feature of El Nino conditions, and shows no evidence of non-uniformity great enough to affect BACIP tests.

Temperature

The object of using diffusers to achieve a high degree of dilution was to meet the State thermal standards. SONGS' compliance with thermal standards has been verified by a two-year record of hourly temperature differences between water in the plume and ambient water on the other side of the diffusers [TR L: 6.0].

Chapter 7

EFFECTS OF SONGS ON GIANT KELP IN THE SAN ONOFRE KELP BED*

Summary

The MRC's studies of giant kelp in the San Onofre kelp bed (SOK) and in the San Mateo kelp bed (SMK; the Control area) have included sampling of the natural populations, field experiments, and field and laboratory studies of the influence of physical factors on the survival and development of kelp. Concomitantly, the effects of the SONGS' discharge plume on the physical environment in the SONGS' area were analyzed.

In recent years, there has been a general increase in the abundance of kelp in northern San Diego County. However, the increase was much less at SOK than it would have been in the absence of SONGS. SONGS' operation caused a reduction in the area covered by kelp at moderate to high density in SOK, relative to SMK, of about 60 percent (80 hectares), and resulted in a similar percentage relative reduction in the density of kelp. The effect was greatest in the offshore half of the bed, especially upcoast. These are substantial impacts on a valuable local kelp bed.

SONGS affected kelp by increasing turbidity in SOK. The plant withdraws turbid nearshore water and discharges it over the kelp bed. It also entrains bottom

* Drs. Tom Dean and Larry Deysher (Marine Science Institute, UCSB) headed the team of scientists who carried out most of the studies of kelp on behalf of the MRC. Contributing studies were also done by Drs. John Dixon and Stephen Schroeter (University of Southern California), and by Dr. John Reitzel and Mr. Karel Zabloudil (Eco-M). Drs. T. Dean, S. Schroeter and J. Dixon prepared the Contractors' Final Reports. The Technical Report (K) to the CCC was prepared by Drs. James Bence (UCSB) and Stephen Schroeter, with assistance from Drs. John Dixon and Tom Dean.

water, which is often turbid, and adds it to the plume. The discharge plume then frequently moves this turbid water towards the surface, offshore, and downcoast over the kelp bed. The increased turbidity suppresses development of the microscopic stages of kelp, probably by increasing the flux of suspended particles and by reducing light levels near the ocean floor.

Introduction

Adult giant kelp plants (*Macrocystis pyrifera*) are anchored by holdfasts to hard substrate on the ocean floor and have fronds that reach the ocean's surface. They occur in water up to 100 feet deep in kelp forests or "beds." Other smaller species of algae also grow in kelp beds, but giant kelp provides most of the three-dimensional structure. Kelp itself is a valuable commercial resource, and kelp forests are productive habitats that shelter hundreds of species of plants, fish and invertebrates, including sea urchins, kelp bass, and other species which are harvested by commercial or sports fishermen (Chapters 8 and 9).

At the start of the MRC study there were 3 kelp beds in the area: San Onofre (SOK), San Mateo (SMK), and Barn (BK) (Figure 7.1). SOK is about 2 km offshore and largely south (0.5 to 2 km) of the diffusers and in 1980 covered about 140 hectares (346 acres), of which 80 hectares was dense canopy. SMK is about 4.5 km north of SONGS and BK is 11 km south. Barn kelp went extinct in 1980 (probably as a result of sand invasion following an unusually severe period of coastal erosion and run-off) and reappeared by early 1987. SOK and SMK are unusual in San Diego County in that their substrates consist largely of boulders, cobbles, and

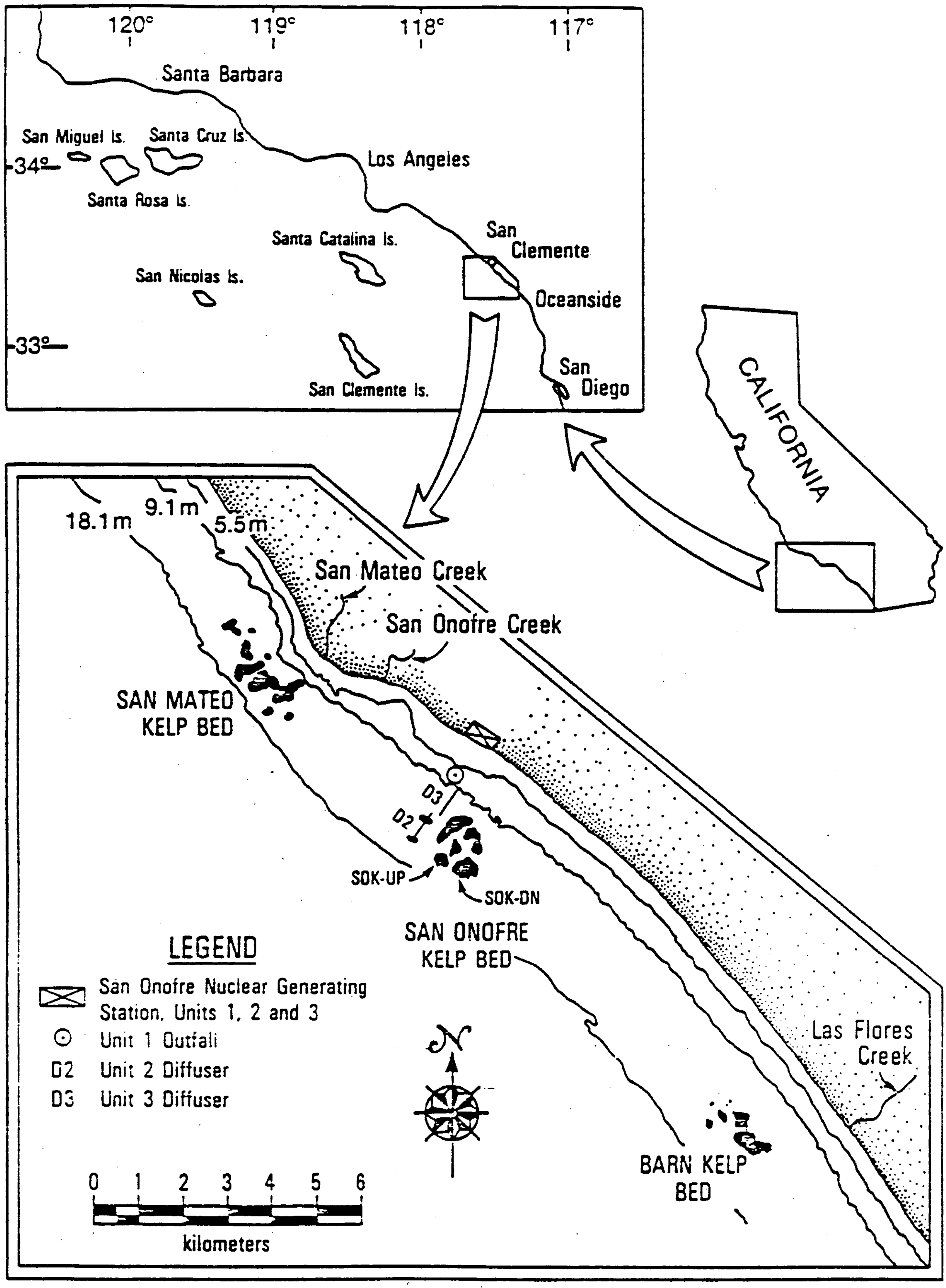


Figure 7.1. **Map of San Onofre area.**

coarse sand, with SOK substrate having a rather lower profile (less relief) than SMK.

Kelp Life History, and Expected Effects of SONGS on Kelp in SOK

The details of kelp's complicated life history (Figure 7.2) bear on the expected effects of the operation of SONGS. **Adults,** whose fronds can be seen floating on the ocean surface, produce millions of microscopic **spores** that usually do not travel far before landing on the ocean floor (although during storms they may be transported up to several kilometers). Here they turn into sessile microscopic **sexual stages:** male or female individuals attached to the bottom that reproduce sexually to produce a microscopic asexual plant (called a microscopic **sporophyte**). This tiny plant grows by absorbing light, and nutrients from the surrounding water. It can first be seen in the field by the naked eye when it has developed a single blade (rather like a leaf). This is called the "**blade-stage.**" It typically ranges from 2.5 cm to 40 cm tall, i.e., from 1 to 15 inches. As the plant grows it becomes structurally more complex and from the time it has two blades until it is 1 meter tall it is called a "**juvenile.**" Between this stage and the adult (i.e., reproductive) stage, which occurs at about 10 meters long, the plant is called a **subadult.** The entire process from spore to adult takes, on average, about a year in the San Onofre area. The median adult life span is also about a year in this area, so local kelp beds need to be replaced by recruitment of new adults every few years.

The microscopic sexual stages often reach densities of several million per square meter, but only about one in 10 million survives to become an adult plant. By the microscopic sporophyte stage, the number may be reduced to 10,000 or fewer

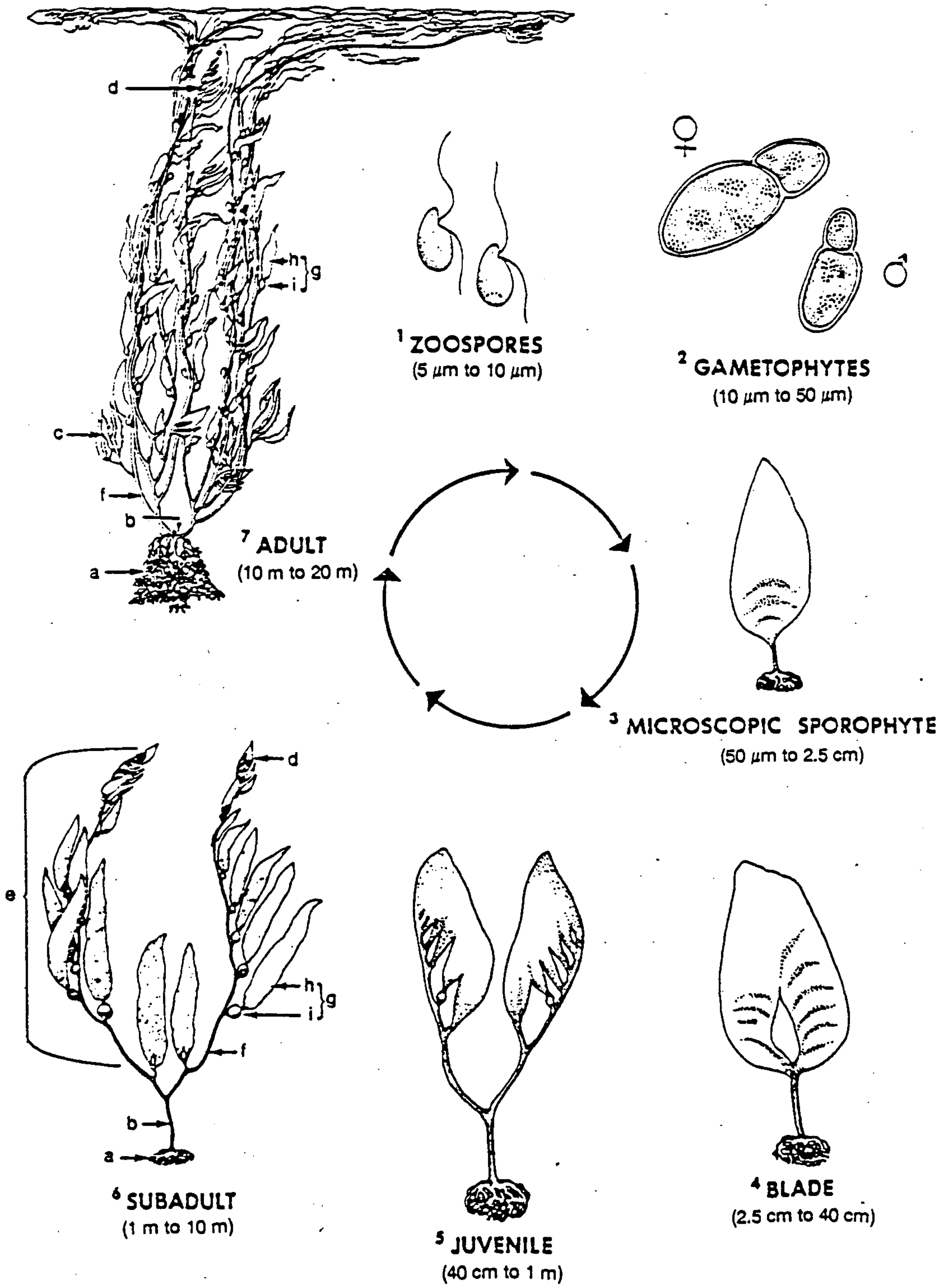


Figure 7.2. Diagram of life-history of giant kelp.

per square meter. Five to 50 per square meter would be considered a high density of blade-stage plants, which provide the first visible sign of successful reproduction. Once a cohort of plants is about 1 meter tall, 0.5 per square meter would be considered a high density [TR K: Figure 11]. Finally, over the period of MRC studies, the average density of adult plants has generally been less than 10 per 100 square meters in the kelp forests in the San Onofre area [TR K: Figure 7].

Although adult plants produce spores for most of the year, sexual reproduction requires adequate light and nutrients at the ocean bottom over a period of at least 10 days, a condition that typically occurs for limited periods between January and May, and occasionally in the fall. In addition, adequate light is required for survival and growth of the resulting tiny plants and the concentration of particles that could result in abrasion or smothering must not be too high.

Large numbers of the blade-stage need to be produced to yield significant replenishment of the adult population, because of the high mortality rate of these small plants. In southern California, such abundant production does not occur every year, in part because the physical conditions in the general area are not appropriate for long enough, and in part because locally high densities of adult plants suppress light levels on the ocean floor. During our studies, small plants appeared in substantial numbers at SMK (the Control) only in 1978, 1981, 1983, 1986 and 1987 [TR K: Figure 11].

At the time of permitting, the Commission was concerned to minimize the effects of SONGS Units 2 and 3 on San Onofre kelp bed. The Permit therefore contained the following condition:

> No diffuser port shall be located within 1,900 feet of the area where the kelp bed to the south of the diffusers is likely to expand. This area shall be determined by a marine biologist of the State Department of Fish and Game or the U.S. Bureau of Sport Fisheries and Wildlife prior to July 1, 1974. (Condition C)

In addition, Finding and Declaration C.6 states that "Substantial harm to the kelp bed could occur through excessive heat or turbidity. Condition C will insure that the effects of Units 2 and 3 on the kelp beds are not substantial."

In its 1980 Predictions report to the Commission, the MRC predicted that increased turbidity would be the major impact of SONGS on the kelp bed, and stated that the microscopic stages were the most likely to be affected. On the basis of oceanographic studies the Committee predicted that light at the bottom in SOK might be reduced during critical periods by as much as 40 percent, owing to increased turbidity from SONGS' plume. The MRC predicted that this would reduce the size of SOK by suppressing the recruitment of new adults. The effect was expected to be most severe in the offshore portion of the bed.

Approaches to Detecting SONGS' Effects on Kelp

The standard approach in most MRC studies has been to compare an Impact station near SONGS with a more distant Control station, in both the Before and After periods, to determine whether there was a change in the difference between the stations during the After period when the new generating units were operating (BACIP - Chapter 5). This approach was applied to kelp. However, it was recognized early on that kelp posed a special problem for this sort of approach because, although the sizes of different kelp beds in an area tend to fluctuate in synchrony, individual beds can show individual variation over short periods. For example, Barn kelp bed disappeared in 1980. Thus, while a BACIP result (i.e., a significant change in the difference between SOK and its control bed) would implicate SONGS, the MRC felt any such claim would be stronger if the mechanism by which the effect occurred could be documented.

In fact, although there was a possibility that SMK would show different dynamics from SOK, and would therefore be a poor control, this was not the case. Based on side-scanning SONAR records, the areas covered by kelp in the two beds tracked each other reasonably well in the period before SONGS began operating (Figure 7.3). This is not surprising since the two beds are on similar cobble bottoms (unlike Barn kelp bed), are in the same depth of water, and are close to each other.

The kelp program comprised a mixture of approaches. (1) Three methods were used to measure the extent and density of kelp in SOK and its control, SMK. (a) From 1978 until 1986 the number of plants was counted 4 times per year on a number of fixed transects in SOK (eventually 20 transects) and starting in 1981 in SMK (4 transects). Individual plants on transects were also marked and followed to determine survival. This method provides data for a BACIP type of analysis. (b) By 1982 the MRC had developed a new method of using down-looking SONAR to count plants on a grid spread over the entire bed. Down-looking SONAR yields two types of information: the area covered by kelp, and the density of plants (number per 100 m^2) on hard substrate. This procedure was done twice per year from 1982 till 1986 by the MRC, and since then has been done by Southern California Edison

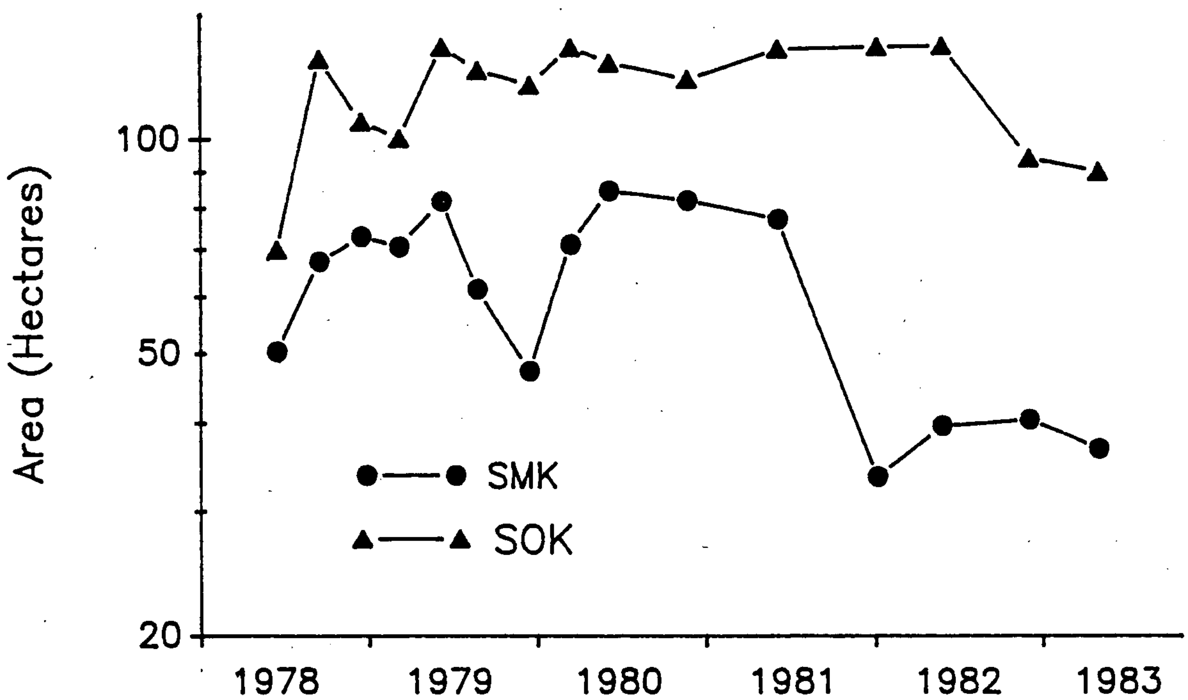


Figure 7.3. Area covered by moderate- and high-density kelp, as detected by side-scan SONAR at San Onofre kelp bed (SOK) and San Mateo kelp bed (SMK).

Company (SCE). Because Units 2 and 3 had reached about 50 percent of their After flow volume by late 1982, and there were therefore not enough "Before" data from down-looking SONAR, the results were used to determine whether kelp abundances at SOK and SMK diverged over time during the operational period. (c) From 1978 through 1989, the area covered by different broad density categories of kelp and by different substrate types was estimated using side-scanning SONAR. While this method does not give as accurate an estimation of density or cover of kelp as the down-looking SONAR, it provides simultaneous estimates of kelp coverage at both SOK and SMK that predate the down-looking SONAR data.

(2) Between 1980 and 1986, usually 4 times per year, searches were made on two sets of quadrats to determine whether any early stages of kelp (blades and juveniles) were present. One set was comprised of quadrats located at one or two stations in each kelp bed used to sample kelp invertebrates (Chapter 9); the quadrats in the other set (begun in 1981) were spread throughout both kelp beds. Data from these approaches were used in a BACIP type of analysis, and also provided evidence concerning mechanisms.

(3) Various experiments were run to separate effects of SONGS from those of other factors (e.g., urchin grazing and substrate changes) and to examine possible mechanisms of SONGS' impact: (a) In 1986, a year when small, newly recruited kelp plants were abundant in the region, cobbles were brought into the laboratory to check for the presence of microscopic stages. Cobbles from SMK were transplanted to various places in the kelp beds to measure survival of these microscopic stages at Impact and Control locations that were chosen because they were free of potential confounding effects such as grazers and competitors [TR K: 3.2.2]. (b) Microscopic

stages were "outplanted" on artificial substrates, usually on the bottom and 2 meters above it, at several stations in SOK and SMK on many occasions between 1977 and 1986 (63 in the case of the sexual stages). The experiments measured the rate at which microscopic sporophytes were produced from sexual stages, or the rate of growth of these tiny plants, and lasted three or six weeks each [TR K: 3.2.1.1]. (c) Over the same period juvenile plants were also outplanted in SOK and SMK, and survivorship and growth recorded over six-week periods [TR K: 3.2.1.2]. (d) An extensive set of experiments was conducted under controlled conditions in the laboratory to determine how physical factors such as light and nutrients affect the performance of the microscopic stages [TR K: 3.3].

(4) Finally, physical and chemical characteristics, including light levels at various depths, water temperature (which gives information on nutrient levels), flux rates of suspended particles, and current speed and direction were measured at many locations. These measurements were obtained to help explain the results of the biological studies. They were also designed to measure the effects of the power plant on the physical and chemical environment near SONGS (Chapter 6).

In analyzing the results, the period before May 1, 1983 was considered pre-operational, and the subsequent period was considered operational. The operating characteristics of the power plant during these periods can be seen in Table 7.1 and Figure 4.3.

Table 7.1

Average flow volume and power production (as a percent of maximum possible) for "Before" (January 1, 1978 - April 30, 1983) and "After" (May 1, 1983 - April 30, 1989) periods.

PERIOD	FLOW VOLUME OF UNITS 2 & 3 (MILLION OF CUBIC METERS PER DAY)	% POWER PRODUCTION OF UNITS 2 & 3
Before	1.0	0.4
After	7.4	60.2

Results

Distribution and Density of Adult Kelp Plants

The last few years have been exceptionally good for kelp populations in San Diego County. The abundance of giant kelp plants has increased at most kelp beds, including those near SONGS. However, the increase at SOK was much less than expected based on comparisons with control populations. Both the area covered by kelp plants at SOK and the density of plants on hard substrate declined in the After period relative to kelp in SMK [TR K: 4.1.1].

Kelp exists at various densities on hard substrate, and in estimating coverage the MRC distinguished between all areas with plants, and those with more than 4 plants per 100 square meters. Areas with less than about 4 plants per 100 m^2 include places where kelp is very sparse, and it is better to concentrate on areas of moderate to high density (i.e., more than 4 per 100 m^2).

The relative decline in area of kelp in SOK is well-documented by the down-looking SONAR surveys, which show a statistically significant decline at SOK relative to SMK over time, both in the total area covered and in that covered by more than 4 plants per 100 m^2 (Figure 7.4). The average area covered by moderate to high density kelp at SOK is estimated to have declined by about 60 percent, relative to SMK, from the period 1982-1983 to the period December 1986-February 1988. This is a reduction of about 80 hectares (200 acres), corresponding to a total of 59,000 plants lost from the average standing stock in SOK. These estimates take

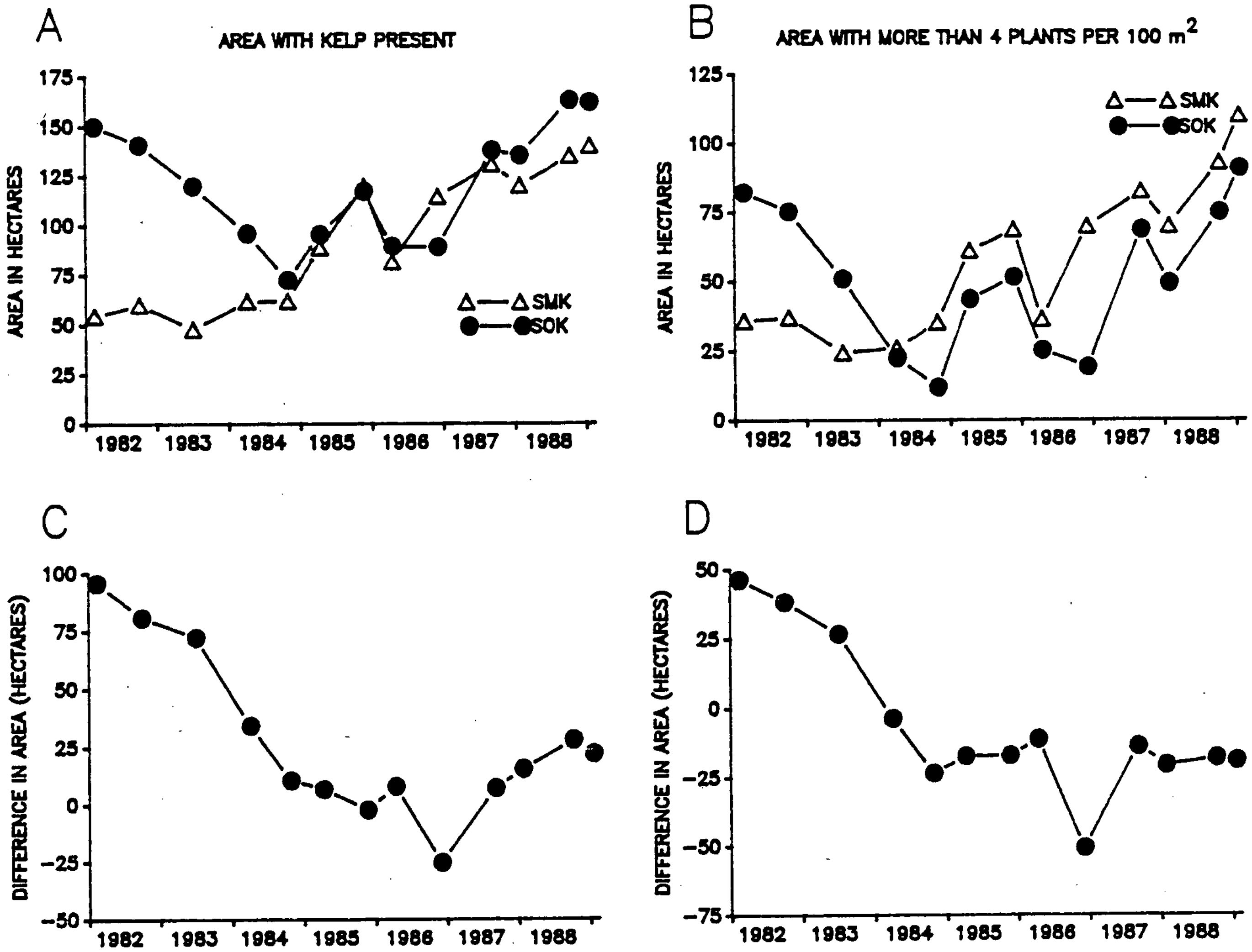
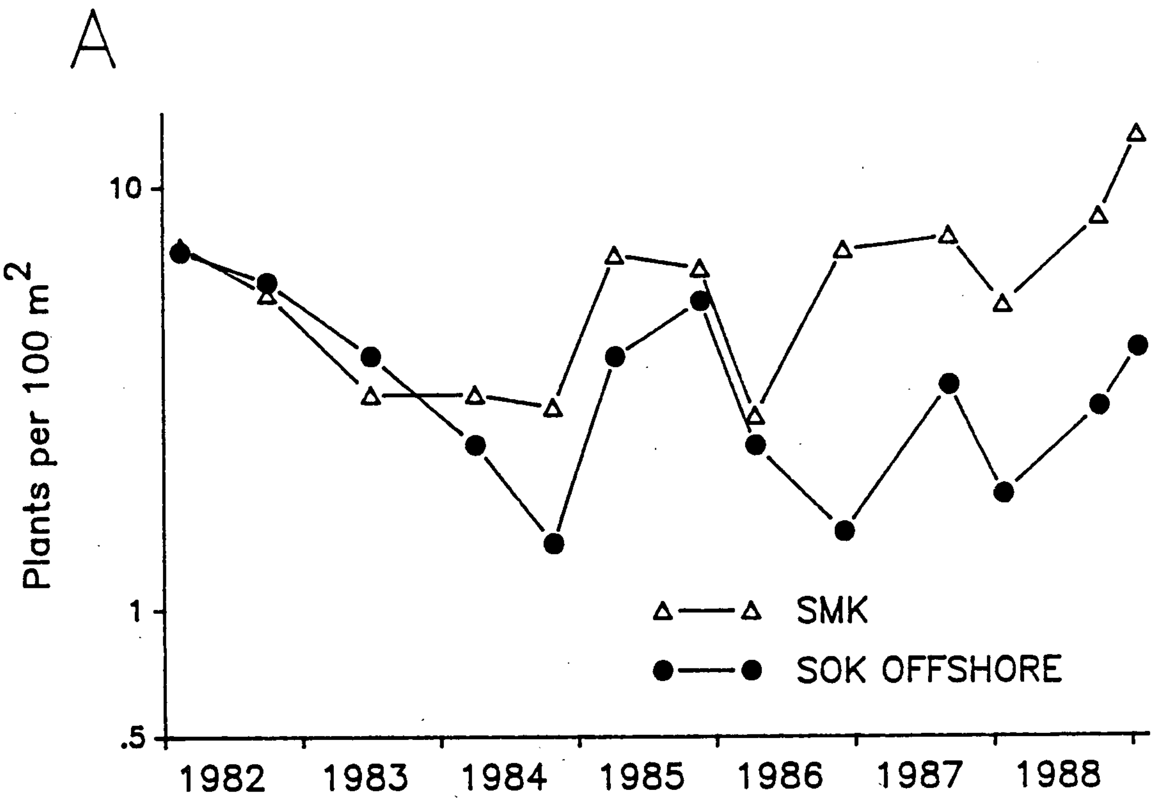


Figure 7.4. Areal extent of SOK and SMK as detected by down-looking SONAR. The top panels show the total areas covered by kelp (A) and that covered by kelp at moderate to high densities (B). The lower panels show the difference between SOK and SMK (i.e. SOK-SMK).

into account the amount of available substrate in the two kelp beds, which increased in SMK but remained constant in SOK [TR K: 4.1.1].

It is worth considering Figure 7.4 in some detail since it illustrates the importance of evaluating changes in SOK relative to what they would have been in the absence of SONGS, i.e., as they are predicted by changes in SMK. The figure shows, first, the areas in both beds that contain any kelp plants at all, even if they are very sparse (Figure 7.4A). Notice that the area covered by kelp in SOK was initially three times greater than that in SMK. By February 1988, the area covered by kelp in SMK had increased threefold. This was an excellent time for kelp throughout the region; kelp had appeared in areas from which it had been absent for many years. The area in SOK also increased at this time - to its 1982 level; but this area is much less than the expected increase as predicted by the control bed. Figure 7.4C shows the change in area covered by kelp at SOK relative to that at SMK; i.e., it shows the difference between the areas at SOK and SMK. This difference declined from 100 hectares to almost zero over the period.
Figure 7.4B shows the changes that occurred in the area covered by 4 or more plants per 100 square meters. In this case too, SOK began with a greater coverage than SMK, but ended with a smaller coverage. Although down-looking SONAR data were not taken early enough in the Before period for us to carry out a formal BACIP statistical test, Figure 7.4D illustrates the change in relative coverage at SOK. The SONAR data show that the decline was most severe in the upcoast, offshore quadrant of the bed. In that area the decline was 80 percent compared to about a 50 percent decline in the downcoast, offshore quadrant. The SONAR data also show that kelp recovered after 1986 in the inshore portion of the bed (Figure 7.5).



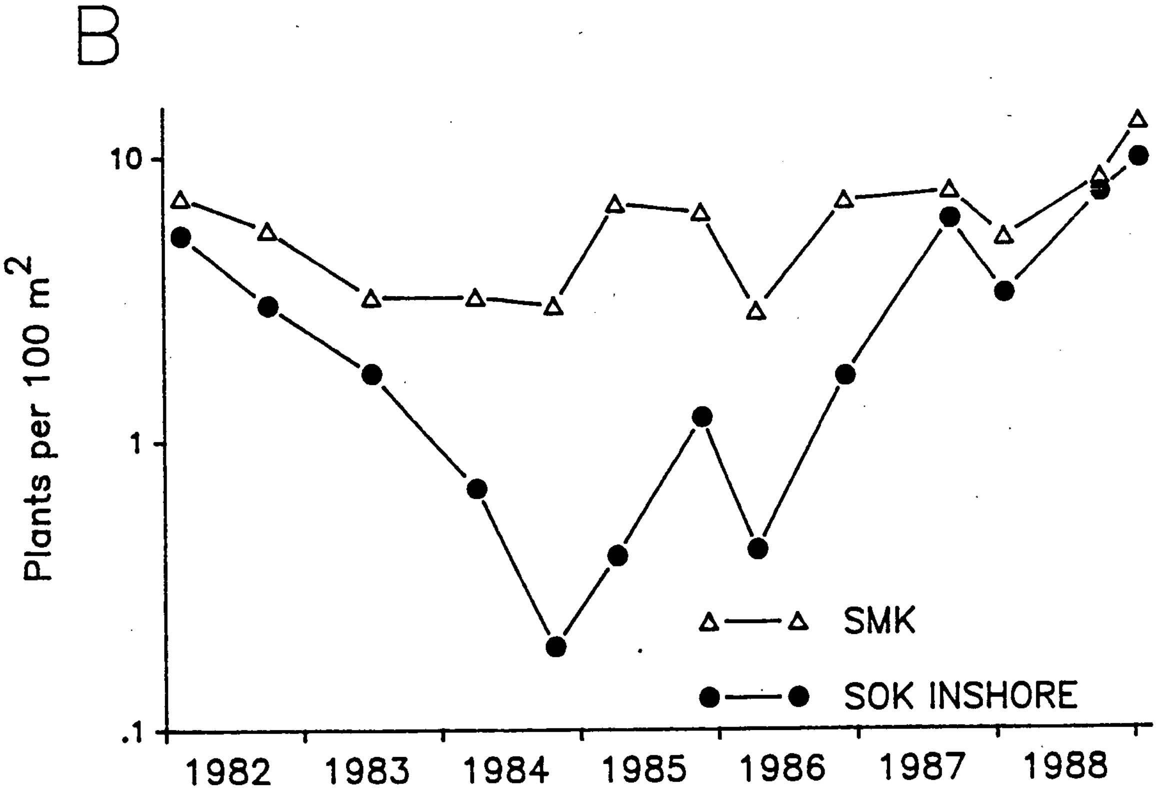


Figure 7.5. The number of adult and subadult plants per 100 square meters of hard substrate in SMK and SOK offshore (A), and in SMK and SOK inshore (B), as detected by down-looking SONAR. Note logarithmic scale.

Counts of plants on transects were primarily designed to provide estimates of mortality and recruitment, but also give good relative estimates of density. Transect locations were not chosen randomly, cover a small area, and include counts of somewhat smaller plants, on average, than down-looking SONAR. Therefore, one should not expect the absolute estimates of bed-wide density to be the same as those obtained from the wide-spread SONAR samples. It is encouraging that the two methods give nearly identical estimates of relative change between SOK and SMK. From the transect data, we estimate a statistically significant reduction in kelp density of SOK of about 60 percent, averaged over the period 1983-1986, relative to that in SMK (Table 7.2, Figure 7.6) Notice that the density of kelp in Figure 7.6 is graphed on a logarithmic scale, each unit on the Y-axis represented a 10-fold difference in density. Thus, in late 1984, the density in SOK was about 30 times lower than in SMK.

Table 7.2

Percent relative change in three aspects of the kelp population in SOK, relative to SMK, between the Before (1981-1983) and After (1983-1986) periods, as detected by counts of adult and subadult kelp plants on fixed transects in the two kelp forests. (Based on TR K: Tables 9 & 10)

	% RELATIVE CHANGE
Density	-64.0
Production of new plants	-84.0
Mortality	-11.7

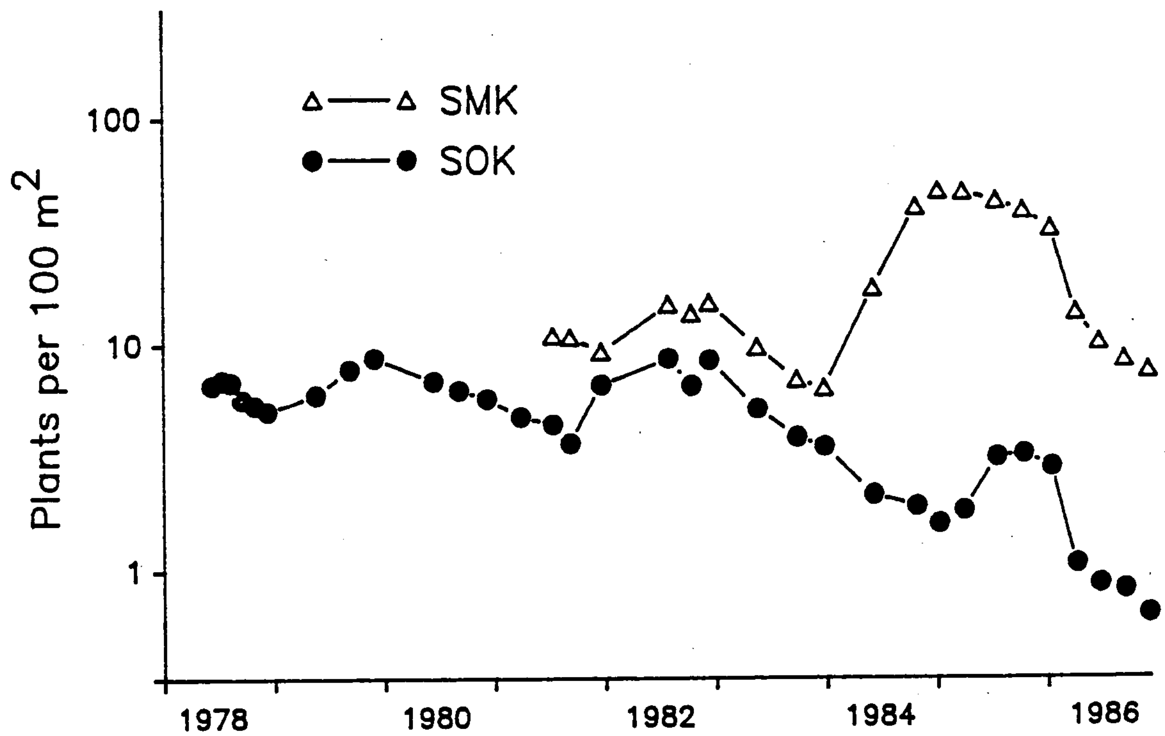


Figure 7.6. **The number of adult kelp plants per 100 square meters in SOK and SMK as detected by counts on fixed transects. Note logarithmic scale.**

The reduction of kelp in SOK, relative to the control bed, provides evidence of an effect of SONGS. It might be argued that the observed effects were all or in part the result of confounding factors such as changes in substrate, grazing, or competition with other algae. However, there are several lines of evidence that argue against the presence of confounding effects. (1) Estimates of change in area covered by 4 or more plants/100 m^2 were adjusted for changes in substrate at SOK and SMK. (2) Our estimates exclude the period from March 1984 to April 1986, in order to avoid using samples from the period that might have been affected by the failure of recruitment during the 1983-1984 El Nino. This is in spite of the fact that losses observed in 1984 may have been caused by an interaction of SONGS and El Nino. (3) The abundances of potential grazers and competitors were monitored at the same time the kelp was studied (Chapter 9). There is no evidence of any differential increases of grazers and competitors in SOK during the after period. (4) During 1986, recruitment was monitored at additional sites where competing algae and urchins were removed. The pattern of recruitment in these additional sites (fewer recruits in SOK than SMK) was indistinguishable from that at the other sites in the bed. (5) Cobbles transferred to SOK and SMK in 1986 indicated poorer recruitment of kelp at SOK even though substrate type was controlled, grazing was prevented, and competitors were removed [TR K: 4.2.1].

Causes of Reduction of Adult Kelp in SOK

The reduction in relative density of adult plants in SOK was largely caused by a markedly reduced rate of production of new adult plants, relative to SMK, and not by an increase in the death rate of existing adults in SOK. While some increase in adult mortality was observed at inshore SOK during the El Nino in 1983-84 [TR K:

Table 10], most of the losses can be attributed to the lack of replacement of adults. Plants continued to die off at about the same rate in SOK as in SMK after SONGS began operation (Table 7.2). This is the pattern predicted by the MRC in 1980.

The failure of adult recruitment was caused by a severe and statistically significant reduction in the production of small plants (i.e., those just visible to the naked eye, and up to about 1 meter tall) in SOK in the After period. SOK produced about 75 percent fewer than expected, which resulted in a very low density of young plants within SOK during this period (Figure 7.7). Again, the scale in the figure is logarithmic, so production in SMK on some occasions was about a hundred times greater than in SOK.

These results show that depletion of the adult kelp population in SOK must have been caused by suppression of the microscopic stages. There are three microscopic stages: spores produced by adult kelp plants, sexual individuals, and the sporophytes that they produce and that grow into visible plants. The evidence strongly implies that there was adequate settlement of spores [TR K: 4.2.1], but either the microscopic sexual stage failed to produce adequate numbers of microscopic sporophytes, or these in turn survived poorly to the smallest visible stage, or both processes operated.

SONGS' effect on the microscopic stages is shown by the results of experimental "outplants." Survival of sporophytes arising from outplanted sexual stages was significantly lower in the After period. In addition, there was a more severe reduction in sporophyte production the longer the discharge plume was over the outplant station [TR K: Table 15].

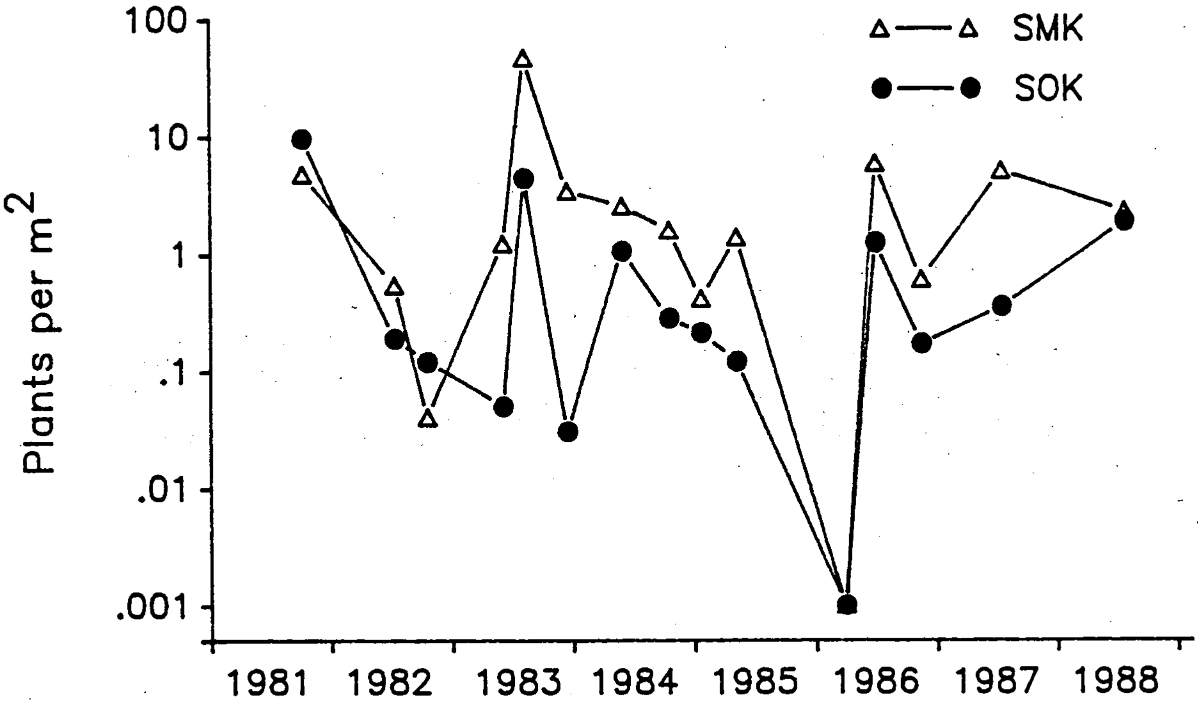


Figure 7.7. The number of small plants (blade stage plus juveniles) per square meter in SOK and SMK as detected by counts in a grid of quadrats spread throughout each bed. Notice the logarithmic scale.

Effects on naturally-occurring microscopic stages were investigated in 1986, when large numbers of sexual stages were seen in the area by February. Microscopic sexual stages were abundant on cobbles in both SOK and SMK between early February and May 1986. Although their abundance in the beds varied from one area to another, the point to be noticed is that they were plentiful everywhere (Table 7.3). In spite of the abundance of these sexual stages in the upcoast half of SOK, no microscopic sporophytes were seen there in May, when this stage was abundant both in SMK and in the downcoast portion of SOK (Table 7.3).

Poorer survival of microscopic sporophytes at upcoast SOK probably also contributed to the subsequent low production of small plants and hence adults, as shown by the following experiment. Cobbles were taken from SMK at a time when microscopic sporophytes were abundant there, and were transplanted to the four SOK quadrants and to SMK. Survival in SOK (measured by the number still present after eight weeks in the field) was less than half that in SMK, was lowest at the upcoast SOK stations, and the differences among stations were significantly different [TR K: Table 16].

Finally, an experiment in 1986 suggested that lower survival of the smallest visible plants at SOK also contributed to the poor production of new adults. Cobbles from SMK with very small visible plants on them were transferred to the two inshore and the upcoast offshore quadrants of SOK as well as to SMK itself. Survival was lower in SOK than in SMK [TR K: Table 26].

In summary, the population of adult kelp plants declined at SOK relative to that in SMK in the After period because production of new adults to replace those

Table 7.3

Mean densities of gametophytes and sporophytes on cobbles during periods of peak abundance in 1986. Based on Table 17, Schroeter <u>et al.</u> (Effects of the operation on SONGS Units 2 & 3 on patterns of kelp recruitment in the San Onofre kelp forest. Final Report submitted to the MRC. 1988), [TR K: Table 12]. The mean values for irradiance, seston flux, and temperature are for the period 27 Feb 86 to 8 May 86. The irradiance value for SOKU35 is from the period 31 Mar 86 to 8 May 86, since data prior to 31 Mar 86 were missing. Based on Tables 18-21, Schroeter <u>et al.</u> (1988), [TR K: Table 13].

STATIONS	AVERAGE NUMBER OF MICROSCOPIC STAGES/100 CM^2		IRRADIANCE ($E/M^2/D$)	SESTON FLUX (MM/D)
	SEXUAL STAGES	RESULTING SPOROPHYTES		
	10 APR 1986	08 MAY 1986		
SMK45	402	32	0.85	5.5
SOK Upcoast	1,682	0	0.58	12.3
SOK Downcoast	623	79	1.01	7.9

dying was much poorer at SOK. Settlement of spores at SOK probably was not lower than at SMK [TR K: 4.2.1]. Instead, the resulting microscopic sexual stages were less successful in producing microscopic sporophytes at SOK, and fewer of those that were produced in SOK survived to become small plants. In 1986, these effects were more marked at the upcoast station of SOK. In addition, there is evidence that small plants survived more poorly in SOK in 1986 [TR K: 4.2.3]. These results confirm the earlier prediction that the operation of SONGS would cause substantial reductions in the SOK kelp population by suppressing development of the microscopic stages essential for the production of new adults.

Mechanisms by which SONGS Affects Kelp

The MRC expected the increased turbidity in SOK to affect kelp by suppressing the development and survival of the microscopic stages, as has occurred. The Committee thought the main agent would be a reduction in light reaching the ocean floor, where the microscopic stages develop. SONGS reduced the light reaching the bottom in SOK in the After period by about 26 percent during periods when the plume was moving towards the bed, and the net reduction, regardless of current direction, was about 16 percent (Chapter 6). Thus the effects on kelp abundance were associated with a general reduction in light, which in turn was associated with the presence of SONGS' plume.

Although lower kelp abundance and poorer performance of microscopic stages are in general correlated with low light levels, seston flux near the bottom also played a role, and may even have been more important than the reduction in irradiance [TR K: Tables 14, 19 & 21]. (Seston is the term for particles in the water that contribute to turbidity, and "flux" is the amount of material passing through a region per unit time.) Decreases in light and increases in seston flux are correlated [TR K: Table A3], and it is difficult to separate their effects; for example, the outplant experiments using microscopic stages on both artificial and natural substrates showed that performance was lower when light levels were lower and seston flux was higher [TR K: 4.2.2, 4.2.3, 4.2.4]. However, (1) the effect of seston flux on the survival of outplanted sporophytes was statistically stronger than that of light, and when the effect of seston flux was taken into account, no additional effect of low light was observed; and (2) the lower survival of very small plants on transplanted cobbles at SOK (inshore) in 1986 was correlated with higher seston flux at these stations but not with light levels. It is also known that burial by sediments in the laboratory reduces survival of microscopic sexual stages. Seston flux increased by 48% in the upcoast portion of the bed (Chapter 6), and is likely to have increased in the downcoast portion as well: analysis of extinction (a measure of the fraction of light passing through a given depth of water) in the bottom 2 m indicates that this increased throughout SOK when the plume was over a station. The concentration of seston is highly correlated with extinction, so this is strong evidence that the concentration of seston increased near the bottom throughout SOK [TR L: 2.2].

SONGS' Operation and the Recovery of Kelp in Inshore SOK

Through the end of 1986, kelp was reduced throughout the bed, as shown by down-looking SONAR surveys (Figure 7.5) and transect counts (Figure 7.6). However, the down-looking SONAR surveys show that the inshore portion recovered after 1986, while the reduction in the offshore portion was maintained to the end of the sampling period in 1989 (Figure 7.5).

The MRC predicted that effects would be greater offshore, because the diffusers push water in that direction. But we do not know why the apparent effect inshore appeared and then disappeared.

Three hypotheses to explain the inshore results are as follows. (1) Light is normally more suitable for kelp inshore, so a given change caused by SONGS is less likely to push light below the threshold that must be met for the adult population to be replenished. SONGS will reduce production of new kelp inshore only in years when these ambient conditions are poorer. (2) SONGS has less effect on light inshore, because the plume is less often there. Again, this suggests that SONGS will suppress recruitment inshore only in years when ambient conditions are poorer. A combination of hypotheses 1 and 2 is also a possibility. (3) Inshore and offshore may not be very different, either naturally or with respect to SONGS' plume. Instead, the different patterns in inshore and offshore kelp in SOK may simply reflect short-term differences in production of new plants that will average out over many years.

There is, however, evidence that the recovery of the inshore portion in 1987 has a yet different explanation: the shut-down of SONGS Unit 3 early in the year. The new plants were first detected as subadults in September. Knowledge of physical conditions at the end of 1986 and in early 1987, and of maximal growth rates ever observed in the area, tell us that these plants must have passed through the crucial microscopic sexual stages about the last 3 weeks of January 1987, and this time lies squarely in the period when Unit 3 (whose diffuser is inshore) did not pump water (beginning of January till the end of February 1987) [TR K: Figure 16].

Unit 3 was also shut down for four months in 1988 (30 April - 30 August). While we lack the detailed data to match the likelihood of kelp recruitment with the shut-down period in 1988, it is not unreasonable to conjecture that such a long shut-down may have increased the recruitment and survival of young kelp in the inshore portions of SOK. The continued recovery of kelp inshore through 1988 could also reflect the fact that the period 1987 - 1988 was exceptionally good for kelp throughout the region, and that SONGS' effect inshore was therefore less marked, in line with hypotheses 1 or 2.

Conclusions

SONGS' operation has led to a reduction of about 60 percent (80 hectares) in the area covered by moderate to high density kelp in SOK, and to an equal reduction in kelp density. This is an ecologically substantial impact on a local kelp bed.

During banner years for kelp, as in 1988, SONGS will slow population growth. During years when conditions are particularly inhospitable, there will be very little recruitment anywhere and SOK and the other kelp beds will probably decline at about the same rate, since SONGS does not appear to affect adult mortality. However, during marginal years for kelp, recovery would be expected at SMK, whereas SOK would be expected to continue to decline. As a result, we predict that SOK will have less kelp, on average, than before the operation of Units

2 and 3, and during periods of successive poor or marginal years could be driven near local extinction.

The major process by which SONGS has had this effect is an increase in turbidity in SOK, which arises from the intake of inshore turbid water and from secondary entrainment of a turbid layer near the ocean floor in the region of the diffusers. The increased turbidity suppresses development of the microscopic stages of kelp, probably through increased seston flux and reduced light levels near the bottom.

Chapter 8

KELP BED FISH*

Summary

The abundance of fish in San Onofre kelp bed (SOK) was reduced, relative to that in the control kelp bed (San Mateo kelp bed - SMK), during the two Operational years in which samples were taken (1985 and 1986). Here as elsewhere in this report a reduction at Impact (SOK) relative to Control (SMK) implies that the abundance at SOK is lower than it would have been had SONGS not operated.

Fish living close to the cobble bottom of the kelp bed (bottom fish) declined in abundance by 70% and in biomass by 73% relative to the control populations. These are substantial declines.

While there are indications that fish living in the water column showed a relative decline in abundance (17%) and in biomass (33%), the declines are not statistically significant. One species of fish in the water column - senorita - showed a substantial relative increase in the Operational period.

The decline in the relative abundance of fish in SOK was associated with, and presumably in part caused by, a concurrent 70% relative decline in the area covered by kelp in SOK in 1985-86. It appears, though, that other alterations in the kelp bed environment associated with SONGS' plume also played a role, since fish

* Drs. Edward DeMartini, Ralph Larson and Larry Allen carried out the scientific studies on kelp-bed fish on which this report is based. Dr. E. DeMartini prepared the Contractor's Final Report. The Technical Report (J) to the CCC was prepared by Dr. Jon Kastendiek and Mr. Keith Parker.

abundances declined in areas where kelp density did not. The MRC concludes that the reduction in fish in SOK was caused by the plant's operation.

The reduction in relative abundance of fish in the bed translates into a loss of about 200,000 fish weighing about 28 tons that would have been present in the absence of SONGS. The absolute losses are thus also substantial.

Introduction

Forests of giant kelp (kelp beds) provide food and shelter for a diverse assemblage of fish species. Among the 40 species of fish sampled during MRC studies of kelp beds near SONGS, a few (kelp perch and giant kelp fish) are particularly associated with kelp, while others (e.g., kelp bass, senorita, halfmoon, rock wrasse and California sheephead) are associated with reefs in general [TR J: 3.1]. Other fish common in the general area are also observed in and near kelp beds (e.g., northern anchovy and jack mackerel). Some species (e.g., kelp bass) that as adults occur also on reefs without kelp, appear to favor kelp beds as a nursery during their first year of life; and for fish in the bed in general, the kelp is thought to provide a refuge and enhance production. In addition, many kelp-bed fish are important sportfish species, such as kelp bass and California sheephead. A list of species commonly found in the two kelp beds near SONGS is in Table 8.1.

While many species of fish occur throughout the water column, i.e., both close to the bottom and up in the midwater, most species are found more often in one or the other of these habitats. For example, California sheephead, rock wrasse, barred sand bass and black seaperch are found almost entirely just above the hard

Table 8.1

Common fish species inhabiting the San Onofre kelp bed in the Before and After periods. Fish species are listed in order of abundance within each habitat and sampling period. Species in bold were common both close to the bottom and up in the water column.

BOTTOM SPECIES

Before	After
white seaperch	**senorita**
kelp bass	rock wrasse
black perch	**kelp bass**
California sheephead	black perch
jack mackerel	barred sand bass
black croaker	pile perch
senorita	**white seaperch**
barred sand bass	California sheephead
pile perch	rubberlip seaperch
rainbow seaperch	**jack mackerel**

WATER-COLUMN SPECIES

Before	After
senorita	**senorita**
jack mackerel	salema
kelp perch	**kelp bass**
kelp bass	halfmoon
silversides spp.	kelp perch
halfmoon	**jack mackerel**
white seaperch	pacific barracuda
silversides spp.	

substrate while others (e.g., halfmoon and kelp perch) occur mainly up in the water column.

No claims were made concerning expected effects on fish in the San Onofre kelp bed (SOK) during the Public Hearings on the Permit. In its 1980 report to the CCC the MRC noted that losses of kelp-bed fish would depend upon the extent to which the kelp itself was reduced, and gave a range of losses of up to 9 tons per year. The greatest reduction in fish abundance in SOK was expected to occur in the upcoast/offshore quadrant of the kelp bed, because the turbid plumes of Units 2 and 3 were expected to reduce the density of kelp in that area.

Sampling Design and Methods

As in other programs, the MRC estimated the effects of SONGS on the abundance of kelp-bed fish in SOK relative to that in a Control bed (San Mateo kelp bed - SMK; Chapter 7 describes the general ecology of these two kelp beds.) However, a major object of the program was to estimate the actual number and biomass of fish lost or gained at SOK as a consequence of SONGS' operation. This task required a series of calculations whose details are sequestered in an appendix at the end of this chapter.

Two types of sampling were done, corresponding to the two habitats found in the bed. "Water-column" fish were sampled by divers swimming along transects in the mid-water and recording with cine camera all fish in the camera's view. "Bottom" fish were sampled by divers swimming along transects close to the bottom and counting all the fish seen in a band 3 meters wide and 1.5 meters deep [TR J: 2.1].

All sampling was done between October and December, when visibility is most consistently high. "Before" samples were taken in 1980 and 1981, "After" samples in 1985 and 1986 [TR J: Appendix A].

There was a general decline from the Before to the After period in the density of many species of fish, and an increase in some others, in both SOK and SMK. The decreases were primarily in "cold-water" species, i.e., those that are close to the southern end of their geographical range (e.g., the several species of sea perches); the increases were in southerly "warm-water" species (e.g., rock wrasse) [TR J: 3.1]. The changes were almost certainly caused by the El Nino condition of 1982-84. Fortunately, the BACIP sampling design allowed us to detect SONGS' effects against this large general change in the fish community.

As noted above, we distinguish between fish found near the bottom and those found in the water-column. The former occur both where kelp grows and where there is hard substrate but no kelp. They were about 2.5 times more abundant in kelp than out of it. "Water-column" fish, on the other hand are essentially absent from transects lacking kelp.

Changes in the Relative Abundance of Fish in SOK

Bottom Fish

We estimate that the total number of bottom fish in SOK relative to that in SMK declined by 70% in the After period. The estimated relative decline in biomass was 73% [TR J: 3.3.2]. As always, these estimates are not precise: the losses could be half as much or slightly more, but they are the best estimates available. They are statistically significant and represent substantial reductions.

Declines in abundance were indicated in nine of the ten bottom species tested (Table 8.2). Due to the uncertainties associated with the variables used to make the abundance estimates, these changes were not statistically significant.

The one species that increased in abundance was the senorita. This fish, the most abundant in SOK, responded differently from the fish as a whole. Non-senorita species, as a group, showed a statistically significant decline in abundance of 82% whereas the relative abundance of senorita actually increased by over 100% (Table 8.2).

The observed reduction in the abundance of bottom fish was associated with, and presumably in part caused by, a decrease in kelp at SOK. Over the two Operational years in which kelp-bed fish were surveyed (1985 and 1986) SONGS' operation reduced the area in SOK covered by kelp by about 70%, and also reduced the density of plants where they occurred, especially in the upcoast/offshore portion of the bed (Chapter 7).

Table 8.2

Estimated percent change in numbers and biomass of kelp bed fish at SOK, relative to SMK. YOY = young-of-the-year.

	NUMBERS % CHANGE	BIOMASS % CHANGE
BOTTOM FISH		
senorita	>100	-
rock wrasse	-19	-
kelp bass	-68	-
YOY kelp bass	-74	-
black perch	-93	-
barred sand bass	-77	-
pile perch	-43	-
white seapearch	-72	-
California sheephead	-73	-
rainbow seaperch	-88	-
Non-Senorita	-82	-76
Total	-70	-73
WATER-COLUMN FISH		
senorita	-25	-
kelp bass	-79	-
YOY kelp bass	-72	-
halfmoon	57	-
kelp perch	-70	-
giant kelpfish	-74	-
white seaperch	>100	-
pile seaperch	-77	-
Non-senorita	-6	-36
Total	-17	-33

In some species of bottom fish there were also changes in density per unit of kelp (i.e., per kelp plant) at SOK relative to SMK. Black seaperch, barred sand bass, and California sheephead showed statistically significant declines in number per unit of kelp in both the upcoast and downcoast portions of the kelp forest, and in general there was a tendency for the number per unit of kelp to decrease in the upcoast half of the bed nearer the diffusers (Table 8.3). These declines in fish density may be associated with changes in the benthic environment in SOK other than changes in the abundance and distribution of kelp, such as the reductions in large invertebrates (Chapter 9) and the increase in the flux of particles (Chapter 6). Note that senorita was again different, and increased in relative density in areas with kelp (Table 8.3).

Water-Column Fish

Smaller declines were seen in water-column species. Taken as a whole, these declined 17% in abundance and 33% in biomass [TR J: 3.3.3]. Most of the individual species also showed a tendency to decline in relative abundance (Table 8.2). However, neither the collective nor the individual results are statistically significant.

Two species in the water column - senorita and halfmoon - showed large and significant increases in density per unit of kelp, and other species also tended to increase, especially at the downcoast station (Table 8.3) This may represent "crowding" of the fish population into the habitat available to it, but it is also possible that there is an increase in the density of food particles in areas with kelp as

Table 8.3

Percent change in density of kelp bed fish per unit of kelp in SOK relative to the control site. Changes in species with numerical values were statistically significant ($P < 0.05$), the others were not. The indicated direction of change, i = increase, d = decrease, is presented for those species where the change was not statistically significant. Results listed under "SOKU" are from the upcoast station, those listed under "SOKD" are from the downcoast station, and those under "SOK" apply to the bed as a whole. YOY = young-of-the-year.

	SOK	SOKU	SOKD
BOTTOM FISH			
senorita	>100	>100	>100
black seaperch	-76	-85	-74
barred sand bass	-60	-74	-43
California sheephead	-59	-46	-70
rainbow seaperch	d	-68	-59
rock wrasse	i	i	i
kelp bass	d	d	d
YOY kelp bass	i	d	i
pile perch	i	d	i
white seaperch	d	d	i
WATER-COLUMN FISH			
senorita	>100	>100	>100
halfmoon	>100	>100	>100
giant kelpfish	67	-42	85
kelp perch	i	-25	86
kelp bass	d	d	i
YOY kelp bass	i	d	i
white seaperch	i	i	i
pile seaperch	i	d	i

a result of SONGS discharge plume. If it is merely a concentration of fish, it is possible that the density will eventually decline, leading to larger losses over the whole bed than were observed to 1986. There is a suggestion in the results of a greater tendency to declines in density closer to the diffusers, in the upcoast portion of the bed, as was seen also in bottom fish (Table 8.3).

Changes in Absolute Numbers and Biomass of Fish

Using the calculations outlined in the appendix below, the MRC estimates that SOK in the After period had almost 200,000 fewer bottom fish than it would have had in the absence of SONGS. (The expected number of fish was estimated to be 275,000.) [TR J: 3.5] The missing fish represent a total weight of 28 U.S. tons. Thus the reductions are substantial in absolute terms.

APPENDIX: METHODS OF ESTIMATING SONGS' EFFECTS ON KELP-BED FISH

A major goal of the kelp-bed fish program was to estimate the number and biomass of fish lost in SOK as a consequence of the operation of SONGS, if any such losses occurred. This goal is additional to the standard goal of this and other programs, where we were trying to measure the proportionate reduction at an Impact station relative to a Control station. This additional goal, plus several aspects of the ecology of fish in SOK, led to a different approach in this program.

First, SONGS' effects were expected to vary systematically from one part of the bed to another; in particular, we expected the most severe effects on kelp to occur in the upcoast half of the bed, which is closer to the diffusers. One Impact station was therefore set up in the upcoast section of the bed, the other in the downcoast section. The Control station was in SMK [TR J: 2.1].

Second, kelp density varies from place to place in SOK, and fish density varies with kelp density. An estimate of numbers lost therefore needs to take account of these two factors.

Third, although we expected SONGS' to affect SOK fish by altering the distribution and density of kelp, it was also possible that SONGS would alter fish density independent of kelp density, and indeed this occurred. Therefore we needed to detect changes in the number of fish per kelp plant in SOK relative to those in SMK.

These difficulties were surmounted by calculating the number of fish lost, using a series of direct and indirect estimates of effects. The procedure was first to calculate the **proportionate** effect of SONGS, and then to transform this into an estimate of actual numbers of fish lost or gained. There are three steps.

(1) An **index** of abundance was calculated for each of four situations: for both beds (SOK and SMK) in the Before period, and for both beds in the After period [TR J: 2.2.1.1]. In each case, the index was calculated as follows. (a) Areas in the bed were divided into those with 4 or more kelp plants per 100 m^2 - designated "kelp" areas, and those with fewer than 4 per 100 m^2 - designated "kelpless" areas. (Side-scanning SONAR cannot detect kelp in the lower density range and classifies such areas as having no kelp.) (b) The number of fish in "kelp" areas was estimated from transects that had not changed in kelp density between Before and After (so we could remove the effects of changing kelp density.) (c) The number in "kelpless" areas was estimated by multiplying estimate (b) by a fraction, f, which is the known abundance on transects without kelp as a fraction of that on transects with kelp. (d) The total number of fish in, say, "kelp" areas in SOK in the After period was estimated by multiplying the number of fish per cubic meter of water in "kelp" transects by the volume of water in SOK containing 4 or more plants per 100 m^2. (e) The total number of fish in SOK in the After was calculated by repeating step (d) for "kelpless" areas and adding the answer to (d).

This calculation is an index, rather than an estimate of actual abundance, because the actual average density of kelp plants in a given bed in a given period was less than 10 per 100 m^2, whereas fish density was estimated on transects with an average of 10 plants per 100 m^2. However, the index is proportional to actual abundance.

The indexes are designated:

SMK, Before = SMK_b

SMK, After = SMK_a

SOK, Before = SOK_b

SOK, After = SOK_a

(2) From (1) we calculate the proportionate reduction (or increase) in abundance at SOK. This is the ratio of the index for fish in SOK in the After period divided by the index that would have been there in the absence of SONGS.

The index that would have been obtained in SOK in the After period in the absence of SONGS is calculated by multiplying the index for SOK in the Before (SOK_b) by the **observed** change in SMK (the Control); i.e., we assume that in the absence of SONGS, SOK would have changed in the same way that SMK did. This observed change is simply SMK_a/SMK_b. Thus the proportionate effect on the index of abundance at SOK, owing to SONGS, is

$$S = SOK_a/[SOK_b(SMK_a/SMK_b)]$$
$$= SOK_aSMK_b/[SOK_bSMK_a].$$

(3) Finally, we convert the proportionate effect into an absolute number of fish by correcting for the fact that the density of kelp in SOK in the After period, averaged across the whole bed, was not equal to the average density on sample transects. This was done in two stages. (a) First we estimated the **actual** number of

fish in SOK in the After period. Fish in SOK in the After period were sampled on transects containing different kelp densities, and a relationship (regression) was established between local kelp density and local fish density. This (linear) relationship allows calculation of the number of fish per cubic meter in an area with the **average** density of kelp plants found in the whole bed. The total number of fish in the bed is then simply this number per cubic meter times the volume of water in the kelp bed. We designate this observed number as O. (b) The actual number of fish lost or gained in the bed is then the number expected minus the number observed. The number expected is O/S, the observed number divided by the proportionate effect of SONGS. So the number lost is (O/S) - O.

For example, if the calculations using the index in steps (a) and (b) tell us that SOK has only 75% of the fish it would have had in the absence of SONGS (i.e., S = 0.75), and if the actual number of fish in SOK were 1000 in the After period, then the expected number is 1000/0.75 = 1333. The number lost due to SONGS would then be 1333 - 1000 = 333.

Chapter 9

INVERTEBRATES ON HARD SUBSTRATES IN KELP BEDS*

Summary

The operation of SONGS Units 2 and 3 has caused declines in the abundance of invertebrates inhabiting the San Onofre kelp bed (SOK). Declines were observed mainly in snails. However, many other groups could not be sampled or tested for a variety of reasons, and it is likely that declines are widespread in these groups. The decreases in abundance were associated with an increased flow of particles from SONGS' turbid plume and cover of new fine sediments.

Within SOK, the abundance of a broad range of invertebrates was reduced in areas containing patches of new fine sediment compared to areas without the new sediment. However, the cover of the new sediment cannot by itself account for the large declines observed in abundances at SOK relative to the control kelp bed.

Introduction

Hard-bottom habitats such as reef outcrops and rocks, including those supporting kelp beds, are inhabited by hundreds of species of animals and plants. Among the common invertebrates are clams, abalones, snails, sea urchins, sea stars and sea cucumbers. The large-invertebrate fauna of the San Onofre kelp bed is

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* Drs. Stephen Schroeter, John Dixon and Jon Kastendiek (University of Southern California) carried out the scientific studies of invertebrates on hard substrates on which this chapter is based. Drs. Stephen Schroeter and John Dixon prepared the Contractor's Final Report. The Technical Report (F) to the CCC was prepared by Drs. James Bence, Stephen Schroeter and Mr. Richard Smith.

typical of that found in other southern California kelp beds. The 37 species sampled in this program were chosen to represent the community of over 100 species of large invertebrates that inhabit the bed [TR F: Table 4]. A more detailed account of the results is presented in *Final Technical Report F: Kelp Forest Invertebrates*.

Patches of fine sediment appeared on some sampling areas and reduced the abundance of invertebrates there. The sediments will be the subject of a separate report, which will aim to determine whether they are caused by SONGS or are natural [TR B]. That report will also describe their effects on a group of smaller invertebrates, such as bryozoans and some sponges, that form a "turf" on many hard substrates. The present chapter describes the effect of the sediments on the large invertebrates.

Testimony presented at the 1973 Public Hearings on the Permit suggested that SONGS might have a large effect on the benthic stages of some large invertebrates by causing substantial losses in their planktonic stages, via entrainment and offshore transport (Chapter 2). The Permit itself, however, makes no reference to expected effects on benthic stages of large invertebrates.

Sampling and Analysis

MRC sampled a diverse group of large benthic invertebrates that are typical of kelp beds in southern California. The species chosen can be counted easily and reliably by divers in the field under conditions of poor visibility. Several of the species, such as sea urchins, have been shown to influence the structure and dynamics of kelp forest communities. Some groups of potential interest, such as lobsters and abalone, were not monitored because they are rare and/or hard to sample. Of the 37 species that were counted, 20 were sufficiently common to be analyzed (Table 9.1) [TR F: Table 4]. Some of the species that were too rare or variable in abundance to be analyzed individually were included by analyzing five groups of pooled species: (1) all snails, (2) muricid snails, (3) non-muricid snails, (4) sea urchins, and (5) sessile invertebrates.

All three kelp beds in the San Onofre area were sampled. MRC intended to use the invertebrate communities in both the San Mateo (SMK) and Barn (BK) kelp beds as Control sites for that in SOK (Figure 9.1). However, kelp at BK disappeared in 1980, so San Mateo was designated as the Control. Two Impact stations in SOK were sampled (Figure 9.2): one was in the upcoast section of the bed, 500 meters downcoast of the diffusers (Near Impact), the other in the downcoast section of the bed, 1500 meters downcoast of the diffusers (Far Impact). Both stations were in water 14 m deep (Figure 9.3), as was the Control site in the San Mateo kelp forest, 4-5 kilometers upcoast of SONGS.

Large invertebrates pose special sampling problems. First, they are relatively uncommon and their habitat at San Onofre (rocks) is vulnerable to disturbance. The animals therefore need to be counted, but not removed, with minimal disruption of the habitat. This requires visual counts by divers.

The main datum of interest is the average abundance at a site on a given survey. The sampling strategy was to sample as large an area as was logistically feasible in such a way as to get the best possible estimate of the mean abundance. Therefore a uniform grid of quadrats was placed over each sampling site. Counts of

Table 9.1

Percent change at Impact Stations.

Percent changes in abundance at the Near Impact (SOKU) and Far Impact (SOKD) sites relative to the values at the control site, SMK. No result (NR) indicates all densities were zero at the test stations. "No test" means that no test could be done since the data did not meet the test's assumptions. * indicates a significant result occurred but is not thought to be a SONGS' effect [TR F: Table 8].

SPECIES/ GROUP	% CHANGE NEAR IMPACT	FAR IMPACT	STATISTICAL RESULT
Snails	-84.0	-73.2	significant
Non-muricid snails	-80.9	-68.3	nearly significant
Astraea undosa	-85.5	-68.2	no test
Calliostoma spp.	-58.9	19.9	significant
Conus californicus	-90.8	-81.0	significant
Crassispira semiinflata	-82.0	-60.1	no test
Cypraea spadicea	-85.5	-55.9	no test
Kelletia kelletii	-63.5	-51.8	significant
Mitra idae	-70.5	-35.0	nearly significant
Nassarius spp.	-36.3	(NR)	no test
Ophiodermella inermis	-32.3	-68.6	significant
Tegula aureotincta	-93.2	(NR)	no test
Muricid snails	-86.2	-74.9	significant
Maxwellia gemma	-88.9	-61.1	significant
Murexiella santarosana	-86.3	-62.8	nearly significant
Pteropurpura festiva	-84.2	-73.6	not significant
Sea Urchins	-51.2	25.9	significant
Lytechinus anamesus	-75.8	-40.4	significant
Strongylocentrotus purpuratus	0.7	47.6	significant*
Sea cucumbers			
Parastichopus parvimensis	83.3	134.4	significant
Sessile invertebrates	36.9	92.3	no test
Muricea californica	318.0	590.6	no test
Muricea fruticosa	58.8	370.8	no test
Styela montereyensis	42.9	-95.2	no test
Tethya aurantia	16.9	85.1	no test

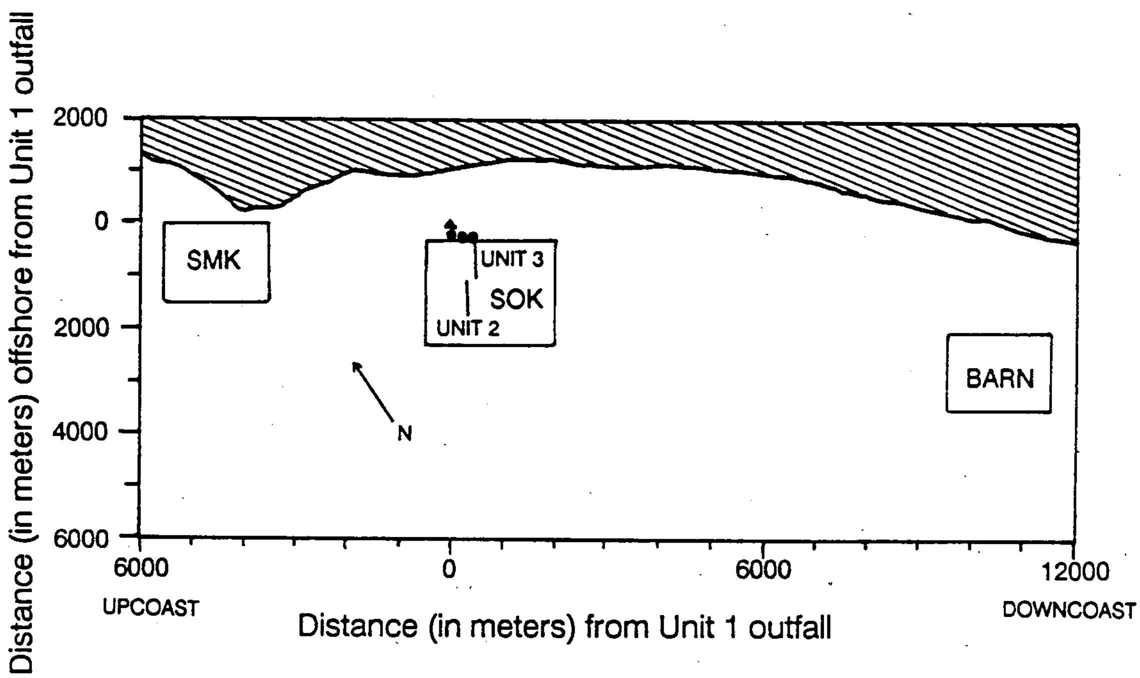

Figure 9.1. Monitoring stations for large invertebrates living on hard substrate. The enclosed rectangles are the approximate boundaries of the three kelp forest studied. San Onofre kelp forest (SOK), San Mateo kelp forest (SMK), and Barn kelp forest (BARN). The intakes for Units 1, 2 and 3 are denoted by circles, the Unit 1 discharge by a triangle, and the discharge pipes of Units 2 and 3 are the labeled lines in SOK.

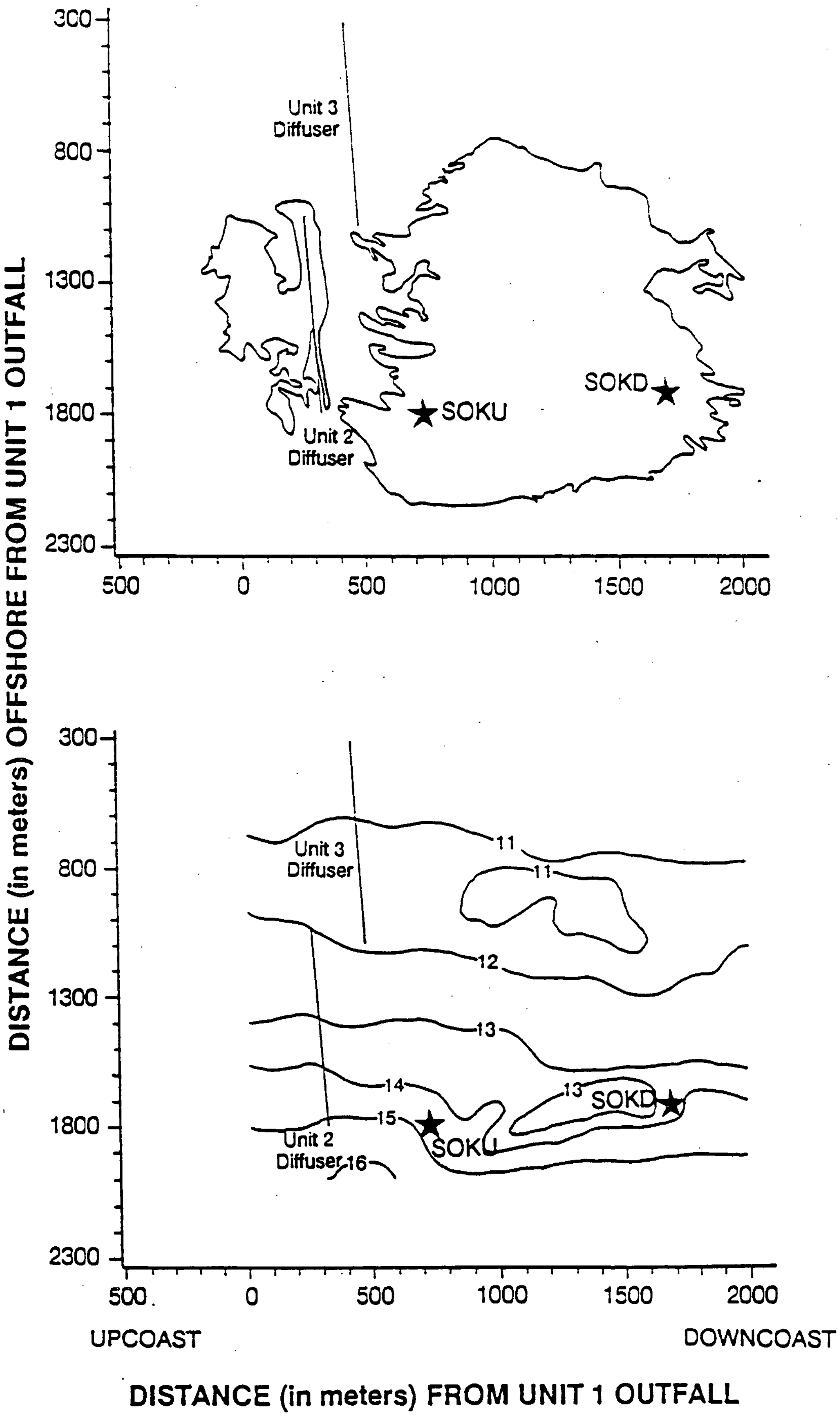

Figure 9.2. The area with hard substrate at San Onofre kelp bed is outlined in the upper panel, and the depth contours in the bed are shown in the lower panel., The tow stars indicate the Near and Far Impact sites that were sampled regularly for large benthic invertebrates.

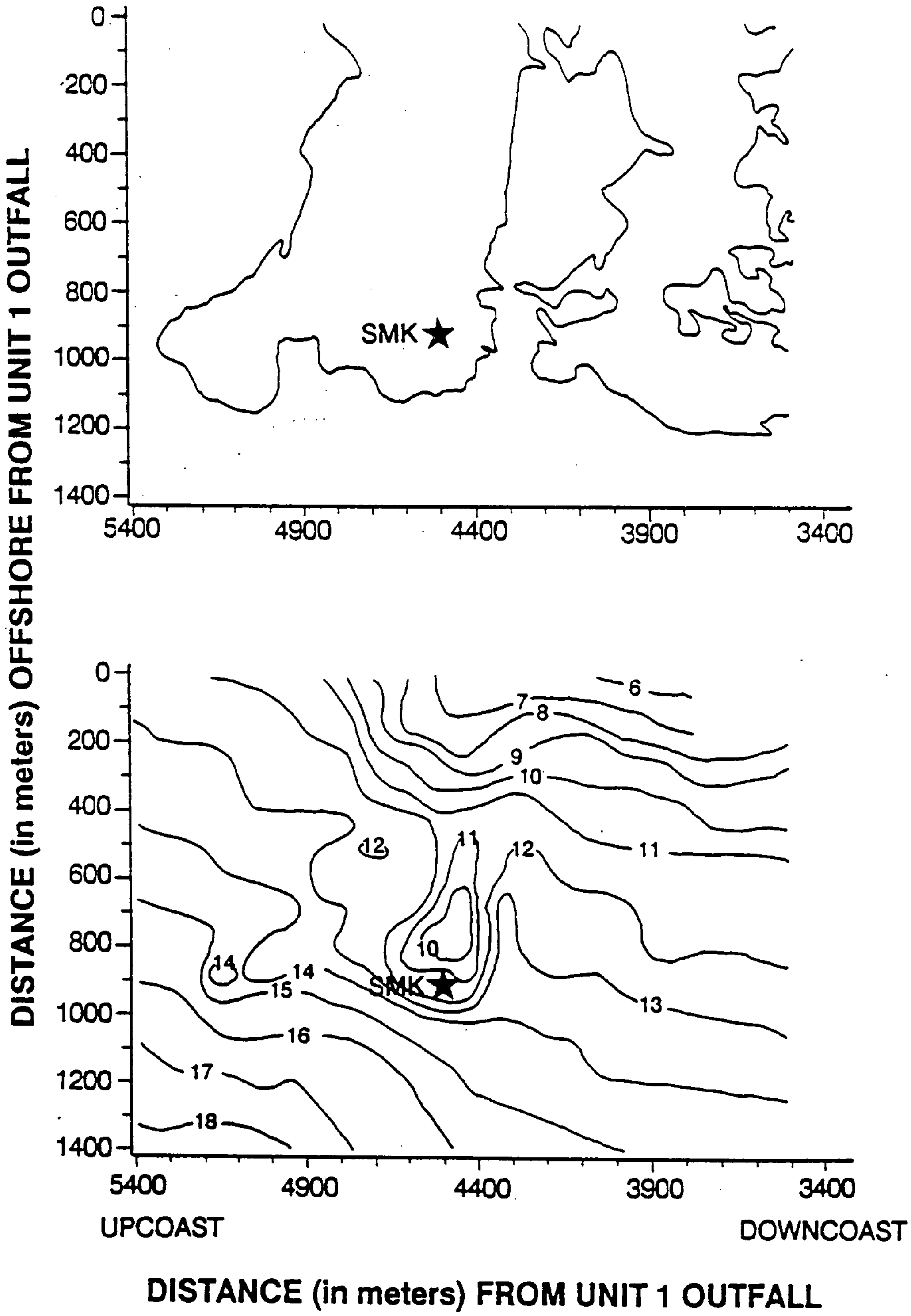

Figure 9.3. The area with hard substrate at San Mateo kelp forest is outlined in the upper panel, and the depth contours in the bed are shown in the lower panel. Large benthic invertebrates were sampled regularly at the site indicated by a star.

large invertebrates were made on 10 occasions before Units 2 and 3 began commercial operation and on 8 occasions afterwards [TR F: 2.2]. The data were analyzed using the BACIP approach, modified to take account of the special features of the large invertebrate sampling program, namely the two Impact stations.

In October 1985, long-lasting patches of fine and eventually compact sediment covered areas of hard substrate in SOK [TR B]. Their effects on the large invertebrates are evaluated in this chapter by comparing densities in quadrats containing the sediment with those in quadrats from which it was absent.

Changes in abundance of invertebrates

The majority of invertebrates for which tests were possible, both as individual species and pooled groups, are snails (Table 9.1) [TR F: Tables 8 & 9]. However, tests were also possible in two species of sea urchins and a sea cucumber. Sea stars and red sea urchins were sampled but SONGS' effects on them could not be evaluated because populations in SOK suffered different rates of mortality from disease (sea stars) and fishing (urchins) than did those at the Control site. This mortality may be confounded with, and therefore obscure, differences that might have been caused by SONGS. We can evaluate the effects of fine sediments on sea stars because this does not involve comparisons with populations in the other beds.

Effects were detected in large invertebrates in most cases in which tests could be run, and the great majority were declines in density at Impact sites relative to Control [TR F: Table 8]. Larger declines were observed nearer the diffusers, at the

Near Impact site. Changes were strongly implied in 10 (67%) of the 15 species or groups in which statistical tests were possible (Table 9.1) [TR F: Table 8]. All but two of these effects were declines in density at SOK relative to SMK. Declines were particularly marked in the snails: considering both impact sites, 29 of 30 changes were declines averaging about 80% at the Near Impact and about 60% at the Far Impact [TR F: Table 8]. The declines were statistically significant or nearly so in each snail group (total, muricids, and non-muricids), as well as for 5 of the 11 individual species [TR F: Table 11]. There was a significant decline in relative abundance of white sea urchins (*Lytechinus anamesus*), the effect again being greater near the diffusers (76%) than at the Far Impact site (40%) [TR F: Table 8]. A sea cucumber increased in relative abundance at SONGS. The remaining species for which a test was possible, the purple sea urchin, also increased. However, this change is unlikely to be caused by SONGS because the increase was bigger (50%) at the Far Impact site than closer to the diffusers (less than 1%).

There was a significant increase in the flux of particles through SOK after SONGS began operating (Chapter 6) [TR B], and we would expect such an increase to have negative effects on most of the large invertebrate species. The observed increase in a sea cucumber, which is a deposit-feeder, may have been caused by an increased flow of organic particles at SOK [TR F: Table 8].

Effects of Fine Sediments

It is likely that the fine sediment degrades the environment for most hard-bottom species since it covers hard substrate. After the new sediment appeared in SOK the abundance of all groups studied declined in quadrats with new sediment present compared with those not affected by it (Table 9.2), although the difference was statistically significant in only half of the groups. The relative declines in the affected quadrats were typically less than 50%. In addition, declines were larger in sea urchins, sea stars, and sessile invertebrates, and smaller in snails, and there was little sediment at the Far Impact site [TR F: Table 11]. For these reasons declines in areas with new sediment cannot alone account for the observed declines in large invertebrates at SOK relative to SMK. This is especially the case for effects at the Far Impact station.

If the new sediments are caused by SONGS, these results indicate that the plant had effects other than those identified in Table 9.1. For example, we found no evidence for a relative decline in sessile invertebrates near SONGS, yet this group was reduced in density by the new sediments (Table 9.2). Again, for reasons discussed above we were not able to estimate reductions in density of sea stars in SOK, relative to the Control site; however, this group also seems to be reduced in density by the new sediments.

The reductions observed in the abundance of large invertebrates in SOK are consistent with other observed effects of SONGS on the bottom environment (Chapters 7 and 8). These are associated with an increased flow of particles caused by the turbid plume [TR F: Table 10].

Table 9.2

Percent change in abundance attributable to new sediments at the Near Impact station.

GROUP	% CHANGE	STATISTICAL RESULT
Snails	-12.7	not significant
Non-muricid snails	-6.4	not significant
Muricid snails	-20.7	not significant
Sea urchins	-36.0	significant
Sea stars	-56.4	significant
Sessile invertebrates	-41.6	significant

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Chapter 10

PROJECTED BIGHT-WIDE REDUCTION IN ADULT FISH STOCKS*

Summary

SONGS kills several billion immature fish (eggs, larvae and juvenile fish) each year. (1) The immediate (short-term) effect of these losses is to reduce the number of new adults recruited into the adult population each year. (2) The long-term effect is to change, and probably reduce, the average size of the adult population itself, the "stock size," over many years.

The amount by which the stock is reduced (effect (2)) depends on the extent to which surviving individuals in the various stages of the life cycle do better ("compensate") at lower densities: i.e., live longer, grow faster, or produce more eggs. This is not known quantitatively for any population, and there are no data available for estimating it. In theory, perfect compensation is possible and adult stocks would not decline. We believe this is unlikely.

(1) With respect to short-term losses, we project significant reductions in adult recruitment as a result of SONGS operation. We express these losses as the reduction in the rate at which new adults enter the population in the Southern California Bight.

* The Technical Report (D) to the CCC was prepared by Mr. Keith Parker and Dr. Edward DeMartini. The Technical Report (M) to the CCC was prepared by Drs. Roger Nisbet, William Murdoch, and Allan Stewart-Oaten.

The largest projected loss, 13%, is in queenfish, which is the most abundant nearshore species in the area and important in the diet of sport and commercial fish species. The projection for white croaker is 6%. (Low, middle and high projections were made for these two species, and these are the middle and most likely projections.) Most other species suffer smaller losses (Table 10.1).

If the effect were to be spread over a smaller area than the Bight, the maximum potential proportionate loss would be correspondingly greater. For example, it would be equivalent to 100% of the new adult production of queenfish within about 60 km of SONGS, and to 100% of the new adult production of white croaker within about 30 km of SONGS.

(2) The long-term losses, expressed as a percent reduction in the average population in the Southern California Bight, are projected to lie between zero and the projected recruitment loss. Thus queenfish are projected to be reduced in population by between 0% and 13%. (Since queenfish is a "fodder fish", we expect much of this reduction to appear as a reduction in the abundance of predator species that feed on it.) Because individuals tend to grow faster when populations decline, the reduction in biomass should be smaller than the reduction in abundance, though we cannot estimate the difference.

We stress that, while we believe the projections are as good as can be made with the available data, they are qualitatively inferior to the estimates the MRC has made concerning SONGS' effects on other species. We are not able to give direct estimates of either short- or long-term reduction for any species. The figures we give are extrapolations supported by sampling data and models, but not by direct

TABLE 10.1

Estimated reduction in adult recruitment and adult standing stock in the Southern California Bight as a result of SONGS' operation.

Each number in this table is both (a) the projected short-term loss (percentage reduction in the annual recruitment of adults to the fish stock in the Southern California Bight) and (b) the projected long-term percent reduction in average abundance of adult standing stock in the Bight, caused by entrapment of immatures by SONGS. Each number is the middle projection for short-term losses, and is probably a higher rather than a lower estimate of the long-term reduction. ^{S} denotes sport fishery, ^{C} denotes commercial fishery, * indicates species suffering relatively high loss rates.

COMMON NAME	PERCENT
TAXA WHOSE JUVENILES ARE ENTRAPPED	
* Queenfish	13
* White croaker ^{S}	6
* California grunion ^{S}	5
* Black croaker ^{S}	4
* California corbina ^{S}	4
* Jacksmelt	3
Salema	0.4
Kelp and barred sand bass ^{S}	0.1
Northern anchovy ^{C}	<0.1

TAXA WHOSE JUVENILES ARE NOT ENTRAPPED

COMMON NAME	PERCENT
* Giant kelpfish	6.9
* Kelpfish (unid.)	5.0
Cheekspot goby	3.0
Reef finspot	2.9
Arrow goby	2.6
Diamond turbot ^{S}	2.1
Shadow goby	2.1
California clingfish	1.4
Blenny (unid.)	0.1
California halibut $^{S, C}$	0.1
Hornyhead turbot	0.1
Pacific mackerel ^{C}	0.1

measurements of the reductions. The models necessarily make assumptions about fish population dynamics, and adequate data do not exist to test these assumptions. Even very similar models can lead to quite different projections, and this is a major reason why we have provided a range of possible effects rather than a single best estimate. Such uncertainties are generic to fisheries biology.

Introduction

SONGS takes in and kills fish eggs, larvae and juveniles. Some of these individuals would have survived to become adult fish had they not been killed in the plant. The purposes of this chapter are to estimate (1) the short-term reduction in the rate at which new adults enter the population, and (2) the likely effects of these losses upon the sizes of the fish populations averaged over time, i.e., the long-term reduction in the standing stock.

It is important to stress at the outset that our estimates of these effects are much less certain than are our estimates of other SONGS effects. Indeed, we prefer to call these numbers "projections" rather than "estimates".

The difference is not merely a matter of greater variability or less precision. The projections of potential fish losses are qualitatively different because crucial components of both the short-term and the long-term projections are based not on data but on assumptions. These are plausible assumptions about unobserved natural processes, and we try to justify them in some detail; but other assumptions can lead to different projections.

The projected short-term losses due to SONGS-induced mortality of immature fish are expressed as the percentage reduction in the rate at which new adults are recruited to the population: "adult equivalent losses." To translate these short-term losses into projected effects on the adult population we need to consider how the fish population might respond, which is the issue of "compensation." This is discussed briefly in the next section.

Compensation and Long-term Effects

Unfortunately, unlike all other potential effects of SONGS examined by the MRC, direct sampling will not measure the long-term reduction of adult fish stocks as a result of the short-term losses. Because the immature stages of most fishes move a great deal, any effects on these species will be spread out over a large area, probably the entire Southern California Bight. Consequently there is no "Control" area with which the Impact area can be compared; and even a major effect will be so diluted that the change will be indistinguishable from natural variation.

Thus the only way for us to assess the effects of the killing of the immature stages is to try to convert the projected short-term changes in recruitment rates into changes in the population size, by means of models. But these models cannot avoid making key assumptions about some natural processes whose operation is almost completely unknown.

Collectively, these processes are called "compensation." If there were no compensation, then rates of birth, death, growth, etc., would be the same regardless of the density of the population. Then, in a population not already expanding, any decrease in the birth rate or increase in the death rate would lead to a decline that would continue until the population was extinct. Obviously this typically does not happen: many fish populations have supported large fishing industries without going extinct.

Birth and death rates do change when population density changes. In particular, if an external source reduces the birth rate or increases the death rate, the resulting decline in the population will usually lead to a secondary increase in the birth rate and/or a decrease in the death rate. Eventually the population will reach a new equilibrium, at which positive rate changes, caused by the decreased population, match (compensate for) the negative rate change caused by the external source. This compensation can arise in several ways, the most obvious being that some limiting resource, such as food or shelter, may become more freely available when the population is reduced.

It is clear that compensation frequently occurs, and the mechanisms by which it might act are well understood in a qualitative and general sense. What is almost completely unknown is the quantitative and particular information needed to assess potential SONGS effects on particular marine fish populations. For a particular population, we do not know how to determine the value of the new equilibrium abundance that will be maintained in response to the added mortality from SONGS. (Extinction is a possibility, but we think it extremely unlikely.)

An additional complication is that some of the most heavily affected species are fodder fish for larger predators, many of which are sport or commercial species. Losses in fodder fish recruitment are likely to appear partly as a reduction in the abundance of the predator species that eat them, to an extent depending on such factors as the predator's ability to compensate or to vary its diet. Thus the actual losses in queenfish (a fodder fish) across the Bight seem likely to be smaller, and losses in sport and commercial species to be larger, than would be expected on the basis of immature entrapment alone.

Our projections of long-term reductions depend heavily on our assumptions concerning compensation. These are discussed in the next section.

Assumptions and methods of calculating projections

Short-term Effects

The number of new adults recruited into the population each year depends in part on the number of adults already there, since it is their reproduction that leads to the new adults. The short-term effect of SONGS-induced mortality on immature fish will be a change in the *rate* at which new adults are recruited, i.e., a change in the ratio of the number of new adult recruits to the number of adults already present.

The Size of the Affected Population

The number already present in a population depends, of course, on what we choose to designate as "the population," i.e., on the size of the area over which the losses are spread. Because eggs and larvae are transported by water movements, losses are expected to be spread over all or most of the interbreeding population.

The area covered by this population varies among species and is usually not known precisely. This report is made clearer by using a single area for all species, and we chose this area to be the Southern California Bight (the area between Point Conception and Cabo Colnett in northern Baja California).

The Bight is a convenient natural feature, and although some affected species extend further, the larvae killed by SONGS will almost all have been born inside the Bight and the losses are unlikely to be significant outside it. The choice is mainly one of convenience: if we had chosen a larger or smaller area, the percentage losses would be smaller or larger respectively, but would give the same values when converted into numbers of adults lost in any given year.

<u>Calculation of Losses</u>

To project adult equivalent losses for a species we need to know (a) the fraction of the bight-wide population of each immature stage that is entrapped each day by SONGS, and (b) the number of days each stage lasts. The losses for each stage are then combined, following the methods described in *Technical Report D*.

Calculation of (a) is the more difficult problem. We assume that eggs and larvae cannot actively avoid SONGS intake if they are in water being taken into the plant. The fraction entrapped each day is the number taken in by SONGS per day, divided by the total number in that stage in the Bight. The number entrapped per day is the estimated density of the stage in the water taken in by SONGS, which comes from the nearshore region, times the volume of water taken in per day. The total number of the stage in the Bight is estimated by multiplying the density of the stage in a meter-wide strip of water extending from the shore to the outer limits of the stage's offshore distribution, by the number of such strips in the Bight (500,000). The density of the immature stage in these two regions - the nearshore withdrawal zone and the wider offshore zone - is estimated from MRC's extensive sampling program (Chapter 13).

Estimation of entrapment rates of juvenile fish is much more problematical in some species: we do not have reliable estimates of their density, and juveniles can avoid entrapment to an unknown degree. Of the 21 species for which there are adequate data on eggs and larvae, 12 do not occur as juveniles near SONGS' intakes and are only rarely entrapped as juveniles; thus no estimate of juvenile losses is needed for these species.

For two of the remaining nine species (white croaker and queenfish), there are good estimates of the entrapment rates of the oldest larval stage and of the youngest adult fish (one-year olds). It seems reasonable to assume that, in vulnerability and availability, early juveniles are like late larvae, and late juveniles are like young adults. Entrapment rates for juveniles between these ages are likely to decline with length since (i) swimming speed, and thus the ability to resist withdrawal into the intakes, increases, and (ii) the preferred habitat becomes more like that of the adults, which is further from the power plant than is the habitat of late larvae.

There are many different mathematical functions that could describe the decline in entrapment rate as fish size increases, all fitting the above basic description. We have no data allowing us to choose among these functions, but the juvenile stage is so long and important that different functions lead to very different projected losses. We have dealt with this by giving "high", "middle" and "low" projections. The details are presented in *Technical Report D*.

No estimate of juvenile losses is possible for the remaining species whose juveniles are entrapped, because we do not have estimates of the entrapment rates of their adults. The juveniles of these species, however, are much less susceptible to entrapment, relative to their larval stages, than are queenfish, because they move away from the intake depth and nearer to the bottom.

Long-term Losses

As noted in the Introduction, there is almost certain to be compensation. What is not at all certain are the mechanisms by which, or the stage in which, compensation will occur, or the amount of decline needed for compensation to balance the additional mortality caused by SONGS. Failure to answer such questions have dogged all efforts to estimate the effects upon adult marine fish stocks of human activities that kill early stages.

To determine how the addition of SONGS-induced mortality on immatures is likely to affect adult abundance of fish populations showing one or other of a number of compensating mechanisms, we examined several simple models of fish population dynamics (*Technical Report M*). These simple models are not meant to portray the dynamics of fish in accurate detail, though fish populations probably behave in broadly the way described by the models. We looked at four types of compensatory mechanisms. The first three relate to species that are not mainly food for other species.

Case 1. *Responses by adults.* (a) Adults experience higher fecundity at lower adult density. (b) Adult survival may increase when there are fewer adults.

Case 2. *Response by immatures to adult density.* (a) Cannibalism of immatures by adults decreases as adult density decreases. (b) Survival of immatures is higher at lower adult density (e.g., each egg may be larger).

Case 3. *Response by immatures to immature density.* (a) SONGS imposes substantial mortality on both the planktonic and the juvenile stages, and both stages survive better at lower densities. (b) SONGS imposes substantial mortality on the planktonic stages but not on the late juveniles; however, the late juveniles can compensate for this early mortality by surviving better at lower densities. (c) Cannibalism of planktonic stages by juveniles decreases as juvenile density decreases.

Case 4. *Predation by other species.* This case differs from the other three in that the affected species is fodder fish, i.e., it is a major prey item for a predator (e.g., a sport/commercial) species. Our main concern here is whether SONGS-induced mortality affects the average long-term abundance of the fodder fish or of the predatory fish.

We also considered the case where several of these mechanisms operate together.

Case 3(b) requires particular comment. In this case, the adult stock can show no change ("perfect" compensation) or can even increase ("overcompensation"). A hypothetical example of perfect compensation is a species in which each adult must have a "home" (e.g., a shelter) in order to survive and reproduce. If there is a fixed number of homes, then juveniles in excess of this number are superfluous: they cannot become adults because there will be no homes for them. Thus a power plant that kills juveniles will have no effect on the adult population provided enough juveniles survive to fill the homes.

Over-compensation could occur if, when the early stages are too numerous, they deplete the food supply so that they later starve. If an external source kills some of the early stage individuals, the increased success of the survivors may lead to larger numbers reaching adulthood.

However, these results seem unlikely because the mechanisms that could produce perfect or overcompensation probably do not occur in the fish species in question. The scanty evidence available suggests that species like those we are concerned with can increase their fecundity, perhaps the survival of the larval stages, and possibly the survival of adults, when their adult abundances are lowered. But this means that a reduced adult population is a pre-condition for compensation to operate. Thus compensation cannot lead to an unchanged or increased number of adults [TR M: 3.4].

Projected short- and long-term losses

Short-term Losses

Table 10.1 presents the estimated percent reductions in the rate at which new adults are recruited to the Bight-wide populations of fish. In the case of queenfish and white croaker these are the middle of low, middle and high projections.

The largest percentage reduction is in queenfish, and is about 13%; the low projection is 10% and the high projection is 17%. In white croaker the low and middle projections are 6% and the high projection is 8%. In seven species the reduction is around 5% (white croaker, black croaker, California corbina, California grunion, giant kelpfish, unidentified kelpfish, and jacksmelt). Seven species have losses of less than 1%, including several such as northern anchovy, kelp and barred sand bass, halibut, and Pacific mackerel that have minute losses (Table 10.1).

Some perspective on these losses can be gained from the following considerations. First, the most valuable sport/commercial species, the halibut, is hardly affected because its immatures are rarely entrapped. This holds true also for Pacific mackerel, another commercial species. Second, the species with the greatest potential losses, queenfish, is not a sport or commercial species, though it is an important source of food for species that are. Third, several species with moderately high adult-equivalent losses (in the 5-7% range) are mainly fodder fish but are also fished for sport.

Long-term Effects: Projected Changes in Fish Stocks

The projected effects of these short-losses on standing stocks of adult fish in the Bight were calculated using the models summarized above. Except for Case 3(b), the models all provide the same qualitative answer: *compensation does not prevent the abundance of adult fish from declining to a lower average level except under unlikely conditions.* Case 3(b) does allow the standing stock to stay the same ("perfect" compensation) or even to increase ("overcompensation"), but there is no evidence that it can occur in the species affected by SONGS.

The models cannot give detailed insight into how much the average abundance in the Bight will be lowered. However, quite reasonable assumptions lead to a reduction in average abundance by a proportion equal to the additional mortality imposed by SONGS (thus each number in Table 10.1 is a projection of both short-term and long-term losses). That is, if SONGS kills 10% of the immatures, there could be a reduction of 10% in the affected population. Reasonable assumptions, however, would also allow the percent decrease in average abundance to be greater or less than 10%. *There is thus a great deal of uncertainty in the projections of Table 10.1 since different populations have different compensatory abilities.*

When more than one compensatory mechanism is operating (especially if one compensation is via adult survival), the same reasonable assumptions suggest that the reduction could be about half of the reduction when only one mechanism operates. Thus, if SONGS kills 10% of the immatures, there could be a reduction of

5% in the affected population. The percentages in Table 10.1 are therefore likely to be higher rather lower than the actual reductions.

In the special case of "fodder fish", such as queenfish, that are major food items for piscivorous sport/commercial species, it is likely that the SONGS-induced mortality on immatures will lead to a decrease in the production of adults available to the sport/commercial species. This will in turn "transfer" much or most of the potential reduction in the adult population from the fodder fish to the sport/commercial species. The extent of this transfer will depend on the importance of the fodder fish to the sport/commercial species in question. Too little is known about the diets of these species, and their flexibility in using other options, for us to make numerical projections. This difficulty is especially marked for queenfish, which is almost entirely a fodder fish, but it also applies to white croaker and sport/commercial species, which are eaten by piscivorous fish but are also sportfish species. In acknowledgement of the absence of good information on this subject, Table 10.1 presents losses without any allowance for a transfer to other species.

The percent reduction in biomass is likely to be smaller than the reduction in abundance, since individual adults are likely to grow bigger in a reduced population. We have not attempted to estimate the reduction in biomass.

Overall Conclusions

SONGS-induced mortality on immature fish has the potential to have ecologically significant effects on the standing stock of some species in the Southern

California Bight, particularly white croaker and queenfish. The immature mortality could lead to reductions of a few percent to around 10% in the adult populations of these fish in the Southern California Bight. In the case of white croaker, for example, a 5% reduction would represent about 3 million fish and 300 tons.

Reductions in abundance could be lower than these projections. However, it seems most probable that some effects will occur, and the assumptions leading to these projections are not unreasonable.

A similar degree of uncertainty pervades the evaluation of almost any single human action that causes mortality or reduced reproduction or growth of marine fish. Yet the cumulative result of such actions over the past several decades has been the decline of many fish populations in the California Bight. For this reason the MRC believes, in spite of the uncertainty concerning the populational effects of deaths of immature fish in SONGS, that we should proceed on the assumption that the losses are only partially compensated, and that there are significant reductions in standing stocks of several species.

Chapter 11

LOCAL FISH POPULATIONS*

Introduction

MRC sampled the three major fish communities in the SONGS area: fish living up in the water column ("midwater fish"), those living on or close to the sandy bottom ("bottom fish"), and those associated with kelp beds. This report discusses the first two communities; the kelp bed fish are discussed in Chapter 8. Readers wishing a more detailed account of the results than is presented here should turn to the *Interim Technical Report: 3. Midwater and Bottom Fish.*

Little mention was made in the public hearings of the likely effects of SONGS on the local fish fauna, other than the fact that large amounts of fish would be taken into the plant. The Permit also discussed intake losses and estimated they would be between 14 and 70 tons per year. The uncertainty in these figures mainly reflected the fact that the design of Units 2 and 3 included a new and untested Fish Return System intended to return fish live to the ocean. No mention was made in the hearings or Permit of the possible effects of these losses upon the local abundance of fish.

It is by no means self-evident that reductions in *local* fish abundance should occur as a result of intake losses. Midwater fish are mobile, and immigration might

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* Drs. Ed DeMartini, Ralph Larson and Larry Allen carried out the scientific studies of fish populations on which this report is based. Dr. DeMartini prepared the Contractor's Final Report. The Interim Technical Report (3) to the CCC was prepared by Dr. Jon Kastendiek and Mr. Keith Parker. Drs. Susan Swarbrick and Richard Ambrose prepared the Technical Report (C) to the CCC.

spread the effect of local losses. Indeed, the major outside expert on assessing effects of power plants on fish populations advised that we would not be able to detect local effects on these populations.

The MRC (in its 1980 report to the CCC: *Predictions of the Effects of San Onofre Nuclear Generating Station, and Recommendations*) predicted that there would be a local reduction in the abundance of young queenfish, an abundant midwater species.

MRC thought it possible that SONGS might increase the abundance of some bottom fish in the area. The plant was expected to increase the organic matter reaching the bottom, largely through the conversion into detritus of organisms taken into the plant, and hence to increase the populations of detritus-feeding species, upon which the fish feed. Since bottom fish are thought to be more sedentary than midwater species it seemed possible that we might see a local increase in their density, since gains would not be completely dissipated through emigration.

The Fish Fauna

Sixty six species of fish were sampled during the two years of Before and three years of After midwater sampling [ITR 3: Appendix C]. These included all of the abundant species in the area. Among the ten most common species only the northern anchovy is a major commercial resource, although Pacific mackerel, Pacific barracuda and white croaker are sport fish. The remainder of the abundant midwater fish are typically small schooling species that are important as food for larger sport and commercial species. The two most abundant species are northern anchovy (63%) and queenfish (16%), which together account for about 79% of all fish caught in midwater sampling [ITR 3: Table 5]. The queenfish and white croakers found in the midwater are generally younger individuals; older and larger members of these species are found close to the bottom, where they are sampled as bottom fish. These two species are nearshore fish while the anchovy is widespread and is also abundant in offshore waters.

The midwater fish assemblage changes between MRC's shallow-water (5-10 m) and deep-water (11-16 m) stations [ITR 3: 7]. Although anchovy dominates in abundance and queenfish and white croaker are common at both depths, larger pelagic predatory fish, such as Pacific mackerel and jack mackerel, become relatively common only in the deeper water.

It is in the bottom fish community that we find many species of sport and commercial fish such as halibut, turbot, and sanddabs, together with the larger bottom-oriented individuals of white croaker and queenfish. Sixty-eight species of bottom fish were sampled over the two-year Before and three-year After sampling programs [ITR 3: Appendix F].

Intake Losses

We estimate that SONGS takes in at least 5.9 million fish (45 tons) per year. Of these, we estimate that at least 21 tons die in the plant [TR C: 3.3]. These estimates were made during a period (1983-86) when the abundance of most species in the SONGS area (except anchovy) were reduced below their previous level. If fish numbers over the long term are similar to the preoperational levels, the estimated annual intake increases to about 121 tons and the weight killed in the plant increases to about 57 tons per year [TR C: 4.2]. Eighty-four species of fish were taken into the plant between May 1983 and August 1986 [TR C: Table 8]. The minimum estimated annual losses are summarized in Table 11.1 [TR C: 3.3 & 4.2].

Table 11.1

Estimated annual intake losses (in tons) at SONGS.

		ENTRAPPED	KILLED
1983-86	Unit 1	4.6	4.6
	Units 2 & 3	40.6	16.5
	Total	45.2	21.1
Long term total		122	57

The basis for these minimum estimates of losses due to SONGS is outlined below.

The minimum estimate of total intake (entrapment) of fish by SONGS, 45 tons, is based on sampling at Units 2 and 3 during the 1983-1986 period. During that period, we estimate that these two Units entrapped 5.6 million fish (almost 41 tons) each year, of which over 4 million were anchovy.

Our estimate of intake of fish at Units 2 and 3 is equal to the sum of our estimates of the numbers of fish impinged on the screens that prevent their entry into the cooling system, those that are diverted before they reach the screens to the Fish Return System (FRS), and those killed in heat treatments. Some small fish will pass through the screens, which have a mesh size of 3/8", in Units 2 and 3. While these fish may be numerous, they are not likely to increase substantially the estimated weight of fish killed [TR C: 4.1].

Two steps were taken in estimating entrapment at Unit 1 [TR C: 2.3.2]. Because the larger-mesh screens at Unit 1 allow more small fish to pass through, entrapment at Unit 1 of northern anchovy, queenfish and white croaker, the three most abundant small species, was estimated from their entrapment at Units 2 and 3. Entrapment of all other species was estimated from their entrapment at Unit 1.

Our minimum estimate of 21 tons of fish killed assumed that all fish (4.6 tons) that enter Unit 1 will be killed (since there is no Fish Return System for that Unit), but takes into account the fact that some of the fish diverted by the Fish Return System of Units 2 and 3 will survive. The fraction surviving transport through the FRS varies from species to species, and large fish generally survive transit better than small fish. Queenfish and white croaker, two small species of interest, survive entrapment quite poorly (68% and 48% respectively) [TR C: Table 17]. All together, we estimate that 16.5 tons out of the 41 tons of fish taken in by Units 2 and 3 are killed [TR C: 3.3].

The intense El Nino episode of 1982-84 depressed the abundance of many fish species in the general area over much of the 1983-86 sampling period, and intake rates were therefore lower than can be expected over the long term. If we assume that the abundance of fish in the SONGS area will in general reach its preoperational level, total intake should increase to about 121 tons and total losses in the plant to about 56 tons [TR C: 4.2].

If the average pumping rates were to increase on average in the future, the rate of entrapment could also be expected to increase.

The bulk of fish entrapped by Units 2 and 3 (97% by number, 54% by weight) are anchovy, queenfish and white croaker [TR C: Table 11], which are the three most abundant species in the midwater. These small species are at much greater risk of entrapment than are larger, stronger-swimming, predatory, pelagic fish, such as the mackerels, which are at low risk and are only rarely entrapped. Among entrapped species, small individuals are at greater risk, and make up the great majority of those taken into the plant.

It is not known whether fish that survive transport through the Fish Return System of Units 2 and 3 are thereafter more susceptible than other fish to mortality factors in the ocean. However, it has been observed that some individuals were eaten by predatory fish as they came out of the system, and predatory fish have been seen congregating near the exit port. It is not possible to estimate what fraction of the fish suffer increased mortality as a result of their sojourn in SONGS.

Some perspective on the estimated annual losses can be gained by using white croaker as an example, since it is a commercial and sport fish species. Each year SONGS has taken in and killed about 130,000 white croaker, with a total weight of about 1 ton [TR C: Table 11]. Taking El Nino into account yields an estimate of around 350,000 individuals. These are, however, very small fish and, under natural mortality rates, would have yielded about 175,000 mature individuals (i.e., one year olds) and about 33,000 3.5 year-olds, which is the average age of fish when they are caught. These 33,000 fish would weigh about 3.5 tons. For comparison, over the last 8 years the average annual catch of this species in southern California has been 150 tons by the commercial fishery and 350 tons by the sport fishery.

Changes in Local Density of Midwater Fish

The MRC sampling program was based on the possibility of a local negative effect on midwater fish, via losses in the plant, although we could not predict its extent. Lampara net samples were taken at three distances from SONGS: "Near-Impact," which was within 1 km of the intakes, "Far-Impact" at 1.5-3 km south of the intakes (i.e., just south of San Onofre kelp bed), and Control at 18-19 km south of SONGS. At each station, samples were taken in shallow (between a depth of 5 m and 10 m) and deep (at 11-16 m) water (Figure 11.1). There are thus four Impact stations: a Near and a Far in both shallow and deep water; and there are therefore four comparisons that can be made between Impact and Control stations (two for the shallow stations and two for the deep stations).

There were substantial reductions in the relative abundance of two midwater fish species near SONGS (Table 11.2), and evidence that reductions might be widespread among other species in this group of fish. It is useful to separate the results into three groups.

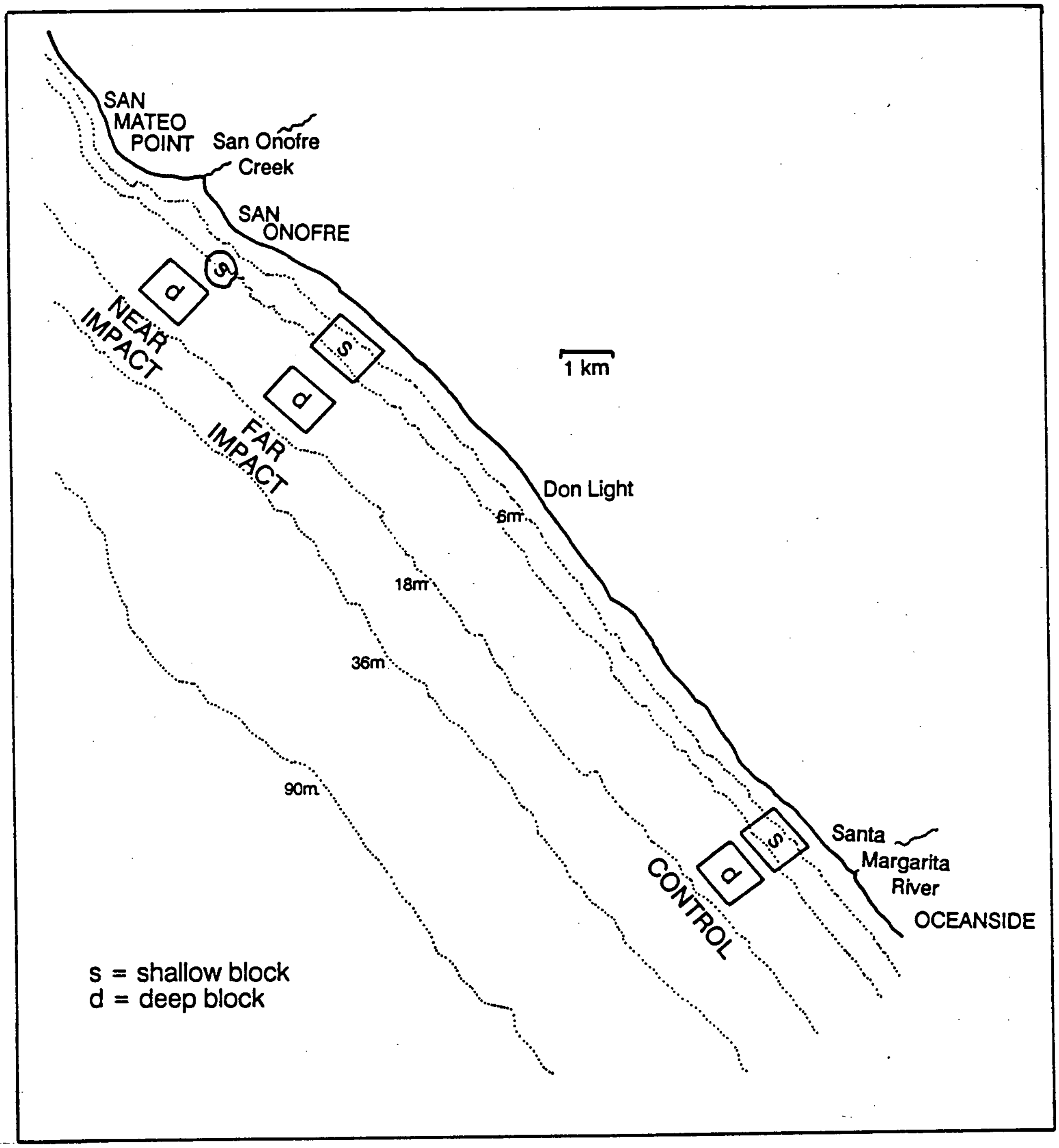

Figure 11.1. Chart of the general San Onofre area. Noted are the locations of the lampara seine stations. Bottom contours and sampling depth are noted in meters below MLLW.

Table 11.2.

Statistically significant (and nearly significant) changes in density of midwater and bottom fish at SONGS in association with operation of Units 2 and 3.

NC indicates no statistical change could be detected. Last column shows the percentage contributed by each species or group (by number) to total fish abundance in each habitat. It is given simply to indicate the general abundance of the species affected.

SPECIES OR GROUP	% RELATIVE CHANGE SHALLOW 1 km	SHALLOW 2-3 km	DEEP 1 km	DEEP 2-3 km	% OF TOTAL
A. Midwater Fish					
Queenfish	-61	(-34)	-50*	-70	16
White croaker	-63	(-36)	NC	NC	3
Silversides (3 species)	NC	+ > 100	NC	NC	5

B. Bottom Fish	SHALLOW	DEEP	% OF TOTAL
White croaker	NC	+ > 100	28
Queenfish	(+80)	+ > 100	12
Longfin sanddab	+ > 100	NC	7
Lizardfish	+ > 100	+37	1
Fantail sole	NC	+39	1
Speckled sanddab	-40	NC	7
Hornyhead turbot	-20	NC	2
Bigmouth sole	NC	-62	1
Total weight	+57	+ > 100	

* No statistical test is possible for this change, but the result can be accepted because of the large decrease even further from the plant.

Note: Increases of more than 100% are indicated by + > 100.

First, there are three species for which statistically reliable conclusions can be reached. Among these, two common nearshore species, queenfish and white croaker, were markedly reduced in relative density. In shallow water the queenfish and white croaker declined by about 60% within 1 km of SONGS, and by about 35% out to 1.5-3 km from SONGS. In deep water, queenfish were reduced by 50%-70%, out to 1.5-3 km from the plant [ITR 3: 12-16]. There was no statistically significant change in the abundance of the third species, the anchovy, which is the most common species in the SONGS area. Decreases in anchovy of 40%-60% (depending on the sampling station) would have been detected statistically had they occurred. Disregarding statistical considerations, three stations saw increases in relative abundance of this species, and the fourth saw a relative decrease [ITR 3: 11-12, Table 6].

Second, one species group, the silversides, showed a large relative increase (more than 100%) in density at one station - shallow water at 1.5-3 km from SONGS [ITR 3: 17].

Third, a group of six additional species were common enough for us to measure "tendencies" to change in relative abundance at one or more of the four Impact stations, although the individual changes cannot be tested statistically. This group consists of three predatory pelagic species (jack and Pacific mackerel and Pacific barracuda), salema, and walleye and white seaperch. These species showed mostly relative declines at the stations where they occurred. Adding the relative increases and decreases shown by these species to those shown by the four species discussed in detail above, there were 29 relative decreases and only 8 relative increases in this group of midwater fish at the various sampling stations [ITR 3:

Table 5]. This is a statistically significant imbalance of decreases over increases. These species, combined, constitute 94% of the fish caught in lampara samples. There is thus a general pattern of relative decreases near SONGS.

Losses in the plant no doubt contribute to the local declines in queenfish and white croaker. These two species are the most at risk to entrapment and the poorest survivors once entrapped. Calculations suggest, however, that losses of adult fish in the plant cannot account for much of the observed local declines (see below).

Changes in Local Density of Bottom Fish

Trawl samples for bottom fish were taken at two Impact stations (one in shallow and one in deep water) within 1.5 km of SONGS, and at two Control stations (one in shallow and one in deep water) 17-20 km south of the plant. The shallow stations were at the 18 meter depth and the deep stations were at the 30 meter depth, to bracket zones where the discharge plume might have its impact (Figure 11.2). Several bottom species were also sampled by lampara net.

Among bottom fish, there was a general tendency for relative abundance to increase near SONGS. Eight individual species, including queenfish and white croaker, showed changes in relative density near SONGS that were statistically significant (or nearly so); five showed increases, three decreases (Table 11.2) [ITR 3: 22, Table 11]. The total weight of bottom fish increased relative to the control, by

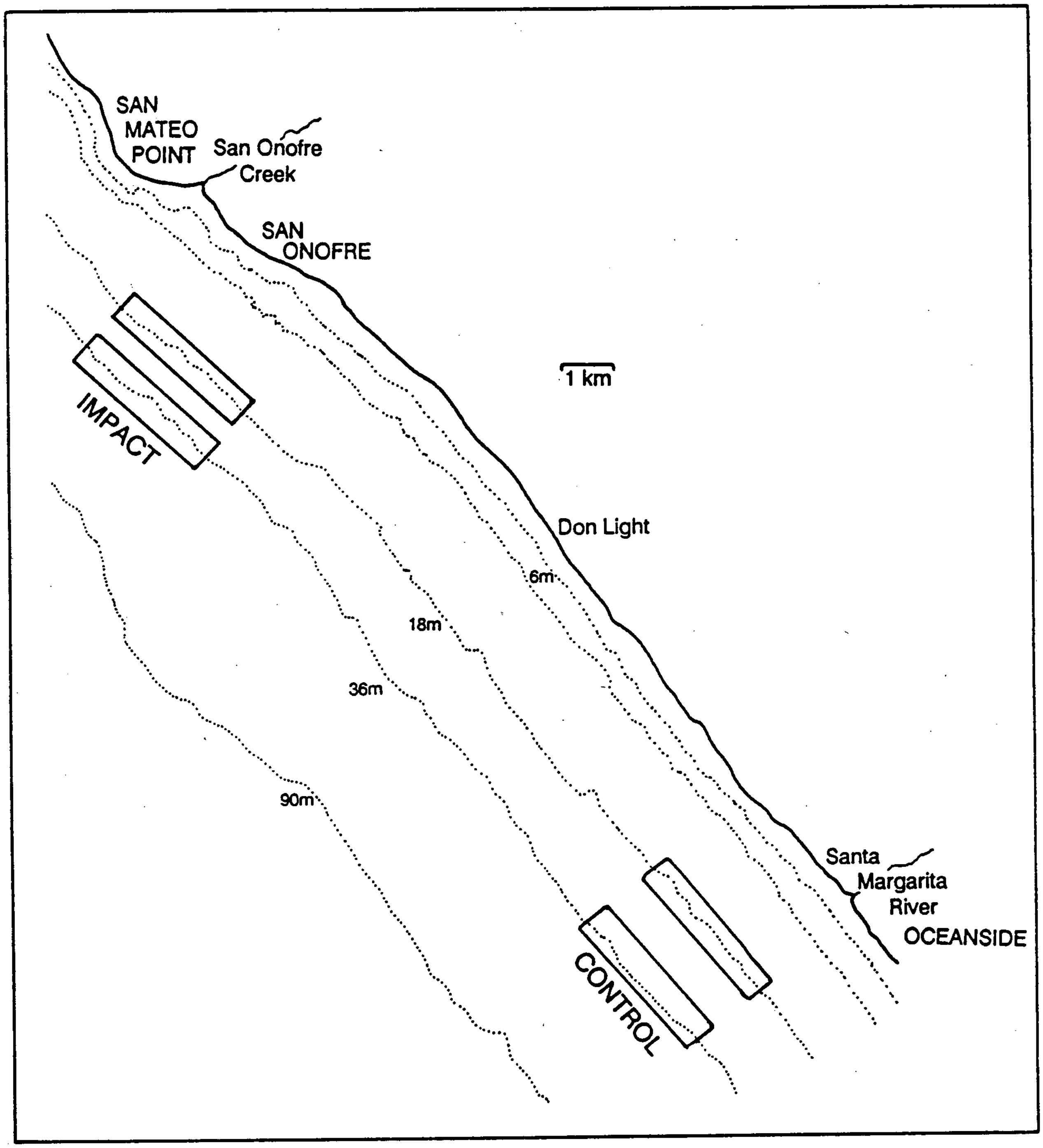

Figure 11.2. Chart of the general San Onofre area. Noted are the locations of the benthic trawl stations. Bottom contours and sampling depth are noted in meters below MLLW.

about 60% in shallow water and more than 100% in deep water[1] (Table 11.2) [ITR 3: Table 11].

An additional 16 species occurred often enough at one or more stations that we can measure tendencies to change in relative abundance. These include four species (halibut, corbina, bat ray and cuskeel) that also occurred frequently in lampara samples. Adding these changes to those observed in the eight species discussed above, there were 36 relative increases and 16 relative decreases, a statistically significant imbalance of increases over decreases. The 24 species in this combined group constitute 97% of the fish caught in trawls [ITR 3: 29, Table 9-11].

Concurrent MRC studies of animals living in soft bottoms show that the density of some groups increased near SONGS relative to Control sites (Chapter 14). The increase in the abundance of some fish species may be related to the increase in this type of food.

Comparison of gains and losses among local fish populations

Technical Report N presents calculations converting the above estimated relative percent losses (in the water column) and gains (on the bottom) of queenfish and white croaker into estimates of weight lost or gained. However, we do not present these calculations here because the assumptions needed to make these estimates are too uncertain to produce reliable estimates of the weight of fish lost and gained in the two habitats.

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[1] Dr. Fay doubts that SONGS has an effect at a depth of 30 m.

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Chapter 12

PLANKTON*

Zooplankton

Zooplankton are small animals that drift in the water. They feed mainly upon the tiny plants - the phytoplankton - that are the basis of the marine food web (although some zooplankton feed on other zooplankton). In turn, zooplankton are fed upon by fish and other organisms that ultimately support most of the sport and commercial fish species in the oceans.

The zooplankton may be subdivided into three groups: 1) those that spend all their lives as plankton (holoplankton), 2) the early stages of species (such as barnacles and clams) whose adult stages live on the ocean floor (meroplankton), and 3) the larvae of many fish species. The last group is sufficiently important that it was studied in a separate program (see Chapter 13); the first two groups are discussed together here. A more detailed account of the results (including those for phytoplankton) is given in the *Interim Technical Report: 4. Plankton.*

As noted in Chapter 2, experts at the public hearings predicted severe and widespread declines in the abundance of zooplankton, and especially of meroplankton, mainly because of their possible transport offshore by SONGS' discharge plume. This concern was the major motivation for the creation of the MRC. In a report to the CCC *(Predictions of the Effects of San Onofre Nuclear*

* Dr. Arthur Barnett (Marine Ecological Consultants) carried out the scientific studies of plankton on which this report is based, and also prepared the Contractor's Final Report. The Interim Technical Report 4 to the CCC was prepared by Dr. Jon Kastendiek and Mr. Keith Parker.

Generating Station, and Recommendations (1980)), the MRC concluded that the evidence was not adequate to make firm predictions that such adverse changes in abundance would occur.

The zooplankton were sampled at an Impact site 0.3 km north of the Unit 2 diffuser, and at a Control site 12 km south of the plant (Figure 12.1). Samples were taken using the BACIP design at Impact and Control both in the Before and After periods (Chapter 5).

The zooplankton were sampled over a 5-year period before Units 2 and 3 became operational, and for three years afterwards [ITR 4: Appendix C]. During the operational period we concentrated samples into those periods when SONGS was operating well above its average level, so if an effect were to occur we should be more likely to catch it.

Intake Losses

We estimate that about 1350 tons dry weight of zooplankton are taken into the intakes each year. This total is made up of 1000 tons of the zooplankton groups analyzed in our samples, plus an estimated 350 tons of very small individuals - the microzooplankton, which we do not sample [ITR 4: 20-21, Appendix K]. The latter estimate is based on results of sampling for this group in the nearshore near La Jolla. The 1000 tons estimate matches the MRC 1980 prediction. Although this is a large loss, it is clearly not sufficient to cause a local depression in the zooplankton, as we discuss below.

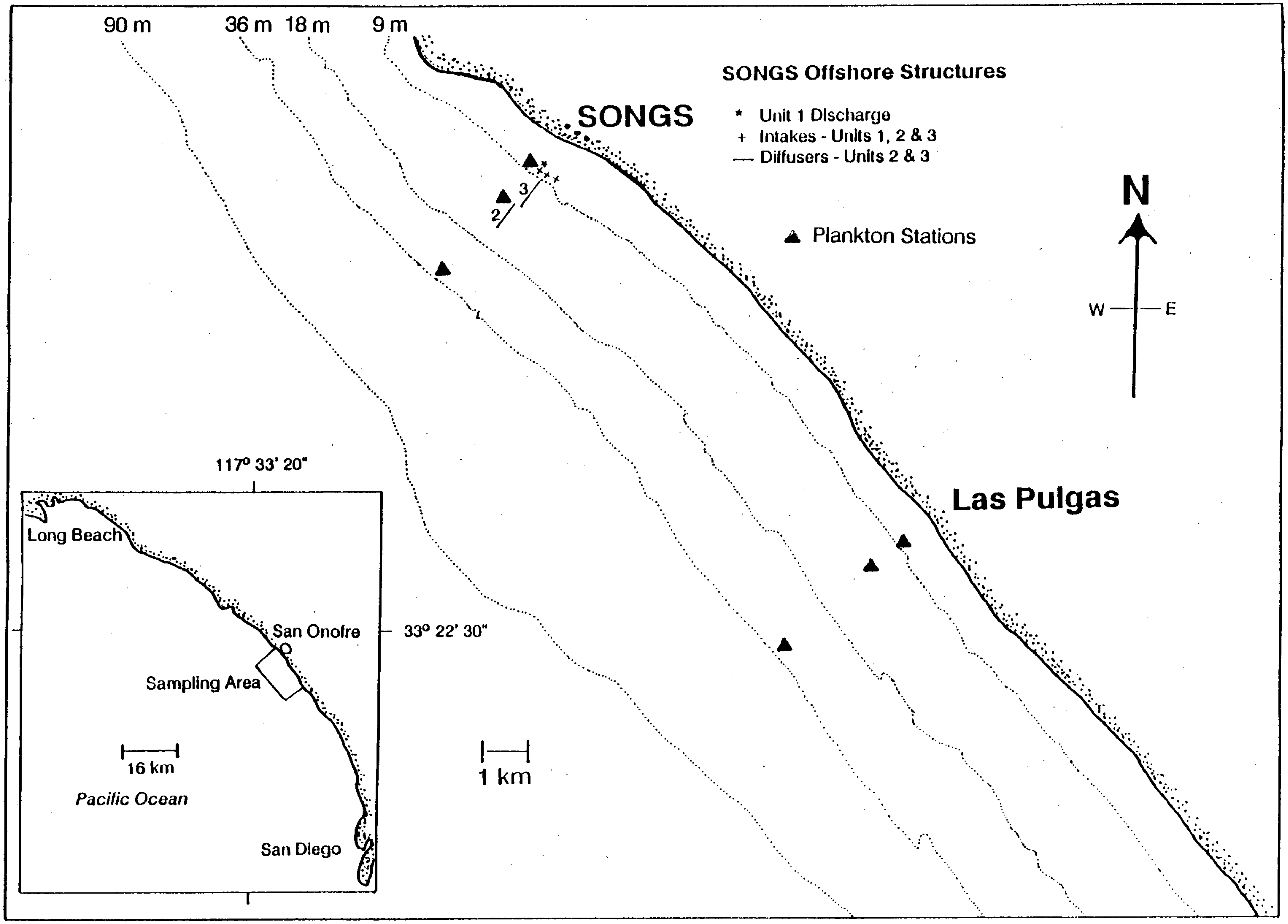

Figure 12.1. Locations of stations sampled for plankton.

Changes in Abundance[1]

Contrary to expectations, the plant appears to have increased the local abundance of meroplankton, and to have had no effect on the remaining zooplankton - the holoplankton.

The abundance of meroplankton (which comprise about 6% of the zooplankton) increased at SONGS relative to Control by about 60% on average (Table 12.1) [ITR 4: 12-13). Within meroplankton, the three subgroups examined tended to increase (Table 12.1). Our confidence that these increases are SONGS effects is increased by the fact that they remain when we examine data only from dates, both before and after operation, when the plume was passing over the Impact area, and sometimes disappear when the plume was moving in the opposite (south) direction.

Table 12.1

Statistically significant, (or nearly significant), changes in abundance of zooplankton at SONGS relative to the Control site in the operational period. The second column gives the percentage that each group contributes to the total zooplankton abundance.

SPECIES OR GROUP	RELATIVE % CHANGE	% OF TOTAL
Meroplankton	+64	6.3
Barnacle nauplii	+ >100	0.4
Bryozoan larvae	(+38)	2.4
Unidentified meroplankton	(+68)	3.5

[1] Dr. Fay does not agree with the conclusions in this section.

The holoplankton constitute the remaining 94% of the zooplankton [ITR 4: 13]. SONGS had no effect on the holoplankton as a group. This result was independent of the direction of the current. Eighteen species or species groups of holoplankton were studied individually, and statistically significant changes were observed in one uncommon genus of holoplankton (*Evadne*) [ITR 4: Table 2]. The changes seen in this genus may be unrelated to the plant's operation and are discussed in *Interim Technical Report 4*.

No other species showed statistically significant changes, although nine showed a tendency towards a relative increase and three showed a tendency towards a relative decrease [ITR 4: Table 2]. Early predictions were for a greater than 50% local decline in abundance of zooplankton populations; but for the holoplankton as a group and the meroplankton as a group, we can state with statistical confidence that a 50% decline did *not* occur. The same can be said, individually, for a set of 12 species and species groups [ITR 4: Appendix J].

Reasons for the Absence of a Reduction in Zooplankton

As noted in Chapter 2, the primary motivation for the creation of the MRC was a concern that severe and widespread reductions in zooplankton abundance would occur as a result of SONGS' operation, and that this in turn would result in a nearshore marine "desert." The results discussed above show that in fact no substantial changes have occurred in the zooplankton, and we provide here the likely reasons why this is so.

Two mechanisms by which SONGS might reduce the zooplankton were envisaged at the original hearings. The first was direct killing of zooplankton taken into the plant. It is now clear that this is not a feasible mechanism for producing local depressions. For example, under typical conditions, a sample of seawater taken from the discharge plume about 1 mile downstream of the plant will consist almost entirely of unaffected water; only about one-fortieth of the sample will have passed through the plant. If we think of the plant as removing all organisms from the water that passes through it, thus diluting the concentration of organisms in the area, the dilution is thus only a few percent one mile downstream. No feasible sampling program would be likely to detect such a reduction amidst natural variation.

The second and major mechanism by which SONGS was expected to reduce zooplankton abundance was by transporting them offshore to an inhospitable environment where they would die. There are now two reasons for believing that this is not a cause for concern. First, the zooplankton data were examined to see whether the distribution shifted offshore in the diffuser zone and beyond it (such a shift would not prove there was transport, but it would be consistent with it). In fact, the only changes observed were in the opposite direction; i.e., they were increases in the diffuser zone relative to the zone just offshore. Second, studies of the plume (Chapter 6) show that the movement of water offshore is less than was expected; thus plankton do not appear to have been transported to unsuitable habitat.

Similar arguments should apply to fish larvae, and this is a reason that we have difficulty in explaining the effects that were observed in a small fraction of these species (Chapter 13).

Phytoplankton[2]

The MRC also looked for effects on the phytoplankton (the single-celled plants that are the basis of much of the life in the oceans), by measuring the concentration of the plant pigment, chlorophyll, in sea water. This study used the BACIP design, and the sampling stations were the same as for zooplankton. There is good evidence that SONGS has not reduced the local abundance of phytoplankton: no statistically significant change was detected [ITR 4: 16] and, ignoring statistical considerations, there was an increase in relative concentration near SONGS [ITR 4: H-27].

[2] Dr. Fay does not agree with the conclusions on phytoplankton.

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Chapter 13

FISH LARVAE*

A more detailed account of the results concerning the local effects on fish larvae and eggs can be found in the *Interim Technical Report: 5. Fish Larvae and Eggs*.

Most species of marine fish release sperm and eggs into the water, the eggs are fertilized, and the young stages drift in the water column with other plankton. A small supply of yolk sustains these larvae initially, but they gradually develop and begin to feed actively on other planktonic organisms. After one to three months they develop to a stage at which they look like very small adults, and can actively swim, at which time they are no longer considered plankton.

Fish larvae drift through the SONGS area and are sucked into the plant with other planktonic organisms. During the Permit Hearings and in the Permit, fish larvae were included (in passing) with other zooplankton as being especially vulnerable to the operation of the plant. Offshore transport and consequent death, in addition to losses via passage through the plant, were again the mechanisms that were expected to lead to severe and widespread declines in fish larval abundance around SONGS (Chapter 2).

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* Dr. Arthur Barnett, Mr. William Watson and Ms. Susan Watts (Marine Ecological Consultants) carried out the scientific studies on fish larvae on which this report is based and prepared the Contractor's Final Report. The Interim Technical Report (5) to the CCC was prepared by Dr. Jon Kastendiek and Mr. Keith Parker.

Fish larvae were sampled in the BACIP design (Chapter 5), both Before and After SONGS became operational, along roughly 5-kilometer onshore/offshore transects at an Impact station 1-3 km south of SONGS and a Control station 18.5 km south of SONGS (Figure 13.1).

Fish larvae are the only group in this report that present major difficulties of interpretation. MRC originally intended to sample this group only to determine losses in the intakes, and to determine the group's onshore/offshore distribution. By 1979, however, it appeared possible to monitor the fish larvae in a standard BACIP program, with the constraint that most of the Before samples would be taken in a single year (1980). This constraint contributes to the difficulties of interpretation discussed below, since we cannot investigate annual variation in the Before period. The After samples were collected over a three-year period (1983-86).

We caution that the following analyses concern only local changes in observed relative abundance of fish larvae at SONGS and Control stations. In Chapter 10 we discuss a potentially more serious effect, namely the consequences of larval mortality upon adult fish populations in the SONGS area and beyond.

Intake Losses

SONGS takes in over 4 billion fish larvae per year [ITR 5: 29]. The potential consequences of these losses for adult fish are discussed in Chapter 10.

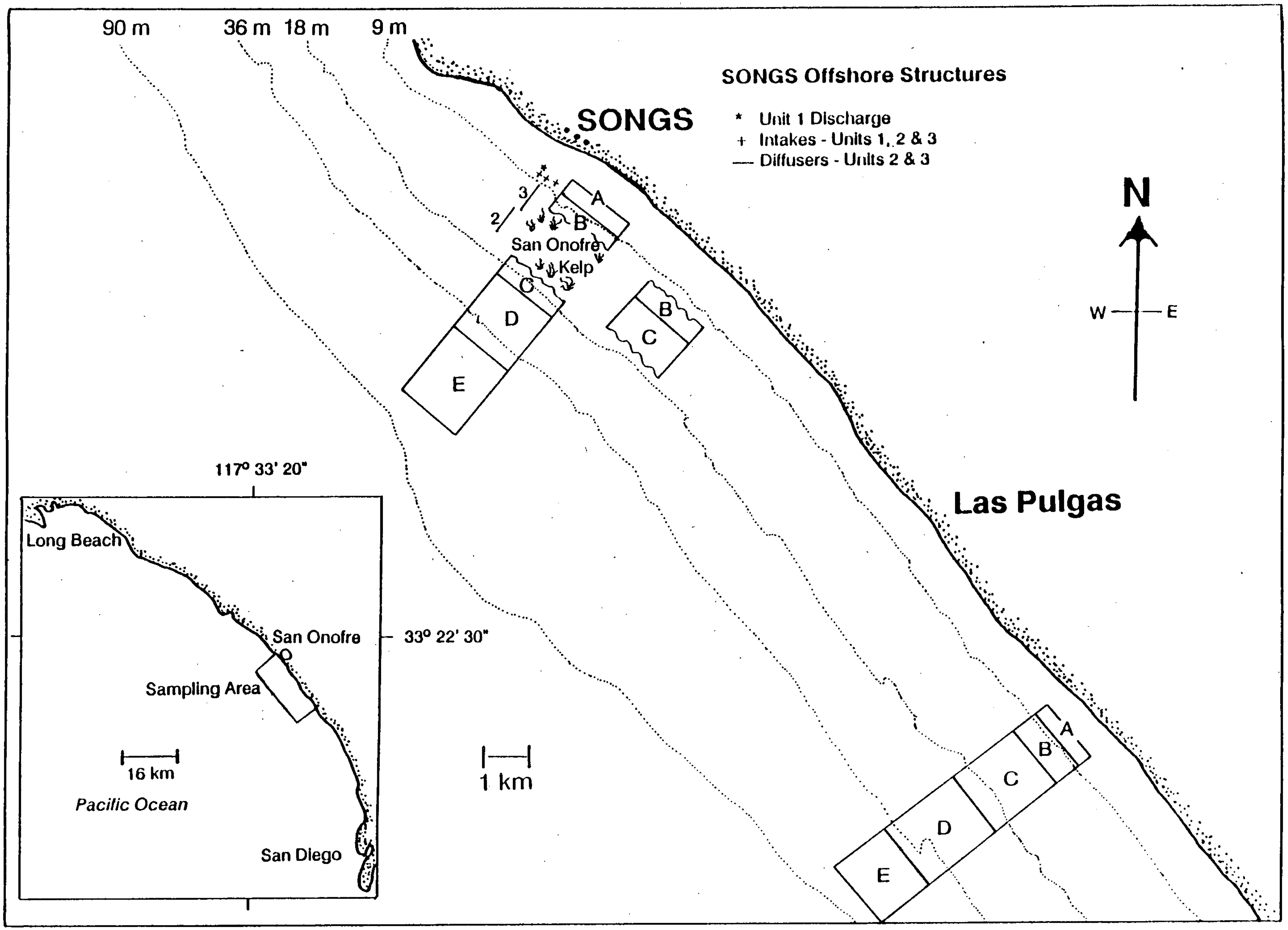

Figure 13.1. Locations of monitoring sampling blocks for ichthyoplankton. Samples are collected at a randomly selected isobath within each block during each survey.

Changes in Abundance

There was no general deep depression in fish larval abundance at SONGS of the sort predicted by some experts during the Permit Hearings in 1973-74. A few significant changes were observed among the 85 species and species groups for which BACIP analysis was done; some were increases, others were decreases [ITR 5: Table 2].

For statistical reasons, we cannot analyze the fish larvae as a single unit, as we did for the other zooplankton groups. However, two large groups can be analyzed: anchovy larvae, and all the remaining 164 species, or species-groups, combined. The major effect observed was a 30% decline in the relative abundance of anchovy larvae, which account for a little over half of the individuals sampled (Table 13.1) [ITR 5: Appendix H]. This effect remains when we examine data only from dates on which the plume passed over the Impact sampling station, but disappears when we examine data from "non-plume" dates, lending credence to the claim that it is caused by SONGS [ITR 5: Appendix I]. Anchovy eggs, by contrast, showed a statistically significant increase of more than 100% in relative abundance near SONGS (Table 13.1). This change is seen whether the current is going north or south. While anchovy larvae declined at SONGS relative to Control, all species other than anchovy, combined as a group, did not change in density after SONGS began operation [ITR 5: 12].

Three species, in addition to anchovy, showed statistically significant changes: two increased (by about 70% and over 100%) and one decreased (by 40%); of these, white croaker (67% relative increase) comprise about a tenth of the

Table 13.1

Statistically significant, and nearly significant, changes in abundance of fish larvae and eggs at SONGS relative to the Control site in the operational period.

TAXON	RELATIVE % CHANGE	% OF TOTAL FISH LARVAE
<u>Significant changes</u>		
Northern anchovy	-30	56
White croaker	+67	10
California grunion	+ > 100	0.1
Arrow goby	-40	0.2
Anchovy eggs	+ > 100	
<u>Near significant changes</u>		
Jacksmelt	-46	0.2
California corbina	+ > 100	0.3
Reef finspot	-65	0.1
Northern lampfish	+ > 100	0.5

* During a two-month period of high density, the relative decrease is estimated to be almost 50%.

fish larvae, while the other species are uncommon near SONGS [ITR 5: 13-15]. Thus a total of four species (including anchovy) showed statistically significant effects. Another four species showed almost significant changes: two decreased and two increased (Table 13.1) [ITR 5: 15-18].

These results show no tendency for decreases to outnumber increases, and this pattern is general. First, among the remaining species and species groups (which did not show significant changes), 64 could be evaluated for a tendency towards either an increase or a decrease. For 41 of them the tendency was towards an increase at SONGS, and for 23 it was towards a decrease. The preponderance of increases is itself statistically significant [ITR 5: Table 2].

Second, for a total of 16 species, which together comprise 92% of the fish larvae in samples, we can confidently state that none declined in relative abundance at SONGS by as much as 50% [ITR 5: Appendix J]. There was thus no general tendency for substantial declines in fish larvae.

Causes of Changes in Abundance

The larval fish results pose difficulties of interpretation: the results are mixed, and we do not know the mechanisms involved. It is difficult to see how SONGS could have reduced the abundance of anchovy larvae by as much as 30%, and yet simultaneously increased anchovy eggs by more than 100% (Table 13.1). With respect to mechanisms, the dilution of discharged water by ambient water is estimated to be about 40 to 1 in the Impact sampling area, so intake losses alone cannot account for the 30% (1 in 3) decline in anchovy larvae [ITR 5: 32]. The decline in anchovy larvae also cannot be explained by offshore transport because this species is abundant to great distances offshore. A number of possible mechanisms for the anchovy reduction are discussed in the *Interim Technical Report*; none seem convincing. Nevertheless, the relative declines that were observed in four species persist when data from only "plume" dates were examined, and sometimes disappear on non-plume days, which gives support to the claim that these declines are induced by SONGS.

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Chapter 14

EFFECTS OF SONGS ON SOFT BENTHOS*

Summary

Widespread increases in the abundance of animals living in and on soft sediments of the ocean floor (the benthos) occurred near SONGS. Increases in species feeding in the sediments extend to about 1 km downcoast from the plant. The abundance of species feeding on and just above the surface of the sediments is increased out to 3 km in many cases. Increases related to the plant may have occurred out to 6 km in a few cases. The benthos near SONGS continued to increase in abundance over the sampling period. Organic material falling from SONGS' discharge plume onto the soft sediments may cause these changes in the benthos.

The benthos was sampled at two depths: at 8 meters (25 feet), which is the depth of water where the intakes are sited, and at the 18-meter (60-foot) depth, which is where SONGS' discharge plume is often present. The effects were more marked in the deeper stations; there the increases were more widespread among different groups of the benthos and occurred over a larger distance downcoast from the plant. A few decreases were observed at this depth within 1 km downcoast of the diffusers, but these appear to be temporary.

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* Dr. Arthur Barnett, Mr. Laurence Lovell, Dr. Thomas Johnson and Ms. Karen Green (Marine Ecological Consultants) carried out the scientific studies of soft benthos on which this report is based, and also prepared the Contractor's Final Report. The Technical Report (I) to the CCC was prepared by Dr. Jon Kastendiek and Mr. Keith Parker.

These changes are substantial, but they are not adverse. They provide a possible explanation for the observed increase in the abundance of bottom-dwelling fish near SONGS (Chapter 11).

Introduction

The ocean floor in the SONGS' region is an extensive shelf of soft sediments (coarse to fine sands) that is interrupted only occasionally by areas of hard substrate. The invertebrate animals living in and on these soft sediments, known collectively as the soft benthos, are a major food source for benthic fish such as turbot. The MRC studies identified over 600 species of such invertebrates, the most common groups being worms (polychaetes) and crustaceans [TR I: Appendix J]. The great majority of these species were very rare in the samples.

The fate of organisms on the bottom was a major concern in the Public Hearings on the Permit in 1973. It was predicted that the plant would create an extensive inshore "desert" by killing the planktonic larvae of benthic organisms, thus drastically reducing recruitment of these species to the bottom in the SONGS' region (Chapter 3). In 1980, by contrast, the MRC predicted that SONGS' operation might increase the abundance of the soft benthos by converting planktonic organisms taken into the plant into an increase in the organic material on the bottom. In Chapter 12 we noted that indeed each year SONGS takes in and kills 1400 tons dry weight of zooplankton, and probably more of phytoplankton.

The soft benthos is of particular interest because it has the potential to record the spatial extent of SONGS' cumulative effects. First, the animals in the soft sediments are relatively sedentary and remain in an area for long periods, so SONGS' local effects on this community can be expected to persist, rather than being dissipated as they are in the case of the plankton. Second, the bottom and the soft benthos are continuous and rather uniform over large areas, thus making alterations to the existing fauna relatively easy to detect along a grid of stations downstream from SONGS.

Sampling Methods and Tests for Effects of SONGS

With these expectations in mind, the soft benthos was sampled at six stations located along each of two lines stretching downcoast from the plant (Figure 14.1). One line was in 18 meters of water, the depth just seaward of the end of the Unit 2 diffuser, where the plume was expected to occur frequently. The other line was in 8 meters of water, which is the depth of the intake. The stations were at 400, 800, 1600, 3000, 6400 and 9100 meters from SONGS' diffusers.

Divers sampled the soft benthos by taking cores of sediment at each of the stations on 16 occasions between November 1979 and June 1981 in the Before period and on 30 occasions between June 1984 and December 1986 in the After period. Sampling in the After period was begun about a year after the plant had reached its operational level, to allow cumulative effects on the benthos to manifest themselves. Animals in the cores were identified and counted in the laboratory. Cores were also taken to provide measurements of physical (e.g., grain size) and chemical (e.g., the amount of organic material) properties of the sediments. It was hoped that these measures would provide a record of the spatial extent of SONGS

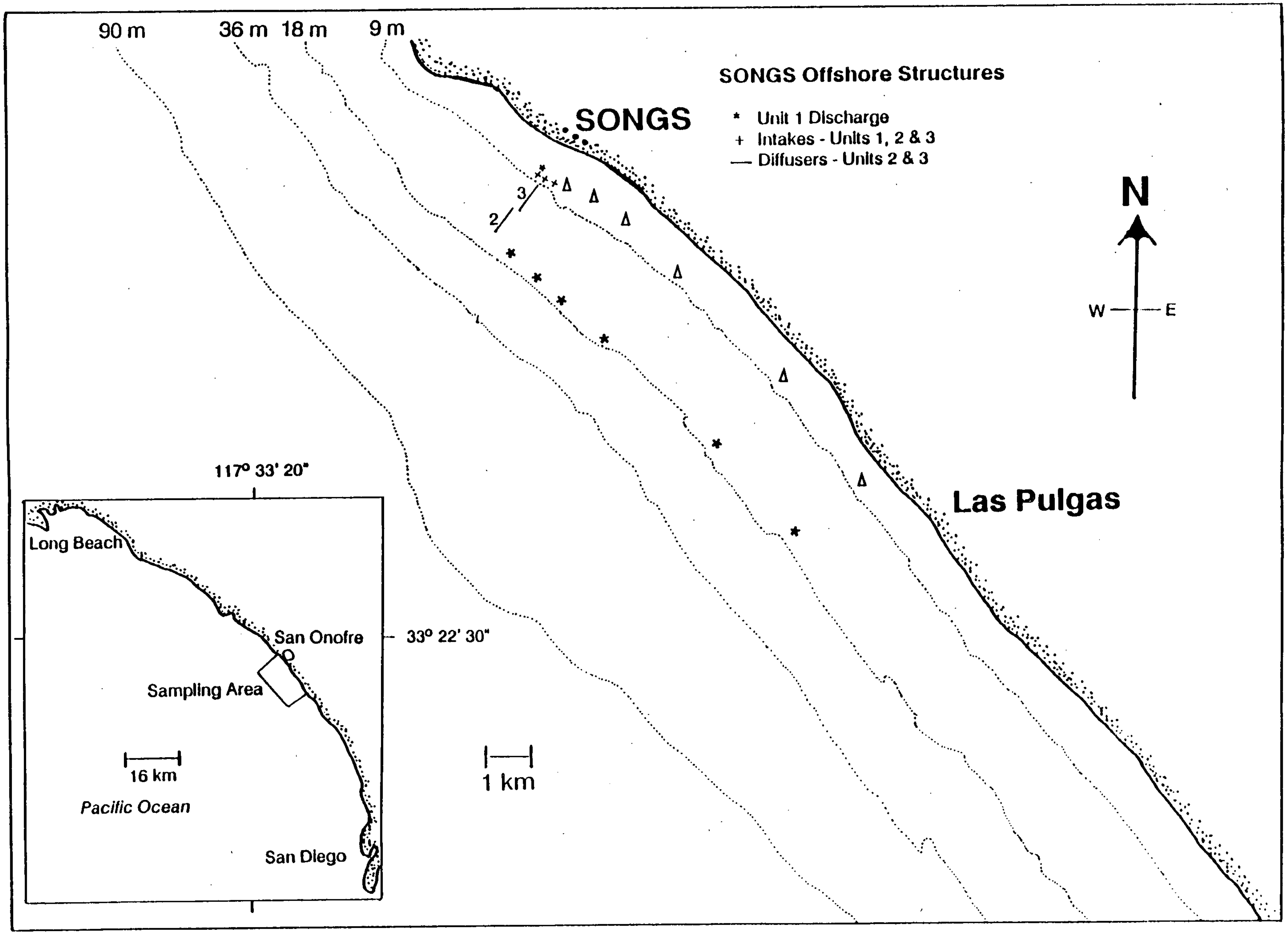

Figure 14.1. Locations of benthic sampling stations. Δ indicates a depth of 8 m. * indicates a depth of 18 m.

effects on the sediments and would also help explain any changes seen in the benthos.

We tested for effects of SONGS on various groups of organisms (Table 14.1). First, organisms were placed into taxonomic groups: all worms, all crustacea, and all molluscs (which were mostly clams). Almost all crustacean species feed at the surface of the soft sediments, while among worms and molluscs some species feed on or just above the surface of the sediments and others feed within the sediments. Second, we also placed organisms into ecological groups defined by their mode of life, for example surface-feeders (which includes species feeding at and just above the surface), subsurface-feeders, sessile deposit-feeders, motile deposit-feeders, and so on. There were 19 mutually exclusive ecological groups, but here we concentrate on the larger categories. Third, some individual species were analyzed. Finally, the abundance, biomass and numbers of species of all the benthos taken together were analyzed.

Because we have a grid of stations at each depth rather than only one Impact and one Control station, we used a modification of the BACIP approach. The two most distant stations, at about 6 and 9 kilometers from the plant, were treated as Control stations; the observations from the two stations were averaged to provide a single Control observation. This leaves four Impact stations at which we might detect a SONGS' effect, the furthest being about 3 km from the plant. The analyses compared the observation from *each* Impact station, to the Control observation, and also compared the four Impact observations, as a group, to the Control. Using this approach, (1) a statistically significant effect at any one of the Impact stations will be detected. (2) A statistically significant effect at *any* Impact station leads to the

Table 14.1

Statistically significant effects of SONGS on the soft benthos [TR I: Table 3, 4, 9 & 10]

GROUP	18 METER DEPTH		8 METER DEPTH	
	CHANGE IN RELATIVE ABUNDANCE AT SONGS	CHANGE IN RELATIVE ABUNDANCE AT SONGS OVER TIME	CHANGE IN RELATIVE ABUNDANCE AT SONGS	CHANGE IN RELATIVE ABUNDANCE AT SONGS OVER TIME
Total benthos	Increase	Increase	Decrease	Increase
All worms (polychaetes)	Increase	Increase	Decrease	Increase
All crustaceans	Increase	Increase	Increase	--
All molluscs	Increase	--	--	--
All surface feeders	Increase	Increase	Decrease	Increase
All subsurface feeders	Increase	Increase	--	Increase

conclusion that there was an effect, and (3) a statistically significant effect on the Impact stations as a group can be detected, if it occurs, even if the effect at each station is not statistically significant. This analysis was performed on ecological groups and species only if they occurred a sufficient number of times in the Before and After periods. Nineteen ecological groups met the criterion, as did 19 of the 600 or so species.

By examining the pattern of effects with distance from the plant, we can estimate the spatial extent of SONGS' impact on the environment. In some groups of organisms SONGS' effect extends to the 3 km Impact station. In these cases we repeated the analysis, this time setting the 9 km station as the Control and including the 6 km station among the Impact stations.

We also examined a much larger group of individual species for changes in frequency of occurrence close to SONGS relative to Control. We made this comparison to test for effects on species that were less common than those tested for changes in abundance. The Impact location chosen for comparison with the distant Control location (9100 m downcoast) was the site closest (400 m) downcoast from the diffusers because we expected any potential SONGS effect to be most apparent there. Forty-six species were tested at the 8 meter depth, and 85 were tested from the 18 meter depth. These species, which include those tested for changes in abundance, account for over 95% of the total benthos at both depths [TR I: Appendix J].

As in other parts of the community near SONGS, the El Nino condition of 1982-84 had a marked effect on the abundance of many benthic species, so that the community along the entire sampling grid changed markedly between the Before and After periods.

Changes in Relative Abundance at Impact vs. Control Stations

18 Meter (60 Foot) Depth

There have been substantial increases in density at Impact relative to Control stations along the 18 meter line throughout the soft benthos community. All the major taxonomic and ecological groups, and the benthos as a whole ("total benthos") increased (Table 14.1). Five of the seven individual species that showed a statistically significant change in abundance at this depth increased (Table 14.2).

The number of species found per sample also increased at this depth [TR I: Table 6].

At 18 meters there was no increase in the biomass (weight) of organisms, even though increases in abundance were so widespread [TR I: 3.2.2.3]. This may be because the biomass of the animals in samples was highly variable, in part because occasional large individuals had a large influence on the results. Alternatively (or additionally) there may now be more, but smaller, organisms in the benthos at Impact stations at this depth. Such a change would be consistent with an increase in production (turnover rate) of the populations and with greater harvesting of this productivity by organisms that feed upon them. In turn this provides a possible explanation for the observed increase in benthic fish (Chapter 11).

Table 14.2

Number of species in the soft benthos showing statistically significant effects of SONGS [TR I: Tables 1, 2, 6, 7, 15 & 16]

	NUMBER OF SPECIES SHOWING CHANGE				
	18 METER DEPTH			8 METER DEPTH	
	INCREASE	DECREASE	INDETERMINATE*	INCREASE	DECREASE
Change in Relative Abundance at SONGS	5	1	1	2	0
Change in Relative Frequency of Occurrence at SONGS	18	2	--	7	3
Change in Relative Abundance at SONGS over time	7	1	0	3	1

* Species that increased at one Impact location and decreased at another.

8 Meter (25 Foot) Depth

The tendency within groups at this depth was for decreases at Impact sites relative to Control, but as will be seen below, these effects are generally restricted in space and they are not persisting. Total benthos, all worms and all surface-feeders decreased; all crustaceans increased; and all molluscs and all subsurface-feeders did not change (Table 14.1). The only two individual species showing a significant change both increased in abundance (Table 14.2), and there were increases in two minor ecological groups [TR I: Table 3].

Changes in Relative Frequency of Occurrence at Impact vs. Control Stations

The number of times a given species was present in the Before and After samples at either the 400 meter Impact station or the Control station was calculated for 46 species at the 8 meter depth and 85 at the 18 meter depth. These analyses confirm the pattern of relative increases at the 18 meter depth seen in the abundance results discussed above, and they show mainly relative increases at the 8 meter depth. At the 18 meter depth, 18 species were found relatively more frequently near SONGS in the After period than in the Before, while only two were found relatively less frequently (Table 14.2). Fewer changes were found at eight meters. At this depth seven species increased in relative frequency of occurrence at SONGS and three decreased (Table 14.2). Only one of these species was seen at both stations in the Before period but only at Control in the After period [TR I: 3.4.1].

Changes in Effects over Time

The changes in relative abundance presented earlier come from averaging the abundance at each station over the entire After sampling period. However, we expected that the effects themselves might change with time as material from SONGS' plume continued to affect conditions on the bottom, and we therefore analyzed for changes over time in the After period.

The change is positive at both the 8 and 18 meter depths; that is, the organisms at the Impact stations are becoming more abundant over time relative to the Control. At the 18 meter depth, only molluscs among the major taxonomic and ecological groups failed to increase through time (Table 14.1). Thus the pattern is very widespread in the benthic community at this depth. In almost all cases the increases were occurring at all Impact stations [TR I: Appendix G]. A possible explanation for the increases over time is a continuing accumulation of materials from the plume.

A pattern of increases over time at Impact relative to Control also prevailed at the 8 meter depth (Table 14.1). The benthos as a whole, worms as a whole, and surface- and subsurface-feeders as a whole all showed increases over time. The positive trends in the benthos as a whole, in all worms, and in all surface-feeders as a group, are particularly important. These groups all showed reductions in density at Impact relative to Control when the results were averaged over the After period, and the changes in time show that these reductions are temporary. SONGS' effects on the community at the 8 meter depth are changing over time towards the pattern of general increases seen at 18 meters.

The facts that the decreases at 8 meters are restricted to within a kilometer downcoast of the diffusers, and that they are disappearing over time, suggest that they may have been a response to a temporary condition. One possible cause is the release of SONGS' lay-down pad in December 1984 to January 1985 (sampling was done between June 1984 and December 1986) [TR L: 2.3].

Spatial Extent of Changes in Abundance

18 Meter Depth

As noted above, at this depth there was a broad pattern of increases at Impact relative to Control. Statistically significant increases occurred at all stations out to 3 km downcoast of the plant, but they tended to be more frequent at the two stations within 1 km of the plant than at the more distant stations (Table 14.3).

There seem to be two patterns. Groups that feed to a large extent beneath the surface (all subsurface-feeders, molluscs and worms) show no effects beyond 1 km from the plant, while effects beyond 1 km appear in surface-feeders and crustacea, which also commonly feed at the surface (Table 14.3). The sizes of the observed changes lend support to this generalization. The relative increase in abundance declines in the first set of organisms (Figure 14.2a), whereas the relative increase in abundance remains high out to 3 km in surface-feeders and crustacea (Figure 14.2b).

A possible explanation for the different patterns is that the subsurface-feeders are affected mainly by heavier particles that fall out of SONGS' discharge

Table 14.3

Spatial extent of SONGS' effects on the soft benthos [TR I: Table 3 & 9]. -- means no change.

Group	Distance Downcoast from SONGS (meters) 400	800	1600	3000
<u>18 meters</u>				
Total benthos	Increase	Increase	--	Increase
All worms (polychaetes)	Increase	Increase	--	--
All crustaceans	--	Increase	Increase	Increase
All molluscs	Increase	Increase	--	--
All surface feeders	--	Increase	--	Increase
All subsurface feeders	--	Increase	--	--
<u>8 meters</u>				
Total benthos	Decrease	Decrease	--	--
All worms (polychaetes)	Decrease	Decrease	--	--
All crustaceans	--	--	Increase	Increase
All molluscs	--	--	--	--
All surface feeders	Decrease	Decrease	--	--
All subsurface feeders	--	--	--	--

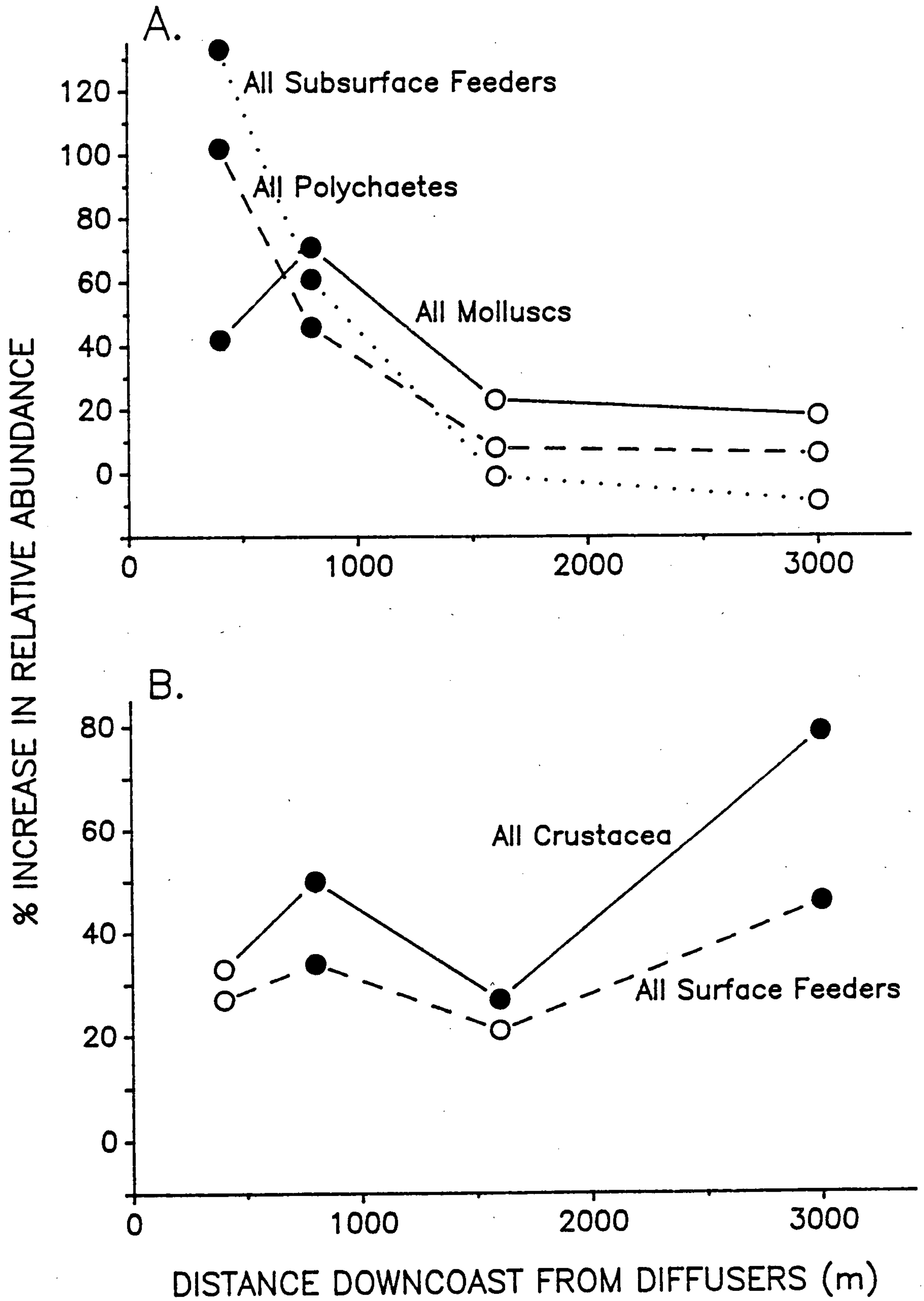

Figure 14.2. Examples of extent of increases in abundance at 18-meter Impact stations with distance downcoast from the diffusers, illustrating the two classes of effects discussed in the text. In (A) there are no statistically significant increases (solid circles) beyond the 800-meter station. In (B) statistically significant increases occur out to 3 km.

plume earlier, while the surface-feeders are more influenced by lighter particles that fall out of the plume over a larger distance downcurrent.

8 Meter Depth

No decreases were observed farther than 1 km downcoast from the diffusers (Table 14.3). Thus, whatever negative effect SONGS had on the benthos at this depth cannot be detected beyond 1 km. Figure 14.3 shows the same pattern in the size of the relative decreases in abundance. Once again, the crustacea increased out to 3 km.

Some increases have been observed at both depths as far as 3 km downcoast of the diffusers (Table 14.3). Increases at 3 km were detected in a total of 12 individual species or ecological groups, ten at the 18 meter depth and two at the 8 meter depth [TR I: Table 11]. To determine if increases ever extend to the next station downcoast, at 6 km, the analyses were repeated on these 12 cases, except that this time the 6 km station was treated as an Impact station and the 9 km station was treated as the Control.

Three species or groups (two at 18 meters and one at 8 meters) increased significantly in relative abundance at 6 km [TR I: Table 11]. These three effects, from among the 38 species and mutually-exclusive ecological groups are too few to provide a reliable claim that SONGS has effects on the surface at a distance of 6 km downcoast, but it is possible that such an effect occurs on a small fraction of the biota.

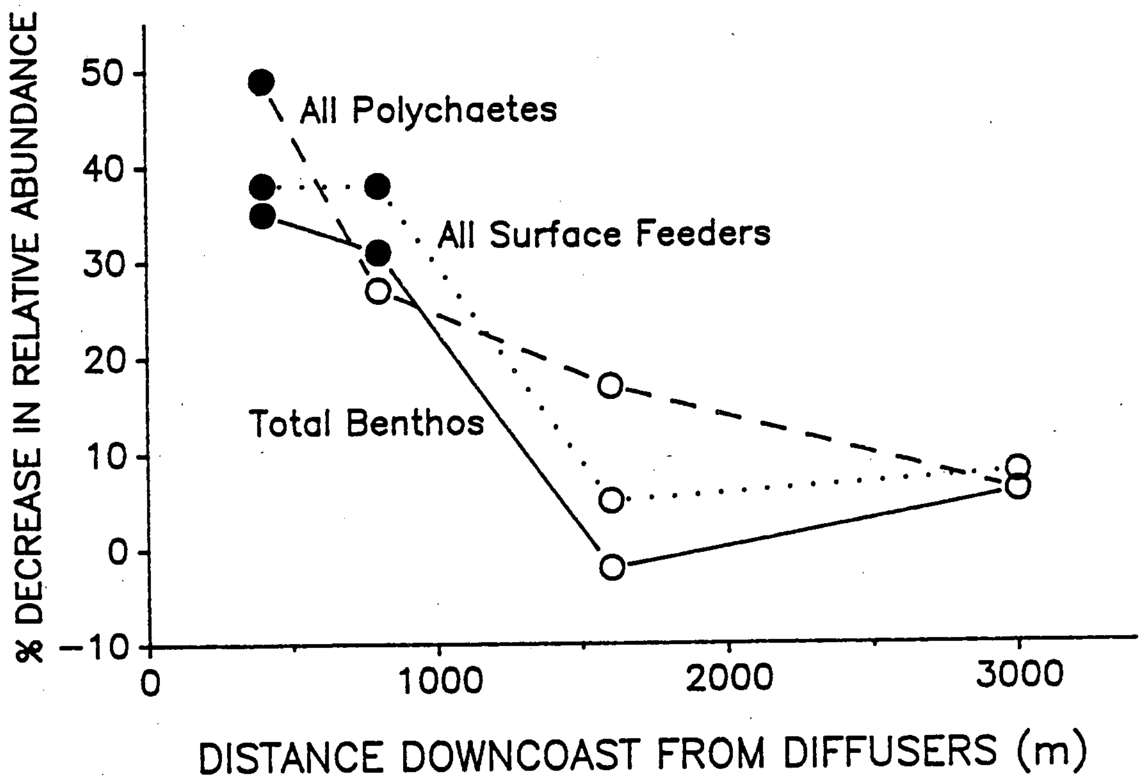

Figure 14.3. **Examples of extent of decreases in abundance at 8-meter Impact stations with distance downcoast from diffusers. Statistically significant decreases (indicated by solid circles) do not extend beyond 800 meters from the diffusers.**

Possible Mechanisms Causing SONGS' Effects

A reasonable explanation for the observed increases in the benthos is an increase in the supply of organic material reaching the bottom. The MRC has not made measurements of the rate of supply of organic material at the bottom above soft sediments, but the plume probably adds several thousand tons (dry weight) to the bottom area near SONGS (Chapter 6).

A variety of measurements were made on cores taken from the soft sediments at the sampling stations in an attempt to find correlations between the abundance of organisms and various attributes of their environment that might be affected by SONGS. Although many such correlations occur, especially at the 18 meter depth where there is a more consistent pattern of effects on organisms, the correlations are weak and do not, in a statistical sense "explain" much of the difference between Impact and Control. The main features of the sediments that are related to changes in abundance of organisms are the relative proportions of various sizes of grains, and factors associated with the amount of organic content of the sediments and hence with their potential as a source of food [TR I: Tables 12-14].

The weakness of the correlations between organisms and our measures of environmental conditions may mean that the physical/chemical measurements have missed SONGS' effects on the sediments. One possibility, for example, is that the cores penetrated deeper into the sediment than have SONGS' effects; this might blur any real correlations between sediment characteristics and the abundance of various species. However, in retrospect, it appears that we could not have expected to detect some of the effects. For example, the benthos can be expected to consume additional organic material as it arrives, turning it into higher benthos productivity and leaving the standing amount of organic material in the sediments little changed (as was observed). Thus, the increases in surface-feeders may have been caused by an increase in the flux of food materials just at or above the surface of the sediments, which would not change the sediments themselves.

Conclusions

SONGS has had a pervasive effect on the soft benthos out to 3 km downcoast of the diffusers. The effects are most frequent and extensive at a depth of 18 meters, which is the region where the discharge plume commonly occurs [TR L]. However, there are also effects in shallower water, at the 8 meter depth, some of which extend to 3 km.

The majority of effects are increases in the abundance of organisms living on and in the soft sediments. The decreases in abundance are almost entirely in the shallow water stations, are restricted to within 1 km of the diffusers, may have been caused by a temporary release of sand, and are disappearing over time. A possible explanation for the increases is an increase in organic matter deriving from the discharge plume. Although these effects are substantial, they are not adverse effects.

Chapter 15

EFFECTS OF SONGS ON MYSIDS*

Summary

SONGS takes in and kills about 6.5 billion mysids (14 tons) per year. In spite of these losses, SONGS actually causes an increase in the relative abundance of mysids at the Impact sampling site, 2 - 3 km downcoast of the diffusers.

Introduction

A group of small "semi-planktonic" crustacea typically spend the daylight hours swarming just above the ocean floor, making occasional forays into the substrate, but at night move up into the water column to become part of the plankton. They are an important part of the diet of local midwater fish, such as queenfish, and of benthic fish such as sanddabs. Mysids are the most abundant members of these semiplanktonic organisms, and for this reason the MRC chose them to represent this group. Mysids, shrimp-like animals up to about an inch long, are omnivores, feeding on small live animals, plants and detritus.

Mysids were expected to show more markedly any negative effects that SONGS might have on planktonic organisms. In contrast to zooplankton proper, mysids can orient by sight in daylight and, by swimming against the current, can

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* Dr. Arthur Barnett, Ms. Linda Gleye and Dr. Thomas Johnson (Marine Ecological Consultants) carried out the scientific studies of mysids on which this report is based, and also prepared the Contractor's Final Report. The Technical Report (G) to the CCC was prepared by Drs. Jon Kastendiek and John Dixon.

maintain their position to some extent. They can therefore remain in an area much longer than zooplankton, and thus SONGS might have a cumulative, rather than only an instantaneous, effect on local mysid populations. In addition, mysid populations turn over much more slowly than most species of zooplankton and would likely take longer to recover from reductions in their density. The mysid populations near SONGS thus appeared to have a greater likelihood than zooplankton of showing reductions in density.

Unlike zooplankton, however, mysids are also affected by conditions on and close to the ocean floor. Thus it is also possible that they will show effects related to those found in organisms living in soft bottoms, a group that showed increases in abundance (Chapter 14).

(Not all mysid species live mainly near the ocean floor; for example several species are tightly associated with kelp canopy and others occur both there and near soft bottoms. The MRC investigated the possibility of studying mysids in kelp, but found too much spatial variability in mysid abundance for this to be feasible. The results in this chapter refer only to semiplanktonic species.)

Mysids were not singled out for comment in the Public Hearings on the Permit. In the 1980 Predictions Report to the CCC, the MRC was not able to make firm predictions about effects on mysids. The Report indicated that reductions of up to 50% might occur within several km of SONGS as a consequence of intake losses and offshore transport. This prediction was based in part on a model of ocean currents in the SONGS area that has since been shown to be wrong: it underestimated the amount of mixing that occurs, and thus overestimated the extent to which a reduction in density would be manifest.

Mysids were sampled in the daytime, when they are mainly concentrated just above the bottom, using a sled pulled along the bottom [TR G: 2.2]. Sampling was done under a BACIP design. The Impact site was placed at 2 to 3 km south of SONGS' diffusers, for two reasons. First, earlier sampling along a gradient extending downcoast from SONGS Unit 1 showed that mysids were more abundant closer to the plant, probably as a consequence of enriched bottom sediments [MRC Doc. 80-04-(1)]. Thus it appeared that SONGS might increase the abundance of mysids close to the plant, and that we would need to sample some distance downcoast to detect any negative effects that might occur. This conclusion was reinforced by predictions of the scientists working on this group that the most severe reduction in density would occur about 3 km south of the plant. Second, mysids could not in any case be sampled on the bottom closer than about 2 km from the plant because of the presence close to SONGS of hard bottom north of the plant and the kelp bed south of the plant. The Control area was 17.5 to 18.5 km south of SONGS (Figure 15.1).

The Before samples were taken between October 1979 and December 1981, and mostly before August 1980. The After samples were taken between December 1983 and September 1986 [TR G: Appendix A]. As in the case of the zooplankton, samples were concentrated during operational days when the plant was operating well above its average level; in addition, the operational level was well above average during the 30-day periods preceding sampling days (Table 15.1).

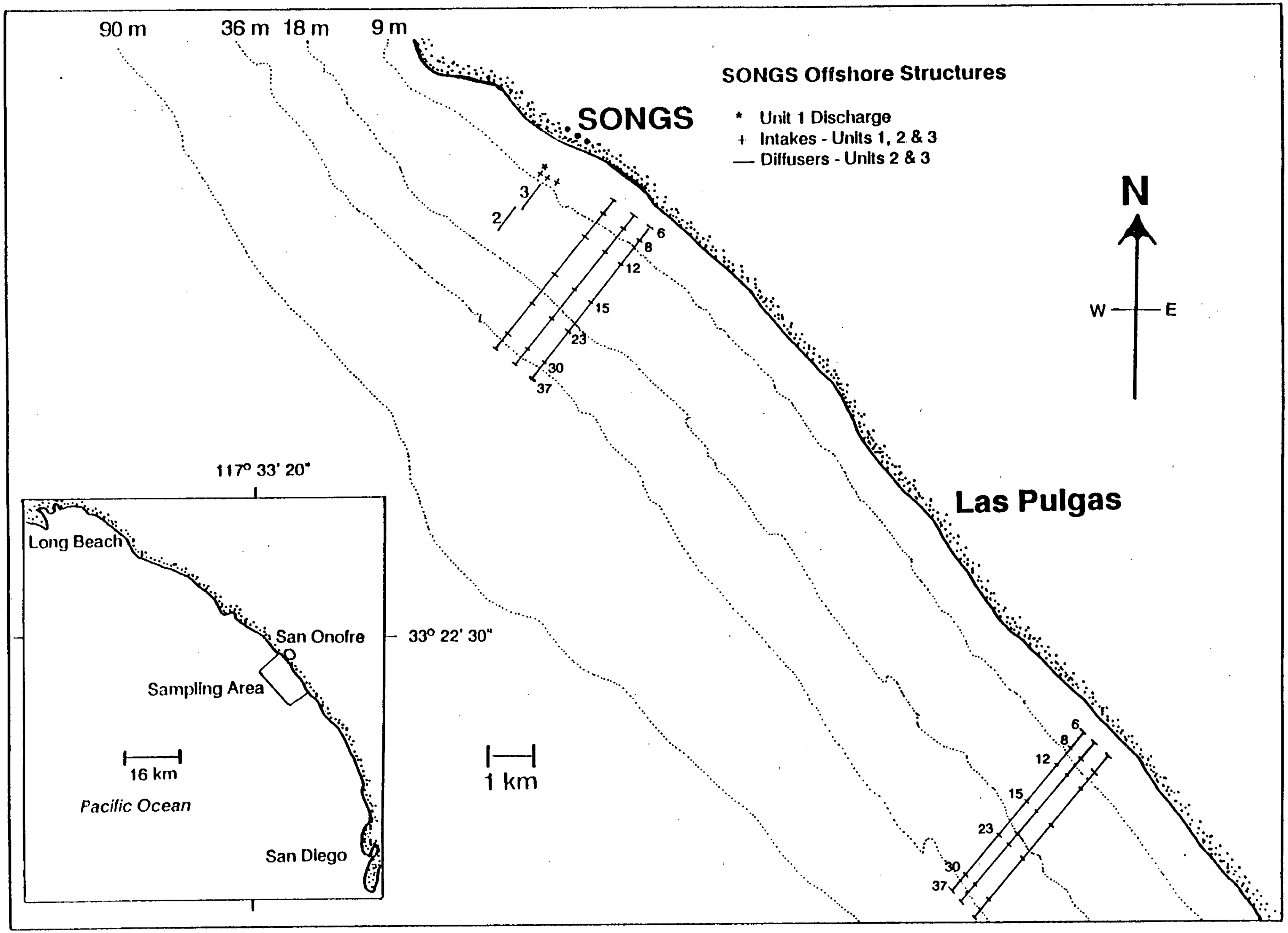


Figure 15.1. Locations of monitoring transects sampled for mysids.

Table 15.1

Operational levels of SONGS Units 2 and 3 during sampling of mysids and on average.

	NUMBER OF PUMPS OPERATING	% POWER PRODUCTION
A. "BEFORE" PERIOD		
Average for period (July 79 - Dec 81)	0.30	0
Average on sampling days	0.31	0
Average on 30-day periods preceding sampling	0.36	0
B. "AFTER" PERIOD		
Average for period (July 83 - Oct 86)	6.1	56.2
Average on sampling days	6.8	67.7
Average on 30-day periods preceding sampling	6.8	65.4

Intake Losses

Mysids are less vulnerable to being taken in by SONGS in the day when they are capable of a limited degree of avoidance behavior. Our estimate of intake losses takes this into account by assuming that 64% of those in the water column near SONGS are taken into the plant at night, and only 16% in the daylight hours [TR G: 2.5]. We estimate that SONGS has withdrawn and killed about 6.5 billion mysids per year, which is equivalent to approximately 14 tons of mysids [TR G: 3.4, Table 5].

These intake losses are significantly lower than those predicted by the MRC in 1980 (50-60 tons). The difference arises because the early estimate was based on a small number of samples with atypically high densities of mysids taken inside the plant, rather than from the ocean, and on the use of a maximum rather than the average intake rate [TR G: 3.4].

Changes in Abundance

Overall there was a tendency in the After period for mysids near SONGS to increase in abundance relative to those at the Control station.

Because of sampling variability, only two species out of nine analyzed showed a statistically significant change in density at SONGS relative to the Control station (Table 15.2). Both species, accounting together for about 19% of the total mysids, showed approximately a doubling in relative abundance at SONGS. In seven other species we could determine the direction of change in relative abundance, and six

Table 15.2

Changes in abundance of mysids at SONGS relative to the Control site in the operational period.

Changes in the first two species were statistically significant (P < 0.05), the others were not. The indicated direction of change, i = increase, d = decrease, is presented for those species where no statistically significant change was observed. The second column gives the percentage that each species contributes to the total mysid abundance.

TAXON	RELATIVE % CHANGE	% OF TOTAL
Mysidopsis intii	+116	11.1
Neomysis kadiakensis	+126	7.6
Acanthomysis davisii	i	3.9
Acanthomysis macropsis	i	18.6
Acanthomysis nephrophthalama	i	1.5
Holmesimysis costata	d	3.9
Metamysidopsis elongata	i	47.8
Mysidopsis cathengelae	i	4.3
Neomysis rayii	i	1.3
Total Mysids	i	100.0

out of the seven tended towards a relative increase in abundance at SONGS, as did the mysids taken as a whole, although none of these results were statistically significant (Table 15.2) [TR G: 3.2.1, 3.2.2, 3.2.3, Tables 1 & 2]. Thus, of the nine species examined, eight showed either a significant increase or a tendency to increase, which is a statistically significant imbalance of increases over decreases.

There was no evidence of losses from offshore transport. The distribution of mysids along a transect from nearshore to offshore was measured. Major offshore transport and subsequent mortality could be expected to change this distribution, however it did not change from the Before to the After period at SONGS relative to Control [TR G: 3.2.3, Table 3].

The tendency for mysids to increase in relative abundance near SONGS is consistent with observed increases in other species associated with soft bottoms (Chapters 11 and 14). A possible explanation is an increase in organic material from SONGS' plume, but the reduction in midwater fish (Chapter 11), some of which feed on mysids, may also play a role in mysid increases.

Chapter 16

SAND CRABS*

Summary

In contrast with all other groups of organisms studied by the MRC, it has been suggested that SONGS Unit 1 has had substantial adverse effects on sand crabs that extend for about 10 miles from the plant. Because Unit 1 began commercial operation in 1968, it has therefore not been possible to use the BACIP approach, which requires sampling before the plant begins operation.

Sand crabs at beaches near SONGS have often been different in some respects from those at more distant beaches: they have usually been smaller, and egg development has been observed to be less successful on some surveys, beginning in 1981. Poorer egg development has been seen in a very large area around SONGS and has extended at least 12 km (8 miles) upcoast of the plant. In other regards (e.g., total abundance and proportion reproductive), however, sand crabs near SONGS have not been different from those at more distant beaches.

We conclude that these spatial patterns most likely reflect differences in the physical characteristics of the beaches near and far from SONGS and are not related to the operation of the plant.[1] The beaches in the SONGS area have a high proportion of cobble and a correspondingly low proportion of sand. The MRC

* Dr. Arthur Barnett (Marine Ecological Consultants) was the Principal Investigator for most of the studies on sand crabs, with assistance from Ms. Karen Green and Ms. Linda Gleye. Contributing studies were also done by Ms. Janet Auyong (1976-77) and Dr. Adrian Wenner (1980-82). Dr. James Bence prepared the Contractor's Final Report and the Technical Report (A) to the CCC.

[1] Dr. Fay does not agree with the conclusions reached in this chapter.

failed to find evidence that the biology of sand crabs is related to the level of operation of the plant, or to the release of metals or radionuclides by SONGS.

Introduction

Readers looking for a more detailed analysis of the data on sand crabs should go to *Technical Report A*, on which this account is based.

The sand crab program has differed from other MRC studies in several respects, two of which are most important. First, possible effects were detected in 1976-78, while only Unit 1 was operating [TR A]. At least for these effects, there was therefore no chance to employ the BACIP approach, which entails sampling at Control and Impact stations before the plant turns on. Second, for at least some of the time it has not been clear precisely which aspects of crab biology might require analysis, or over what geographic areas and by what mechanisms SONGS might be affecting sand crabs, so that different aspects of crabs and their environment have been studied at different times and in different ways. In this Introduction we describe briefly the natural history of sand crabs, the measurements taken, and the history of the program.

It will be important throughout to bear in mind the difference between "location effects" and "SONGS effects." The former are differences in various aspects of sand crabs between beaches near and far from SONGS. They cannot be considered "SONGS' effects," however, without further evidence implicating the plant.

Sand Crab Biology

Sand crabs are usually found in the top few inches of sand in the intertidal zone. They feed by straining food particles from the wave wash. Females reproduce in summer, carrying their eggs attached to their appendages. A given female may have one to four clutches between April and October. The embryos develop into larvae and then hatch into the plankton and return to beaches the following spring and summer. The population on the beach peaks in spring [TR A: 1.1]. Overwintering crabs (mostly females) appear to move to subtidal sand areas over winter.

Sand crabs are difficult organisms to study and sample. They are buried and are very patchily distributed, so that many samples taken on a beach purely at random may find no or few crabs. Furthermore, a patch of beach that contains thousands of crabs one day may have none or few the next. It is especially difficult to estimate their abundance within a well-defined fixed area on a particular beach; indeed, the 1983 MRC study is the only case we know of where this was done systematically.

Some aspects of sand crab biology have been studied by a number of authors, including the fraction of crabs falling into various sizes classes, or the fraction of females bearing eggs. It is also known that these characteristics vary among beaches in response to natural factors such as latitude, food supply, water temperature, and physical aspects of the beach environment. They also vary from month to month and from year to year on particular beaches, again in response to variation in natural factors.

The sand crab characteristics examined by MRC at one time or another include: total abundance (density), aspects of the size distribution including the abundance of larger size classes, individual growth, fraction of females carrying clutches of eggs (fraction reproductive), fraction of females with completely spent clutches, and fraction of females with partially-spent clutches.

The abundance and size aspects are self-explanatory, as is the fraction reproductive; a word is needed on the other measures. When the eggs have hatched, the spent shells remain until they are sloughed off. There may be nothing intrinsically "unhealthy" about a "spent clutch," since it may indicate merely that the female has recently reproduced. Nor is there necessarily anything suspect about samples that have a very high fraction of females with completely spent clutches, since breeding on a beach may be synchronized. In addition, the MRC found good evidence that spent clutches remain on females for extended periods at the end of the breeding season (around September) [TR A: D-16]. Nevertheless, if some populations persistently exhibit throughout the season relatively high fractions of females with spent clutches, it strongly suggests that their reproduction is less successful than that of populations elsewhere. Finally, in 1983 it was noticed that some females on some beaches had a mixture of egg cases that were spent and others that were intact. Since all eggs in a clutch develop synchronously under natural conditions, the spent eggs may have been released too soon, and such "partially-spent" clutches may indicate that something is interfering with egg development.

History of MRC Sand Crab Studies

Evidence that sand crabs might be smaller within a few km of SONGS became available from a study done between 1976 and 1978, before Units 2 and 3 began operation, at five beaches within 6.5 km of SONGS, and at several others more than 15 km from the plant. Additional studies were done in 1980 and 1981, samples coming from a few beaches between Goleta in the north and La Jolla in the south. Evidence that the development of eggs might be interrupted over a large area was first reported in 1982, based on data collected in 1981 at the original five beaches and at several more distant sites in southern California. That report also stated that some crabs collected in 1980 at a beach 6.5 km north of SONGS showed evidence of interrupted egg development, although quantitative data on this characteristic was not recorded at the time [TR A: 1.3]. The MRC did not have adequate information, however, on several key issues such as: the aspects of crab biology in which spatial differences occurred; how far any such location effects might extend from SONGS; whether crabs on beaches close to SONGS or in the general SONGS area were statistically different from those on other southern California beaches in general; whether any differences that might exist could be tied to the operation of SONGS or might be related to natural variation in the beach environments; and what the mechanism(s) might be by which SONGS could cause such location effects.

The MRC therefore commissioned a new study over a large spatial scale in 1983, and followed this up with studies relating to specific topics in 1984 and 1986. The 1983 study sampled crabs at the original five beaches near SONGS, at several other more distant beaches in the SONGS area, and at a number of other beaches in southern California. In an attempt to get at possible causes of any spatial patterns that might appear, measurements also were taken of a number of physical and chemical characteristics of the beaches and their sediments, including the concentrations of eight metals, which were also measured in sand crab tissue. The 1984 study looked at the question of synchronized reproduction in crabs. The 1986 study measured metals and radionuclides in crabs at many beaches within 20 km of the plant. Various aspects of sand crab biology, as discussed in the previous section, were measured in these studies.

In 1985 the MRC began a systematic reanalysis of the data collected, and analyzed to a greater or lesser extent, by the different contractors who had collected them. In the presentation to follow we discuss the entire corpus of results rather than dealing with each separate study in turn.

Results

Location effects

MRC looked for a location effect in two ways [TR A: 2.2.2]. First, beaches were divided into Near, i.e., those out to 6.5 km (north or south) of SONGS, and Far, i.e., those more distant. (This analysis was also repeated using a 12 km "Near" zone. The results are qualitatively the same [TR A: 2.2.2.1 & Appendix F] so we do not refer again to that analysis.) Second, considering SONGS as a potential point-source of some disturbance, we asked if effects declined with distance from SONGS. Here only beaches within 20 km of SONGS were analyzed since it is very unlikely that any effect could operate or be detectable beyond that distance.

A summary of the patterns found in the various surveys is as follows (Table 16.1 [TR A: Table 1]). First, sand crabs near SONGS are in many respects indistinguishable from those living elsewhere. In particular, there was no consistent tendency for sand crabs to be less abundant near SONGS than farther way, nor for the fraction of females reproductive to be smaller near SONGS. For example, the fraction of females bearing eggs was higher near SONGS in 1977, lower near SONGS in 1983, and not consistently different from the fraction elsewhere in 1980, 1981 and 1986.

Second, the following differences were observed.

(a) Sand crabs often were smaller at two beaches north of SONGS - 0.4 and 1.5 km north - than at other beaches near SONGS (Figure 16.1a and b), and in addition the minimum size of females that carried eggs was at times lower at these two beaches (Figure 16.1c). This pattern did not always occur, and in one year the smallest (female) crabs in the SONGS' area were at the beach 6.5 km south of the plant. Crabs on beaches in the general SONGS area (i.e., within 6 or 12 km from the plant) typically have not been smaller than those from elsewhere in southern California (Figure 16.1) [TR A: iv, 3.1.2, 3.1.3].

(b) In three years out of four (1981, 1982, and 1983, but not 1986), the fraction of females whose eggs were completely spent was greater in a wide zone around SONGS than at more distant beaches in southern California [TR A: iv, 3.1.5.2]. When data were available and the pattern occurred (1982 and 1983), the zone extended at least 12 km north and south of SONGS (Figure 16.2a). Within

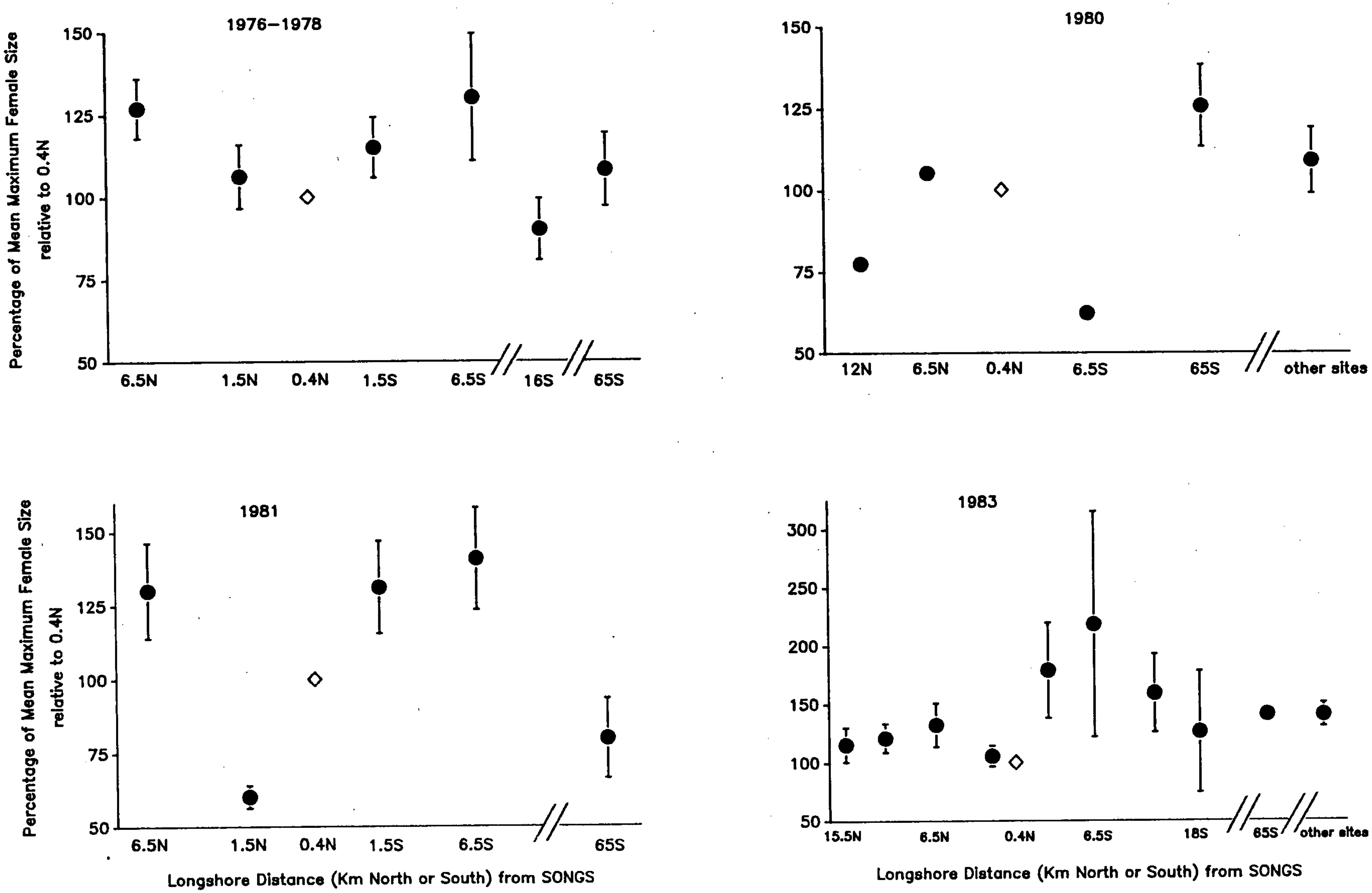
Table 16.1

Summary of location effects, for each study, and overall. ⇩ indicates lower values near SONGS (suggesting that sand crab performance was poorer near SONGS), ⇧ indicates higher values near SONGS, NDP indicates no distinct pattern, and -- indicates no data were available. Larger, solid symbols indicate more clear cut results. Patterns are evaluated for trends among SONGS beaches (i.e., within 20 km of SONGS) and for differences between Near (within 6.5 km) and Far beaches.

		1976-1978	1980	1981	1983	1986	OVERALL
Catch per unit effort of larger crabs	Among SONGS Beaches	↓	--	--	NDP	NDP	⇩
	Near vs. Far	--	--	--	↓ (June only)	NDP	⇩
Average maximum size of crabs	Among SONGS Beaches	↓	NDP	↓	NDP	--	↓
	Near vs. Far	NDP	NDP	NDP	NDP	--	NDP
Growth rate	Among SONGS Beaches	↓	--	--	--	--	--
	Near vs. Far	↓	--	--	--	--	--
Fraction with eggs	Among SONGS Beaches	↑	NDP	↑	↓	NDP	NDP
	Near vs. Far	↑	NDP	⇩	↓	NDP	NDP
Fraction without spent egg masses	Among SONGS Beaches	--	--	NDP	↓	NDP	NDP
	Near vs. Far	--	--	↓	↓	NDP	↓
Fraction with complete egg clutches	Among SONGS Beaches	--	--	--	↓	NDP	⇩
	Near vs. Far	--	--	--	↓	NDP	⇩
Minimum size when reproductive	Among SONGS Beaches	↓	NDP	↓	↑	--	↓
	Near vs. Far	NDP	NDP	NDP	NDP	--	NDP

Source: Final *Technical Report A. Sand Crabs*, Table 1. Note, names of some variables have been changed from their form in that table.

Figure 16.1: Mean maximum female (a) and male (b) size, and mean minimum size of reproduction (c). Results are plotted as a percentage of the value at the station 0.4 km north of SONGS, which is indicated by a diamond. Results are the mean (plus or minus one standard error of the mean) at each beach within 20 km of SONGS and at La Jolla (65 km south of SONGS). Data used in these plots are analysed in Technical Report A, Volume I, Sections 3.1.3 and 3.1.6.


1976–1978
1980
1981
1983
Percentage of Mean Maximum Female Size relative to 0.4N
6.5N
1.5N
0.4N
1.5S
6.5S
16S
65S
12N
other sites
15.5N
18S
Longshore Distance (Km North or South) from SONGS

Figu[illegible].1a

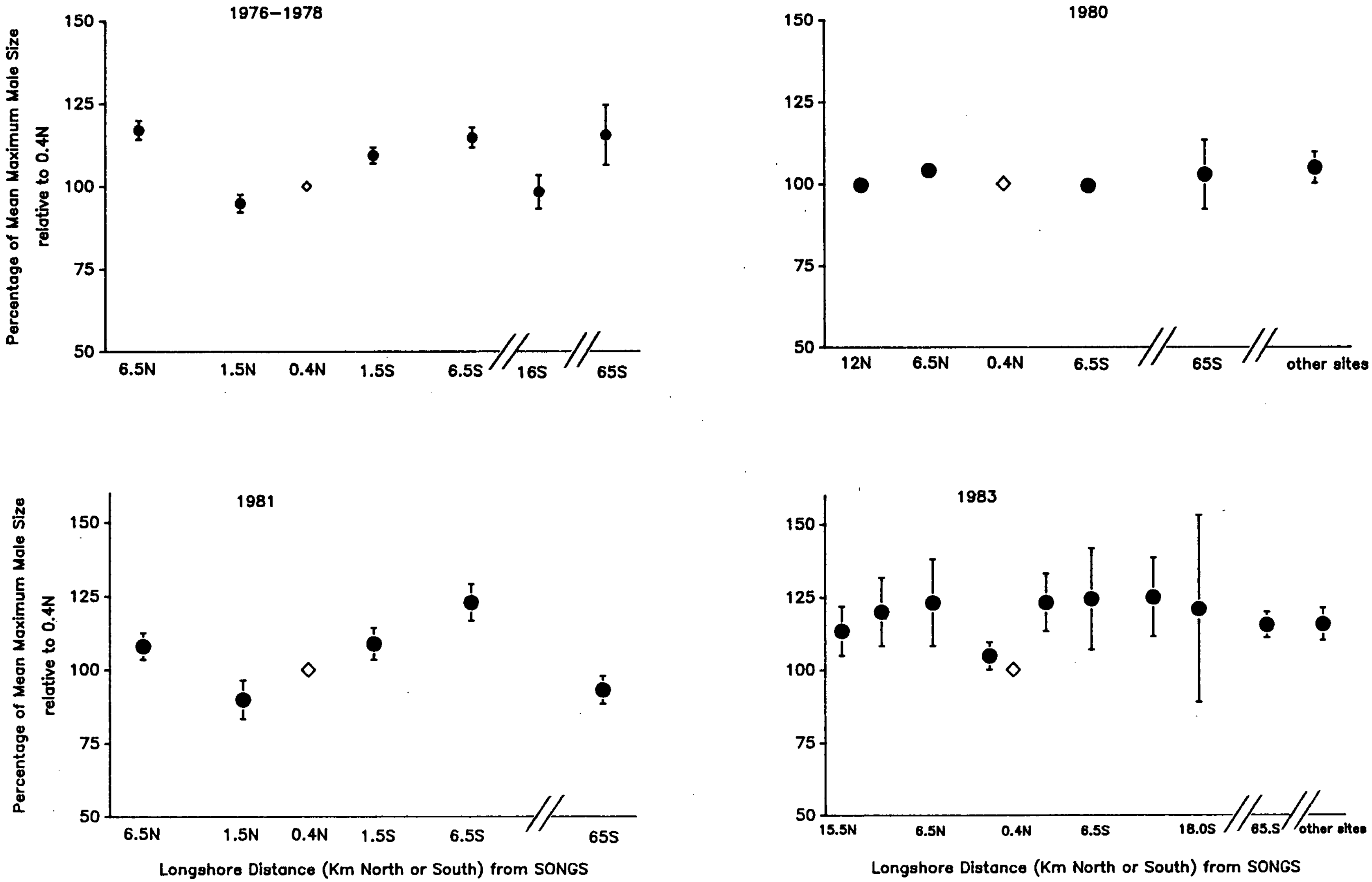
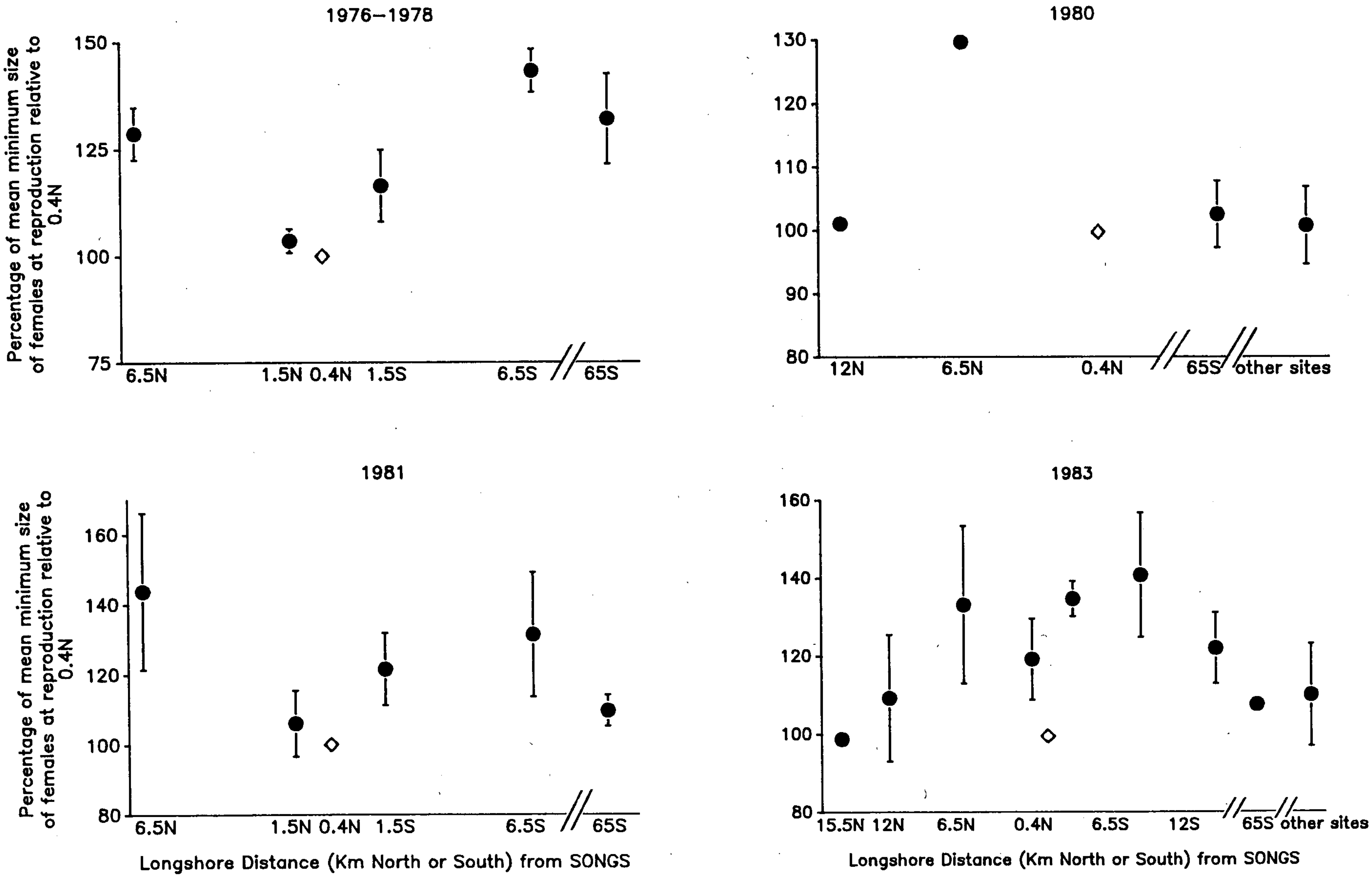

1976–1978
Percentage of Mean Maximum Male Size relative to 0.4N
150
125
100
75
50
6.5N
1.5N
0.4N
1.5S
6.5S
16S
65S
1980
150
125
100
75
50
12N
6.5N
0.4N
6.5S
65S
other sites
1981
Percentage of Mean Maximum Male Size relative to 0.4N
150
125
100
75
50
6.5N
1.5N
0.4N
1.5S
6.5S
65S
Longshore Distance (Km North or South) from SONGS
1983
150
125
100
75
50
15.5N
6.5N
0.4N
6.5S
18.0S
65.S
other sites
Longshore Distance (Km North or South) from SONGS

Figure 16.1b



1976–1978
Percentage of mean minimum size of females at reproduction relative to 0.4N
150
125
100
75
6.5N
1.5N 0.4N 1.5S
6.5S
65S
1980
130
120
110
100
90
80
12N
6.5N
0.4N
65S
other sites
1981
Percentage of mean minimum size of females at reproduction relative to 0.4N
160
140
120
100
80
6.5N
1.5N 0.4N 1.5S
6.5S
65S
Longshore Distance (Km North or South) from SONGS
1983
160
140
120
100
80
15.5N 12N
6.5N
0.4N
6.5S
12S
65S
other sites
Longshore Distance (Km North or South) from SONGS

Figure 16.1c

Figure 16.2: Fraction of female crabs with spent (a) and partially spent (b) eggs. Results are plotted as in Fig. 1. Data used in these plots are analysed in Technical Report A, Volume I, Sections 3.1.5.2 and 3.1.5.3.

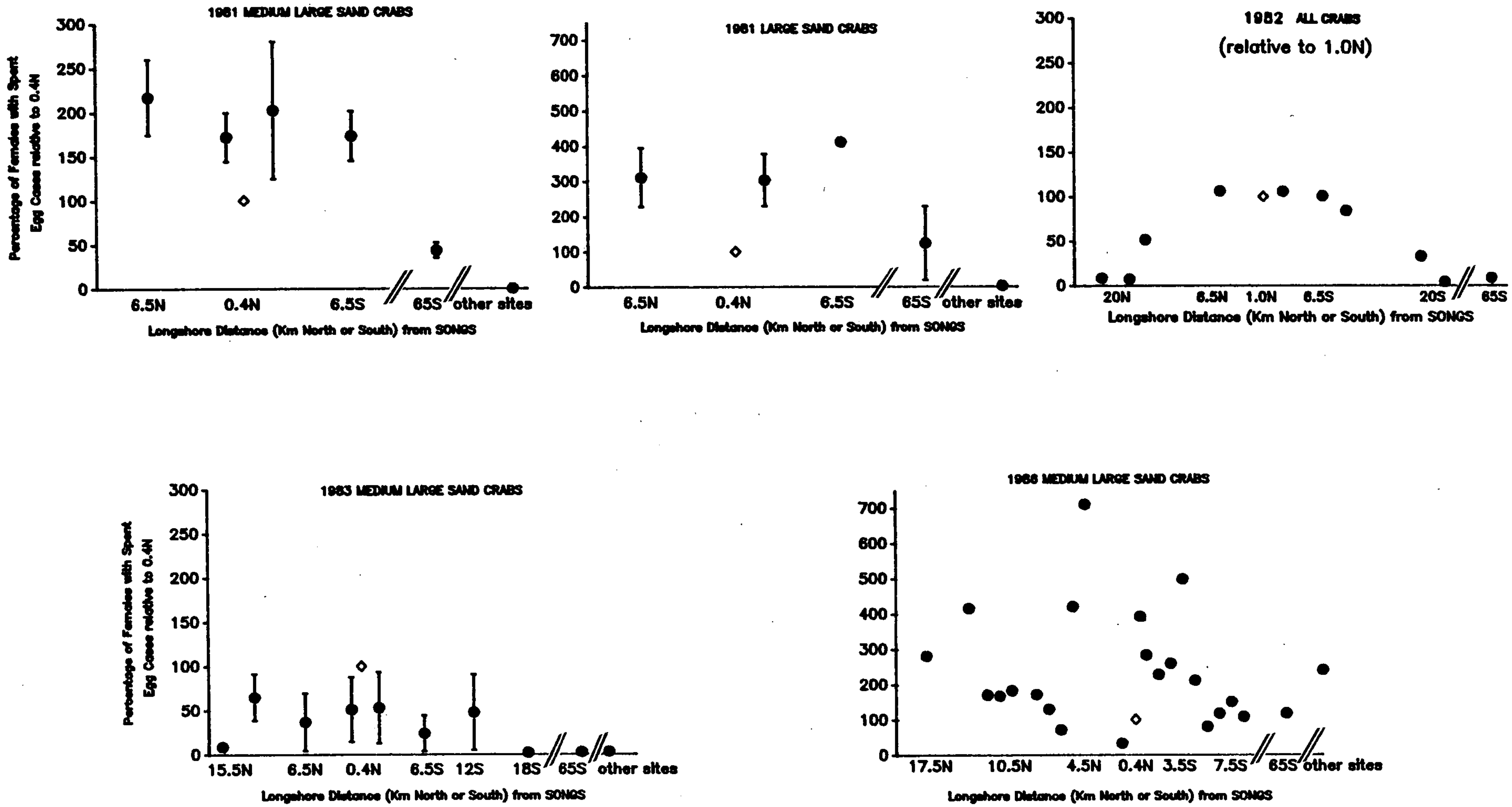

1981 MEDIUM LARGE SAND CRABS
Percentage of Females with Spent Egg Cases relative to 0.4N
6.5N
0.4N
6.5S
65S
other sites
Longshore Distance (Km North or South) from SONGS
1981 LARGE SAND CRABS
1982 ALL CRABS
(relative to 1.0N)
20N
1.0N
20S
1983 MEDIUM LARGE SAND CRABS
15.5N
12S
18S
1986 MEDIUM LARGE SAND CRABS
17.5N
10.5N
4.5N
3.5S
7.5S

Figure 16.2a

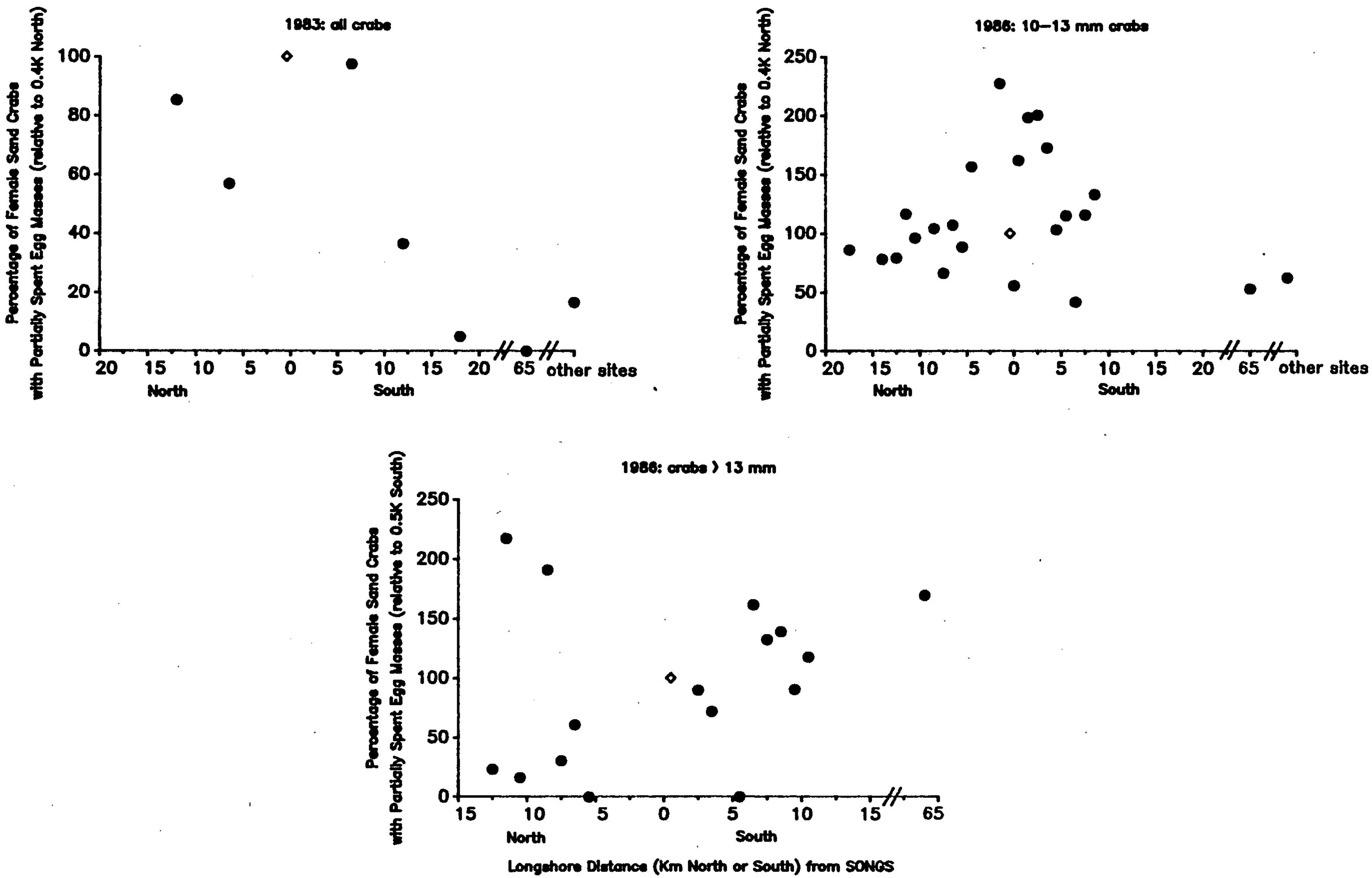

1983: all crabs
Percentage of Female Sand Crabs with Partially Spent Egg Masses (relative to 0.4K North)
100
80
60
40
20
0
20 15 10 5 0 5 10 15 20 65 other sites
North
South
1986: 10–13 mm crabs
Percentage of Female Sand Crabs with Partially Spent Egg Masses (relative to 0.4K North)
250
200
150
100
50
0
20 15 10 5 0 5 10 15 20 65 other sites
North
South
1986: crabs > 13 mm
Percentage of Female Sand Crabs with Partially Spent Egg Masses (relative to 0.5K South)
250
200
150
100
50
0
15 10 5 0 5 10 15 65
North
South
Longshore Distance (Km North or South) from SONGS

Figure 16.2b

SONGS beaches, however, the effect generally does not become more severe nearer the plant; indeed, a statistically significant opposite pattern prevailed in 1981. Crabs from the beaches at 0.4 and 1.5 km north were typically not "worse" than at other SONGS beaches.

(c) In one year (1983), the fraction of females with partially spent egg clutches was significantly higher at beaches within 6.5 km of SONGS than at those further from the plant [TR A: 3.1.5.3]. The fraction partially spent also decreased significantly with distance from the plant within SONGS beaches [TR A: 3.1.5.3], because of low values downcoast of SONGS (Figure 16.2b). These patterns were seen in the other year (1986) when this variable was measured, in one size class of crabs (Figure 16.2b), but not in the other [TR A: 3.1.5.3].

Thus, we conclude *there are location effects in some aspects of sand crab biology*. Although there are location effects, the biology of sand crabs near San Onofre is not qualitatively unique; the differences are, rather, quantitative.

Relation between location effects and level of SONGS' operation

Although concerns eventually focused on metals as a potential cause of the location effects, at first there was simply a general concern that something about the plant's activities affected sand crabs. The most obvious way to test this hypothesis is to determine whether the severity of the effects is related to the degree of operation of the plant.

Analyses of the data show that there was no relationship between the level of SONGS' activity (as measured by volume of water pumped) and the severity of location effects on crabs (e.g., the amount by which crabs near SONGS are smaller than those further away) [TR A: 3.2]. Of 21 such correlations, only two were statistically significant and in both cases (one relating to crab size, the other to spent eggs) crabs at SONGS did relatively *better* the higher the plant's pumping rate was. In the first case, female crabs were larger when Units 2 and 3 pumped more water; this is mainly because crabs were smaller at the Impact site in 1976-78, before Units 2 and 3 had begun operating. In the second case, the spent condition was *less* prevalent at the Impact site when Unit 1 was pumping at a *higher* rate.

Metals and Sand Crabs

As work on sand crabs progressed, two potential mechanisms were emphasized: (1) SONGS releases metals (eventually, it was hypothesized, chromium in particular) and these cause the observed location effects in sand crabs, and (2) SONGS releases radionuclides with the same effect.

Unlike the general contention that something related to SONGS affects crabs, the metal hypothesis does not require that SONGS has its worst effects when it is most actively pumping. Indeed, it has been suggested that SONGS effects on sand crabs are likely to be greater, *not* when the plant is in full operation, but when it is beginning operation again after having been offline for some time. The argument here is (a) that metals accumulate in the plant when it is non-operational, due to corrosion, and are flushed into the environment in a large pulse when the plant begins pumping again, and/or (b) that systems in the plant requiring chromated coolant are drained at such times, and the coolant is replaced. Thus these are the times when spills of chromated coolant could occur (SCE states that this has never occurred [TR E: Appendix E]).

We deal first with metals. The postulated mechanism requires that three conditions be satisfied:

(1) concentrations of metals in the environment or in sand crabs near SONGS are substantially higher than those at control beaches;

(2) SONGS produces enough metals to increase substantially their concentrations in the SONGS area;

(3) the location effects in sand crabs are associated with substantially higher concentrations of metals.

Three main sources provide information on possible gradients of metals in the environment north and south of the plant. First, the MRC measured sand crab biology and eight metals in beach sediments and in sand crabs at many beaches in July and August 1983. Initial analyses suggested the concentrations of three of these metals (chromium, manganese and iron) might be in higher concentrations in crabs near SONGS, so their concentrations, and those of radionuclides, were measured in sand crab tissues in a third survey in August 1986. Wenner (1988) also reported concentrations of metals in sand crabs collected in 1982 from a few beaches near SONGS and elsewhere.

The best source of information on concentrations of metals near SONGS in fact comes, not from sand crabs, but from various studies using mussels, which are a standard organism used to detect metal pollution in the ocean. Data on mussels are available from three studies. In a 1977 MRC study, mussels were hung directly in the discharge plume of Unit 1 on two occasions, once for two and once for four months, at various distances north and south of the plant. This study overlapped, in part, the 1976-78 sand crab study. MRC also hung mussels upcoast and downcoast of the discharges of Units 2 and 3 in 1986-87, for 5 months. Finally, State Mussel Watch had a single station in the SONGS discharge plume for 4.9 months during 1985.

We next examine each of the above required conditions in turn.

<u>Concentrations of metals near SONGS and at control beaches</u>

A summary of the findings is as follows. There is no evidence that metal concentrations are consistently and substantially higher in the SONGS area. On the contrary, there is good evidence that the area is typically low in metals. There is evidence that manganese is somewhat higher at two beaches immediately upcoast of SONGS (0.4 and 1.5 km north), compared with beaches immediately downcoast of the plant. In the one case where metal concentrations were measured at sites between 1.5 and 6.5 km north of SONGS, the highest concentrations were found near the outfall of San Mateo Creek (4.5 km north of SONGS) [TR E: Summary]. Details follow.

The mussel data all show that the concentrations of metals, including chromium, in the SONGS area have been low in comparison with the concentrations considered high by State Mussel Watch [TR E]. The chromium and manganese concentrations from MRC's 1986 mussel outplants are included in Figures 16.3a - 16.3d.

There was also no consistent pattern for metals to be in higher concentrations in beach sediments or sand crab tissues near SONGS (Figure 16.3a and 16.3c) [TR A: 3.3.1, Appendix B]. In the sediments the only statistically significant relationship was that chromium was lower at beaches nearer the plant [TR A: B-10].

In sand crab tissues, chromium was once significantly higher at beaches within 6.5 km of SONGS than at more distant beaches, but there was not a consistent pattern either across categories of crabs or through time [TR A: 3.3.1]. Furthermore, the values at the beaches close to SONGS were not high on an absolute scale (Figure 16.3bvii). On one occasion (August 1983) chromium (and iron) were relatively very high in one category of female crabs at the beach 0.4 km north of SONGS (Figure 16.3bvi). However, the other category of females had low values of these two metals at that beach, and had even higher values of chromium (and iron) at the beach 12 km north of the plant (Figure 16.3bv) [TR A: B-12]. Only 2 out of 27 analyses of metals in sand crab tissues in 1983 and 1986 indicate higher concentration of metals within 6.5 km of SONGS in comparison with more distant beaches [TR A: B-11 & B-14]. High concentrations of zinc, nickel, manganese and iron reported near SONGS in 1982 appear to be restricted to a very narrow range of beaches north of SONGS [TR E; see also following paragraphs].

Figure 16.3: Chromium (a, b) and manganese (c, d) concentrations in tissues of sand crabs (i-vii) and mussels (viii) from beaches within 20 km of SONGS. Where available, concentrations at La Jolla (65 km south of SONGS) are also plotted. Data are plotted for all cases where at least one station was located upcoast (north) of SONGS. Data used in these plots are analysed in Technical Report A, Volume I, Section 3.3.1 and Appendix B (sand crabs); and Technical Report E, Section 3 (mussels).

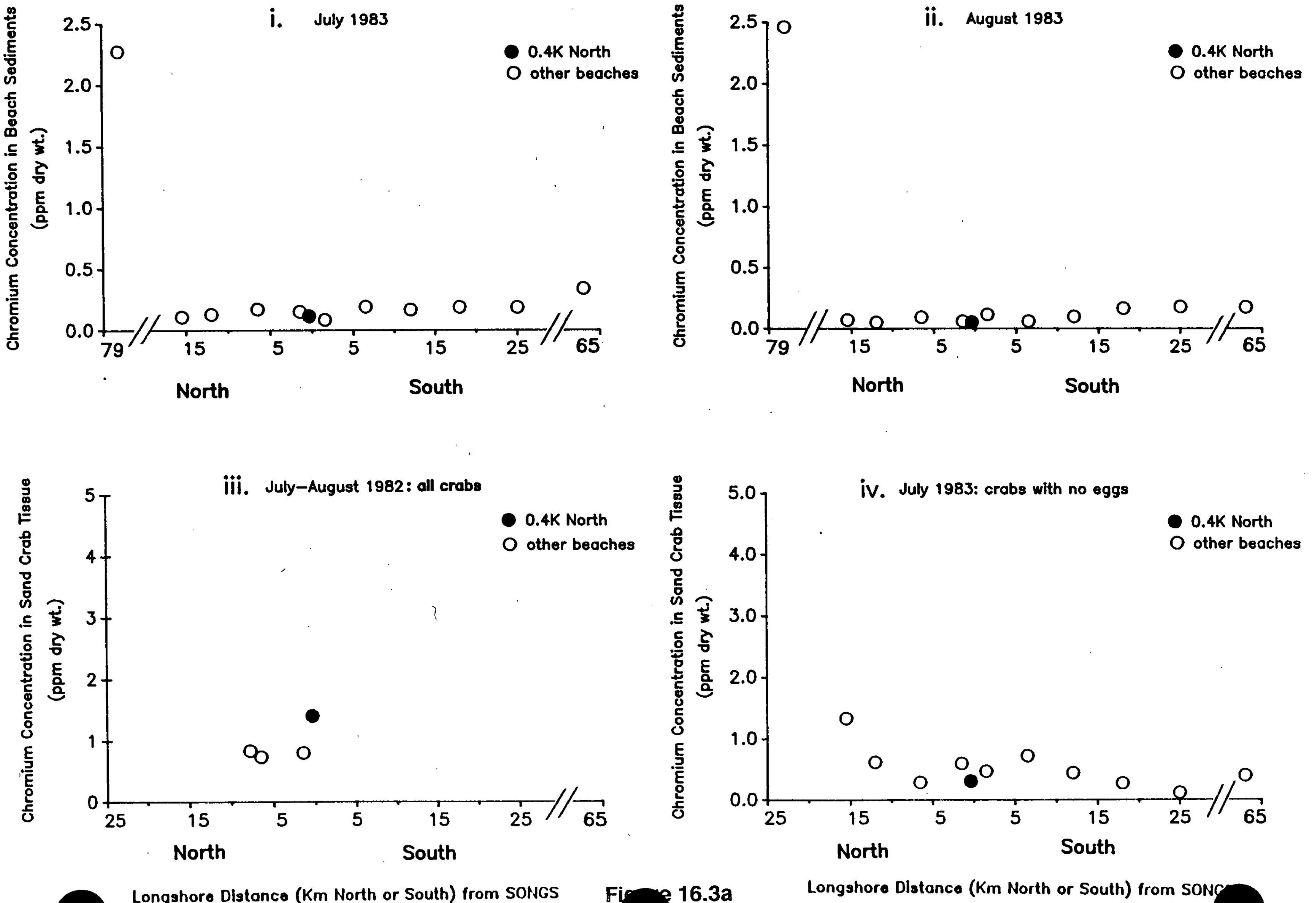

i. July 1983
ii. August 1983
0.4K North
other beaches
Chromium Concentration in Beach Sediments (ppm dry wt.)
2.5
2.0
1.5
1.0
0.5
0.0
79
15
5
5
15
25
65
North
South
iii. July—August 1982: all crabs
iv. July 1983: crabs with no eggs
Chromium Concentration in Sand Crab Tissue (ppm dry wt.)
5
4
3
2
1
0
5.0
4.0
3.0
2.0
1.0
0.0
25
Longshore Distance (Km North or South) from SONGS

Figure 16.3a

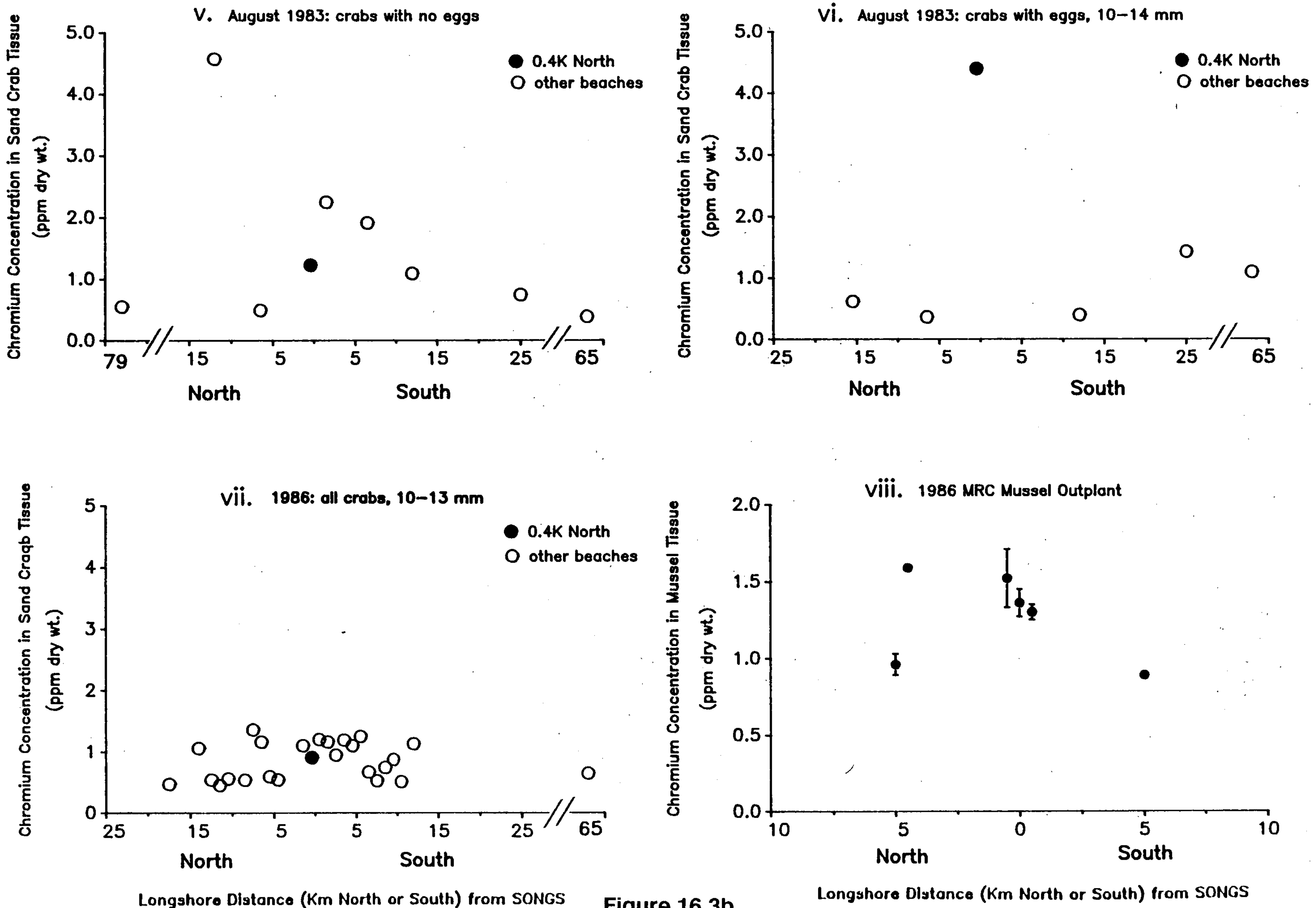

V. August 1983: crabs with no eggs
0.4K North
other beaches
Chromium Concentration in Sand Crab Tissue (ppm dry wt.)
5.0
4.0
3.0
2.0
1.0
0.0
79
15
5
5
15
25
65
North
South
Vi. August 1983: crabs with eggs, 10–14 mm
0.4K North
other beaches
Chromium Concentration in Sand Crab Tissue (ppm dry wt.)
5.0
4.0
3.0
2.0
1.0
0.0
25
15
5
5
15
25
65
North
South
Vii. 1986: all crabs, 10–13 mm
0.4K North
other beaches
Chromium Concentration in Sand Craqb Tissue (ppm dry wt.)
5
4
3
2
1
0
25
15
5
5
15
25
65
North
South
Longshore Distance (Km North or South) from SONGS
Viii. 1986 MRC Mussel Outplant
Chromium Concentration in Mussel Tissue (ppm dry wt.)
2.0
1.5
1.0
0.5
0.0
10
5
0
5
10
North
South
Longshore Distance (Km North or South) from SONGS

Figure 16.3b

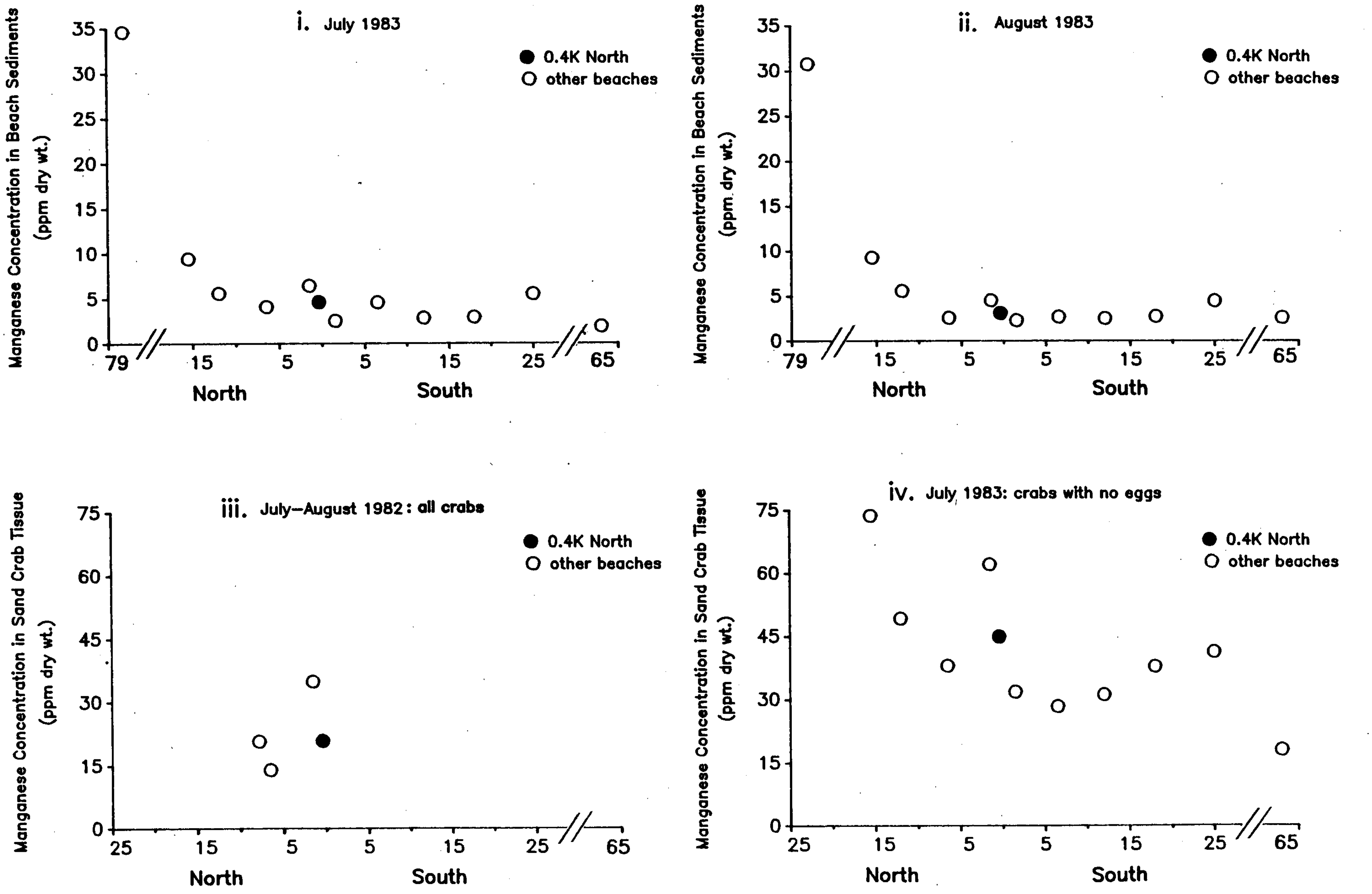

i. July 1983
Manganese Concentration in Beach Sediments (ppm dry wt.)
0.4K North
other beaches
35
30
25
20
15
10
5
0
79
15
5
5
15
25
65
North
South
ii. August 1983
Manganese Concentration in Beach Sediments (ppm dry wt.)
0.4K North
other beaches
North
South
iii. July–August 1982 : all crabs
Manganese Concentration in Sand Crab Tissue (ppm dry wt.)
0.4K North
other beaches
75
60
45
30
15
0
25
15
5
5
15
25
65
North
South
iv. July 1983: crabs with no eggs
Manganese Concentration in Sand Crab Tissue (ppm dry wt.)
0.4K North
other beaches
North
South
Longshore Distance (Km North or South) from SONGS
Longshore Distance (Km North or South) from SONGS

Figure 16.3c

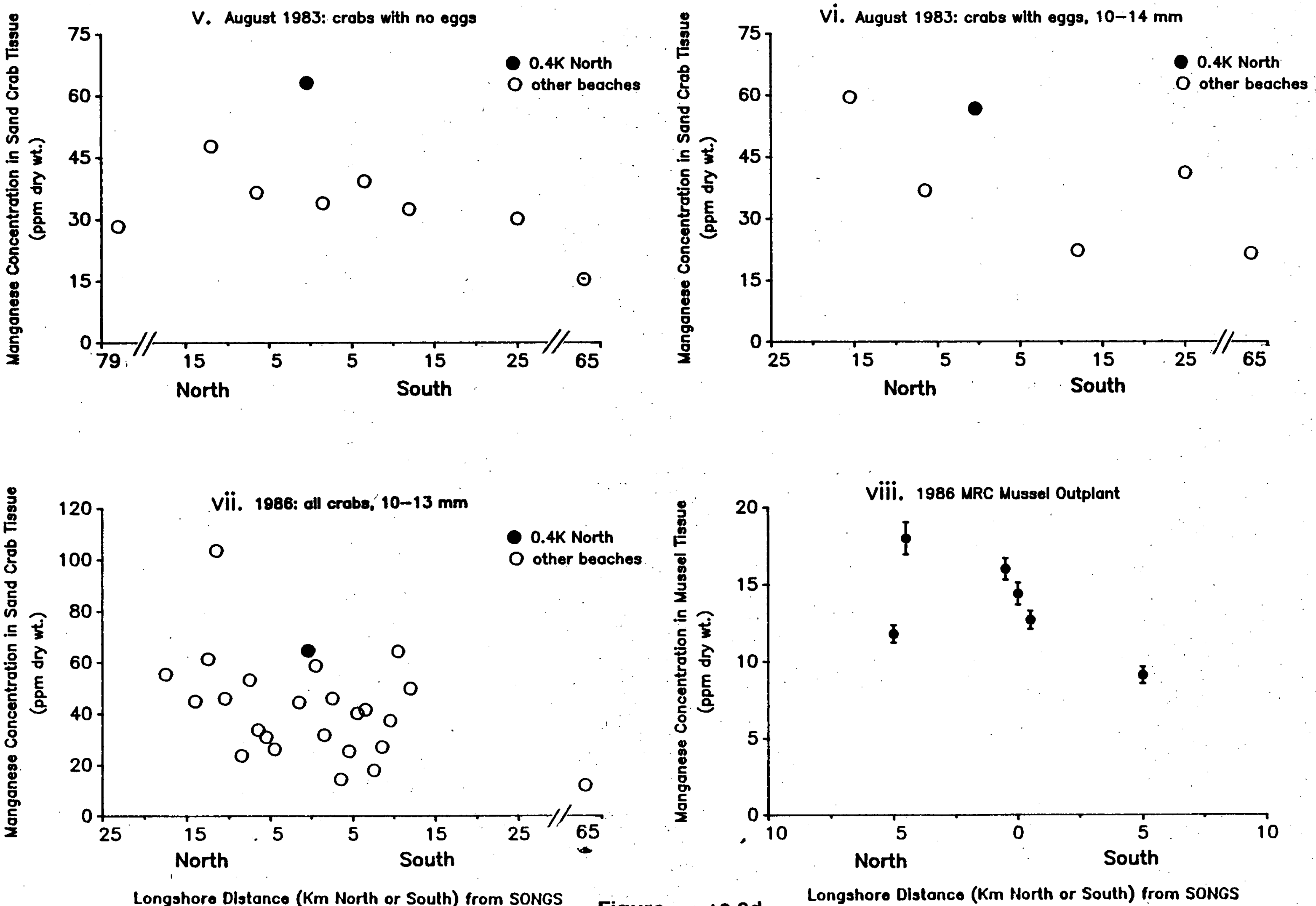

V. August 1983: crabs with no eggs
0.4K North
other beaches
Manganese Concentration in Sand Crab Tissue (ppm dry wt.)
75
60
45
30
15
0
79
15
5
5
15
25
65
North
South
Vi. August 1983: crabs with eggs, 10–14 mm
0.4K North
other beaches
Manganese Concentration in Sand Crab Tissue (ppm dry wt.)
75
60
45
30
15
0
25
15
5
5
15
25
65
North
South
Vii. 1986: all crabs, 10–13 mm
0.4K North
other beaches
Manganese Concentration in Sand Crab Tissue (ppm dry wt.)
120
100
80
60
40
20
0
25
15
5
5
15
25
65
North
South
Longshore Distance (Km North or South) from SONGS
Viii. 1986 MRC Mussel Outplant
Manganese Concentration in Mussel Tissue (ppm dry wt.)
20
15
10
5
0
10
5
0
5
10
North
South
Longshore Distance (Km North or South) from SONGS

Figure 16.3d

There is quite consistent evidence that manganese was at high concentrations at the beaches 0.4 and 1.5 km north of the plant, relative to beaches immediately downcoast of SONGS (Figures 16.3c and 16.3d) [TR E]. The pattern can be seen, for example, in the 1986 mussel data, in which concentrations were high also at the beach 4.5 km north of the plant; concentrations became progressively lower at the beaches immediately south of the plant (Figure 16.3dviii; a similar pattern can be seen in chromium, Figure 16.3bviii). High values for manganese were often seen also in sand crabs from the two beaches immediately north of SONGS, relative to those from beaches immediately downcoast of the plant or from the beach at 6.5 km north (Figures 16.3c and 16.3d) [TR E]. Again, these values were not absolutely high - higher values occurred at other beaches in the area.

Manganese was in general at higher concentrations in the SONGS region than at La Jolla (Figures 16.3c and 16.3d). However, in State Mussel Watch studies, high manganese concentrations are seen in areas north (Dana Point) and south (Oceanside). In addition, the concentrations of manganese are not high in comparison with those considered high by State Mussel Watch (compare the values in Figure 16.3d with 35.9 ppm dry weight: 15% of resident California mussel populations sampled by State Mussel Watch have manganese concentrations above 35.9) [TR E].

What is the probable source of the generally relatively high values of manganese immediately north of SONGS? It is not likely to be SONGS. First, there is no evidence that SONGS emits significant amounts of manganese (SONGS releases small quantities of radioactive manganese, but this arises from the decay of other radioactive elements, not from stable manganese). Second, if SONGS were the source, maximum concentrations would be expected *south* of the plant, since the longshore currents move in this direction more than 60% of the time [TR L]. The most likely source of this metal is San Mateo Creek, which enters the ocean 4.5 km north of the plant; the highest values of manganese between 6.5 km north and 6.5 km south of the plant tended to occur at the station nearest the creek on the downcoast side, and the concentration declined for several kilometers with distance southward (e.g., Figures 16.3c and 16.3d).

We showed above that the intensity of reproductive disruption is not related to SONGS' pumping rate. A possible response to this result is to argue that the plant produces metals mainly in brief periods when it is turned on after having been offline for an extended period. This hypothesis predicts that reproductive effects should be associated particularly with such events. The effects might appear immediately, or with a time lag, but they should appear sporadically in time. To the contrary, however, spent and partially spent clutches occur throughout periods when the plant has been operating continuously for long periods.

SONGS as a source of metals

A detailed analysis of evidence relating to SONGS as a source of metal pollutants is presented in *Final Technical Report E.* The *Sand Crab Technical Report (A)* also calculates an upper bound on the releases of chromium from the systems chromated to inhibit corrosion within SONGS. The highest calculated releases of chromium from the chromated systems would not lead to detectable changes of chromium concentrations in seawater in the SONGS area. The Technical Report concludes that there would need to be a large but unrecognized source of chromium at SONGS for the power plant to increase appreciably chromium concentrations in the environment. The *Metals and Radiation Technical Report (E)* reviews the available data and concludes there is no evidence for substantial elevation of chromium concentrations in the environment near SONGS (see also Chapter 17). Concentrations of some metals, particularly manganese, are sometimes higher north of the plant than at other nearby locations, suggesting that San Mateo Creek is a source.

Sand crab biology and chromium in tissues

It is noted above that the concentrations of metals in the environment and in crab and mussel tissues near SONGS typically are similar to those found at other beaches that are distant from the plant and are not near known sources of pollutants. It also appears that SONGS is not a significant source of metals. Chromium, however, has been the major focus of concern as the most likely metal that might be released by SONGS into the oceans in significant quantities; this metal was occasionally in higher concentrations in crabs near SONGS than at more distant beaches, and high concentrations of chromium have been shown to reduce brood size in a marine worm in the laboratory. We therefore examined the relationship between sand crab biology and tissue concentrations of chromium.

We caution that, perhaps surprisingly, there is little relationship between the concentration of any particular metal in the sediments and its concentration in the tissues of sand crabs from that environment [TR A: B-18]. For example, Cabrillo beach (in Los Angeles harbor) is highly polluted and metals were 10 times more abundant in its sediments than at other beaches, yet metal concentrations were not especially high in sand crab tissues from that beach. In addition, concentrations in tissue vary greatly among different classes (e.g., reproductive categories) of crabs taken from the same beach. It thus seems that concentrations of metal in crab tissues may not be a reliable indicator of the exposure level.

There is no consistent relationship between sand crab biology and chromium in the tissues, across either space and or time. First, sand crab biology at a beach on a particular date was typically not related to the concentration of chromium in the tissues of these crabs [TR A: B-19 & B-20]. In 1983 and 1986, in 7 of 41 cases, sand crab biology was related to chromium concentrations, but the relationships were not consistent. For example, in August 1986 for one category of crabs, the fraction reproductive *increased* with chromium concentration, while in another the fraction reproductive decreased with chromium concentration. The same kind of reversal between categories was seen for spent clutches in this month. In 1986 there were no significant correlations between sand crab biology and chromium concentrations in the tissues, yet this was the only survey in which we found a significantly higher concentration of chromium in crabs over the stretch of beaches near SONGS (TR A: 3.3.1).

The lack of an association between location effects in crabs and chromium is especially striking across years. In 1982 and 1983, chromium concentrations in crab tissues were *not* raised in the general SONGS area, yet these two years provide the best evidence that egg development is sometimes disrupted (high fraction of females with completely spent clutches) over a large area near SONGS (Figure 16.2). By contrast, 1986 is the only year in which there was evidence that chromium in crab tissues was relatively high in a range of beaches near SONGS, but the fraction of females with spent clutches was *not* different near SONGS from elsewhere in that year.

No work has been done, that we know of, that relates sand crab physiology with the concentration of metals in the tissues. As noted above, however, this problem has been studied in marine worms. Negative effects were not found until the worms were chronically exposed to the most toxic form of chromium at concentrations that led to tissue concentrations 9 times the highest concentrations seen in sand crabs near SONGS.

Crabs typically are small at the beaches at 0.4 and 1.5 km north of the plant, and manganese also tends to be high there relative to other nearby beaches. We do not believe, however, that manganese causes the crabs to be small. The manganese concentrations are not absolutely high, and large crabs are found where manganese concentrations are higher. Thus we do not believe that manganese is the cause of the observed differences in crabs.

Sand Crabs and Radiation

In 1986, samples of sand crabs from over 20 locations within 20 km north and south of SONGS were analyzed for tissue concentrations of radioactive isotopes. Detectable concentrations of the radioactive isotopes of manganese and cobalt were found in crabs at beaches more than 10 km from the plant. There is no known local source of these isotopes other than SONGS. In general, plant-related radionuclides were more often at detectable concentrations in sand crabs collected nearer to and downcoast of SONGS. However, they were not detected at a number of beaches that were closer to the plant than the farthest beaches where they were detected. This suggests that the radioactive isotopes at these more distant beaches may have been carried there by sand crabs rather than directly in SONGS' discharge water.

The internal radiation activity levels received by crabs from these radionuclide concentrations is less than one millionth of the minimum rate that has ever been shown to have even a sublethal effect on a marine invertebrate. Indeed, the rates are well within natural background variation [TR A: B-27]. The concentrations are similar to those found in other organisms sampled and analyzed by SCE to comply with NRC regulations for monitoring the environment near SONGs.

There is thus no basis for suspecting that radioactive substances released from SONGS can account for any observed location effects in sand crabs.

Sand crabs and variation in the natural environment

The most likely explanation for the location effects in sand crabs is variation in the natural beach environment. Our explanation cannot be complete, in part because too little is known about sand crab biology, and in part because the MRC mandate did not include studies of basic biology for its own sake.

Clues to the probable causes of the location effects come mainly from the 1983 and 1986 studies. Overall, beaches made up of coarser materials (cobble and gravel rather than sand), which also tend to be steeply sloping beaches, are "poor" sand crab beaches, and they tend to be prevalent in the SONGS area (Figure 16.4)

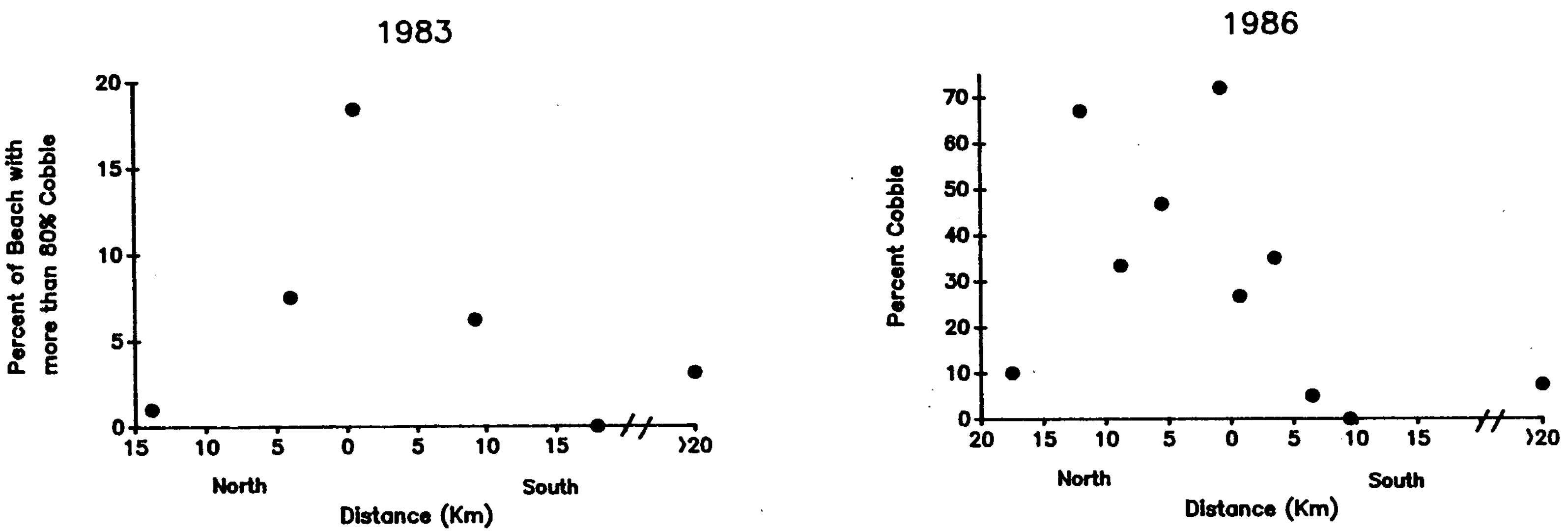


Figure 16.4. Environmental data on mean cobble cover from the 1983 and 1986 sand crab surveys. These data are analyzed in Technical Report A, Volume I, Appendix C.

[TR A: 3.3.2 & Appendix C]. Statistical analyses show that, in 1983, key attributes of the crabs (such as abundance, fraction with spent eggs, fraction with partially spent clutches) could be explained by the natural physical/chemical environment. These aspects of crab biology tended to be "worse" on beaches with a high fraction of cobble and/or coarse sediment, and that were steeper. These physical features also tended to be associated with smaller crabs. Again, the fraction partially spent was higher on beaches with more cobble. In this year the crabs were categorized into only two size classes and all samples were of the qualitative type. Thus we were less able to evaluate the effects of cobble and substrate on crab size in that year.

Although no truly comparable data exist from before Unit 1 became operational in 1968, samples of crabs were taken in the area at various times beginning in 1963. These samples consistently show a marked absence of large individuals, suggesting the absence of large crabs near SONGS is a natural characteristic of the local beaches, rather than a result of SONGS [TR A: C-17].

Sand crabs in a broader perspective

Two types of location effects have been seen in sand crabs.

1. *Size Effects*

Large crabs tend to be absolutely or relatively rarer on beaches at 0.4 and 1.5 km north of SONGS. This pattern was first noticed while only Unit 1 was in operation, and there has been no detectable tendency for the extent of the effect to increase as Units 2 and 3 have come on line.

MRC reported, in 1978, on extensive studies on a diverse group of organisms around Unit 1. Few effects were detected, and of those that were, none extended beyond about half a mile from SONGS. There was probably a change in the size composition of queenfish (which is taken into the intakes in large numbers) out to about 0.5 km. Organisms living on the soft bottom were altered out to 200 meters, an area affected by back-flushing of organic debris from the plant during heat-treatments.

Effects detected in two studies are particularly relevant. First, mussels were hung directly in the discharge plume of Unit 1 for periods of two and four months in 1976-77. At the end of the four-month experiment, reductions in growth of mussels were detected as far as 800 meters downcoast and 400 meters upcoast of the plant (the asymmetry being consistent with the generally southward flow of the currents). No reductions occurred at 1600 meters from the plant, or beyond. The most likely cause of the reduced growth is the high concentration of seston in the plume [TR E].

Second, juvenile kelp plants were transplanted into the discharge plume of Unit 1 in 1979. The currents flowed mainly upcoast during this experiment. Effects, including fouling of blades and loss of blades and fronds, were found out to 300 m upcoast of Unit 1, but not beyond; one other effect (on the growing tips) was found out to 600 m upcoast. No effects were detected at the next most distant upcoast station (4000 m).

In both of these cases, the organisms were exposed over long periods to concentrations of discharge materials much higher than those that would reach the intertidal environment of sand crabs, yet effects in the northward direction extended no further than 600 meters. Sand crabs, of course, might stay in one location for long periods, and they might be much more sensitive than, say, mussels to environmental disturbance. But the observations on mussels and kelp certainly do not make it more probable that the variation in size of crabs is attributable to the plant, or that effects of the plant should be as or more marked to the north than to the south.

2. *Reproductive effects*

The location effects on "spent eggs" have typically extended for at least 12 km north and south of SONGS, and perhaps for 20 km in either direction. The very extent of these effects, in the context of other findings from MRC studies, argues strongly against their being related to SONGS' operation. There are other powerful reasons for rejecting SONGS as the cause.

The spent egg condition was reportedly seen at one beach (6.5 km north) in July 1980, but was first estimated quantitatively in 1981. It has been suggested that this was a disruption of egg development that had not previously occurred, and the implication is that it was caused by the onset of pumping by Unit 2 in 1980. In addition to the reasons elaborated in earlier parts of this chapter, others that make this an extremely unlikely explanation are as follows.

(1) The spent egg condition has been observed in sand crabs from relatively unpolluted beaches far from SONGS (e.g., at La Jolla, 65 km south of SONGS). It is most unlikely that this is a new phenomenon created by the plant. It is more

likely that it was not observed before 1980 because no one had looked for it. The same is true for the partially-spent condition.

(2) We noted above that effects from Unit 1 operation have not been detectable beyond about half a mile from SONGS, even on organisms hung for long periods in the discharge plume. It is therefore hard to see how it could have effects on the beach out to 12 or 20 km. It is also hard to conceive that Unit 2 could have had environmental effects extending at least 12 km and perhaps 20 km, at the low pumping rates of 1980 and 1981 (Figure 16.5). The case against Units 2 and 3 having distant effects *onshore* is, indeed, even stronger than that for Unit 1. These units were designed specifically to move their discharge *offshore*. That they do so is the reason we detect effects in the San Onofre Kelp Bed (Chapters 7 - 9). Typically, discharge water from these units makes up less than 1% of the water reaching the beach within 10 km of SONGS, and the concentration falls with distance from the plant (Chapter 6).

(3) The location effects detected in sand crabs are most evident to the north (i.e., upcoast) of the plant. Yet the nearshore currents, and SONGS' discharge plumes, flow to the south more than 60% of the time. Clearly, effects should be more prevalent to the south, and where we have an estimate of effects in other organisms in both directions, this is the case. Mussels were hung in the discharge plume of Units 2 and 3 for five months in 1986 and provide insight into the spatial scale of SONGS' effects. Growth was reduced in mussels near SONGS, but the effect was seen only at the two stations within 0.5 km *downcoast* of the plant and was not detectable at stations 5 km downcoast and 0.5, 4.5 and 5 km upcoast of the plant.

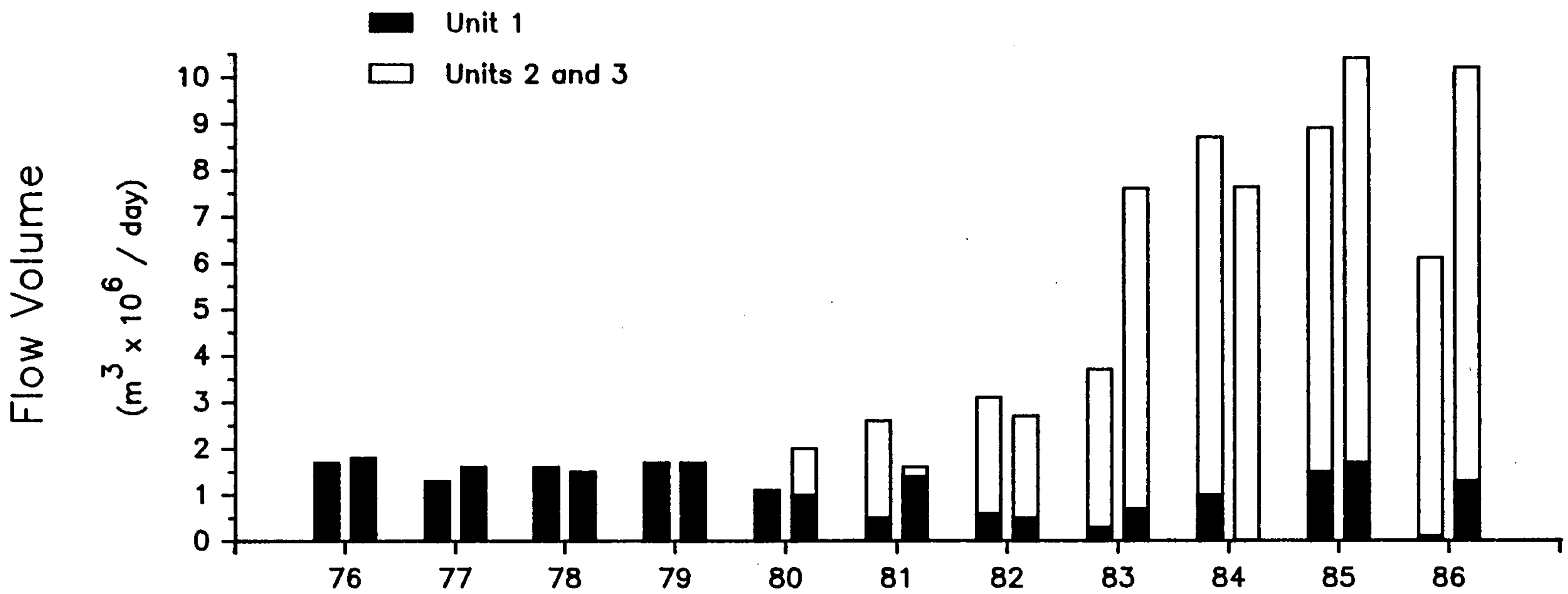


Figure 16.5. Average volumes of seawater discharged from SONGS. In each pair of yearly histograms, the first is the mean daily volume pumped between February 1 and May 31 (spring), and the second is the mean daily volume pumped between June 1 and September 30 (summer).

The reproduction of the mussels was not affected by proximity to the plant (or by the concentration of metals in the tissues).

Conclusions

Sand crabs near SONGS are different in some respects from those more distant from the plant. The evidence strongly supports the conclusion that the large-scale location effects on reproduction are not caused by SONGS. It seems most likely that the patterns reflect differences among beaches that are unrelated to the operation of SONGS, although the actual mechanisms are not known.

The evidence also indicates that SONGS is not responsible for the smaller sizes of crabs at beaches 0.4 and 1.5 km north of SONGS, which are most probably due to the physical characteristics of these beaches. However, because these beaches are so close to the plant, it is not possible, with the available evidence, to rule out completely the possibility of a SONGS effect.

The overall conclusion reached in this report differs from those reached in some reports and publications of Dr. Adrian Wenner, which are based in part on data collected by Dr. Wenner in 1980-81 for the MRC. Reasons for the differing conclusions are discussed in *Technical Report A: Discussion*.

Chapter 17

METALS AND RADIATION*

Summary

There is good evidence that the concentrations of metals in the SONGS area are low relative to other areas along the coast and are similar to those at "clean" reference beaches. There is no evidence that SONGS releases metals at rates that would raise significantly the concentrations in the surrounding environment. There is no good evidence that metals released by SONGS (or deriving from any other source) have caused detectable ecological effects on the marine biota near SONGS.

SONGS does release radionuclides into the environment at rates sufficient to lead to detectable, but extremely low, concentrations in organisms and, occasionally, in nearby sediments. These concentrations do not raise the radiation dose rates received by the organisms substantially above the background level and are far below the levels known to cause physiological impairment. There is no good evidence that radionuclides released by SONGS have caused detectable ecological effects on the marine biota near SONGS.

Introduction

A more detailed presentation of the material in this chapter is in *Technical Report E*, on which this account is based.

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* The data on which this report is based are from numerous sources including MRC-sponsored studies, SCE reports, State Mussel Watch data and the published literature. Dr. James Bence and Mr. Mark Schildhauer prepared the Technical Report (E) to the CCC.

The large quantities of seawater passed through SONGS receive both radioactive and non-radioactive effluents from a variety of sources, including metals from erosion and corrosion of metal-containing structures in the plant. Federal and state water-quality monitoring programs include procedures aimed at either measuring the levels of such materials released by SONGS into the marine environment or determining whether the plant is increasing their concentration above acceptable levels in the environment.

In response to suggestions that various metals and radionuclides might be having effects on some organisms (mainly sand crabs), the Committee carried out several studies. Metal concentrations and radionuclide activity levels were measured at various times in marine organisms and sediments collected near SONGS and elsewhere. Estimates were also made of potential releases of metals in SONGS' effluents, based on knowledge of plant structure, operation, and chemical inputs. (The MRC did not make direct measurements of chemical or radionuclide discharges to the ocean, nor did it determine the total amount of metals entering and leaving the plant.) Finally, we have also reviewed information from other sources, including that collected as part of federal and state monitoring programs.

The results of MRC field work in relation to metals and radiation were presented in Chapter 16, and we present only a summary here.

Metals

(1) Evidence from studies of sediments and tissues of organisms

The State Mussel Watch (SMW) program has used mussels to monitor the quality of California coastal waters since 1977. In 1985-86 they measured metal concentrations in mussels suspended in SONGS' discharge plume. The concentrations near the plant were similar to those found at relatively "clean," i.e., unpolluted sites, along the coast, including those at the Channel Islands, and were lower than concentrations in the source material collected at Bodega Head [TR E: 2.0]. Concentrations at SONGS were lower, for eight of the nine metals assessed, than those at the beach at Oceanside - a reference station specifically sited "away from known sources of pollution." (Although this site was intended to represent clean, unpolluted conditions, it is just south of Oceanside harbor, where levels of copper and zinc were relatively high in 1985-86. However, these metals were not elevated at the Oceanside beach site.) State Mussel Watch discontinued the San Onofre station in 1986 because the levels were so low.

The MRC also hung mussels in SONGS' discharge plume and other sites in 1976-77 and 1986, on the latter occasion placing mussels upcoast as well as downcoast of SONGS [TR E: 3.0]. Metal concentrations in mussels at SONGS were in general agreement with those determined by State Mussel Watch (even though a different species of mussel was used). Some of the chromium values in 1976 were lower than any ever recorded by SMW. Values for manganese (which is not a particularly toxic metal, and for which we have been able to find no evidence of significant production by SONGS) were somewhat high at SONGS in 1986, but even higher levels were found at this time at the two SMW stations substantially north and south of the plant.

The mussel data thus show that the San Onofre site has been an area of low metal concentrations relative to other areas along the coast in the years when data were taken. MRC's mussel data also show gradients of decreasing metal concentrations that originate upcoast of SONGS at the mouth of San Mateo Creek, and it appears that the creek may be the source of somewhat higher metal concentrations in this immediate vicinity.

Extensive data were collected by MRC on metals in sand crabs in 1983 and 1986 [TR A; TR E: 4.0]. Metal concentrations in sand crabs were not generally higher near SONGS than elsewhere. There is no work that we know of that investigates the concentrations of metals needed to impair the physiology of sand crabs. Concentrations of chromium found in crabs were one-ninth of the lowest concentration of that metal at which an effect (reduced brood size) was seen in a marine worm. Local concentrations again peaked south of San Mateo Creek but north of SONGS, suggesting (given the predominant downcoast current-flow) that the creek was a source of modest local increases in some metal concentrations.

(2) Evidence from concentrations in sediments and seawater

Concentrations of metals in seawater and marine sediments near San Onofre and elsewhere have been measured by Southern California Coastal Water Research Project (SCCWRP) and Southern California Edison Company (SCE), and the MRC has measured metal concentrations in sand from beaches near and far from

SONGS. The results of these sampling programs show that metal concentrations in the vicinity of SONGS are low in comparison with other sites in southern California. In addition, they do not suggest that there has been a substantial increase in metal concentrations specific to sites near SONGS since Units 2 and 3 have come on line [TR E: 5.1].

The reference surveys done by SCCWRP show that the concentrations of seven metals in marine sediments at the 30 m and 60 m depths near SONGS are representative of those found at "uncontaminated" mainland shelf sites [TR E: 5.4]. Metal concentrations found at San Onofre in these studies were also similar to those found at control sites to the immediate north and south.

Both the SCE measures of metals in sediments at 15 m depth and in seawater, and MRC studies of beach sediments [TR E: 5.4] fail to implicate SONGS as a major source of metals. MRC examined metal concentrations in an extensive set of sediment samples from beaches near and more distant from SONGS.[1] In general, metal concentrations in sediments were low at beaches near SONGS relative to other beaches. The concentrations observed in the receiving waters during the period that Units 2 and 3 have been operating (1985 - 1987) have at all times when measured been well below current conservative estimates of chronic toxicity.

The routine operation of SONGS appears to involve the addition of non-hazardous concentrations of metals to the local marine environment [TR E: 6.0]. Metal concentrations in samples of SONGS' discharges are usually well within limits

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[1] Dr. Fay believes the "weak acid extraction" technique used in these studies was inadequate.

set in SONGS' NPDES permit [TR E: 6.1]. Higher concentrations of various metals do occasionally occur. Owing to the sparseness of the sampling regime, however, it is not possible to determine whether these elevated levels reflect rare and intermittent events, sampling variability, or high concentrations in the effluents for longer periods [TR E: 6.1]. These different possibilities lead to quite different conclusions regarding the extent of metallic emissions from SONGS, and they cannot currently be distinguished based on the effluent sampling data alone. Episodic releases of corrosion products may be expected to occur during maintenance periods, during start-up and testing, or during periods when the plant is changing the level of power production. Other information suggests that the occasional high values do not lead to substantial increases in metal concentrations in the receiving waters or sediments (see above). The relatively low metal concentrations in mussels and sediments suggest that SONGS probably does not release high concentrations for long periods, since mussels and sediments integrate metals over time.

The concentrations of metals in the combined discharges of Units 2 and 3 are sampled by SCE, and reported to the Regional Water Quality Control Board, only every six months. This is too infrequent to provide a clear picture of release rates. More frequent sampling or continual placement of mussels in the discharge plume would provide more reliable monitoring.

(3) Estimates of potential release rates by SONGS

There has been particular concern over the levels of chromium discharges by SONGS because preliminary research indicated that there might be an association between unusual patterns in egg production among sand crabs living on beaches near the station, and high concentrations of chromium in the tissues of specimens from those same areas (Chapter 16). The MRC sponsored two studies that used information on the chemical and mechanical aspects of SONGS' operation to estimate the station's potential metallic emissions into the ocean [TR E: 6.3].

These reports encountered difficulties in estimating accurately the likely release rates of chromium and other metals. In particular, estimates were not made of releases rates from corrosion and erosion of metallic surfaces and from surfaces painted with chromium-based paints.

The two studies did not uncover sources of metals large enough to lead to significant contamination of the receiving waters or to chronic violations of effluent limitations established in SONGS' permits. Liberal estimates of mass emission discharges of chromium from systems chromated to inhibit corrosion amount to less than two metric tons per year [TR E: 6.1]. This level of release is far below the effluent limitation requirement specified in the National Pollutant Discharge Elimination System permits for SONGS Units 1, 2, and 3, and would not result in significant increases in the concentration of chromium in the local marine environment. The effluent limits are based on measured toxicity levels [TR E: 5.5], so that these chromium discharges are not expected to affect adversely the local marine biota. For SONGS to cause a substantial increase in chromium concentration in the local environment, a much larger source of the metal is needed and, although we cannot rule out this possibility, there is no evidence that such a source exists. Other evidence points firmly to the conclusion that SONGS is not a source of ecologically significant levels of metals.

Radiation

The burden of radionuclides was measured in sand crabs taken from 27 beaches spread over a 40 km region centered around SONGS. Several radioactive isotopes that could only have come from SONGS were found in these organisms. The activity from these artificial sources was far below that due to naturally-occurring radioactivity. The internal radiation activity levels experienced received by these organisms from these radionuclides are within background radiation levels and are about one millionth of the rates required to cause sublethal effects [TR E: 7.0].

These studies confirm those conducted over the lifetime of SONGS' operation by the NRC: the concentrations of radionculides in the marine environment that arise from the operation of SONGS are extremely low and are far below those that would produce ecological effects.

The presence in the environment, or in organisms, of radionuclides released by SONGS, but not by other sources in the area, can provide a way of determining either that the discharge plume has been in the area, or that the materials or organisms were at one time exposed to the discharge plume.

Conclusions

There is no good evidence that metals or radionuclides released by SONGS (or deriving from any other source) have caused detectable ecological effects on the marine biota near SONGS. There is good evidence that the concentrations of metals in the SONGS area are low relative to other areas along the coast and are similar to those at "clean" reference beaches. There is no evidence that SONGS releases metals at rates that would raise significantly the concentrations in the surrounding environment.

SONGS does release radionuclides into the environment at rates sufficient to lead to detectable, but extremely low, concentrations in nearby organisms and, occasionally, in nearby sediments. The internal radiation activity levels in local organisms are raised only slightly above the background level and are far below the levels known to cause physiological impairment.

It is of course in principle not possible to establish that pollutants produced by SONGS have no ecological effects on the marine biota. It is always possible to hypothesize the existence of another pollutant or another mode of action by known pollutants, and exploring each of these possibilities in turn would be a potentially endless process. For example, to our knowledge no work has been done to establish that metals and radionuclides at levels far below toxic concentrations do not operate synergistically to cause physiological impairment. There is no evidence supporting such a hypothesis. Nevertheless, the work needed to examine it rigorously would take years to accomplish.

Eventually a judgement has to be made on the basis of available evidence that further exploration of *ad hoc* hypotheses about pollutants is not defensible. The Committee's judgement is that that point has been reached. The observed ecological effects are well-explained by the known physical consequences of SONGS' operation. An explanation of the observed effects does not require the existence of so-far-undetected pollutants, or of unsubstantiated modes of action of pollutants whose concentrations have already been determined to be below the levels needed to cause ecological damage.

SECTION IV.

COMPLIANCE

Chapter 18

WATER QUALITY COMPLIANCE*

The State Water Quality Control Board (State Board) is responsible for monitoring the quality of ocean waters along the coast of California. The State Board is divided into Regional Boards which write the National Pollutant Discharge Elimination System (NPDES) permits that regulate sources of effluents discharged to the ocean in their regions. The San Diego Regional Board is responsible for writing the NPDES permits for SONGS Units 1, 2 and 3. When writing the permits, the Regional Board considers regulations from a number of federal and state agencies and plans, such as the Environmental Protection Agency and the California State Ocean Plan.

The NPDES permits include a program for monitoring the water quality of the effluent, and the ocean waters surrounding the discharge outfall (receiving water). The program includes studies to monitor physical characteristics of the water, such as temperature, turbidity and the concentration of metals, and biological characteristics, such as the abundances of marine plants and animals. The results of the studies are submitted by SCE to the Regional Board each year. In the annual report, SCE must determine whether SONGS is in compliance with the NPDES permit issued by the Regional Board which incorporates conditions to ensure compliance with water quality regulations.

In the 1974 permit for SONGS, issued by the California Coastal Commission to SCE and San Diego Gas and Electric, the MRC is instructed to compare the

* Dr. Susan Swarbrick prepared the Technical Report (O) to the CCC.

results of MRC studies with NPDES permit limitations to determine whether SONGS is in compliance with water quality regulations. We have reviewed the MRC Technical Reports to the Coastal Commission and extracted the results that pertain to the water quality regulations. The MRC has collected data that relate to regulations for temperature, irradiance, metals and marine organisms, in the receiving water (Table 18.1). (The determination of compliance for sediments depends on the results of an ongoing study).

MRC results applied to water quality regulations

Temperature

Results of MRC studies indicate that SONGS is in compliance with regulations for water temperature. The NPDES permits state that the discharge of heated effluent from SONGS can not increase the temperature of the surrounding water by more than 4°F either at the ocean bottom, or at the ocean surface more than 1,000 ft from the discharge lines for more than half a tidal cycle (about 6 hours). The results of MRC studies found that the water temperature at the bottom, 1,600 ft downcoast of the diffusers (the bottom station closest to the 1,000 ft limit), was less than 1°F warmer than the temperature at reference stations located 4,200 ft downcoast of SONGS and at SMK. The temperature of the water near the surface at the impact station (about 1,200 ft from the diffusers) was never more than 4°F higher than the near-surface temperature at the reference sites for more than 3 hours at a stretch. This is well within the regulation.

Table 18.1

Summary of SONGS' compliance with water quality regulations in the NPDES permits.

REGULATION	MRC FINDING	COMPLIANCE
D.1.a Increases in natural water temperature shall not exceed 4°F at the ocean surface 1000 ft beyond the diffusers or at the bottom.	Maximum increase in temperature was about 1°F	YES
D.1.c.3 Natural light levels shall not be reduced outside the zone of initial dilution.	Irradiance was reduced by 6 - 16% outside the ZID	NO
B.4.c The discharge shall not contain substances (metals) that accumulate to toxic levels in marine life. and D.1.d.4 Concentrations of metals shall not increase to levels that would adversely affect marine life	No evidence for accumulation of metals due to SONGS	YES
D.1.c.2 Changes in the rate of deposition of sediments should not adversely affect marine life.	awaits completion of sediment studies	?
D.1.e.1 SONGS shall not have adverse effects on marine organisms.	1. reductions in local populations of midwater fish 2. reductions in kelp, fish and invertebrates in SOK	NO

Metals

MRC studies suggest that SONGS is in compliance with regulations for metals. The NPDES permit prohibits the release of metals from the power plant at rates that would increase local concentrations to toxic levels. The MRC found no evidence to indicate that concentrations of metals in the tissues of marine organisms or in beach sediments near SONGS were higher than levels at "clean" sites along the coast and at the Channel Islands. Local increases occurred near the mouth of San Mateo creek which suggests that the runoff from the creek is a source of metals.

Natural Light

MRC results suggest that SONGS is not in compliance with regulations that govern natural light levels in the receiving water. The NPDES permit states that the operation of the power plant should not cause a decrease in the level of natural light that penetrates the water outside of the zone where the initial mixing of discharged and receiving water occurs. MRC used irradiance to measure light levels. Irradiance is a measure of the amount of light that travels through the water column to a specified depth. The light is used by kelp and other algae for photosynthesis. When light levels are too low, plants can not produce the energy needed to meet metabolic demands or reproduce. A comparison of irradiance at the bottom in SOK relative to a reference site in SMK found that natural light was reduced when the plume of turbid water from the diffusers travelled downcoast, over SOK. When the plume travelled upcoast, the water at SOK was slightly clearer. If periods of decreased irradiance are averaged with periods of increased irradiance, the level of natural light at the bottom downcoast from the power plant was 6 - 16% lower than it would have been in the absence of SONGS, and thus is not in compliance with the NPDES regulation.

Marine life

The results of MRC studies suggest that SONGS is not in compliance with regulations for plants and animals in the ocean near SONGS. The NPDES regulations for power plant effects on marine life prohibit the degradation of populations of vertebrates, invertebrates and plants. Degradation is defined as a statistically significant difference in characteristics such as the abundance of organisms in the water near SONGS compared to reference sites. MRC studies found significant reductions in populations of giant kelp, kelp-bed invertebrates and fish, and midwater fish.

Comparison of MRC results and NPDES monitoring studies

The NPDES permits for SONGS Units 2 and 3 require that a discussion of compliance with NPDES conditions is included in the annual report on the results of monitoring studies done during the previous year. Each year, SCE has concluded that SONGS is in compliance with all the NPDES permit conditions as determined through analysis of monitoring data required by the permit. The results of MRC studies suggest that SONGS is not in compliance with NPDES permit regulations for natural light and marine life in the receiving water.

We have reviewed the annual reports of the NPDES monitoring program, and found that the results of the monitoring studies and the MRC results differ with respect to compliance because (1) populations that declined in MRC studies were not monitored in the NPDES program, (2) sampling methods were different, and (3) the analytical approaches used to determine if adverse effects occurred were different.

(1) The NPDES permit does not require studies of midwater fish, kelp-bed invertebrates or kelp-bed fish (although SCE sampled sea stars and urchins, and conducted a short-term special study of kelp-bed fish). MRC found a decline in these populations near SONGS.

(2) The sampling design for monitoring natural light levels was different in the NPDES and MRC studies. The NPDES study measured light transmissivity only 6 times per year from 1964 to 1981, and only 4 times per year since mid-1985. The MRC study measured irradiance continuously for at least 175 days before Units 2 and 3 began full operations and for more than 1,000 days after they were fully operational. Current direction was measured at the same time in the MRC study so that the position of the discharge plume with respect to the irradiance stations could be included in the analysis. Thus the MRC study had many more samples on which to base conclusions, and could subtract out the variability caused by changes in the position of the turbid plume.

(3) The NPDES permit requires that the effect of SONGS on the marine environment should be determined by comparing stations near SONGS (impact) with reference stations (control). Comparisons of impact and control stations in NPDES monitoring studies were generally qualitative. Temporal changes in the mean abundances of populations or the mean values of physical characteristics at

impact and control stations were described, and often related to natural events such as storms. The conclusion reached in these studies was that spatial and temporal variability is naturally large, and that changes caused by natural phenomena are much greater than any effects caused by the operation of the power plant.

In MRC studies, statistical tests were used to compare impact and control sites. The method used most often was the Before-After/Control-Impact Pairs (BACIP) design. The reasoning behind this design acknowledges that natural temporal and spatial variability may be large. Natural fluctuations are subtracted out by comparing the average difference between impact and control sites in the Before period, with the average difference in the After period. Using this method, MRC has been able to isolate the effect of SONGS from the background variability caused by natural phenomena.

Recommended additions to the NPDES monitoring program

As a result of the comparison of differences in the results of MRC and NPDES studies, we have formulated a set of suggestions for changes in the NPDES monitoring program (Table 18.2). The intent of these recommendations is to focus the monitoring studies on the biological and physical characteristics that will most likely be affected in the future, and to increase the likelihood that studies will detect effects, if they occur.

Midwater fish, kelp-bed fish and kelp-bed invertebrates should be monitored regularly to assess whether SONGS-induced effects diminish or accumulate through time.

Table 18.2

Recommended additions to the NPDES monitoring program for SONGS Units 2 and 3.

STUDY	RECOMMENDATION
Turbidity	1. measure irradiance instead of transmissivity 2. measure currents at the "irradiance" stations 3. sample continuously
Marine Biota	1. survey midwater fish 2. survey macroinvertebrates and fish in kelp beds, as well as kelp
Sampling design and analyses	1. impact and control sites should be compared using statistical analyses 2. utilize a Before-After/Control-Impact Pairs design

We suggest that natural light levels should be measured continuously using irradiance instead of transmissivity, because irradiance is a more direct measure of the light available to plants for photosynthesis. As a beam of light travels directly down through the water column, light is lost from the beam when it is either absorbed, or deflected (scattered light) by particles in the water. Absorbed light is not available to plants, but scattered light can be used for photosynthesis. Transmissivity measures the loss of light from absorption and scattering, while irradiance measures the loss of only absorbed light. Since light intensity measured using irradiance includes both direct and scattered light, it is a better measure of the light available for photosynthesis.

Currents should also be measured continuously at the stations established for continuous irradiance measurements so that the position of the turbid discharge plume can be taken into account when testing for a SONGS' effect.

The regulations require that compliance should be determined by statistical tests of differences between impact and control sites, but the permits do not discuss the statistical approach that should be used. We suggest that the permits should include specific guidelines for sampling designs and statistical procedures. The BACIP design has been successful in detecting effects in MRC studies and we suggest that the NPDES permits adopt this approach, or some other quantitative approach that allows for and largely eliminates temporal and spatial variation, whenever possible.

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SECTION V.

RECOMMENDATIONS

Chapter 19

BASIS FOR RECOMMENDATIONS ON PREVENTION AND MITIGATION*

Introduction

This chapter discusses the basis for the MRC's mitigation recommendations. First, we briefly list the results of the MRC's study, since these indicate the impacts to be mitigated. Second, we discuss the Permit and CCC guidelines that have governed our approach. Finally, we present two options for mitigating the effects of SONGS.

Results

The operation of SONGS has affected organisms through two main mechanisms: (1) killing organisms, especially immature and adult fish, that are taken into the plant with the cooling water, and (2) creating a sometimes turbid plume that affects the kelp, fish and invertebrates in the San Onofre kelp bed (SOK). The findings are discussed in detail in the other sections of this report.

Substantial adverse effects are inferred for a number of populations of fish throughout the Southern California Bight. In addition, substantial adverse effects have been measured in (1) a range of organisms in the San Onofre kelp bed, including giant kelp, several fish species, and invertebrates that live on the rocky bottom in the bed, and (2) a number of populations of fish near SONGS.

* Dr. Richard Ambrose (UCSB) carried out the scientific study of mitigation, prepared the Contractor's Final Report, and prepared the Technical Report (H) to the CCC.

Approach

The MRC's approach to developing recommendations has been mandated by the Permit and subsequent guidelines issued by the CCC. Although we have considered various laws and policies related to mitigation, our recommendations have not been constrained or limited by them.

The Permit states that the MRC is responsible for recommending to the Commission "any changes it believes necessary in the cooling system for Units 2 and 3" (Condition B.4). Condition B.6 provides that:

> Should the study at any time indicate that the project will not comply with the regulatory requirements of State or Federal water quality agencies, or that substantial adverse effects on the marine environment are likely to occur, or are occurring, through the operation of Units 1, 2, and 3, the applicants shall immediately undertake such modifications to the cooling system as may reasonably be required to reduce such effects or comply with such regulatory requirements (which can be made while construction is going on and could be as extensive as requiring cooling towers if that is the recommendation). The State Commission shall then further condition the permit accordingly.

In November 1979 the CCC expressed interest in evaluating means of mitigating adverse effects other than changes to the cooling system, and directed the MRC as follows:

> Mitigation Alternatives to Design Changes. The Commission also recognizes that operational changes or mitigation measures might adequately compensate for any marine life damages resulting from the operation of Units 2 and 3. The Commission, therefore, requests the MRC to study the feasibility and effects of selected promising mitigation measures, including construction of an artificial reef, as suggested by Southern California Edison. The MRC should recommend what measures might be taken to assure there would be no net adverse effect on the marine environment from operation of SONGS Units 2 and 3. (Staff Reports 11/9/79, 4/4/80)

The Permit states that the Committee is responsible for "recommending ... any changes it believes necessary in the cooling system for Units 2 and 3" (Condition B.4), with no mention of operational changes or mitigation. **Option 1: Changes to the Cooling System** to prevent losses, below, responds to this charge. In **Option 2: Prevention and Mitigation,** below, we have considered recommendations in light of the November 1979 resolution as well as the Permit. We first recommend techniques for reducing as many of SONGS' impacts as can reasonably be accomplished, and then recommend compensation techniques to mitigate the remaining losses to the point of no net adverse effect. This priority was chosen because the Permit stresses reduction of impacts; preventing losses is also given precedence over compensating for lost resources by state and federal resource agencies. For each mitigation technique, initial and ongoing costs and the amount of resources mitigated are estimated. However, many of these estimates are rough at best, and some techniques should not be required until tests determine that they will substantially reduce the impacts of SONGS.

Condition B.6 implies that recommendations should pass a criterion of "reasonableness," and although the Commission makes the ultimate judgement of what is reasonable, the MRC has provided information as well as its own judgement on this matter. We do not recommend several technically feasible techniques because of associated impacts, uncertainty, expense or a combination of factors, all of which bear on the "reasonableness" of recommended techniques. In order to help the Commission to evaluate the reasonableness of different techniques, we have made general comments about the risks and expenses of each technique; more detail can be found in *Technical Report H.*

Option 1: Changes to the Cooling System

Conditions B.4 and B.6 of the Permit state that, if the MRC finds that SONGS causes substantial adverse effects on the marine environment, the Committee is responsible for recommending "such modifications to the cooling system as may reasonably be required to reduce such effects...".

There are reasons besides the mandate of the Permit to prefer structural changes as a means of reducing the impacts of SONGS. Structural changes could remove or reduce the mechanisms of impact, thereby insuring that SONGS has the least possible impact on the marine environment. Such changes not only minimize the impact a project has on the local ecosystem, they also avoid the problems associated with trying to (1) estimate the value of resources produced by imperfectly understood mitigation techniques, and (2) compare the values of dissimilar resources.

In this section, we address changes to the cooling system at SONGS that would reduce the substantial impacts of SONGS. We focus on two changes, constructing cooling towers and moving the discharge.

Option 1a. Cooling towers

The substantial impacts are directly related to the intake and discharge of a large volume of water at SONGS; cooling towers could reduce this flow by 90% or more, thereby substantially reducing all of SONGS' effects on the marine environment that the MRC has measured [TR H: 5.1.1].

Cooling towers present their own suite of problems. Any one of several different cooling tower designs could be used at SONGS, but all have technical or environmental problems. One design that seems suited to the San Onofre environment, dry cooling towers, has never been used at a plant larger than 200 MW, so it is uncertain whether the engineering obstacles of applying this technology to a 1100 MW scale could be resolved; furthermore, dry cooling towers would be expected to decrease plant capacity by 20% [TR H: 5.1]. Wet cooling towers would also result in a significant decrease in plant capacity. Any decrease in efficiency would likely increase emissions in the Los Angeles Basin, because fossil fuel power plants in the Basin would need to operate more to make up the lost power.

Salt water would need to be used for wet cooling towers at San Onofre because of the scarcity of fresh water, and the resulting salt drift would cause substantial terrestrial impacts within a few miles of the towers [TR H: 5.1.2]. Although a smaller volume of water would be discharged from SONGS than with the present once-through cooling system, the discharged water would have higher concentrations of toxic chemicals and other contaminants (which are used as anti-corrosion materials) [TR H: 5.1.2].

Retrofitting SONGS for cooling towers would be a complex engineering and logistical project [TR H: 5.1.3]. SCE would need to acquire the land on which the cooling towers would be built from either Camp Pendleton or the State Park. There may not be enough room to build the towers next to Units 2 and 3; if not, they would need to be located at least a mile away from the plant on the other side of the freeway. The intake pipes, which are pointing the wrong way, would need to be extended in a sweeping circular pipe out and back up the beach. If the towers are located across the freeway, the pipes would need to be buried deep beneath the freeway (the Department of Transportation would have to give permission to tunnel beneath the freeway) and up into the hills, and additional pumps would be needed to move the water uphill against a head of about 200 feet. The sea cliffs would probably have to be destroyed no matter where the cooling towers were constructed.

Cooling towers are also likely to affect human safety by increasing the frequency of ground-level fogging around San Onofre [TR H: 5.1.2]. The cooling towers would have to be located adjacent to Interstate 5, where weather conditions that produce a visible plume from the towers would sometimes reduce visibility on the highway. Although this would probably occur only rarely (according to the 1973 Final Environmental Statement for Unit 1, SCE estimated that conditions conducive to fog would probably occur during 90 hrs/year), the probability of automobile accidents near SONGS would be slightly higher as a result of constructing cooling towers.

Finally, cooling towers are expensive, with an estimated cost of about $1 billion for construction [TR H: 5.1.4]. In addition, the decrease in plant capacity would be expected to cost at least another $1 billion over the life of the plant.

Cooling towers were considered in the Final Environmental Statement for Units 2 and 3 and by the MRC in its 1980 report to the CCC, and in both cases rejected as unnecessary for the anticipated level of impacts. None of the recent information indicates that they would now be a better alternative.

If cooling towers are required, their environmental impacts would be substantially different than the impacts measured by the MRC; these impacts should be monitored even though they would be measurably lower than the present impacts. The appropriate monitoring would depend on the specific design characteristics of the towers; because it is not possible to anticipate these characteristics, we have not made specific monitoring recommendations for this option in Chapter 20.

<u>Recommendation</u>: **The majority of the Committee (Mechalas and Murdoch) recommends rejection of the cooling tower option because its technical, environmental and safety disadvantages and high costs outweigh its advantages at SONGS. Dr. Fay recommends acceptance of Option 1a.**

Option 1b. Moving the discharge

An alternative to cooling towers is to move the discharge so that the plume does not pass over the San Onofre kelp bed. This would eliminate the impacts on the kelp bed.

This option has the following disadvantages: (1) Changes to the discharge system must accommodate the plant's finely-tuned hydraulic requirements, and this restricts the distance at which a new discharge could be located [TR H: 4.6.3]. (2) There would be new impacts on the marine environment, some of which we are not able to predict [TR H: 4.6]. (3) It would not reduce the adverse effects on fish populations, which are caused by the entrapment of fish. (4) The exact cost would depend on the specific location and design of the new discharge (and would require a detailed analysis), but would be hundreds of millions of dollars [TR H: 4.6.3].

Recommendation: **The MRC recommends rejection of the option of moving the discharge structures because its considerable technical and environmental disadvantages and high costs outweigh its advantages.**

Option 2: Prevention and mitigation

The MRC considered other means for reducing impacts and mitigating those that cannot be prevented. In doing so, the Committee has been guided by the 1979 CCC resolution quoted above.

This section presents techniques that, combined, could be used to compensate for the resources lost as a result of the operation of SONGS. The goal of this option is to have no net adverse effect resulting from the operation of SONGS.

The MRC has evaluated more than 30 different techniques for preventing or mitigating losses due to SONGS (Table 19.1). Unfortunately, most techniques that have been developed to reduce impacts associated with power plant cooling systems have never been adequately tested. Furthermore, most development and testing have focused on power plants that are much smaller than SONGS and are not located on the coast of a temperate ocean. It is therefore difficult to evaluate the feasibility of these techniques at SONGS, and there is uncertainty associated with

Table 19.1

List of potential techniques for mitigating the effects of SONGS

All techniques, including those that would not be feasible or would not provide adequate mitigation at SONGS, are included in this list. The most promising techniques are noted by *.

Loss prevention techniques	Compensation techniques
Structural changes - Intake	*Construct artificial reef
Modified travelling screen (e.g., low-pressure wash, small mesh)	*Create new kelp bed
Infiltration bed	*Restore coastal wetland
Porous dike	Construct fish hatchery
Barrier systems	Coastal preservation
Moving intake	Information acquisition
Structural changes - Discharge	Information dissemination
Cover diffuser ports with rock	Water quality improvement
Modify diffuser ports (e.g., increase height/exit diameter, change discharge angle)	
Change to single-port discharge	
Relocate discharge (to shallow water or to deep water, upcoast or downcoast)	
Convert to closed-cycle cooling system (cooling ponds, canals or towers)	
Nonstructural changes	
*Sonic devices	
*Light systems	
*Reduce flow/maintain power	
*Reschedule flow	
Electric fields	
Bubble curtains	
Water jets	
Modify bottom topography	
Reduce flow/reduce power	
Modify FRS operations	
Modify heat treatment procedures	

even the most promising of them. In addition, there have been few attempts to mitigate nearshore coastal impacts, so there is little precedence or experience for guidance. The relatively few techniques included in Option 2 are the techniques the Committee feels are the most likely to be successful with no unacceptable effects; other potential techniques that are not recommended are discussed in *Technical Report H*.

<u>Recommendation</u>: **The MRC recommends acceptance of Option 2, which consists of a possible combination of four different techniques for reducing or mitigating fish losses and one technique for mitigating the impacts to the San Onofre kelp bed community.**

The detailed recommendations in this section are organized according to two major categories of losses: fish and kelp forest community.

Fish losses

The MRC recommends a possible combination of four different techniques for mitigating the fish losses: (1) reduce the number of larvae entrained (by reducing the flow rate at SONGS or other coastal power stations or by scheduling SONGS so it does not operate during periods of maximum abundance of fish larvae), (2) construct an artificial reef, (3) restore a wetland, and (4) reduce the in-plant loss of juvenile and adult fish.

Rescheduling operations and reducing flow would prevent losses of some fish larvae, but a substantial number of larvae would still be killed. There is no feasible technique for replacing all of these larvae in-kind; although some in-kind replacement would occur on an artificial reef or with wetland restoration, these techniques would be primarily out-of-kind. An artificial reef or wetland restoration would also serve as compensation for any in-plant fish losses that cannot be prevented.

This section discusses each of these techniques. In addition, we recognize that different combinations of the first three techniques could each result in complete mitigation, and we present a framework for combining the techniques.

2a. Reschedule operations and reduce flow

These two techniques, considered together because they could be implemented in a complementary manner, would be used to decrease the loss of fish larvae by reducing the volume of water that flows through SONGS. We present the techniques in relation to SONGS, but note that an equivalent reduction in entrainment from lower flow at other SCE coastal stations could be an acceptable substitution.

Reschedule operations

The water flow through SONGS is shut off regularly for routine maintenance and refueling. By scheduling downtime during the period of maximum abundance of fish larvae, the number killed could be reduced substantially. If the 60 days a Unit is down for refueling and maintenance occurred during March and April, losses of fish larvae could be reduced by about 50% [TR H: 6.1.1]. Obviously, more days with no flow will give greater savings but higher costs (approximately $4 million/week) to SCE.

Flow could be stopped each year during the period of highest larval abundance with either a 12-month or a 24-month refueling cycle. There are technical and financial objections to a 12-month cycle. Although difficult to achieve, a 24-month cycle, with Units 2 and 3 down in alternate years, would have the advantages of fewer manpower or safety conflicts (which would occur if Units 2 and 3 were down at the same time), a lower volume of radioactive wastes, and lower costs [TR H: 6.1.2].

In spite of the advantages of a 24-month cycle, unexpected interruptions in the operation of SONGS and other factors will make it difficult to adhere to any set schedule. In fact, it may be impractical to require SCE to cease operating Units 2 or 3 during any specific period of time. The period scheduled for maintenance and refueling is subject to a complex suite of factors, many of which are not under SCE's control. Nonetheless, larval fish losses can be substantially reduced, at no cost to SCE, by scheduling SONGS to avoid operations during March and April, and the adoption of such a policy by SCE should be encouraged.

Reduce flow

Reducing the rate of water flow through SONGS while operating the plant at full power would also reduce losses of fish larvae. The flow rate could potentially be reduced by 33% or more [TR H: 6.2.2]; a 33% flow reduction would maintain the thermal standard of <4°F increase at 1000 feet from the diffusers, although a waiver would be required to allow an increase across the condenser of 30°F instead of 20°F. Operating the plant at 67% flow for February through May (and full flow the rest of the year) would reduce fish larval losses by 15% [TR H: 6.2.1]. (Most of the savings in February comes from anchovies.) Savings would be somewhat higher for more months; however, fish larval abundances are not particularly high in October through January, and higher water temperatures after June would reduce the efficiency of the turbines and substantially increase costs.

The costs of this technique include over $10 million to retrofit the pumps, plus annual costs that depend on (1) when flow is reduced and (2) the number of days with reduced flow [TR H: 6.2.3]. For technical and financial reasons, it might be best to reduce flow during the months with low ambient water temperatures. Alternatively, it might be best simply to allow SCE to adjust the flow in response to ambient conditions and power requirements, as long as the required reduction in entrainment was achieved. For the proposed 4-month reduction, the annual costs would be about $430,000 to $600,000 (based on a net electrical cost of 0.4%-0.6% [5-7/1100 MW] and differential fuel costs of $4 million/week/Unit; the fuel costs are keyed to oil prices and will fluctuate accordingly).

In addition to reducing the flow rate through SONGS, SCE might be able to reduce larval entrainment by reducing the volume of water passing through other coastal power plants. Studies at SONGS indicate that the thermal effluent from the plant is of little environmental concern. We believe that the environmental advantages of reduced flow that can be achieved by having a higher condenser temperature will generally outweigh any potential environmental hazards at coastal power plants. The greatest environmental protection might result from a waiver of thermal standards at SCE's coastal power plants, since this would minimize the volume of water pumped through the plants.

Reschedule operations and reduce flow

The most cost-effective means of reducing losses of fish larvae would be to schedule SONGS so it does not operate when fish larvae are most abundant and to reduce the flow of water through the plant during a few other months. Of course, the actual savings in larvae will vary depending on the specific timing implemented; no flow during March and April and 67% flow during February and May would reduce larval fish losses by nearly 60% [TR H: 6.3].

No monitoring would be required for rescheduling or reducing the flow rate through SONGS.

<u>2b. High-relief artificial reef</u>

One way to increase the general production of fish would be to construct an artificial reef. There are many problems associated with using an artificial reef as out-of-kind mitigation, stemming from uncertainty about the amount of fish produced on artificial reefs [TR H: 8.5.2]. Any estimate of the size of reef needed will be mainly a best guess, and since there is no impact to a specific habitat it is not possible to come up with compensation ratios. On the positive side, reef design would not be as constrained as with in-kind mitigation, and in fact the reef should be built to produce as many fish as possible.

The approach we have used for determining the reef size needed to compensate for the fish losses, described in *Technical Report H* [TR H: Appendix D], is to convert the fish losses from biomass of soft-bottom fish to biomass of reef fish and then calculate the size of reef needed to support that biomass of reef fish. This approach relies on many rough estimates, since virtually none of the necessary information is accurately known, and on a judgement about the relative worth of midwater fodder fish versus a rocky reef community. Using the values described in *Technical Report H*, our best estimate is that a 60-ha artificial reef would compensate for the unavoidable loss of fish.

We consider that monitoring the reef is an integral part of this recommendation. The physical structure of the reef should be monitored immediately after construction to verify that it meets the design specifications; if it does not, additional construction should be required to bring it up to the specifications. The principal evaluation of this technique should take the form of a comprehensive study of the amount of fish produced on the reef, to be completed over a period of perhaps five years. Although information from this study should not be used to require additional mitigation from SCE, it will be extremely valuable for evaluating future proposals to use artificial reefs as mitigation.

Cost of constructing a high-relief artificial reef is estimated to be $250,000 per ha [TR H: 8.3.4], so the cost of constructing a 60-ha reef would be about $15 million.

2c. Restore wetland

Coastal wetlands are valuable habitats because they serve as nurseries for some marine fish, are productive, and provide habitat for rare and endangered species. In Southern California, less than 25% of the original wetlands remain and nearly all of these have been degraded. Wetland restoration would be an appropriate means of mitigating the loss of fish larvae caused by SONGS.

Two difficulties with implementing this technique are: (1) *Location.* Wetlands in Southern California are in high demand for restoration and the alternatives are limited, but SCE owns some property in the Huntington Beach wetland and there are several other possibilities (including the Ballona Wetland) [TR H: 10.4.1]. (2) *Amount of restoration needed.* As with all out-of-kind techniques, it is difficult to determine the amount of mitigation needed to achieve the appropriate amount of compensation [TR H: 10.5]; this is particularly difficult under the present circumstances, where the impacted resources are tied to a habitat (open water) that we cannot restore. Furthermore, the amount of restoration needed will depend on the specific design of the restoration: shallow-water habitats such as estuaries and embayments will provide more in-kind, and perhaps out-of-kind, value than most salt marshes, although marsh habitat that supports endangered species would be especially valuable. While it is impossible to determine precisely the amount of restoration needed, we propose that, depending on the particulars, 30 to 60 ha would adequately mitigate for the fish losses; this calculation is presented in *Technical Report H.*

If wetland restoration is chosen to replace losses, the restoration must be monitored carefully to insure that it is successful. Previous monitoring efforts have generally evaluated only whether transplanted vegetation grew as expected; this is not sufficient. Specific criteria for success (i.e., particular hydrological, physical and biological characteristics that must be realized) and the time frame for their achievement should be established when the restoration plan is developed. If monitoring indicates that these objectives have not been accomplished on schedule, additional efforts should be required to ensure that the best possible effort is made to establish the target community. The monitoring would be completed over a period of perhaps five years.

The cost of restoring a wetland will vary tremendously depending on the specific project [TR H: 10.4.2]. The recently completed restoration of 9.7 ha at the Huntington Beach wetland cost $488,000, or $50,000 per ha. The proposed restoration of Bataquitos Lagoon (as mitigation for development in the Ports of Long Beach and Los Angeles) is expected to cost about $15 million for 160 ha, or $94,000 per ha. Restoration costs could be higher if the cost of acquiring the land is unusually high. For example restoring 18 ha in the Huntington Beach wetland might involve purchasing the land for $250,000/ha and restoring the wetland for $55,000/ha, for a total cost of $5.5 million, or $305,000 per ha.

For the current best estimate of 30 to 60 ha, the cost of restoration could be between $3 million and $18 million.

Combined approach to mitigating losses of fish larvae

Different combinations of these three techniques (reducing entrainment, constructing an artificial reef, and restoring a wetland) could each result in complete mitigation for the loss of fish larvae.

We suggest that an explicit framework for combining these techniques would allow SCE to choose its own mix of the three techniques, but would insure that the impact is fully mitigated. This framework is described in more detail in *Technical Report H*, with an example provided below.

Our best estimates indicate that either constructing a 60-ha artificial reef or restoring a 60-ha wetland would completely compensate for the loss of fish larvae (This estimate for wetland restoration is used here for illustration purposes; the actual wetland value will depend on the nature of the restoration proposed.) Based on these numbers, one ha of artificial reef is worth 100%/60=1.67%, and each ha of wetland is worth 100%/60=1.67% of the required total. Likewise, each percent reduction in entrainment losses would be one percent of complete reduction.

Complete mitigation for the fish larval losses would be achieved when the combination of techniques adds up to 100%. For example, complete mitigation would be accomplished by the following combination:

Method	Relative value
20% reduction in entrainment	20%
24 ha of artificial reef	40%
24 ha of restored wetland	40%
TOTAL	100%

By this method of combining techniques, each technique is considered equally acceptable for mitigation. In fact, there is an advantage to *preventing* the entrainment of larvae, since this will reduce the loss of real fish (as opposed to compensating on the basis of inferred losses) and does not rely on the assumptions needed to determine the appropriate amount of out-of-kind mitigation. The MRC strongly supports any effort to reduce the loss of fish larvae, and recommends that volume of water flowing through SCE's coastal power plants be reduced as much as possible.

On the other hand, the Committee believes that an artificial reef or wetland restoration will satisfactorily mitigate any unavoidable fish losses. We have provided our best estimates for the sizes of these projects that would be needed for complete mitigation. Although there is a great deal of uncertainty about these estimates, one factor favors using these techniques: they will continue to produce resources after SONGS has stopped operating. An artificial reef or wetland restoration has the potential for actually having a greater long-term resource value than a prevention technique.

2d. Reduce fish impingement losses

SONGS already employs two effective techniques for reducing midwater fish losses: velocity caps on the intakes, and the Fish Return System. Although these two techniques drastically reduce the number of fish entrapped and killed by the plant, at least 20 metric tons (MT) of fish are still killed each year.

There may be new techniques that could be used to reduce the impingement of fish, and SCE should be able to choose any technique that they think will effectively reduce these losses. The MRC has identified two techniques that could potentially reduce the impacts of SONGS on midwater fish populations: mercury lights and sonic devices. Because the effectiveness of these techniques has not been adequately tested, we recommend that they be tested and their implementation be required if they will reduce impingement losses by 2 MT/year.

The arrangement of intakes for Units 2 and 3 is suitable for controlled tests of mercury lights and sonic devices; a system could be operated at one unit, and entrapment when the system is operating compared (using simultaneous 24-hour samples) to entrapment over the same period and flow rate at the other unit. To control for differences in the species entrapped by the two Units, the test and control units could alternate between Units 2 and 3 during a series of trials. Effectiveness should be evaluated in terms of overall fish entrapped and on a species-by-species basis; both numbers and biomass should be considered. The tests should be performed during normal operations and during heat treatments.

Mercury lights

Mercury lights would be used in the Fish Return System chamber to attract fish out of the screenwell. This could increase the diversion efficiency of the FRS at all times, but would be particularly important during heat treatments because the fish killed during heat treatments tend to be the largest and most economically important of those killed by SONGS [TR C: 3.1.1]. Mercury lights (perhaps in conjunction with sonic devices) might be able to save up to 2.7 MT of these large fish per year [TR H: 3.3.3.1]. The cost of mercury lights is estimated to be roughly $100,000.

Mercury lights are recommended because they appear to be a simple and inexpensive way to reduce losses. But they might not be worth implementing if they are not effective or do not prove to be simple and inexpensive, so we recommend that a feasibility study be performed before they are implemented.

Sonic devices

Sonic devices, such as pneumatic guns or "hammers," could be placed in the screenwell area to increase diversion of fish into the Fish Return System and/or at the intakes to reduce entrapment of fish [TR H: 3.3.1]. Sonic devices in the screenwell area are likely to be effective for all species and sizes of fish entrapped, although large individuals might benefit the most because they are disproportionately killed during heat treatments. Sonic devices (perhaps in conjunction with mercury lights) might be able to save up to 3 MT of fish per year. The cost of sonic devices in the screenwell area is roughly estimated to be about $100,000 [TR H: 3.3.1.3].

Sonic devices in the intake would probably be most effective for schooling fish. Transient schooling species such as northern anchovy would be in the vicinity of SONGS' intakes for only a short time, so sonic devices might effectively disperse these fish away from the intakes without habituation to the devices. If the sonic devices can reduce the entrapment of schooling fish by 50%, they will save about 5.4 MT of fish [TR H: 3.2.2.1.1]. The species that would be saved comprise a large proportion of the *number* entrapped by SONGS, but they are the smaller and younger fish of those entrapped and do not contribute much to the weight entrapped. The cost of sonic devices at the intakes is roughly estimated to be $300,000 [TR H: 3.3.1.3].

Kelp forest community impacts

<u>2e. Low-relief artificial reef with kelp</u>

The fraction of the kelp community lost at San Onofre kelp bed should be replaced by constructing an artificial reef that develops and maintains a kelp bed. Few artificial reefs have been used for mitigation because there is substantial uncertainty about the resources they provide [TR H: 8.2]. The safest way to insure that an artificial reef is adequate for mitigation is to build the reef larger than the impacted reef, since kelp would probably not cover the entire reef, the density of kelp might be lower on the artificial reef, and the kelp community on the artificial reef might not be as productive or diverse as the natural community [TR H: 9.3]. This approach, in which the ratio of created habitat to impacted habitat is greater than one, has been used extensively in mitigation. A reasonable size for the artificial reef would be 120 ha.

In order to insure that the community that develops on the mitigation reef is as similar as possible to the impacted community at SOK, the physical structure of the reefs should be as similar as possible to SOK's [TR H: 8.5.1]. Although SOK may not be the most productive or diverse kelp bed in Southern California, there are few kelp beds in which the kelp plants grow on "cobbles" or scattered boulders as in SOK. The characteristic organisms that live in this habitat would best be replaced by an artificial reef with a physical structure similar to SOK's. Ideally, the substrate itself should mimic SOK, that is, it should consist of cobbles and boulders identical to those at SOK. However, there is a risk that a low-relief artificial reef will be more prone to being inundated by sand than a high-relief reef; this risk could be minimized by using larger rocks and having occasional areas of somewhat higher relief.

Two difficulties with implementing this technique are: (1) *Location*. Ideally, the reef should be located as close as possible to SOK, but if it is too close it also will be impacted by SONGS [TR H: 9.2.1]. Likely locations for the mitigation reef include upcoast and downcoast of SMK and several kilometers downcoast of SOK. (2) *Techniques for establishing kelp*. Although kelp is now present on several artificial reefs, there have been many problems with establishing kelp on artificial reefs [TR H: 9.1.2]. Different techniques are available for establishing kelp, including transplanting adults, transplanting sporophylls, and outplanting juveniles [TR H: 9.2.2]. These techniques could be employed in an experimental design during the first year after construction, with a decision about the technique(s) to be used in successive years made after their effectiveness has been evaluated.

Independent monitoring of the artificial reef is an integral aspect of this recommendation. First, it is essential that giant kelp become established quickly on the reef and that it persists. Performance criteria can be used to establish a timetable for giant kelp development. A reasonable timetable would be to establish giant kelp within 3 years; if monitoring indicates that giant kelp has not been established on schedule, additional efforts should be required until the target community is established. Because the densities of fish and benthic algae and invertebrates should eventually be similar to the densities that would have occurred at SOK in the absence of SONGS' impacts, these organisms also should be monitored.

The cost of a low-relief artificial reef is estimated to be roughly $62,500 per ha [TR H: 8.3.4]; the cost of establishing kelp on the artificial reef is estimated to be several million dollars [TR H: 9.2.3]. The total cost of constructing a 120-ha low-relief artificial reef with kelp is estimated to be about $10.5 million.

Summary

The options considered in this chapter are summarized in Table 19.2. Other possible techniques for reducing or mitigating losses caused by SONGS may be proposed in the future. The CCC may wish to consider these alternatives if they seem appropriate.

Table 19.2

Options for reducing or mitigating the impacts of SONGS

OPTION	TECHNIQUE	OBJECTIVE	RECOMMENDATION
1: Changes to cooling system			
1a	Cooling towers	Reduce all losses	Reject (WM, BM) Accept (RF)
1b	Moving discharge	Reduce discharge losses	Reject
2: Prevention and mitigation			Accept
2a	Reschedule operations[1] Reduce flow[1]	Reduce larval fish losses (1-10% reductions in standing stocks of some species)	
2b	Artificial reef (60 ha)[1]		
2c	Restore wetland (30 to 60 ha)[1]	"	
2d	Reduce impingement losses	Reduce fish intake losses (21 tons/yr)	
2e	Artificial reef (120 ha)	Replace kelp community losses (80 ha kelp and associated invertebrates and fish)	

[1] A combination of these techniques could be used as long as overall result was complete mitigation.

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Chapter 20

FUTURE MONITORING

The MRC recommends three different types of programs for future monitoring, each of which is motivated by its own set of objectives.

First, the MRC recommends additional monitoring for compliance with water quality regulations. The MRC's evaluation of SONGS' compliance with the regulatory requirements of State and Federal water quality agencies (Chapter 18) has led to recommendations for improved water quality monitoring. These recommendations are intended to focus the existing NPDES monitoring program on the resources that are most likely to be affected by SONGS. Much of the crucial information is already being collected by SCE (including data on plant operations, fish entrapment and diversion, and giant kelp), and so no recommendations are made to duplicate these efforts. It is important that SCE's data continue to be made available in a timely fashion to whomever does the proposed additional monitoring. Recommendations for achieving this goal are described in *Water Quality Compliance*, below.

Second, the MRC recommends that mitigation measures be evaluated to ensure that the objectives of the recommendations are achieved. Not all mitigation measures will need an extended period of monitoring, but the progress and success of complex projects such as wetland restoration or artificial reef construction should be monitored. In these cases, monitoring can be used to confirm that the projects are proceeding on schedule and, if necessary, to identify where remedial work might be needed. In addition, the design and evaluation of techniques for mitigating coastal impacts are hindered by the lack of relevant information; careful, quantitative monitoring of implemented projects will provide information that is critical for future resource management decisions. Mitigation monitoring would be needed for the first few years after implementation to evaluate the success of the technique, after which no additional monitoring would be necessary. Results of the mitigation monitoring should be reported to the CCC (or its designate).

Finally, the MRC recommends continued monitoring of the effects of SONGS. The object of this monitoring is to determine (1) whether the magnitude of an adverse effect detected by the MRC changes because of changes in the plant's operations or changing environmental conditions, or (2) whether there are cumulative effects that were not detected during the relatively short After period of the MRC's studies. Note that most questions about possible changes in the effects of SONGS can be resolved by the recommended compliance monitoring, and are included under those recommendations.

In this chapter, we briefly describe the monitoring recommended for each of the three types of programs; these recommendations are summarized in Table 20.1. We have made some suggestions about the information that should be collected or the frequency of sampling, but we have not designed complete monitoring programs. It should be noted, however, that the specific design of each program and the analysis and interpretation of the data will be critical to the successful completion of the objectives of these recommendations.

Table 20.1

Summary of Monitoring Recommendations

CATEGORY	MONITORING RECOMMENDED	FREQUENCY
A. Compliance		
Irradiance	Measure irradiance and currents	Continuous
Fish	Densities of midwater fish	4x/yr
Kelp Community	Density of giant kelp adults* Recruitment of giant kelp* Densities of large invertebrates Densities of kelp bed fish	2x/yr 1x/yr 4x 1st yr, 1x/yr thereafter 1x/yr
B. Mitigation		
Low-relief artificial reef	Density and recruitment of giant kelp Densities of fish, algae & invertebrates	4x/yr 1st 3 yrs, 2x/yr thereafter 4x/yr 1st 3 yrs, 2x/yr thereafter
High-relief artificial reef	Fish production	8x/yr for 2 years
Wetland	Depends on restoration plan; might include: Densities of fish larvae and adults Productivity estimates Physical and chemical measurements	 6x/yr for 2 yrs
C. Effects		
Soft Benthos	Densities of infauna	4x 1st yr, 1x/yr thereafter

* Already being monitored by SCE at present.

The recommended compliance monitoring could be easily incorporated into SCE's NPDES monitoring program, but the other recommendations do not fit obviously into an existing program.

Water quality compliance

As a result of differences in the results of MRC and NPDES studies, we have suggested changes in the NPDES monitoring program. The intent of these recommendations is to focus the monitoring studies on the physical and biological characteristics that are most likely to be affected by the operation of SONGS and to increase the likelihood that studies will detect effects, if they occur. We include suggestions for additional studies of marine organisms and physical characteristics, and changes in sampling design and analytical procedures used to determine if the power plant is in compliance with water quality regulations.

Irradiance

The California Ocean Plan states that reduction of natural light may be determined by measuring light transmissivity or irradiance. We suggest that irradiance is better than transmissivity for detecting reductions in natural light because irradiance is a more direct measure of the light available to plants for photosynthesis. Downward planar irradiance was used to measure natural light at depth in MRC studies. The detector measures both direct and scattered light, counts photons in the photosynthetic band, and is a direct measure of light used by plants.

Results of SCE and MRC studies show that natural light levels are highly variable, and that light must be measured frequently to detect effects. Irradiance was measured continuously by the MRC at control and impact stations. Currents were also measured continuously at these stations so that the position of the discharge plume could be included in the analysis.

We recommend that the NPDES monitoring program for SONGS be amended to replace the quarterly transmissivity samples with measurements of irradiance and currents taken continuously (e.g., every hour). We also recommend that future sampling stations include the stations used in MRC studies so that data collected at these sites in the Before period can be used in BACIP analyses. The continuation of measurements at MRC stations will enhance the ability to detect long-term trends in natural light levels, if they occur, as the data set is extended through time.

Fish

Results of MRC studies detected reductions in local populations of midwater fish, and detected increases in abundance of benthic fish. The NPDES permits require that only benthic fish be monitored.

The MRC recommends that populations of midwater fish be monitored near SONGS.

Kelp forest community

Giant kelp

Kelp forests are productive habitats that support a diverse group of algae, fish and invertebrates. Giant kelp studies are presently included in the NPDES monitoring program. We believe that continued monitoring of adult, subadult and juvenile kelp is particularly important because it is possible that effects that could not be detected during the few years of the MRC's study would become evident with a longer monitoring period, or the magnitude of the effects might change.

Kelp forest invertebrates and fish

Studies of invertebrates and fish in kelp forests are not required by the NPDES permit (although SCE contractors did sample fish periodically and counted sea stars and urchins in kelp transects). However, MRC studies detected reductions in the abundance of fish and kelp forest invertebrates, as well as kelp.

The Committee recommends that NPDES monitoring studies of kelp forests include regular samples of large invertebrates and fish, in addition to kelp.

We recommend that large invertebrates be sampled on a broad scale throughout the San Onofre and San Mateo kelp beds (including the BACI stations that were sampled by the MRC). Because we are most concerned with long-term changes, and these invertebrates are long-lived, annual sampling should be adequate; intensive sampling the first year would serve to firmly establish current densities. All of the species sampled by the Kelp Forest Invertebrate Project should be included.

We recommend that bottom fish be sampled in San Onofre and San Mateo kelp beds. The same stations and techniques (diver visual transects) used by the MRC's Fish Program should be used in future monitoring; sampling should occur in the Fall of each year, after the major recruitment period and when conditions are most suitable for sampling.

Sampling design and analysis

The California Ocean Plan and NPDES permits for SONGS state that compliance with many of the receiving water regulations should be determined by statistical tests of differences for physical and biological characteristics at impact and reference sites. The permits do not discuss the statistical approach that should be used.

SCE generally relies on descriptions of temporal and spatial patterns to determine if there is a SONGS effect, and rarely uses statistical comparisons. It would be extremely difficult to detect SONGS effects, if they occur, using descriptive comparisons because it would be difficult to separate effects from the large, natural spatial and temporal variability in the marine environment. The MRC has used the BACIP design (Chapter 5), which can often detect SONGS effects in spite of large spatial and temporal variability.

The BACIP design can only be used if the same impact and control stations were sampled both before and after SONGS began operating. There may be ongoing NPDES studies, such as kelp densities, that can use the BACIP design. However, it may be difficult to meet the BACIP requirements for other studies because few samples were taken in the Before period. In some cases, such as midwater fish, MRC samples in the Before period could be used if the MRC impact and control stations are sampled in the future. If there are few or no samples in the Before period but many samples in the After period, an alternative to BACIP is to test for a trend in the difference between impact and control stations through time (*Technical Report K*). A significant regression of the difference between the impact and control stations for each survey, against time, may indicate that an effect had "accumulated" through time. This test must be used with caution because a trend may be a continuation of a pattern begun before Units 2 and 3 began operating, in which case the effect might not be caused by SONGS.

We recommend that the NPDES permits should include specific guidelines for sampling designs and statistical procedures. The BACIP approach has been successful in detecting effects in MRC studies and we suggest that the NPDES permits adopt this approach whenever possible.

Mitigation

Low-relief artificial reef

The major uncertainty associated with using a low-relief artificial reef to replace kelp forest resources is whether giant kelp can be successfully established on the reef. As noted in Chapter 19, different techniques for establishing kelp could be evaluated in an experimental design during the first year, with a decision about the technique(s) to be used in successive years made after their effectiveness has been evaluated.

We recommend that the artificial reef be monitored (1) to ensure that it is constructed according to its design specifications, and (2) to check the progress of giant kelp on the artificial reef. The physical structure of the reef should be monitored immediately after construction to verify that it meets the design specifications; if it does not, additional construction should be required to bring it up to the specifications. In addition, giant kelp should become established on the reef within a reasonable period of time, perhaps within three years. (Specific goals of area and density would have to be defined.) If monitoring indicates that giant kelp has not been established on schedule, additional efforts should be required to ensure that the target community is established.

We recommend that several other sampling programs coincide with the giant kelp monitoring. If giant kelp does not become quickly established, it will be important to identify the cause(s). Information on the physical conditions (especially irradiance, currents and temperature) on the reef during attempts to establish kelp will be indispensable; sampling the recruitment of giant kelp on the reef is also recommended. Finally, the densities of fish and benthic algae and invertebrates should eventually be similar to the densities that would have occurred at San Onofre kelp bed in the absence of SONGS if the artificial reef is to mitigate successfully the impacts of SONGS, so these organisms should also be monitored.

High-relief artificial reef

The two main uncertainties associated with constructing a high-relief artificial reef as out-of-kind mitigation for fish losses are: (1) the density of fish that will occur on a large artificial reef, and (2) the amount of fish that will be produced by the reef. Both of these uncertainties need to be resolved before the size of reef needed to mitigate a particular resource loss can be accurately estimated. At present, the size of reef recommended as out-of-kind mitigation for SONGS' impacts is our "best professional judgement" based on all available information, but there are many uncertainties involved in calculating this estimate; resolving these uncertainties would be extremely valuable for evaluating future proposals to use artificial reefs as mitigation.

We recommend that the high-relief reef be monitored (1) to ensure that it is constructed according to its design specifications, and (2) to evaluate the amount of fish produced on the reef. The comprehensive evaluation of fish produced by the reef, which should include an assessment of the density and standing stock of fish on the reef, would be extremely valuable for evaluating future proposals to mitigate coastal impacts; regardless of the results of the study, the reef and study should constitute adequate mitigation for the estimated losses.

Wetland

As with using an artificial reef for out-of-kind mitigation, there is uncertainty about how much wetland restoration would be needed to mitigate a particular impact. In addition, there is uncertainty about the success of wetland restoration because few previous restorations have been adequately evaluated. Previous monitoring efforts throughout the country generally have evaluated only whether transplanted vegetation grew as expected; this is not sufficient because it does not reflect the overall biological value (particularly to invertebrates, fish and birds) of the restored wetland.

We recommend that specific criteria for success (i.e., particular hydrological, physical and biological characteristics that must be realized) and the time frame for their achievement be established when the restoration plan is developed, and the status of the restoration be monitored. Monitoring, which should involve a comprehensive evaluation of the restoration project, would have two goals. First, if monitoring indicates that the restoration did not meet its design specifications or the specific objectives have not been accomplished on schedule, additional efforts should be required to ensure that the target community is established. Second, monitoring should assess whether the anticipated resource value of the restored wetland was actually achieved. As with artificial reefs, this study would be extremely valuable for evaluating future proposals; regardless of the results of the study, the restoration and study should constitute adequate mitigation for the estimated losses.

Effects

Soft benthos

SONGS increased the densities of infauna near the plant. Although this is not considered an adverse effect, the soft benthos sampling employed a gradient sampling design that could be used as an indicator of the extent of SONGS' effects.

Future sampling of the soft benthos could determine if the spatial extent of SONGS' effects increases through time.

We recommend that the soft benthos be sampled at the same stations used by the MRC, with the addition of a more distant control, to estimate any future increases in the area affected. Semi-annual sampling would be useful because most infauna have shorter lifespans than hard-bottom invertebrates; intensive sampling the first year (perhaps four times) would serve to firmly establish current densities. The major taxonomic and ecological groups should be sampled.

Anomalous sediments

At this point, the MRC has not made a determination about the link between SONGS and the anomalous sediments in the San Onofre kelp bed. If SONGS is linked to these sediments, it will be important to monitor their distribution and abundance, since they may either continue to accumulate or may disappear. We would recommend that the sediments be sampled in San Onofre and San Mateo kelp beds using the same methods and sites used in 1989, with permanent stakes added to measure changes in sediment depth. Sampling should be done twice per year in case there is a seasonal pattern to sediment deposition and erosion.

There have been few long-term marine ecological studies in spite of their obvious value in understanding the ecology of marine communities. The future value of the monitoring data will be greatly increased, for both scientific and coastal-management purposes, if they are recorded and maintained in such a way that they can be analyzed in conjunction with those already collected by MRC. This goal will be facilitated by placing the data into data sets that are comparable in format to those developed by the MRC.

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APPENDICES

APPENDIX 1.

CALIFORNIA COASTAL COMMISSION PERMIT 183-73

February 1974

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STATE OF CALIFORNIA
RONALD REAGAN, Gov.
CALIFORNIA COASTAL ZONE CONSERVATION COMMISSION
580 MARKET STREET, 2nd FLOOR
SAN FRANCISCO, CALIFORNIA 94102
(415) 557-1001

RECEIVED
1978
CALIFORNIA
COASTAL COMMISSION

February 28, 1974

PERMIT NO. 183-73

Southern California Edison Company
P. O. Box 800
2244 Walnut Grove Avenue
Rosemead, California 91770

San Diego Gas and Electric Company
P. O. Box 1831
San Diego, California 92112

Gentlemen:

On February 20, 1974, by a vote of 10 in favor, 2 against, the California Coastal Zone Conservation Commission adopted the resolution below that, subject to the conditions noted below, authorizes the construction of Units 2 and 3 at the San Onofre nuclear generating station, as described in your application.

Resolution of Approval

I. Approval of Modified Proposal. The California Coastal Zone Conservation Commission hereby approves a permit for the proposed development as modified by the conditions below, on grounds that, as conditioned, the proposed development would not have any substantial adverse environmental or ecological effects and would be consistent with the findings, declarations, and objectives of the California Coastal Zone Conservation Act of 1972.

II. Conditions

A. Public Access Around Construction Site

1. The applicants shall provide public access between the two parts of the San Onofre State Beach, around the construction site, from 8 a.m. to sunset on Saturdays, Sundays, and National Holidays in the months of June, July, August, and September, beginning in the year 1975 and continuing through the construction period.

2. The access shall be provided by means of a walkway no less than 6 feet wide.

3. Signs shall be posted by the applicants at both ends of the walkway to provide reasonable notice to the public of the existence of the walkway and of the days and hours it will be open.

4. Public use of the walkway may be interrupted for a maximum of one hour per day, with each interruption to last no more than 15 minutes, to allow the movement of construction equipment or workmen.

B. Marine Environment

1. Immediately upon approval of this permit, a comprehensive and continuing study of the marine environment offshore from San Onofre shall be begun to predict, and later to measure, the effects of San Onofre Units 2 and 3 on the marine environment, with emphasis on (a) the effects of the new units on zooplankton and larval organisms, and (b) compliance with the regulatory requirements of State and Federal water quality agencies. This study shall be in addition to any other study programs affecting the marine environment, but this and other studies may be combined or otherwise conducted in a manner that will result in the broadest possible consideration of the effects of Units 1, 2, and 3 on the entire marine environment in the vicinity of San Onofre.

2. The study program shall be designed and conducted under the direction of a Review Committee consisting of 3 persons with professional experience in marine biology and knowledge of the issues involved; one to be chosen by the applicants, one to be chosen by the appellants, and one to be chosen by the State Commission (to serve at the pleasure of the Commission) from a list submitted by the Execut Director of the State Commission (hereinafter referred to as "staff"). The members of the Review Committee shall be designated within 30 days of the date of State Commission action on this permit. If a member is not chosen within that period, and the name transmitted to the staff, that member's place on the Review Committee shall be promptly filled by a member chosen by the State Commission in the manner provided above.

3. All costs of the study, including any special reviews necessary to evaluate study data, shall be borne by the applicants.

4. The Review Committee shall be responsible for determining the desig of the study program, reviewing the data collected, interpreting the results of the studies, and recommending to the State Commission any changes it believes necessary in the cooling system for Units 2 and 3. The State Commission shall then further condition the permit accordingly.

5. The Review Committee shall make reports to the State Commission at least semi-annually as to the status, findings, and recommendations of the study.

6. Should the study at any time indicate that the project will not comply with the regulatory requirements of State or Federal water quality agencies, or that substantial adverse effects on the marine environment are likely to occur, or are occurring, through the operation of Units 1, 2, and 3, the applicants shall immediately undertake such modifications to the cooling system as may reasonably be required to reduce such effects or comply with such regulatory requirements (which can be made while construction is going on and could be as extensive as requiring cooling towers if that is the recommendation). The State Commission shall then further condition the permit accordingly.

7. If at any time the State Commission, the Review Committee, and the applicants cannot reach agreement on (a) the scope, form, and methodology of the study; (b) the results of the study, i.e., whether the study shows that operation

of Units 2 and 3 would or would not have, or is or is not having, a substantial adverse environmental effect; or (c) the steps necessary to deal with any substantial adverse environmental effects shown by the study, a 3-member board of arbitration sha be selected to resolve the matter in dispute. The board shall consist of 3 persons with professional knowledge of the issues involved, one to be chosen by the State Commission, one by the applicants, and the third by the first two. The decision of the board of arbitration shall be binding on both the State Commission and the applicants.

8. Compliance with the conditions in Section B, Marine Environment, shall be monitored and enforced by the State Commission or by its successor, and if there is no successor, then by the State Water Resources Control Board, or, if that body so designates, the San Diego Regional Water Quality Control Board.

C. Kelp

No diffuser port shall be located within 1,900 feet of the area where the kelp bed to the south of the diffusers is likely to expand. This area shall be determined by a marine biologist of the State Department of Fish and Game or the U. S. Bureau of Sport Fisheries and Wildlife prior to July 1, 1974.

D. Use of Project Site

1. Prior to commencement of construction, the applicants shall guarantee the protection, in their natural condition, of the areas shown in Exhibit designated as "Bluff Area (unexcavated) (approx. 5 acres)" and also an area extendin north from the "Bluff Area (unexcavated) (approx. 5 acres)" for .10 mile and bounded by the mean high tide line and a line 100 feet east of the top edge of the bluff. The property immediately east of the areas to remain undisturbed may be graded and filled for use as a level site for construction equipment; such leveling and grading shall be to an elevation of approximately one hundred (100) feet in the area east of the "Bluff Area (unexcavated) (approx. 5 acres)" and shall be to an elevation of not less than forty-five (45) feet in the area east of the above described one-tenth (1/ mile area, except for grading necessary to provide an access road to the constructic site for Units 2 and 3 (Exhibit 1A, revised 2/26/74).

2. As part of the construction of Units 2 and 3, the applicants shall institute a program to prevent erosion and to stabilize the bluff-canyon area in its present condition.

3. Upon completion of the erosion control and canyon stabilization program described in paragraph 2 above, the applicants shall allow full and uninterrupted public access to the beach, bluff, and canyon area that is to remain in its present condition.

4. The guarantee required by this condition shall be for the durati of applicants' site easement (expiration date, May 1, 2023) and shall be satisfied by means of a duly executed instrument submitted to and approved, for form and cont by the Executive Director and the Attorney General to assure conformance with the intent of this condition, and which instrument shall be duly recorded. The intent of this condition is to assure that, through the Commission's planning program and other means, this area, which is the most scenic part of the project site, will be provided permanent protection.

5. Compliance with the conditions in Section D, Use of Project Site, shall be monitored and enforced by the Commission or by its successor, and if there is no successor, then by the State Parks and Recreation Commission.

E. Plant Reliability

In order to insure that these units will provide a reliable source of power, particularly in light of present reliability performance of nuclear units in general, the applicants will establish a reliability organization. This organization shall report at a vice presidential position which is separate from, but an equal leve with, vice presidential positions of organizations responsible for engineering, constr tion, procurement and operation of these units. This reliability organization shall have the authority and organizational freedom to (a) identify reliability problems; (initiate, recommend, or provide solutions to these problems; (c) verify implementatio of solutions; (d) control further processing, delivery or installation of problem ite until proper dispositioning of the deficiency or unsatisfactory conditions has been a

This organization shall prepare and file reports with the California Pub Utilities Commission on a semi-annual basis. These reports shall describe the activi of the reliability organization including specific measures implemented to insure reliability of these units.

F. Regional Commission Conditions

All conditions imposed by the Regional Commission and not modified above shall remain in effect.

G. Acceptance of Conditions

No construction shall take place until the applicants have acknowledged in writing that they understand all the conditions imposed herein and agree to abide by all of them.

III. Findings and Declarations. The Commission finds and declares as follows:

A. Summary. Unlike most developments proposed for the coastal zone, the ac tion of Units 2 and 3 at San Onofre would have an impact on all 3 parts of man's phys environment—air, land, and water.

The impact on the air would be beneficial, in that the generation of el tric power by nuclear means would not pollute the air as would the generation of the same amount of power by burning fossil fuels. Many of the oil-burning power plants in the coastal zone, and thus they affect the quality of the coastal environment.

The impact on the land would be adverse, in that about .51 mile of coas bluffs would be destroyed. But, as provided by Condition D above, the most importan and most scenic area of canyons and bluffs, about .31 mile long, would be protected for the duration of the site easement.

The impact on the offshore ocean waters is not yet sufficiently known. But, as provided by Condition B above, a detailed study of the possible effects o Units 1, 2, and 3 on the ocean waters will be undertaken, with emphasis on the pl and larval forms that are the basis of the ocean food chain and thus of the ocean's sport and commercial fisheries. The conditions provide for modifying the plant's cooling system if the study shows that there are substantial adverse effects on the offshore waters.

For these reasons, the Commission finds that, overall, the proposed development would not have a substantial adverse environmental effect and that a permit may be approved under the California Coastal Zone Conservation Act of 1972.

B. Nuclear Hazard Not a Factor in Decision

The Commission, in reaching its decision on this application, has been advised by its legal counsel, the Attorney General, that the Federal Government appears to have exclusive authority to regulate and control radiation hazards posed by nuclear power plants. Accordingly, the Commission expresses no opinion and makes no finding with regard to nuclear safety, and declares that questions of nuclear safety have played no part in its decision.

C. Marine Environment

1. Introduction. Although most public attention has focused on therm[al] pollution from power plants, it appears likely that the most significant adverse impacts on the marine environment at San Onofre would occur through entrainment of marine organisms in the plant's cooling system. Water would be drawn through Units [2] and 3 at a rate of 1.6 million gallons per minute, equivalent to a body of water about 1 mile square and 11 feet deep every day. When Unit 1 is operating together with Units 2 and 3, the amount of water directly entrained will amount to 1.95 mill[ion] gallons per minute or about a square mile 14 feet deep every day. The total amount of water affected will undoubtedly be much greater because about 2/3 of the heat generated by the reactors is dissipated in the ocean (1.5×10^{10} BTU per hour from Units 2 and 3) and currents may be induced in the area from the vast quantities of water forced through the system.

2. Plankton Entrainment. The potentially most significant environmen[tal] effect of the proposed project, destruction of the nearshore plankton population, h[as] been the subject of the least reliable studies. Plankton represent the main source of food for most organisms in the nearshore environment and include the immature stages of most nearshore marine animals such as clams and mussels and many fish. Plankton sampling studies were made for the applicants between 1965 and 1971, but their quality is a matter of dispute, and further information is clearly needed.

At issue are two possible effects of the plant's operation on plan[kton:] the massive transporting of plankton from nearshore waters to an offshore area, ca[used] by the cycling of ocean water through the power plant, and the killing of plankton [when] they are entrained in the plant's cooling system, and afterward if they are return[ed] to the ocean in an unhealthy condition.

3. Entrainment and Mortality of Fish During Normal Plant Operation. Fish as well as plankton will be entrained in the cooling system. If not removed [and] returned to the ocean in a healthy condition, they too will be killed. The Atomic Energy Commission estimated that between 28,000 and 142,000 lbs. of fish would be killed per year from the normal operation of Units 2 and 3, depending upon the effectiveness of the fish return system. No fish return system is operating or

planned for Unit 1 and the Atomic Energy Commission has estimated that 30,000 lbs. of fish per year are being killed by that unit. The applicants contend, on the basis of small-scale experiments (e.g., use of a flume measuring 50'x 6'x 4' to model the intake structures that are 3,500 feet long) conducted at another generating station, that the effectiveness of the fish return system can be estimated at 70-80%. Although not conclusive, the results are promising.

4. Entrainment and Mortality of Fish During Heat Treatment. Every 5 or 6 weeks, the applicants propose to heat the water in the cooling system to 125°F to remove marine organisms growing within the system. These elevated temperatures will kill virtually everything entrained within the system. It is expected that between 11,000 and 28,000 lbs. of fish may be killed per year in this manner. The procedure does not comply with the general standards established by the State's Thermal Plan and an exception from these standards was requested by the applicants. An exception was granted, but with a condition that studies be conducted over the next 3 years to determine whether the heat treatment proposed is the least environmentally destructive method of controlling marine growths within the cooling system, or whether the system should be redesigned to permit lower-temperature or less-frequent treatment. Until these studies are completed, no finding can be made as to the least destructive method.

5. Thermal Discharges. Changes in the design of the cooling system or the proposed operation of the plant may be needed to meet both Federal and State standards with regard to the discharge of heated water into the ocean (thermal pollution). In issuing a permit at this time, the Commission makes no finding as to the adequacy of the present proposal to meet the standards of the State Water Resources Control Board or the Federal Environmental Protection Agency. The facts regarding State and Federal standards are as follows:

a. State Standards. The State Thermal Plan adopted by the State Water Resources Control Board and accepted by EPA establishes minimum thermal discharge standards that must be met by the project. Among the standards imposed is a requirement that the temperature of the discharge water not exceed the temperature of "receiving" waters by more than 20°F. However, due to the fact that the intake point for the cooling system is located offshore at a depth of 20 feet and the diffuser ports are at depths of 20 to 40 feet, there may be a difference in temperature of about 6° between the ocean water at the intake and portions of the diffuser. Because the applicants plan to operate the plant with a 20°F increase in temperature across the condensers, the temperature of the discharge waters may therefore be 26°F higher than the receiving waters. Therefore, no finding can be made that the project as proposed will meet the requirements of the State Water Resources Control Board.

b. Federal Thermal Standards. The 1972 Amendments to the Federal Water Pollution Control Act (PL 92-500) require effluent limitations "which shall require the application of the best practicable control technology currently available" to minimize thermal discharges. It would appear that this may require the use of closed-cycle cooling towers, because they are presently in use, they minimize thermal discharge, and a consultant to EPA has recommended this solution. The proposed plant at San Onofre would not use this cooling system but instead would use single-pass cooling, which does not minimize thermal discharges.

The Federal Water Pollution Control Act does contain an excepti procedure, provided the discharger can show that the proposed non-complying discharg will "assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on that body of water" into which the thermal discharge will occur. Although EPA has not yet issued its regulations interpreting the provisions, the AEC concluded that "the heated water will result in changes in the species composition in the vicinity of the outfall; but no general ecological changes are expected" (AEC EIS, p. i). Regardless of the fact that "no general ecological changes are expected" according to the AEC, the language of the statute would appear to preclude any changes in the characteristics of the existing indigeno species. If such an interpretation is adopted by EPA, it would mean that the proposed cooling system would not comply with Federal water quality standards and the project could not be constructed as proposed because there is insufficient acreage at the proposed site for closed-cycle cooling systems, such as cooling towers or spray ponds.

Thus conformity with the provisions of the Federal Water Pollution Control Act cannot be definitively resolved until EPA issues its regulations.

6. Impact on Kelp. A kelp bed has re-established itself to the south of the diffusers of the project during the past 2 years. Because many kelp beds ha deteriorated, the growth of this bed is of particular scientific value. It is also a marine resource that is commercially harvestable and that provides a valuable habi for various fish and other marine organisms. Substantial harm to the kelp bed could occur through excessive heat or turbidity. Condition C will insure that the effects of Units 2 and 3 on the kelp beds are not substantial.

D. Project Site

1. Bluffs and Canyons. Although motorists cannot see it from Interstate 5, the project site possesses a unique beauty. The narrow, twisting canyons, formed by erosion, and the bluffs towering more than 100 feet over the sand beach, combine to create a particularly scenic area.

Under the application before the Commission, the entire .51 mile of this unique site would be leveled for construction of Units 2 and 3. Under Condition D, however, construction of Units 2 and 3 will take about .21 mile of the bluffs and the most spectacular part of the site—the southernmost .31 mile—wi be protected for the duration of the site easement. This will allow time for the Commission and others concerned about this important area to provide for its perman protection.

2. Beach Access. Under the application before the Commission, about 1,000 feet of the San Onofre beach would be closed to the public during the entire 6-year construction period. Under Condition A, however, the beach area will be completely closed off only until June, 1975, and lateral access around the construction site will be provided by means of a walkway on summer weekends and holidays for the remainder of the construction period, except for brief intervals to permit the movement of construction crews and equipment.

E. Total Environmental Effect

A finding that this project conforms to the provisions of the California Coastal Zone Conservation Act of 1972 requires consideration of the positive environmental effects of the project on air pollution along with the adverse effects of the project on the bluffs and the uncertainty of the extent of its adverse effects on the marine environment. All the conditions are required to permit a finding that the project, as conditioned, conforms to the provisions of the Act.

IV. Acknowledgment of Conditions

Before any activity authorized by the permit is to take place, you must return to this office and to the San Diego Coast Regional Commission office copies of this statement with your signature acknowledging that you have received it and understand its contents.

Yours very truly,

JOSEPH E. BODOVITZ
Executive Director

Attachment
cc: San Diego Coast Regional Commission

The undersigned permittees acknowledge receipt of the California Coastal Zone Conservation Commission Permit No. 183-73, and fully understand its contents, including all conditions imposed.

Date	For Southern California Edison Company
Date	For San Diego Gas and Electric Company

APPENDIX 2.

STAFF RECOMMENDATION ON RADIOLOGICAL DISCHARGE MONITORING AND CONDITIONS TO BE ADDED TO PERMIT 183-73 FOR THE SAN ONOFRE NUCLEAR POWER PLANT

and

DIRECTION TO THE MRC REGARDING MITIGATION

November 1979

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CALIFORNIA COASTAL COMMISSION
631 Howard Street, San Francisco 94105 — (415) 543-8555

November 9, 1979

TO: STATE COMMISSIONERS

FROM: MICHAEL L. FISCHER, EXECUTIVE DIRECTOR

SUBJECT: STAFF RECOMMENDATION ON RADIOLOGICAL DISCHARGE MONITORING AND CONDITIONS TO BE ADDED TO PERMIT A 183-73 FOR THE SAN ONOFRE NUCLEAR POWER PLANT (For Commission consideration at the November 19-21, 1979 meeting in Los Angeles.)

SYNOPSIS

Following their August 15, 1979 public hearing on the findings of the San Onofre Marine Review Committee (MRC), the Commission asked the MRC to evaluate the radiological discharge monitoring program at the San Onofre Nuclear Generating Station (SONGS). The MRC reports the program, conducted by Southern California Edison, is "grossly inadequate" and "makes it impossible to determine with accuracy the amounts of radioactive material being released by SONGS." Staff therefore recommends that the Commission inform the Nuclear Regulatory Commission (NRC) of the inadequacy of the design and implementation of SCE's monitoring program and ask Edison to immediately develop an independent and accurate monitoring program. If Edison does not, staff recommends the Commission formally intervene in the NRC operating license proceedings for SONGS. The NRC has exclusive authority to regulate radiological discharges from nuclear power plants.

Staff also recommends the Commission adopt two new conditions for SONGS that were recommended by the MRC: minimal use of chlorine and other biocides in the SONGS cooling water system and use of non-corrosive titanium alloy in the SONGS condensers. Because it may be difficult to require major design changes such as cooling towers or extended diffusers after the units are licensed and operating, the Commission should direct the MRC to determine if such changes are warranted prior to the conclusion of the Nuclear Regulatory Commission's operating license proceedings. The Commission should also request the MRC to evaluate possible mitigation measures, including an artificial reef suggested by Edison. The Commission could add such measures to the SONGS permit in lieu of or in addition to plant design or operational changes, if the MRC monitoring determines fish, kelp or plankton will be damaged by operation of the SONGS cooling water systems.

Also, in response to Commission request, the MRC has focused and reduced its project research expenditures from a 1979 projected cost of nearly $5 million to 1980 projected cost of $3.2 million.

PURPOSE OF REPORT

At their meeting of August 15, 1979, the Commission held a public hearing on a staff recommendation to review the status of the San Onofre Marine Review Committee (MRC) and the March 1979 Interim Report of the MRC. In response to staff's recommendation and to testimony received at the hearing, the Commission then adopted the following statement:

> The Commission requests the MRC to more closely focus its study and monitoring program on kelp bed effects, effectiveness of the fish return system and effects of transport to deeper water on nearshore species and to modify five study program which the staff evaluation concludes are not likely to develop decision-making information. The MRC should study the ecological effects of extending the diffusers beyond the kelp bed. The MRC should also evaluate the adequacy of Nuclear Regulatory Commission and California Department of Health monitoring of radiological discharges from the plant and should evaluate recently published reports which conclude such discharges are not a threat to the marine environment. The MRC is requested to include this evaluation and their recommendations to the Commission on whether to initiate a radiological monitoring program as part of their revised study program to be submitted to the Commission.

The attached MRC report entitled, "Radiological Discharges from Nuclear Power Plants - An Evaluation of Present Monitoring at SONGS, of the Ecological Effects of Radionuclides, and a Recommendation for an Independent Program of Monitoring", and the attached letter to the Chairman of the Commission on "Future Plans of the MRC" respond to the above request.

The staff recommendation which follows includes recommendations from the MRC on radiological monitoring for the San Onofre plant, several conditions on the operation of the plant submitted by the Committee and requests for additional analysis from the MRC which will guide the Commission in making further decisions.

STAFF RECOMMENDATION

Staff recommends the Commission adopt the following resolution:

I. Monitoring of Radiological Discharges. The Commission finds that the current radiological discharges monitoring program being conducted by Southern California Edison Company at the San Onofre Nuclear Generating Station is grossly inadequate. The Marine Review Committee created pursuant to the Coastal Zone Conservation Commission permit for SONGS Units 2 and 3 has determined that the present monitoring program makes it "impossible to determine with accuracy the amounts of radioactive material being released by SONGS" into the marine environment (p. 5, MRC October 9, 1979 report, Radiological Discharges from Nuclear Power Plants).

The ecological effects of such discharges from nuclear power plants cannot be judged at this time due to lack of studies on such effects. But the MRC notes that the doses of such discharges from nuclear power plants are lower than discharges from other activities such as nuclear fuel reprocessing and hydrogen bomb blasts. Nevertheless, the Commission finds it is important for protection of public health and safety in addition to protection of the marine environment to accurately determine the level of radionuclide discharges from SONGS Units 1 and from Units 2 and 3 if they become operational.

Therefore, the Commission hereby resolves:

1. That staff shall inform the NRC of the inadequacy of the design and implementation of SCE's radiological monitoring program.

2. That Southern California Edison should immediately retain a completely independent contractor, as recommended by the MRC, to develop and implement an improved radiological discharge monitoring program that exceeds the Nuclear Regulatory Commission's minimum standards. The program should reflect the recommendations of the MRC.

3. That if Southern California Edison does not make such a commitment, the Coastal Commission will formally intervene in the NRC proceedings on operating licenses for SONGS Units 2 and 3. The Commission will request the NRC to exert its jurisdictional authority to require a comprehensive and accurate radiological discharge monitoring program as part of the operating licenses, if they are granted.

4. That if the NRC does not make such a requirement, the Commission directs staff to work with representatives of the Resources Agency and the Department of Health Services in exploring the feasibility of using the Commission's Coastal Energy Impact Program funds to carry out the independent monitoring program recommended by the Marine Review Committee.

II. <u>Added Permit Conditions</u>

Pursuant to the provisions of Conditions B-4 and B-6 of Permit A 183-73, the Commission hereby adopts the following additional conditions to be added to Permit A 183-73:

> B-9. Chlorine, other oxidants, or biocides shall not be used in the cooling water system at SONGS Units 1, 2, and 3, except in the event of failure of the physical cleaning system when minimal application rates of biocides should be used. Such rates should be determined by the MRC.
>
> B-10. Only highly corrosion resistent titanium alloy shall be used where determined by the MRC to be essential in the condenser system of SONGS Units 2 and 3, and the existing copper-nickel alloy condensers of Units 1 shall be replaced with titanium alloy condenser tubing.

<u>FINDINGS AND DECLARATIONS</u>:

The Commission finds and declares as follows:

1. <u>Permit A 183-73</u>. Within the terms of this permit granted under Proposition 20, marine life offshore of the San Onofre Power Plant would be protected by a continuing surveillance program to be conducted by the independent Marine Review Committee. That permit also empowered the MRC to design a study program, review the data collected, interpret the results of the studies, determine if adverse effects were occurring and recommend to the State Commission any changes it believed necessary in the cooling system for Units 2 and 3 (Condition B-4 and B-6).

COMPARISON OF SCE AND MRC FINDINGS:

SCE	MRC
PLANKTON - EFFECTS OF UNIT I	
No patterns were observed that could be related to operation of SONGS Unit 1 (SCE, Annual Operating Report, 1978, Vol. IV).	The usual distribution is disrupted out to 500 yards...some species increased 20-fold, a few species reduced by 100-fold. Mysid shrimps are more abundant at about 200 yards than at stations closer to or further from the plant (MRC, Interim Report, 1979).
FISH - EFFECTS OF UNIT I	
The fish community offshore does not appear to be adversely affected by the discharge of Unit 1 cooling water (SCE, Annual Operating Report, 1978, Vol. IV).	About 75% of the fish entrained by Unit 1 (are queenfish). Although there is no detectable difference in the density of this fish species near the Plant and elsewhere, there is a much lower proportion of immature fish within 500 yards of the plant compared with other areas (MRC, Interim Report, 1979).
PLANKTON - PREDICTIONS OF EFFECT	
SCE, p. viii: It is unlikely that the effect will be other than local and insignificant when compared to the processes in the southern California coastal region (SCE Thermal Effects Study, 1973).	Mortality will be increased in species that live largely in a band within 2.5 miles of shore. This will be equivalent to imposing an additional 1 - 10% mortality per day over an area of about 30 square miles during slow current regimes. The maximal rate would be roughly the same as the natural mortality rate and may be great enough to cause a reduction in plankton density around the Plant. A similar effect may occur with mysid shrimps. Within a similar-sized area, the numbers of planktonic larvae of benthic animals available for settlement will also be reduced to a greater degree than are the other zooplankton (MRC, Interim Report, 1979).
FISH - PREDICTIONS OF EFFECT	
SCE, p. ix: Generating station operations likely have had no adverse effect on regional fish communities (SCE Thermal Effects Study, 1973).	If the fish return system is ineffective, the amount of fishes killed will be almost 5 times that of Unit 1, which would result in loss equivalent to about 13% of the queenfish living along 27 miles of coastline near SONGS. If part or all of the San Onofre kelp bed is destroyed, the loss of this habitat will probably reduce the abundance of certain sport-fish in the area. The density of fish larvae may be reduced in an area at least as large as the area of reduction of zooplankton (MRC, Interim Report, 1979).

2. MRC Recommendation. Under the authority vested in them by Permit A 183-73 the majority of the MRC forwarded Conditions B-9 and B-10 to the Commission based on the following resolutions:

a. The MRC recognizes that chlorine has been widely identified as a major cause of mortality of organisms at power plants employing single pass cooling water systems. Further, recent studies have demonstrated undesirable synergistic interactions among chlorine, heavy metals and marine sediments, and consequent effects on marine organisms. The MRC is aware that other power plants such as the Calvert Cliffs Nuclear Facility in Maryland, have operated successfully in marine environments with physical cleaning methods rather than with biocides.

b. The MRC recognizes that a number of coastal power plants employing single pass cooling water systems have had undesirable effects due to corrosion of tubing and leaching of heavy metals, such as copper, from the condenser system into the environment.

3. Protection of Marine Life. Under the Coastal Act, the adverse effects of waste water discharge and entrainment must be minimized in order to protect the quality and productivity of coastal waters. Section 30230 states:

> Marine resources shall be maintained, enhanced, and where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.

Section 30231 states in part:

> The biological productivity and the quality of coastal waters, streams, wetlands, estuaries, and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment, ...

The Commission finds that the conditions set forth above are necessary to protect marine life offshore of the San Onofre plant complex.

III. Direction to the Marine Review Committee

Because the MRC was created to conduct research oriented toward possible actions by the Commission and, if necessary, to add conditions to the SONGS permit to further protect the marine environment, the Commission makes the following requests of the MRC:

1. Major Cooling System Design Changes. The Commission recognizes the difficulties in requiring major design changes to SONGS Units 2 and 3 after the NRC grants operating licenses and the units are generating electricity. Changes such as requiring cooling towers, extended diffusers or single point discharges could cost hundreds of millions of dollars and result in unit shutdown for a period of time.

The Commission has the authority to impose such changes, however, if recommended by the MRC after unit operation in order to prevent significant environmental damage. The MRC has not made such a recommendation to date. In order to permit the Commission to decide upon the necessity for design changes prior to operation if possible, the Commission requests the MRC to report to the Commission by June 1, 1980, prior to the completion of NRC operating license hearings, whether the Commission should consider and impose any major design changes on the cooling water systems for Units 2 and 3.

2. Mitigation Alternatives to Design Changes. The Commission also recognizes that operational changes or mitigation measures might adequately compensate for any marine life damages resulting from the operation of Units 2 and 3. The Commission, therefore, requests the MRC to study the feasibility and effects of selected promising mitigation measures, including construction of an artificial reef, as suggested by Southern California Edison. The MRC should recommend what measures might be taken to assure there would be no net adverse effect on the marine environment from operation of SONGS Units 2 and 3.

3. MRC Program and Budget. The Commission appreciates the MRC's efforts to focus and reduce the MRC research program and budget to those subjects given priority by the Commission. These subjects include predicting and later measuring effects on the San Onofre kelp bed, studying the offshore transport of larvae, and evaluating the effectiveness of the fish return system. The Commission requests that the MRC attempt to conduct the mitigation measures research program within the limits of the projected 1980 expenditures of $3.2 million. The Commission also requests the MRC to work with Commission staff in assessing the need for selected research program areas where already completed research seems adequate for decision-making purposes or where the level of effort may not be needed for decision-making purposes. Areas to be further assessed include: hard benthos, subtidal soft benthos, zooplankton, ichthyoplankton, oceanography and data management.

BACKGROUND AND STAFF ANALYSIS

The California Coastal Zone Conservation Commission established the Marine Review Committee (MRC) in 1974 as a condition of Permit A 183-73 for Units 2 and 3 of the San Onofre Nuclear Generating Station. The MRC is composed of three scientists: one appointed by the Commission, another by the applicants, Southern California Edison Company and San Diego Gas & Electric Company, and the third by the appellants, who are coordinated by the Friends of the Earth.

The purpose of the MRC is to study the effects of the existing Unit 1 cooling water system on marine life, to predict and later to monitor the effects of Units 2 and 3, and to recommend to the Commission new conditions on Unit 2 and 3 cooling system design and operation to prevent significant damage to marine resources. The same permit condition enables the Commission to impose new cooling water system requirements on the permitee, based on MRC recommendations, at any time.

At their meeting of November 14, 1978, the Commission requested the Marine Review Committee to prepare an interim report which would begin to reach conclusions about the effects of the cooling system of the San Onofre Nuclear Generating Station and develop recommendations to protect marine life offshore of the plans. On March 12, 1979, the MRC submitted a report indicating that future monitoring might confirm predictions of damage to the San Onofre Kelp Bed, ineffectiveness of the fish return system, and extensive mortality of small inshore marine organisms that are transported offshore by the system's diffusers. But the report recommended no design changes until predictions were confirmed by operational monitoring. The report suggested that the Commission consider recommending that the MRC evaluate the current radiological discharge monitoring issue, the added conditions and the state of MRC findings on impacts of SONGS on marine life, and the future MRC research program.

ISSUES

1. Radiological Discharge Monitoring. The accompanying MRC report, "Radiological Discharges from Nuclear Power Plants" responds to the Commission's August 15, 1978, request for such an evaluation.

The findings of the MRC (majority) as a result of that investigation are highly critical of the current self-monitoring program being conducted at San Onofre by SCE. According to the Committee, because of the inadequacy of the monitoring program, it is impossible to determine with accuracy the amounts of radioactive material being released by SONGS in the marine environment. Further, the annual reports by SCE to the Nuclear Regulatory Commission (NRC) contain many gross errors. In particular, the average values are calculated in such a way as to underestimate many of the concentrations of radioactive materials being discharged from SONGS.

While the MRC criticized the utility for not using their "good professional judgment in the development of the surveillance program", as recommended in the EPA monitoring program guidelines, they found the basic problem arose with the NRC regulations which do not require adequate replication or independent monitoring. Overall, the MRC found the present monitoring and reporting of radiological discharges at SONGS "grossly inadequate," and they believe that adequate monitoring can be assured only if it is done by an agency that is independent of the power companies. Though a strong case is made for independent monitoring, the MRC does not feel it should take over the responsibility for radiological monitoring at SONGS. It has been clearly established that radiation affects the health and survival of individual marine organisms and studies have indicated that certain species do have higher concentrations of certain radionuclides nearer SONGS than further away. However, the main task of the MRC is not to monitor substances discharged, but to assess the ecological consequences of the cooling system of SONGS. Although the evidence is sparse, MRC review of past studies of the ecological effects of radiological discharges suggests that such effects are to be expected mainly with high rates of discharge, much higher than have been measured from nuclear power plants. Therefore, they conclude that the ecological impacts of radiological discharges from SONGS is probably of less consequence than the ecological impact of other factors which they have been predicting from past studies. They suggest that if the Coastal Commission or some other State agency wants to know the probable ecological effects of radionuclides in the marine environment, it would be better to fund a study that examined an ecosystem subjected to the highest radionuclide levels that can be found and to combine this with experimental laboratory radiation studies.

Recommendation Course of Action

The MRC does offer assistance to the State Department of Health Services, which, they suggest, is the most logical agency to carry out a complete program of radiological monitoring. At present, the California Department of Health Services (DOHS) analyzes some samples, but these are collected by the contractor for the power companies (SCE and SDGE) that operate SONGS. To extend the DOHS program to include the collection of the samples would be the best way to achieve a completely independent monitoring program. The MRC recommendation that the DOHS expand its program in this way supports a similar recommendation made in the recent March 1979 State Resources Agency report "Radioactive Materials in California".

As the MRC points out, additional funding would be necessary to support the collecting itself and to analyze the greater number of samples required for an adequate program. They have given a preliminary estimate of these costs (attached).

It is important that funding be obtained for such a program. The Resources Agency in "Radioactive Materials in California" recommends that the NRC fund expanded State auditing of nuclear power plant environmental surveillance programs. To date, such funding has not been forthcoming from the NRC.

To improve the radiological monitoring program staff recommends the Commission adopt a resolution with a number of stages, after informing the NRC of the program's shortcomings. First, SCE itself should develop a credible, objective and comprehensive monitoring program along the lines recommended by the MRC. The program should involve independent review of the design of the program, independent collection and analysis of samples, and full documentation of methods and results. The program should reflect prudent and responsible "judgment" well beyond that required by the minimal EPA guidelines on establishing such a program. If SCE refuses to develop and fund such a program, the second step of the recommended resolution is for the Commission to formally intervene in the Nuclear Regulatory Commission's operating license proceedings on SONGS Units 2 and 3. The objective of the intervention would be for the NRC to - require a detailed, step-by-step independent monitoring program as part of the operating licenses for Units 2 and 3, if they are granted. Under federal law the NRC has sole authority to regulate radionuclide discharges. But the State can monitor the discharges. So if the NRC does not make more detailed monitoring program requirements part of the operating licenses, it seems important enough to accurately know what the discharges are to justify Commission consideration of using the limited Coastal Energy Impact Program funds to conduct some independent monitoring. This would be considered as a last resort because the annual cost would be $200-300,000 for the program suggested by the MRC (attached).

2. MRC Recommended Conditions. The MRC recommended three conditions to the Commission to be added to the SONGS permit. Two of the conditions, on minimizing use of chlorine and other biocides in the cooling water system and on use of corrosion resistent titanium alloy in the condenser are included in the staff recommended resolution. The third MRC recommended condition was: "B-11. A thorough and independent study shall be undertaken to evaluate the adequacy of the fish return system's design and operation and, further, if this new design proves ineffective, appropriate design changes shall be developed to reduce damage to the fin fish populations." This condition is more appropriate as Commission direction to the MRC rather than as a formal condition to add to the permit. The condition does not bind the application to an action. The MRC can undertake this evaluation task on its own, and the Commission has indicated it is a high priority.

3. Major Design Changes. The MRC has not recommended that the Commission require any major design changes to the SONGS cooling systems at this time. Condition B.6. of the SONGS permit states:

> Should the study (MRC study) at any time indicate that ... substantial adverse effects on the marine environment are likely to occur, or are occurring, through the operation of Units 1, 2, and 3, the applicants shall immediately undertake such modification to the cooling system as may reasonably be required to reduce such effects or comply with such regulatory requirements (which can be made while construction is going on and could be as extensive as requiring cooling towers if that is the recommendation). The State Commission shall then further condition the permit accordingly.

Because the MRC has not been able to determine whether design changes should be required at this time, SCE faces a major uncertainty. Design changes such as cooling towers, extending the diffusers hundreds of feet or converting the discharges to single point discharges could cost hundreds of millions of dollars and, if required after unit operation could result in temporary removal from operation until the design changes are completed. Staff scenarios of possible "worst case" damage to fish, kelp and smaller marine organisms based upon MRC predictions indicate that there would probably have to be massive unexpected additional damage to marine life to require cooling towers after Units 2 and 3 begin operating. The fish return system, the locations of the intake and outfall and the diffusers, however, are areas where design changes should be more closely studied.

The NRC operating license proceedings are just beginning and as currently scheduled will probably end in early fall of 1980. The MRC should provide the Commission with its best scientific judgment prior to the conclusion of those proceedings as to whether the Commission should impose major design changes on the Units 2 and 3 cooling systems. Therefore, staff recommends the Commission direct the MRC to make that evaluation for submission to the Commission prior to June 1, 1980. Staff has deleted a condition recommended in its August 3, 1979 report that would have required extending the diffusers if the diffusers if the MRC finds 25% of the San Onofre kelp bed is being destroyed. Such a condition is not supported by MRC recommendations at this time, and as explained above would be difficult to implement after the plants begin operating.

4. Mitigation Alternatives to Design Changes. While there is no disagreement that there are measurable effects from Unit 1 and there will be effects from the operation of Units 2 and 3, both in kind and degree, the controversy arises over the exact nature and significance of the impacts. As can be seen from the comparison of SCE conclusions and MRC conclusions on the following chart, there is a clear disagreement over the significance and the actual existence of impacts. However, the MRC does indicate that post-operational monitoring could discover kelp, fish and plankton damage resulting from the cooling water systems. The MRC suggested that possible conditions to prevent such damage might involve engineering changes such as extending the diffusers well beyond the kelp bed or plant operating changes. SCE in its testimony to the Commission suggested that mitigation measures might be appropriate, at much less cost, if such damage is predicted with confidence or discovered through monitoring. The attached letter from SCE recommends that the Commission direct the MRC to evaluate promising mitigation measures, particularly the artificial reef concept that SCE believes may provide a net increase in marine life productivity in the area. (Some reef designs only attract marine life without increasing overall productivity.) Staff is recommending the Commission provide such direction to the MRC, including MRC evaluation of other promising mitigation measures if they can be identified. The results would provide the Commission with mitigation alternatives that might be imposed as conditions of the SONGS permit.

5. <u>Future MRC Research Program and Budget</u>. The MRC responded to the Commission's August 15, 1979 request "to more closely focus its study and monitoring program on kelp bed effects, effectiveness of the fish return system and effects of transport to deeper water on nearshore species" with the attached letter (October 27, 1979) from Dr. Joe Connell, MRC Chairman to Chairman Dorill Wright. The projected 1980 expenditures indicate about a one-third reduction in rate of expenditures from the project 1979 rate. Staff has not yet had time to evaluate the changes or to assess the contractor work programs and budgets in light of the Commission's direction. The Commission has also requested modification of five study programs which do not seem likely to develop additional decision-making information. Therefore, staff intends to evaluate some of the research programs with the MRC and to report back to the Commission on the evaluation. The programs include hard and subtidal soft benthos, zooplankton, ichthyoplankton, oceanography and data management.

Further budget assessments will also be necessary because the recommended research program on mitigation measures may be quite costly. Staff is recommending the mitigation research program be conducted within a $3.2 million ceiling because staff had anticipated in its August 3, 1979 report that MRC expenditures might be reduced to a rate of about $2 million a year. The revised MRC budget goes a long way in the direction of meeting the Commission's concerns about high cost and lack of focus of the research program.