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CONTENTS

I. INTRODUCTION

In 1974, the California Coastal Zone Conservation Commission issued a permit (No. 6-81-330- A, formerly 183-73) to Southern California Edison Company for Units 2 and 3 of the San Onofre Nuclear Generating Station (SONGS). A condition of the permit required study of the impacts of the operation of Units 2 and 3 on the marine environment offshore from San Onofre, and mitigation of any adverse impacts. As a result of the impact studies, in 1991 the Coastal Commission added new conditions to mitigate the adverse impacts of the power plant on the marine environment which require SCE and its partners to: (1) create or substantially restore at least 150 acres of southern California wetlands, (2) install fish barrier devices at the power plant, and (3) construct a 300-acre kelp reef (Conditions A through C). The 1991 conditions also require SCE to provide the funds necessary for Commission contract staff technical oversight and independent monitoring of the mitigation projects (Condition D). In 1993, the Commission added a requirement for SCE to partially fund construction of an experimental white sea bass hatchery. Due to its experimental nature, the Commission did not assign mitigation credit to the hatchery requirement.

After extensive review of new kelp impact studies, in April 1997 the Commission approved amended conditions which: (1) reaffirm the Commission's prior decision that San Dieguito is the site that best meets the permit's standards and objectives for wetland restoration, (2) allow up to 35 acres credit for enhancement of wetland habitat at San Dieguito Lagoon by keeping the river mouth permanently open, and (3) revise the kelp mitigation requirements in Condition C. Specifically, the revised Condition C requires construction of an artificial reef large enough to sustain 150 acres of medium to high density kelp bed community (which could result in a reef larger than 150 acres) together with funding for a mariculture/marine fish hatchery as compensation for the loss of 179 acres of high density kelp bed community resulting from the operation of SONGS Units 2 and 3. The artificial reef is to consist of an initial small experimental reef (~ 22 acres) and a subsequent larger mitigation reef that meets the 150-acre requirement. The purpose of the experimental reef is to determine which combinations of substrate type and substrate coverage will most likely achieve the performance standards specified in the permit. The design of the mitigation reef will be contingent on the results of the experimental reef. The Commission also found in April 1997 that there is continuing importance for the independent monitoring and technical oversight required in Condition D to ensure full mitigation under the permit.

Condition D establishes the administrative structure to fund the independent monitoring and technical oversight of the mitigation projects. It specifically: (1) enables the Commission to retain contract scientists and technical staff to assist the Commission in carrying out its oversight and monitoring functions, (2) provides for a scientific advisory panel to advise the Commission on the design, implementation, monitoring, and remediation of the mitigation projects, (3) assigns financial responsibility for the Commission's oversight and monitoring functions to SCE and its partners, and sets forth associated administrative guidelines, and (4) provides for periodic public review of the performance of the mitigation projects in the form of a public workshop.

Condition D requires SCE and its partners to fund scientific and support staff retained by the Commission to oversee the site assessments, project design and implementation, and monitoring activities for the mitigation projects. Scientific expertise is provided to the Commission by a small technical oversight team hired under contract. The technical oversight team members include three Research Biologists from UC Santa Barbara: Steve Schroeter, Ph.D., marine ecologist, Mark Page, Ph.D., wetlands ecologist (half time), and Dan Reed, Ph.D., kelp forest ecologist (half-time). Ms. Jody Loeffler, a half-time administrator completes the contract program staff. In addition, a science advisory panel advises the Commission on the design, implementation, monitoring, and remediation of the mitigation projects. Current science advisory panel members include Richard Ambrose, Ph.D., Professor, UCLA, Peter Raimondi, Ph.D., Professor, UC Santa Cruz, and Russell Schmitt, Ph.D., Professor, UC Santa Barbara. In addition to the science advisors, the contract program staff is aided by a team of field assistants hired under a contract with the University of California, Santa Barbara to collect and assemble the monitoring data. The contract program staff is also assisted on occasion by independent consultants and contractors when expertise for specific tasks is needed. The Commission's permanent staff also spends a portion of their time on this program, but their costs are paid by the Commission and are not included in the SONGS budget.

II. OVERVIEW OF THE EXPERIMENTAL REEF DESIGN AND MONITORING

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MITIGATION REQUIREMENT

Condition C of the permit requires construction of an artificial reef in two phases; an experimental phase that is relatively short in duration (i.e. five years) and small in size (~ 20 acres), and a mitigation phase that is larger in size (at least 150 acres) and of a duration equivalent to the operating life of SONGS Units 2 and 3 (i.e. 20 to 30 years).

The primary goal of the experimental reef is to determine the substrate types and configurations that best provide: (1) adequate conditions for giant kelp recruitment, growth and reproduction, and (2) adequate conditions for establishing and sustaining other reef-associated biota, including benthic algae, invertebrates and fishes. Originally the SONGS coastal development permit required that the mitigation reef be constructed of quarry rock, and that the rock cover at least two-thirds of the sea floor within the boundary of the mitigation reef. On April 9, 1997 the Commission agreed to allow the Executive Director to change these requirements if the results of the experimental reef indicated that a different coverage or substrate type would replace a minimum of 150 acres of medium to high density giant kelp and associated kelp forest biota. Thus, a major objective of the experimental reef is to determine whether substrate coverages less than two-thirds and substrate types other than quarry rock (e.g., recycled concrete) can be used to meet the performance standards for the mitigation reef. Information obtained from the experimental reef will form the basis of the Executive Director's decision on the type and percentage cover of hard substrate required for the mitigation reef

EXPERIMENTAL REEF SITING AND DESIGN

SCE submitted a preliminary conceptual plan to the CCC to build the experimental reef in June 1997. The plan was approved by the Executive Director and forwarded to state and federal agencies for review. The environmental review process was finalized in June 1999 and construction of the experimental reef was completed on September 30, 1999.

The final design of the experimental reef approved by the CCC and built by SCE is a low-lying modular artificial reef located off San Clemente, CA that tests eight different reef designs that vary in substrate composition, substrate coverage and presence of transplanted kelp (Table II.1). All eight reef designs are represented as individual 40 m x 40 m modules that are replicated in seven areas (i.e., blocks) for a total of 56 artificial reef modules totaling 22.4 acres (Figure II.1). The modules were constructed to form low-lying reefs (i.e., < 1 m tall) that mimicked natural reefs in the region.

MONITORING GOALS AND RATIONALE

Deciding upon a design for the mitigation reef using information from the experimental reef entails uncertainties that stem from the length of the experiment (five years), which may not be sufficient for the development of a mature kelp forest community on a newly constructed reef. Moreover, because five years is short relative to the generation times of most kelp forest species (other than giant kelp), there is no guarantee that reef designs that appear successful at the end of the experiment (i.e. meet the performance criteria) will continue to perform successfully in the future. Given these uncertainties, it is possible that none of the experimental modules will develop a sustainable kelp community that meets the performance criteria for the mitigation reef. In this event the Executive Director will need to rely on information that best *predicts* which of the reef designs will meet the performance standards when applied to the mitigation reef.

To address this possible need, the Commission's contract scientists are taking a three-part approach to evaluating the results of the experimental reef. Evaluation of the experimental phase consists of: (1) monitoring a variety of physical and biological variables to determine the degree to which the eight reef designs achieve the performance criteria, (2) using the monitoring data to evaluate the performance of the eight reef designs relative to each other, and (3) collecting data from additional monitoring and experiments that will aid in predicting which design(s) will most likely be successful if applied to the larger mitigation reef. These additional data relate key physical and biological processes to: (1) specific aspects of community development, and (2) the degree of success in achieving the performance criteria. This last approach acknowledges that there are both processes that facilitate the development of kelp and related biota and those that suppress it. An example of the former is an adequate rate of dispersal and successful settlement of kelp spores. An example of the latter is too high a rate of recruitment and development of invasive species (e.g., sea fans) that can monopolize space on the reef and prevent the establishment of kelp and other biota. Results from these process studies are being used to predict whether the criteria for evaluating the performance of the different reef designs are likely to be met and how long it will likely take to meet them. Information obtained from process studies also are being used to gain insight into how physical and biological variables of interest are affected by specific reef characteristics that are not explicitly tested in the experiment (e.g. the size and shape of rocks and concrete rubble).

The three-fold approach depends in part on the idea that the dynamics of a kelp forest community can be predicted from: (1) the values of the variables that describe the state of the kelp forest community on which the performance standards for the mitigation reef are based (e.g. the area of medium-to-high density kelp, the density of fish and number of fish species, etc.), and (2) a knowledge of the physical and biological processes that control the average values and dynamics of the state variables (e.g., the effects of sand scour on community structure, lack of giant kelp due to insufficient spore dispersal, etc.). Information on the values of variables that describe the state of the community is being obtained from spatially representative monitoring of the experimental modules and reference reefs to describe "what's there." Additional insight into processes is being obtained from focused sampling and experiments aimed at predicting "what will be there over the long term."

PERFORMANCE CRITERIA

Although success of a particular reef design does not depend on the achievement of specific performance standards, the criteria by which the experimental reef will be evaluated are a subset of the permit performance standards by which the success of the larger mitigation reef will be judged. This choice of criteria was motivated by the need to predict which of the reef designs are most likely to produce a full-sized mitigation reef whose performance will meet the standards of the permit. The following performance standards for the mitigation reef will be used as criteria to evaluate the performance of the different experimental reef designs:

1. Substrate characteristics
    - At least 90% of the area of hard substrate (as determined by the first post-construction survey) must remain available for attachment of reef biota.
2. Giant Kelp
    - There must be a sustained giant kelp density of at least 4 adult plants per 100 m^2.
3. Kelp-bed fish
    - Resident fish assemblage shall be similar in density and species number to natural reefs within the region.
    - Young-of-year fish assemblage shall be similar in density and species number to natural reefs within the region.
    - Fish production shall be similar to natural reefs in the region.
    - Fish reproductive rates shall be similar to natural reefs in the region.
    - The standing stock of fish on the mitigation reef shall be at least 28 tons.
4. Kelp-bed invertebrates and understory algae
    - Benthic community (both algae and macro-invertebrates) shall have coverage or density and number of species similar to natural reefs within the region.
    - Benthic community shall provide food-chain support for fish similar to natural reefs within the region.
    - Important functions of the reef shall not be impaired by undesirable or invasive benthic species

These above performance criteria fall into two categories: absolute standards, which require that the variable of interest attain or exceed a predetermined value, and relative standards, which require that the value of the variable of interest be similar to that measured on natural reference reefs. The rationale for requiring that the value of a resource be similar to that on natural reefs is based on the requirement that to be successful the mitigation reef must provide the types and amounts of resources that occur on natural reefs. Resources on natural reefs, however, vary tremendously in space and time. Differences in physical characteristics of a reef (e.g., depth and topography) can cause plant and animal assemblages to differ greatly among reefs while seasonal and inter-annual differences in oceanographic conditions can cause the biological assemblages within reefs to fluctuate greatly over time. Ideally, the biological assemblages on a successful artificial reef should fluctuate in a manner similar those on the natural reefs used for reference. One way to help ensure that this will be the case is to select reference reefs that are close to and physically similar to the experimental reef. The premise here is that nearby reefs with similar physical characteristics should support similar biota, which should fluctuate similarly over time. Temporal variability, especially of the sort associated with changes in oceanographic conditions, can be accounted for more easily by sampling the experimental and natural reference reefs concurrently. Concurrent monitoring of the natural reefs helps ensure that regional changes in oceanographic conditions affecting the experimental reef are reflected in the performance criteria, since nearby natural reefs will be subjected to similar changes in oceanographic conditions.

San Mateo kelp bed located adjacent to the southern end of the experimental reef and Barn kelp bed located approximately 12 km south of San Mateo kelp bed were chosen as reference reefs for the artificial reef experiment (Figure II.1). A single transect was established at nine permanent stations at each reference reef and are used in comparisons with transects on the experimental reef. Coverage of hard substrate was not an explicit criterion for selecting these sites or for selecting the location of transects within them. Instead, the criteria used in choosing plots within reference reefs were that they: (1) have a history of sustaining giant kelp at medium to high densities, (2) be located at a depth similar to the experimental reef, and (3) be primarily low relief, preferably consisting of cobble or boulders. The criterion that the reference reefs have persistent stands of giant kelp is important because communities on reefs without giant kelp can differ dramatically from those with kelp. Because medium to high density giant kelp is required of the mitigation reef, it is important that it be present on the natural reference reefs during the five-year experiment. Because species composition and abundance vary greatly within and among natural reefs it is important that the number and spacing of reference transects be sufficient to allow the performance of different reef designs to be compared to the wide range of variation that occurs naturally. Also kelp persistence can vary greatly within and among sites over a five year period as a result of localized disturbances (e.g. sea urchin grazing, or sediment scour). This is a concern for the experimental reef because the plant and animal assemblages associated with persistent populations of kelp are needed to evaluate the performance of the different reef designs. The use of multiple reference plots helps ensure that a standard for comparison for the experimental reef is maintained, even in the event of localized extinctions of giant kelp.

There are two general ways to use data collected from San Mateo and Barn kelp beds to assess similarity for purposes of evaluating the relative performance standards. One method is to assume that San Mateo and Barn kelp beds are the only reefs that can be used for reference in evaluating the different reef designs on SCAR and hence represent the “universe” of possible reference sites. In this case a given artificial reef design might be considered similar to natural reference sites if the mean value for a given standard (e.g. the abundance of residence fish) fell within the range of values defined by the means for San Mateo and Barn kelp beds. An alternate approach for evaluating similarity is to assume that San Mateo and Barn kelp beds represent a random sample of all possible natural reference reefs that are suitable for use as used as standard for comparison. Here a range of statistical methods could be used to determine whether a given reef design is similar to (i.e. not significantly different from) from natural reference reefs. To determine the appropriateness of these two approaches we evaluated similarity in the abundances of understory algae and mobile and sessile invertebrates between the different artificial reef designs and San Mateo and Barn kelp beds for using six different methods including the range of the mean values of San Mateo and Barn and five statistical procedures (Table II.2). We found that the six different methods were very comparable in their assessment of similarity. Consequently for this report we evaluate similarity for the various relative performance standards using the range of the mean values recorded at San Mateo and Barn kelp beds.

MONITORING

Prior to the reef construction we prepared a monitoring and management plan for the experimental reef that was reviewed by SCE, various resource agencies and other technical specialists, and also was included in the draft PEIR for general public review. The plan provides an overall framework to guide the monitoring and describes the sampling methodology, analytical techniques, and methods for measuring performance of the different experimental reef designs relative to the performance criteria listed above. The monitoring and management plan for the experimental reef was approved by the Commission on July 15, 1999. The field work required to do the monitoring is contracted out to the University of California Santa Barbara. The field work is being done by a team of university scientists under the direction of Drs. Steve Schroeter and Dan Reed.

In the fall of 1999 four permanent 40 m transect lines were installed on each of the 56 modules and nine permanent 40 m transects were install at each of the two reference reefs. These lines are used to mark the areas on each module that are routinely monitored. The abundance of giant kelp, kelp-bed fish, and large macro invertebrates and understory algae are surveyed each year in a 2 m wide swath along the permanent transect lines. The abundances of smaller algae and invertebrates, cryptic fish and area and coverage of hard and soft substrates are recorded in six permanent 1 m^2 quadrats spaced evenly along each transect. Analyses of data collected during the first two years of the experiment (i.e., 2000 and 2001) indicated a 50 % reduction in sampling effort would result in little change in statistical power to detect the differences among different reef designs. Consequently, sampling effort beginning in 2002 was reduced from four transects per module to two. In addition, sampling of the 14 kelp transplant modules was suspended after 2001. This was done because: (1) dense colonization by giant kelp was observed on all modules during 2000 reducing the need to artificially establish kelp, and (2) the methods used to transplant juvenile kelp on SCAR were deemed to be a feasible means of augmenting the abundance of adult giant kelp on the mitigation reef if the need ever arises.

The experimental modules and natural reference reefs are being monitored for the entire five year experiment. The purpose of collecting data throughout the experiment is to assess differences in rates of development (and processes affecting development) between the different reef designs, and to determine whether the biota on the different reef designs has stabilized. Monitoring reference reefs for the duration of the experiment is critical. If the biological assemblages on any of the experimental modules have not stabilized after five years, then data collected from natural reference reefs will be used to determine whether the lack of stability reflects natural variability in the region. Permanently fixed quadrats and transects are being used to ensure that differences observed over time reflect temporal rather than spatial variability in the performance of the experimental modules.

During the first four years of the experiment (January 1, 2000 through December 31, 2003) a total of 7075 dives (amounting to 4982 hours underwater) were made on the artificial reef and reference reefs.

Table II.1. The eight reef designs tested in the experimental phase of the San Clemente Artificial Reef

67% bottom cover of quarry rock
34% bottom cover of quarry rock
34% bottom cover of quarry rock with transplanted kelp
17% bottom cover of quarry rock
67% bottom cover of concrete rubble
34% bottom cover of concrete rubble
34% bottom cover of concrete rubble with transplanted kelp
17% bottom cover of concrete rubble

Table II.2. Results from different methods of estimating similarity between the six artificial reef designs and the natural reference reefs. Values = 1 indicate the mean of artificial reef are greater than that measured at San Mateo and Barn kelp beds, values = 0 indicate the mean of artificial reef are similar to that measured at San Mateo and Barn kelp beds, and values -1 indicate the mean of artificial reef are similar to that measured at San Mateo and Barn kelp beds.

		Concrete			Rock		
Taxonomic Group	Method	Low	Medium	High	Low	Medium	High
Sessile Invertebrates	1	1	1	1	1	1	1
	2	1	1	1	1	1	1
	3	0	1	1	0	1	1
	4	0	0	1	0	1	1
	5	1	1	1	1	1	1
	6	0	0	1	1	1	1
Understory Algae	1	-1	-1	-1	-1	-1	-1
	2	-1	-1	-1	-1	-1	-1
	3	-1	-1	-1	-1	-1	-1
	4	0	0	0	0	0	0
	5	-1	-1	-1	-1	-1	-1
	6	-1	0	-1	-1	-1	-1
Mobile Invertebrates	1	1	1	1	1	1	1
	2	0	0	0	0	1	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0

Method 1: Means of artificial reef designs are within the 95% confidence interval of the means of the control sites. Replicates for reference sites are year means for each site (e.g. BK in 2000).

Method 2: Means of artificial reef designs are within the range of the means of the control sites.

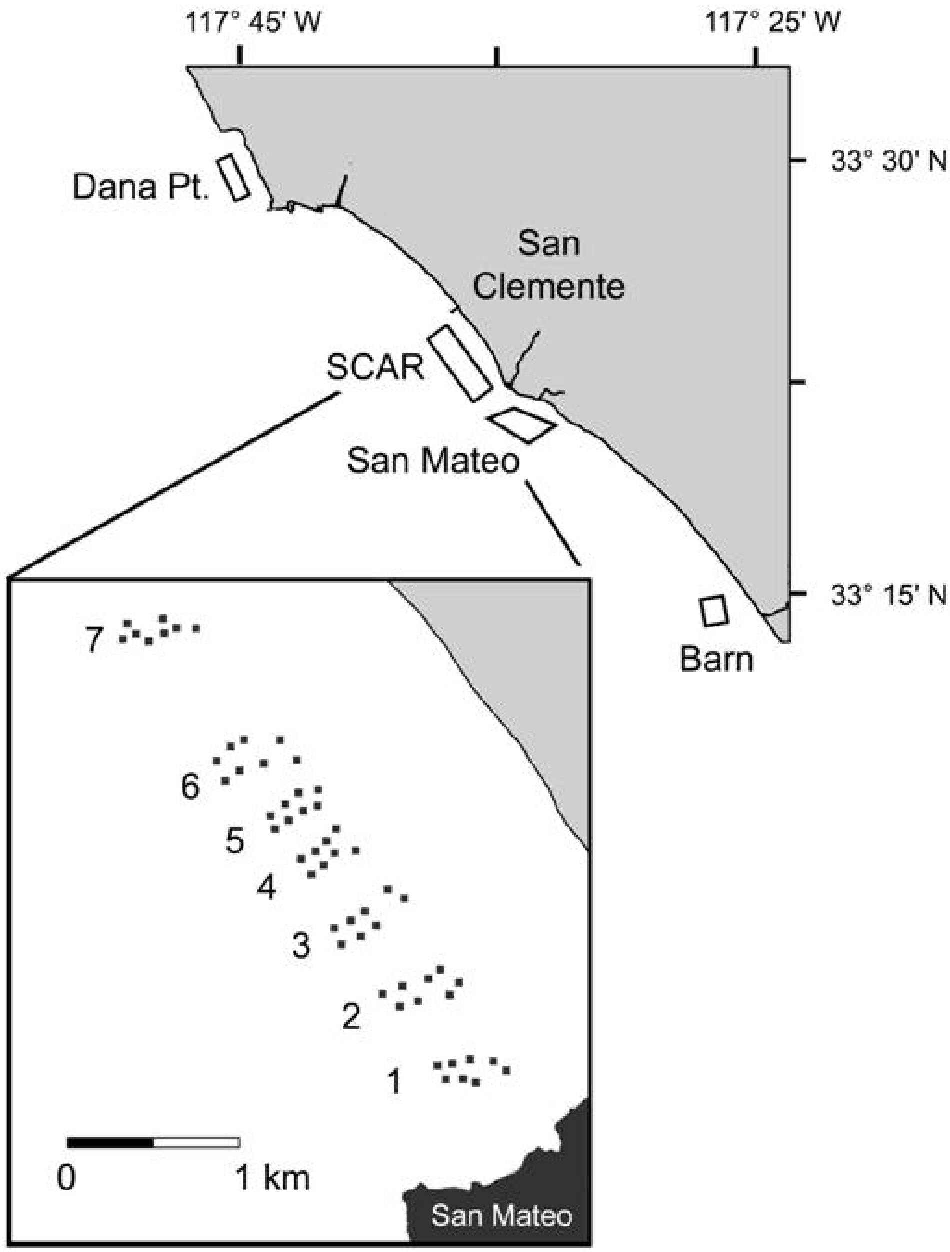
Method 3: Means of artificial reef designs are within the range set by the highest and lowest values of the 95% confidence intervals of the reference sites.

Method 4: Means of the artificial reef designs are within the 95% confidence interval of the mean of the reference sites for a given year (n=2 reference sites, BK and SMK).

Method 5: Same as method 4, but with sample size increased (n=5 in example) to reduce 95% confidence interval on mean of reference sites.

Method 6: Means of artificial reef designs are not significantly ($p < 0.05$) different from mean of reference sites in a given year as determined by a Dunnett's test.

Figure II.1. Location of the experimental phase of the San Clemente Artificial Reef (SCAR).



III. RESULTS FROM THE EXPERIMENTAL PHASE OF THE SAN CLEMENTE ARTIFICIAL REEF, 1999-2003

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HARD SUBSTRATE

Mitigation requirement

The SONGS coastal development permit requires that the mitigation reef be constructed of rock, concrete, or a combination of these materials at a coverage that is suitable for sustaining giant kelp and associated kelp forest biota similar in composition and diversity to nearby reference reefs, as determined by results from the experimental artificial reef. The total aerial extent of the mitigation reef shall be no less than 150 acres. The lone physical performance standard for the mitigation reef is that at least 90 percent of the area of exposed artificial substrate must remain available for the attachment of reef biota. SCE will be required to add sufficient artificial reef material to the mitigation reef to replace lost or unsuitable hard substrate, if at any time the Executive Director determines that more than 10 percent of the artificial reef material has become covered by sediment, or has become unsuitable for growth of attached biota due to scouring and there is no sign of recovery within three years. In accordance with Condition D, scientists contracted by the Commission shall initiate surveys to monitor the amount and distribution of exposed artificial reef substrate. These surveys shall begin immediately after construction of the mitigation reef is complete and continue for at least 10 years.

Methods

The amount and distribution of artificial reef material is being surveyed on the experimental reef modules to determine the likelihood of the different experimental reef designs in meeting the performance standard for hard substrate required of the mitigation reef. The area of exposed artificial reef substrate for a given module is being estimated as the product of the area defined by the perimeter of the module (i.e. the module footprint) and the percent cover of artificial substrate within the module's perimeter. Footprint area is estimated using side scan sonar and percent cover of artificial substrate is estimated by divers using a uniform point contact method.

Ecosystems Management Inc. was issued a contract by the CCC to monitor changes in the footprint areas of the 56 artificial reef modules. The navigation for the side scan sonar surveys is performed using a Differential Global Positioning System (DGPS) in conjunction with navigational software to navigate the vessel. The side scan sonar data are collected using a Side Scan Data Acquistion System that consists of the data acquisition software, computer with A/D Data Acquisition Board, and the 500 kHz Klien Digital Side Scan sonar Model 595.

Each of the 56 modules was pre-plotted with 4 lines, each about 10 m on the outside of each of the four sides of the module. The vessel runs a transect along each of the pre-plotted lines until a “good” image is obtained. The criteria for a “good” image are that the image is not distorted, the vessel track is relatively parallel to the edge of the module, and that the entire module is visible. This digital image is stored on hard disk and processed at a later date. The processing involves the justification of the image. The two axes of each image are the axis of the vessel track and the axis perpendicular to the vessel track. The dimension of the axis perpendicular to the vessel track is accurate because the speed of sound in water during the survey is relatively accurate.

This axis is also corrected for slant range within the side scan sonar processing software. The dimensions of the vessel track axis vary because of vessel speed changes and are corrected by using the dimensions measured from the perpendicular passes to justify the image. Consequently, the north and south passes are used to justify the dimensions of the east and west passes, and conversely, the east and west passes are used to justify the dimensions of the north and south passes. The justified image is then digitized and the area and perimeter of the module is determined. The mean of the four images is calculated (in some cases, an image is not used due to distortion, or indistinct boundaries) and used to estimate the footprint area. To date, there have been three side-scan sonar surveys of module footprint areas: September/October 1999 immediately following construction, October 2000, and July 2001. Side scan surveys were suspended in 2002 and 2003 to reduce costs. A final survey is scheduled for the last year of the five year experimental phase during summer 2004.

The percent cover of hard substrate on each module is measured by divers using a uniform grid of 20 points placed in the six permanent 1 m^2 quadrats that are uniformly arranged on each permanent 40 m transect. The grid of 20 points consists of five knots spaced every 20 cm on each of four equally spaced lines that are positioned parallel to the transect line. The observer draws an imaginary line through each of the points that is perpendicular to the bottom, and records the substrate intercepted by the line extending below the point. Substrates are categorized as bedrock (continuous rocky reef), mudstone, large boulder (rock ≥ 1 m), medium boulder (50 cm ≤ rock < 1 m), small boulder (25.6 cm ≤ rock < 50 cm), cobble (6.4 cm ≤ rock < 25.6 cm), pebble (2 mm ≤ granule < 6.4 cm), sand/silt/clay (granule < 2 mm), and shell hash. When a hard substrate was covered with 1 cm or less of silt it was noted as being silted. Hard substrates having a thin layer of silt were considered available for the attachment of reef biota for the purpose of evaluating the performance standard for hard substrate.

Results

Changes in the area of artificial substrate

The module footprint areas of all reef designs increased by 8 to 15% during the first year following construction (Figure III.1). Much smaller changes in footprint area were observed during the second year. Redistribution of artificial substrates by wave action is believed to have caused the increase in footprint area. Observations by divers that artificial reef material had been deposited on permanent transect lines confirmed that some redistribution had occurred. Initially, the footprint areas of the low coverage rock and concrete modules were noticeably smaller than those of the medium and high coverage modules. Overtime, there has been a convergence of the footprint areas of rock modules and by summer 2001 there was little difference in the areas of rock modules having different bottom coverages. In contrast, substantial differences in footprint areas among concrete modules having different bottom coverages were relatively constant from 1999 to 2001.

<u>Changes in the cover of artificial substrate</u>
There was substantial variation in the bottom cover of artificial substrate among modules of the same reef design (Figure III.2). The percentage of the bottom covered by artificial substrate by the different reef designs was substantially higher than the targeted values of 17%, 34% and 67%; the mean percent cover of artificial substrate for the low, medium, and high cover modules was 41% 67% 82%, and 35%, 50% 73% for rock and concrete, respectively. By comparison the average percent cover of naturally occurring hard substrate at the two reference reefs was 50% and 48% for Barn and San Mateo, respectively. The percent cover of hard substrate on the artificial modules and the reference reefs has changed little over the period 2000 – 2003. Importantly, with the exception of the low cover concrete design, all artificial reef designs have been consistently above the standard that requires at least 90% of the initial cover of hard substrate must remain exposed for colonization by reef biota (Figure III.3). The low cover of concrete design dropped slightly below this standard in 2003.

Summary of hard substrate

- The percentage cover of artificial substrate on the experimental modules continues to be substantially greater than the intended nominal coverages of 17%, 34% and 67%.
- The variability in the cover of hard substrate at the reference reefs largely encompassed the range of cover in hard substrate observed on the artificial reefs, however, none of the coverages of hard substrate on the artificial reef designs were below the lower range of coverages found on the reference reefs.
- All but the low cover of concrete design are currently above the performance standard for hard substrate.

GIANT KELP

Mitigation requirement

An important performance standard for the mitigation reef is that it sustain 150 acres of the giant kelp, *Macrocystis pyrifera* at medium to high densities. For purposes of the SONGS coastal development permit, medium to high density kelp is defined as more than four adult plants per 100 m^2, which was the definition used by the Marine Review Committee to estimate the amount of kelp loss attributed to SONGS during the impact assessment phase of the SONGS monitoring program.

Methods

A multi-component approach to monitoring giant kelp is being used during the experimental phase to obtain the pertinent information needed to evaluate the performance of the different reef designs with respect to the standard for giant kelp. The monitoring involves collecting information on the following range of size classes of giant kelp:

- *Adult* – an individual having eight or more stipes *or* having haptera extending up to or above the primary dichotomy.
- *Sub-adult* – an individual exceeding one meter in height having fewer than eight stipes *and* having no haptera that extend up to or above the primary dichotomy.
- *Juvenile* – a small blade having a split *or* an individual consisting of only fronds that are < 1 m tall.
- *Recruit* – a small blade lacking a split that can be identified as *Macrocystis* by the undulation at the base of the blade.
- *Unidentified kelp blade* – a small kelp blade (generally < 2 cm tall) that cannot be identified to species.

Data collected on adults in the experimental phase of the artificial reef mitigation project are used to evaluate how well the different experimental reef designs will meet the performance standard for giant kelp that will be applied to the mitigation reef. Data collected on the abundances of sub-adults, juveniles, and recruits provide insight into the biological processes needed to sustain adult giant kelp at densities at or above the performance standard.

Adult and sub-adult plants were sampled annually in spring in permanently located 40 m x 2 m transects on the artificial reef modules of SCAR and at San Mateo and Barn kelp beds in 2000 and 2001 . All transects are marked with lead line anchored to the bottom with stakes. A pair of divers swimming on opposite sides of the 40 m long lead line record information on all adult and sub-adult plants encountered in a one meter wide swath adjacent to the lead line. Frequently, only a portion of a plant is located within the 1 m swath. Of special concern is the case when a plant recruits outside the swath and then encroaches into the swath on subsequent surveys via the spreading of its holdfast. To avoid counting "encroaching" plants that were not located in the swath in previous surveys, divers only count adult and sub-adult plants if their primary dichotomy is located within 105 cm of the lead line.

Every adult plant encountered along each transect is counted and tagged and its survivorship is followed on subsequent surveys. Tags consist of a white plastic paper label containing a unique alpha-numeric identification number. Tags are fastened with a nylon cable tie to either the holdfast or the secondary dichotomy. The dimensions of the reef substrate to which the plant is attached is recorded at the time of initial tagging. Data on the size of all tagged adults are collected on each survey. Plant size is measured in two ways: by the number of fronds >1 m tall, and by the basal area of the holdfast. Holdfast area is calculated from measurements of holdfast length and width using the equation for an ellipse (area = length*width*π/4). Data on fecundity is recorded for the first 30 adult plants encountered on each transect. The fecundity of a plant is based on its total sorus area (spore-bearing areas on specialized blades called sporophylls), which is estimated as the product of the number of sporophylls having sori and the average length and width of sori on a plant.

Sub-adults are not tagged until they reach adulthood. Data collected on sub-adults include the number of stipes greater than 1 m tall and the category of substrate to which the plant is attached. Substrate categories are as follows: bedrock, large boulder (> 100 cm in length), medium boulder (51 to 100 cm in length), small boulder (26 to 50 cm length), cobble (7 to 25 cm length), and pebble (2 to 7 cm length).

Juveniles and recruits of giant kelp are sampled once per year in the summer. Juveniles are counted in the same 2 m x 40 m areas that adults and sub-adults are counted in. Because it is inefficient to count numerous small kelp plants in an area as large as that delineated by the transects, recruits of *Macrocystis* are counted in six fixed $1m^2$ quadrats that are evenly spaced along each transect.

Results

Colonization

Substantial recruitment of giant kelp occurred on SCAR during the late spring and early summer of 2000. Colonization by giant kelp was slightly higher on rock compared to concrete modules (FigureIII.4). More strikingly, the density of kelp recruits increased with increasing cover of artificial substrate; medium and high cover modules had two to three times more juvenile *Macrocystis* than did the low cover modules. With the exception of block 1, the density of kelp recruits generally decreased with increasing distance from the San Mateo kelp bed (Figure III.5). Nonetheless, substantial recruitment of giant kelp still occurred in block 7, which is located approximately 3.5 km up coast of San Mateo, the nearest kelp bed. In contrast to SCAR, only sparse recruitment of giant kelp was observed at the two natural reference reefs (SMK and BK, Figure III.4). Shading by a dense surface canopy was the most probable cause of poor kelp recruitment at these sites. Very little kelp recruitment has been observed at SCAR or the reference sites since this large initial colonization event.

Adults

The cohort of plants that recruited in summer 2000 appeared in the adult survey of winter/spring 2001. Patterns of adult *Macrocystis* abundance in this survey resembled those of juvenile recruitment observed in summer 2000. Adult abundance increased with increasing cover of artificial substrate and decreased with distance from San Mateo kelp bed (Figures III.6 & III.7). Adult densities on rock modules were initially higher than those on concrete modules; adult kelp abundance on both types of artificial reef modules were substantially greater than those observed at San Mateo and Barn. Adult kelp densities have declined since 2002 and were much more similar on all reef designs and in all blocks in 2003. Despite these declines, the density of adult giant kelp continues to be well above the standard of four plants per 100 m^2 for all artificial reef designs and substantially greater than that at San Mateo and Barn.

The performance standard for giant kelp stresses sustainability of medium to high density kelp. One component of sustainability is survivorship. We examined adult survivorship in the fraction of plants that recruited to SCAR in 2000 and reached adulthood in spring of 2001. We observed little differences in adult survivorship between rock and concrete modules (Figure III.8). Nearly half of the adults present in 2001 survived to 2003. Survivorship was slightly lower on modules with a high cover of hard substrate. Recall that adult densities were initially highest on these modules, suggesting that patterns of adult survivorship on SCAR were influenced by density dependence. An important consideration in the design of the mitigation phase is the size of the material used to construct the reef. Interestingly, substrate size had little effect on adult survivorship when plants were attached to boulders that were greater than 25 cm in their longest dimension (Figure III.9).

Summary of giant kelp

- *Macrocystis* recruited to all artificial reef modules in summer 2000.
- The density of *Macrocystis* recruits increased with bottom cover of artificial substrate and decreased with distance from San Mateo kelp bed.
- Patterns of adult abundance on SCAR in summer 2001 reflected patterns of juvenile abundance in summer 2000.
- Adult density declined over time and by 2003 there was little difference in the density of adults on the different reef designs and on the different blocks.
- All reef designs and blocks continue to exceed the performance standard for adult kelp (i.e., > 4 four adults / 100 m^2) in summer 2001.
- Adult density continues to be substantially higher on SCAR than on the natural reference reefs
- Nearly 50 % of individuals that reached adulthood in 2001 survived to 2003.
- Adult survivorship was lower on modules with higher cover of hard substrate, which had higher initial densities of adults.
- Adult survivorship was unaffected by substrate size in plants that were attached to boulders > 26 cm in length. Adults attached to cobble generally suffered higher rates of mortality.

Benthic Community

Mitigation requirement

The SONGS permit specifies three performance standards for the kelp forest benthic community (invertebrates and understory algae) on the mitigation reef. These are: 1) the benthic community shall have a coverage (i.e. percent cover) or density and number of species similar to natural reefs within the region, 2) the benthic community shall provide food-chain support for fish similar to natural reefs within the region, and 3) the important functions of the reef shall not be impaired by undesirable or invasive benthic species. Information as to whether the different reef designs are likely to meet all three of these performance standards can be obtained by monitoring the abundance and species composition of benthic algae and invertebrates at SCAR , San Mateo, and Barn.

Methods

The benthic communities at SCAR and Barn and San Mateo were sampled once per year (in the summer) during 2000 to using the same permanent transects that kelp was sampled in see *Giant Kelp* above). All transects are marked with lead line anchored to the bottom with stakes. There are six uniformly spaced 1m x 1m permanent quadrats on each transect. A pair of divers swimming on opposite sides of the 40 m long lead line counts large algae and invertebrates in a 1 m swath. Abundances of algae and invertebrates were estimated as counts per unit area or percent cover. Large invertebrates (e.g. sea stars, sea urchins, and lobsters) and algae (e.g. palm kelp, *Pterygophora californica*) were counted in replicate 40 m x 2 m band transects on the artificial reef modules of SCAR and at Barn and San Mateo. Smaller invertebrates were counted in replicate 1m x 1m quadrats on each band transect. Abundances of sessile invertebrates and understory algae that are either difficult to distinguish as individuals (e.g. foliose red or brown algae) or lie flat on the bottom (the brown algae *Desmarestia ligulata* and *Laminaria farlowii*) were measured as percent cover. Percent cover was estimated by noting the identity and vertical position of all organisms under 20 uniformly placed points within each 1m x 1m quadrat, giving a total of 120 points per transect. Using this method the total percent cover of all species can exceed 100%; the maximum percent cover possible for any single species cannot exceed 100%. Both count data and percent cover data were used in estimating species richness. Species richness at Barn and San Mateo was determined by the number of species of algae and invertebrates encountered in the nine permanent transects at each site. Because estimates of species richness are highly dependent on sampling effort and sampling effort was greater for the six artificial reef designs compared to the reference reefs (i.e. 14 vs. 9 transects) we used data from nine transects chosen randomly from the 14 permanent transects (two transects per module x 7 modules per reef design) to estimate the species richness of algae and invertebrates for the different artificial reef designs. The similarity (S) in the relative species composition of the different artificial reef designs and the reference reefs was estimated as:

$$S = \sum_{i=1}^{n} \min(P_{1i}, P_{2i})$$

where P_{1i} is the relative abundance of species i at site 1. While the degree of similarity in the species assemblages of the artificial and reference reefs is not a standard that will be used to evaluate the performance of the mitigation reef, it is useful in assessing whether a particular reef design is more or less likely to attain the mitigation goal of replacing resources that are similar to natural reefs in the region

Results

Understory algae

Understory algae quickly colonized SCAR and in the summer following construction (i.e., 2000) their bottom cover on all artificial reef designs was within the range defined by the means of Barn and San Mateo (Figure III.10). The kelp *Laminaria farlowii* and numerous species of foliose red algae were among the most abundant colonists. Crustose coralline algae, which is abundant on the reference reefs has been relatively sparse on SCAR. The percent cover of understory algae was positively correlated to the cover of artificial substrate, but unrelated to the type of hard substrate (i.e., algal cover was generally similar on rock and concrete modules). Since 2001 understory algae has declined in abundance on all artificial reef modules, and by 2003 was approaching zero and well below the range defined by the means of Barn and San Mateo. The cover of understory algae at Barn and San Mateo in 2003 was approximately 30% and 15%, respectively. Patterns of species richness in understory algae followed the same decline as those observed for percent cover with the exception that the number of species of understory algae on the artificial reef modules has been consistently below the range set by the reference sites since 2001 (Figure III.11). The type and bottom coverage of artificial hard substrate have had little effect on algal species richness. The species composition and relative abundance of understory algae on SCAR during the first four years of the experiment has differed noticeably from that of the reference reefs. The algal assemblages at Barn and San Mateo have been much more similar to each other than they have been to any of the six artificial reef designs (Figure III.12). The kelp *Laminaria farlowii* and numerous species of foliose red algae have been the most abundant algae on SCAR, while crustose coralline algae, which is abundant on the reference reefs, has been relatively sparse on SCAR.

Benthic invertebrates

A diverse assemblage of sessile invertebrates (consisting largely of tunicates, bryozoans, hydroids and sponges) rapidly colonized SCAR and attained relatively high cover within the first year following construction (2000, Figure III.13). The percent cover of invertebrates was positively correlated with the bottom cover of artificial substrate. Rock modules tended to have slightly greater cover of sessile invertebrates than concrete modules. The abundance of sessile invertebrates on all reef designs has steadily increased over time and in summer 2003 all six designs had percent cover values that were greater than those observed at the reference reefs. Colonization of SCAR by mobile invertebrates was initially low, but has steadily increased over time and the abundance of these organisms has been within or above the range for all reef designs since 2002 (Figure III.14). Their abundances appear to be less influenced by the amount and type of hard substrate than were the abundances of sessile invertebrates. The most abundant group of mobile invertebrates on SCAR has been brittle stars. Other common echinoderms such as sea stars and sea urchins have been relatively slow to colonize SCAR. The number of species of all benthic invertebrates (i.e., sessile and mobile combined) has steadily increased over time with nearly identical numbers of species observed on all reef designs during each of the four annual surveys (Figure III.15). Since 2001 the species richness of sessile invertebrates on the six artificial reef designs has been very similar to that observed at San Mateo. Initially the species assemblages of sessile and mobile invertebrates on the six artificial reef designs were much less similar to the reference reefs than the invertebrate assemblages on the reference reefs were to each other (Figure III.16). Within a couple years the benthic invertebrate assemblages on the artificial reef designs have become much more similar to those on the reference reefs.

One of the more notable invasive species on shallow reefs in southern California is the sea fan *Muricea* spp. It has been known to form high densities on artificial and natural reefs and is thought to exclude other reef biota. Of particular concern to the SONGS mitigation project is the ability of *Muricea* to withstand disturbance and ultimately displace giant kelp, which appears to have happened on nearby Pendleton Artificial Reef. Ambrose et al. (1987) working under the auspices of the Marine Review Committee surveyed the abundance of *Muricea* and *Macrocystis* on 27 artificial and natural reefs in southern Californian and found that giant kelp was absent on reefs having adult sea fan densities > 10 m^{-2} suggesting that a threshold density of *Muricea* exists above which

Macrocystis is excluded. (Figure III.17). The concern about the potential for *Muricea* domination was heightened in winter 2002 when large numbers of small (i.e., 1 cm tall) *Muricea* recruits were first observed on SCAR. By summer 2002 densities of *Muricea* recruits were at or above the 10 m^{-2} threshold for all reef designs (Figure III.18). In contrast, relatively low recruitment of *Muricea* was observed on the nearby reference reefs at Barn and San Mateo. *Muricea* abundance at SCAR was positively correlated to the bottom cover of hard substrate. Relatively little difference in the density of sea fans was observed between rock and concrete modules. By summer of 2003 the *Muricea* recruits on SCAR had grown to five to ten cm in height and consisted of multiple branches. Importantly there was little or no decline in sea fan density from the previous year when one might expect mortality to be greatest. This high survivorship of recruits coupled with the high densities of juveniles raise the possibility that the cohort of *Muricea* that recruited in 2002 could maintain densities near or above the threshold level until they grow to adulthood.

Summary of benthic community

- The abundance and species richness of understory algae continues to decline and is currently well below the range of the two reference reefs.
- The abundance of benthic invertebrates (both sessile and mobile) continues to increase and is currently within or above the range of the two reference reefs.
- The species richness of benthic invertebrates (both sessile and mobile) continues to increase and is currently within or slightly below the range of the two reference reefs.
- High densities of juvenile *Muricea* persist on all artificial reef designs

KELP BED FISH

Mitigation requirement

The abundance of fish in the San Onofre kelp bed was reduced by approximately 70% relative to the San Mateo kelp bed during the impact assessment phase of SONGS Units 2 & 3. The Marine Review Committee concluded that this reduction was caused by the operation of the power plant. The reduction in the relative abundance of fish in the San Onofre kelp bed translates into an estimated loss of about 200,000 fish (weighing about 28 US tons) that would be present in the absence of SONGS. The performance standard that the standing stock of kelp bed fish at the mitigation reef be at least 28 US tons is intended to insure proper compensation for this estimated loss. In addition to this fixed requirement, there are four relative performance standards for the mitigation reef that pertain to kelp bed fish: (1) the resident fish assemblage shall have a total density and number of species similar to natural reefs within the region, (2) the total density and number of species of young-of-year fish (fish less than 1 year old) shall be similar to natural reefs within the region, (3) fish reproductive rates shall be similar to natural reefs within the region, and (4) fish production shall be similar to natural reefs in the region. Here we report on results from the experimental phase that pertain to all but the last two relative performance standards for fish.

Methods

Fish abundance and size were recorded at three depth strata along the permanent transects used to sample kelp and the benthic community at the artificial reef and reference reefs. Sampling was done in the surface region of the kelp canopy (0 to 2 m depth below the water surface), the midwater region (approximately 7 m depth between the surface and bottom), and at the bottom (14-15 m). The dimensions of the volume of kelp forest sampled at each stratum were 2 m wide x 2 m high x 40 m long for a total volume of 160 m^3. To avoid disturbance of fish by air bubbles expelled from divers, the surface stratum was sampled first, followed sequentially by the midwater and bottom strata. Two transects were sampled on each module at SCAR during each survey for a total of 14 transects per each reef design. Two transects were sampled at each of the nine sampling stations at Barn and San Mateo during each survey; sampling was done along the permanent transect used to sample kelp and the benthic community at each location and along transects located 10 m inshore of the permanent transects. In order to standardize sampling effort at the artificial reef and reference reefs, 14 of the 18 transects at Barn and San Mateo were randomly selected for estimates of species richness. Each resident (i.e. reef associated) and young-of-year fish encountered along each transect was recorded and its total length was estimated to the nearest centimeter. For .aggregating species such as the blacksmith, the number and mean size of individuals in a group were estimated. Cryptic fishes such as the blackeye goby and the California scorpionfish were recorded along an additional two bottom transects at each module as divers returned along the bottom after completing sampling of less cryptic fish.

The performance standard for fish standing stock was evaluated for each reef design by estimating the biomass of fish throughout the water column per square meter of reef and scaling up to 150 acres. This was done by converting the fish density and size data collected on the permanent transects to mass using species-specific length-weight regressions. These values were used to estimate the mean mass of all fish species per cubic meter of bottom, midwater and surface habitats. The amount of midwater habitat was defined as the depth in meters minus the 2- meter strata at the surface and bottom (i.e. midwater = Z – 4 m). The mass of fish in surface, midwater and bottom habitats was summed to obtain the standing stock of fish throughout the water column per m^2 of reef. This value was converted to US tons per 150 acres for the purpose of evaluating the performance standard. It is important to note that scaling up from the size of a module to a 150 mitigation reef has the potential to introduce significant error in estimates of fish standing stock and the projections presented in this document should be viewed with caution.

Results

Abundance and species richness of resident fish

Reef-associated fish rapidly colonized the bottom two meters of the artificial reef modules and by summer of 2000 all six reef designs displayed densities of fish that were similar to or greater than those observed on the nearby reference reefs (Figure III.19). Fish abundance on SCAR was positively related to the cover of hard substrate for both rock and concrete modules. Because resident fish are by definition older than one year, this initial colonization reflects the immigration of older fish rather than the recruitment of young fish. A surface canopy of kelp had not developed by summer of 2000 and the fish that typically associate with kelp in the water column and at the surface were largely absent then. A dense canopy of kelp has been present on all artificial reef modules since the summer of 2001 and the abundance of kelp bed fish near the bottom, in the midwater and at the surface of all artificial reef designs has been similar to or greater than that observed at San Mateo and Barn since that time (Figure III.19). Interestingly, there has been a general decline in the abundance of kelp bed fish at SCAR and the reference reefs since 2001. Reasons for this decline are presently unknown. Differences in fish abundance among reef designs have become smaller over time as overall fish abundance declined. The number of species of kelp bed fish on the artificial reef modules has also been similar to or greater than that observed at the reference sites (Figure III.20). As observed for fish abundance, the number of species of kelp bed fish has generally declined since the summer of 2001, especially in the midwater and surface layers. The percent similarity in species composition between the reference reefs and SCAR ranged from about 45% to 75 %, with the fish assemblage on the low cover modules generally being the most similar to the reference reefs and the high cover modules the least similar (Figure III.21). The type of hard substrate (rock vs. concrete) had no obvious effect on abundance or species composition of kelp bed fish.

<u>Abundance and species richness of young-of-year fish</u>
Patterns of abundance of young-of-year (YOY) kelp bed fish were similar to those observed for older stages (Figure III.22). Substantial recruitment of YOY was observed on the bottom in the first summer following reef construction (2000). The abundance of YOY on the bottom in 2000 was positively related to the cover of hard substrate for both rock and concrete modules. The recruitment of kelp bed fish on the bottom in the subsequent three years (2001 to 2003) has been negligible at SCAR and the reference reefs. YOY abundance in the water column and at the surface increased in 2001 in the presence of a kelp canopy. Since 2001 YOY abundance for the three depth strata on all reef designs has been similar to or greater than that observed at the reference sites. The type of hard substrate appears to have had little effect on YOY abundance as no consistent trend in recruitment has been observed between rock and concrete modules. Species richness of YOY has been relatively low compared to that of older stages (Figures III.23 vs. III.20). Nonetheless, the number of species of YOY kelp bed fish on the artificial reef modules has been similar to or greater than that observed at the reference sites (Figure III.23).

<u>Standing stock of kelp bed fish</u>
The standing stock of kelp bed fish on SCAR peaked two years after construction (summer 2001) before declining the last two years. Fish standing stock was positively related to the cover of artificial hard substrate and unrelated to the type of hard substrate (i.e. there was little difference in fish standing stock between rock and concrete modules; Figure III.24). Projections based on the artificial reef modules indicate that all but the low cover artificial reef designs are currently near or above the standard of 28 US tons for a 150 acre reef. It is important to note that the estimating standing stocks of kelp bed fish at Barn and San Mateo have declined over the last few years, and they are currently below the 28 ton standard required for the artificial reef.

Summary of kelp bed fish

- The abundance and species richness of resident and YOY kelp bed fish have declined in recent years, but are nonetheless still within the ranges observed at the reference reefs
- Fish standing stock is currently projected to be above or near the standard of 28 tons / 150 acre reef for the medium and high cover substrate designs. Low cover designs are currently below the standard, but are within the range of the reference reefs

AREAS OF CONCERN

Results obtained thus far from the experimental phase of the mitigation project are promising and suggest that mitigation for the loss of kelp bed resources caused by the operation of SONGS is possible through the creation of an artificial reef. Successful mitigation, however, is not guaranteed and several results from the experimental phase give reason to question whether a mitigation reef built in the same location as the experimental reef, and having a design similar to one tested in the experiment will succeed in meeting all of the performance standards required by the SONGS coastal development permit. The primary areas of concern include: (1) potential for dominance by the invasive sea fan *Muricea*, (2) uncertainty about the long-term sustainability of giant kelp and (3) the continuing decline in the abundance and species richness of understory algae. Below we discuss these concerns and the work that is being done to address them.

Potential for dominance by *Muricea*

One of the performance standards for the mitigation reef is that its functions shall not be impaired by undesirable or invasive benthic species. The sea fan, *Muricea californica* is known to monopolize space on artificial reefs and exclude kelp, understory algae and other sessile invertebrates. During the spring 2002 survey of giant kelp, dense recruitment of *M. californica* was observed at SCAR, but not at San Mateo and Barn (Figure III.18). We are evaluating the effects of different artificial reef designs on the colonization, growth and survival of *Muricea* recruits by following changes in their density and size structure in the permanently marked 1 m^2 quadrats that are sampled each summer as part of the benthic monitoring surveys. Data collected on the physical attributes of each quadrat (e.g. substrate type, substrate slope, location on a module, and distance from San Mateo kelp bed) will allow us to assess the extent to which sea fan growth and survivorship varies as a function of different reef characteristics. In June 2003 we began additional studies aimed at following the growth and survivorship of approximately 200 individually marked *Muricea* over the next several years. Marked individuals were located in areas that differed with respect to the density of giant kelp and *Muricea* and to their proximity to the reef/sand interface. Data on growth and survivorship of marked individuals will be used to corroborate the more spatially comprehensive and numerically abundant estimates of *Muricea* growth and mortality that are being obtained from cohort analyses using data collected during the benthic monitoring surveys. Collectively, these data will enable us to make reasonable predictions concerning how growth and survivorship of *Muricea* is related to a variety of different physical attributes of the reef. Data on the benthic biota collected during the summer benthic monitoring surveys will provide additional information as to how *Muricea* growth and survival are related to different biological characteristics of the reef.

Data collected by scientists commissioned by the Marine Review Committee indicated that the *Muricea* typically excludes giant kelp when adult sea fan densities are ≥ 10 m^2 (Figure III.17). Because it takes *Muricea* many years to reach adult size, it will not be possible to directly measure how different physical attributes of the reef affect the densities of adult sea fans on SCAR during the five-year experiment. Consequently adult densities of sea fans will need to be predicted from survivorship curves obtained from the cohort that recruited in 2002. Sampling *Muricea* abundance and size in 2005 will provide three years of data on survivorship, which is the minimum number of years needed to estimate a survivorship function from which reasonable predictions of adult densities can be made. Survivorship of sea fans after three years will be assessed only in relation to physical attributes of the reef because data on reef biota other than *Muricea* will not be collected after 2004 as per the requirements of SCE's Coastal Development Permit.

Long-term sustainability of giant kelp and understory algae.

In order for the mitigation reef to be successful it must "sustain" 150 acres of medium to high density giant kelp. For populations to be sustainable the recruitment of new individuals must balance the loss incurred by the death of established individuals. A large cohort of giant kelp recruited to SCAR during the first year following construction. Individuals from this cohort grew to adulthood by summer of 2001 and have gradually declined in abundance since then (Figure III.6). Importantly, there has been little recruitment of new plants since the initial colonization event in 2000 (Figure III.4). It is difficult to evaluate the potential for the different reef designs to support sustainable populations of giant kelp in the absence of substantial adult mortality and subsequent recruitment during the first four years of the experimental phase.

The SONGS coastal development permit also requires the mitigation reef to support an understory algal assemblage that is similar in abundance and species number to natural reefs in the region. Like giant kelp, understory algae also rapidly colonized SCAR and their abundance and species number on all artificial reef designs were within the ranges of those observed on San Mateo and Barn soon after construction of SCAR (Figures III.10 and III.11). The abundance and species richness of understory algae has drastically declined since 2001 and they are now relatively uncommon on SCAR and well below the values observed on the reference reefs. Meanwhile, benthic sessile invertebrates (the other prime occupier of primary space on the reef) have increased in abundance over time on SCAR, and in the case of the medium and high substrate cover designs, are well above the levels observed on the reference reefs (Figure III.13).

Two of the most likely reasons for the lack of kelp recruitment and the decline in understory algae on SCAR are increased competition for space with sessile invertebrates, and increased competition for light due to excessive shading by dense kelp canopies. The expectations for these two mechanisms would be different if they were responsible for producing the observed patterns on SCAR. For example, if the low kelp recruitment and understory algal abundance resulted from sessile invertebrates out competing algae for space, then one would expect:(1) an inverse relationship between the percent cover of sessile invertebrates and understory algae, (2) an inverse relationship between the percent cover of sessile invertebrates and density of kelp recruits, and (3) little hard substrate available for colonization by giant kelp and understory algae.

Data collected from SCAR during the first four years of the experiment show a declining wedge-shaped relationship between the cover of understory algae and cover of sessile invertebrates, which is somewhat consistent with the hypothesis that invertebrates out compete algae for space (Figure III.25, top). Understory algae was only abundant in quadrats having a low cover of sessile invertebrates and the highest abundances of invertebrates were recorded in quadrats with low algal abundance. Algae and sessile invertebrates were simultaneously present in low abundance in many quadrats, whereas they never simultaneously occurred in high abundance in any quadrat. Unlike understory algae, the density of kelp recruits showed a bell-shaped relationship with sessile invertebrate abundance as the highest densities of kelp recruits were recorded in quadrats with intermediate cover of sessile invertebrates (Figure III.25, bottom). Interestingly, the cover of bare hard substrate has remained relatively constant over time and well above zero for all artificial reef designs (Figure III.26). These latter two patterns (Figure III.25 bottom and III.26) are not consistent with the hypothesis that the low kelp recruitment and understory algal abundance on SCAR results from increased competition for space with sessile invertebrates.

The ability of dense surface canopies of giant kelp to inhibit its own recruitment on the bottom as well as that of understory algae has been widely documented. The density of giant kelp fronds is a good predictor of the biomass of the surface canopy and its shading capacity (unpublished data, Santa Barbara Coastal LTER). Thus, if low kelp recruitment and declining understory algal abundance on SCAR resulted from increased competition for light due to shading by a dense kelp canopy one would expect to see an inverse relationship between: (1) frond density and the cover of understory algae, and (2) frond density and the density of kelp recruits. Such expectations are borne true by data collected from SCAR (Figure III.27). Dense assemblages of understory algae and high densities of kelp recruits were found only on transects characterized by relatively low densities of kelp fronds. Understory algae were observed over a range of kelp frond densities (Figure III.27, top), whereas kelp recruits were rarely observed on transects where densities of kelp frond exceeded 6 m^2 Figure III.27, bottom). Low frond densities, however, did not always coincide with high cover of understory algae or high numbers of kelp recruits as numerous transects had low abundances of adult kelp, kelp recruits, and understory algae.

It is likely that several mechanisms interact to produce the wedge-shaped relationships seen in Figures III.26 and III.28. Competition for space between benthic algae and invertebrates shifts the abundance of these two groups relative to each other as space occupied by one group becomes unavailable to the other group (Figure II.28). Shading by the surface canopy of giant kelp inhibits the recruitment and growth of benthic algae and leads to an overall reduction in the understory algal assemblage. This in turn may have positive indirect consequences on the abundance of sessile invertebrates by reducing the abundance of understory algae, which compete with sessile invertebrates for space. Severe disturbances that result from large waves or episodes of intense grazing not only remove the surface canopy but also scour the bottom and reduce the abundances of both algae and invertebrates.

To avoid costly errors when designing the mitigation reef it is important that we understand which mechanisms are most responsible for causing the decline of understory algae and the lack of continued kelp recruitment on SCAR. In the absence of natural disturbance during the five year experiment, this understanding can only come about by experimental manipulations that isolate the effects of competition with sessile invertebrates from the effects of shading by giant kelp. In spring 2004 we initiated such a 2 x 2 factorial experiment using the kelp transplant modules constructed with a medium cover of quarry rock (Figure III.29). Sampling of these modules was discontinued in 2001 after kelp transplant techniques were developed and tested. Thus the use of these modules in this experiment does not affect our ability to evaluate a five-year time series for the six combinations of substrate type and cover that are being tested in the experimental phase. The surface canopy was manipulated on six of the seven kelp transplant modules by cutting off all kelp fronds 1 meter above the holdfast (one of the kelp transplant modules is being used in a different experiment investigating the timing of colonization on community development). The benthic assemblage of invertebrates and algae was removed with scrapers in six 1 m^2 quadrats on each of the six kelp transplant modules. Another six 1 m^2 quadrats on each module were left undisturbed. The six non-kelp transplant modules of medium cover of quarry rock are being used as kelp canopy control plots for this experiment. Six scraped and undisturbed 1 m^2 quadrats are being followed on each on these modules as well. The scraped quadrats on the non-kelp transplant modules are located on transects that are no longer be used in the routine monitoring of the experimental reef, which again is designed to preserve the five-year times series of the six reef designs tested in the experimental phase. Kelp removal and quadrat scraping were completed in April 2004. The cover and density of algae and invertebrates in all quadrats and the density of giant kelp fronds along all transects used in the experiment were sampled prior to removals. The quadrats will be re-sampled in late summer/early fall 2004. Increases in the cover of understory algae and density of kelp recruits on modules where kelp was removed will indicate a canopy shading effect, whereas greater abundances of algae in scraped vs. undisturbed quadrats will indicate competition for space with invertebrates is the main cause for the declining abundance of algae on SCAR.

Figure III.1. Footprint area (m^2) estimated from side scan sonar for the three levels of bottom coverage of quarry rock and concrete modules.

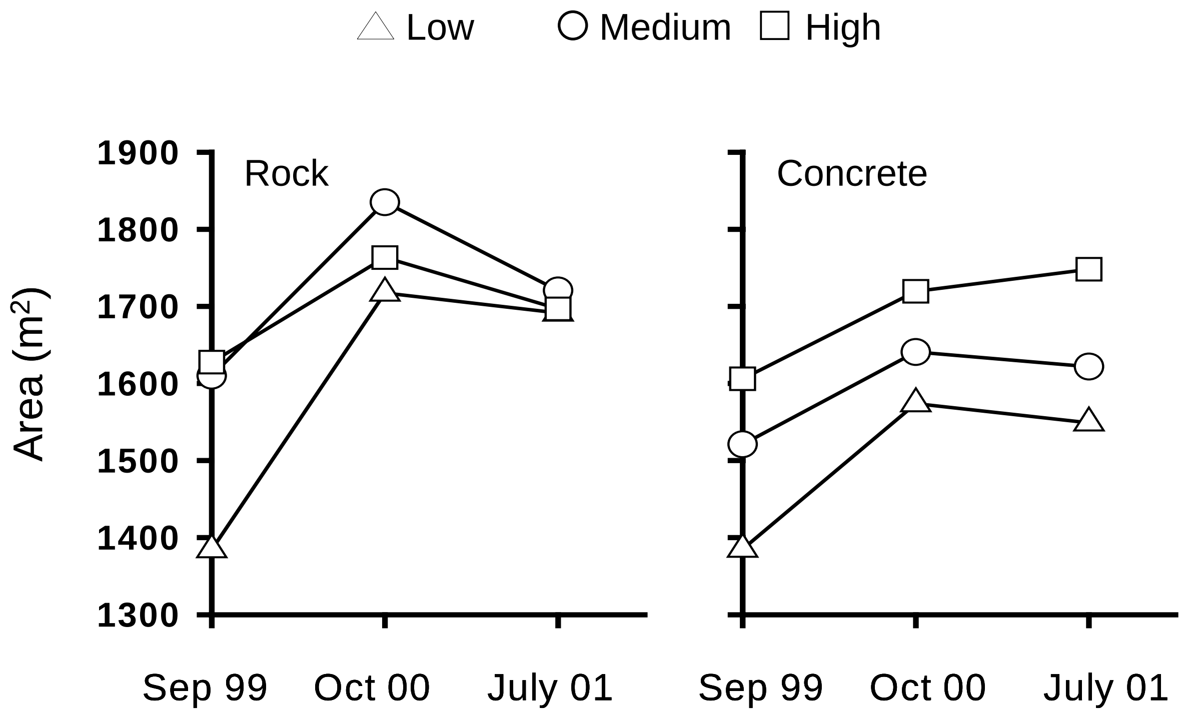


Figure III.2. Percent cover of hard substrate estimated by divers using a uniform point contact method for the three levels of bottom coverage of quarry rock and concrete modules at SCAR and for the reference reefs at Barn (BK) and San Mateo (SMK). Data for the artificial reef modules include only artificial reef substrate.

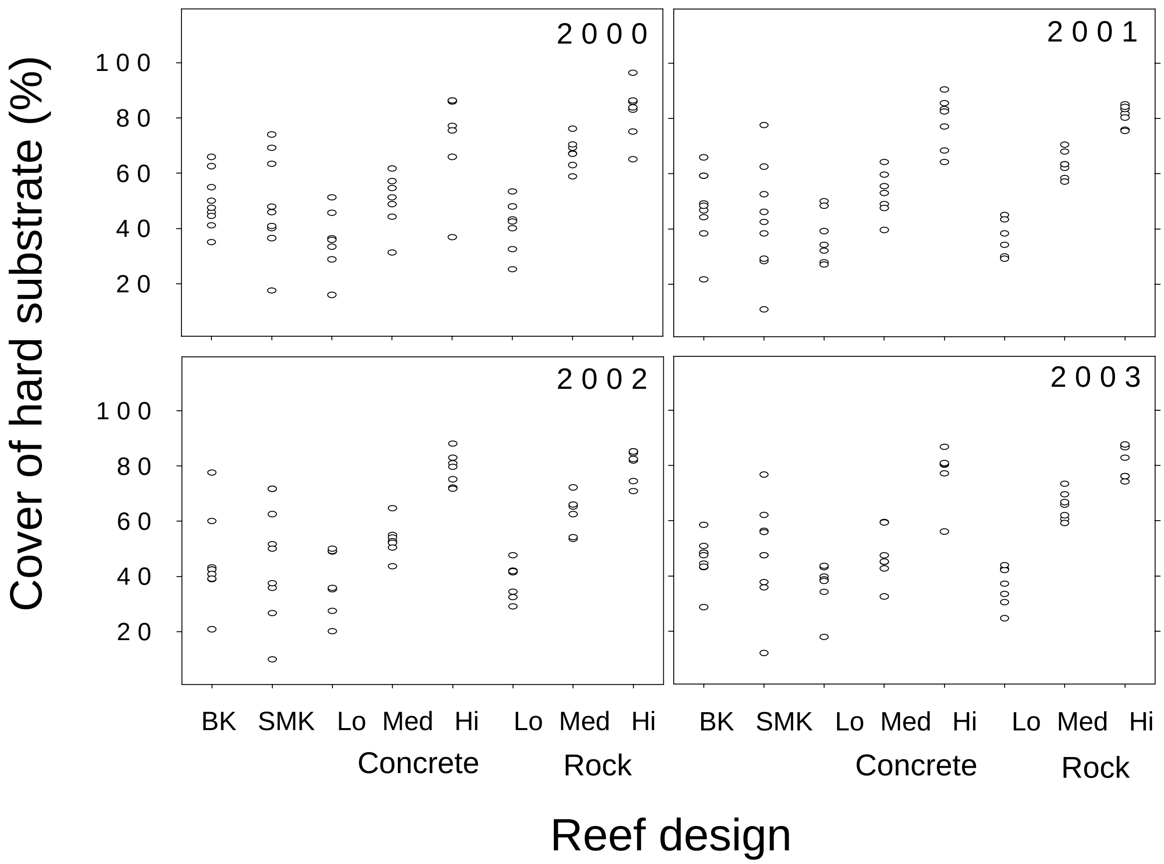


Figure III.3. Change in area of artificial substrate over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high). Dashed horizontal line indicates the performance standard of 90%.

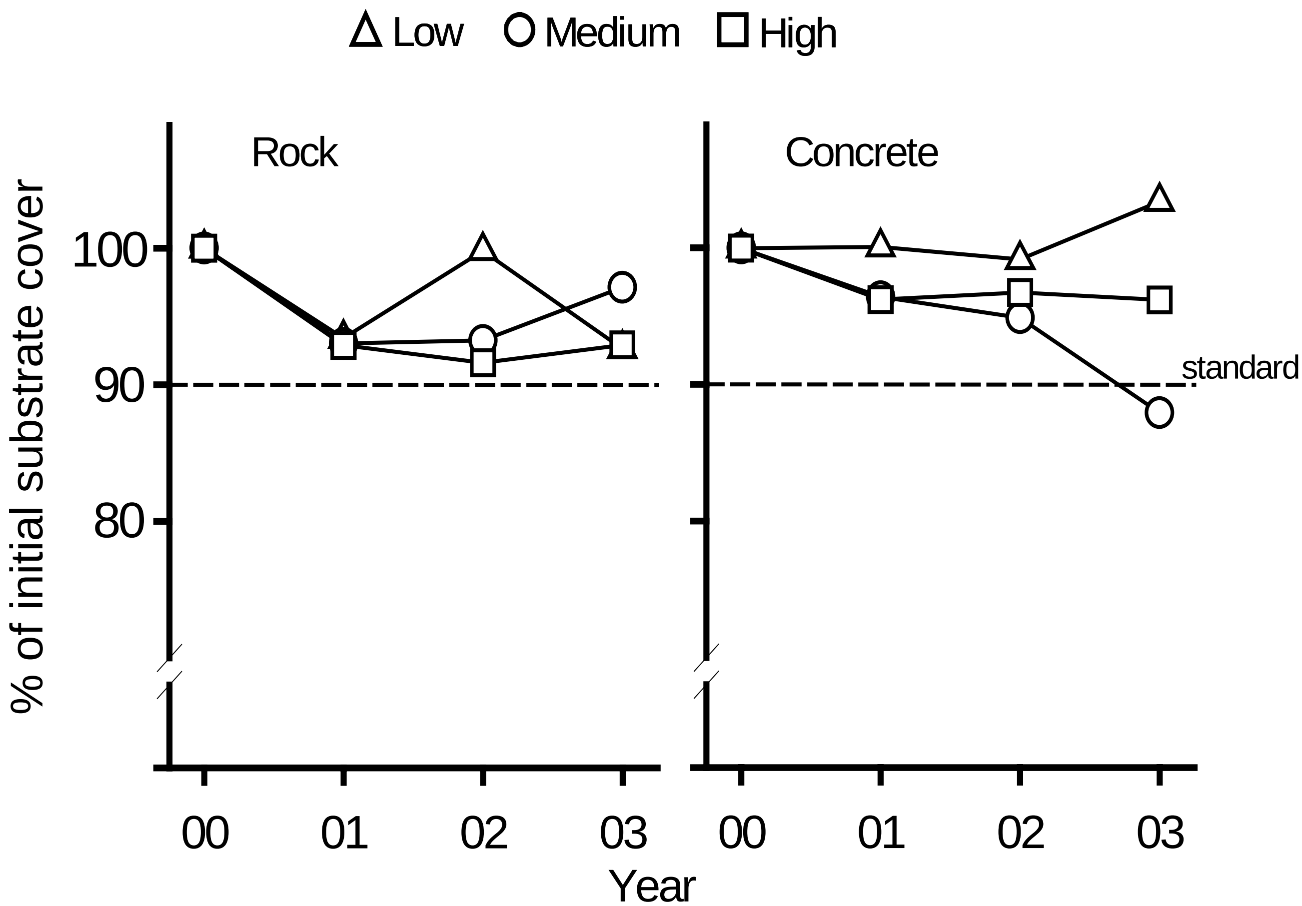


Figure III.4. Change in the density of small (< 1 m tall) recruits of giant kelp over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK).

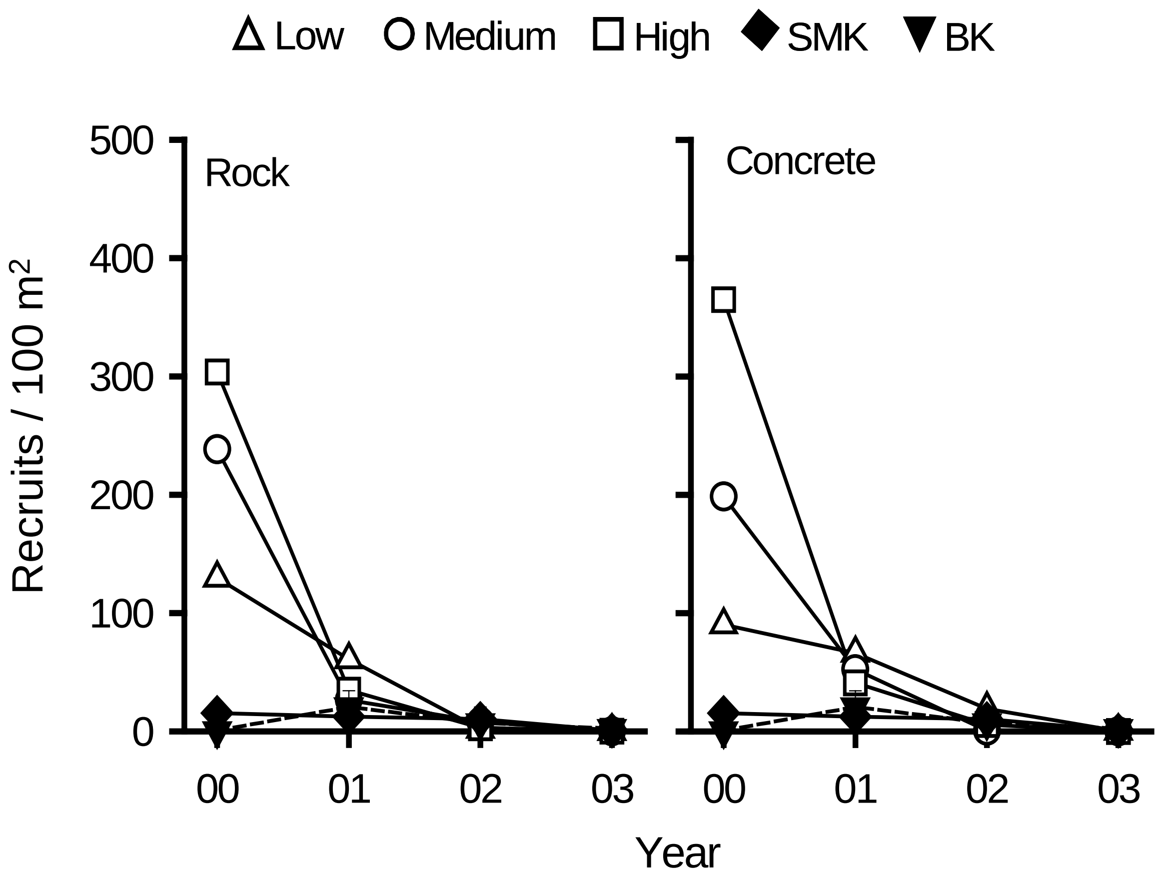


Figure III.5. Abundance of giant kelp recruits at SCAR vs. distance from San Mateo kelp bed. Data are the mean number of recruits (±SE) for rock and concrete modules combined (n=8 modules). Numbers above the mean indicate the block number the modules were located in.

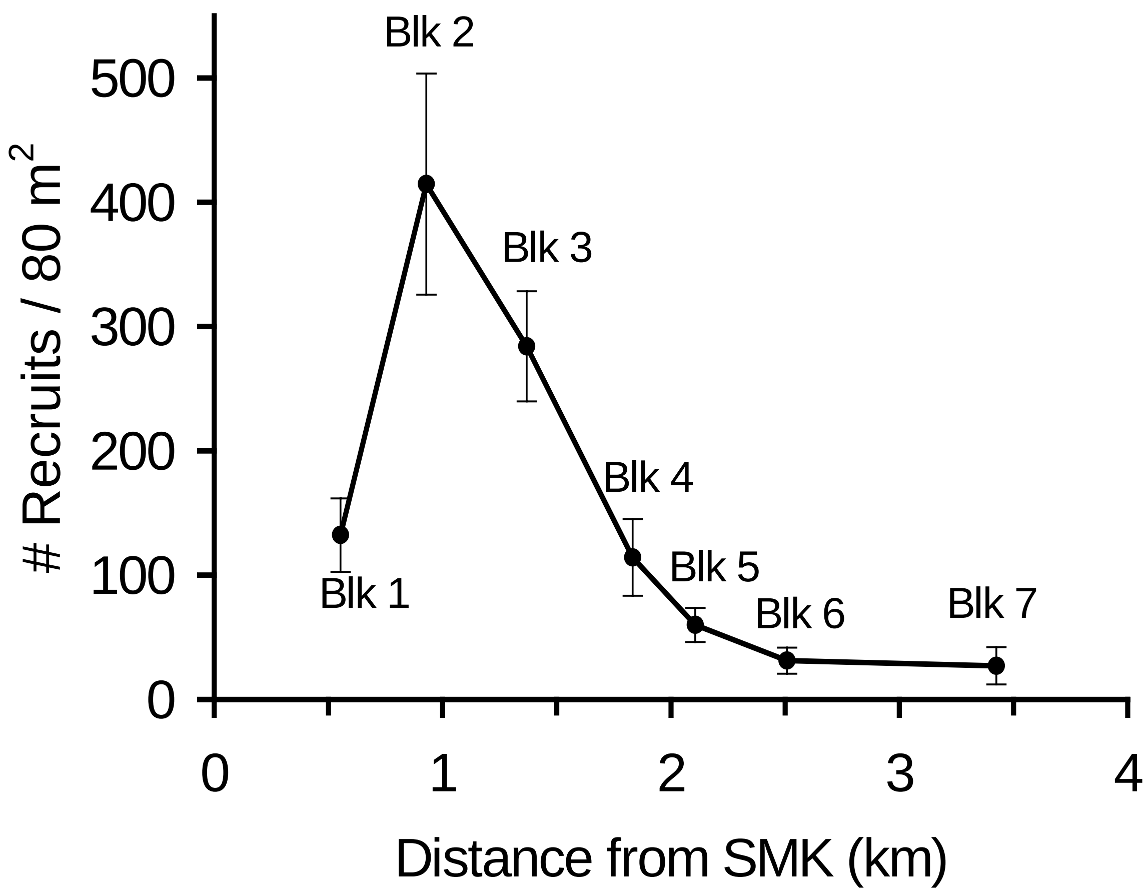


Figure III.6. Change in the density of adult giant kelp over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low, medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). The dashed horizontal line indicates the permit standard of four adult plants 100 m^{-2}

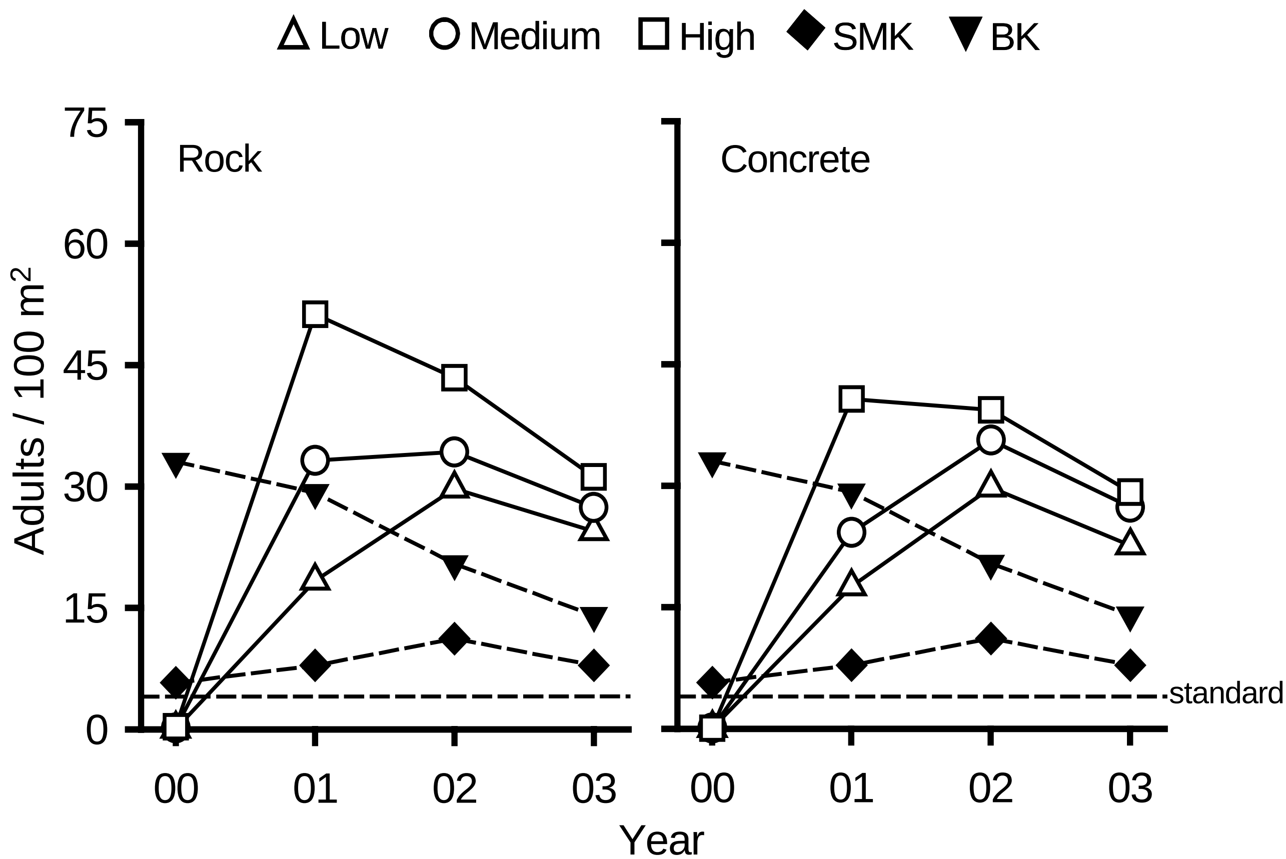


Figure III.7. Change in the density of adult giant kelp over time for the seven blocks of artificial reef modules on SCAR and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). The dashed horizontal line indicates the permit standard of four adult plants 100 m^{-2}.

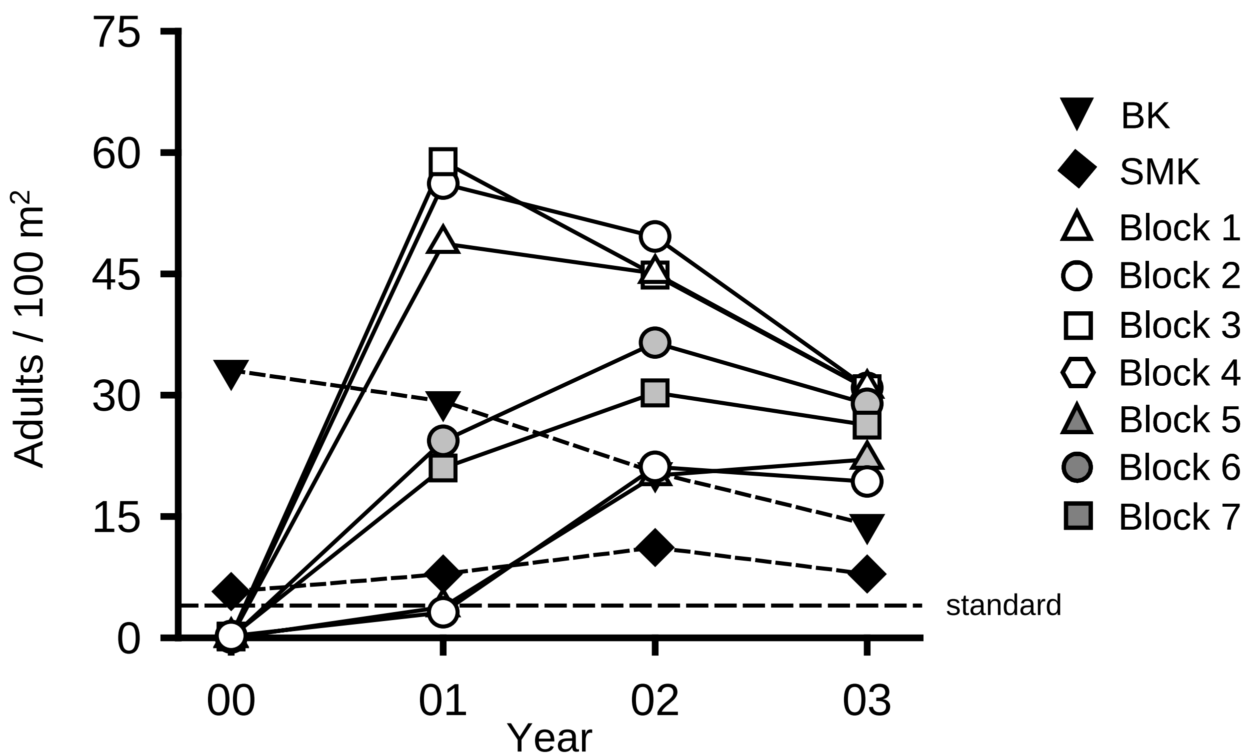


Figure III.8. Percent of one year old adult giant kelp in 2001 that survived to 2003 for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high.

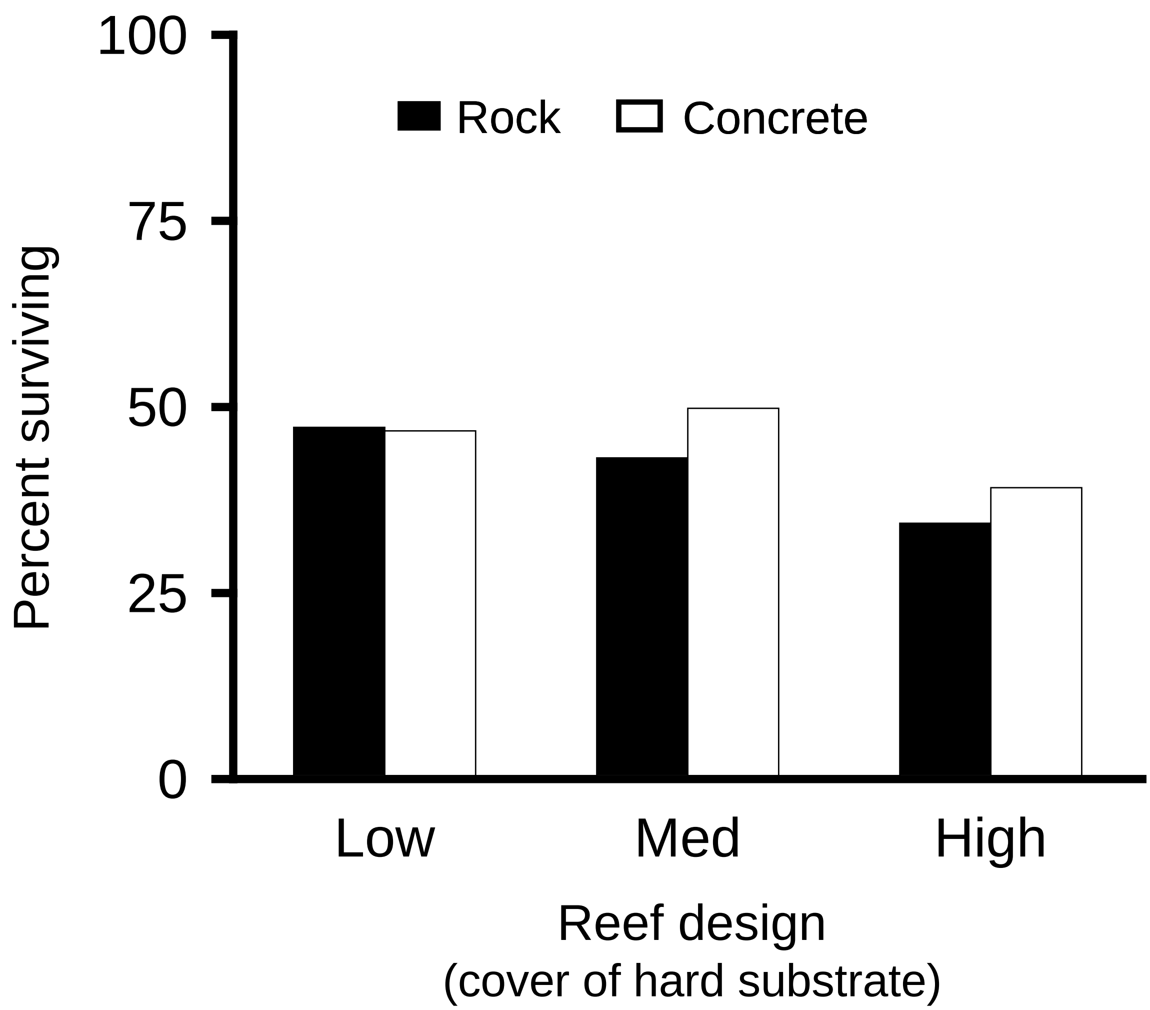


Figure III.9. Percent of one year old adult giant kelp in 2001 that survived to 2003 for different sizes of rock and concrete.

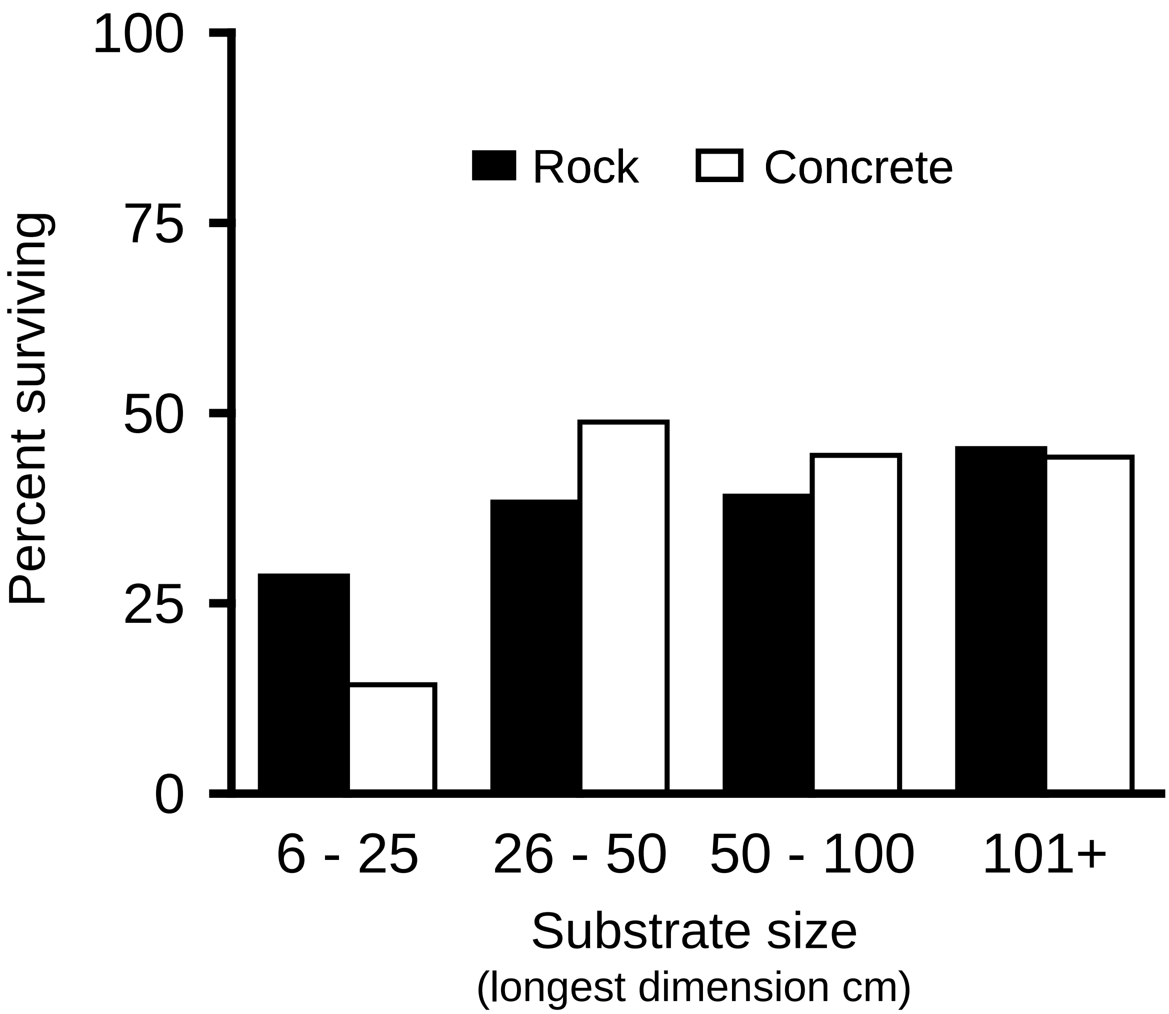


Figure III.10. Change in the mean total percent cover of understory algae over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

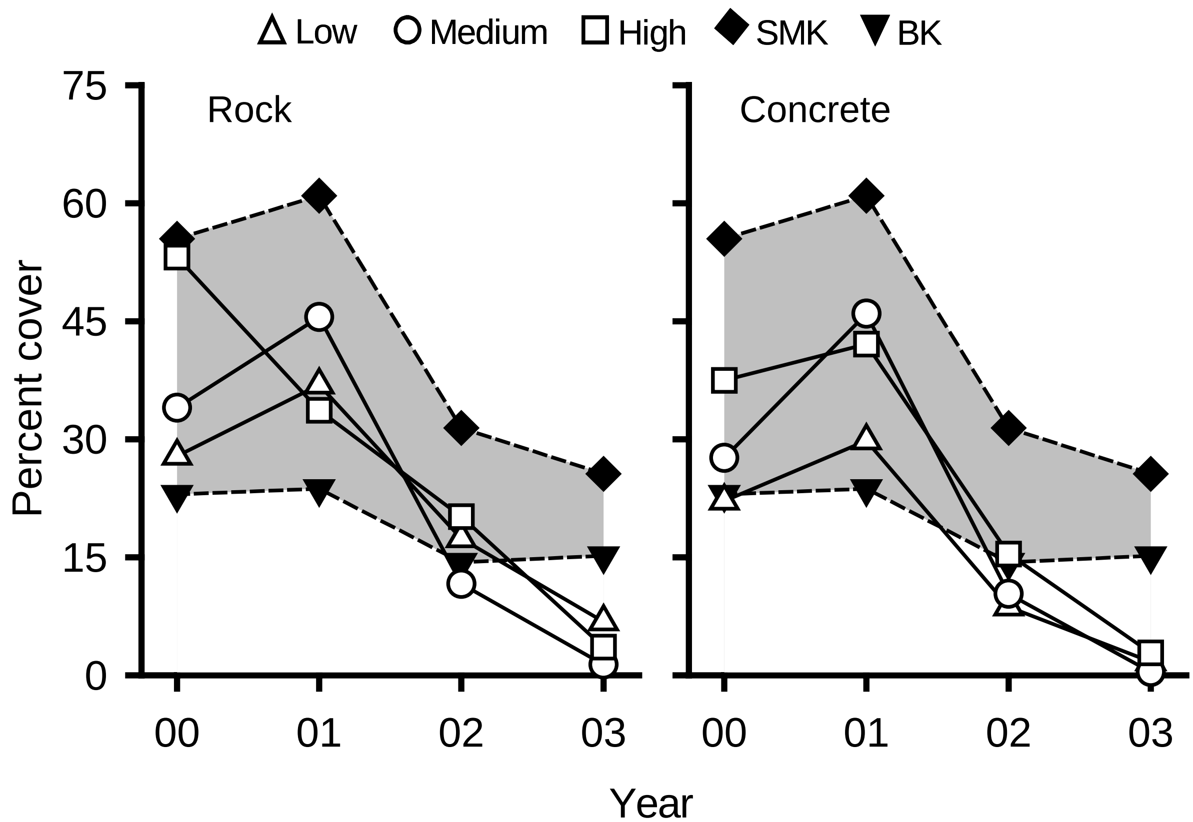


Figure III.11. Change in the number of species of understory algae per reef design over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). N = nine 40 x 2 m transects for each reef design and reference site. Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

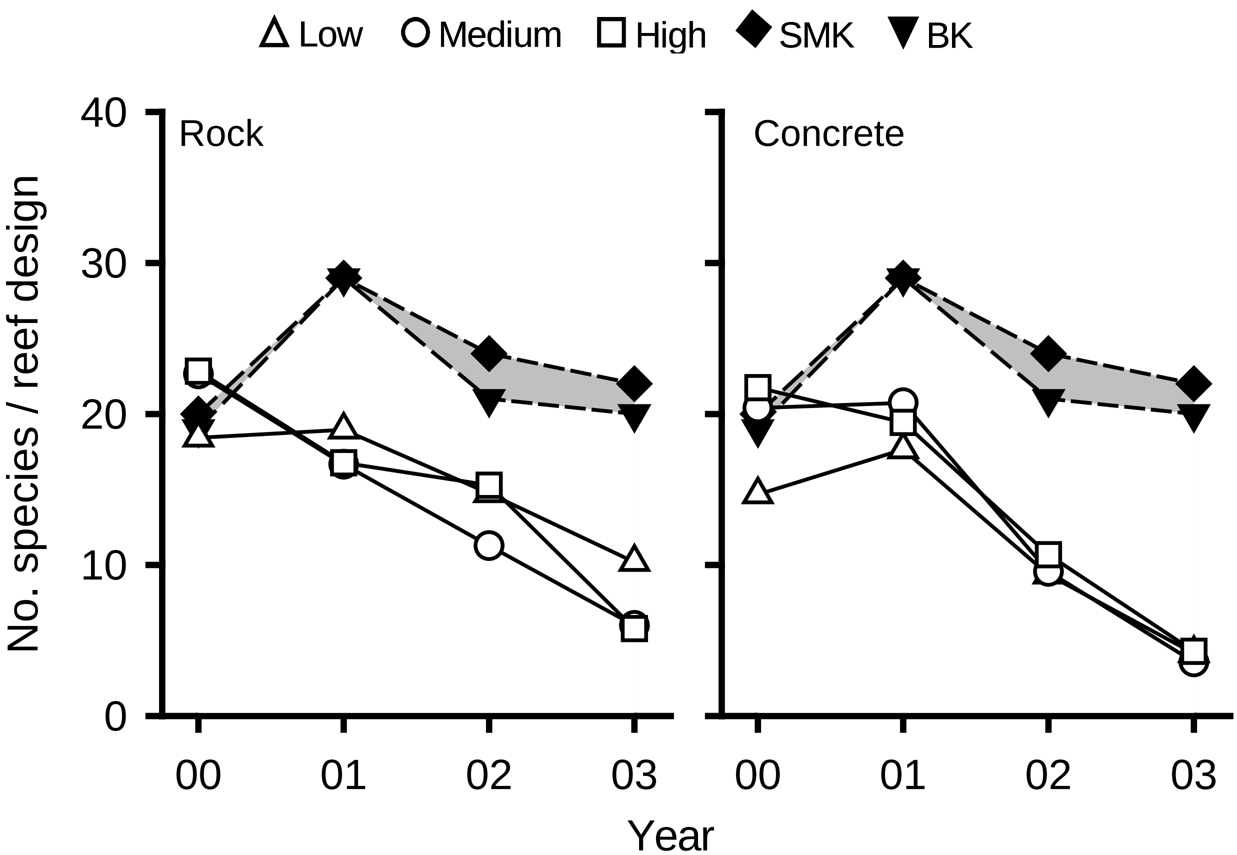


Figure III.12. Percent similarity in the understory algal assemblage between the six artificial reef designs and the mean of the reference reefs Barn (BK) and San Mateo (SMK) (open symbols and solid lines) and between BK and SMK (closed symbols and dashed lines).

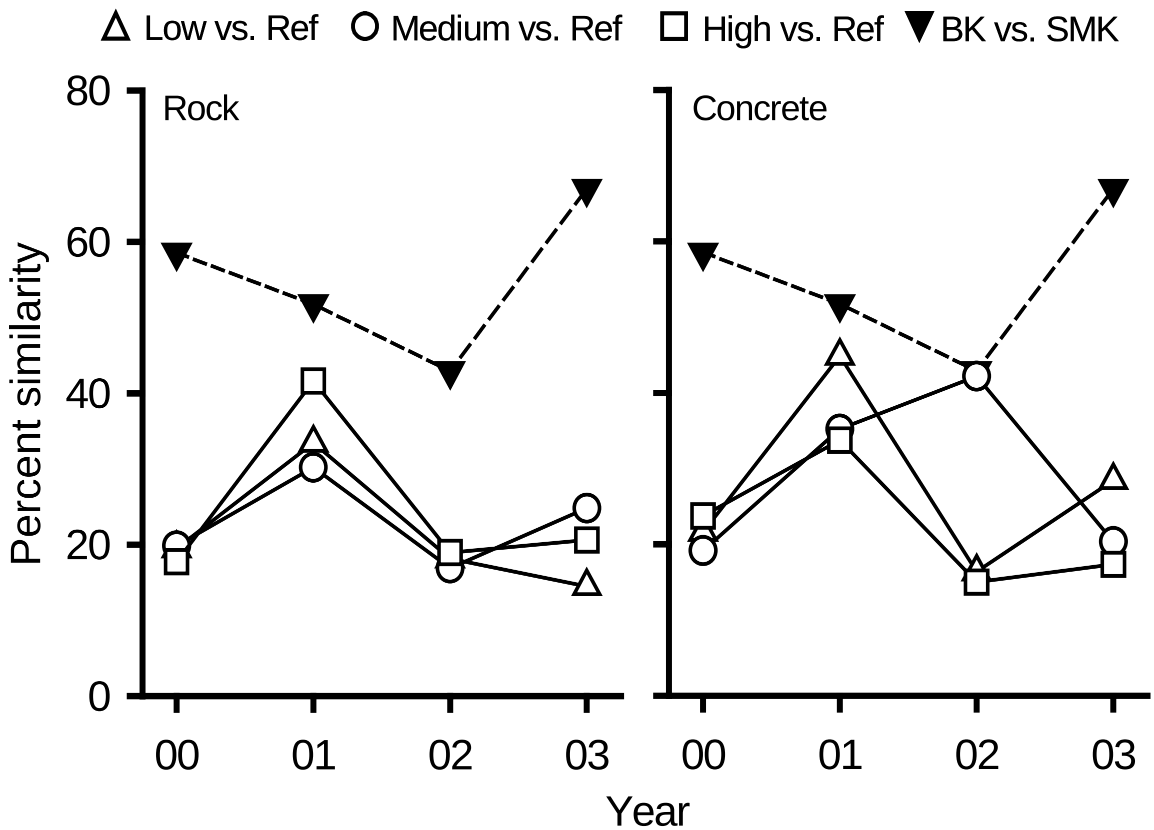


Figure III.13. Change in the mean total percent cover of sessile invertebrates over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region. Values can exceed 100% due to layering of different species.

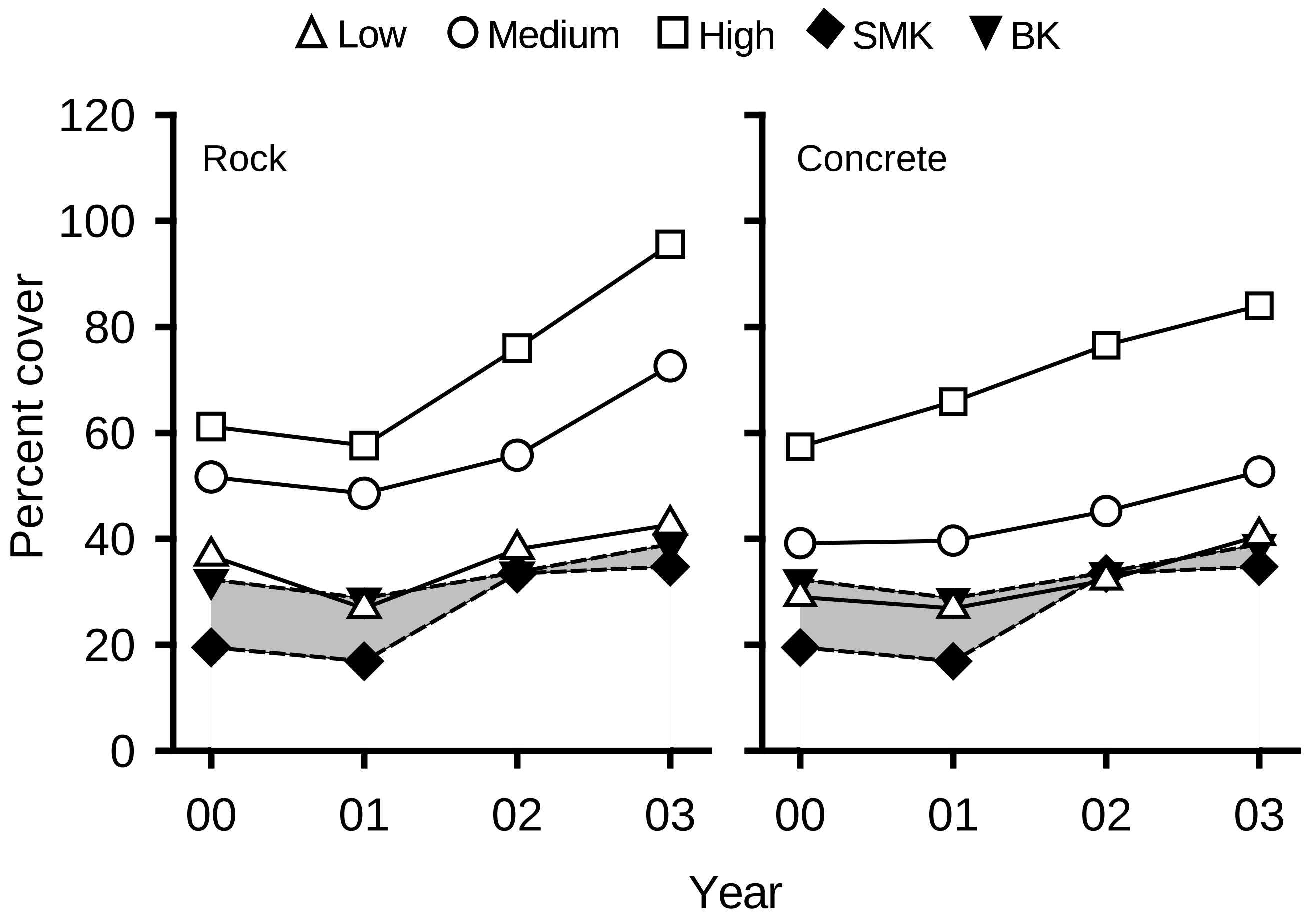


Figure III.14. Change in the mean density of mobile invertebrates over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

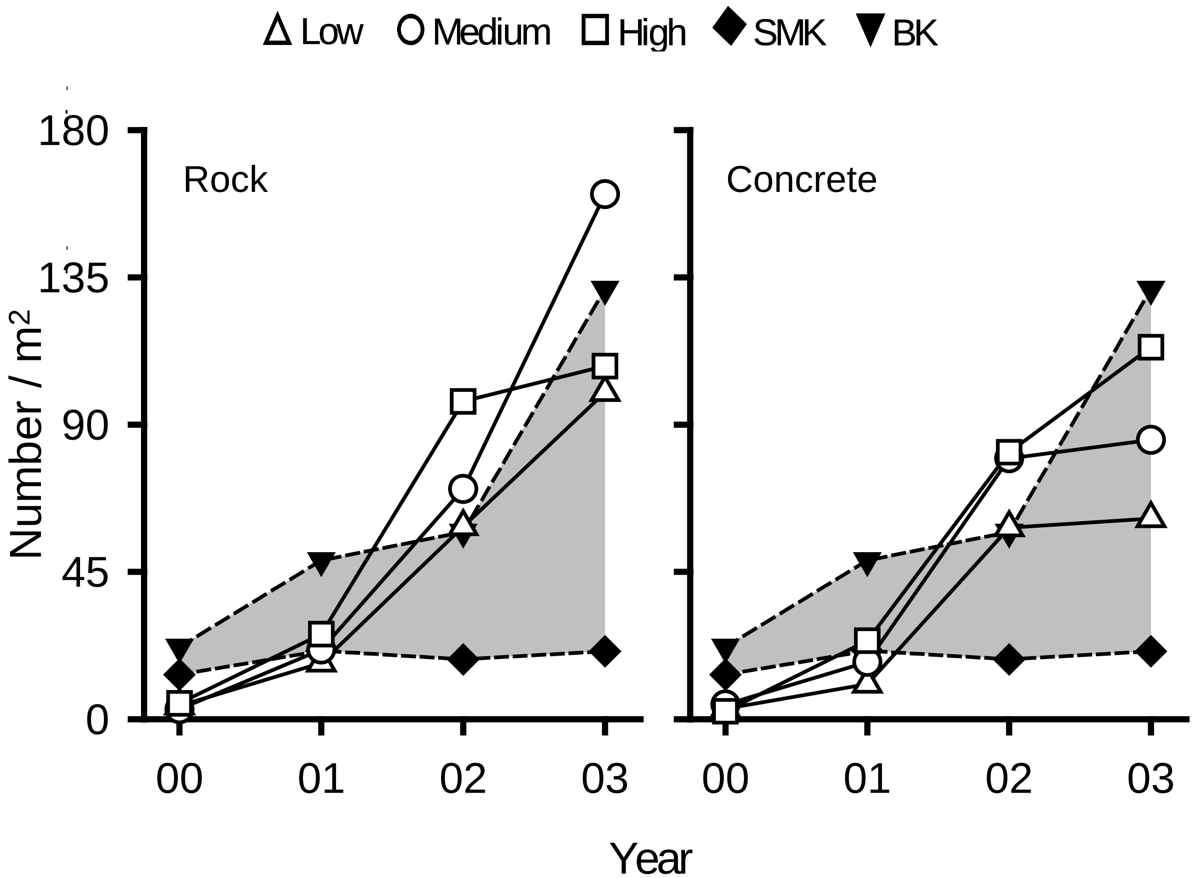


Figure III.15. Change in the number of species of sessile and mobile invertebrates per reef design over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). N = nine 40 x 2 m transects for each reef design and reference site. Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

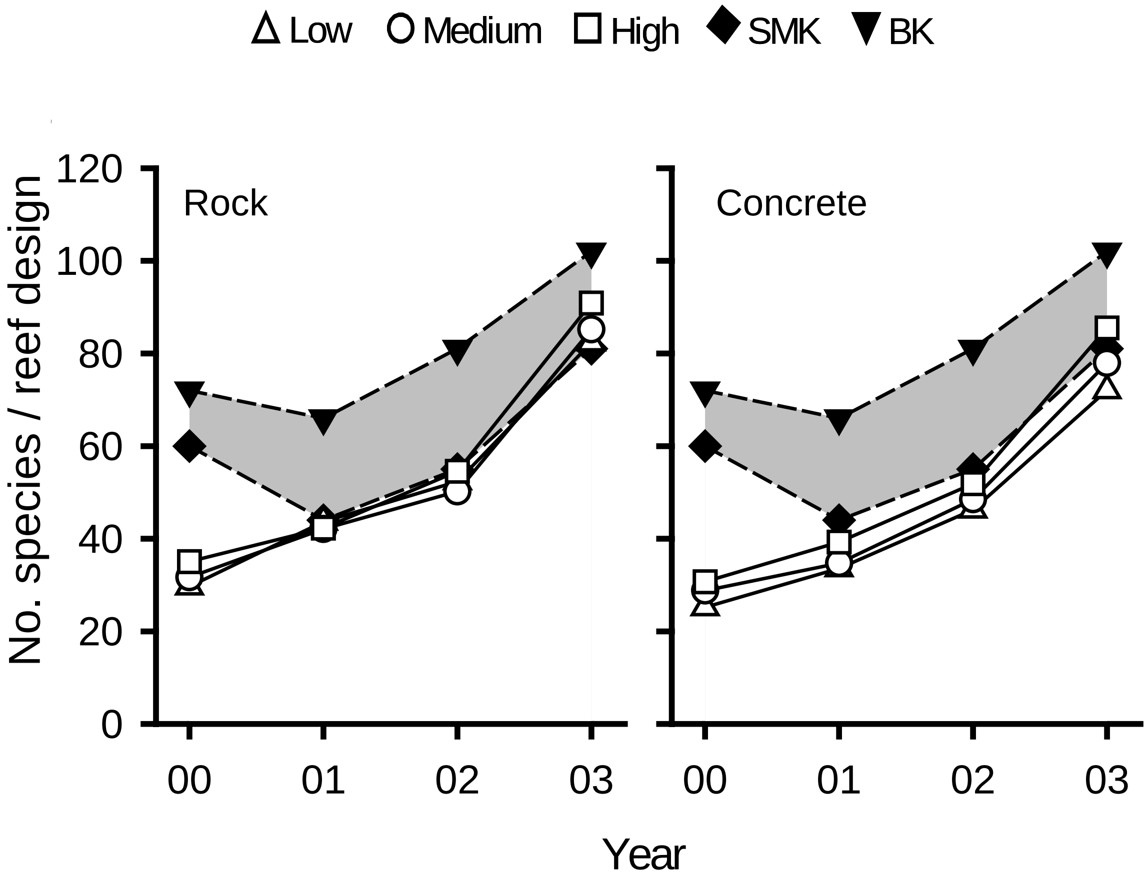
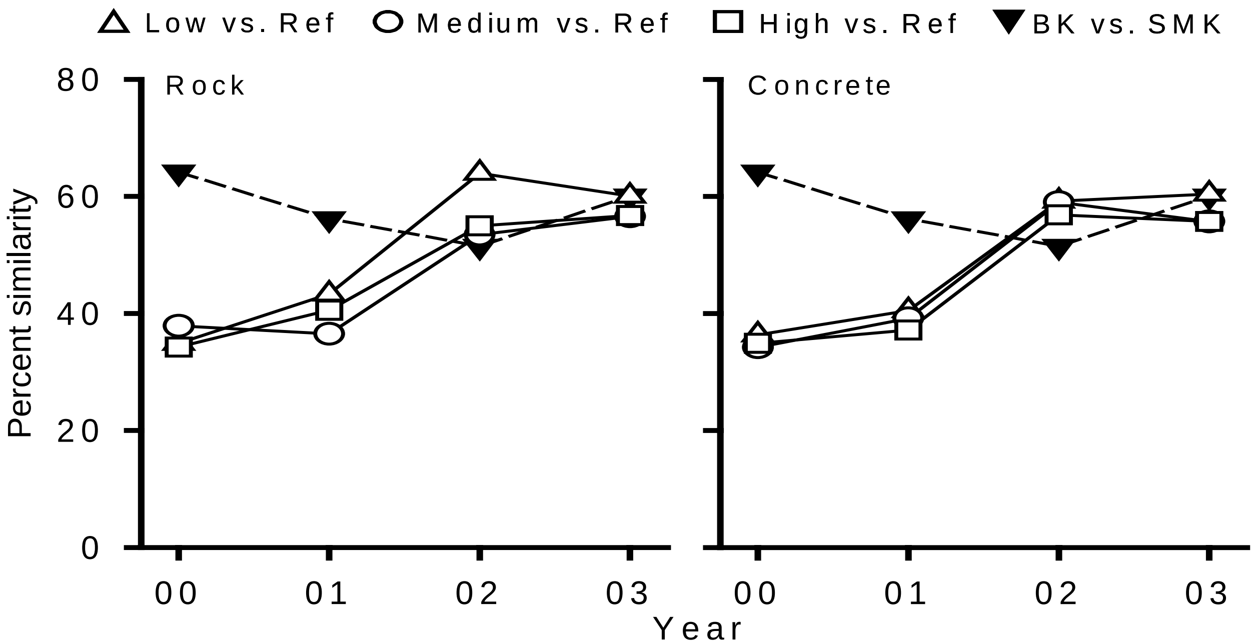


Figure III.16. Percent similarity in the invertebrate assemblage between the six artificial reef designs and the mean of the reference reefs Barn (BK) and San Mateo (SMK) (open symbols and solid lines) and between BK and SMK (closed symbols and dashed lines).

a) Sessile Invertebrates



b) Mobile Invertebrates

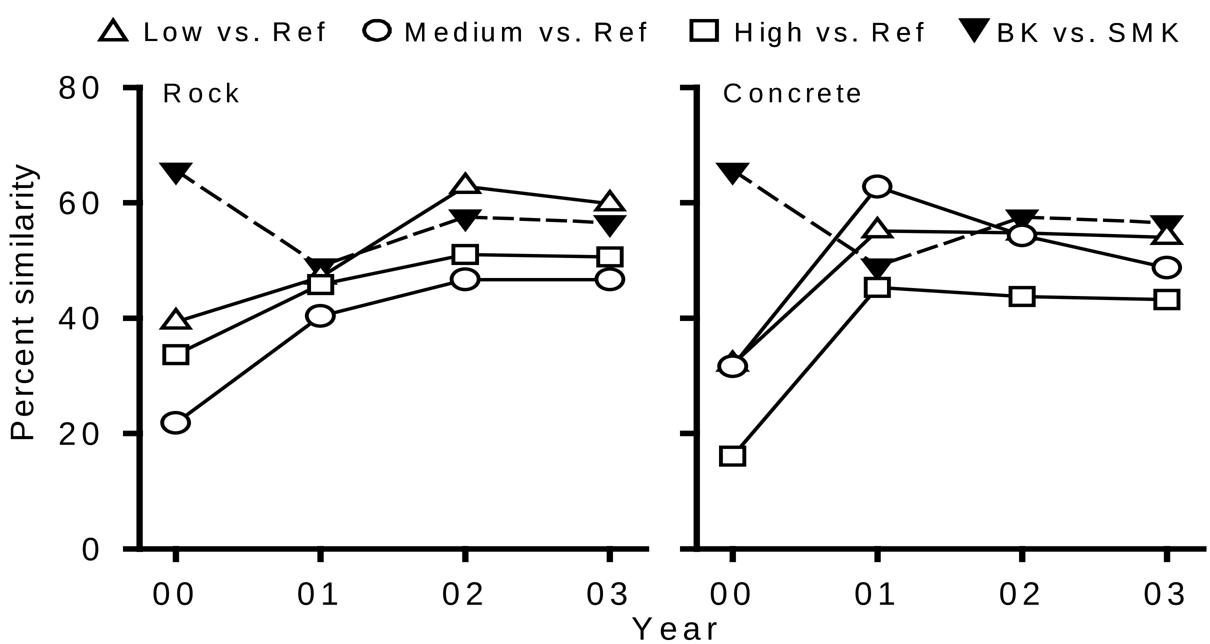


Figure III.17. The relationship between the mean density of the sea fan *Muricea* spp. and the mean density of giant kelp fronds at 26 artificial and natural reefs in southern California. Data from Ambrose et al. 1987. The vertical dashed line indicates the density of sea fans above which no kelp was observed.

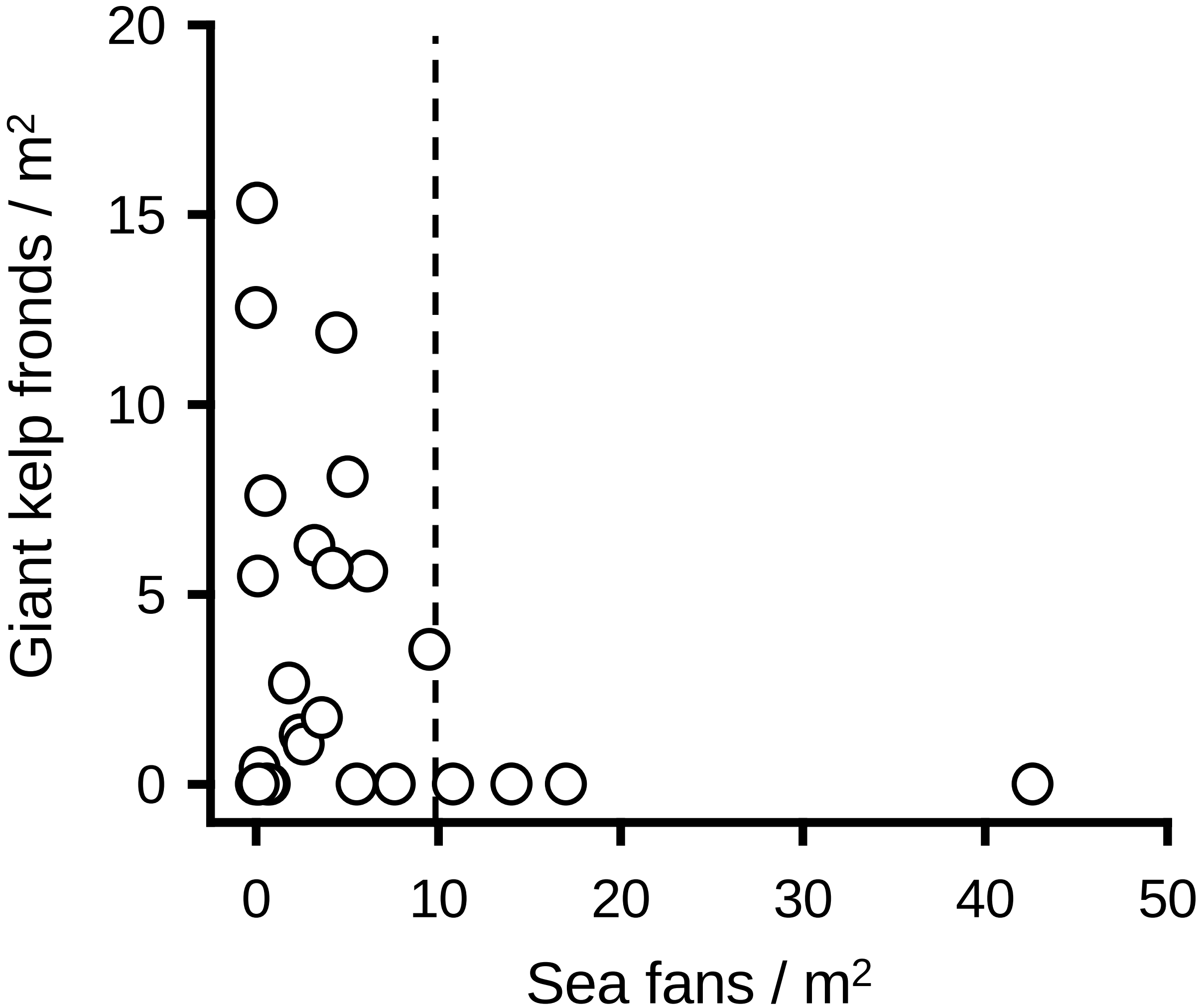


Figure III.18. Change in the mean density of the sea fan *Muricea* spp. over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

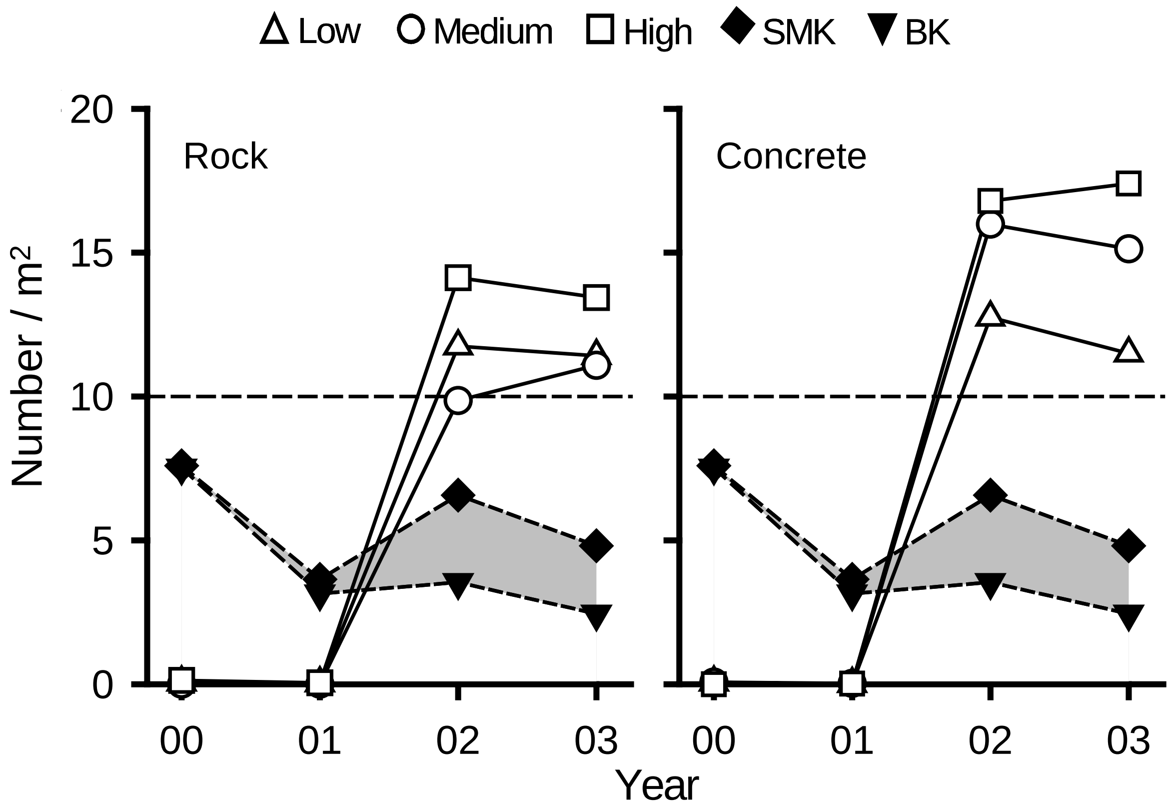


Figure III.19. Change in the mean density of resident kelp bed fish over time at the bottom, mid depth and surface canopy for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

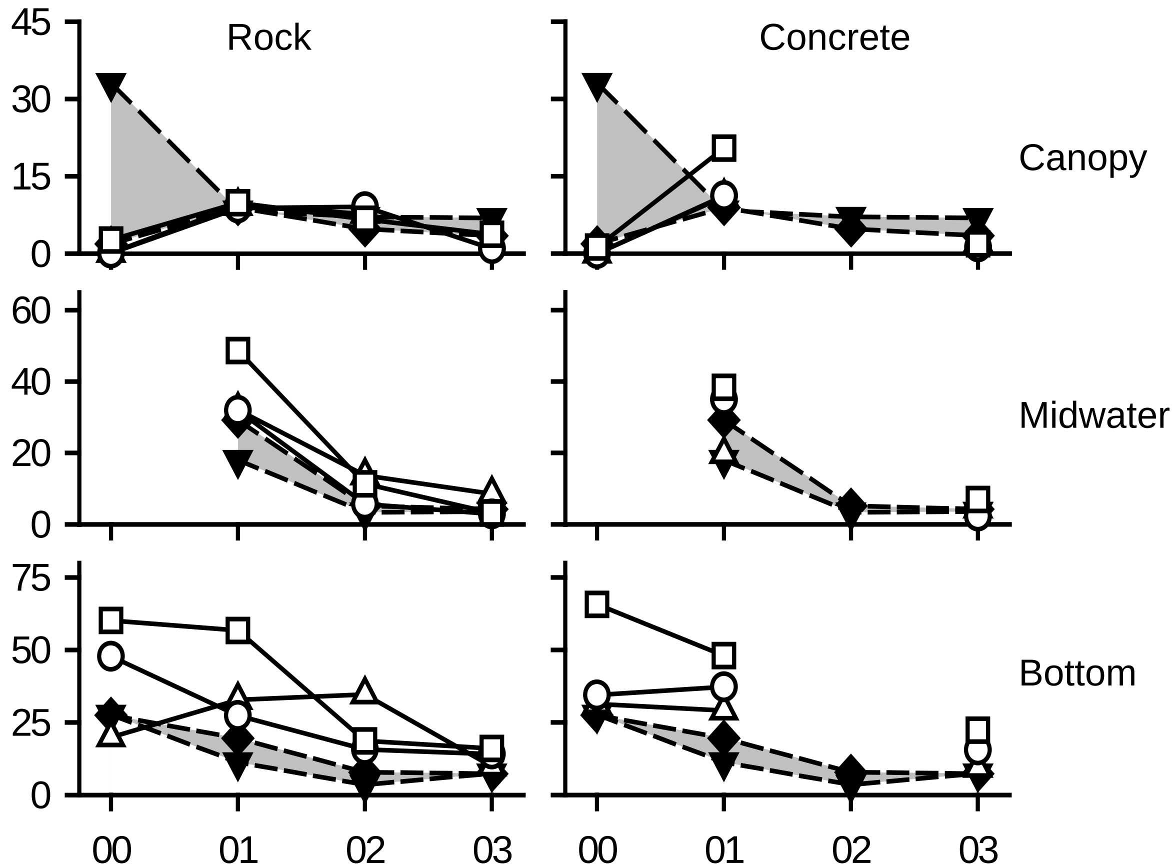


Figure III.20 Change in the number of species of resident kelp bed fish over time at the bottom, mid depth and surface canopy for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

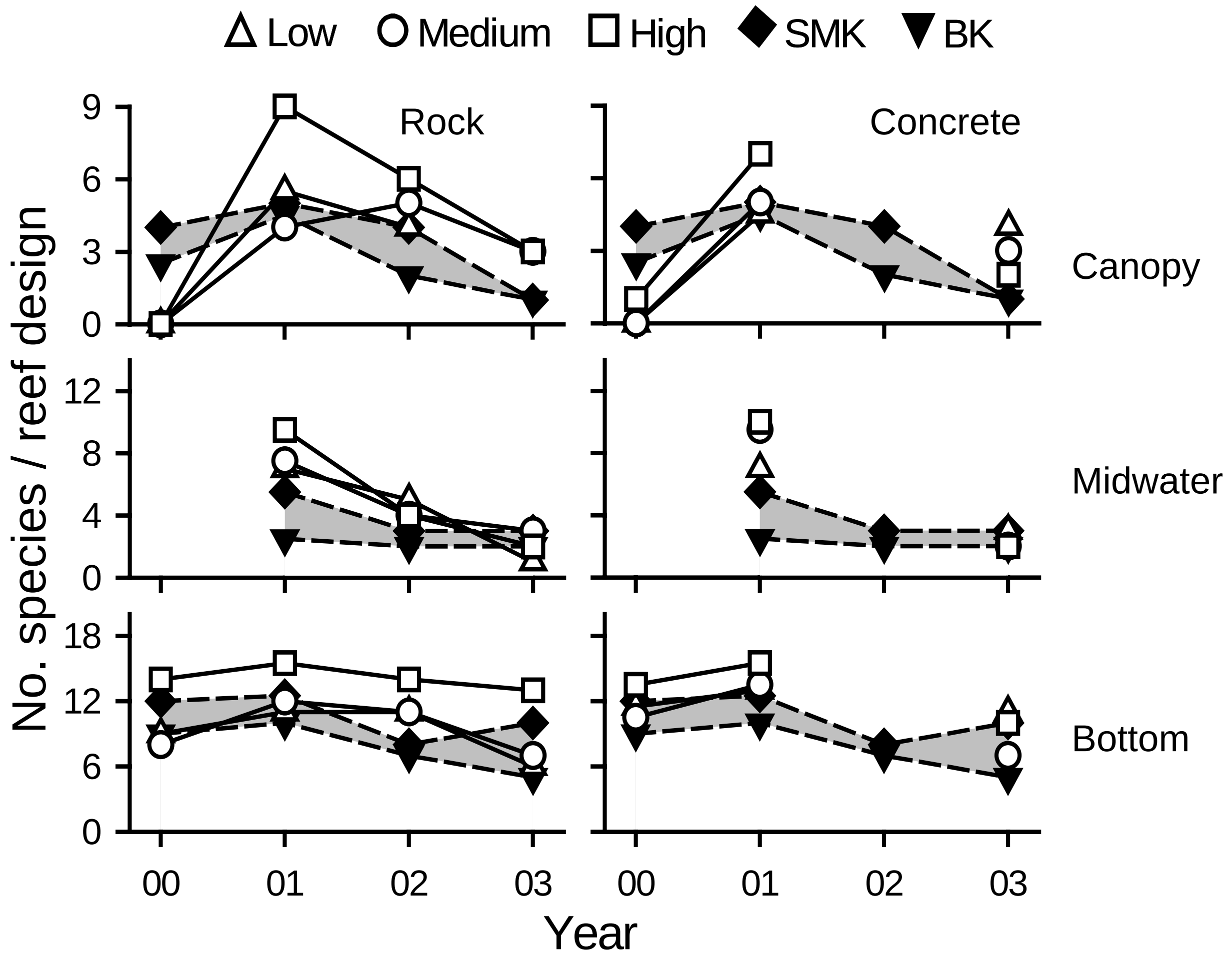


Figure III.21. Percent similarity in the assemblages of resident kelp bed fish between the six artificial reef designs and the mean of the reference reefs Barn (BK) and San Mateo (SMK) (open symbols and solid lines) and between BK and SMK (closed symbols and dashed lines).

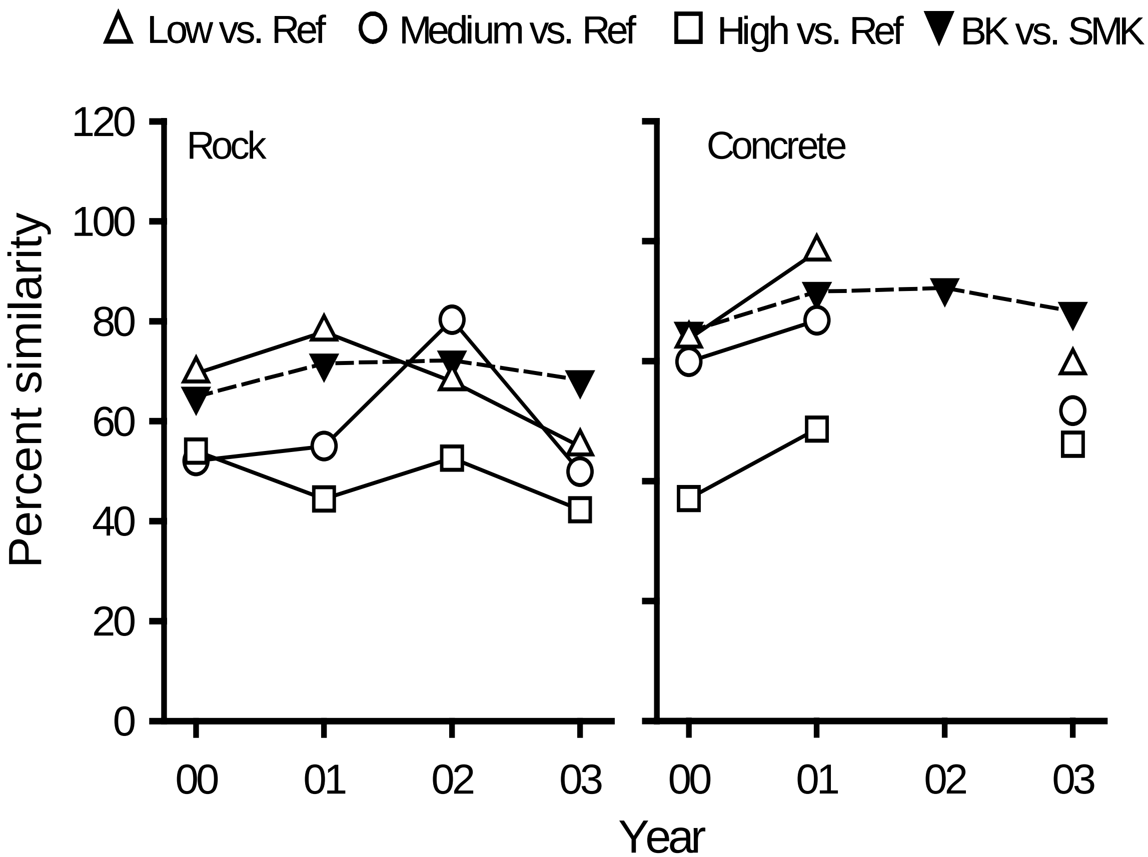


Figure III.22 Change in the mean density of young-of –year kelp bed fish over time at the bottom, mid depth and surface canopy for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

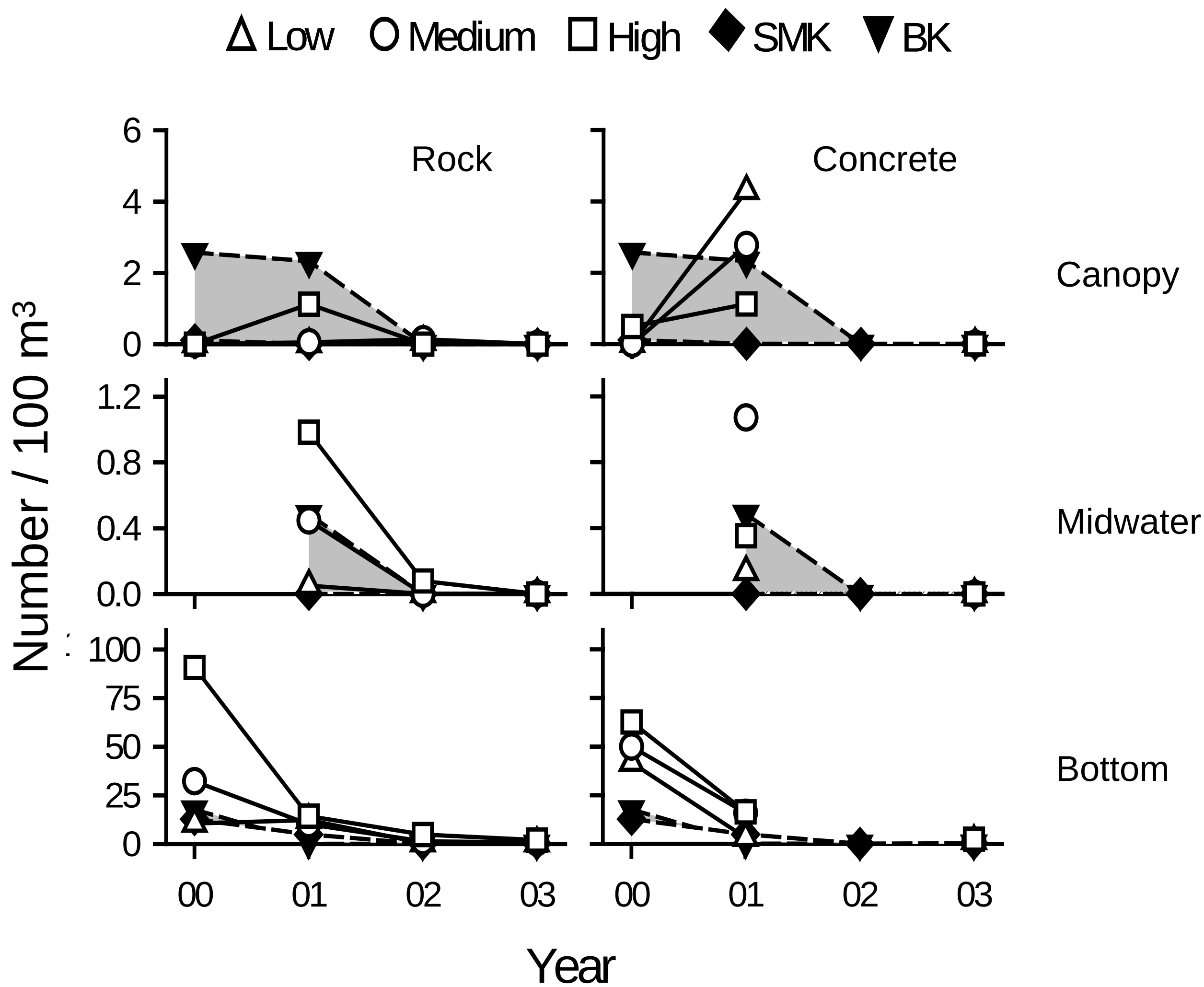


Figure III.23. Change in the number of species of young-of-year kelp bed fish over time at the bottom, mid depth and surface canopy for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

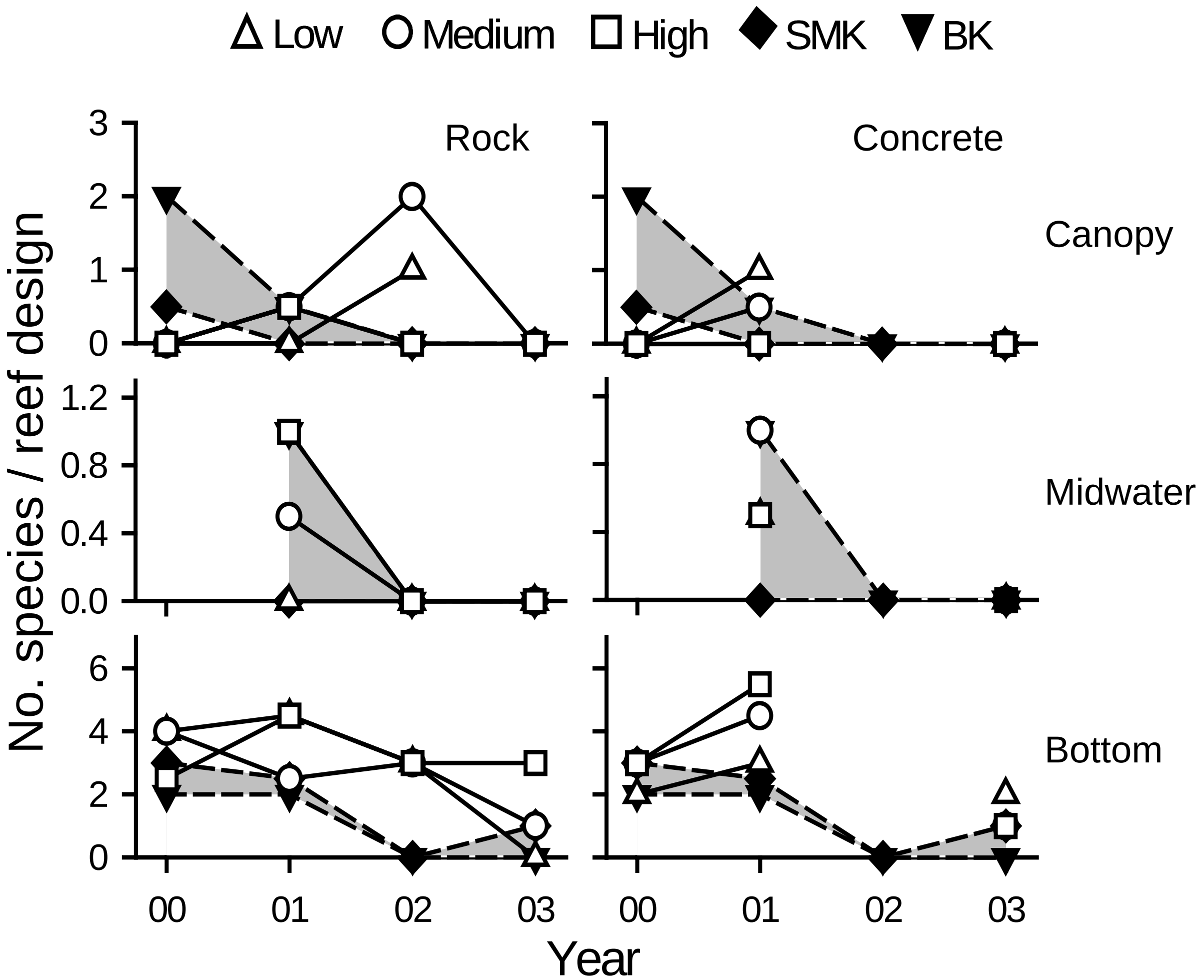


Figure III.24. Change in the projected standing stock of kelp bed fish over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). The dashed horizontal line indicates the permit standard of 28 tons for the 150 acre mitigation reef. See text for how projections were made.

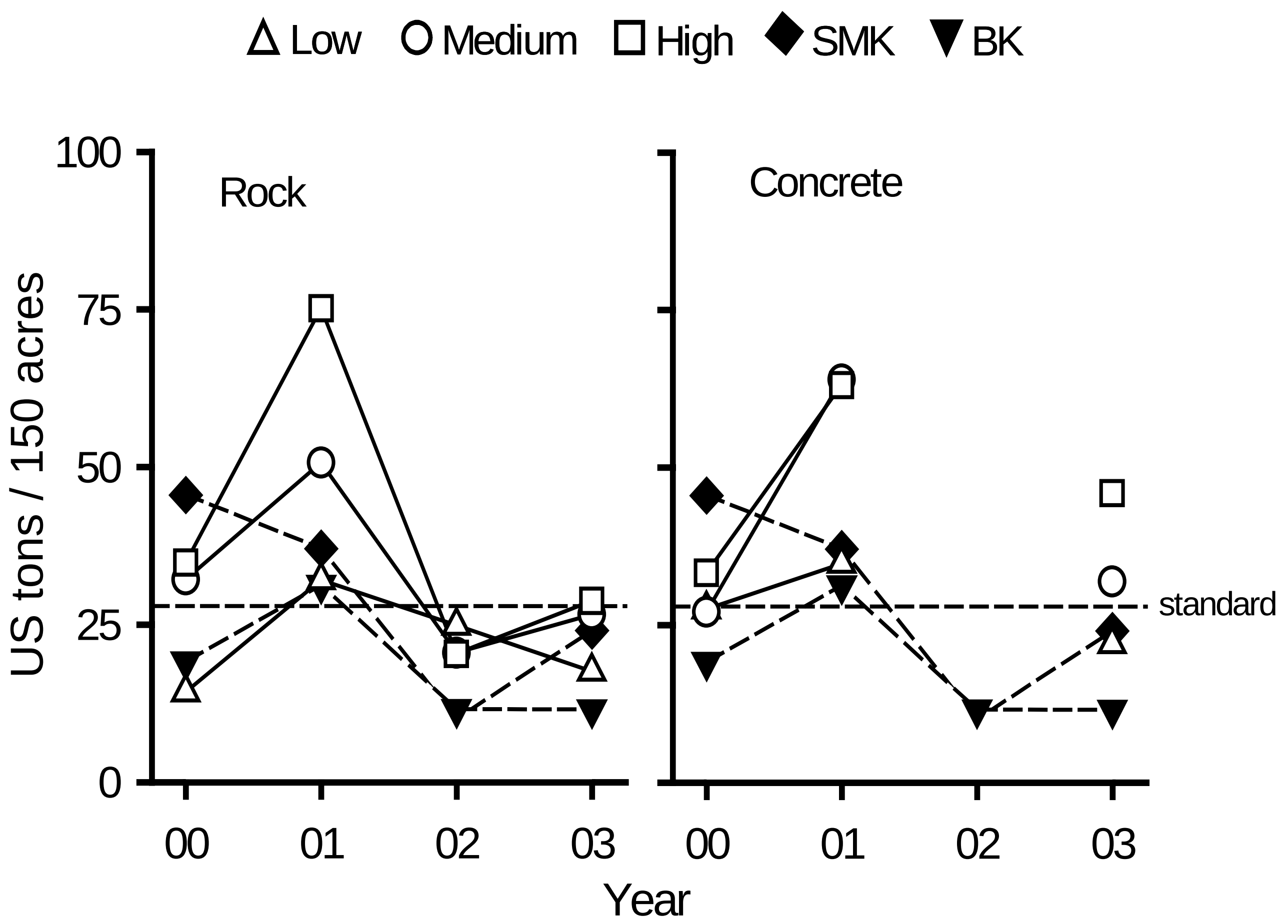


Figure III.25. The relationship between the percent cover of understory algae and the percent cover of sessile invertebrates (top). The relationship between the density of giant kelp recruits and the percent cover of sessile invertebrates (bottom). Data were collected from SCAR during 2000 – 2003 in permanent 1 m^2 quadrats on 42 artificial reef modules (i.e. all artificial reef designs excluding the 14 kelp transplant modules).

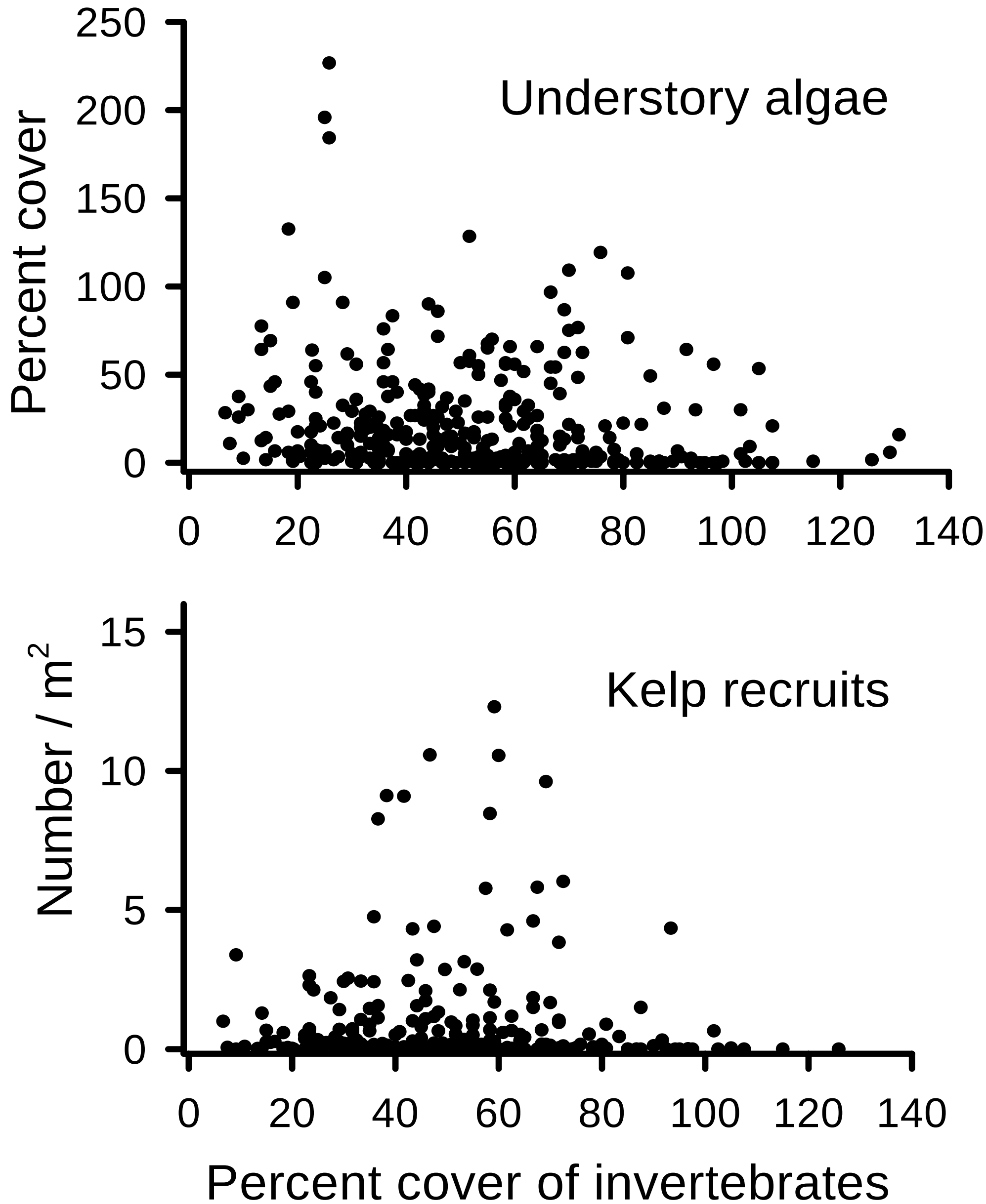


Figure III.26. Change in the mean percent cover of bare substrate over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK).

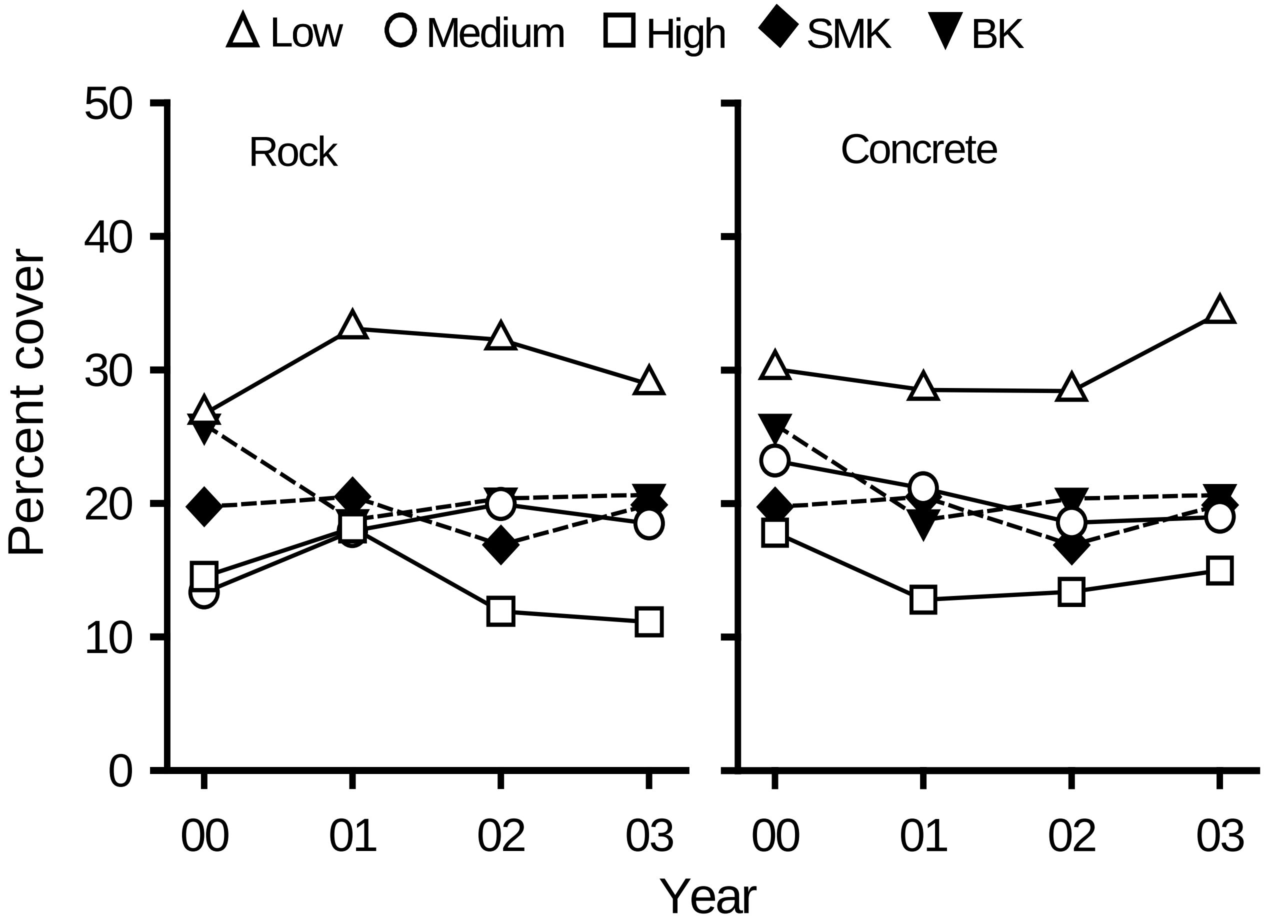
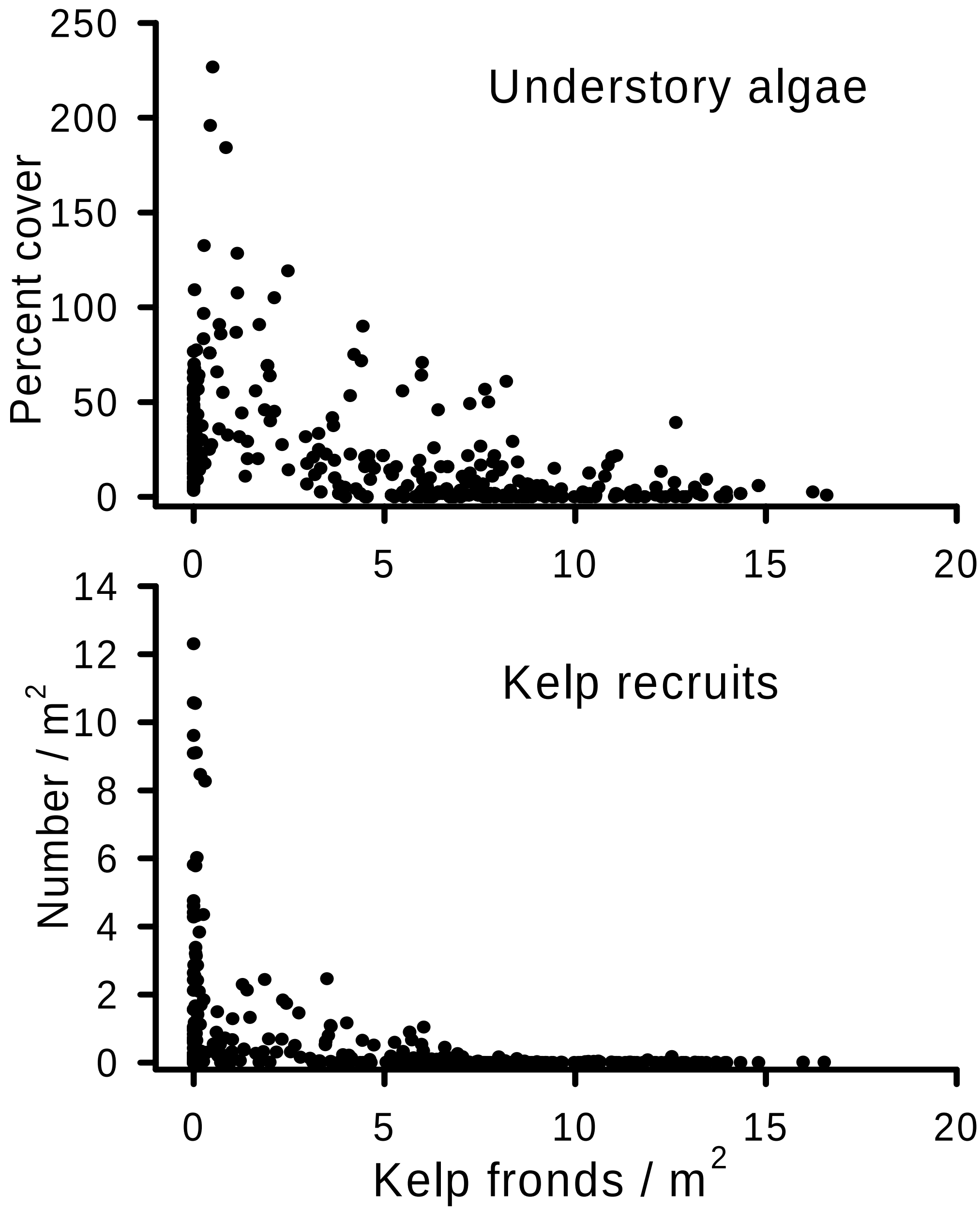


Figure III.27. The relationship between the percent cover of understory algae and the density of giant kelp fronds (top). The relationship between the density of giant kelp recruits and the density of giant kelp fronds (bottom). Data were collected from SCAR during 2000 – 2003 in permanent transects on 42 artificial reef modules (i.e. all artificial reef designs excluding the 14 kelp transplant modules).



FigureIII.28. Wedge-shaped relationship between the abundance of kelp forest algae and invertebrates on the artificial reef modules at SCAR. Competition for space between bottom-dwelling algae and invertebrates drives the relationship along a diagonal (red arrow). Shading from kelp leads to a reduction in understory algae (solid green arrow), which allows invertebrate abundance to increase (dashed green arrow). Severe disturbances decrease the abundances of both algae and invertebrates (blue arrows).

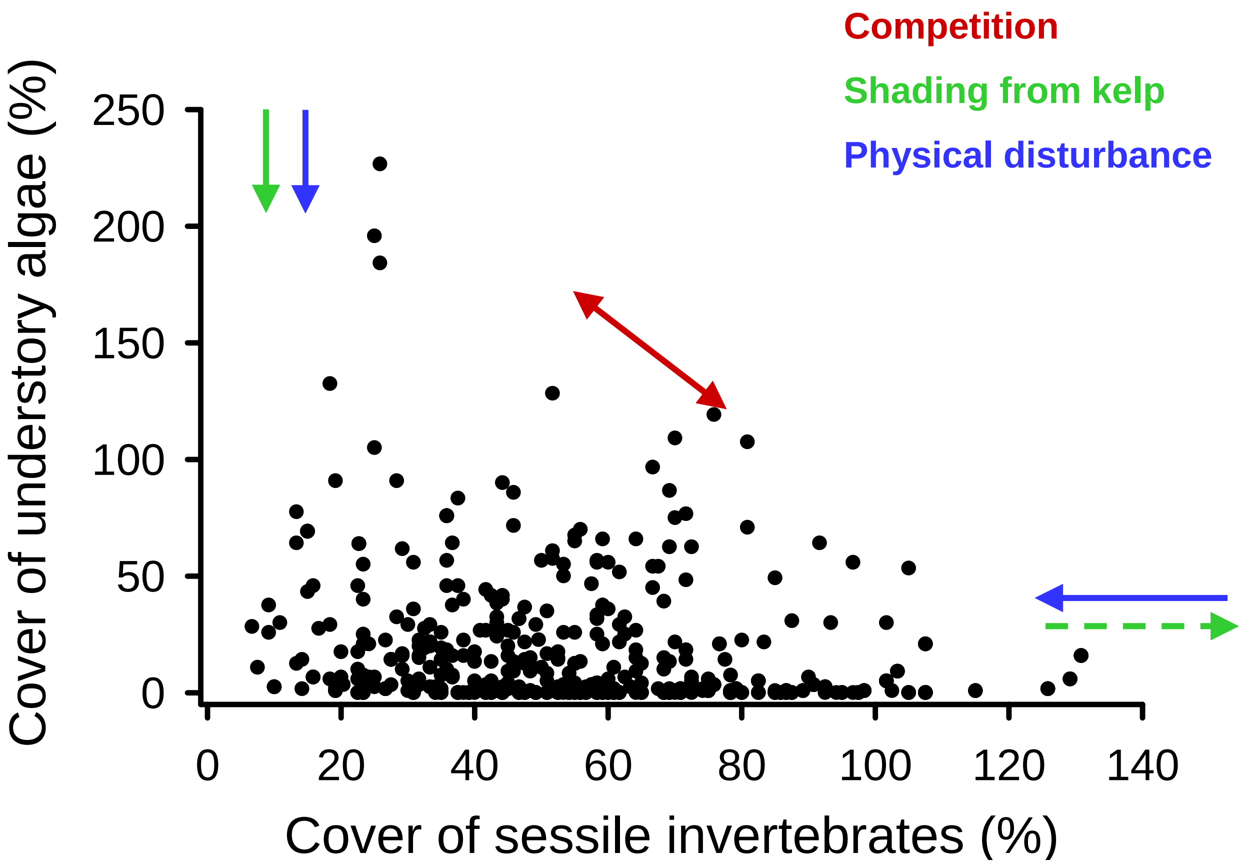


Figure III.29. Experimental design to test the effects of the giant kelp canopy and percent cover of sessile invertebrates on the abundance and species richness of the understory algal assemblage at SCAR using the six kelp transplant modules constructed of a medium cover of quarry rock

Sessile invertebrates	Giant kelp canopy +	Giant kelp canopy -
+	n = 6 medium rock modules, 6 quadrats / module	n = 6 medium rock kelp transplant modules, 6 quadrats / module
-	n = 6 medium rock modules, 6 quadrats / module	n = 6 medium rock kelp transplant modules, 6 quadrats / module

IV. Beach Monitoring
November 2002 through October 2003

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INTRODUCTION

Beach Monitoring Program Objective

This is the fourth year of a six-year study of beach conditions at San Clemente. The object of this study is to routinely document kelp wrack and artificial reef building material, quarry rock and broken concrete, on the San Clemente beach that fronts the San Clemente Experimental Artificial Reef.

Beach Monitoring Program Purpose

The purpose of monitoring the San Clemente beach is to fulfill:

1. Condition 9 of the Coastal Development Permit, Number E-97-10, issued by the California Coastal Commission on July 26, 1999; and,
2. Conditions for beach monitoring as specified in Volume II, Appendix H, *Section 3 - Geology*, and *Section 10 - Public Services and Utilities,* in the Final Program Environmental Report for the Construction and Management of an Artificial Reef in the Pacific Ocean Near San Clemente, California , dated May 1999, (EIR).

The wording in these two documents is similar.

The Coastal Development Permit, Condition 9, states:

> "***Development Adjacent to Parks and Recreation Areas: 9.*** *The applicant [SCE] shall monitor the beach adjacent to the project site from 1 km up coast to 1 km down coast from the project boundaries. Monitoring shall be conducted bi-weekly during the period December through March and monthly during the rest of the year. Monitoring shall include (1) quantitative estimates of the amount of kelp (percent of beach covered and volume) on the beach; (2) a count of rocks and concrete pieces present, in the unlikely event of artificial reef material washing ashore, and; (3) documentation of beach clean-up activities by state or municipal agencies. The applicant shall remove form the beach any rocks or concrete washed ashore from the experimental reef. Monitoring shall commence within 1 month of the completion of construction and shall continue for a*

period of 6 years or until the beginning of construction of the mitigation reef, whichever is earlier. An annual report shall be submitted to the Executive Director within 3 months of completion of each 12-month monitoring period." (CCC, 1999)

San Clemente Experimental Artificial Reef - Project Description

The San Clemente Experimental Artificial Reef was built between August 18 and September 29, 1999. It was constructed by Southern California Edison Company (SCE), as managing partner, according to specifications set forth in Coastal Development Permit Number E-97-10 (CCC, 1999). The San Clemente Experimental Artificial Reef is one of the projects (Condition C) designed to mitigate adverse marine impacts of the operation of the San Onofre Nuclear Generating Station, as determined by the CCC, and as set forth in Coastal Development Permit 6-81-330-A adopted on April 9, 1997 (CCC, 1997).

The San Clemente Experimental Artificial Reef consists of 56 low relief squares or "modules" that each covers an area of 40 m by 40 m (132 ft x 132 ft) on the bottom in 12 to 14.5 m (39 to 47 feet) of water (Figure 1). The modules are located about 1 km (0.6 miles) offshore paralleling 4 km (2.5 miles) of the San Clemente Beach between the San Clemente Pier to the north and San Mateo Point to the south (Figure 1). The reef modules cover approximately 22.4 acres of ocean floor, but are spread out fairly evenly in seven groupings, or "blocks" of eight modules within a 356-acre project site. The average variation in height of the reef above the ocean floor is 0.5 m to 1.0 m (1.7 to 3.3 ft), with none of the modules higher than 1.25 m (4 ft). Half of the experimental reef modules were constructed with large chunks of broken concrete and the other half were made of quarry rock obtained from Catalina Island. The quarry rock consists of pieces that measure, on average, 2 feet by 1.5 feet by 15 inches. The recycled concrete includes a mix of shapes and sizes: part of the material is 6 inch slabs with an average size of 4 to 6 feet, and part of the concrete with shapes more similar to the quarry rock. The total weight of material in the Experimental Reef is 13,860 short tons of recycled concrete, and 17,640 short tons of quarry rock.

The objective of the experimental reef is to determine which of several designs are most likely to support the development of a giant kelp forest community. The results of the five-year experimental study will be used to design an artificial reef that provides at least 150 acres of high-density kelp forest and associated fish and benthic communities (see Resource Insights, 1999, the Final Program Environmental Report, for a more detailed project description).

San Clemente Beach Project Setting– Oceanographic and Littoral Zone Influences.

<u>Coastal Setting</u>

The study area that includes the San Clemente beach and the San Mateo Point beach is situated on the edge of a narrow and undulating coastal plain. The plain extends from the coastline to a range of low hills two miles inland that have a maximum elevation of 1,725 feet (518 m) above sea level. The sloping plain terminates at the beach in a line of coastal terrace bluffs that extend up to 60 to 80 feet (18 to 24 m) above the sandy beach. The bluffs undulate such that some areas behind the beach are near the elevation of the back beach. One set of railroad tracks with shore-protection rip-rap is situated directly behind the beach and in front of the bluffs along the entire length of the San Clemente beach. Further, numerous ravines are cut into the bluffs as a result of erosion and storm runoff from the coastal plain. Housing is situated along the top of most of the bluffs throughout San Clemente, and even through some of the larger ravines. Open bluff-top is found at only one location in the study area, at the San Clemente State Park south of Avenue Calafia. The only other underdeveloped area adjacent to the study zone is at San Mateo Point in front of San Mateo Creek.

Climate and Hydrology

San Clemente lies within a climatic regime broadly defined as Mediterranean, which is characterized by short, mild winters and warm, dry summers. The climate is influenced chiefly by the East Pacific high-pressure area, whose center on average lies to the northwest, between Hawaii and Alaska. In summer, this pressure system intensifies, resulting in mild, dry weather and a blockage of storms. In winter, the high pressure area weakens and moves to the south and west. Cold fronts occasionally cross the southern California coast resulting in cooler weather and occasional rain. Superimposed on this basic climate pattern are modifications that result from local land topography and coastline orientation.

Long-term annual precipitation recorded near San Clemente averages about 12 inches (30 cm) per year and occurs mostly in the winter. The rainiest month is typically January, with an average of up to 3 inches (8 cm); the driest is July, with an average of less than 0.04 inch (0.11 cm). Measurable precipitation occurs only about 40 days per year.

The wind along the coast is greatly influenced by local topography. Measurements at San Onofre, just south of San Clemente, show that the wind comes predominantly from the north and west, with mean wind speeds of approximately 7 mph (11.2 kph). The diurnal wind pattern along the coast consists of afternoon onshore winds and offshore nighttime winds generated as a result of the differential heating of water and land surfaces. The sun heats the land to temperatures warmer than the sea surface during the day, and radiant cooling to the atmosphere cools the land to temperatures cooler than the ocean surface during the night. During the day, relatively cool air comes in contact with the land surface, thus generating a sea breeze. At night, subsiding air cooled through contact with the land flows offshore, displacing the air over the ocean, thus generating a land breeze. This diurnal pattern is interrupted on overcast days and during stormy weather.

Runoff from rainfall on the coastal hills behind San Clemente collects in small intermittent drainage streams and discharges into the ocean at a number of locations along the beach. The three larger nearby streams, San Juan Creek to the north, and San Mateo Creek and San Onofre Creek to the south (Figure 2) also flow only intermittently. Average annual runoff is 15,790 acre-feet per year for San Juan Creek (1986-1997), 5150 acre-feet per year for San Mateo Creek (1953-1997) (USGS, 1997), and median annual discharge is 290 acre-feet per year for San Onofre Creek.

Nearshore and Central Shelf Marine Geology

The nearshore and central shelf between Dana Point and Oceanside is 3 to 5 miles (5-8 km) wide and extends seaward to a water depth of approximately 300 feet (90 m). The nearshore or inshore zone in front of San Clemente, from the surf to 40 feet (12 m) below mean lower low water, is a gently sloping bottom reaching out to 3,000 feet (984 m) from the beach. The surficial layer of unconsolidated sediment in this zone is mainly sand-sized material. The predominant direction of sediment transport in the nearshore region is seaward, perpendicular to the coastline (Kolpack et al., 1990). The patchy distribution of bottom sediments inshore of the 40-foot (12 m) depth contour includes stretches of sand interspersed with areas of cobble. San Mateo Point, at the south end of this San Clemente study area, has patchy domes of cobbles near the beach. Surfers have understood, since the inception of surfing in the 1940's that these subtle domes or ridges at San Mateo Point create an excellent surf break, and this is one of the more popular surfing areas in southern California. Most of the intertidal and nearshore cobble areas in the San Clemente-San Onofre area show evidence of periodic burial (Marine Biological Consultants, 1978). The active sedimentary material is mainly composed of quartz, feldspar, and biotite sand.

The inner shelf, between the 40 and 60 foot (12 and 18 m) contours, is covered with relic deposits of boulders, cobbles, gravel, and isolated patches of sandy silt. This erosional platform resulted from large climatic oscillations and tectonic activity over the past 12,000 years (the Holocene). This 40-60 foot (12-18 m) shallow-shelf zone has numerous ribbons and ridges of sand, isolated patches of sandy silt, and occasional areas with a thin veneer of sand overlying a basal terrace platform of gravel, cobbles, and boulders. These outcrops of sedimentary strata and terrace boulders provide a suitable substrate for kelp off San Mateo Point (the San Mateo Kelp Bed) directly south of San Clemente, at San Onofre (the San Onofre Kelp Bed), and at the Las Pulgas Canyon area downcoast of San Onofre (the Barn Kelp Bed and the Las Pulgas Kelp Bed).

The central San Clemente/San Onofre Shelf sediment prism is located between the 50 and 230 foot (15 m and 70 m) contours. This sediment prism has a mean thickness of 20 feet (6 m), with a range of 0 to 66 feet (0 to 20 m). The long-term, mean, net sediment accumulation rate for this area is about 0.02 in/yr (0.5 mm/yr) (310 $mg/in^2/yr$ (50 $mg/cm^2/yr$)), with a range of 0 to 940 $mg/in^2/yr$ (0 to 150 $mg/cm^2/yr$). A continuous, side-scan survey of the shelf was conducted in 1988 as part of the Kolpack et al. (1990) study. The survey revealed that the central shelf off San Onofre seaward of the 50-foot (15 m) contour is a smooth, featureless plain with occasional outcrops of Pliocene-Miocene sedimentary rocks and patches of gravel and boulders where modern sediment does not cover the Holocene terraces.

San Clemente Beach and Littoral Processes

San Clemente is located near the northern end of the Oceanside Littoral Cell, as shown in Figure 2. A littoral cell is defined as an isolated geographical compartment, usually bounded by headlands, which contains a complete cycle of sand sources, transport paths and sinks (Inman and Frautschy, 1965). The Oceanside Cell is fed by the San Juan, San Mateo, and Santa Margarita drainage systems. Its northern boundary is Dana Point and its southern boundary is at the Point La Jolla and Scripps-La Jolla submarine canyons. San Mateo Point, in the northern sector of the cell, is a local promontory that exerts an effect on sediment distribution in the San Clemente area. This

region of low rainfall receives an extremely limited amount of material and is an example of a sediment-starved shelf.
Sand reaching the southern limit of the Oceanside Littoral Cell at La Jolla is intercepted by the Scripps and La Jolla Submarine Canyon system. The material accumulates in the canyon heads or landward branches until high waves flush it out to deep water. On the average, about 270,000 yd^3 (200,000 $m^{3)}$ per year of sand are lost from the littoral cell in this way (Inman et al., 1976).

Natural Sand Delivery at the San Clemente Beach

Natural sediment is delivered to the San Clemente beach and inner continental shelf by local streams and erosion of coastal bluffs. Stream discharge is limited by the small drainage area, low rainfall, the rip-rap placed on the back-beach to protect the rail road track in front of the San Clemente bluffs, and construction of flood control facilities. The primary local sources of sand supply to the San Clemente littoral zone and central portion of the adjacent shelf are: 1) San Juan Creek, 2) San Mateo Creek, 3) Las Pulgas Canyon/Las Flores Creek, 4) debris from erosion of the Camp Pendleton cliffs and bluffs, and 5) San Onofre Creek. Additional sediment is derived regionally from the Santa Margarita River, and from regional bluff erosion (Table 1).

Sediment yield estimates for the San Clemente area vary according to investigator and period of time considered in each investigation (DNOD, 1977; Simmons, Li, and Associates, 1988; Flick and Wanetick, 1989; USACE, 1991). Cliff erosion from uncontrolled surface runoff is most dramatic during large rainfall events and can cause significant gullying and episodic deposits of sand on the beach, especially at areas in the Oceanside Cell further south of San Mateo Point (Kuhn et al., 1980). Additionally, the occurrence of unusual flooding, such as in the winters of 1977-78, 1979-80, 1982-83, and 1997-98, contributed substantial quantities of sand to the area.

Island Shadowing Effect on Waves and Littoral Drift

Waves generated by storms in the Pacific Ocean are the most important forcing function for transporting sand in the Oceanside Littoral Cell, both onto the beach from the local cliffs, as well as alongshore and onshore and offshore. Cliff erosion and wave attack on the shore-protection rip-rap can occur because of direct wave interaction at the base. Wave-induced cliff and rip-rap undermining and collapse is most serious when the beaches are narrow and unable to provide a wave-dissipating buffer.

The Southern California Bight is a very complicated region for wave processes, since the offshore islands greatly affect the wave exposure (Figure 3). The islands and associated shoals both shelter the coast by blocking wave energy and refracting wave trains that pass through the gaps (Pawka et al., 1984). As a result of island sheltering, wave exposure in the Bight is a strong function of location and of deep-water wave approach angle. Pawka (1982) calculated these dependencies for the San Diego region. San Clemente is sheltered from the west by the Santa Catalina and San Nicholas Islands, and from the northwest by the Santa Cruz, Santa Rosa, and San Miguel Islands. In contrast, San Clemente is relatively exposed to the southwest, but not as much as is the San Onofre beaches directly south of San Mateo Point.

Seasonal Beach Width Changes

Seasonal changes in beach width have been extensively documented on southern California beaches (Thompson, 1987; Elwany et al, 1999). These changes are associated with seasonal variations in wave energy and steepness (Inman, 1980). The higher, steeper waves of winter generally pull sand offshore, flattening the beach profile. Lower waves, as well as the summer southern swell, with its longer periods, tend to push sand onshore, widening and steepening the overall profile. Deviations from this pattern have been noted where the presence of headlands or other obstructions partially compartmentalizes a beach into a sub-cell (Thompson, 1987).

Seasonally, changing wave exposure also tends to reverse the longshore transport of sand. At San Onofre, just to the south of this San Clemente study area, this tendency may be very pronounced, with generally southward transport during winter, and northward transport during summer (Shepard, 1950a and b). Limited directional wave measurements made during 1985-1986 (Schroeter et al., 1989) show a close balance between southward and northward transport rates, implying little net transport over at least this 2-year period. Long-term net sand transport must, however, be to the south. This is strongly suggested by the build-up of littoral sand on the northern, upcoast side of temporary barriers such as the SONGS Unit 1 and Units 2 and 3 laydown pads, and permanent installations like Oceanside Harbor.

Elwany, Flick and Aijaz (1992, 1993, and 1994) estimated the seasonal beach width cycle at various ranges north, adjacent to and south of the San Onofre beaches, from beach profile data taken from 1991 through February 1994. On average the seasonal cycle was a modest 32 feet (9.8 m). The San Clemente beaches appear to be as stable as the adjacent San Onofre beaches.

Currents and Sediment Movement at San Clemente

The longshore currents off the San Clemente beach tend to be consistent with the prevailing wind direction. The result is a southward flowing current along the shoreline that predominates in every season. Strongest southerly flow occurs in the summer months (Daley et al. 1993). These currents, along with large storm waves are the primary forces that suspend and transport sediments (Cacchione et al. 1987; Wiberg and Smith 1983; Cacchione and Drake 1982).

STUDY METHODS

Monitoring Obligations and Schedule

The beach monitoring program is being accomplished in-house by SCE. The field effort consists of routine beach surveys on a bi-weekly (twice a month) basis from November through March and monthly from April through October. Edison monitors the "beach adjacent to the project site, from 1 km up coast to 1 km down coast from the project boundaries" (Coastal Development Permit, Condition 9). This area extends from 1 km north of the San Clemente pier and south for approximately 3.2 miles, to the mouth of San Mateo creek at the "Trestles" wooden railroad bridge (Figure 4). Monitoring includes:

"1) quantitative estimates of the amount of kelp (percent of beach covered and volume) on the
beach [five five-hundred-foot stations are surveyed quantitatively];
2) a count of rocks and concrete pieces present, in the unlikely event of artificial reef material
washing ashore [five five-hundred-foot stations are surveyed quantitatively], and;
3) documentation of beach clean-up activities by state or municipal agencies" (Coastal
Development Permit, Condition 9).

This project is also responsible to remove any rocks or concrete washed ashore from the experimental reef (Coastal Development Permit, Condition 9; EIR, Vol. II, Appendix H, page 3).

Monitoring began in October 1999 with the assessment of aerial photography that is performed routinely for the SONGS NPDES (National Pollutant Discharge Elimination System) permit monitoring and with a preliminary beach survey. By November 1999 the quantitative/qualitative routine beach surveys were established for this program, and these are envisioned to continue through October 2005 ("for a period of 6 years or until the beginning of construction of the mitigation reef, whichever is earlier" - Coastal Development Permit, Condition 9). Annual reports shall be submitted to the Executive Director within 3 months of completion of each 12-month monitoring period per the Coastal Development Permit, Condition 9. The 12-month monitoring period of November 1 to October 31 has been chosen for this program. The routine field effort will result in field notes of conditions as noted above as well as a pictorial representation of conditions on the survey days, taken at reasonable low-tide conditions. The critical time for these assessments, according to the Program EIR [p. 4.10-7], is "immediately after any large storm events (by the next day)". A major goal of this effort, according to the EIR, is to collect data on the amount of kelp washing onto the beaches currently and establishing a baseline because the City of San Clemente and the California Department of Parks and Recreation do not collect this information.

Data Collection and Management

Surveys are performed as close to the lower-low-tide as practical on each survey day, and the survey days are scheduled for the more extreme lower-low-tides of each month as practical (surveying during day-light hours and avoiding darkness is one of the limiting parameters of practically, for example).
Qualitative observations of kelp wrack, hard substrate along the sandy beach, and general beach conditions are recorded for each bi-monthly (winter) and monthly (summer) low tide beach survey.

Quantitatively, five permanent transects (see map, Figure 4; and coordinates of survey stations, Table 2) and standard data collection procedures were established during the November 1999 surveys to record estimates of the amount of kelp, in cubic feet, the percent of beach covered by kelp, and the count of concrete and rocks present. For this quantitative analysis of kelp wrack in the study area, five 500-foot stations were established in accordance with past kelp wrack assessment in the area (ZoBell, 1959). The amount of seaweed, in cubic feet, on the 500-foot length of beach was estimated so that the results could be comparable over time and with historical results.

All information is recorded on standard data sheets. A hand-held global positioning system (GPS) instrument was used to initially record the exact positions (Table 2) of the north and south ends of these transects. The five transects are each 500 feet long, parallel to the water's edge, and are located (from south to north) at:

1. *San Mateo Point*: The south end of this transect is at the very north edge of the permanent natural cobble field that is exposed at low tide. This point on the beach is directly below a red and white navigation marker (circular sign on post) positioned on the bluff above the beach. The north-end of this Station 1 (500-foot) transect is at a point along the beach in front of the bluff where a grid of horizontal/vertical concrete retaining revetment is visible in the bluff face behind and above the railroad tracks and rip-rap.
2. *State Beach*: The San Clemente State Beach (off of Avenida Calafia), Camping Access Trail: The north end of this transect is out on the beach directly in front of the railroad track underpass at the State Beach camping grounds trail. The south end of the transect is directly in front of the next drainage culvert that also goes under the railroad tracks.
3. *Calafia*: The Calafia Park State Beach (this parking lot is operated by the City of San Clemente, but it is a State Beach), at the end of Avenida Calafia: The south end of the transect is directly out from the beach access point along the railroad track rip-rap. There is a railroad flashing light signpost at this position. The north end of the transect is adjacent to a railroad sign up on the riprap that is small, white, and with black numbering, stating "206".
4. *San Clemente Pier*: The City of San Clemente Municipal Pier: The south end of the transect is adjacent to a set of permanent picnic tables up on the beach, about 200 feet south of the pier. The north end is 250 feet north of the pier opposite a children's area permanent swing set.
5. *Buena Vista*: El Portal Street beach access point along Avenue Buena Vista, 1 km north of the Municipal Pier: The north end of the transect is directly out on the beach from the small bridge that supports the railroad tracks and is a beach access point from a long, steep stairway down from Avenue Buena Vista near the cross street of El Portal. This bridge was originally built of wood, as evidenced in the first-year pictures, but was re-built out of concrete in mid-2001.

Data from these 500 foot transects are recorded at 50 foot intervals, and from both below the berm/scarp (wet beach area), and above the berm/scarp (dry beach area). Photographs of the beach are also taken during each survey. Marine Advisors (1964) first took these types of photographic surveys in the San Onofre area in 1963. Photographs are taken at low tide looking back up the beach toward the railroad tracks, and north and south along the beach at each of the transect locations. Any perceived unusual disturbances of the beach, materials on the beach, or algal wrack are also photographed and location noted during each 3.7-mile beach survey.

Tracking Project-Related Beach Clean-Up Activities by State or Municipal Agencies

Any beach clean-up activity that could be construed to be connected with or involving material or kelp from the San Clemente Experimental Artificial Reef is recorded and reported as part of this project. Typically, the State Beach is not cleaned, but the City Beach is routinely cleaned. The City does not keep historical or detailed records of their beach cleaning activities (Resource Insights, 1999).

RESULTS FROM NOVEMBER 2002 – OCTOBER 2003 SURVEYS

Beach surveys were performed on the following days, as covered in this annual report:

1. Beach walk surveys: November 5, 2002; November 14, 2002; November 20, 2002; December 3, 2002; December 18, 2002; January 3, 2003; January 16, 2003; February 1, 2003; February 17, 2003; March 4, 2003; March 19, 2003; April 15, 2003; May 18, 2002; June 18, 2003; July 3, 2003; August 1, 2003; September 11, 2003; and October 10, 2003.
2. Aerial fly-over surveys (these survey pictures were taken as part of another study, one required for SONGS 2 and 3 NPDES marine monitoring): October 18, 2002; December 26, 2002; March 18, 2003; May 12, 2003; August 29, 2003; and October 21, 2003. Note: These aerial fly-over pictures will be assessed in context of this beach survey project as long as they are required for the NPDES program.

Quantitative Beach Surveys - Results

Table 3 summarizes the beach seaweed wrack measured at the five quantitative beach survey stations, November 2002 through October 2003.

Table 3. Seaweed wrack on San Clemente beach, at five 500-foot stations, November 2002 through October 2003. Wrack volume in cubic feet per 500-foot station.

This year's survey results, November 2002-October 2003, at the five quantitative 500-foot sample stations, revealed that there was no single station that experienced consistently significantly greater amounts of kelp wrack compared to the other sampling stations. The San Mateo Point station, San Clemente Pier station, and the Calafia station had 23.4, 19.2, and 17.3 cubic feet of kelp wrack per 500 feet of beach frontage, respectively, on average over the 18 surveys. The previous year's data, November 2001-October 2002, showed similar averaged results at these three stations: San Mateo Point – 21.6 ft^3, Pier – 19.2 ft^3, and Calafia – 17.4 ft^3. Further, two years ago, November 2001 to October 2002, the Pier area had the most kelp wrack, on average, during that survey period; with 22 ft^3 per survey, average; while San Mateo Point had 17 ft^3, and Calafia had 13 ft^3.

The range of kelp wrack volume for the five quantitative stations for this year (2002-2003) was 0 to 216 ft^3, while the previous report period (2001-2002) had a range of 0 to 71, and two years ago the average was 0 to 101 ft^3.

Similar to the previous study years, kelp wrack was least at the most northerly station, Station #5 - Buena Vista and Station #2 - State Beach. Further, both of these beach areas, Buena Vista and State Beach, had 13 and 9, respectively, out of 18 surveys when there was less than 4 cubic feet of kelp wrack present, meaning the 500-foot beach areas were essentially clear of any major kelp wrack clumps or balls. Neither of these beaches was cleared of kelp wrack by human intervention during the year. Eight surveys out of the 18 for the 2002-2003 survey year were days when kelp wrack was less than 4 cubic feet per 500 feet of beach frontage in the survey areas, on average. This compared to 3 out of 18 survey days in 2001-2002 being free of kelp wrack.

The average kelp wrack amount per 500-foot quantitative survey station is 14.6 cubic feet for November 2002-October 2003. The November 2001-October 2002 survey year had the same 14.6 ft^3 amount, on average. This compares to 5 and 14 cubic feet, respectively, for the first year, October 1999 through October 2000, and the second year, November 2000-October 2001.

The adult *Macrocystis* plants that appeared as wrack on the beach during this survey year were carefully observed for any scientific survey tags that would have indicated they came from the San Clemente Experimental Artificial Reef. The California Coastal Commission marine scientists conducting the monitoring of the Artificial Reef initially tagged many of the adult kelp plants on the Reef as they could during 2000-2001. Tagging stopped once it became evident that the artificial reef was growing too many kelp plants to keep up with. Nevertheless, no kelp wrack plants with scientific tags still attached were observed during the beach surveys over this past year, or any previous year of this survey program. The only know instance of a tagged kelp plant from the artificial reef program appearing on any beach was observed by Jim Elliott at a Leucadia beach during the summer of 2002 (Jim Elliott and Steve Schroeter, personal communication).

Qualitative Assessment of Kelp Wrack and Beach Conditions

The following table (Table 4) provides a qualitative assessment of beach kelp wrack and beach conditions as observed at the five beach survey stations, November 2002 through October 2003. Conditions at the five sample stations appeared representative of the entire beach during the surveys. Field data sheets, notes and photographs depicting beach conditions for each 3.7-mile beach survey are on file at the Southern California Edison office at Rosemead, in the Environmental Projects section.

Area of Greatest Kelp Wrack for the Survey Year

The last two monthly surveys, September 11, 2003 and October 10, 2003, had the most kelp wrack on the San Clemente quantitative beach areas for the survey year (254 ft^3 and 321 ft^3 respectively). The previous survey year had highest kelp wrack amounts of about half of this amount per survey: May 28, 2002 had 138 ft^3, September 7, 2002 had 111 ft^3, and October 23, 2002 had 161 ft^3. Both years had similar storm and higher-energy wave conditions, but neither year had any really large storms or really high surf.

At a specific quantitative survey station, the greatest amount of kelp wrack during the November 2002-October 2003 survey year occurred on October 10, 2003: 216 ft^3 at

Station #4, the Pier. The next largest amount of wrack appeared at Station #3, Calafia, on September 11, 2003: 120 ft^3. Photographs of these quantitative areas are arranged chronologically in Appendix A of this report.

From the qualitative part of the survey of the whole 3.7 mile study area, the section of shoreline north of the lifeguard office north of the San Clemente Pier was found to have large amounts of wrack periodically in the summer and early fall seasons: 210 ft^3 on August 1, 2003 (Figure 5), 48 ft^3 on September 11, 2003 (Figure 6), and 144 ft^3 on October 10, 2003 (Figure 7). This qualitative survey area is between the quantitative stations #4: San Clemente Pier, and # 5: Buena Vista. A 500-foot beach frontage area was paced off that bracketed the majority of this wrack. The kelp wrack was then measured using the standard quantitative mythology, as described in Section 2 of this report. By comparison, in the previous year (2001-2002), this same area also had a maximum (100 ft^3) of wrack material, which occurred on August 1, 2002 (Figure 8). The wrack consisted mostly of *Macrocystis* in all of these quantitative and qualitative measurements.

<u>Big storm – big wave-event survey days</u>:

During 2002-2003, there were three surveys done after bigger wave sets had come through the area: November 14, 2002, December 18, 2002, and March 18, 2003. None of these episodes had really big storm waves, but rather larger than normal swell (in the 3-8 feet range compared to 1-3 feet), and none had long-period storm waves. Yet, the November (150 ft^3) and December (129 ft^3) surveys did have more kelp wrack than usual (72.6 ft^3); while the March survey actually had less (9 ft^3) than usual (72.6 ft^3). Further, none of these surveys had kelp wrack amounts approaching the late summer/early fall amounts of September 11, 2002 (254 ft^3) or October 10, 2003 (321 ft^3). By comparison, there were four "bigger wave" survey days during the previous survey year, November 2001-October 2002; and none of these survey days had unusually high amount of kelp wrack compared to the rest of the year. But, this previous survey year also had rather mild oceanographic conditions, and no major storm events.

Observations of Kelp Holdfasts and Attached Hard Substrates

Individual kelp wrack plants were studied as part of the March 2002-October 2003 surveys. The plants' holdfasts (also called haptera) were assessed for any evidence of attachment to hard substrate material and indications of where the plants may have originated. Many holdfasts showed evidence of bleaching and/or continued growth: their holdfast strands were not flat or uniformly curved on their underside as though they had just ripped off of a rock or the bottom, but rather straggly and wildly curly. Curly and/or irregular holdfasts is an indication these plants had been uprooted for a long time and floating about on the ocean surface as a kelp patty (Figure 9). Chances are great that these types of plants did not come from the nearby San Clemente Artificial Reef, but from further "up-current". Some holdfasts have mild curling and may or may not have come from nearby beds (Figure 10). Further, holdfasts that have extremely flat bottoms and look more like a volcano mound could be easily associated with local, nearby flat-surfaced natural or artificial substrate (Figure 11).

Other kelp wrack holdfasts still incorporate the hard substrate or segments of the rock that they were anchored or attached to (Figure 12a and 12b). Many of these rocks were of the mudstone variety: soft stone, gray or black in color, and some with boring clam holes in them. This soft mudstone has been observed as ubiquitous at the San Mateo Kelp Bed over the years of studying this bed as part of the San Onofre Nuclear Generating Station marine monitoring program (Dr. Jake Patton, personal communication). Further, these types of rocks are commonly observed in the surf zone along the San Clemente beach, and it is assumed they are not unusual in the nearshore areas throughout this region of north San Diego/south Orange Counties.

Other small rocks, clusters of small rocks, sea shells, and various small and soft-ball- size cobbles were found throughout the last two survey years washed up on the beach with the kelp wrack haptera still attached (Figure 13a and 13b). Some kelp wrack clumps had as many as 28 small *Macrocystis* plants with their holdfasts intact and one or two complete large plants with large (1-3 feet diameter) holdfasts tangled together (Figure 14). No attached rocks appeared to be sharp-edged quarry rock or broken concrete.

About the same amount of large holdfasts (1-4 feet diameter) were observed on the beach this year as compared to last year (Figure 15a and 15b). And about the same amount of these holdfasts appeared to have flat bottoms, again comparing this year to last year. These flat-bottom holdfasts, indicate the giant kelp plants were attached to either flat natural bottom hard substrate or possibly flat artificial reef material -possibly the larger flat pieces of broken concrete. As mentioned earlier, no San Clemente Artificial Reef scientific tags were found on any of the kelp wrack plants, and some of the flat-bottom holdfasts showed signs of being attached to natural mudstone (Figure 12a), so no specific conclusions can be drawn. Generally, these large-wrack holdfasts, measuring one to four feet across their base, appear to be in the same age category as those plants present on the artificial reef. Since, the whole region had excellent natural kelp recruitment occurring in the time frame of the reef installation, these wrack plants could be from anywhere along the San Diego/Orange County coast; including possibly from the artificial reef.

Beach Area Covered by Kelp Wrack and Systematic Beach Survey Pictures

The percentage of the San Clemente beach typically covered by the seaweed wrack observed from November 2002 through October 2003 is less than 1%. Two or three representative photographs of beach and kelp wrack conditions for each survey at San Clemente along the five quantitative survey stations are shown in Appendix A. The widths of the beaches at San Clemente are relatively wide at low tide, mostly between 100 – 200 feet. The seaweed wrack is usually immediately inshore of the surf zone, in a band with a width of 10 to 50 feet. On occasion, wrack is scattered further up the beach face (see Figures 5 -8), sometimes after large storms for instance, but the density cover has not been observed to be necessarily significantly greater at these times. Even at the times when the beaches had relatively substantial amounts of kelp wrack upon them, the percent wrack cover for the total usable beach appeared small. As stated earlier, all surveys in this study were performed at low tide conditions. It may be that at high tide, the kelp wrack occupies a greater percent of the beach area; but it is also possible that much of the kelp wrack washes back down the beach into the surf zone during the high tide conditions.

Observations of Quarry Rock and Concrete on the Beach

No quarry rock or broken concrete from the San Clemente Experimental Artificial Reef was observed on the beach during this November 2002 to October 2003 survey period. At times, some small chunks of granite were observed on the beach near the base of the back-beach shore-protection rip-rap (at the base of the railroad tracks), and in the surf zone during times when the beach was cut lower due to storm wave-induced sand erosion. Also, at least two small chunks of old or semi-eroded concrete were found along the beach when the beach was cut low due to high-wave conditions. Further, patches of natural rocks and boulders emerging from the sandy beach were visible at the low tide surveys near the Buena Vista survey station north of the Pier (Figure 16), directly south of the Pier (a ridge of flat rocks perpendicular to the beach, and seen only during low sand tide and sand-eroded conditions, see Appendix A, the Pier Station on February 1, 2003), and between the State Beach and Calafia Beach survey stations (Figure 17; and Appendix A, February 1, 2003). As mentioned above, during the beach surveys, some of the kelp wrack was found to be still attached to rocks at their holdfasts. The features of these rocks on the beach were similar to the cobble and scattered rocks periodically present during the beach surveys. These features further indicated that these rocks are not from the experimental artificial reef.

Documentation of Beach Clean-Up Activities by State or Municipal Agencies

Any beach clean-up activity that could be construed to be connected with or involving material or kelp from the San Clemente Experimental Artificial Reef is recorded and reported as part of this project. Typically, the State Beach is not cleaned, but the City Beach is routinely cleaned. The City does not keep historical records of their beach cleaning activities (Resource Insights, 1999). No such project-related clean up was noted in 2000, 2001, 2002, or 2003.

Bill Humphreys, Marine Safety Lieutenant, City of San Clemente (949) 361-8219 has been periodically contacted about any unusual beach rock or kelp wrack episodes. Mike Morgan, Parks and Recreation Department, City of San Clemente (949) 279-5420 is also contacted periodically regarding the City's beach clean-up activities. He stated on November 29, 2002: generally the City of San Clemente does not keep kelp-wrack clean-up data. He added that his impression is that the last El Nino period of 1997-1998 had significantly higher levels of kelp wrack drifting onto the City beaches, and since that time, beach kelp wrack and beach clean up activities have been "average". Further, he reiterated that the City's beach clean up policy now is to allow any kelp wrack that has appeared on the beach a chance to migrate to the higher (upper, back-beach) areas of the beach for a couple of days before they pick it up and haul it away (see Appendix B for reference to a recent concern about beach clean up activities and the issue of attempting to protect grunion).

The most recent contact with Mike Morgan was made on January 28, 2004. It is his opinion that conditions have not changed much over the last couple of years regarding kelp wrack and possible sightings of broken concrete or quarry rock: the beaches of the City of San Clemente have not experienced any unusual kelp wrack or rock/concrete pieces this past year. Further, Mike stated that other than some larger swell and more kelp wrack appearing on the city beach in the Fall of 2003 (see Table 3, page 15) this past year has been relatively mild both in local wave climate and kelp wrack on the beach.

DISCUSSION

Historical Studies of Southern California Kelp Wrack

Dr. Claude E. ZoBell of the Scripps Institution of Oceanography performed an eleven-year study of drift kelp washing up on 29 beaches in San Diego County. His is the definitive work on this subject (ZoBell, 1959). He concluded that large amounts of drift seaweed on beaches result from heavy storms, strong winds, and/or high waves. The quantity of seaweed littering a beach is influenced by the supply of seaweeds in offshore waters, water movements, and by beach conditions. Supply is a function primarily of the quantity, kind, and condition of seaweeds growing relatively nearby. With advancing age or maturity, most kinds of seaweeds slough off, thereby contributing to the supply in the surf and on the beach. Throughout ZoBell's investigations, attempts were made to find correlations between the amounts of seaweeds on the beaches with sand levels, season, surf action, kelp harvesting operations, and other concurrent phenomena or conditions. Positive correlations were apparently found only for high surf action and for high sand levels on the beaches.

One of ZoBell's 500-foot survey stations was on San Clemente Pier, frequented twice per month from mid-1954 through 1956. Table 5 describes the average monthly amount (1954-1956) of drift seaweeds observed in cubic feet for the total 500-foot beach section. Table 6 describes other representative beaches surveyed by ZoBell in the same 1954 to1956 time frame. Figure 19 shows the locations of the complete series of the ZoBell 1945-1956 survey stations.

4.2 Comparison of San Clemente Reef Program Study with ZoBell Historical Study

Where ZoBell found 92 cubic feet of kelp on the San Clemente Pier beach, this 2001-2002 San Clemente survey shows 19.2 cubic feet of seaweed wrack per 500-feet of beach front at the same San Clemente pier. And, San Clemente appears to be on the low end of the range of seaweed wrack, according to the ZoBell data. Obviously, many local kelp beds have changed in size, most getting smaller since 1954-1956, but ZoBell's is the only comparative seaweed-wrack data available. These data do show the north San Diego and south Orange County beaches have experience large amounts of kelp wrack, historically.

Pictorial representations of the range of seaweed on typical beaches was documented by ZoBell (1959) as shown here in Figures 20 and 21. The beach in Figure 20 is at Doheny State Park, and the quantity of drift seaweed shown on the beach ranges from 10 to 2,150 cubic feet per 500 feet of beach frontage.

Figure 21 shows seaweed wrack under the Scripps Institution of Oceanography Pier in December 1945.

Overall Findings of the San Clemente 2002-2003 Survey Project

As in the previous three study years of this San Clemente Artificial Reef program, the amount of kelp wrack at the Pier station appeared to be influenced by the pier pilings, which snagged the large *Macrocystis* stipes and holdfasts. The kelp wrack under the pier would end up wrapped around the pilings in clumps.

Also, the large amounts of kelp wrack appearing at San Mateo Point is not unexpected. San Mateo's beach is the nearest one to the natural San Mateo Kelp Bed, directly offshore. San Mateo Point's kelp wrack may also be due to the fact that this location is a natural point that may collect wrack in the downshore lee of any longshore current curling around the point.

Over the four years of this kelp wrack survey program along the beach at San Clemente, the average wrack amount per 500-foot quantitative survey station is 5, 14, 14.6, and 14.6 cubic feet, respectively. Data for the first year was taken from October 1999 through October 2000, and represented a time when natural kelp in the general vicinity was only starting to recover from the 1997-1998 El Niño storms. This was also the first year of data after the artificial reef was built, so although the artificial reef had surprisingly good initial kelp recruitment, the plants were still mostly juveniles. These next two survey years saw extraordinary growth of natural kelp beds in the general area as well as significant kelp growth and kelp retention on the artificial reef modules. The artificial reef modules are now four years old and have a substantial single recruitment/single age-class kelp population, with dense surface canopies, residing on them. M*acrocystis* has an expected life of 4 to 6 years in this area (Dayton et al, 1989). Therefore, this survey year, November 2002-October 2003, could be viewed as a time in the reefs' kelp life cycle of maximum kelp biomass retention. This possible maximum amount of kelp on the artificial reef modules could also be influenced greatly by the fact that there have not been many locally disruptive wave storms or El Niño storms since the reef was built in 1999.

This November 2002 to October 2003 annual report covers the four year of a planned six-year study. Comparisons with the previous three years, October 1999 – October 2000 (SCE, 2001), November 2000-October 2001 (SCE, 2002), and November 2001-October 2002 (SCE, 2003) shows similar results. But, there are some differences being observed in kelp wrack amounts between the four years, too. Overall, there have been low-volumes of kelp wrack at San Clemente, and this was not unexpected, because:

- Natural kelp in the area at San Mateo Point and San Onofre (Figure 22) is still substantially reduced from its average populations and from the extreme highs seen in the late 1980's and early 1990's (MBC, 1999; MBC, 2002; and, Personal communication, Mike Curtis, MBC, 2004).
- The kelp that is naturally present near and at San Mateo Point still appears healthy, having mostly established since the severe stormy seasons of the 1997-98 El Nino. ZoBell states (1959) that it is the older kelps and kelp weakened from parasite attack, high temperatures, and/or disease that seem to tear away more prevalently and end up on the local beaches.

- Correspondingly, the kelp growing on the San Clemente Experimental Artificial Reef is still relatively young, since the reef was not installed until September 1999; and the Artificial Reef kelp, from all indications, appears healthy so far (personal communication, Steve Schroeter, CCC, 2002; MBC, 2004).
- The 1999-2000 through 2002-2003 storm seasons winter storm were all relatively mild. It is the large, more El Niño-type, clusters of winter storms that typically drive kelp up onto the beaches and create the most wrack from the local beds (Seymour et al, 1989).
- The kelp plants present on the San Clemente Experimental Artificial Reef have formed dense canopies at each of the 56 modules. The wave storms that have occurred over the last three years with the canopy present have not ripped away the plants, either because the kelp plants are still very healthy and strong, and/or because the waves have not been large enough to have sufficient power to dislodge the plant's holdfasts, drag them around, or rip blades and stipes away in great numbers.

Table 7, compares monthly kelp wrack volume at the San Clemente Pier station for each year of this study to the ZoBell data for San Clemente from 1954-1956. Table 8 compares monthly kelp wrack volume averaged over the five kelp wrack study stations for each year to the ZoBell monthly data.

This fourth year of kelp wrack data show that kelp quantities per 500-foot length of beach have remained similar to the second and third years of the study, and about three times compared to the first year (5 cubic feet), but are still much less than the amounts of kelp wrack seen in the 1950's by ZoBell at San Clemente (92 cubic feet). The monthly amounts specifically at the San Clemente Pier are 6 times greater in the fourth year than the relative amount of kelp at the pier in the first year of study (4 cubic feet).

In the fourth year of this study, there were at least four significance factors that could have influenced kelp wrack amounts seen at the San Clemente beach:

- The 56 San Clemente Experimental Artificial Reef modules continue to support dense kelp stands that retain a stable surface canopy.
- The kelp on the modules is now four years old. This is a stage in their life history when they should be their strongest and most resistant to environmental stresses (Dayton et al, 1989; ZoBell, 1959).
- The giant kelp plants have not appeared to encounter extreme temperatures, extreme wave storms, or lack of nutrients in their existence, so far. And, there has been no evidence of any possible massive parasite attacks or extreme grazing episodes.
- The City of San Clemente was influenced to some degree by a well publicized ecological concern in San Diego County that routine beach clean-up activities of kelp wrack could cause unnecessary ecological harm (San Diego Union-Tribune, July 12, 2001; and Los Angeles Times, July 22, 2001), these articles are reprinted in Appendix B. The City of San Diego stopped their routine daily clean-up

activities along their 17 miles of beaches, and the City of San Clemente apparently reduced their clean-up activities, too. Mr. Mike Morgan (personal communication) did state that the City of San Clemente is now allowing kelp to age a bit and migrate up higher on the beach before it is routinely picked up. As Table 7 shows, the kelp wrack quantities at the Pier station increased from 4 to 29 cubic feet/500 feet of shoreline from the first study year to the second, then 21 cubic feet/500 feet over the third year, and now appears to be stable at 25 cubic feet/500 feet over the fourth year.

The study of the kelp wrack on the beach during 2002-2003, as stated earlier herein, included detailed assessment of the adult *Macrocystis* wrack to discern if there was evidence that any had come from the new Artificial Reef. None of the wrack on the beach appeared to have the Artificial Reef monitoring project study identification tags. Also, none of the wrack had any discernable pieces of quarry rock or broken concrete attached. Some of the wrack appeared in the form of beached kelp patties that had drifted in from non-local beds, and some of the wrack that included hold fasts had pieces of mud-stone and small rounded cobbles attached to them. A few kelp holdfasts did appear to be flat on the bottom, possibly indicating it was growing on flat concrete pieces; while others had sharp angles to their holdfasts, possibly indicating they had pulled off of angular quarry rocks.

CONCLUSIONS

Observations were made at the San Clemente beach for this fourth year study period, November 2002 through October 2003. The amount of seaweed wrack was recorded and artificial reef building material, quarry rock and broken concrete, was sought out for documentation. These measurements were compared to the first three years of this program, from October 1999 to October 2002, and to historical kelp wrack data from the area beaches.

The amount of seaweed wrack and reef building material was quantitatively assessed during 18 surveys over the year at five 500-foot beach frontage survey stations using survey methodology developed by ZoBell, 1959. The San Clemente beach was also qualitatively observed along the entire 3.7-mile survey zone during the 18 separate surveys performed throughout this November 2002 - October 2003 survey year.

The fourth-year quantitative surveys showed that kelp wrack ranged from 0 to 216 cubic feet of seaweed material per 500-foot survey area. The average for all five stations for this 2002-2003 survey period was 14.6 cubic feet of seaweed per 500-feet, the same as the preceding year (2001-2002), and remarkably similar to the 14 cubic feet average of 2000-2001, and up from 5 cubic feet for the 1999-2000 survey year. The average monthly range was 2 to 64 cubic feet of seaweed material for this 2002-2003 survey year. These four years of data from this study compared to the monthly average of 92 cubic feet and a range of 10 to 225 cubic feet of wrack as observed in the only other quantitative seaweed wrack study performed at San Clemente, a two-year study at one 500-foot survey station at the San Clemente Pier, 1954-1956 (ZoBell, 1959).

These fourth-year kelp wrack observations at San Clemente were not unexpected, because:

- There is a substantial amount of natural kelp in the area at San Mateo Point and at this time, yet it is mostly a healthy 4-year age class of giant kelp.
  The kelp that was naturally present near and at San Mateo Point is still relatively young, having mostly established since the severe stormy seasons of the 1997-98 El Nino. ZoBell (1959) states that it is the older kelps and kelp weakened from parasite attack, high temperatures, and/or disease that seem to tear away more prevalently and end up on the local beaches.

- Correspondingly, the kelp growing on the San Clemente Experimental Artificial Reef is also relatively young, since the reef was not installed until September 1999; and the Artificial Reef kelp, from all indications, appears healthy so far (personal communication, Steve Schroeter, CCC, 2003).
- The 1999-2003-winter storm seasons were all relatively mild. It is the large, more El Niño-type storms, that typically drive kelp up onto the beaches and create the most wrack from the local beds.
- The kelp plants present on the San Clemente Experimental Artificial Reef have formed a dense surface canopy and the canopy has appeared to be stable throughout the survey year.

The fourth-year San Clemente Artificial Reef Program kelp wrack amounts are low, as were the first three-year amounts, compared to the 1950's kelp wrack results for the San Clemente area. The most significant kelp wrack in this fourth-year study were seen at San Mateo Point and the San Clemente Pier.

No quarry rock or broken concrete that could be associated with the San Clemente Experimental Artificial Reef was observed on the San Clemente beaches during this study. No special beach clean up was noted for this time frame, either.

The overall conclusions of this four year of study are:
1. No artificial reef substrate material, either quarry rock or broken concrete appears to be washing up on the beaches at San Clemente.
2. Kelp wrack does not appear to be substantial on the San Clemente beaches.
3. Kelp from the artificial reef modules does not appear to be making a substantial contribution to the limited amount of kelp wrack that does routinely appears on the San Clemente area beaches.

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This effort is dedicated to the late Dr. Wheeler North, who laid the foundation for kelp research in Southern California.

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Table 1. Natural beach sand delivery sources and amounts in the San Clemente (Oceanside Littoral Cell) area.

Source	Location Relative to San Mateo Point	Sand Delivered to Beach (yd^3/yr)
San Juan Creek	7 mi (11 km) north	34,000-56,000 (25,000 - 40,000 m^3/yr)
San Mateo Creek	0.1 mi (0.16 km) south	8,100-32,000 (5,900 - 23,300 m^3/yr)
San Onofre Creek	0.8 mi (1.4 km) south	1,800-5,000 (1,300 - 3,600 m^3/yr)
Camp Pendleton Cliff Erosion	South of San Mateo Point, and south to Oceanside	294,000 (214,000 m^3/yr)
Las Pulgas Canyon (Las Flores Creek)	8 mi (13 km) south	2,700-4,000 (1,900 - 2,9000 m^3/yr)
Aliso Canyon Creek	9 mi (15 km) south	900 (660 m^3/yr)
Santa Margarita River	13 mi (21 km) south	7,000-19,000 (5,100 - 13,900 m^3/yr)

Table 2. San Clemente Beach Monitoring Project, locations of the five 500-foot quantitative survey stations, Global Positioning System designated positions (north and south end points)

Survey Station #	**Station Location**	**North End of Survey Station**		**South End of Survey Station**	
		Lat.	**Long.**	**Lat.**	**Long.**
1	San Mateo Point	33 33 392	117 35 870	33 23 275	117 35 811
2	State Park Beach, Camping Access	33 24 091	117 36 260	33 24 024	117 36 205
3	State Beach, Califia Parking Lot	33 24 370	117 36 483	33 24 304	117 36 420
4	San Clemente City Pier	33 25 209	117 37 260	33 25 127	117 37 196
5	Buena Vista/El Portal Avenues	33 25 533	117 37 625	33 25 606	117 37 714

Table 3. Seaweed wrack on San Clemente beach, at five 500-foot stations, November 2002 through October 2003. Wrack volume in cubic feet per 500-foot station.

Station	**1 San Mat. Point**	**2 State Beach**	**3 Calafia**	**4 San Clem. Pier**	**5 Buena Vista**	**Total (for all 5 stations)**	**Average**
Date	**Amount of seaweed wrack in cubic feet/500 feet of beach**						
11-5-02	36	14	9	6	0	65	13
11-14-02*	72	17	20	35	6	150	30
11-20-02	7	0	6	1	4	18	4
12-3-02	55	5	16	5	0	81	16
12-18-02*	69	11	16	33	0	129	26
1-3-03	7	1	0	2	0	10	2
1-16-03	3	0	1	0	0	4	1
2-1-03	2	3	4	0	0	9	2
2-17-03	4	1	4	1	1	11	2
3-4-03	1	0	1	2	0	4	1
3-19-03	2	1	3	3	0	9	2
4-15-03	31	1	6	3	1	42	8
5-18-03	16	8	16	9	0	49	10
6-18-03	6	2	13	2	1	24	5
7-3-03	9	6	8	1	4	28	6
8-1-03	20	14	49	14	2	99	20
9-11-03	73	9	120	13	39	254	51
10-10-03	9	6	19	216	71	321	64
Totals	422	99	311	346	133	1307	263
Average	**23.4**	**5.5**	**17.3**	**19.2**	**7.4**	**72.7**	**14.6**

* Survey taken within 24 hours of large storms with high waves.

Table 4. Seaweed wrack on San Clemente beach, at five 500-foot stations, qualitative description of seaweed wrack and beach conditions per survey.

Date	**Qualitative description of seaweed wrack and beach conditions/survey**
11-5-02	Moderate amounts (36 ft^3) of *Macrocystis* at San Mateo Point, mostly as clumps of holdfasts and stipes: . No wrack on beach at Buena Vista, and only a little wrack between stations. About 34 ft^3 of wrack north of City Life Guard Station, north of Pier. Low-cut flat sandy beaches only limited small patches of small gravel and small cobble throughout 3.7-mile study area.
11-14-02*	Large wave swell (5-6 feet) was prevalent from 11-9 to 11-13, 2002. Large amount (over 120 ft^3)of kelp wrack observed north of Life Guard Office and at patchy locations throughout the study area. Most of the wrack in the quantitative areas was seen at San Mateo Point (72 ft^3) and the Pier (35 ft^3) – probably the residual of higher wave sets from the previous days. The beach was cut back with no berms or scarps. The low, flat beaches were mostly sand, no areas of gravel and small cobbles.
11-20-02	No big waves in the interval since the last survey. Very small (1-2 feet) waves on the survey day. There was little wrack. The bulk of the kelp wrack during this survey was seen at San Mateo Point (7 cubic feet). Flat low-cut sandy beaches with only limited gravel and small cobble. No real berms or scarps.
12-3-02	Small wave swell over previous interval and on survey day (1-2 feet). Little wrack on beach except at San Mateo Point (55 ft^3). No wrack north of Life Guard Office or at Pier Station. Flat sandy beach throughout entire study area, no gravel or cobble patches; except for a few areas at San Mateo Point..
12-18-02*	Heavy rains and big storm waves over the preceding three days. Persistent 4-6 foot waves at San Clemente over this interval and on the survey day. Very little seaweed on beach north of Pier. Some kelp wrack under Pier (33 ft^3) and moderate wrack at San Mateo Point (69 ft^3). Flat sandy beaches with low/no berms. No gravel and no cobble throughout study areas.
1-3-03	Very little seaweed on beach; some scattered strands of *Egregia* and *Macrocystis*. The exception was at the southerly station, were more wrack was present: San Mateo Point (7 ft^3, wet and dry) and at the Pier (2 ft^3). No berms or scarps, very significant bed-rock exposure at Station 4 - south of Pier - flat sand stone ledges. Little gravel or cobble in quantitative areas. All sandy beach, qualitatively throughout 3.7 mile study area..
1-16-03	Light swell (1-2 feet), and no real kelp wrack in study areas.. The most kelp wrack was at San Mateo Point (3 ft^3). Flat sandy beaches. No berms or scarps. Some gravel and small cobble at MLLW-exposed areas.

2-1-03	Very little kelp wrack was on the study beaches, except at Calafia (4 ft^3), and at State Beach (3 ft^3). Low-cut, sandy beaches, wash right up to rip-rap at high tide in many areas. Some gravel and small cobble patches throughout study areas.
2-17-03	Very little kelp wrack was on the study beaches, except at San Mateo Point (4 ft^3), and at Calafia (4 ft^3). Exposed bedrock at Buena Vista; all sand beaches; but some small patches of gravel and small cobble all along the beaches.
3-4-03	Very little kelp wrack was on the study beach. What was present consisted mainly of blade chunks and broken-off air bladders of *Macrocystis.* The greatest amount of wrack was observed at the Pier (2 ft^3) and San Mateo Point (1 ft^3) and at Calafia (1 ft^3). Some small areas of gravel and small cobbles on a predominantly sandy beach. No berms or scarps on south beaches A 1 foot scarp at Calafia and Buena Vista.
3-19-03*	Large (4-8 feet), choppy (9-10 sec. period) surf/swell conditions the previous three days. Very little kelp wrack was on the beach (9 ft^3, total for entire study area). Mostly all sand beaches. Patches of some gravel and small cobbles at Pier, and some boulders exposed at Calafia and State Beach in the surf and low beach areas (they appear to be from the rip-rap.
4-15-03	Very little kelp wrack was on the study beaches except at San Mateo Point (31 ft^3).. Mostly all sand beaches, very little gravel or cobble. Some exposed rocks and ledges at State Beach. No real berms or scarps.
5-18-03	Very little kelp wrack was on the study beaches. San Mateo Point (16 ft^3) and Calafia (16 ft^3) had the most kelp. Two large kelp plants were wrapped around the Pier pilings (9 ft^3 total). Mostly all sand beaches, very little gravel or cobble. Some exposed rocks and ledges at State Beach. No real berms or scarps.
6-18-03	West swell the preceding 4 days, choppy and 3-5 feet. Little wrack on the beaches. The wrack was somewhat evenly spaced (1 ft^3 to 13 ft^3) throughout the study beach. Calafia had the most (13 ft^3) with most of that in two small clumps. Low-cut sandy beaches, little cobble, very little gravel at the south beaches; but large patches and long exposed beds of gravel along the low-tide areas at Calafia, the Pier, and Buena Vista.
7-3-03	Persistent longer period (12-15 second) swell (3 foot) out of the west and southwest. The beach had little kelp wrack, amounts ranged from 1 ft^3 (at Buena Vista) to 9 ft^3 (at San Mateo Point). The beaches were low-cut and with exposed gravel all along the north end (Buena Vista through the Pier stations, patches of gravel at Calafia, and no gravel-all sand at State Beach and San Mateo Point. .

8-1-03	There was larger (3-4 feet), longer period (12-14 second), swell out of the west over the previous days through the survey day. Large** and small*** clumps of *Macrocystis* totaling 210 ft^3 in the area between Buena Vista and the Pier (about 500 feet upcoast of the Life Guard Office) was observed, mostly on the upper (back) beach area. The scattered adult *Macrocystis* plants were common all along the beach, and their holdfasts were typically less than 1 foot in diameter, and multiple - tangled into tight balls. This material was on the back-berm beach, typically. The beach was low-cut and with intermittent exposed gravel.
9-11-03	There was some moderate (3-4 feet, 10-13 second) west swell coming in between September 8 and 11. The greatest amount of kelp wrack was present at Calafia (120 ft^3), followed by the Pier (73 ft^3), followed by the wrack was collecting just north of the Life Guard Office (48 ft^3). Most of the wrack was again *Macrocystis* in scattered clumps, in the 4 to 8 foot range. All sand beaches, no gravel, no cobble. Moderate (1-3 ft.) new berm and vertical scarp at San Mateo, no scarps/berms further north.
10-10-03	This survey had the most kelp wrack of this fourth year of study (321 ft^3, total over the five quantitative areas; verses the second biggest day, 9-1-2003 with 254 ft^3). Yet, 206 ft^3 of this wrack was found on the Pier pilings and inspection of this wrack revealed that it was *Macrocystis* drifters, large holdfasts with curling haptera. In the qualitative areas, large and small clumps of adult *Macrocystis* were again seen throughout the north study areas: 144 ft^3 between Beuna Vista and the Pier stations, and 305 ft^3 between the Pier and Calafia. No kelp wrack was seen between State Beach and San Mateo Point. Sloped and flat sandy beaches, no gravel and no cobble, along the entire survey area.

* Survey taken within 24 hours of large storm with high waves.

** A “large clump” is considered anything over 2 cubic feet in estimated volume.

*** A “clump” or “small clump” is between 0.5 and 2.0 cubic feet.

Note: individual *Macrocystis* or *Egregia* plants as well as clumps are characterized in cubic feet.

Table 5. Average monthly kelp wrack at San Clemente Pier (1954-1956), in cubic feet per 500-foot beach section (from ZoBell, 1959).

Month	**Average per month (1954-56) in cubic feet per 500-foot length of beach**
January;	55
February	10
March	10
April	10
May	10
June	65
July	206
August	73
September	98
October	128
November	225
December	82
Grand average per monthly period for all observations	**92**

Table 6. Monthly range and monthly average amounts of drift seaweed on 14 northern San Diego County beaches, 1954-1956, as surveyed by ZoBell (1959).

500-Foot Station Location and Station #	Monthly range of seaweed wrack in cubic feet	Monthly average for seaweed wrack in cubic feet
Laguna Beach, 49	7 to 680	221
Dana Point, 48	10 to 410	87
Doheny Park Beach, 47	10 to 1,581	421
Capistrano Strand, 46	5 to 153	60
San Clemente Beach, 45	10 to 225	92
San Onofre Beach, 44	10 to 1,106	430
North Leucadia, 43	20 to 330	130
Moonlight – Encinitas, 42	33 to 631	233
N. Cardiff-by-the-Sea, 41	23 to 2,097	353
S. Cardiff-by-the-Sea, 40	100 to 628	336
N. Solana Beach, 39	8 to 467	108
S. Solana Beach, 38	10 to 407	168
Del Mar, 37	37 to 260	116
Torrey Pines, 36	25 to 292	119
	Grand Monthly Average:	**205**

Table 7. Average monthly kelp wrack at San Clemente Pier (1954-1956), in cubic feet per 500-foot beach section (from ZoBell, 1959) verses kelp wrack data at San Clemente Pier, 1999-2000, 2000-2001, 2001-2002, and 2002-2003.

Month	**Monthly average (1954-1956) in cubic ft. / 500-foot length of beach**	**Nov 1999- Oct. 2000, kelp wrack, San Clement Pier**	**Nov, 2000- Oct. 2001, kelp wrack, San Clemente Pier**	**Nov, 2001- Oct. 2002, kelp wrack, San Clemente Pier**	**Nov, 2002- Oct. 2003, kelp wrack, San Clemente Pier**
November	225	10	6	30	14
December	82	0	5	13	19
January;	55	1	13	2	1
February	10	0	4	1	1
March	10	3	6	13	3
April	10	4	77	11	3
May	10	3	46	35	9
June	65	0	13	8	2
July	206	17	10	37	1
August	73	1	99	39	14
September	98	9	32	37	13
October	128	4	38	24	216
Overall Monthly Average at Pier	**92**	**4**	**29**	**21**	**25**

Table 8. Average monthly kelp wrack at San Clemente Pier (1954-1956), in cubic feet per 500-foot beach section (from ZoBell, 1959) verses kelp wrack data averaged from all five San Clemente Stations, 1999-2003.

Month	**Monthly average (1954-1956) in cubic ft. / 500-foot length of beach**	**Nov 1999- Oct. 2000, kelp wrack at all five San Clemente stations**	**Nov 2000- Oct. 2001, kelp wrack at all five San Clemente stations**	**Nov 2001- Oct. 2002, kelp wrack at all five San Clemente stations**	**Nov 2002- Oct. 2003, kelp wrack at all five San Clemente stations**
November	225	6	19	10	16
December	82	5	4	11	21
January;	55	1	9	14	2
February	10	3	9	3	2
March	10	2	4	9	2
April	10	3	35	8	8
May	10	11	22	17	10
June	65	10	13	28	5
July	206	4	7	22	6
August	73	7	34	21	20
September	98	5	19	22	51
October	128	15	13	32	64
Overall Monthly Average per period for all observations	**92**	**5**	**14**	**15**	**17**

Figure 1. The San Clemente Experimental Artificial Reef is scattered offshore of the San Clemente Beach between the San Clemente Pier to the north and San Mateo Point to the south. The Reef consists of 56 - 132 ft x 132 ft low relief modules in 40 to 50 feet of water, about ½ mile offshore of the beach. The Reef fronts about 2 ½ miles of beach

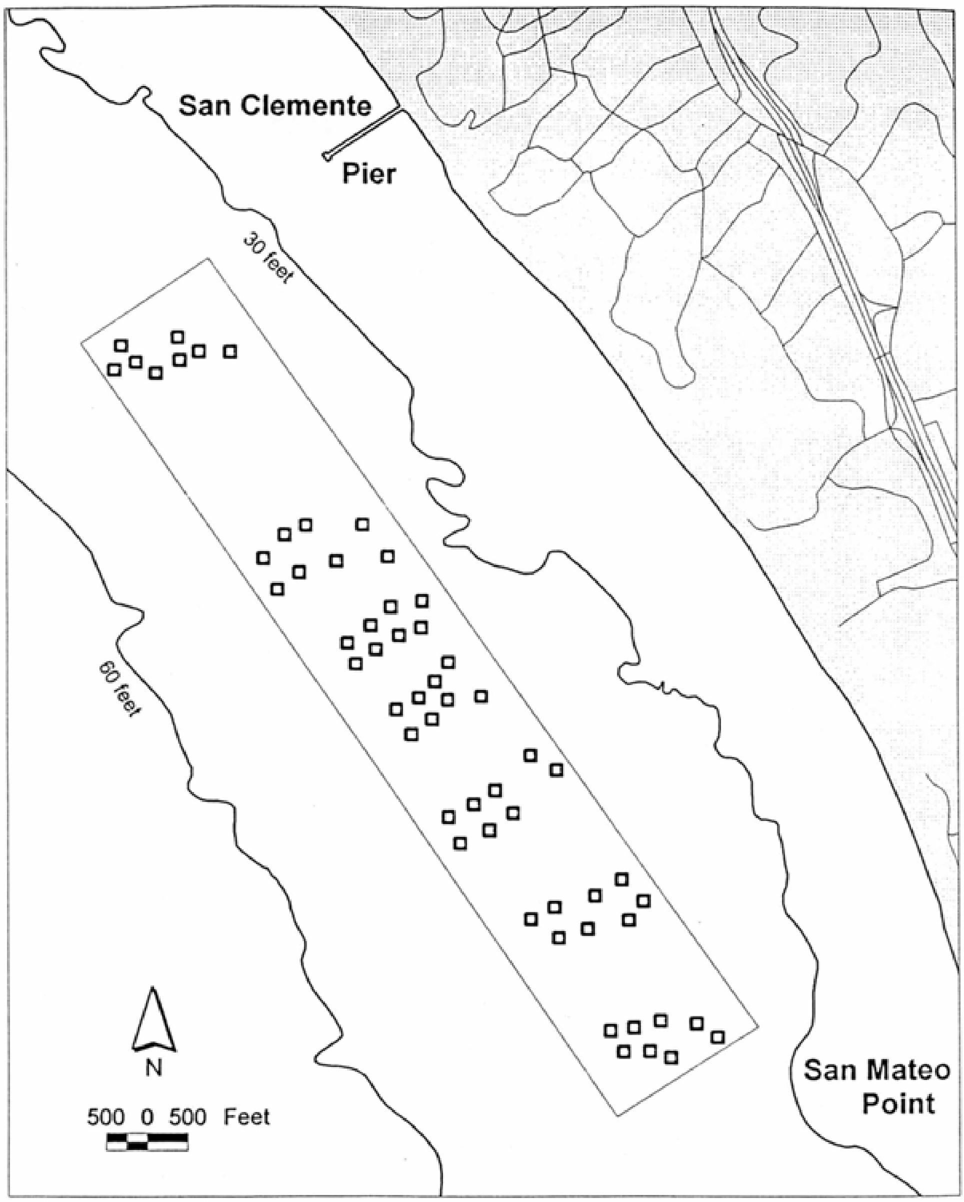


Figure 2. Oceanside Littoral Cell. Runoff from rainfall on the coastal hills behind San Clemente collects in small intermittent drainage streams and discharges into the ocean at a number of locations along the beach. The three larger nearby streams are San Juan Creek to the north, and San Mateo Creek and San Onofre Creek to the south.

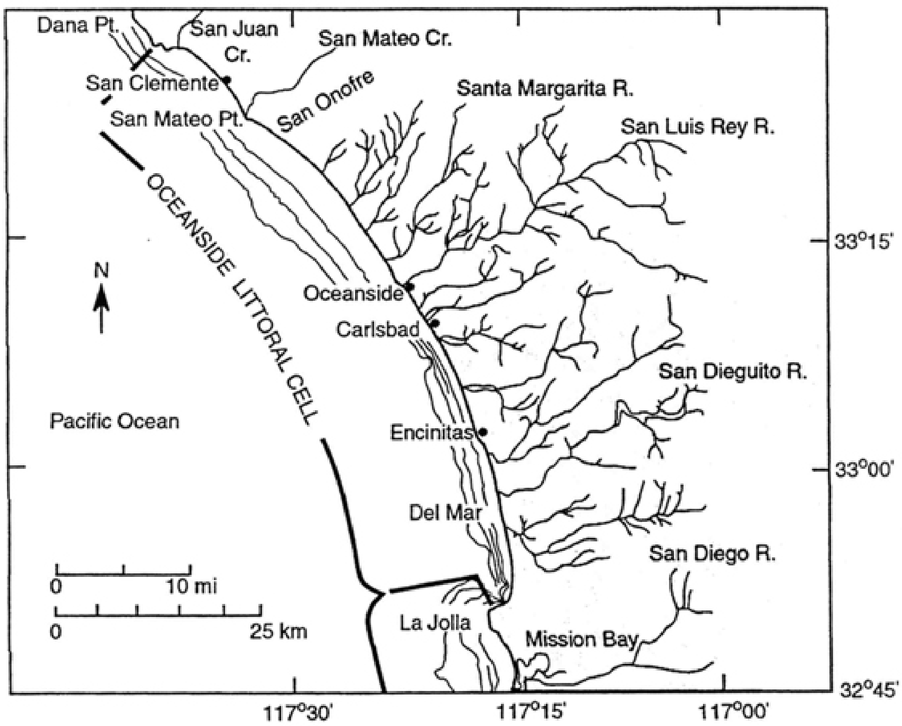


Figure 3.. Wave exposure for San Clemente schematically illustrating island shadowing effects. Note two large shadows at San Clemente; one from the southwest due to San Clemente Island and the second from the west because of Santa Catalina. Modified from Pawka and Guza (1983), and Army Corps of Eng. (1989).

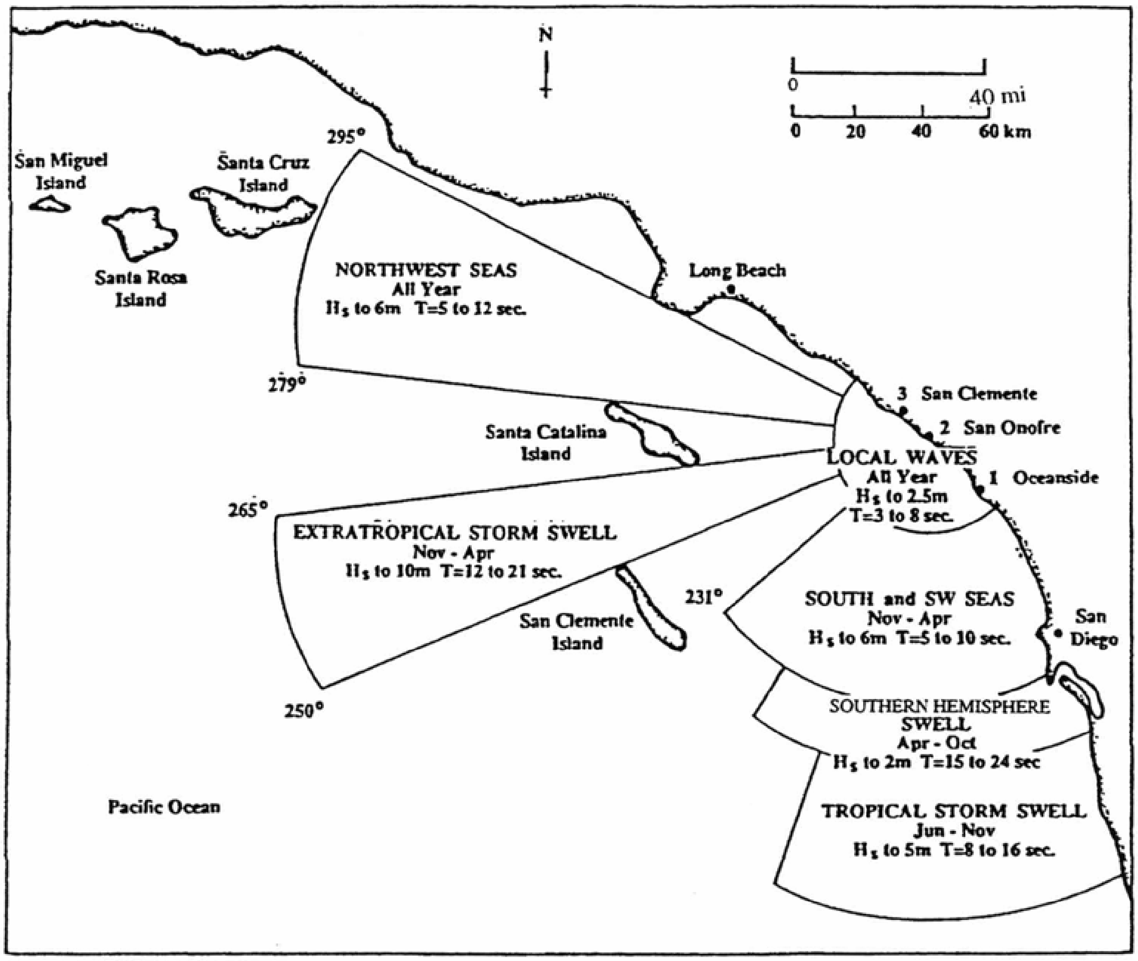


Figure 4. Location of the five permanent 500-foot transects for the quantitative assessment of kelp in the San Clemente study area

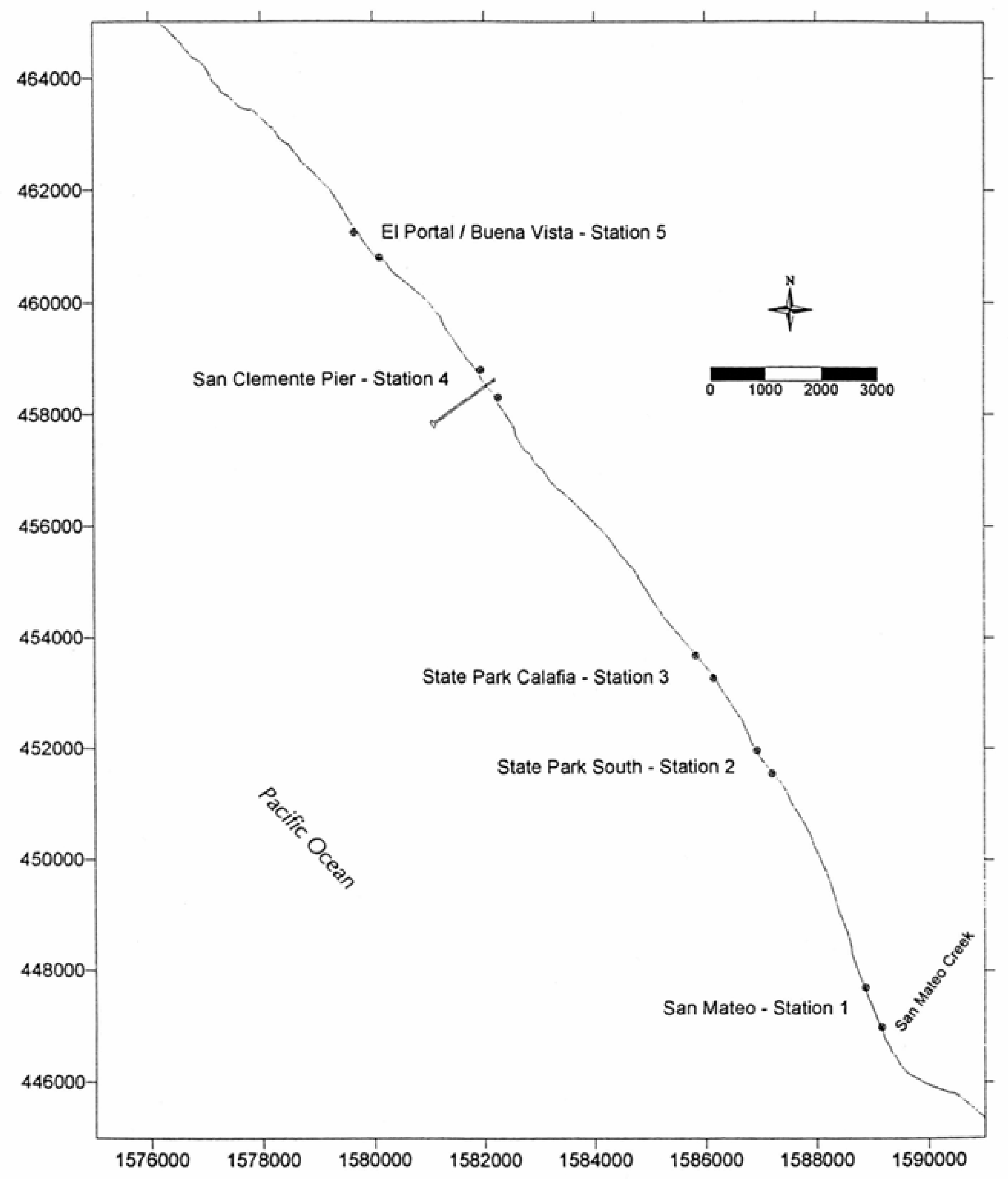


Figure 5: A large amount of kelp wrack, 210 ft^3, observed on August 1, 2003, along a 500 foot stretch of beach north of the San Clemente Pier and south of Buena Vista.

Figure 6: A large amount of kelp wrack, 48 ft^3, observed on September 11, 2003, along a 500 foot stretch of beach north of the San Clemente Pier and south of Buena Vista

Figure 7: A large amount of kelp wrack, 144 ft^3, observed on October 10, 2003, along a 500 foot stretch of beach north of the San Clemente Pier and south of Buena Vista.

Figure 8: A large amount of kelp wrack, about 100 ft^3, observed on August 1, 2002, along a 500 foot stretch of beach north of the San Clemente Pier and south of Buena Vista.

Figure 9. An example of kelp wrack that is an adult kelp plant with a curled and bleached holdfast, indicating the plant has been drifting in a kelp paddy for some length of time before washing up onto the beach. From San Clemente, June 27, 2002

Figure 10. An example of kelp wrack that is an adult kelp plant with slightly curled and bleached holdfast, indicating the plant may have drifted in a kelp paddy for some length of time before washing up onto the beach. From area upcoast of San Clemente Pier, December 3, 2002.

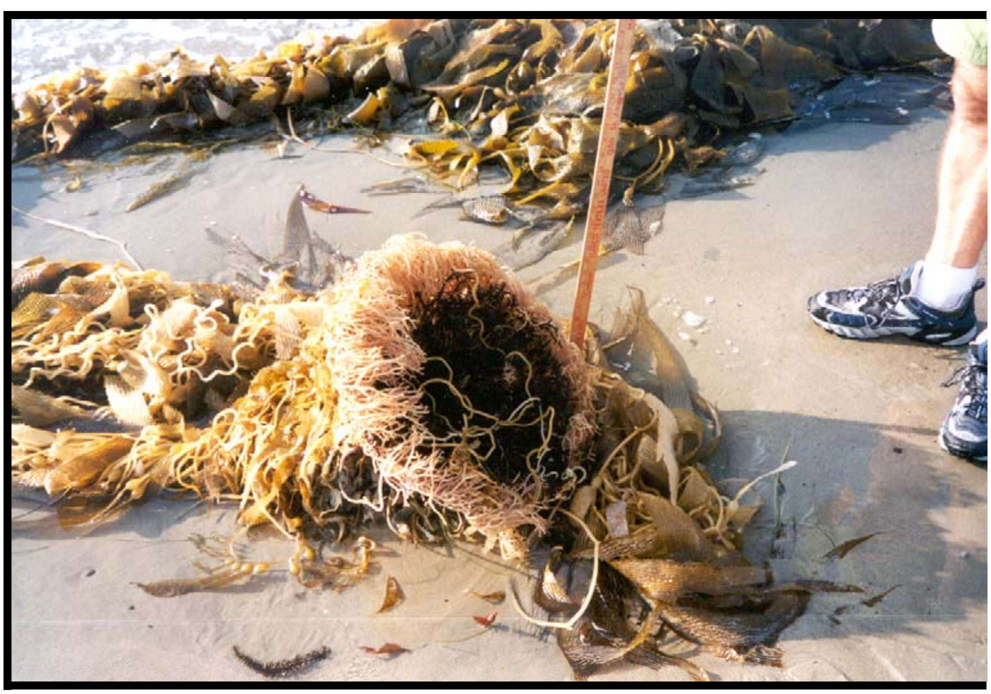


Figure 11. An example of kelp wrack that is an adult kelp plant with a very flat holdfast, indicating the plant may have recently dislodged from a nearby flat natural or artificial reef before washing up onto the beach. From San Mateo Point, September 11, 2003

Figure 12a. Kelp wrack holdfast ripped away from mudstone; at Pier, Station #4, 9/7/02

Figure 12b:Example of kelp wrack with holdfast attached to mudstone and shell fragment. From State Beach, Station #2,3/11/02

Figure 13a. Example of kelp wrack with holdfast attached to a small cobble. From State Beach, Station #2, 3/26/02

Figure 13b. Kelp wrack close-up showing holdfasts on shells and small cobbles. From Calafia, Station #3, 8/1/02.

Figure 14. 8/1/02. San Mateo Survey Station #1, kelp wrack showing clump of large *Macrocystis* plants with 1-3 ft. holdfasts

Figure 15a. Example of kelp wrack with holdfasts with flat bottoms. From State Beach, Station #2, 6/27/02

Figure 15b. Example of kelp wrack holdfasts. Large holdfast has flat bottom. Small holdfast still attached to a rock. Near Station #2, State Beach, 7/12/02

Figure 16: Boulders, flat bedrock, and granite rip-rap that is periodically exposed and buried by beach sand along the area between the San Clemente Pier and Buena Vista. November 14, 2002

Figure 17: Natural flat bedrock ledges at State Beach survey area. February 17, 2003

Figure 18: Beach Clean-up Activity at the Municipal Pier, May 18, 2003, 6:00 am.

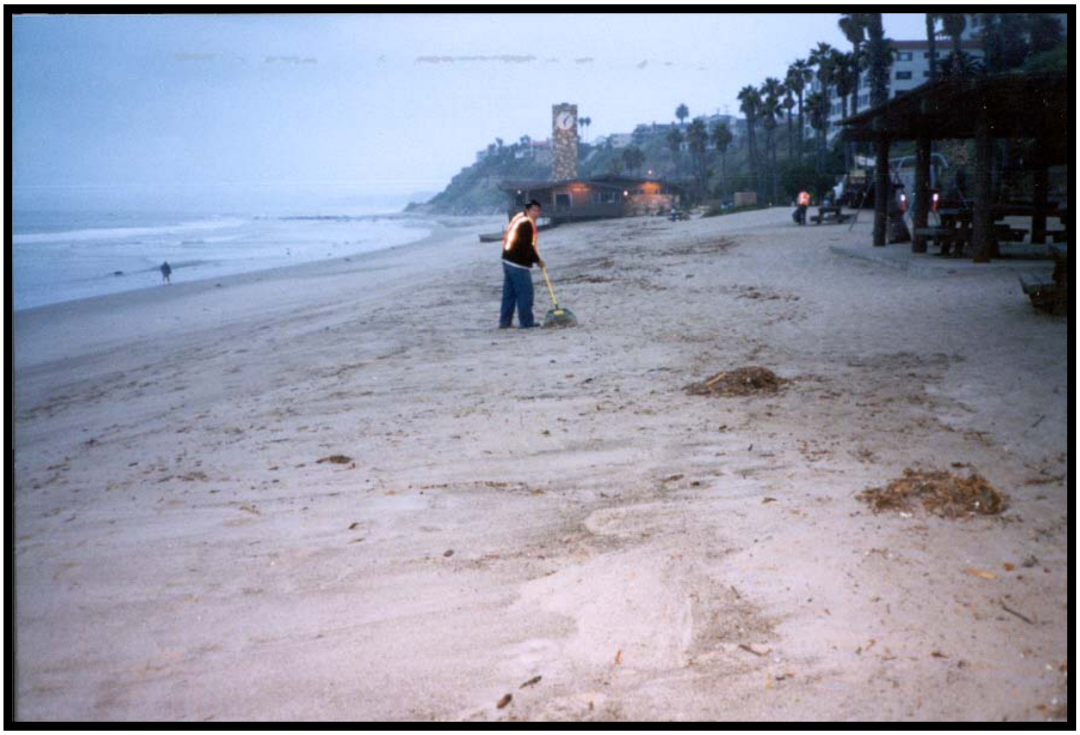


Figure 19. Location of beach Stations 36 to 49 from Laguna Beach, north, to Torrey Pines State Park, south. The area kelp beds are noted by encircled numerals. From ZoBell, 1959

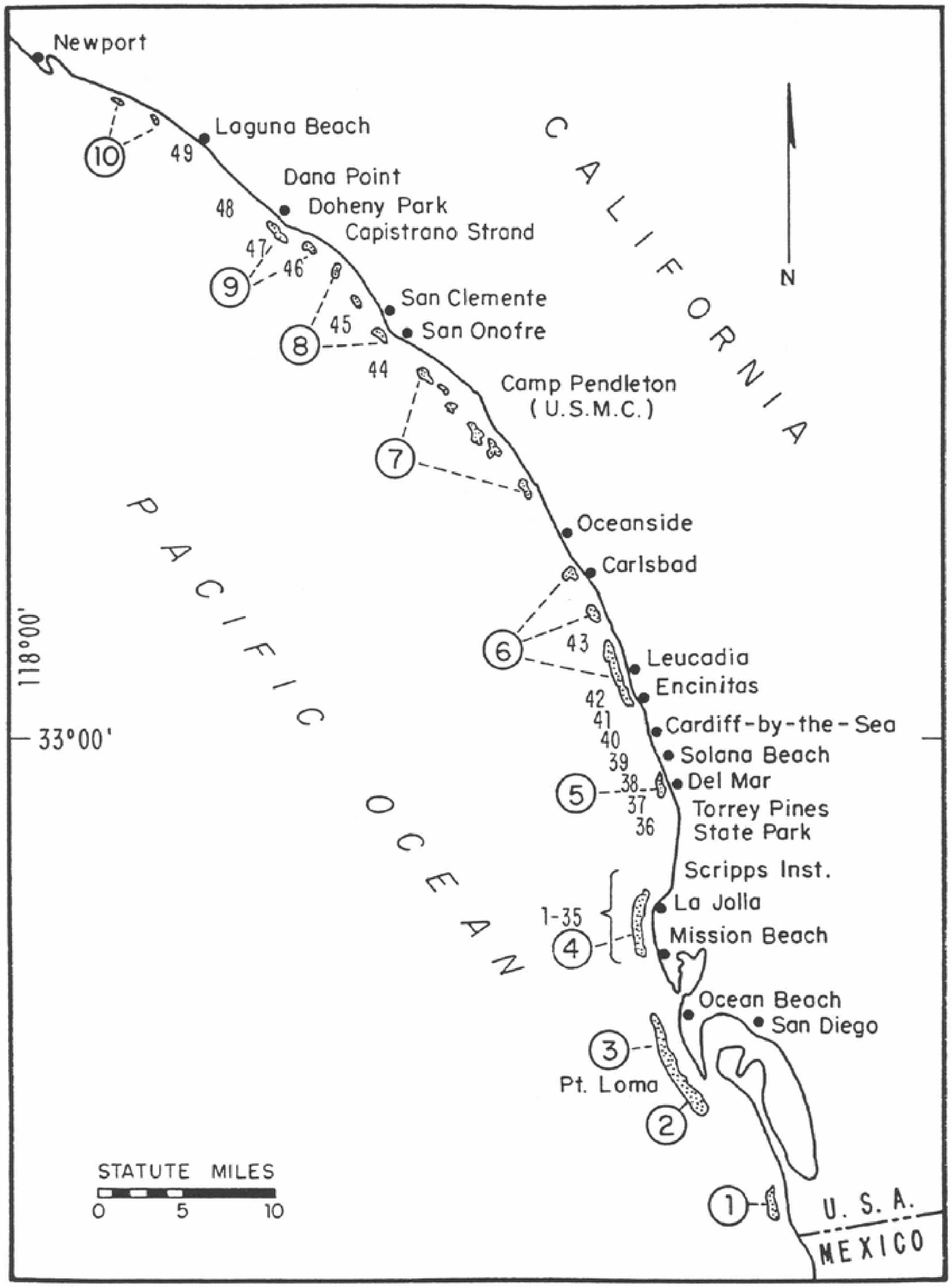


Figure 20. Changes in beach conditions and seaweed wrack at Doheny State Park from 1954-1956 showing from 10 to 2,150 cubic feet of drift seaweed per 500-foot beach frontage (from ZoBell, 1959).

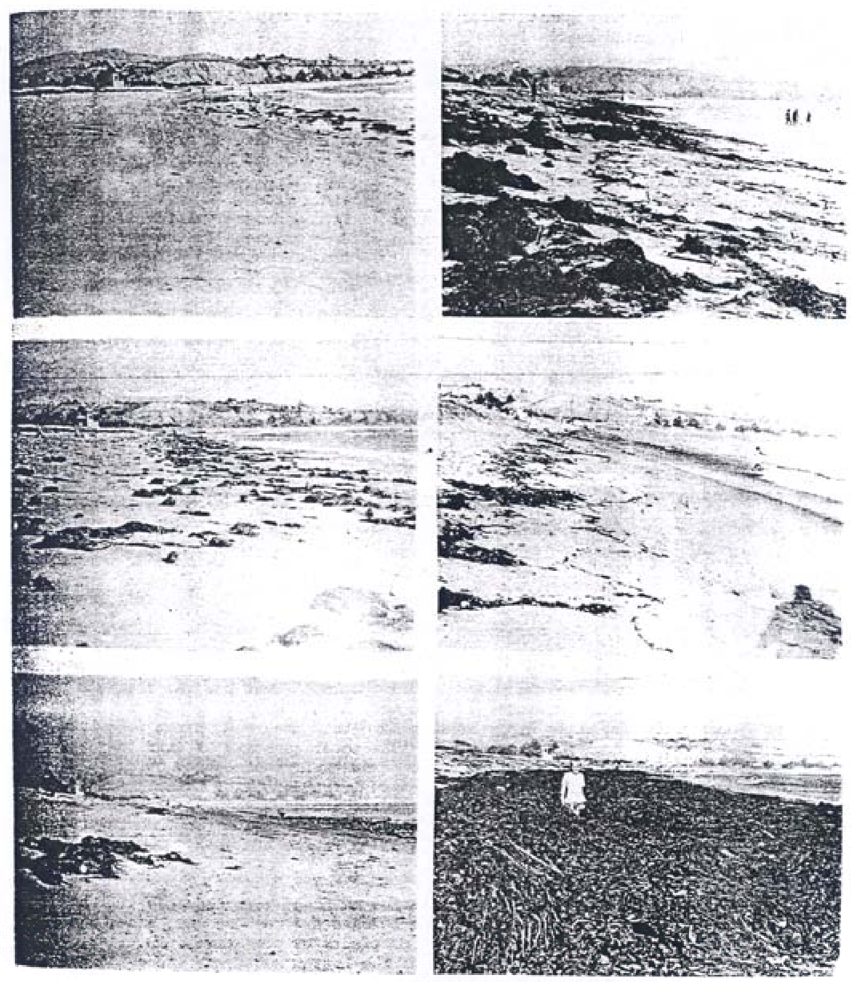


Figure 21. Seaweed wrack under the Scripps Institution of Oceanography Pier in December 1945 (from ZoBell, 1959)

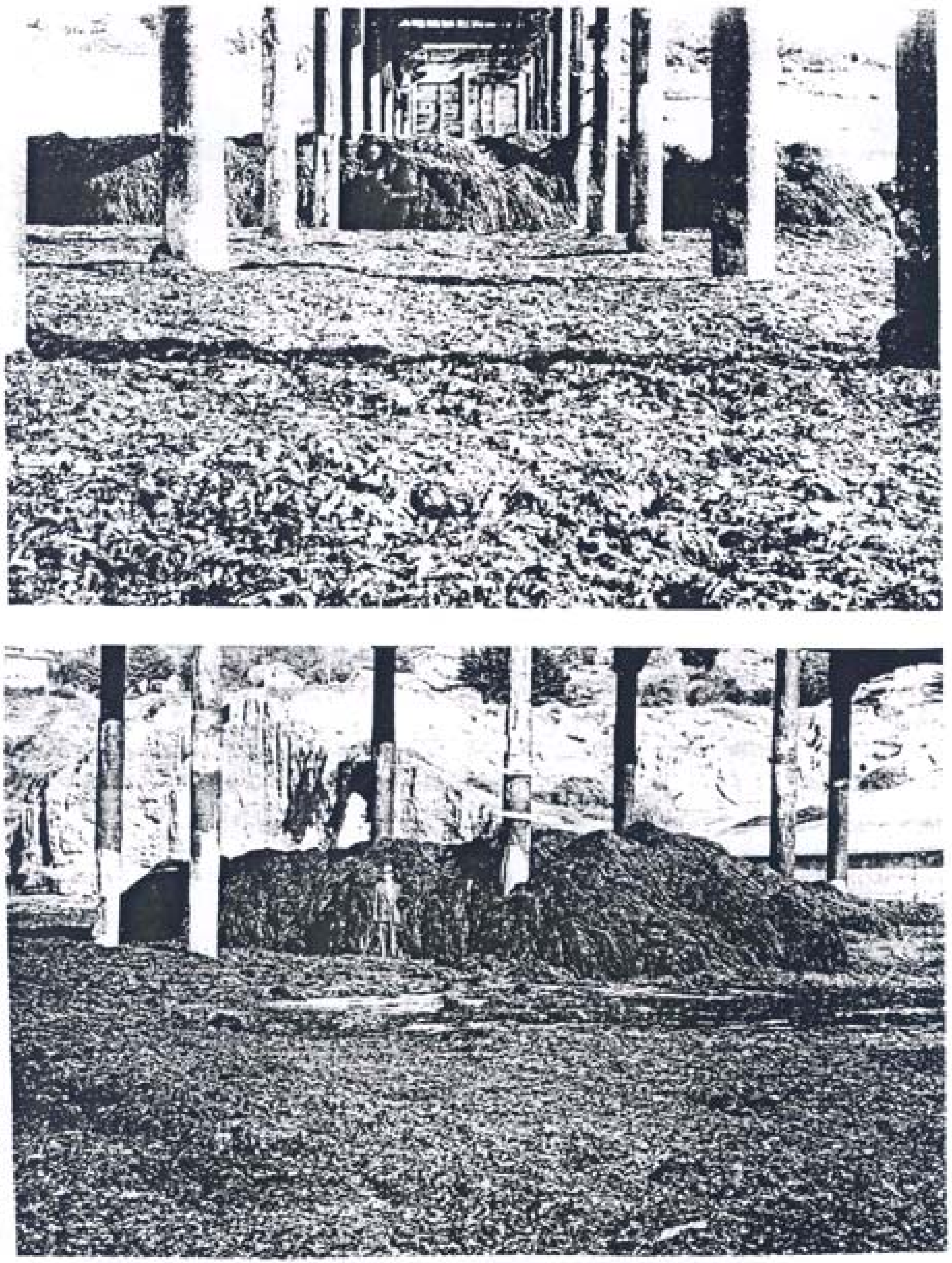
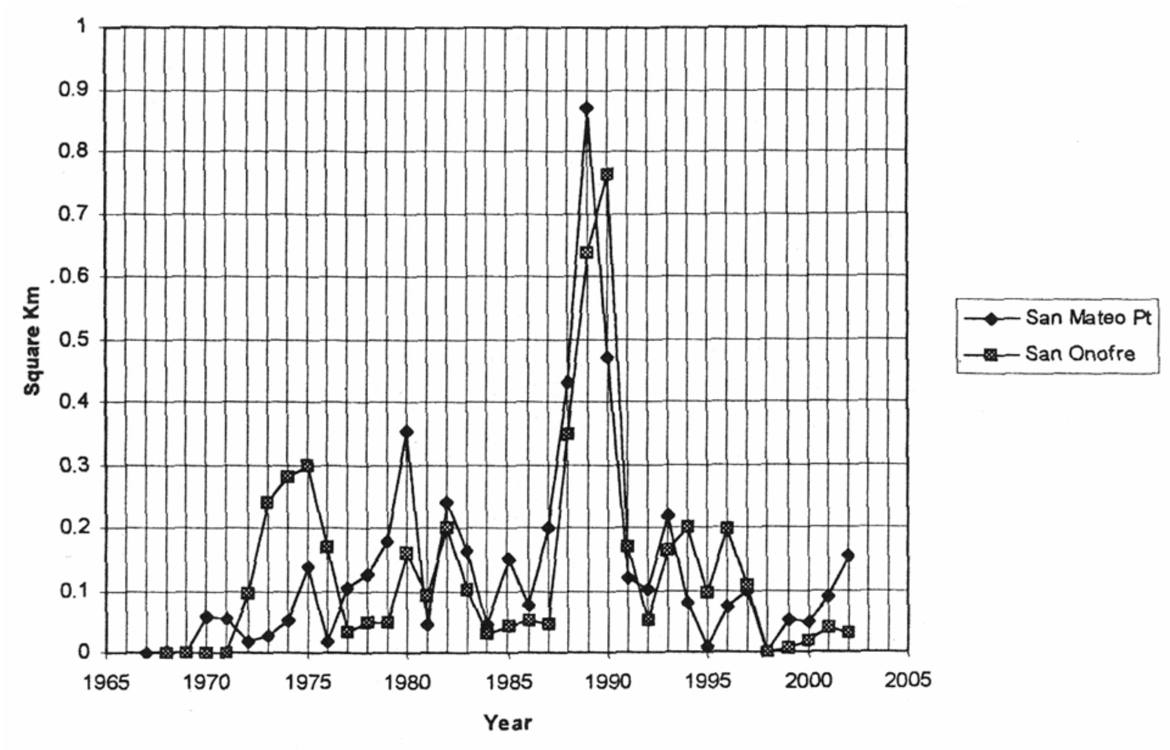


Figure 22. Kelp canopy coverages from 1967 through 2002 at the San Mateo Point and San Onofre Kelp Beds, in km². Values represent approximately the maximum coverages for each year as recorded from aerial infrared photographs, by the Region Nine Kelp Survey Consortium (adapted from MBC, 2004).



Appendix A: Photographs of the San Clemente Beach Survey Stations, Typical Conditions, November 2002 through October 2003

11/5/02

San Mateo

Survey Station #1,

at north end looking south (36 cu. ft. of kelp wrack per 500 ft.).

11/5/02

San Mateo

Survey Station #1,

at south end looking north (36 cu. ft. of kelp wrack per 500 ft.).

11/5/02

San Clemente

Survey Station #4,

at north end looking south (6 cu. ft. of kelp wrack per 500 ft.).

11/14/02

San Mateo

Survey Station #1,

at south end looking south (72 cu. ft. of kelp wrack per 500 ft.).

11/14/02

Calafia

Survey Station #3,

at north end looking south (20 cu. ft. of kelp wrack per 500 ft.).

11/14/02

Buena Vista

Survey Station #5,

at north end looking south (6 cu. ft. of kelp wrack per 500 ft.).

	11/20/02 San Mateo Survey Station #1, at south end looking north (7 cu. ft. of kelp wrack per 500 ft.).
	11/20/02 Calafia Survey Station #3, at north end looking south (6 cu. ft. of kelp wrack per 500 ft.)
	11/20/02 Buena Vista Survey Station #5, at north end looking toward rip rap (8 cu. ft. of kelp wrack per 500 ft.).

	12/3/02 San Clemente / Buena Vista Between Survey Stations 4 & 5 kelp wrack, macrocystis with large holdfast (9 cu. ft. of kelp wrack per 500 ft.).
	12/3/02 State Beach Survey Station #2, at north end looking south (5 cu. ft. of kelp wrack per 500 ft.).
	12/3/02 Calafia Survey Station #3, at north end looking south (16 cu. ft. of kelp wrack per 500 ft.).

12/18/02

San Mateo

Survey Station #1,

at north end looking south (69 cu. ft. of kelp wrack per 500 ft.).

12/18/02

Calafia

Survey Station #3,

at north end looking south (16 cu. ft. of kelp wrack per 500 ft.).

12/18/02

San Clemente

Survey Station #4,

at north end looking south (33 cu. ft. of kelp wrack per 500 ft.).

1/3/03

State Beach

Survey Station #2,

at north end looking south
(1 cu. ft. of kelp wrack
per 500 ft).

1/3/03

Calafia

Survey Station #3,

at north end looking south
(0 cu. ft. of kelp wrack
per 500 ft).

1/3/03

Buena Vista

Survey Station #5,

at north end looking south
(0 cu. ft. of kelp wrack
per 500 ft.)

1/16/03

San Mateo

Survey Station #1,

at south end looking north
(3 cu. ft. of kelp wrack
per 500 ft.).

1/16/03

State Beach

Survey Station #2,

at south end looking north
(0 cu. ft. of kelp wrack
per 500 ft.).

1/16/03

Buena Vista

Survey Station #5,

at north end looking south
(0 cu. ft. of kelp wrack
per 500 ft.).

	2/1/03 San Mateo Survey Station #1, at north end looking south (2 cu. ft. of kelp wrack per 500 ft.).
	2/1/03 State Beach Survey Station #2, at mid point looking north (3 cu. ft. of kelp wrack per 500 ft.).
	2/1/03 San Clemente Survey Station #4, at south end looking north (0 cu. ft. of kelp wrack per 500 ft.)

2/17/03

San Mateo

Survey Station #1,

at north end looking south

(4 cu. ft. of kelp wrack per 500ft.)

2/17/03

Calafia

Survey Station #3,

at north end looking south

(4 cu. ft. of kelp wrack per 500 ft.).

2/17/03

San Clemente

Survey Station #4,

at south end looking north

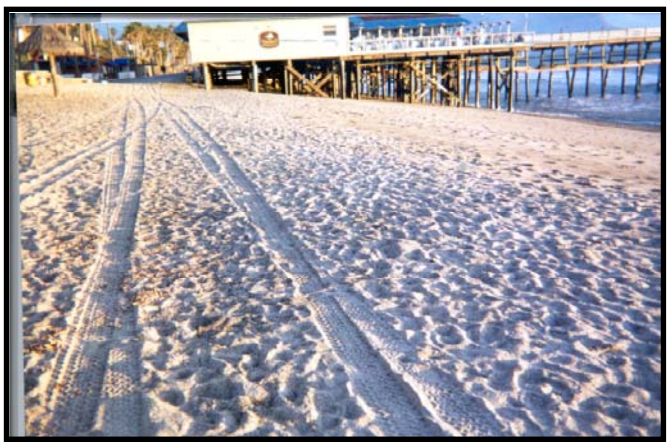
(1 cu. ft. of kelp wrack per 500 ft.).

3/4/03

Calafia

Survey Station #3,

at north end looking south
(1 cu. ft. of kelp wrack
per 500 ft.).



3/4/03

San Clemente

Survey Station #4,

at north end looking south
(2 cu. ft. of kelp wrack
per 500 ft.).

3/4/03

Buena Vista

Survey Station #5,

at north end looking south
(0 cu. ft. of kelp wrack
per 500 ft.).

	3/19/03 San Mateo Survey Station #1, at north end looking south (2 cu. ft. of kelp wrack per 500 ft.).
	3/19/03 Calafia Survey Station #3, at north end looking south (3 cu. ft. of kelp wrack per 500 ft.).
	3/19/03 San Clemente Survey Station #4, at south end looking north (3 cu. ft. of kelp wrack per 500 ft.).

4/15/03

San Mateo

Survey Station #1,

at south end looking north
(31 cu. ft. of kelp wrack
per 500 ft.).

4/15/03

State Beach

Survey Station #2,

at north end looking south
(1 cu. ft. of kelp wrack
per 500 ft.).

4/15/03

San Clemente

Survey Station #4,

at north end looking south
(3 cu. ft. of kelp wrack
per 500 ft.)

	5/18/03 San Mateo Survey Station #1, at south end looking north (16 cu. ft. of kelp wrack per 500 ft.).
	5/18/03 Calafia Survey Station #3, at north end looking south (16 cu. ft. of kelp wrack per 500 ft.)
	5/18/03 Buena Vista Survey Station #5, at north end looking south (0 cu. ft. of kelp wrack per 500 ft.).

6/18/03

San Mateo

Survey Station #1,

at south end looking north
(6 cu. ft. of kelp wrack
per 500 ft.).

6/18/03

State Beach

Survey Station #2,

at north end looking south
(2 cu. ft. of kelp wrack
per 500 ft.).

6/18/03

Calafia

Survey Station #3,

at north end looking south
(13 cu. ft. of kelp wrack
per 500 ft.).

	7/3/03 San Mateo Survey Station #1, at north end looking south (9 cu. ft. of kelp wrack per 500 feet.).
	7/3/03 State Beach Survey Station #2, at south end looking north (6 cu. ft. of kelp wrack per 500 ft.).
	7/3/03 Buena Vista Survey Station #5, at north end looking south (4 cu. ft. of kelp wrack per 500 ft.).

8/1/03

State Beach

Survey Station #2,

at north end looking south (14 cu. ft. of kelp wrack per 500 ft.).

8/1/03

Calafia

Survey Station #3,

at north end looking south (49 cu. ft. of kelp wrack per 500 ft.).

8/1/03

Buena Vista

Survey Station #5,

at north end looking south (2 cu. ft. of kelp wrack per 500 ft.).

9/11/03

San Mateo

Survey Station #1,

at south end looking north

(73 cu. ft. of kelp wrack
per 500 ft.).

9/11/03

State Beach

Survey Station #2,

at north end looking south
(9 cu. ft. of kelp wrack
per 500 ft.).

9/11/03

Calafia

Survey Station #3,

at north end looking south

(120 cu. ft. of kelp wrack
per 500 ft.).

	10/10/03 San Mateo Survey Station #1, north end looking south (9 cu. ft. of kelp wrack per 500 ft.).
	10/10/03 Calafia Survey Station #3, at north end looking south (19 cu. ft. of kelp wrack per 500 ft.).
	10/10/03 Buena Vista Survey Station #5, looking north (71 cu. ft. of kelp wrack per 500 ft.).

Appendix B: Newspaper Articles, San Clemente Beach

DON BARTLETTI / Los Angeles Times

Three 12-year-old friends use a kelp stem as a jump rope at La Jolla Shores Beach in San Diego. Clumps of the marine plant wash ashore and cover eggs that grunion lay this time of year. Beach raking has been halted until mid-September.

San Diego Hatches Plan to Protect Grunion Spawning Sites at Beaches

Environment: The city suspends the rigorous grooming that has kept sand pristine while its effect on the species' eggs—laid in the sand—is studied.

By TONY PERRY
TIMES STAFF WRITER

SAN DIEGO—Beaches are serious stuff here, both for the sun-drenched lifestyle of locals and for the millions of tourists who keep the economy afloat.

"Beaches are at the core of San Diego's identity," said Councilman Scott Peters.

For more than three decades, San Diego has had an aggressive program of daily raking, cleaning and grooming its 17 miles of beaches, particularly the most popular: Ocean Beach, Pacific Beach, Mission Beach and La Jolla.

Other cities along the Southern California coast may care for their beaches, but none more extensively or obsessively than San Diego. Key to its cleanup efforts is the daily removal of copious amounts of rubbery greenish-brown kelp that floats ashore.

But now questions are being raised about whether the mechanized raking has disturbed the shorefront ecology, particularly affecting those silvery fish called grunion (*Leuresthes tenuis*) that make periodic spawning runs on to the beach.

Grunion lay eggs in and around the kelp; critics claim that raking the beach kills some egg masses and leaves others without protection from the tides.

After several citizen complaints—particularly from Pat Gallagher, 72, a veteran diver and beach activist—the city's Park and Recreation Department in May imposed a moratorium on the raking of kelp until mid-September, the traditional end of grunion spawning season.

Meanwhile, a blue-ribbon committee, with members including scientists from UC San Diego and the Scripps Institution of Oceanography, has been asked to determine whether the raking is hurting the grunion and other creatures.

"The problem is that nobody knows for sure," said Ted Medina, head of the coastal parks division of the Park and Recreation Department. "Everybody has anecdotes, but nobody has done a count of the grunion."

This week, as spawning grunion flop and slither on the beach in response to a nighttime full-moon high tide, committee members will be there to gather some of the first grunion data of its kind.

Gallagher, whose complaints went unheeded for decades, thinks she knows the answer.

"When I was a kid, you could stand on the beach under the moonlight and see nothing but grunion as far south and north as you could see," Gallagher said. "Now it's pitiful. A sensible person knows we've virtually destroyed the grunion."

Although the grunion spawn on several beaches in Southern California, only in San Diego has the combination of kelp, fish and beach maintenance turned into a political issue. One reason may be that the raking here is especially vigorous.

Each year the city rakes up more than 20,000 cubic yards of kelp from its beaches and carts it to Fiesta Island to dry. Just how many grunion eggs may be destroyed in the process is unknown.

What is known, however, is that left undisturbed, kelp will deteriorate and begin to stink and draw flies. Smelly and fly-ridden beaches are a tourist turnoff.

Though the visitors' bureau has yet to record anyone canceling a San Diego vacation because of the kelp buildup, visitors have been quick to notice that something is different this year.

"We've been coming to San Diego for 20 years, and I've never seen it or smelled it like this," said Phyllis Hale of Phoenix, supervising her two children at popular South Mission Beach. "This isn't the San Diego we love."

Park and Recreation Department workers continue to clean litter and dead birds and other flotsam from the beaches. But removing kelp below the mean high-tide line has been put in abeyance.

The city committee has invited Jenny Dugan, a researcher in the Marine Science Institute at UC Santa Barbara, to join its kelp-raking study. Since 1996, Dugan has been studying the effect of beach grooming in Santa Barbara and Ventura counties.

Her preliminary studies show that grooming significantly decreases the population of insects and crustaceans and of shore birds, such as the snowy plover, that lay their eggs on shore. Her working thesis is that the same is true for the grunion of San Diego.

"I think the effect is probably very large because of the level of grooming," Dugan said. "I'm not here to say that you shouldn't groom the beaches, just that you should know the impact."

Beaches are a contentious political issue in San Diego and, so far, no consensus has formed on the City Council regarding kelp.

Councilman Byron Wear wants to resume raking except for those few days during a run. "We must be doing something right," he said. "The grunion keep coming."

But a colleague has suggested stopping the raking altogether and letting the tide carry away the kelp. "Maybe we should trust Mother Nature, rather than bulldozers," said Councilwoman Donna Frye.

Medina of the coastal parks division ordered the raking halted after the kelp-grunion issue was discussed at a council meeting.

"Before that, grunion were not on my radar," Medina said. "Now they are, although in unknown numbers."

[PARA]San Diego calls off the rakes; kelp will be left from surf to tide line[PARA]By Terry Rodgers [NL]UNION-TRIBUNE STAFF WRITER [PARA]July 12, 2001 [PARA]San Diego's beaches will have more brine flies and rotting kelp -- maybe not an attraction for sun worshipers but good news for the grunion. [PARA]For the first time, city maintenance crews this week have stopped raking the city's sandy beaches below the high-tide line, to avoid disturbing areas where grunion spawn. [PARA]Kelp won't be raked and removed from the water's edge until grunion spawning season ends in early September, said Ted Medina, San Diego's coastal parks chief. City crews will still remove marine mammal carcasses, trash and dangerous debris. [PARA]Although the move probably means more tiny flies and smell from deteriorating kelp, it reflects a changing attitude about the effects of beach cleaning on the shoreline ecosystem. [PARA]Medina said he's unaware of any scientific studies proving that kelp raking harms grunion eggs. But he agreed to modify routine beach maintenance after concerns were raised by Mission Beach activist Pat Gallagher. [PARA]"We would rather err on the side of caution," Medina said. [PARA]A butter knife-sized fish native to Southern California, grunion are unusual in that they hop ashore during high tides between late February to early September to bury their eggs in the sand. [PARA]While parks officials worry the buildup of kelp may trigger complaints from tourists and other beachgoers, environmentalists applaud the city's decision. [PARA]"We ought to be real conservative until we know what we're doing" to the grunion, said Jim Peugh, spokesman for the San Diego Audubon Society. [PARA]Local beaches that once hosted grunion spawning runs in the tens of thousands today have only spotty runs of a few hundred, if any, according to Gallagher. She is a pioneer female free diver who said she learned about the fish from the late Carl Hubbs, a marine scientist with Scripps Institution of Oceanography. [PARA]Gallagher believes sand raking disturbs grunion eggs during their delicate incubation period and exposes them to hungry shorebirds. [PARA]Also, removal of kelp robs the shoreline of a critical food source for intertidal creatures from sand crabs to sandpipers, she said. [PARA]"San Diego will be faced with having a dead beach if this (sand) plowing continues," Gallagher told city officials. [PARA]The effects of beach grooming haven't been widely studied, but recent surveys by UC Santa Barbara researcher Jenny Dugan indicate sand maintenance activities could be altering the shoreline ecosystem. Beach surveys begun by Dugan in 1996 in Santa Barbara and Ventura counties show that beach grooming decreases the overall biomass and abundance of invertebrates such as insects and crustaceans. [PARA]"A lot of small things that feed on kelp are affected," said Dugan. "What grooming does is take away one whole branch of the food web." [PARA]In addition to reducing the biodiversity of shoreline life, grooming also eliminates dune plants that enhance beaches' ability to withstand wind and water erosion, she said. [PARA]Dugan, a researcher at UCSB's Marine Science Institute, recently received a grant for a two-year study of the effects of beach grooming on the ecology of the shoreline in San Diego County. [PARA]Approximately 100 miles of beaches south of Point Conception are affected by maintenance activities, she said. [PARA]Project Pacific, a San Diego-based nonprofit group dedicated to improving the marine ecosystem, has assembled a scientific panel to examine the relationship between beach maintenance and grunion populations. [PARA]Panel member Richard Rosenblatt, professor emeritus of marine biology at UCSD's Scripps Institution of Oceanography, cautioned against jumping to conclusions. [PARA]"Everyone is entitled to their own opinion, but they aren't entitled to their own facts, and we don't have the facts yet," Rosenblatt said. [PARA]"The city has been doing this beach grooming for 30 to 40 years," Rosenblatt said. "We don't know how bad (grooming) is, but it obviously wasn't catastrophic because there are still grunion." [PARA]Dennis Simmons, San Diego's chief of beach maintenance, said his crews try to avoid raking kelp in areas where it's obvious that grunion have spawned. [PARA]"We rake at the high tide line and we rake as shallow as we can," Simmons said, estimating that the rake tines extend roughly three inches into the sand. [PARA]He disagrees that routine maintenance of the beaches is harming the grunion. [PARA]During an average year, city maintenance crews remove about 20,000 cubic yards of kelp from the city's 17 miles of beaches, he said. That can more than triple during an El Niño year that produces large storm waves. [PARA]The kelp is trucked to Fiesta Island, where it is dried under the sun. Thousands of yards of sand that stick to the kelp are then trucked back to the beach at the beginning of winter to help construct sand berms that protect against wave damage. [PARA]"I believe our procedures are responsible," Simmons said. "They are not destroying habitat in a wholesale manner." [PARA]Maintenance crews for the state beaches generally don't remove kelp from beaches controlled by the state Parks & Recreation Department, according to state lifeguard chief Denny Stoufer. [PARA]Various forms of beach grooming are done in Imperial Beach, Coronado, San Diego, Del Mar and Oceanside. [PARA]

By Terry Rodgers November 14, 2002

UNION-TRIBUNE STAFF WRITER

City officials exploring impact on marine life of removing kelp from San Diego's beaches

Beach cleaning practiced along San Diego's coast protects spawning grunion, but the jury is still out on whether kelp removal harms other near-shore marine life. That was the consensus reached yesterday by city officials in the wake of a summer-long research study that found healthy populations of grunion spawning at local beaches. Testifying before the council's Natural Resources and Culture Committee, Pepperdine University professor Karen Martin said grunion here are being protected by city maintenance crews who normally keep their heavy-duty rakes and grooming machinery above the high-tide line during spawning season. Grunion are small, sardine-like fish that come ashore during high tides between March and July to lay and fertilize their eggs in the sand. While they are not a commercial fish, grunion are not endangered and it is legal to catch them by hand. Martin also conducted an experiment in which beach-grooming machinery raked areas where grunion eggs were buried, which devastated the unhatched eggs buried in the sand. “Grooming in the intertidal zone over the grunion spawning sites causes significant loss of grunion eggs," Martin wrote in her report to the city. "Removal of kelp also removes nearly all incubating eggs." The intertidal zone is the fringe of land that is alternately covered and exposed by the rise and fall of the tides. While the study was being conducted this summer, parks maintenance crews twice violated their department's informal beach-grooming procedures and wiped out thousands of grunion eggs by raking too close to the water's edge, Martin said. Martin's report offered reassurance that the city's beach-grooming practices, when correctly followed by maintenance workers, protect grunion. But the controversy over the impact that beach cleaning and kelp removal might have on other marine life is far from resolved. Jim Peugh of the San Diego Audubon Society reminded the five council members on the committee of similar studies by UC Santa Barbara researcher Jenny Dugan. Dugan has found that beach maintenance disrupts the shoreline food chain by wiping out large numbers of invertebrates, including beach fleas and kelp flies, which are food to shorebirds and other marine life. Committee members agreed that Dugan, who has included San Diego's beaches in her research, should be invited to present her findings to help further fine-tune the city's beach-maintenance practices. Councilwoman Donna Frye pushed for a more restrictive beach-maintenance policy but backed off after it became clear she didn't have the votes. "We need a year-round policy that protects not only grunion but other marine life in the intertidal zone," Frye said in an interview. The city should investigate the possibility of using lighter machinery that does less harm to small creatures in the sand, she said. Mission Beach activist Pat Gallagher, whose concerns about overly aggressive beach-cleaning methods triggered the city's review, left the committee meeting shaking her head in frustration. "What this does is give them the latitude to keep taking kelp from anywhere they want," she said. City maintenance crews should not be removing any kelp at all, she argued, because its presence marks the sensitive intertidal zone. Committee chairman Jim Madaffer said he would oppose any radical change in beach-maintenance procedures, which have been roughly the same for 45 years. "I want to make sure we have a balance between science and people," said Madaffer, adding that the public expects to come to a beach that is not stinky from fly-invested, rotting kelp.

RECOMMENDATION FOR THE CONCEPTUAL DESIGN AND PLACEMENT FOR THE BUILD-OUT PHASE OF THE SAN CLEMENTE ARTIFICIAL REEF

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Summary

Background

The California Coastal Commission has required the mitigation of kelp impacts at SONGS to include a 150-acre artificial reef that maintains 150-acres of functioning kelp habitat. As the first step, a 22.4-acre Experimental Reef was constructed at San Clemente in 1999. The design of the remaining 128-acres will be determined, in part, in response to the results of the five-year study of the San Clemente Experimental Reef which is now in its fifth year.

Purpose of report

The CCC Permit-driven scheduling for this project is expeditious and necessitates that Edison work in close collaboration with CCC staff scientists to derive an effective Preliminary Plan for the 128-acre build-out reef. This report is intended to provide a starting point in the dialog, review, and approval process by proposing a build-out reef design based on information from the Experimental Reef phase of the project.

Project schedule

A preliminary plan describing the reef location and design must be submitted by Edison to the CCC Executive Director by June 2005, which is 6 months after the completion of the Experimental Reef field work. We estimate a final plan will be submitted by January 2006, and construction is estimated to begin in the second or third quarter of 2007. Construction completion is estimated to be by the end of 2008.

Siting

The location of the 150-acre kelp mitigation artificial reef was determined through a series of rigorous scientific studies and a review process that involved State and Federal resource and regulatory agencies, local government, the public, and concerned environmental groups. The San Clemente offshore area, between the Municipal Pier and San Mateo Point, is the approved site.

Design – preliminary recommendations

<u>Material selection</u>

Quarry rock is recommended. The experimental phase demonstrates that either rock or concrete is acceptable; yet, quarry rock now appears more readily obtainable and controllable from a design/quality assurance perspective.

Size of material

For the build-out reef, rock can be less rigorously sorted than in the experimental phase. The size constraints placed on the experimental phase materials allowed for effective comparisons of material spread and density distribution as well as useful comparisons between quarry rock and concrete. Yet, a wider allowable spread of size material has more environmentally beneficial aspects, and would be more cost effective.

Density of material

A bottom coverage of 10 to 20% is recommended, as this meets the Permit requirements, based on CCC-performance monitoring. However, occasional stable high density micro-reefs as well as areas of very low density substrate will promote biological diversity throughout the reef complex.

Spacing and Positioning

The entire 150-acre reef should not be built as a monolithic reef due to possible interference with local boat traffic and possible disruption of longshore sand transport in the surf zone. Reef rock can be placed around the perimeter of and in-between the seven blocks of eight modules in such a way as to: 1) continue to stay within the depth range of 12 to 15 meters and in areas that have a sand veneer of less than 0.5 meters over an existing base of hard substrate, 2) avoid existing viable natural and artificial reef kelp habitat, 3) involve the existing artificial reef square modules as much as possible – but with minimum disruption of existing module habitat, and 4) provide as many sand corridors and sand/rock interfaces as possible throughout the lease area. Adhering to "Criteria 4", above, will promote biological diversity throughout the overall reef area. These four criteria are best captured in "Alternative 3", which is shown in Figure 5 of the body of this report.

Construction Methodology and Scheduling – Preliminary Recommendations

Barge Mooring and Operations

The six-point mooring system and barge configuration used for the Experimental Phase construction were refined and proven to be effective and are recommended for the build-out phase. A two-barge per day operation is feasible when building low-density (10-20%)-cover reefs, which means there is a chance the build-out reef could be completed in one year, instead of two.

Barge Scheduling and Logistics

Connolly-Pacific developed efficiencies though their Experimental Reef construction experiences that will allow the build-out reef to proceed at a much faster pace than in 1999. We therefore estimate that the build-out reef will progress at the rate of at least two barge-loads of rock per day. One barge-load of rock could make up to four 17% bottom-cover Experimental Reef modules, or 1,600 m^2 of reef area times 4. This means a barge could spread up to 6,400 m^2 of phase-two reef per load. Using

"Alternative 3" and a 10-20% coverage as an example, one of the seven diagramed areas (one of the groupings around an existing block area) could be completed in 6 work days. The seven block areas could be completed in 42 work days. The PEIR estimates a "worst-case" 67% rock reef totaling 127.6 acres of needing 177 work days to complete. Our estimate of 42 days is possibly too optimistic, but it begins to give an indication of how efficient the building method could become and how much less of a construction impact a 10% to 20% reef would impose compared to higher densities of bottom cover.

Scheduling Construction with a La Niña

The El Niño/La Niña cycle appears to be important in influencing reef project success. Storm conditions associated with El Niño years could periodically interrupt and seriously delay construction operations. The construction barges must seek harbor shelter when long-period swell is predicted. Further, the success of kelp growth on the Experimental Reef may be in response to the fortuitous time of the reef's construction just after the 1997-98 El Niño and at the onset of a long La Niña. The construction schedule needs the flexibility, based on the near-term ENSO forecasts, to avoid building the 128-acre reef during or just prior to an El Niño episode.

INTRODUCTION

Background

The Experimental phase of the San Clemente Artificial Reef is in year five of the Permit-mandated (Coastal Development Permit No. 6-81-330-A) five-year study. This first phase of the kelp mitigation reef project is designed to determine the optimal spatial hard substrate coverage and material type (quarry rock or broken concrete) to be used in the second phase to assure that a sustainable 150-acre medium-to-high density kelp bed (defined as having a minimum of 4 plants per 100 square meters) with associated kelp bed biota can be achieved. See **Appendix A** for a description of giant kelp, the background of kelp impacts, and kelp mitigation using artificial reefs as they pertain to the San Onofre Nuclear Generating Station (SONGS).

The California Coastal Commission (CCC) has required the owners of the San Onofre Nuclear Generating Station (SONGS) to create this 150-acre artificial reef kelp bed to mitigate for resource losses at the nearby San Onofre Kelp Bed (SOK) associated with operation of SONGS Units 2 and 3.

The project has an approved Final Program Environmental Impact Report (PEIR) for the Construction and Management of an Artificial Reef in the Pacific Ocean near San Clemente, May 1999 (Resource Insights, 1999). The PEIR allows the project to be developed in the two phases. Only the 22.4-acre Experimental Reef was permitted and built in 1999.

The project has a lease with the California State Land Commission (CSLC) off of San Clemente of 862 acres. The lease site is located 0.6 miles offshore along a 2.5-mile stretch of San Clemente beach between the San Clemente City Pier to the north and San Mateo Point to the south. The lease area includes 356 acres of suitable sand substrate for artificial reef construction (defined as the project site) and the remaining lease area is considered a buffer zone (Figure 1). The Experimental Reef, the first phase of the project built in 1999, consists of 56 modules. Each module is 132 ft x 132 ft (40m x40m) in bottom coverage and the modules are grouped in seven clusters or blocks in the lease area (Figure 1 and Figure 2).

Purpose and Strategy for this Initial Reef Design Report

From the Permit scheduling criteria (critiqued in **Appendix B**), a few salient points concerning the development of the design of the mitigation reef become apparent:

1. The time between the conclusion of field work by the CCC-directed UCSB scientific team and the preliminary plan that Edison must submit to the Executive Director is only six months. Before Edison can develop this plan, the scientists must complete their final five-year study analysis and complete their final report. They must also provide their preliminary recommendations on 1) the potential for success of kelp mitigation using artificial reefs at San Clemente, 2) the build-out reef percent hard substrate reef cover, and 3) the build-out reef hard substrate type.
2. The Executive Director will determine the percent cover and type of hard substrate used in the build-out reef at the time of review of the Edison-written preliminary plan.
3. And, within 12 months of the Executive Director's approval of the preliminary plan for the mitigation reef, Edison must submit a final plan and apply for the project's Coastal Development Permit.

This scheduling for the preliminary plan does not allow sufficient time for peer review of reef design details by independent third-party scientists or the public. It is therefore necessary that close collaboration and consensus be achieved by Edison project personnel, CCC staff scientists, and UCSB scientists to derive a well-thought-out and workable preliminary plan. This paper is intended to jump-start a preliminary plan by proposing a build-out reef design based on data from the experimental phase as well as other knowledge acquired from the scientific community.

BUILD-OUT REEF PROJECT SCHEDULING CONSIDERATIONS

Timing and milestones for the continuing project are directed by specifications within the SONGS Coastal Development Permit - No. 6-81-330-A (CCC,1997). We have reevaluated the anticipated schedule as of March 2004 and this is summarized in **Appendix B** of this report. The PEIR - p. 3-27 (Resource Insights, 1999) estimated that the start date for the build-out reef construction would be 7 years and 5 months after the beginning of the monitoring of the Experimental Reef, which was October 1999. That would place build-out construction to start in March 2007. The PEIR further states that the reef can only be built between May 1 and September 30 of each year due to lobster fishing season and agreed-upon project mitigation constraints. Therefore, May 1, 2007 appears to be a reasonable estimate for starting construction.

REEF SITING CONSIDERATIONS

The San Clemente site was chosen after an intensive siting study during 1991-1999, involving eleven potential sites between Laguna Beach to the north and Mission

Beach off of San Diego to the south. **Appendix C** provides a summary of this siting evaluation process and outcome. The SONGS Coastal Development Permit No. 6-81-330-A (CCC, 1997) requires that nine specific siting conditions be met, and these are reviewed in **Appendix C**. We do not anticipate further discussion of siting issues to arise as part of this second phase, the build-out reef project.

REEF DESIGN CONSIDERATIONS

Background – historical and ongoing design studies

An account of relevant historical studies as well as the results, to date, of the ongoing Experimental Reef Monitoring Study are provided in **Appendix D**. The results of the Experimental Reef study, in part, provide the basis for the design recommendations of the build-out phase of the San Clemente Artificial Reef.

There is scientific consensus that artificial reefs targeting kelp growth in southern California would benefit from a design of very low-relief, scattered cobble or concrete, and placed on a thin veneer of sand sea floor that has stable under-layers. The concept is that the constructed reef material needs to be exposed to periodic episodes of sand abrasion, extreme currents that tear off old growth, and even rock over-turning; all of which exposes new rock surfaces for kelp settlement. Yet, placement on a thin sand veneer assures that the reef material will not sink and permanently disappear into the sand seafloor. Further, the periodic disturbance will crop or eliminate any sea fans (*Muricea*), which is a colonial gorgonian that appears to out-compete kelp over time on artificial reefs if they are constructed to be high-relief and very stable (Bedford, 1999).

Build-out reef design recommendations

<u>Spacing and positioning of material within the site</u>

The site offers 356 acres of bottom that may be used to build the 150 acre mitigation reef. The existing 22.4 acres of reef material are grouped in seven blocks throughout the entire permitted area. The reef will be expanded by 128 acres. The alternatives in constructing the build-out reef include:

1) Clustering the remaining 128 acres in large groupings as close to San Mateo Kelp Bed as possible. There would still be three to five major groupings since periodic corridors of sand are considered necessary so as to not disrupt either boat traffic or littoral drift and sand migration (Figure 3).
2) Spreading rock more uniformly within the perimeters of each of the seven blocks, essentially eliminating much of the spacing between modules within each of the seven blocks, but not eliminating much of the spacing between each of the seven blocks (Figure 4).
3) Spreading the rock between the seven blocks, while assuring the existing 56 Experimental Reef modules are left undisturbed; but still leaving periodic corridors of sand (Figure 5).
4) Scatter clusters of rock along either the inside (landward) edge of the area, or along the deeper (seaward) edge of the reef site. This could be a possibility if the Experimental Reef phase started to reveal depth preferences in the remaining (fifth) year of monitoring. This fourth alternative is not shown with a figure in this report.

We recommend building the remaining 128 acres using "Alternative 3: Spreading the rock between the seven blocks", while assuring the existing 56 Experimental Reef modules are left undisturbed; but still leaving periodic corridors of sand (Figure 5). This design will leave some corridors of open sand between the block groupings and will avoid existing hard substrate, be it natural or from the Phase I experiment. Within each of the blocks, there will still be some patchy pathways of sand bottom simply due to the construction technique we are suggesting. We recommend this for four very different reasons:

1) There is a biological benefit of interstitial spacing (the ecological "edge effect" – where more organisms tend to prefer to be) with sand corridors and pathways. This has been demonstrated in past reef monitoring efforts (ref.).
2) There is a possible physical oceanographic constraint: The 1993 study required by the CCC Permit for this project entitled, *Effects of Kelp Bed Artificial Reefs on Beaches* (Coastal Environments, 1993), concluded that kelp beds did not affect littoral currents in the surf zone or littoral drift of sand along the Southern California beaches. However, the quantitative results of this study were limited to the Carlsbad Kelp Bed as a representative North San Diego County kelp bed. The Carlsbad bed is, at most, about 600 meters long. If a kelp reef is built as single continuous bed longer than this, then there is no assurance this larger reef would not disrupt the natural littoral drift and possibly erode the adjacent sandy beaches. We would have no empirical data to assure otherwise. And, there is no biological reason to build a longer contiguous kelp reef. In fact, conventional wisdom suggests just the opposite.
3) If the Phase II build-out 128 acres of material is placed exclusively within each existing block (around each Phase I module – Alternative #1, above), then the six-cable mooring system of the construction barge will assuredly cut through and rip out all of the existing 22.4 acres of kelp. This would be a temporary disruption, but for the greater good, though.
4) Finally, the San Clemente commercial fishermen expressed a concern (Nilsson, 1999 and 2003) that the San Clemente Mitigation Reef should not be built in such a way, when kelp is flourishing on it, that it becomes a hindrance or obstruction to navigation through the area.

Building the necessary 128 acres adjacent to the existing Experimental Reef blocks requires that about 18.2 acres of new hard substrate needs to be integrated around each of the seven existing block areas. The existing blocks have eight 132' x 132' (40m x 40m) modules in them (Figure 1). The outer edges of these modules form block perimeters of about 600' x 1400' (19.4 acres) to about 800' x 1500' (26 acres). The eight modules presently occupy 3.2 acres of bottom in each block. Therefore, the new material could be placed just on the outside and around each block of eight existing sets of modules (Alternative 3 - Figure 5). Yet, there is some existing natural hard substrate around and in each existing block. These areas will be avoided. The substrate in the lease area will need to be re-surveyed to assure natural viable kelp growing substrate will be avoided in the build-out phase.

Density of material

The purpose of the Experimental Reef phase of this project was to compare substrate densities of 17%, 34%, and 67%. The understanding and one of the major hypotheses was: over-building the reef with too much material and/or too much structural stability could jeopardize the ability of kelp to out-compete more long-lived and stable invertebrate communities such as *Muricea* in the long-term. See **Appendix D** for further discussion of substrate density differences with respect to *Muricea* and reef stability experiences.

The build-out reef could be built with varying substrate densities, spanning the treatments used in the first phase, throughout the 128 remaining acres of construction. These rock density variations throughout the reef would be incorporated to possibly allow for a richer or more diverse marine community. Yet, the Experimental Reef monitoring findings would have to demonstrate that these density variations: 1) would be necessary to achieve the Permit performance standards, and 2) have this intended added-benefit effect and that this effect supersedes the lower-density/higher-disturbance effect that better assures kelp growth.

Since all densities appear to Achieve Permit standards, we recommend the least rock-dense reef in the next phase. Further, the design we are recommending will take advantage of the higher density Experimental Reef modules in this hoped-for added benefit capacity, since the higher-density Experimental Reef modules will be integrated into the overall mitigation reef.

Further, since all of the Experimental Reef modules appear to be achieving the Permit kelp density performance criteria, it makes sense to build the full reef at the lowest rock density. The down-side to this approach would be that more material may need to be added at a later time if standards are not being met, and there is evidence that more material would correct this. Conversely, if the full reef is initially built with too much material, then the extreme down-side would be that eventually some of this material would need to be removed from the mitigation site; a very costly and disruptive proposition. The former "adaptive management" approach would be more prudent.

The "least substrate density" cover designed for in the Experimental Reef phase was 17%. The actual construction of this low density was determined to be closer to 20%, on average, according to the post-construction sonar monitoring verification surveys done in the Fall of 1999. Since then, the diving biologists have estimated the cover to be 34%, using point-contact line-transect estimations. It appears that the lowest density areas within the Experimental Artificial Reef, those with the "17%" cover, are both similar to natural reefs near San Onofre as far as: 1) having similar large cobble and boulder density cover, and 2) growing kelp at a density that meets Permit performance standards (4 kelp plants/100 m^2). Study results show that this kelp density is easily achievable with the 17% cover. It seems reasonable that a 10% quarry rock cover could also satisfy the two above criteria. We therefore recommend that the build-out reef be constructed with a rock density of 10% to 20% cover.

Size of substrate material

The Experimental Reef was built with quarry rocks and broken concrete pieces that were sorted to be generally in the quarter-ton size range. The logic for this Experimental Reef study phase approach was:

1. The reef site has a sand veneer of about 0.2m to 0.5m in depth over a hard substrate of bed rock and/or gravel-shell hash. It was expected that reef rocks, over time, get sand-abraded, partially buried and re-exposed, occasionally flipped over, and the like. All of these are potentially good for kelp, which needs "bare rock" to re-establish on a reef. Yet, if smaller rocks are placed on this sand veneer, there is a greater likelihood they could be buried, and possibly permanently, due to subsidence and scour.
2. If there is a great portion of reef material in the size range from large gravel to 8 inch to 10 inch diameter rocks, this material has a greater likelihood washing up on the beach after storms, either on their own, or attached to kelp holdfasts. This material, if washed onto the beach is not only lost to the reef, it could become a hazard to swimmers and beach walkers.

To be conservative, regarding possible subsidence during the five-year Experimental study (the Permit says rocks can stay buried for up to three years before they are considered lost to the reef), the specific material specifications in the Edison 1999 Request for Proposal for the Experimental Reef Project (SCE, 1999) required:

1. <u>Rock</u>: Rock length may vary between 1 to 3 feet with an average length of 2 feet. Rock width may be between 1 and 2 feet and rock height specifications are as follows: a) less than 1 foot, 0% to 5% of the pieces; b) between 1 and 2 feet, 75% to 90% of the pieces; c) between 2 and 3 feet, 5% to 10% of the pieces; and d) greater than 3 feet, 0% of the pieces. The distribution of the rocks in any one module shall conform to the specifications. These specifications conform to the provisions of CALTRANS Standard Specifications, Section 72, Slope Protection for "Quarter-Ton Rock".
2. <u>Concrete</u>: Concrete shall be broken such that the longest two dimensions, length and width, sum less than 8 feet for each piece. Pieces with length or width below one foot are not acceptable. The distribution of the remaining orthogonal dimension, height, in the recycled concrete shall conform to the following: a) height less than 6 inches, 0% to 5% by weight; b) height between 6 inches and 12 inches, 85% to 100% by weight; c) height between 12 inches and 24 inches, 0% to 15% by weight; and d) height greater than 24 inches, 0% by weight.

Representative sampling was performed on the concrete and quarry rock as it was placed on the Experimental Reef in September 1999. The Experimental Reef construction contractor, Connolly Pacific Company, was successful in meeting the specifications.

1. <u>Rock</u>: Length, width, and height measurements were taken from a sample of 145 quarry rocks selected randomly from the stockpile of 20,000 tons. The mean and standard deviation of the rock dimensions were recorded (Coastal Environments, 1999). Rock length varied between 1 and 3 feet, with an average length of 2 feet. Rock width varied between 1 and 2 feet with an average width of 1.5 feet. The mean rock height was 1 foot. The maximum measured rock height was 2.1 feet.

2. Concrete: Concrete was gathered from the various demolition sites. The concrete had a mean length of 3 feet and a mean width of 2 feet. The mean height of concrete was 10 inches. Concrete dimensions varied form block to block, depending on the source (e.g. building demolition, freeway demolition). In general, the concrete used throughout the Experimental Reef Project was reasonably consistent in term of size, and conformed to the project specifications.

Since no reef material appeared on the beach during the Experimental Phase, it is reasonable to conclude that quarry rock reef material does not migrate over time into the surf zone. The build-out reef may environmentally benefit from a broader size-mix of quarry rock:

1. Different size rocks grouped together and adjacent to each other produce diversity through a larger variety of reliefs, crevasses, and cave-like habitats that could accommodate and shelter a broader range of species and year-classes within species.
2. There would be a further environmental efficiency in constructing the build-out reef with quarry rock that does not conform to the "Quarter-Ton Rock" requirement, because the rock would not have to be handled and sorted as intensely. Less handling would directly equate to less air pollution from the heavy equipment needed for moving and sorting the material at the quarry.

Material Selection - Concrete or Quarry Rock?

The material of choice, based on the Experimental Phase, is quarry rock.

Construction experience

The construction of the Experimental Reef demonstrated that quarry rock was preferable for the following reasons:

1. Its source and abundances are assured - Catalina Island has two large quarries.
2. Appropriate sizes of quarry rock are assured since accurate and economic sorting is feasible at the quarry.
3. The availability of concrete rubble will always be episodic and the quantities needed for this project cannot be guaranteed for the time of construction.
4. Even if the concrete is available at the time of construction, it would have to be stock-piled in a large holding yard adjacent to the docks in Long Beach. The barge operation cannot delay or go into a holding pattern waiting for concrete to accumulate, and concrete cannot be driven right onto the barges (see #5, below). This means concrete always needs to be handled twice, and moved twice, which causes twice the air emissions.
5. Quarry rock does not have to be inspected load by load, and environmentally unacceptable pieces handled and/or removed in the way concrete does. Rubble concrete deliveries have the potential for unallowable (CDFG, 1986; and Resource Insights - PIER, 1999) exposed rebar, oil-contaminated pieces, paint-contaminated pieces, too many small or large pieces, and mixed-in pieces of asphalt.
6. Quarry rock from Catalina Island is environmentally preferable from an air-quality/transportation perspective compared to broken concrete. Broken concrete

has to be driven to the Long Beach docks from possibly anywhere in the Air Basin; then offloaded for temporary storage, sorting, and inspection; then reloaded onto a barge. This process adds much more emissions into the formula compared to barging quarry rock directly from Catalina.

Biological results: The findings of the Experimental Reef Monitoring Program indicate that either quarry rock or broken concrete are acceptable in meeting Permit performance standards. The Japanese had tested both types of material for optimum kelp settlement (Kawasaki, 1992), and concluded that sharp edges appear to be more conducive for kelp settlement over flat smooth surfaces such as what is more prevalent with broken concrete. Quarry rock has more irregularities and sharp edges than broken concrete and may allow for more kelp settlement. Yet, in southern California, both materials have successfully grown kelp, as evidence on historic artificial reefs, and this study found similar non-preferential results.

Artificial reef perception issues: California Department of Fish and Game (Bedford, 1999; and CDFG, 1986) allows for using either concrete rubble or quarry rock for artificial reefs. There are trade offs involved with each material. Quarry rock is surfaced-mined from Catalina Island and from inland southern California quarries. Quarry rock, although not scarce, is a finite resource whose use involves environmental impacts in the area of land management, energy consumption, and air quality that must be addressed for each project. Yet, quarry rock may be viewed as the environmentally more acceptable material because there are also environmental issues with concrete rubble: Some environmentalists still have the perception that some artificial reefs are constructed to irresponsibly dispose of waste materials. Yet, on the other hand, others view concrete reefs as a sustainable design strategy that reuses materials and is often cost effective.

REEF CONSTRUCTION METHODOLOGY

The 22.4-acre Experimental Reef was built using a six-point anchoring system centered off of a stationary barge (Figure 6) that stayed positioned over each block as eight modules were built. The modules were built as squares with critical density allowances and very accurate distance specifications to allow for accurate biological monitoring using transects and survey grids. The build-out reef does not need to be constructed with this degree of exactness, either in position, boundaries, or rock coverages. Even so, the critical aspects of construction in this next phase will be to assure the Experimental Reef modules do not get buried by new rock, that existing natural hard substrate interspersed throughout the area does not get overly disturbed, and that the anchor cables and anchors do not cause unnecessary or extreme damage to the existing natural and artificial reef structures throughout the site.

Therefore, we recommend that the same construction barge operation be used as in the first phase. We also suggest retaining the six-point mooring system, now a proven technology. The anchors can be fixed outside the existing Experimental Reef block areas. This was done at the first phase construction, and these general perimeter areas can be used again. In the 1999 construction work, it was demonstrated that these anchor locations, on both the shoreward and seaward edges of the blocks were neither overly sensitive biological areas (Elwany and Deysher, 1998), nor did the anchors irreversible damage resources present. Nevertheless, the cables will cause some damage as they traverse and drag through the existing modules. This damage will be minimized by avoiding the main clusters of modules altogether, and using temporary floats and buoys along the line when necessary. The existing modules can be marked with both buoys and on the barge GPS maps, so as to be more readily avoided. Then, each of the existing block areas can be filled in and worked around before the barge moves to the next block area.

RECOMMENDED CONSTRUCTION SCHEDULING AND BARGE LOGISTICS

The 22.4-acre reef was built over a span of 41 days, total, with a 5-day period of down-time due to bad weather (long-period swell); and with weekends off. The construction barge had to leap-frog over some areas due to concern that operations may be damaging to more sensitive parts of the zone before methods could be perfected; and due to fishermen wanting the northern blocks, some of the sensitive areas, constructed well before lobster season started. Fortunately, after a shorter than anticipated learning curve, the contractor was able to place one barge-load of rock per day, which resulted in two 40m x 40m modules being built per day. The PEIR estimated that the Experimental Reef might take twice as long to build on a daily basis (only accomplishing ½ barge-load per day), but that the build-out reef might take half of this time (one barge per day), due to the lesser precision required for the build-out reef (p. 3-19). Connolly-Pacific developed efficiencies though their Experimental Reef construction experiences that were better than this. We estimate that the build-out reef may progress at a rate of at least two barge-loads of rock per day as opposed to the one per day estimated in the PEIR - p 3-18 (Resource Insights, 1999).

Informal discussions with Connelly-Pacific, the phase-one construction contractor, reveal some efficiencies that can be accomplished in the build-out phase of the project, if we choose to use C-P, and/or their methods (Connelly-Pacific, 2003):

1. It is best to perform the construction in a strictly north-to-south or south-to-north sequencing to avoid having to move anchors too often or too far each time.
2. The construction barge can stay in position and rocks can be dropped off of the supply barge, just like in the first phase; but the material does not have to be placed in squares on the bottom, so the whole process can be much faster. More non-uniformity in spacing and density will most likely be better for biodiversity. The barges can re-position faster, and the supply barges brought along side faster.
3. The dropping of rock off the supply barge will be the same as the first phase: the scoop loader will move up and down the moving barge like a type writer carriage.
4. The contractor orients to tons per given area, not percent bottom cover. Therefore, as a first order priority, we would strive to achieve a mono-layer of material, but percent bottom cover in any general area would not necessarily be perfectly uniform.
5. The construction crew works best with a rhythm. Unnecessary variations and constant adjustments in their work schedule and work routine slow them down considerably.

Based on these ideas, and because we are recommending 10% to 20% bottom cover, the reef can be built faster and with much less impact (air quality) than the PEIR states.

The PEIR-projected schedule spans two building seasons: 1 May 2007 through 30 September 2007, and 1 May 2008 through 30 September 2008. Even though we are recommending the least bottom cover, 10% to 20%, we still suggest the build-out phase reef span two building seasons. This would allow for any construction breakdowns, construction adjustments, and weather delays, as well as biological cycles to have a more positive effect on the process. We remember the frustrating experience of the Pendleton Reef growing essentially nothing useful or significant for its first 1.5 years because of a C*ryptoarachnidium* covering (a colonial tunicate that once established on the new rock surface, appears to cover the rock with a uniform and complete a slime layer, thus not allowing anything else to settle until there is a major die-off or disturbance) that initially plagued it – due to the unpredictable timing of the settling of certain organisms.

A barge can hold 1000 to 1500 tons of quarry rock (Coastal Environments, 1999). One barge-load of rock could make up to four 17% bottom-cover Experimental Reef modules, or 1,600 m^2 of reef area times 4. This means a barge could spread up to 6,400 m^2 of phase-two reef per load. A block area will require 18.3 acres of new reef, or 74,089 m^2 of material. So, if two barges of material were placed per day, at this rate a block could be completed in 6 work days. The seven block areas could be completed in 42 work days. The PEIR estimates a "worst-case" 67% rock reef totaling 127.6 acres of needing 177 work days to complete. Our estimate of 42 days is possibly too optimistic, but it begins to give an indication of how efficient the building method could become and how much less of a construction impact a 10% to 20% reef would impose compared to higher densities of bottom cover which fare no better in terms of producing a biologically successful reef.

Further, the El Niño/La Niña cycle appears to be important in influencing reef project success. Storm conditions associated with El Niño years could periodically interrupt and seriously delay construction operations. The construction barges must seek harbor shelter when long-period swell is predicted. Further, the success of kelp growth on the Experimental Reef may be in response to the fortuitous time of the reef's construction just after the 1997-98 El Niño and at the onset of a long La Niña. The construction schedule needs the flexibility, based on the near-term ENSO forecasts, to avoid building the 128-acre reef during or just prior to an El Niño episode. Figure 7 shows the recent historical cycle of El Niños and La Niñas through the Experimental Reef monitoring phase of this project. The weak El Niño shown in the diagram for the 2001-2003 time-frame is misleading in that there was very little real manifestation of this El Niño event in southern California. The 1999-2004 period is better characterized as a time of mild to cool sea temperatures and a period with no dramatic winter or summer storms or episodes of extreme-swell.

PROJECTED PROJECT COSTS

The above tonnage estimates include the 15% rock overlap factor that was used in the initial phase reef construction estimates. This 15% addition of material was eliminated during construction of modules in the second block because it was determined to be unnecessary (the percent coverages was too great with the added 15%). Therefore, we are eliminating the 15% "added rock contingency" to each barge load. Rather, we will factor in a contingency to the total project cost.

Each barge can carry about 1500 tons of rocks and each barge can spread this rock with a 17% bottom coverage over an area of 6,400 m^2. The cost per ton of rock placed is about $47/ton (PEIR). Therefore each barge load is about $70,500. Each block would require 12 barge-loads times $70,500 or $846,000; and the total cost would be 7 blocks times $846,000 or $5.9 million.

The PEIR estimated $4.2 million for a 17% bottom cover quarry rock reef of 127.6 acres in total size (p.3-28). My numbers need to be re-checked, they should be less than the PEIR.

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Figure 1: The San Clemente Artificial Reef showing the 356-acre lease area and the 56 modules of the Experimental Reef grouped in seven block areas between the San Clemente Pier and San Mateo Point.

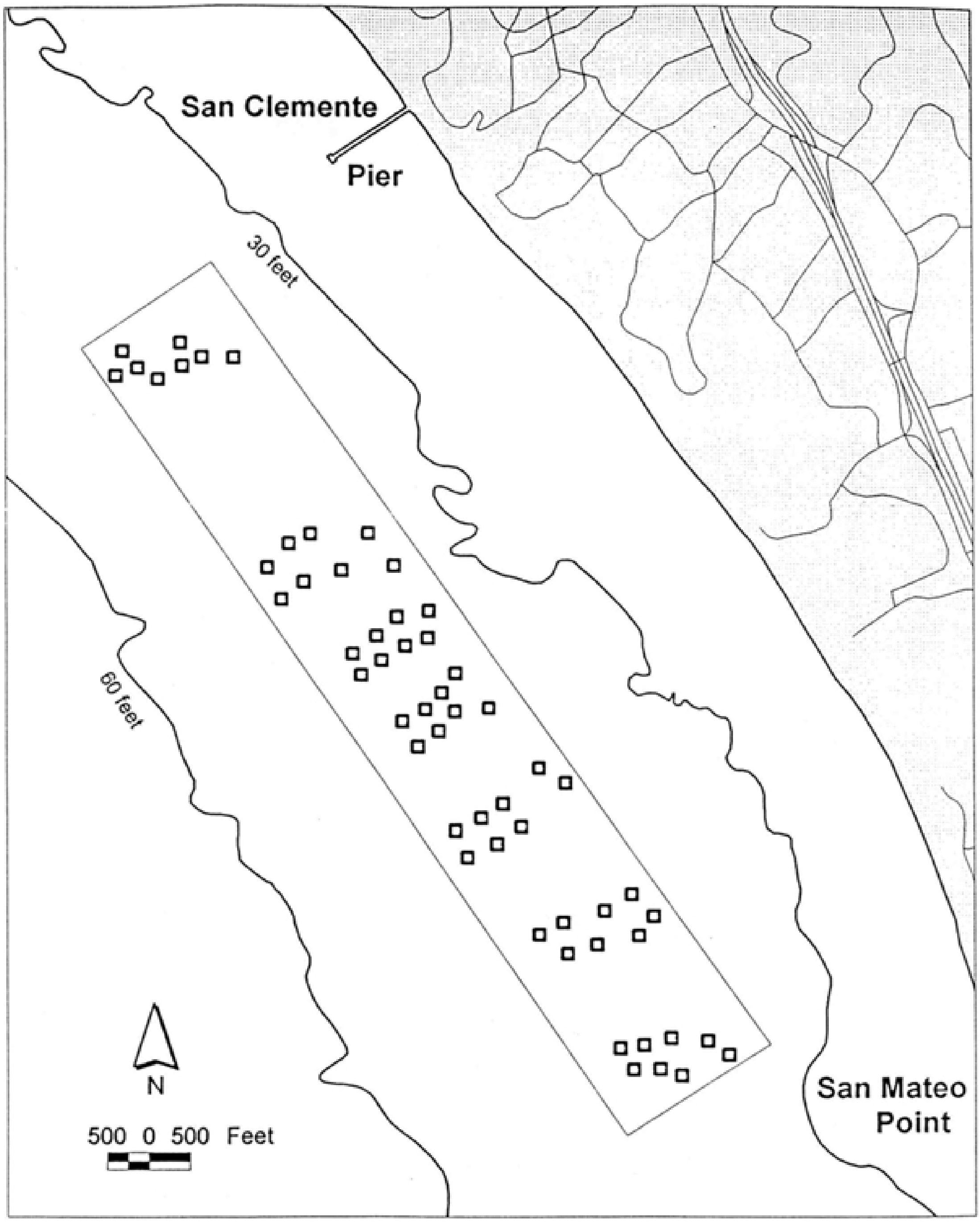


Figure 2: Kelp canopy aerial photograph, December 30, 2002, just north of San Mateo Point; showing 36of the 56 modules of the San Clemente Experimental Artificial Reef. Block 1 is to the south (right side of photo), showing five of its eight modules; Blocks 2, 3, and 4 show all eight their modules; and seven of the eight modules of Block 5 are to the extreme left of the photo. The kelp canopy of some of the natural reefs is also shown, especially between Blocks 1 and 2, and Blocks 3 and 4. From: MBC, 2004.

Figure 3: Alternative 1 for the potential configuration for the 128-acre build-out reef within the area of suitable substrate at the San Clemente site: Clustering the rock in large groupings as close as possible to San Mateo Kelp Bed (there would still be three to five major groupings since periodic corridors of sand are considered necessary so as to not disrupt either boat traffic or littoral drift and sand migration).

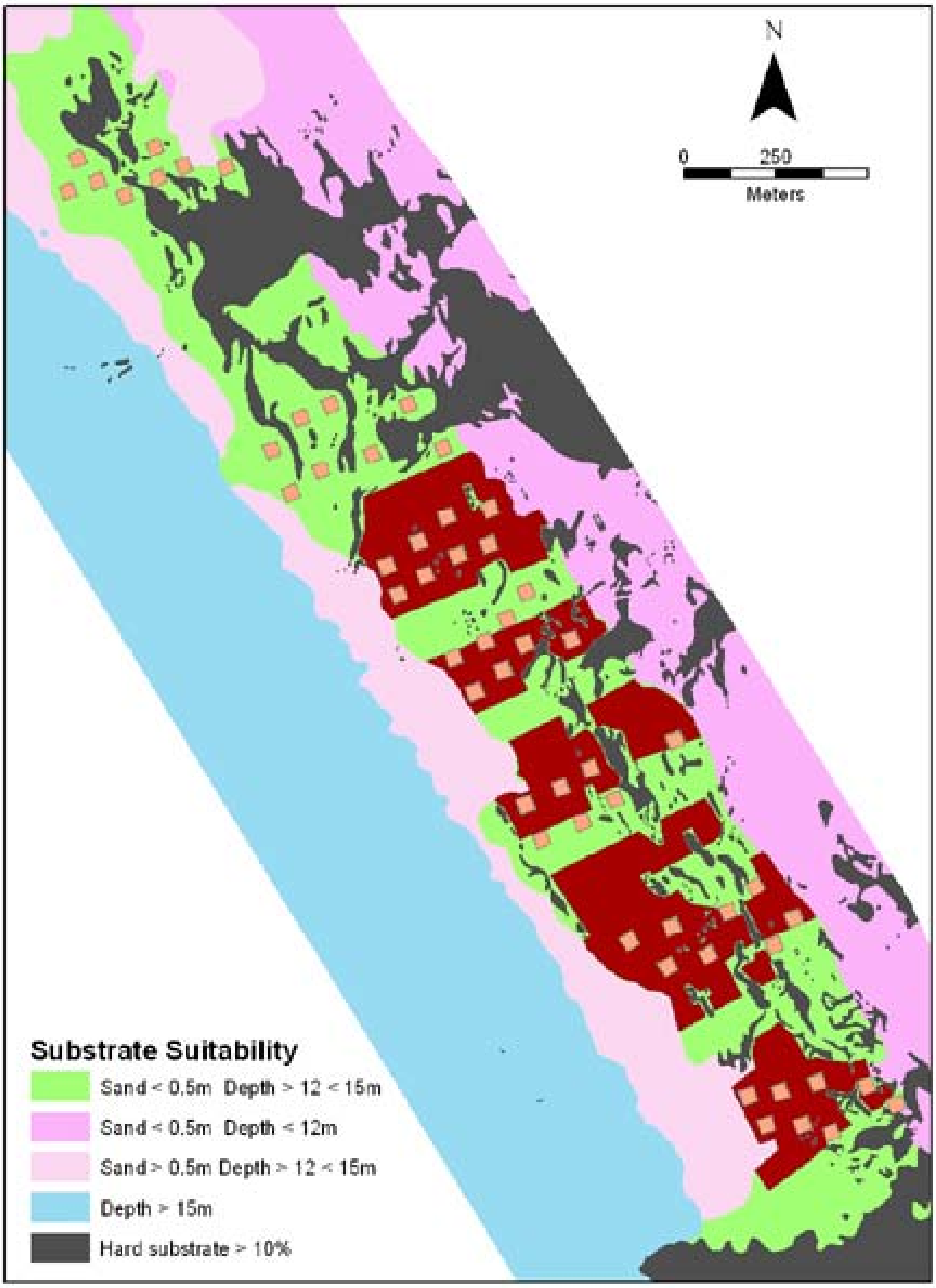


Figure 4: Alternative 2 for the potential configuration for the 128-acre build-out reef within the area of suitable substrate at the San Clemente site: Spreading rock more uniformly within the perimeters of each of the seven existing blocks (essentially eliminating much of the spacing between modules within each of the seven blocks, but not eliminating much of the spacing between each of the seven blocks).

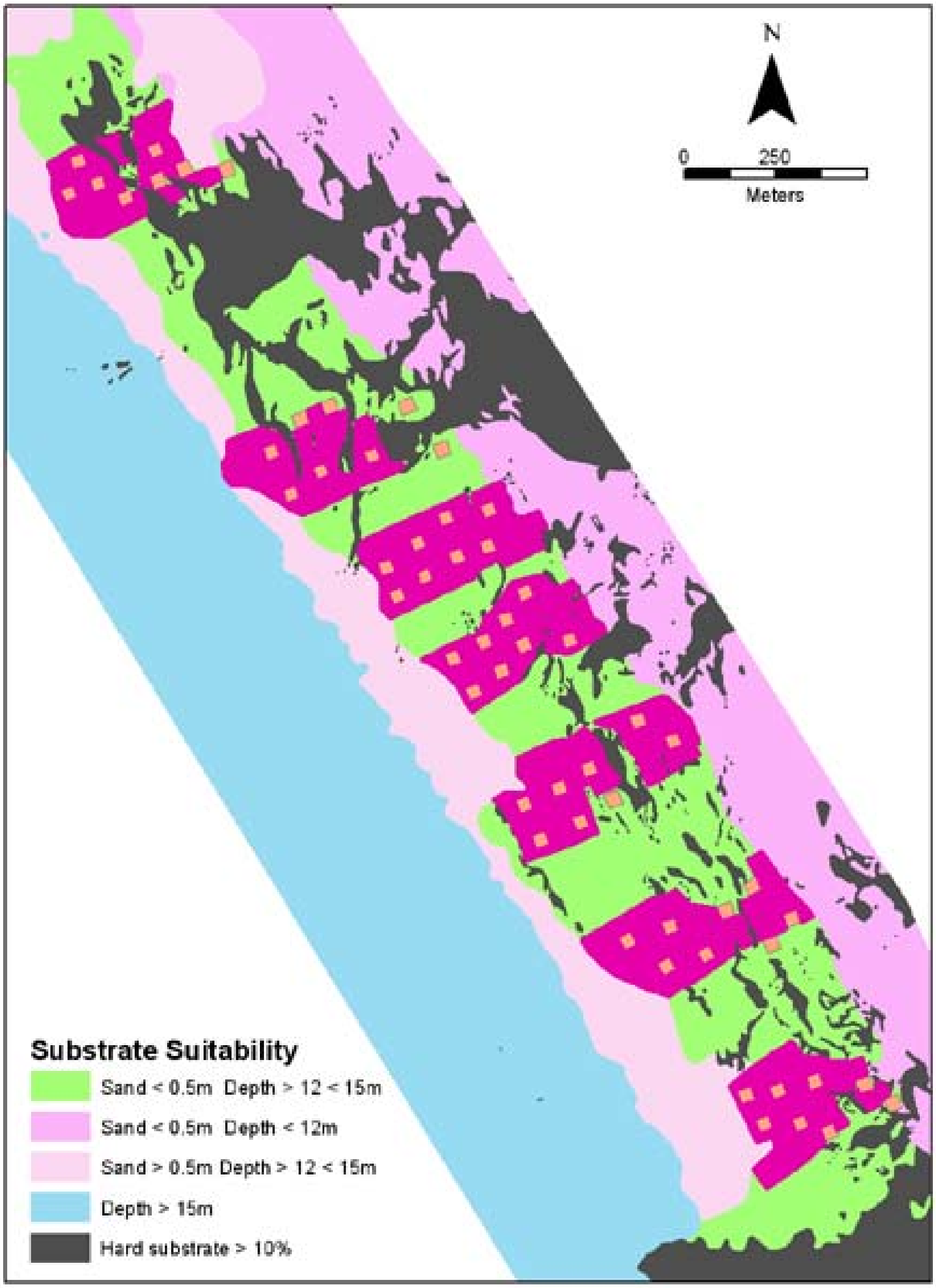


Figure 5: Alternative 3 for the potential configuration for the 128-acre build-out reef within the area of suitable substrate at the San Clemente site: Spreading the rock between the seven existing blocks, while assuring the existing 56 Experimental Reef modules are left undisturbed; but still leaving periodic corridors of sand

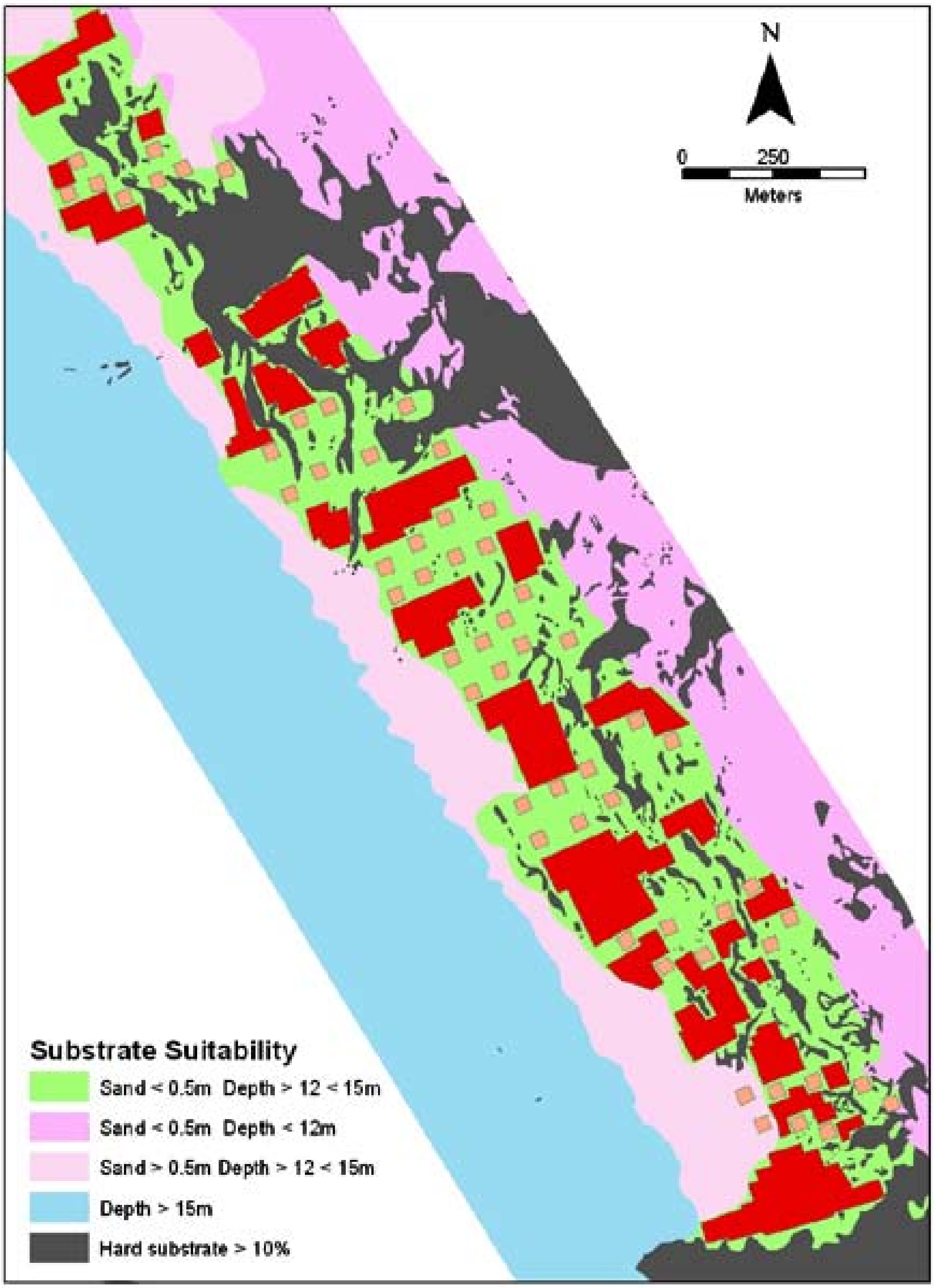


Figure 6: Recommended derrick barge and supply barge configuration and 6-anchor positioning for the construction of the 128-acre kelp mitigation build-out artificial reef at San Clemente.

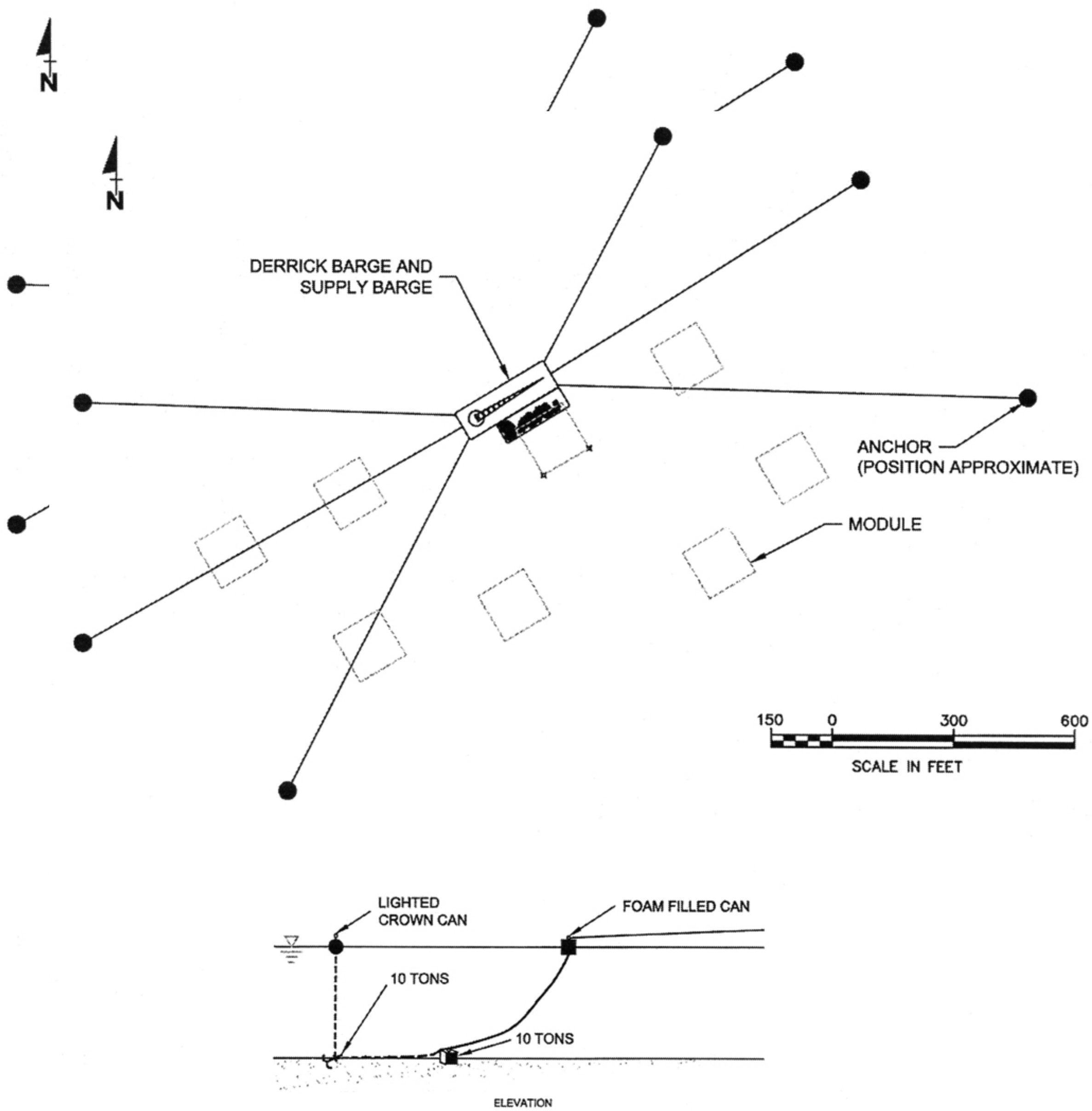
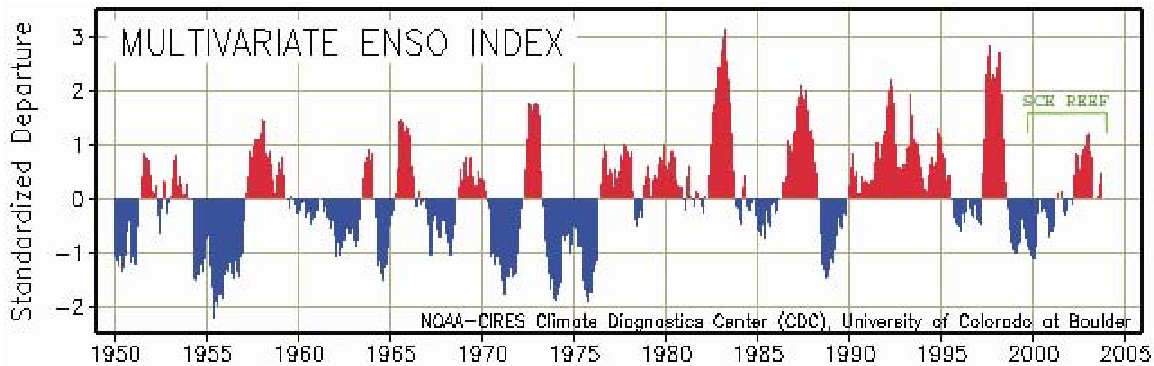


Figure 7: El Nino – Southern Oscillation (ENSO) Index calculated by the NOAA Climate Center in Boulder, Colorado. The red areas show the relative strength of El Nino conditions and the blue areas show La Nina conditions that are usually associated with cooler more nutrient rich water.



APPENDIX A: AN UNDERSTANDING OF KELP AND ARTIFICIAL REEFS FOR KELP MITIGATION

Artificial Reefs Development and Kelp Mitigation at San Onofre

Artificial reefs can be designed to enhance or restore marine habitats (Ambrose,1994; Cheney et al., 1994). As such, they typically target the enhancement of specific biological communities that have well-defined depth ranges and seafloor constraints. In Southern California natural giant kelp habitat is located just beyond the surf zone, and consists of hard substrate interspersed on an otherwise sandy seafloor. Artificial reefs targeting giant kelp therefore need to be designed and properly placed to withstand the harsh oceanographic conditions and unstable bottom characteristics of the nearshore environment.

The importance of kelp

In species diversity, biomass, and productivity, a kelp forest is the temperate nearshore marine equivalent of a tropical rainforest or coral reef (Garrison, 2003). Kelp habitat is also about 19 times more productive than adjacent sandy seafloor habitat (North, 1971).

The mitigation potential of kelp*:*

The potential exists to mitigate impacts caused by coastal development by installing artificial reefs to create or expand marine communities. If impacts in the coastal zone directly affect a local kelp forest community, then the priority to provide successful “in-kind” mitigation is especially critical. Kelp beds are typically located on hard substrate in harsh nearshore areas with shifting sand. Therefore, the design of an artificial reef that targets kelp enhancement is critically reliant on the proper characterization of bottom conditions and coastal processes, both during the feasibility stage and during the siting and design phase.

San Onofre Impacts and Mitigation:

The San Onofre Nuclear Generating Station - SONGS - (Figure A-1) is located south of San Clemente, California, and uses ocean water as the primary coolant for the steam cycle process in generating electricity. Southern California Edison Company (SCE) operates SONGS. A 15-year marine study was conducted by the Marine Review Committee of the California Coastal Commission (CCC) to assess the impact that the SONGS cooling system has on the surrounding nearshore environment. This study determined that the operation of the SONGS cooling system was impacting local fish and the adjacent natural kelp forest community. In 1991, the CCC required SCE to create a kelp forest community on a 150-acre artificial reef to mitigate the impact of SONGS on the nearby San Onofre Kelp Bed (Ambrose, 1994). Through a series of further studies and public hearings, the San Clemente Artificial Reef Project was developed to satisfy the CCC permit kelp mitigation requirement (Resource Insights, 1999).

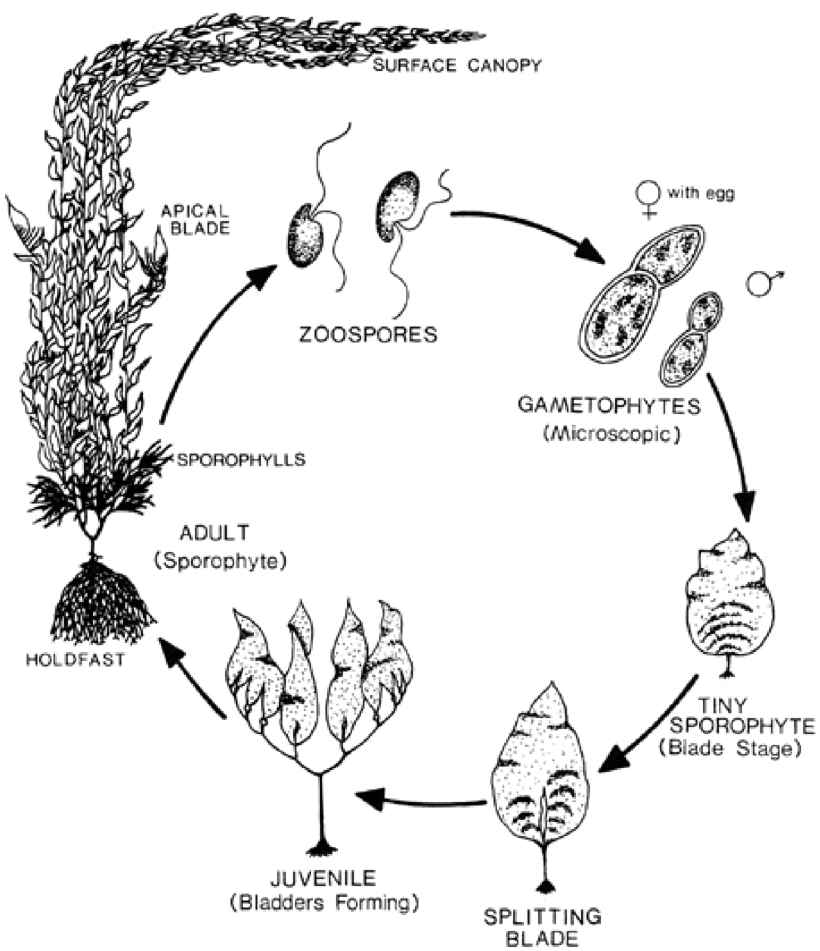
The Life History of Kelp

To properly design an artificial reef for kelp, it is important to first understand the nature of kelp. The kelp forests that are most common in southern California are composed of adult sporophyte stage of giant kelp, *Macrocystis pyrifera*. These adults usually live an average of 4 to 6 years and with some individuals perhaps surviving for more than twice that long. The initial development and perpetuation of kelp beds is dependent on successful completion of the life cycle. Spores are produced by sporophylls, specialized leaf-like structures near the base of the adult. These spores are released into the water, are carried by currents over distances ranging from several meters to several kilometers, and then settle onto hard surface (usually rock or boulder reefs). The spores then develop into microscopic male and female gametophytes. The male produces a sperm that then swims to and fertilizes the egg in the female gametophytes. The small sporophyte stage is then produced, develops into a small visible single blade, and eventually grows to be an adult (Figure A-2).

Successful kelp recruitment (production of small sporophytes) varies from year to year, and is dependent on a number of factors, especially the combination of sufficient flight and nutrients required for production of small sporophytes. In natural kelp beds near the San Clemente reef site, historically successful kelp recruitment occurs about once every three years (Carter et al. 1985; Dean and Deysher, 1997). Successful recruitment seems to be limited by the availability of spores. The existing nearby kelp bed, the San Mateo Kelp Bed – downcoast to the southeast, serves as a source of spores for the San Clemente Artificial Reef. Further, now that adult kelp exists on all modules in the San Clemente Experimental Artificial Reef and at upcoast (northwest) natural kelp beds nearer Dana Point and Doheny Beach, the chances for future successful recruitment on the build-out mitigation kelp reef would appear to be even better.

Figure A-1:   Location of San Clemente Kelp Mitigation Artificial Reef, San Onofre Nuclear Generating Station, and the Pendleton Artificial Reef.

Figure A-2: The life history of giant kelp (from McPeak et al, 1988)



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APPENDIX B: PROJECT SCHEDULING FOR THE BUILD-OUT PHASE OF THE SAN CLEMENTE ARTIFICIAL REEF FOR KELP MITIGATION

Timing and milestones for the continuing project are directed by specifications within the SONGS Coastal Development Permit No. 6-81-330-A (CCC, 1997). The Final Program Environmental Report for Construction of the San Clemente Artificial Reef (PEIR) (Resource Insights, 1999) estimated the schedule for this project, but we have re-evaluated the project schedule based on what is known as of March 2004. The anticipated schedule for the build-out phase of this project will begin with the conclusion of the five-year Experimental Reef Monitoring field work in December 2004; and the actual construction will begin as soon as May 2007.

We base this schedule on our most recent interpretation of the Permit:

1. The independent monitoring of the Experimental Reef is a five-year monitoring study (October 1999 through December 2004).
2. Edison must "within six months after completion of independent monitoring of the experimental reef … submit a preliminary plan describing the location and design of the mitigation reef to the executive Director for review and approval" (by June 2005).
3. "The type of hard substrate and the percent cover of hard substrate proposed in the preliminary plan for the mitigation reef shall be determined by the Executive Director."
4. "The Executive Director will consult with the CCC scientists, scientific advisors, resource agencies, and other as appropriate to evaluate whether the preliminary plan meets the goals set forth in Section 2.2" of the Permit. The time duration of this project component is not specified in the Permit. We anticipate this aspect of the project could take from 2 to 12 months; and this review will be completed between July – December 2005.
5. "Within one month following the Executive Director's determination that the preliminary plan meets the specified criteria", Edison must initiate the development of a final mitigation plan along with appropriate CEQA and/or NEPA environmental impact analyses necessary in connection with local, State or other agency approvals.
6. Edison must "submit a final mitigation plan to the CCC in the form of a coastal development permit application" "within 12 months of the Executive Director's approval of a preliminary plan for the mitigation reef". The final plan must "specify location, depth, overall hard substrate coverage, size and dispersion of reef materials, and reef relief and shall substantially conform to the preliminary plan approved by the Executive Director". We estimate our final plan will be submitted by June 2006.
7. CCC must approve a coastal development permit for the project. The CCC will not put this on their agenda until all other permits are obtained by Edison. The biggest hurdle in this permitting process for the Experimental Reef was with the U.S. Army Corps of Engineers. The process from the completion of the Final PEIR (which in itself took about one year) until the proper permits were obtained

took about 4 months (May to July 1999). The CCC then approved the coastal development permit at their next monthly meeting. We anticipate our coastal development permit process for the build-out reef will take about 6 months - completion: April 2007.

8. Edison must begin constructing the build-out reef no later than 6 months after CCC approval of a coastal development permit for the reef. Based on the above estimates, and because the construction contractor will need to be selected and procured toward the end of this process, we estimate the reef construction to begin in May 2007. The build-out reef would then be completed by October 2008.

As part of the timing described above, when Edison completes the second phase reef design (the final mitigation plan), and Edison applies for permits for construction, it may be determined at that time that additional environmental documentation is needed (Resource Insights, 1999 – page 1-1). CSLC is serving as the Lead Agency pursuant to the California Environmental Quality Act (CEQA).

Regarding the duration of construction, the PEIR does establish that the time of year construction is possible is the period between May 1 and September 30, due to the need to avoid lobster fishing season. This is a project mitigation measure that has been incorporated into the project description PEIR, p. 3-18).

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<u>APPENDIX C</u>: SONGS MITIGATION KELP REEF SITING STUDIES

SONGS permit site criteria development

Site selection for the SONGS kelp mitigation reef is governed by the CCC-permit constraints (Section 1.2 of Condition C of the Permit). These site criteria have been further refined or characterized (Ambrose, 1994; and Resource Insights, 1999) by the following list:

1) suitable kelp growth depths–approximately 11 to 16 m;
2) a thin, less than 0.5 m, layer or veneer of sand on top of bedrock or existing natural hard substrate (to avoid having the reef disappear into soft, deep sand);
3) near-persistent natural kelp forests;
4) not directly on existing natural hard-bottom substrate (in order to avoid impacts on or disruption of possible sensitive or rare benthic habitat and associated communities);
5) at a distance from areas with major sediment deposition, such as river mouths;
6) at a distance from areas near wastewater discharge or other human perturbations;
7) at a distance from areas of historical or cultural resources (including areas where there is evidence of possible buried shipwrecks); and
8) as near as practical to the SONGS-impacted natural kelp reef (in an effort to achieve reasonable in-kind, in-place mitigation), and not further than South Laguna Beach to the north and Leucadia to the south.

As the SONGS kelp mitigation project plan evolved and matured from 1991 through 1999, the project participants also agreed that it would be most advantageous to build the entire 150-acre kelp mitigation artificial reef at one location (Resource Insights, 1999). Splitting it into smaller components at various locations could result in less satisfactory and/or possibly less understandable kelp performance results, because:

1) Site-to-site differences might mask or overwhelm the critical design variables that are being tested in Phase One of the project, especially if the Phase One modules were too small and spread out to properly represent the build-out phase reef.
2) Past studies have shown that more fish are attracted to small artificial reef modules than are seen on natural reefs; and graze more persistently and “unnaturally” on the recruiting kelp at these smaller artificial modules (Carter et al. 1985; Patton et al., 1994).
3) Relying on small, scattered reefs would negate the benefits that large reefs are likely to have, including self-sustaining kelp recruitment. This seems especially relevant since long-distance advection of kelp spores is limited (Anderson and North, 1966; Reed et al., 1996). Specifically, data on kelp spore dispersal indicate that, on average, >90% settle within 1.5 m of the parent plant. Successful colonization of more distant sites requires massive dispersal events of clouds of spores from large beds (Anderson et al., 1966; Reed et al., 1988).

Development of Site Assessment and Site Ranking for the Mitigation Reef

The six sites initially surveyed in 1991 (South Laguna, Dana Point, San Clemente, San Onofre, Carlsbad, and Leucadia) were further sub-divided and re-evaluated as nine sites in 1993 (from north to south): South Laguna, North San Clemente, Mid San Clemente, South San Clemente, South San Mateo Point, South San Onofre, North Carlsbad, South Carlsbad, and Leucadia. These nine sites were given a combined ranking based on all of the CCC-permit siting and geological study criteria, which included (EcoSystems M., 1993):

1) area available, based on bathymetry for kelp-appropriate depths: between 11 and 16 m;
2) area available, based on side-scan for avoiding exposed hard substrate;
3) area available, based on sub-bottom sonar, to find shallow sand veneer with more desirable sub-bottom foundation materials;
4) possible additional area, based on acceptance of slightly thicker sand veneer;
5) assessment, based on diver probes, of percent fine and coarse materials in the exposed veneer and makeup of the hard sub-bottom;
6) apparent wave exposure/disturbance;
7) runoff from adjacent streams or anthropogenic disturbances; and
8) proximity to existing kelp beds.

The 1993 ranking (EcoSystems M., 1993) was: 1) South San Clemente, 2) South San Onofre, 3) Mid San Clemente, 4) South San Mateo, 5) North San Clemente, 6) South Laguna, and 7) the two Carlsbad sites. The Leucadia site was dropped from the evaluation for being too far from the point of impact at SONGS.

In the 1997-1998 re-evaluation (Elwany and Deysher, 1998), the sites were again ranked in support of the Draft Environmental Impact Report (Resource Insights, 1998). The primary criterion for siting the project artificial reef was that a site could accommodate the full 150-acre kelp mitigation reef on a sand bottom of less than 0.5 m of veneer over a hard sub-bottom. The draft EIR needed to describe and assess alternatives to a preferred project. As a result, the 1997-98 assessment included one new northern site: Salt Creek; and five new southern sites: Encinitas, Cardiff, Solana Beach, Del Mar, Torrey Pines, and Mission Beach. San Clemente was also evaluated from the San Clemente Pier to San Mateo Point. The ranking of the six best sites were (the acres available are in parenthesis): 1) San Clemente, from the Pier to San Mateo Point (356 acres), 2) Leucadia (25 acres), 3) Encinitas (25 acres), 4) North Carlsbad (30 acres), 5) South Carlsbad (64 acres), and 6) Mission Beach (85 acres) (Elwany and Deysher, 1998). Other sites did not fit criteria and were eliminated.

Public comments concerning site selection in the Final EIR stage of 1998-1999 project environmental evaluation process necessitated that the San Clemente area be further evaluated. Special emphasis was placed on areas: 1) to the north of the San Clemente Pier, and 2) to the seaward side of the preferred Pier-to-San Mateo area. These two areas were evaluated, and they ranked low for two reasons: 1) deeper sand, and 2) deeper sand plus water too deep to support kelp, respectively.

Table C-1 summarizes the Final EIR (Resource Insights, 1999), reef-siting evaluation results and includes the potential sites with acreages approaching or exceeding the 150 acres needed to build the mitigation reef. This assessment was done as part of the final EIR process. It divides San Clemente into four sub-areas, and looks only at the sites deemed promising in earlier studies that are closer to being in the "in-place, in-kind" mitigation. This final evaluation also includes Mission Beach for two reasons: 1) it is the area with the only persistent kelp bed growing on an artificial reef in southern California (Deysher et al., 2002), and 2) it has enough area to build at least a significant portion of the mitigation reef. The ranking draws from all previous assessments: the initial studies of 1991-1993 (EcoSytems, 1993), the follow-up studies of 1997-1998 (Elwany and Deysher, 1998), and the thinking that went into the EIR (Resource Insights, 1999). The San Clemente (Pier to San Mateo Point) site prevailed as the highest ranked site and the most conducive to single-site total mitigation reef success.

Determining the Preferred Site for the SONGS Mitigation Reef

The preferred site, San Clemente from the City Pier south to San Mateo Point, was fully characterized, combining the geological parameters, to allow for effective reef module placement. The 22.4-acre experimental kelp reef was designed to allow for study of various bottom coverage densities - 17%, 34%, and 67% - and for comparison between quarry rock and broken concrete material (Resource Insights, 1999; Deysher et al., 2002). All of the siting data that were collected in the geophysical and geologic surveys were incorporated into ARC/INFO GIS coverages. In this manner, the data layers could be combined, and intersections of the desired unions could be graphically displayed and areas calculated.

The geophysical surveys included substrate type (from side-scan sonar surveys), bathymetry, and sediment thickness. The geotechnical data are from sediment thickness determined by jet probes. ARC/INFO polygon coverages were created for substrate, sediment thickness, and water depth, and for an additional coverage containing a union of all three of these physical parameters. Maps were produced in ArcView using various combinations of coverages.

The final GIS figure (Figure C-1) combines the data from the substrate, sediment thickness, and bathymetry surveys and displays them as a GIS overlay of suitability for reef development. The criteria for suitability were >90% sand on the seafloor, between 12 and 15 meters of water depth, and less than 0.5 meters of sediment thickness. There are approximately 355 acres that qualify as suitable for reef placement in this study area. This is the area that was directed to the California State Lands Commission for a Lease of State Submerged Lands for this project. A buffer zone was also requested and obtained from State Lands Commission, such that the final lease zone granted is 850 acres. The Phase One reef, the San Clemente Kelp Experimental Artificial Reef, was designed as 56 specific 0.4-acre modules, grouped in seven blocks of 8 modules, totaling 22.4-acres (Deysher et al., 2002).

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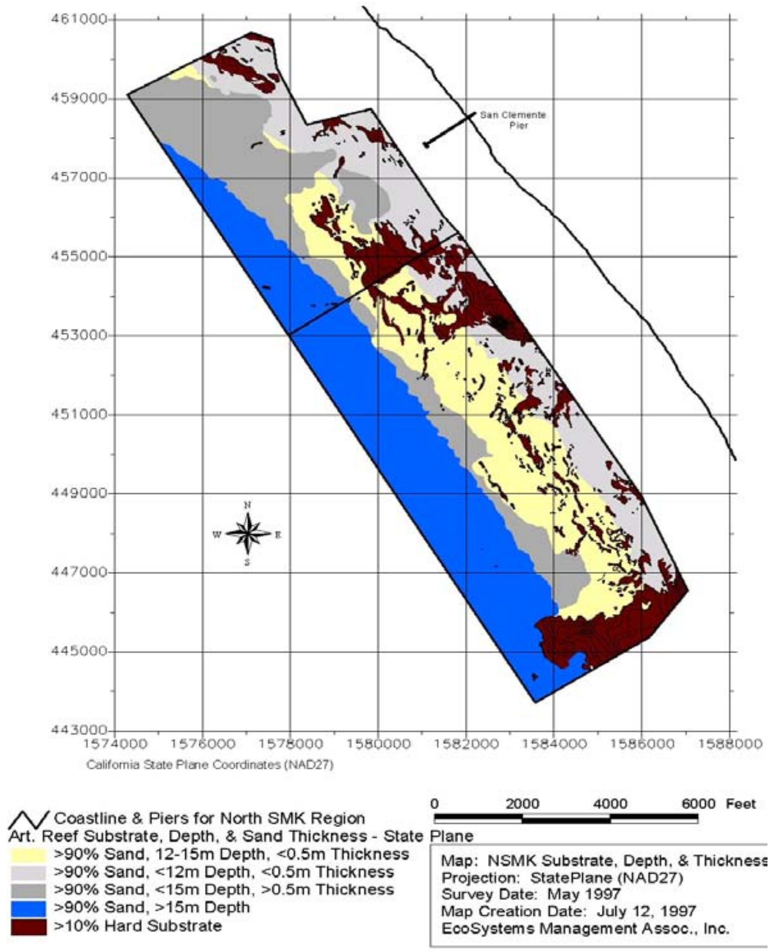
Table C-1 summarizes the Final EIR (Resource Insights, 1999), reef-siting evaluation results and includes the potential sites with acreages approaching or exceeding the 150 acres needed to build the mitigation reef. This assessment was done as part of the final EIR process. It divides San Clemente into four sub-areas, and looks only at the sites deemed promising in earlier studies that are closer to being in the "in-place, in-kind" mitigation. This final evaluation also includes Mission Beach for two reasons: 1) it is the area with the only persistent kelp bed growing on an artificial reef in southern California (Deysher et al., 2002), and 2) it has enough area to build at least a significant portion of the mitigation reef. The ranking draws from all previous assessments: the initial studies of 1991-1993 (EcoSytems, 1993), the follow-up studies of 1997-1998 (Elwany and Deysher, 1998), and the thinking that went into the EIR (Resource Insights, 1999). The San Clemente (Pier to San Mateo Point) site prevailed as the highest ranked site and the most conducive to single-site total mitigation reef success.

Table C-1. The final ranking of the potential sites for development of the artificial reef for kelp.

Site	**Final Ranking or Overriding Factor**	**Stage in Study When Assessed**	**Approximate Area in Acres**	**Other Significant Factors**
Sites of adequate size and near impact site:				
San Clemente – Pier and South	Preferred site (#1)	1991-93; 1997-99	356	Preferred site – thin sand veneer and near existing kelp beds.
San Clemente – North of Pier	Deep sand	1991-93; 1997-99	163	Fishermen prefer this site for reef, yet site has high turbidity.
San Clemente –Nearest Dana Point	Deep sand, near river mouth	1991-93; 1997-99	180	High turbidity, finer sand, deep sand, and near a sewer outfall and river mouth.
San Clemente – Deepwater area, further offshore	Too deep for kelp bed	1998-1999	300+	Fishermen interested in this site, yet too deep for kelp and in an area of deep sand.
Sites too small, but maybe combined:				
South Carlsbad	Near river mouth, abandoned in EIR	1997-99	64	Adjacent to Batiquitos Lagoon and sewer outfall.
North Carlsbad	Maybe combined, abandoned in EIR	1991-93; 1997-99	30	Appropriate sand veneer. Small area, especially for kelp.
Leucadia	Maybe combined, abandoned in EIR	1991-93; 1997-99	25	Appropriate sand veneer. Small area, especially for kelp.
Encinitas	Maybe combined, abandoned in	1997-99	25	Appropriate sand veneer. Small area, especially for kelp.

Site	Final Ranking or Overriding Factor	Stage in Study When Assessed	Approximate Area in Acres	Other Significant Factors
	EIR			
Laguna	Fine sediments, rejected pre-EIR	1991-93	34	Small area, near turbidity sources and near sewage outfall, and no nearby kelp.
Sites no longer considered:				
Mission Beach	Dismissed by resource agencies: too far away	1997-99	85	No exposed hard substrate nearby, deep sand, and far from SONGS, yet adjacent to small artificial reef with kelp.
South of San Onofre	Not allowed: U.S. Marine Base	1991-93; 1997-99	218	On Marine Corps Base (not allowed) and in deep sand area.
South of San Mateo	Not allowed: U.S. Marine Base	1991-93; 1997-99	168	On Marine Corps Base (not allowed) and near creek mouths.

Figure C-1: Final GIS overlay of the San Clemente Artificial Reef area. The overlay combines the data from the substrate, sediment thickness, and bathymetry surveys and displays them for reef development decisions. Sand cover depths show suitable kelp reef habitat: The criteria for suitability were >90% sand on the seafloor, between 12 and 15 meters of water depth, and less than 0.5 meters of sediment thickness.



APPENDIX D: AN UNDERSTANDING OF KELP REEF DESIGN ISSUES, DEVELOPED FROM HISTORICAL STUDIES AND THE EXPERIMENTAL REEF STUDY

Kelp Artificial Reef Height and Stability Design Issues

Assessment of artificial reefs in southern California over the last 40 years has revealed that they can be poorly designed with respect to their surrounding physical environment as well as to their proposed biological function (Deysher et al. 2002; Turner et al. 1969). Pendleton Artificial Reef (PAR) is an example of an over-built artificial reef that failed to achieve its biological function. It was built in 1981 as a research reef and was intended to create a habitat for giant kelp (*Macrocystis pyrifera)* (Grove, 1982; Grant and Wilson, 1982). However, the design was based primarily on fish attraction reefs (Lewis and McKee, 1989; Wilson, 1991): The reef consisted of high (2-3 m), vertical relief modules of rock mound clusters, separated by sandy seafloor. Spacing of the modules was intended to produce more varied ecological zones and create current patterns that would trap drift kelp. These design features did not appear to demonstrate any benefit in growing persistent kelp on PAR (Wilson and Grant, 1987).

The high vertical relief of PAR turned out to be problematic for successful persistent kelp growth (Carter et al, 1985; Patton et al., 1994). Patton et al. (1994) determined, through the study of 24 different artificial and natural reefs in Southern California, that high relief (>1.5 m) reefs: 1) create more turbulence than lower relief reefs, and 2) are ideal habitat for kelp-grazing fish. Both of these factors may contribute to poor kelp growth. Also, high relief reefs appear to favor longer-living attached organisms, such as the sessile invertebrate sea fan *Muricea californica*, which can have longevity of over 45 years. Patton et al. (1994) attributed this to the structural stability of high relief reefs. These types of reefs are much less disturbed by storm wave and high current conditions with respect to: 1) sediment scour, 2) periods of high sand abrasion, 3) episodic reef rock overturning, and 4) intermittent burial.

In contrast to *Muricea*, giant kelp is often one of the first organisms to appear on newly introduced bare rock or recently disturbed hard substrate. Giant kelp has many of the characteristics of organisms specializing in often-disturbed habitats: It is dispersive, fast-growing, short-lived, fecund, fertile all year, and can have massive recruitment after heavy storms (Deysher et al. 2002; Patton et al., 1994; Curtis and North, 2002).

Kelp Persistence Observations on Artificial Reefs

Historically, seven artificial reefs in Southern California were placed in depths that are conducive to kelp growth. All seven reefs had observed kelp growth within the first three years of their construction. Six of these reefs have not had kelp growth after the initial three years (Figure D-1). All six of these reefs are clusters of high-profile rock mounds, essentially designed to target fish attraction. Only the reef at Mission Beach continued to have kelp persistently for more than three years. The Mission Beach Artificial Reef is the only low-relief reef in Southern California (Deysher et al. 2002). The Mission Beach

Artificial Reef is built in 1992 out of concrete rubble from a Mission Bay bridge demolition job. The concrete was dropped into 15.5m to 18m of water from a moving barge (Coastal Resources, 1997). The resulting reef is scattered concrete slabs, with varying amounts of overlapping and very irregularly spaced (Figure D-2).

Kelp Reef Hard Substrate Coverage Issues

Natural Reefs verses Artificial Reefs and the Hard Substrate Calculation Issue

Natural reefs in the area, including the San Onofre Kelp Bed, have a bottom coverage of hard substrate of about 60% to 67%. This coverage has been calculated by side-scan sonar. Side-scan picks up all hard materials and groups them as: "hard" (as opposed to "sand"). The San Clemente Experimental Artificial Reef has been decreed by the Permit to emulate this local natural habitat. Yet, differences in interpreting hard substrate cover prevail because the natural reef hard substrate consists of a range of material from fine gravel and shell hash up through fist-sized cobble and ultimately small boulders and even exposed bedrock. By contrast, the artificial reef consists of 1 foot to 3 foot boulder-size material. The first problem this presents is: how much of the material at the natural reefs is of a size that supports kelp? Dean and Deysher (1997) calculated that the large-size cobble and boulders at SOK really amount to about 20% of the reef area, the rest of the hard material would be too small to allow kelp to successfully reside on the reef. This leads to possible ecological problems such as: if the artificial reef is built with boulders to cover 60% or more of the bottom, then this could lead to a reef that is too stable, thus allowing *Muricea* to dominate.

Construction Issue - Hard substrate: sonar and engineering measurement calculations

The Experimental Reef was designed to have a mono-layer of hard substrate, with treatments (bottom coverages) of 17%, 34%, and 67%. The amount of material needed for each treatment was calculated on a weight/volume basis by coastal engineers. The construction barges were loaded with the proper weight of material to build each specified module. Additionally, the engineers, working with the construction team, conservatively specified 15% additional material on each module to account for any material that could occasionally overlap onto itself in parts of each module. The engineers also used a second estimate for density determinations based on the observed number of bucket loads of material being placed in each module, but this estimate also related to tonnage(weight).

The 56 Experimental Reef modules were individually side-scan sonar surveyed after construction in the Fall of 1999 and were verified to be have acceptable densities (Coastal Environments, 1999). The rock quarry rock densities for the design 17%, 34%, and 67% modules were: 22.2%, 35.2% and 62.6% respectively averaged over the seven sets of blocks. For the concrete modules, the design densities of 17%, 34%, and 67% were: 18.6%, 36.2%, and 61.9% respectively averaged over the seven sets of blocks.

Hard substrate monitoring comparisons: diver transect verses sonar survey calculations

Diver biologists use a different method to calculate bottom density: line transects are strung over the modules at various intervals; and at set points along the line an observation of either sand or rock is made. Then these transect measurements are extrapolated for the entire module.

The diving biologists found that their line transect hard substrate calculations were substantially higher than the initial construction verification sonar survey calculations performed in late 1999. Part of the difference was due to the observation that the scoops of material, as dumped from the barges, were still settling: some of the materials were initially leaning into each other and/or there were pieces balanced on top of each other. Over the first few months of the reef's existence which included winter storms, these materials seemed to have settled and spread out a bit further. This movement was substantiated by the fact that the set of lead-line transects that the biologists strung over the modules immediately after construction ended up breaking and shifting over the first few months of their monitoring project. The reef material was still moving and spreading. The diving method of calculating hard substrate coverage resulted in the design modules of 17%, 34%, and 67% ending up being: 54%, 65%, and 84%, respectively, on average. Yet, it is difficult to grasp that the hard substrate density increase of roughly 2.4 times (54%/22.2%) for the "17%" modules, 1.9 times (65%/34%) for the "34%" modules, and 1.3 times (84%/67%) for the "67%" modules between the accepted sonar density verification surveys done in September-October 1999 and the subsequent diver surveys done over the next few months is totally due to the initial material settling and shifting. This disparity is especially difficult to understand because the greatest portrayed material sorting, separation, and movement seemed to have occurred at the lowest density modules where material stacking and pieces leaning into each other would be least expected. The lesson learned is when using sonar to verify rock densities on the bottom, set your goal at 50% of the intended density, since sonar underestimates b at least 50%, or the diver survey methods significantly overestimate bottom density. Also, the additional 15% for overlap should be dropped in the future.

San Clemente Experimental Reef Study Findings that Influence Design

Through 4 years of the 5 year Experimental Reef Program, the following observations have been made that may influence the final design and placement of the build-out reef (Schroeter, 2003):

Inshore-offshore kelp growth variation

Within the depth range of the modules, 12 to 16 meters, there does not seem to be a noticeable difference in kelp growth densities. The commonly accepted phenomenon of more turbid waters being prevalent in a shoreward direction does appear to apply to the San Clemente area. This would mean the more shoreward modules could be the most affected by turbidity, especially after large storms and episodes of intense river runoff. So, the inshore (12 meter) modules maybe experiencing slightly more turbidity. But, kelp density difference have not been evident.

Hard substrate densities with respect to kelp densities:

All hard substrate density coverages of the 56 experimental modules would meet the Permit-performance kelp density requirement of 4 plants per 100 m^2. Yet, so far, there seems to be a linear relationship that the more hard substrate in the modules, the more kelp.

Quarry rock verses broken concrete

There does not appear to be differences between quarry rock and broken concrete. Both materials appear to adequately support kelp bed habitat.

Muricea observations

Muricea in the Experimental Reef is continuing grow and to spread. It continues to spread from the southerly, San Mateo Point, area. It is spreading uniformly from block to block from south to north. About 90% of the *Muricea* is within the southerly three blocks, and half of that seen is in southerly-most block, as of July 2003. This is slightly different compared to the pattern of kelp growth away from SMK. Kelp was initially more prevalent on the artificial reef blocks closest to SMK, but not as uniformly so, compared to how *Muricea* is now growing. The fate of *Muricea*, and impact on kelp of *Muricea*, in the Experimental Reef is still playing out.

Further, the UCSB scientists are observing significant *Muricea* at the base of the reef rocks. This is surprising, since sand abrasion occurs along the base of rocks, and it was hypothesized that sand abrasion during storms would clear away fauna such as *Muricea* so that kelp could move into these raw-substrate areas.

Reef coverages - stability, rock overturning, and kelp recruitment observations

A major component of the experiment was to assess kelp recruitment differences compared to disturbance rates on the various coverages of hard substrate in the modules. The hypothesis that is the foundation of the experiment is that the lower-density coverages would have higher disturbance rates when large wave storms occurred, and more kelp would grow on the newly disturbed substrate compared to higher density, more stable modules. There have been no storms in the 3.5 years of the experiment that have caused any reef material to be disturbed, either overturned materials, or even significant sand abrasion. Therefore, one of the major components of the Experimental Reef has to date gone untested.

How are kelp densities calculated?

The CCC/UCSB monitoring program is committed to assess kelp densities and bottom substrate coverage in a way that is directly comparable to the 1978-89 Marine Review Committee (MRC) study of the San Onofre and San Mateo Kelp Bed area. The MRC calculated kelp loss in terms of plants per acre and coverage in terms of percent total hard substrate coverage. The performance criteria of 4 plants per $100 m^2$ is equivalent to about 160 plants per acre (2.47 acres = 10,000 m^2 ; and 1 acre = 4,049 m^2) so, 1 acre should support 162 adult kelp plants). Therefore, the kelp performance standard is envisioned to be the total amount of kelp plants within each one-acre area. This translates to mean: if half of the acre has 320 kelp plants, and half has zero kelp plants, the performance criteria of 4 plants per 100 square meters is satisfied.

Weather and Oceanographic patterns during the Experimental Reef Monitoring Program

The Experimental 22.4-acre reef was built within one year of the conclusion of a major El Niño (1997-1998) and during a relatively significant La Niña (1999-2003). The El Niño/La Niña cycle appears to be important in influencing reef project success. Storm conditions associated with El Niño years could periodically interrupt and seriously delay construction operations. The construction barges must seek harbor shelter when long-period swell is predicted. Further, the success of kelp growth on the Experimental Reef may be in response to the fortuitous time of the reef's construction just after the 1997-98 El Niño and at the onset of a long La Niña. The construction schedule needs the flexibility, based on the near-term ENSO forecasts, to avoid building the 128-acre reef during or just prior to an El Niño episode.

This time period (1999-January 2004) is also now classified as possibly being in the initial segment of a cool, dry, less stormy period (1998-2018) of the Pacific Decadal Oscillation weather cycle. Therefore, not only will kelp performance be contingent on when the artificial reef is built within the El Niño/La Niña cycle; but also persistent kelp growth will be contingent on long-term oceanographic conditions that could, for example, mask negative impacts from the next El Niño, or negate the positive influences of future La Niñas.

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Figure D-1: Kelp performance on artificial reefs in southern California from 1975 to 2000: summary of the history (presence/absence) of kelp populations on shallow-water artificial reefs

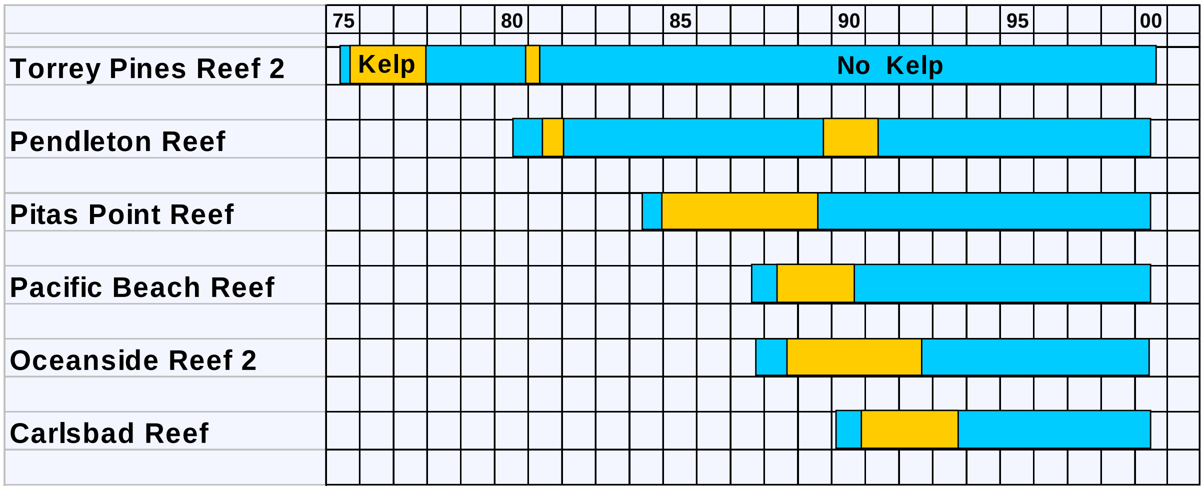

Figure D-2. Classes of concrete coverage density on the Mission Beach Artificial Reef as mapped by side-scan sonar by EcoSystems Management, Inc. The bathymetry of the region is also characterized, with the reef being in 15.5 to 18 meters of water.