University of California

Southern California Educational Initiative

Annual Report

2000-2003

University of California

Southern California Educational Initiative

Annual Report
2000-2003

Russell J. Schmitt
Program Manager, SCEI
and
Director, Coastal Research Center

Marine Science Institute
University of California
Santa Barbara, California 93106-6150

Mission of the Coastal Research Center

The Coastal Research Center of the Marine Science Institute, UC Santa Barbara, facilitates research and research training that foster a greater understanding of the causes and consequences of dynamics within and among coastal marine ecosystems. An explicit focus involves the application of innovative but basic research to help resolve coastal environmental issues.

Disclaimer

This document was prepared by the Southern California Educational Initiative, which is jointly funded by the Minerals Management Service and the University of California. The report to the Minerals Management Service under contract agreement number 14-35-0001-30761 has not been reviewed by the Service. The views and conclusions contained in this document are those of the Program and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

Availability of Report

A limited number of extra copies of this report is available. To order, please write to:

Jennifer Lape
Coastal Research Center
Marine Science Institute
University of California
Santa Barbara, California 93106-6150

A PDF version of this report is available on our web site, http://coastalresearchcenter.ucsb.edu/SCEI

TABLE OF CONTENTS

Program Manager's Report 1

Summary of Research Progress 5

Research Productivity 63

Personnel Funded 73

Curriculum Vitae 79

THE SOUTHERN CALIFORNIA EDUCATIONAL INITIATIVE

A University Research Initiative Program
involving the

University of California,
the State of California

and the

Minerals Management Service
US Department of Interior

ANNUAL REPORT

PROGRAM YEAR 11, 12, 13 & 14

July 15, 2003

PROGRAM MANAGER'S REPORT

The Southern California Educational Initiative (SCEI) was initiated in May 1989 as a cooperative research and research training program involving the Minerals Management Service, the State of California and the University of California. The focus is on long-term environmental, social and economic consequences of oil and gas production activities in the Pacific Outer Continental Shelf region. The university-based research program has just completed its fourteenth year. This Annual Report summarizes activities and research progress during Program Year 11 (July 1, 1999 - June 30, 2000), Program Year 12 (July 1, 2000 - June 30, 2001), Program Year 13 (July 1, 2001 – June 30, 2002), and Program Year 14 (July 1, 2002 – June 30, 2003).

Major programmatic progress achieved during Program Year 11 of the SCEI is summarized below.

- A research retreat, co-sponsored by the SCEI and the complimentary state-funded training program (the UC Coastal Toxicology Program) was held in September 1999 at the Bodega Marine Laboratory to discuss and integrate findings by SCEI natural and social scientists and the UC Coastal Toxicology Program;
- In April 2000, the SCEI, in cooperation with the UC Coastal Toxicology Program, hosted the Annual Symposium of the UC Toxic Substances Research and Teaching Program at San Diego, California, at which studies sponsored by the SCEI were presented;

- This year, SCEI-sponsored studies produced 3 peer-reviewed papers that were published with an addition 3 research presentations;
- One Project Final Report was completed and distributed;
- During the 1999-2000 year 17 regular and research faculty, 30 trainees (4 postdoctoral, 8 graduates, and 18 undergraduates) and 14 staff from 6 campuses and laboratories participated in SCEI research projects.

Major programmatic progress achieved during Program Year 12 of the SCEI is summarized below.

- A research retreat, co-sponsored by the SCEI and the complimentary state-funded training program (the UC Coastal Toxicology Program) was held in September 2000 at the Bodega Marine Laboratory to discuss and integrate findings by SCEI natural and social scientists and the UC Coastal Toxicology Program;
- In April 2001, the SCEI, in cooperation with the UC Coastal Toxicology Program, hosted the Annual Symposium of the UC Toxic Substances Research and Teaching Program at Lake Tahoe, California, at which studies sponsored by the SCEI were presented;
- This year, SCEI-sponsored studies produced 6 peer-reviewed papers that were published with and addition 3 research presentations;
- Six Project Final Reports were completed and distributed;
- During the 2000-2001 year 17 regular and research faculty, 13 trainees (2 postdoctoral, 5 graduates, and 6 undergraduates) and 9 staff from 6 campuses and laboratories participated in SCEI research projects.

Major programmatic progress achieved during Program Year 13 of the SCEI is summarized below.

- A research retreat, co-sponsored by the SCEI and the complimentary state-funded training program (the UC Coastal Toxicology Program) was held in September 2001 at the Bodega Marine Laboratory to discuss and integrate findings by SCEI natural and social scientists and the UC Coastal Toxicology Program;
- In April 2002, the SCEI, in cooperation with the UC Coastal Toxicology Program, hosted the Annual Symposium of the UC Toxic Substances Research and Teaching Program at Long Beach, California, at which studies sponsored by the SCEI were presented;
- This year, SCEI-sponsored studies produced 6 peer-reviewed papers that were published with an additional 5 research presentation;

- During the 2001-2002 year 7 regular and research faculty, 8 trainees (1 postdoctoral, 2 graduates, and 5 undergraduates) and 9 staff from 4 campuses and laboratories participated in SCEI research projects.

Major programmatic progress achieved during Program Year 14 of the SCEI is summarized below.

- A research retreat, co-sponsored by the SCEI and the complimentary state-funded training program (the UC Coastal Toxicology Program) was held in September 2002 at the Bodega Marine Laboratory to discuss and integrate findings by SCEI natural and social scientists and the UC Coastal Toxicology Program;

- In April 2003, the SCEI, in cooperation with the UC Coastal Toxicology Program, hosted the Annual Symposium of the UC Toxic Substances Research and Teaching Program at Oakland, California, at which studies sponsored by the SCEI were presented;

- This year, SCEI-sponsored studies produced 5 peer-reviewed papers that were published with an additional 5 manuscripts that are in press, and 2 research presentations;

- Ten Project Final Reports were completed and distributed with an additional two Draft Final Reports submitted for review;

- During the 2002-2003 year 6 regular and research faculty, 1 graduate trainee and 4 staff from 3 campuses and laboratories participated in SCEI research projects.

SUMMARY OF RESEARCH PROGRESS

Effects of Biologically Degraded Oil on Marine Invertebrate and Vertebrate Embryos and Larvae 7

Detecting Ecological Impacts: Effects of Taxonomic Aggregation in the Before-After/Control-Impact Paired Series Design 11

Variability in the accumulation and persistence of tar in four intertidal communities along the central and southern California coast (Effects of an Oil Spill on Multispecies Interactions that Structure Intertidal Communities) 17

Inventory of Rocky Intertidal Resources in San Luis Obispo and Northern Santa Barbara Counties 28

Inventory of Rocky Intertidal Resources in Southern Santa Barbara and Ventura Counties 35

The Role of Knowledge in the Public's Trust in Science about Offshore Oil and Gas Development (A Design for a Time Series Study of a NIMBY Response) 39

Application of Genetic Techniques for use in Restoration of Surfgrass (*Phyllospadix torreyi*) 46

Early Development of Fouling Communities on Offshore Oil Platforms 50

The Political Economy of the Rigs-to-Reef Option for Decommissioning of Offshore Oil and Gas Structures 58

Effects of Biologically Degraded Oil on Marine Invertebrate and Vertebrate Embryos and Larvae

Principal Investigators: **Gary N. Cherr**, Bodega Marine Laboratory, University of California, Davis, CA 94923, **Rick Higashi**, Crocker Nuclear Laboratory, University of California, Davis, CA 95616, **Frederick J. Griffin**, Bodega Marine Laboratory, University of California, Davis, CA 94923.

Background

The removal of volatile compounds through weathering of crude oil results in the release of low boiling point aromatic and saturated hydrocarbons. It has been thought that those components hold the greatest toxicity to marine life (Capuzzo, 1987; Galt *et al*., 1991; Payne *et al*., 1991; Venkateswaran *et al*., 1995). Although biodegradation of crude oil can be considered a component of the weathering process, the process continues well after initial weathering and the elimination of volatile compounds has occurred. Known results of this continued microbial degradation include a measurable decrease in sediment crude oil along with a measurable organic enrichment in those sediments (Spies, 1987). Recently, studies (including our laboratory) have demonstrated that a by-product(s) of microbial degradation of artificially weathered Alaska North Slope crude oil is a ten fold increase in neutral water soluble hydrocarbons that exhibits significantly high toxicity to developing atherinid and clupeoid fish embryos (Middaugh *et al*., 1996, 1998). Biodegradation of crude oil occurs in regions of natural seepage (e.g., Coal Oil Point) as well as in regions of oil production and transport where elevated populations of crude oil-degrading microbes are purported to exist (Spies, 1987). It can be assumed that the process of oil biodegradation in the Santa Barbara Channel near sites of natural oil seeps and non-catastrophic release (associated with oil production) is an ongoing process and that the products of that biodegradation are chronically present, resulting in profound long range implications to the biota of the area.

Summary of Research

Progress during 1999-2000

We have previously found that biodegraded water soluble fractions of crude oil are toxic to some species of marine larvae. Particularly striking are the dramatic differences in susceptibility observed in larvae from two species native to the California coast, *Lytechinus anamesus* (urchin) and *Urechis caupo* (innkeeper worm). Our research in the current year suggests that BWSF exerts dramatic effects even at low concentrations on urchin embryos. Continuously exposed urchin embryos exhibit dose-dependent delay in development in concentrations as low as 1%BWSF (corresponding to a 1:200000 dilution of crude oil) in filtered seawater (Fig. 1). The effects were evident in BWSF exposed embryos not only at the pluteal stage (Fig. 2) but were also manifested earlier in a delay to hatching.

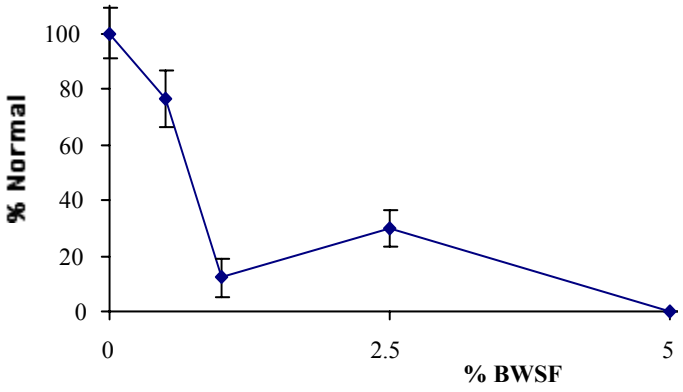


Figure 1. *Lytechinus anamesus* were exposed to different concentrations of BWSF in seawater following fertilization and scored at 96 hrs for percent that reached the pluteus larval stage.

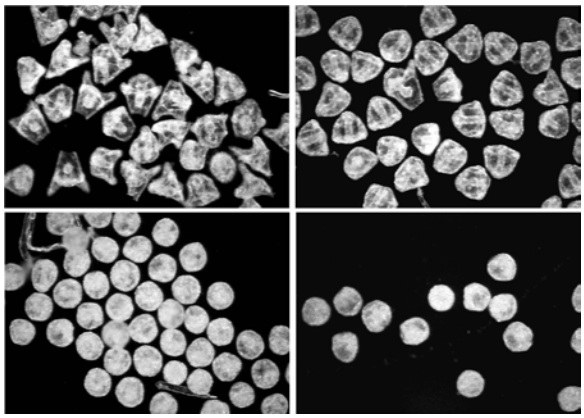


Figure 2. Effects of 1% BWSF exposure on development of plutei at 96 hrs post-fertilization.
A. Control embryos incubated in seawater.
B. Embryos in 1% BWSF in seawater.
C. 2.5 % BWSF in seawater.
D. 5% BWSF in seawater.

Previous research on stress responses of urchins has suggested that urchins do not express the full complement of stress responsive genes until after gastrulation. To investigate the hypothesis that BWSF exerts all of its effects on early life stages (prior to hatching) we assessed normal development in urchin larvae exposed to BWSF only at or after hatching. Similar effects were observed to those seen in continuously exposed embryos. We have also investigated the possibility that the difference in susceptibility to BWSF observed between the two species is caused by the different times taken to develop to larval stage at similar temperatures. We exposed *Urechis* to BWSF for 96 hours (corresponding to the time taken for normal urchins to reach the pluteus stage) and found no significant effect of BWSF.

We have shown that BWSF acts as a competitive inhibitor of ATPase mediated dye efflux. Our results suggest that this efflux is mediated by a homologue of the mammalian multi-drug resistance protein (MXR). Figure 3 shows the expression of multi-xenobiotic resistance protein (MXR) throughout development in both urchins and *Urechis*. Consistent with observations in the purple urchin, *Lytechinus* do not express MXR at any stage. In contrast, *Urechis* express relatively uniform amounts of this protein throughout development. Thus the

expression of MXR is consistent with the observed absence of stage specificity in susceptibility of urchins or *Urechis*.

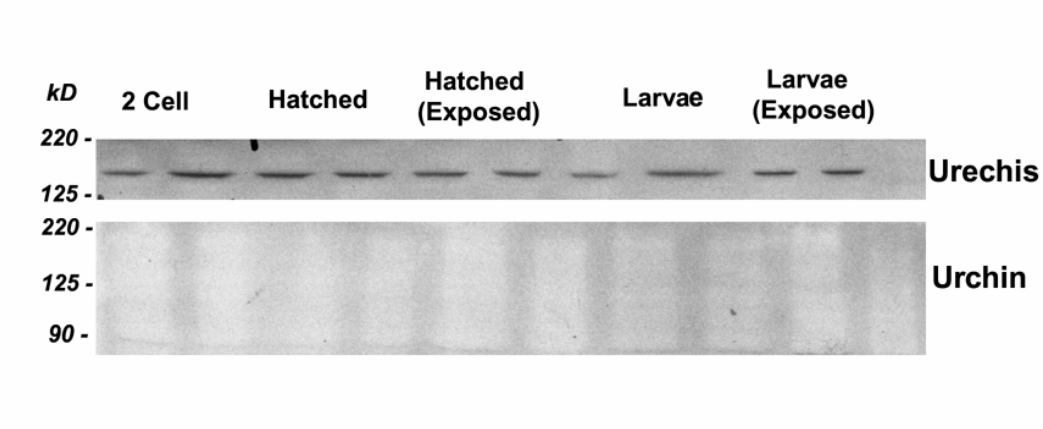


Figure 3. Western blot analyses of *Urechis* and sea urchin embryos using commercial monoclonal (C219) antibody raised against mammalian MDR1. All stages of *Urechis* embryos contain the transporter, but it is absent from sea urchin embryos. All lanes contain equal amounts of protein (30 µg) and blots were developed using a chemiluminescent method which is the most sensitive method of detection available.

To confirm that the dye efflux results observed in urchins and *Urechis* are not due to species specific differences in membrane permeability to dye we developed a dye efflux assay using calcein-AM (acetoxymethyl ester). The AM form of calcein is membrane permeable, while the free form is not. Moreover only the free form is fluorescent. Because the AM group is rapidly cleaved off by intracellular esterases the assay measures only the fluorescence of calcein trapped within the cells. The results are identical to those previously reported using the dye rhodamine.

Progress during 2000-2001

We are in the final stages of completing studies on the toxic effects of BWSF to marine invertebrate larvae. Three major model species remain the focus of our investigations; these are *Crassostrea gigas* (pacific oyster), *Lytechinus anamesus* (white urchin) and *Urechis caupo* (innkeeper worm). We are linking these developmental predictors of response to our functional observations of the multi xenobiotic response (MXR) in these embryos. We had recently developed a new method of measuring MXR dependent dye efflux in batches of whole larvae using the fluorescent probe calcein-AM. This probe has the advantage of being trapped inside larvae once the lipid soluble AM group is cleaved by intracellular esterases. This results in maintenance of a high inwardly driven gradient of calcein- AM even at very low extracellular concentrations. We have obtained a specific inhibitor of the MXR transporter which appears to impart resistance to PAHs in *Urechis*. We are just starting to use this inhibitor (termed "reversin") in order to confirm the MXR transporter's role in PAH tolerance. This compound will be used in both toxicity tests as well as in fluorescence assays.

The new fluorescence assay for MXR transporter activity, calcein AM, works very well and the final replicate experiments are now underway.

To confirm that the dye efflux results observed in urchins and *Urechis* are not due to species specific differences in membrane permeability to dye we modified a dye efflux assay using calcein-AM (acetoxymethyl ester). Urchin and *urechis* embryos were incubated for three hours with 0.5um Calcein-AM either in the presence or absence of BWSF. The AM form of calcein is membrane permeable, while the free form is not. Moreover only the free form is fluorescent. Because the AM group is rapidly cleaved off by intracellular esterases the assay measures only the fluorescence of calcein trapped within the cells.

The results confirmed our previous findings using the dye rhodamine. However the calcein AM assay did prove to be more consistent than the rhodamine assay. Urchins incubated in the presence or absence of BWSF accumulated high levels of free cacein as indicated by bulk fluorimetry (~200 counts/second/embryo). In contrast, urechis embryos accumulated significantly less free calcein in the absence of BWSF (~100 counts/second/embryo), but when incubated in the presence of BWSF accumulated nearly the same level of free calcein as in urchin embryos. The effects of BWSF in *urechis* were similar to those observed in embryos incubated in the presence of known inhibitors of MXR such as verapamil.

Analyses and writing culminated in the Final Report, which was submitted in April 2001.

Detecting Ecological Impacts: Effects of Taxonomic Aggregation in the Before-After/Control-Impact Paired Series Design

Principal Investigators: Sally Holbrook, Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara, CA 93106-9610, **Mark H. Carr**, Department of Biology, University of California, Santa Cruz, CA 95064, **Craig W. Osenberg,** Department of Zoology, University of Florida, Gainesville, FL 32611-8525

Background

Our project has three objectives related to the effect of taxonomic resolution on BACIPS designs. Two objectives include database development and data analysis for three separate datasets collected for three studies: the Carpinteria produce water discharge, Gaviota produce water discharge, and the San Onofre Nuclear Generating Station (SONGS) cooling water intake and discharge study conducted by the Marine Review Committee (MRC). A third objective is the size frequency analysis of targeted species from the Gaviota and Carpinteria studies.

Summary of Research

Progress during 1999-2000

The fourth year of this study involved three overall objectives listed and addressed separately below. Two objectives include database development and data analysis for three separate datasets collected for three studies: the Carpinteria produce water discharge, Gaviota produce water discharge, and the San Onofre Nuclear Generating Station (SONGS) cooling water intake and discharge study conducted by the Marine Review Committee (MRC). A third objective is the size frequency analysis of targeted species from the Gaviota and Carpinteria studies. In addition to the objectives below, we are continuing to work to have the benthic samples archived at the Natural History Museum of Los Angeles County.

<u>Objective 1: Size frequency analyses of Gaviota and Carpinteria benthic samples</u>

Size frequency samples are processed at Carr's lab at UC Santa Cruz. Samples are imaged and digitized with a video camera, frame grabber, and Adobe Photoshop software (Mac and PC-based systems). Images are measured using NIH imaging software. The focus this past year has been on processing (imaging and measuring) bivalve species. We focused primarily on *Tellina carpenteri* because of its abundance and ubiquity among sampling stations and dates. Preliminary size frequency distributions have been, and continue to be, generated and analyzed. This effort produced one undergraduate independent research project and is also the focus of an undergraduate senior thesis.

Objective 2: Database development for MRC and MMS/UC SCEI samples

Data acquisition, transcription and database development

Prior to any transcription of species identities and abundance data into any database, a master species list had to be compiled with the original and revised taxonomic designations for the pre-existing MRC-SONGS species list. This master species list includes all molluscs, polychaetes, crustaceans, and miscellaneous species found in all three studies (MRC, Carpinteria and Gaviota). All species have also been assigned the appropriate phylum, class, order, and family designations. All species have also been assigned an individual species code, compatible with the pre-existing codes in the original MRC-SONGS species list. A large number of taxa were new to the existing species list provided by the MRC surveys, so they have been assigned species-level codes compatible with pre-existing codes assigned to the MRC data. Lovell and Associates supplied the codes, and have reviewed them and the taxonomic classifications to insure that the proper codes were used and the classification of animals is current. This entire file has now been re-checked and validated by cross-reference with SCAMIT (1998). We had originally hoped to provide functional group designations for each taxon also, but we were unable to get the necessary information from a potential collaborator. After many requests and after waiting over a year for the promised information, we have abandoned this aspect of the project (although some portions of this might be salvable using information from the MRC study).

In addition to the master species list, individual databases for both Gaviota and Carpinteria for each sampling method (emergence traps, re-entry traps and biocores) have been compiled as Excel spreadsheets for eventual transformation to SAS datasets. These databases include appendices with information for interpreting the codes used in each database, a process trail indicating personnel involved in the identifications and data transcription and entry, and notes indicating alterations to the databases subsequent to their original formulation. Over 98% of these files have now been proofed and cross-checked by comparison back to the original datasheets and the taxonomic list. This process was extremely time-consuming. As soon as the proofing is completed, we will fully document and archive these files for storage (on CD), and then conduct the final analyses on these data.

Objective 3: Analysis of MRC and MMS/UC SCEI samples

Analysis of each of the three datasets requires complete and updated taxonomic data. It also requires the completed data files. We are now in the very last stages of proofing the files. As soon as this is completed, we will begin our analyses of the patterns of spatial and temporal variation and the influence of taxonomic aggregation for the MRC, Gaviota and Carpinteria studies.

Time Frame

This project has been far more time-intensive that first estimated. In addition, there have been several unforeseen delays. As a result, the project will not be completed by the project end date. We expect completion to require at least one additional year. Carr and Osenberg will, however, allocate time over the coming year to complete the documentation and conduct the

analyses. The delay was caused by an initial delay (of ~1 yr.) in obtaining the species-level identifications, the additional delay caused by the errors in the files provided to Osenberg's lab (which required extensive proofing), the delay caused while waiting for the functional group designations, and associated delays related to personnel (e.g., having people hired when we anticipated having raw data, but then not receiving those data until after the employment period ended). We will also continue our efforts to have all samples not designated for size frequency analysis to be archived at the Natural History Museum of Los Angeles County.

Research Productivity

Despite delays in our analyses of the effects of taxonomic aggregation, we have made significant progress in other areas of great interest to MMS. For example, application of the BACIPS sampling design and analytical framework, which is the focus of this study, was presented at two scientific meetings this year. These talks discussed the application of BACIPS in evaluating the effectiveness of marine reserves and artificial reef programs for management of coastal resources. The theoretical framework developed in the context of artificial reefs also has relevance to the recent discussion of the "rigs-to-reef" programs, and was further discussed in two other presentations.

One paper was published this year using data collected at Carpinteria by the SCEI program; two others related to artificial reefs are in review. New funding was also provided to these new research efforts that were stimulated by the SCEI program.

Progress during 2000-2001

Despite delays in our analyses of the effects of taxonomic aggregation, we have made significant progress in other areas of interest to MMS that are relevant to this project. One paper was published this year using data collected at Carpinteria by the SCEI program; two others related to artificial reefs are in review. New funding was also provided to these new research efforts that were stimulated by the SCEI program.

1) Taxonomic Aggregation and the Portfolio Analogy.

Recent papers by Doak et al. (1999) and Tilman et al. (1999) examined the effects of aggregation on temporal variance. Tilman's approach emphasized the portfolio theory of investment diversification. Although both papers were most interested in the relationship between species diversity and stability, the approach has direct relevance to the effects of taxonomic aggregation in BACIPS designs.

Both models, as well as our own, make the following assumptions. First, that the abundance of each species in a community is random and independent, with all covariances equal to zero. Further the models assume that all members of the community are equally abundant, on average (i.e., $m_1=m_2=\ldots=m_k$). In the Doak et al. model and the Tilman et al. model they further assume that the total community biomass is M. Thus, for a community of k species, $m_i=M/k$. At this point, Tilman et al. argue that a general relationship between the mean, m_i, and variance, $V(m_i)$, can be modeled using

$V(m_i) = cm_i^z$, where z represents the scaling between the mean and variance of a species. They further argued that Doak et al. considered the case of z=2, and that a more appropriate case might be $1 \leq z \leq 1.5$.

The crux of Tilman et al.'s point was that the effects of statistical averaging, as represented by the degree to which the coefficient of variation of the community, $CV_{(M)}$, depends on k, are dependent on the values of z. And that, with what they argue are more realistic values of z, $CV_{(M)}$ is independent of k. While we agree that the magnitude of statistical averaging will depend on z, the models considered by Doak et al. and Tilman et al. both rely on yet another simplifying assumption which, as we will show, affects their results. Specifically, both models assume the total biomass of the community, M, is independent of biodiversity. Thus, a monoculture will have the same mean biomass as a community consisting of several species. This is not certainly not true for our problem that deals with aggregation and it is probably also not true for communities studied in the context of biodiversity-stability relationships. Therefore, we have generalized their models to include the relationship between species numbers and community biomass, such that $M=\mu k^a$ and therefore, $m_i = M/k = \mu k^{a-1}$. In this generalized formulation, a represents the scaling of community biomass with species numbers. For taxonomic aggregation, we are most interested in the case where a=1.

Given this generalized formulation of the model, we can now evaluate the circumstances under which the $CV_{(M)}$ is dependent or independent of k, and to what degree. In the general case, $V(m_i) = cm_i^z = c\mu k^{a-1}$. Thus,

$$M = \sum_{i=1}^{k} m_i = \mu k^a \text{ and } V(M) = \sum_{i=1}^{k} V(m_i) = c\sum m_i^z = c\mu^z k^{z(a-1)+1}.$$

The coefficient of variation of the community is therefore,

$$CV_{(M)} = \frac{V(M)^{\frac{1}{2}}}{M} = \frac{(ck^{z(a-1)+1}\mu^z)^{\frac{1}{2}}}{uk^a} = c^{\frac{1}{2}}\mu^{\frac{z}{2}-1}k^{\frac{z}{2}(a-1)+\frac{1}{2}-a}.$$

This is a messy formulation, but in essence we can now define the conditions under which $CV_{(M)}$ is dependent on k and to what degree by evaluating the exponent of k, namely E=z(a-1)/2 + ½ - a.

First, consider the cases of Doak et al. and Tilman et al. Doak et al. presented the specific case of $a = 0$ and $z = 2$. Thus, $CV_{(M)} \propto k^{-0.5}$. Tilman et al. discussed the case of a=0 and $z = 1$, and later varied z, $0 \leq z \leq 1$. In the first instance, $E = 1$, and thus, $CV_{(M)}$ is not related to k. Tilman et al., then, raise the point that in cases were $z < 1$, $E > 0$. For example, if $z = 0.5$, then $CV_{(M)} \propto k^{+0.5}$, and thus, the averaging phenomenon (caused by aggregation) will result in greater levels of variation in more species rich communities.

In our more general model, the value and sign of E vary considerably with values of a and z. Hence the effect of diversity on stability depends on the parameters a and z. Doak et al. focused their modeling efforts on a special case, when $z = 2$. In this case, E = ½., and is independent of a. However, Tilman et al., did not consider a special case, and their

result does depend on a. In the majority of a, z space, $E < 0$ or $E > 0$. Generally speaking, values of $E < -0.5$ can be expected within two of four quadrants of a, z space, when the quadrants are defined by the lines $a = 1$ and $z = 2$. Positive values of E are associated with the other two quadrants.

For our case, being interested in aggregation in a BACIPS context, diversity is not varied. Instead, we have a particular community and we are choosing to aggregate the data in different ways. This simplies to the case where a=1 (and assuming all species are equally represented – an assumption needed for mathematically convenience, but which can be relaxed via simulation). In this case, $CV_{(M)} \propto k^{-0.5}$, indicating that the CV will decline with aggregation: aggregation will lead to a decline in this measure of temporal variance. What effect it will have on other measures of variability is still unknown.

2) *Application of BACIPS to coastal resource management: the effectiveness of marine reserves and artificial reef programs.*

Application of the BACIPS sampling design and analytical framework, which is the focus of this study, was presented at two scientific meetings in the past two years. These talks discussed the application of BACIPS in evaluating the effectiveness of marine reserves and artificial reef programs for management of coastal resources. The theoretical framework developed in the context of artificial reefs also has relevance to the recent discussion of the "rigs-to-reef" programs, and was further discussed in two other presentations. Some of this work is now in press, and can be obtained from C. Osenberg upon request.

3) *New Funding Stimulated by MMS support.*

National Sea Grant Program: "Fisheries habitat: a field assessment of the effects of artificial reefs and its role in fisheries management" (with C. St. Mary and B. Bolker). $294,088.

Florida Sea Grant Program: "Pilot studies to assess the use of artificial reefs in marine ornamental fisheries" (with C. St. Mary). $6,000.

Progress during 2001-2002

Processing of bivalve and crustacean samples for size-frequency analysis continued in Carr's lab at UCSC with the image analysis system. At present, bivalve samples from Gaviota have been imaged and processing of Carpinteria samples continues. A senior thesis, being conducted in his lab should be completed later this academic year. It is entitled, "Effects of cessation of a produced water discharge on the size frequency of a bivalve, *Telina carpenterii*, off Carpinteria, California".

We continued to seek other applications of the BACIPS design and to promote more sound scientific assessment of human effects in coastal habitats. For example, we now have a paper accepted, pending revision, that extends the BACIPS design to the "attraction-production" controversy that underlies the rigs-to-reef debate (*Osenberg, C.W., C.M. St. Mary, J.A.*

Wilson, and W.J. Lindberg. A quantitative framework to evaluate the attraction-production controversy, with application to marine ornamental fisheries. ICES Journal of Marine Science). We also received funding from the National Sea Grant program to apply this approach to marine ornamental fisheries. BACI and the SCEI projects were highlighted in a lecture in Carr and Raimondi's UCSC undergraduate course, "Conservation in the Sea". Osenberg was an invited participant in a workshop at Lee Stalking Island, Bahamas which had as one goal to interact with Bahamian agencies to assist in the design and monitoring of a marine reserve network. BACIPS and its role in the assessment of Marine Protected Areas and artificial reefs (such as the Rigs-to-Reefs issues) were highlighted by Carr and Osenberg in several public presentations and invited talks. Their insights benefited from MMS-sponsored research on the BACIPS design.

No progress was made on data analyses or in archiving samples at the LA County Museum.

Progress during 2002-2003

We continue to contribute to the application of BACIPS methodology in other contexts. BACIPS and its role in the assessment of Marine Protected Areas and artificial reefs (such as the Rigs-to-Reefs issues) were highlighted by Carr and Osenberg in several public presentations and invited talks, including presentations at UC Davis, Bodega Marine Laboratory, and at the 4th Mote International Symposium in Fisheries Ecology. Insights from these talks benefited from MMS-sponsored research on the BACIPS design.

Analysis and writing culminated in the preparation of a DRAFT Final Report which was submitted July 7, 2003.

Variability in the accumulation and persistence of tar in four intertidal communities along the central and southern California coast (Study Name: *Effects of an Oil Spill on Multispecies Interactions that Structure Intertidal Communities*)

Principal Investigator: Peter Raimondi, Department of Biology, University of California, Santa Cruz, California 95460

Summary of Research

Progress during 1999-2000

Empirical Results

The effects of tar cover on barnacle recruitment
Experiments were designed to (1) assess the effects of disturbance on intertidal community structure and (2) determine if there is a difference in the effects of tar cover and clearings on intertidal communities. If there is no difference in the effects of tar cover and clearings on intertidal populations and/or communities, the wealth of past research on the effects of clearings can be used to further understand the susceptibility of intertidal communities to oil spills and, subsequently, improve management strategies.

Twenty-four 10x10cm^2 plots were permanently marked at Boathouse, Vanderberg Airforce Base, in February 1998. Tar patches were collected from the adjacent beach under the assumption that natural tar produced from subtidal oil seeps can be used to mimic the effects of an oil spill. On half of the plots, tar patches were applied to live barnacles at one of three levels of cover (25%, 50%, and 100%). The remaining plots were cleared of 25%, 50% or 100% of all organisms. Both treatments were randomly assigned to the plots. The number and sizes of barnacle recruits were sampled in the cleared patches every three months. The number and sizes of recruits were sampled in the tar patches quarterly beginning in December 1998. Barnacles were removed from the plots after sampling.

Data on recruitment was analyzed using repeated measures analysis of variance. The percent disturbed had a significant effect on the number of recruits (Table 1). When averaged over time and the type of disturbance, the number of recruits was higher in the 100% disturbed treatment than in the 50% and 25% disturbed treatments (Fig 1). Time also had a significant effect on the number of recruits (Table 1; Fig 2A). The univariate analysis showed no significant difference between tarred and cleared plots on the number of recruits (Table 1).

There was significant interaction between month and the type of disturbance (Table 1). The tarred and cleared plots had about the same number of recruits at the start of the experiment (Fig 2B). The number of recruits was higher in the tarred plots throughout the sampling dates that corresponded with the peak season for barnacle recruitment (Fig 2B). On the last sampling date, the number of recruits was higher in the cleared plots (Fig 2B).

The effect of tarring on barnacle recruitment depends both on the time of year and the size of the disturbance. Thus, the results of this research have important implications to managing coastal ecosystems in the event of an oil spill. The recovery of populations with obligate

dispersive phases, such as barnacles, from oil spills may depend strongly on the size of the spill and the time of year that the spill occurs.

Our results show that barnacles will recruit to tar. The next question to ask is 'how does tar affect the growth and survival of barnacles that recruit onto it?' We are currently monitoring growth and survival of barnacles on the same plots used to test for the effects of tar cover on barnacle recruitment. Growth and survivorship of barnacles on tar will be compared to that of barnacles on rock. The results of this experiment will add to our understanding of how barnacle populations might recover from oil spills.

Variability in tar patch accumulation and persistence
Variability in tar patch accumulation and persistence may result from, temperature, zonation and wave exposure. These factors not only contribute to the weathering (degradation) of tar, but may have an effect on where the tar accumulates. The disappearance of tar may also be a function of the species assemblage upon which it landed.

In November 1999 and May 2000, we performed surveys (at Point Sierra Nevada, Shell Beach and Boathouse) to (1) assess the accumulation and persistence of tar within different zones and (2) to determine which species would potentially be most susceptible to an oil spill. These surveys allowed us to calculate the percent cover of tar in two different zones (barnacle and *Endocladia*) and to do site comparisons (Fig. 4). Overall, we found more tar at both Pt. Sierra Nevada and Boathouse and less tar at Shell Beach. We found that at both Pt. Sierra Nevada and Shell Beach tar cover was consistently higher in the barnacle zone (primarily *Chthamalus sp*.) as compared to the *Endocladia* zone (Fig. 4). This result was consistent with what we expected, based on the analyzed slides from our data base and previous field observations. In contrast, at Boathouse the percent tar cover was lower in the barnacle zone as compared to the *Endocladia* zone (Fig. 4). This may be a result of the upwards shift in species assemblages at this site. For example, in 1992 the mean tidal height of the barnacle zone was approximately 3.5 ft and in 2000 the mean tidal height of the barnacle zone is 5.1 ft. Thus, we predict that with time (at Boathouse), the percent tar cover will increase in the barnacle zone and decrease in the *Endocladia* zone. The number, size and relative freshness of tar patches per marked plot were recorded at each of the three sites. Additionally (during the fall surveys) at Pt. Sierra Nevada, four tar patches were found in the mussel zone (in contrast, no tar was found in the mussel zones at Shell Beach or Boathouse). These four tar patches were marked and measured in late October and when we returned to this site in early December all four of the patches had disappeared. This result was also as expected based on slide data and previous field observations that suggest tar does not persist long in the mussel zone. The insight gained by determining where tar is accumulating and persisting allows us to predict which species would be most impacted by an oil spill.

Experiments were designed to measure variability in tar patch accumulation and persistence as a function of species assemblage. We know that tar accumulates and persists in the barnacle zone longer than any other zone. This may be due to longer exposure period (the tar has a chance to stick) or it may also result in part form the texture of barnacles. In contrast, tar does not accumulate and persist in the algal zones, this may be due to a shorter exposure period (the tar may not heat up enough to stick) or it may also be biological in nature since many alga produce mucilage that may inhibit tar from sticking. To test these ideas we (1)

made casts of barnacles (with a material that not only mimics the texture of barnacles, but also allows tar to stick) and (2) placed sixty 10x10cm^2 barnacle casts in the intertidal at each of our three sites (from north to south: Point Sierra Nevada, Shell Beach and Boathouse) in April 2000. At each of our sites, we placed fifteen casts into each "zone" (the barnacle zone (control), *Endocladia, Pelvetia* and mussel zones). The casts were then checked bimonthly (beginning April 30, 2000) for the presence of tar (Fig.5). At Point Sierra Nevada tar was only found on 12% of the casts in the *Endocladia* zone. At Shell Beach and Boathouse tar accumulated primarily in the barnacle zone, with 27% and 47% respectively (Fig. 5). In contrast to the other sites, 5% of the casts in the *Mytilus* zone at Boathouse had tar. It will be interesting to see if tar persists on the plates in the *Mytilus* zone over the next few months. However, it is still to early to make generalizations about the accumulation and persistence of tar.

We have been utilizing a tide program to make predictions regarding variability in tar patch accumulation and persistence as a function of tidal height and exposure (Fig. 6). Using the tide program we were able to create a model specific to the conditions near Boathouse. Using 10 minute intervals of all outgoing tides during a one month period (April 15, 2000 to May 15, 2000) we were able to get a feel for the proportion of time the mean tide was at a given point on the shore. Then we compared the approximate vertical distributions of the three zones, within which the barnacle casts were placed (Fig. 6). Assuming that most tar is deposited during an outgoing tide and that tidal heights above 4.0 ft are exposed for longer periods, it makes sense that the barnacle zone is accumulating more tar and that when it does it persists longer. Lastly, we assume that wave exposure plays a greater role at tidal heights less than 3.5 ft. While this information is useful, it does not explain the patterns we see entirely. At this point it seems that the variability in tar patch accumulation and persistence can not be simply explained by a single physical or biological factor, in fact, it seems that several factors are working in concert.

We will continue to monitor both the number and size of tar patches, as well as the percent tar cover in the marked plots on a biannual basis. In addition, we will continue to monitor the barnacle casts for tar accumulation on a monthly basis. We also plan to use a thermistor to examine the mean temperatures of each zone and thus, elucidate the effects of temperature on the accumulation and persistence of tar.

Theoretical Results

The effects of tar cover on barnacle recruitment

We investigated the effects of tar cover on growth, reproduction and population dynamics of barnacles using a mathematical model. Increasing the probability of tar cover has little affect on the reproductive output of an individual barnacle. It is only when the probability of tar cover is combined with recruitment variation that differences in population dynamics between populations exposed to high vs. low probabilities of tar cover are seen (Fig 3).

Research Presentations and Publications

A manuscript based on the results of the dynamic state variable model, entitled "Assessing individual-level and population-level consequences of an oil spill: predictions from a dynamic model" is in review in Ecological Applications. Samantha Forde will present the results of the model at the Annual Meeting of the Ecological Society of America in August 2000.

Progress during 2000-2001

Variability in tar patch accumulation and persistence

Variability in tar patch accumulation and persistence may result from both physical and biological factors. Physical factors include temperature, tidal height and wave exposure. The major biological factor of importance relates to characteristics of the species tar lands on. These factors not only contribute to the weathering (degradation) of tar, but may also have an effect on where the tar accumulates.

Permanent Plots

In the Fall of 1999, we established permanent plots at Point Sierra Nevada, Shell Beach and Boat House (Fig. 1). These plots have been surveyed in November 1999, May 2000, November 2000 and May 2001 to: (1) assess the accumulation and persistence of tar within different species zones of different tidal heights and, (2) to determine which species would potentially be most susceptible to an oil spill. These surveys allowed us to calculate the percent cover of tar in two different zones (barnacle and *Endocladia*), to determine the rate of accumulation in these zones and to do site comparisons (Fig. 2). Overall, we found more tar at Pt. Sierra Nevada and Boat House and less at Shell Beach. At all three sites, we found the percent cover of tar to be fairly stable over time in both the barnacle and *Endocladia* zones. We found that at both Pt. Sierra Nevada and Shell Beach tar cover was consistently higher in the barnacle zone (primarily *Chthamalus sp*.) compared to the *Endocladia* zone (Fig. 2). This result was consistent with what we expected, based on the analyzed slides from our database and previous field observations. In contrast, at Boat House the percent tar cover was lower in the barnacle zone compared to the *Endocladia* zone (Fig. 2). This may be a result of the upward shift in species assemblages at this site, which was unprecedented. At each site the number, size and relative freshness of tar patches per marked plot were recorded. Although the percent cover of tar within zones was relatively constant across all sites, the average size of the tar patches as well as the number of tar patches varied (Fig. 3). For example, there seems to be a seasonal signal for Pt Sierra Nevada and Shell Beach. In the fall the average size of the tar patches is greater (Fig. 3A), while the total number of patches is lower (fig. 3B). This pattern is reversed in the spring.

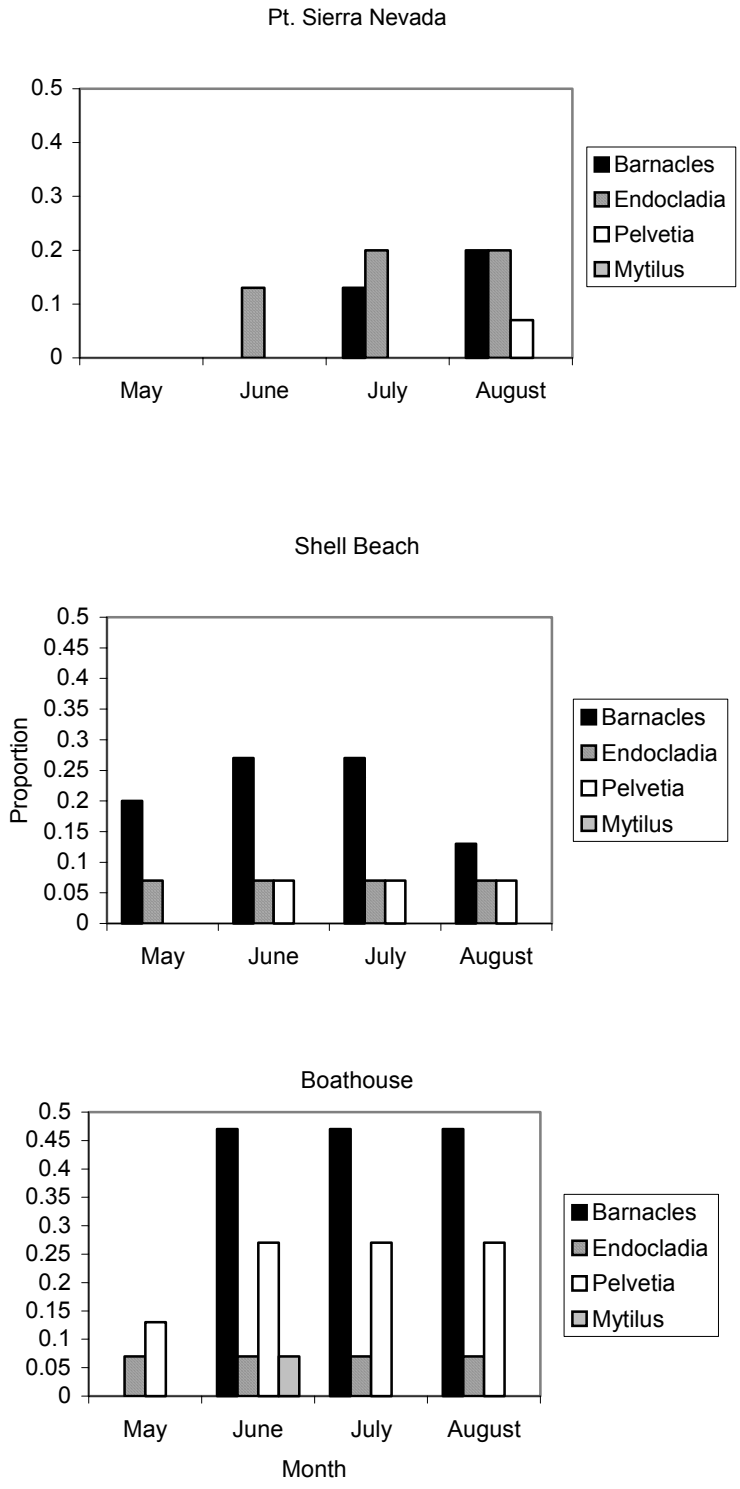


Figure 1.The proportion of barnacle casts in 4 zones that have accumulated tar during May, June July, August and September 2000. Note that the scales are different along the y-axes.

Although plots in the mussel zone were not set up, during the Fall 1999 survey at Pt. Sierra Nevada, four tar patches were found in the mussel zone (in contrast, no tar was found in the mussel zones at Shell Beach or Boat House). These four tar patches were marked and measured in late October 1999 and when we returned to this site in early December 1999, all four of the patches had disappeared. This result was also as expected based on our own data and field observations that suggest tar does not persist long in the mussel zone. Because we were unable to find any tar in the *Pelvetia* and mussel zones no permanent plots were established for these zones. However, during our sample periods, we also search for tar on rock in both the *Pelvetia* and mussel zones. At times we have documented tar stuck to *Pelvetia* or to mussels and rock in the mussel zone, but tar does not reside long (observed less than two weeks). Since we normally sample on a monthly basis (rather than more frequently) we do not have a true sense of the accumulation and persistence of tar in these zones. In order to get to get a more accurate idea of accumulation and loss in these zones, we would need to sample more regularly during periods of low tides

The insight gained by determining where tar is accumulating and persisting allows us to predict which species would be most impacted by an oil spill. Thus, we designed experiments that compliment our surveys and allow us to further elucidate these affects.

Factors affecting accumulation and degradation of tar

Barnacle Cast Experiment

Experiments were designed to measure variability in tar patch accumulation and persistence as a function of species assemblage. We know from our earlier work that tar accumulates and persists in the barnacle zone longer than any other zone. This may be due to longer exposure period (the tar has a chance to stick) or it may also result in part form the texture of barnacles. In contrast, tar does not accumulate and persist in the algal zones, this may be due to a shorter exposure period or it may also be biological in nature since many alga produce mucilage that may inhibit tar from sticking. To test these ideas we (1) made casts of barnacles (with a material that mimics the texture of barnacles) which allowed us to standardize the substrate and (2) placed sixty 10x10cm^2 barnacle casts in the intertidal at each of our three sites (from north to south: Point Sierra Nevada Shell Beach and Boat House) in April 2000. At each of our sites, we placed fifteen casts into each "zone" (the barnacle zone (control), *Endocladia, Pelvetia* and mussel zones). The casts were then checked monthly (beginning April 30,2000) for the presence of tar (Fig. 4). Due to human interference, the barnacle cast experiments (at the Shell Beach site) were abandoned in October 2000. We looked into setting up an additional site at Cayucos (with limited public access) to maintain spatial replication, but we were unable to find an adequate site. However, we will continue to monitor the permanent plots for percent tar cover in each zone at Shell Beach on a biannual basis.

The Barnacle casts that were put out at Pt. Sierra Nevada and Boat House have been in the field for 14 months and have been sampled monthly for the presence of tar (Fig. 4). To date, at Point Sierra Nevada tar has accumulated on roughly 90% of the casts in the barnacle (87%), *Endocladia* (93%) and *Pelvetia* (87%) zones. While 0-7% of the casts in the Mussel zone at Pt Sierra Nevada had tar. At Boathouse tar has accumulated primarily in the barnacle and *Pelvetia* zone, with 80% and 87% respectively (Fig. 4). In contrast, only 53% of the casts in the *Endocladia* zone and 20% of the casts in the *Mytilus* zone (at Boathouse) had tar.

Thus, it appears that (with the exception of the mussel zone) once tar accumulates on a standard surface it persists. For example, in contrast to the other sites, 7% of the casts in the *Mytilus* zone at Boathouse had tar in February 2001 (cast number 15 had the largest patch to date, it covered half of the plate and a portion of the surrounding mussel bed, it was 390mm X 58.3mm), but when sampled again in March 2001 the tar was not present. This was also the case in June 2000 when 7% of the casts in the Mytilus zone at Boat House had tar, but when they were sampled again in July 2000 the tar was absent.

For greater resolution in October 2000 we began recording the presence of tar, the number of patches, the relative location of the tar on the cast and the diameter of individual tar patches. So far all of the casts that have accumulated tar have similar size patches, with an average of 2.75 patches per cast. We are presently only measuring tar patches > or = to 1.0mm. Our data suggest that patches < than 2mm degrade rapidly, while larger patches persist for many months. For example, *Pelvetia* cast number 7 (at Boat House) has a tar patch that first appeared in May 2000 and was initially measured to be 14.7mm and in June 2001 it was 13.7mm.

Tidal Height and exposure

We have started testing the idea that variability in tar patch accumulation and persistence is a function of tidal height and exposure. Using a tide height calculator we were able to create a model specific to the conditions near Boat House. Using 10 minute intervals of all outgoing tides during a one month period (April 15, 2000 to May 15, 2000) we were able to calculate the proportion of time the tide was at a given point on the shore (Fig. 5). In February 2001, we measured the tidal height of all of the barnacle casts and permanent plots at both Pt Sierra Nevada and Boat House (Fig. 6). We found that there was no difference in the mean tidal height of the rock vs. cast substrate (within each zone) at both Pt. Sierra Nevada and Boat House (Fig. 7). Then we compared the approximate vertical distributions of the four zones (at Boat House), within which the barnacle casts were placed (Fig. 5). Our preliminary evaluation of the data indicates that both tidal height and exposure are important. First, our tidal model shows that locations above 4 ft MLLW get exposed to surface water more often than locations less than 4 ft MLLW. Hence we can predict that tar (which floats in surface waters) should be more common in the upper tidal zone. This is what our tarring data also show. Second, accumulation of tar in the mussel zone is lower both on casts and mussels – ruling out a biological process of removal (at least one related to mussels). Also the area in which the mussel experiments were done are on open and exposed locations. We are pursuing these ideas experimentally.

<u>Temperature</u>

In an attempt to elucidate the effects of temperature on the accumulation and persistence of tar (in March 2001) we measured the surface temperature of all the casts, nearby rock and permanent plots at both Pt Sierra Nevada and Boat House. We compared the mean temperature of the cast vs. rock substrate for each community, at both Pt Sierra Nevada and Boat House (Fig. 8). Temperature alone does not explain the patterns we have found. However, (Fig. 8) is based on approximately 300 temperature measurements taken on a single day while the casts were exposed (we followed the tide out and back in). To insure that we were not making any false generalizations, we placed temperature loggers out at the mean

tidal height for each zone (at both Pt Sierra Nevada and Boat House) for a full month (April 24, 2001 to May 25, 2001). These data will be analyzed over the next few months.

Conclusions and Recommendations

Overall findings: It appears that for different species different mechanisms are important. For example, in the *Pelvetia* zone, tar is found on the casts, but not on the rock. This provides evidence that biological factors are more important than physical factors in this zone. In this case, it is not the lack of input, but rather the lack of adherence. We know that *Pelvetia* produces a mucilage that may act to inhibit tar from sticking. In Addition, *Pelvetia* also regularly sloughs cells, which may also lead to the lack of tar accumulation and persistence in this zone. In the mussel zone, we have documented (occasionally) tar sticking on the rock, mussels and casts. However, tar does not persist long in this zone. This provides evidence that in this zone, physical factors are more important than, biological factors. We think that as with *Pelvetia*, it is not the lack of input, but rather the lack of adherence. It is also possible that tar is present, but degrades very quickly in the mussel zone (causing our monthly samples to be too infrequent to detect the input). For the mussel zone, the mechanism is likely due to direct exposure to waves. It seems that in highly exposed areas, the waves regularly scour the tar off the rocks.

For both the barnacle and the *Endocladia* zone, tar seems to accumulate and persist roughly the same on the cast and rock substrate. *Endocladia* neither sloughs cells nor produces mucous. The barnacle and *Endocladia* zones are also less affected by high wave intensity. For barnacles and *Endocladia* it may be that physical and biological factors are working in concert. It also appears that aside from the natural process of weathering, that barnacles and *Endocladia* have no mechanism for tar removal. Once tar accumulates in these zones it persists.

It is important to note that while these findings are valuable for low impact oil stress, we still may be unable to directly predict the effects of a major oil spill. However, some of our results are extendable to larger scale oil spills. We believe that in the short term the upper zones (*Endocladia* and barnacles) are most likely to be affected. However results from our other shoreline studies suggest that these are likely to be the species most able to quickly recover via recruitment. By contrast, mussels and fleshly algae are more resistant (for different reasons) to oiling but are much less likely to recover quickly if damaged via an oil spill. There is a great need to investigate recruitment rates at a variety of sites to assess recovery by recruitment potential in order to more fully estimate effects of oiling – this work has just been partially funded by MMS. Equally important would be an effort to complete our initial work on patterns and mechanisms of oil accumulation in the intertidal. Our recommendation would be to follow the current project with another that extended the survey and experimental work to other taxa including surf grass, *Lottia*, Abalone and tide pool organisms (fish and others) that have not yet been evaluated. In addition, we recommend increasing the spatial scale of the project to encompass sites all along the area of risk.

Future Plans

We will continue to monitor both the number and size of tar patches, as well as the percent tar cover in the marked plots on a biannual basis. In addition, we will continue to monitor the barnacle casts for tar accumulation on a monthly basis.

To date we have not had the opportunity to do a full analysis of the data. In the coming months we plan to tease apart the data to see if there is any correlation between tidal height and temperature, as it relates to tar accumulation and persistence. At this point it seems that the variability in tar patch accumulation and persistence can not be simply explained by a single physical or biological factor, in fact, it seems that several factors are working in concert. In addition, it appears that different mechanisms are operating in the different zones.

Research Presentations and Publications

Samantha Forde presented the results of the model at the Annual Meeting of the Ecological Society of America in August 2000. A manuscript based on the results of the dynamic state variable model, entitled "Modeling the effects of an oil spill on open populations" has been accepted for publication in the Journal of Applied Ecology

Summary/Abstract "Modeling the effects of an oil spill on open populations"
1. Empirically addressing applied issues at an appropriate temporal or spatial scale is often ethically or logistically unfeasible. Modeling provides a format in which questions about the effects of human impacts can be addressed which would be intractable using experiments.
2. I incorporated differences in individual reproductive output, conditional on size and the probability of mortality, into a population model that investigated the combined effects of different intensities of an oil spill and recruitment variation on an open marine population.
3. The model consisted of a source population comprised of individuals that reproduced based on size and the probability of mortality. Larvae from the source population entered a larval pool. A proportion of the larvae from the larval pool recruited to a focal population within the region.
4. I varied (1) the size structure of the source population, (2) the intensity of oil spills in the source population, and (3) recruitment intensity to the focal population.
5. Differences in the size structure of the source population had little affect on the reproductive output of the population relative to the intensity of the oil spill. Similarly, the intensity of the oil spill had a stronger influence on recruitment to the focal population than the size structure of the source population. Size structure of the source population was important, however, when evaluating the seasonal trajectory of the focal population.
6. The results of the model suggest that recruitment variation, along with the processes underlying recruitment variation, are critical to predicting the effects of disturbance on open marine populations.

Christy Roe plans to present the results of this study at the Annual Meeting of the Western Society of Naturalists in November 2001.

Progress during 2001-2002

The Barnacle casts that were put out at Pt. Sierra Nevada and Boathouse have been in the field for 18 months and have been sampled monthly for the presence of tar (Fig. 1). In September, at Point Sierra Nevada tar was found on 80% of the casts in the barnacle zone, while 67% of the casts in the *Silvetia* zone and 47% of the casts in the *Endocladia* zone had tar. In October, at Point Sierra Nevada tar was found on 40% of the casts in the barnacle zone, while 53% of the casts in the *Silvetia* zone and 47% of the casts in the *Endocladia* zone had tar. Overall, at Boathouse tar has accumulated primarily in the barnacle and *Silvetia* zones (Fig. 1). In September, Boathouse tar was present on 13% of the casts in the *Endocladia* zone and on 73% of the casts in the *Silvetia* zone. While, only 7% of the casts in the *Mytilus* zone at Boathouse had tar in September. However, tar does not persist long in the *Mytilus* zone. In October, at Boathouse tar was present on 53% of the casts in the barnacle zone, 73% of the casts in the *Endocladia* zone and on 67% of the casts in the *Silvetia* zone. While, only 27% of the casts in the *Mytilus* zone at Boathouse had tar. However, at Boathouse tar does not persist long in this zone. We are presently only measuring tar patches > or = to 0.5mm, it seems that patches < than 2mm degrade faster, while larger patches persist. For example, *Silvetia* cast number 7 has a tar patch that first appeared in May 2000 and was initially measured to be 14.7mm and in September 2001 it was 13.1mm.

In the fall of 2001, we sampled our permanent plots at Point Sierra Nevada, Shell Beach, Boathouse and Government Point (Fig. 2). The % tar cover is higher in the barnacle plots as compared to the *Endocladia* zone plots for Pt Sierra Nevada, Shell Beach and Government Point. At Boat House a different pattern is observed; the % tar cover is higher in the *Endocladia* zone as compared to the barnacle zone plots. This may be a result of the upward shift in species assemblages at this site, which was unprecedented. At each site the number, size and relative freshness of tar patches per marked plot were recorded. It is important to note that not all tar that accumulates persists. There is import and export of tar into these plots. Once larger tar patches accumulate they persist. With the exception of the *Endocladia* zone at Boat house the % tar cover within zones is relatively constant across our sites. However, the average size of tar patches as well as the average number of tar patches varied (Fig. 3). In the fall the average size of the tar patches is larger, but the average number of tar patches is smaller. In the spring the pattern is reversed there are more tar patches, but their overall size is smaller. This pattern has persisted throughout our study. Overall, the % tar cover remains fairly stable across the zones and across all sites.

In November 2001, Christy Roe presented our data at the Western Society of Naturalists meetings in Ventura, California.

Point Sierra Nevada

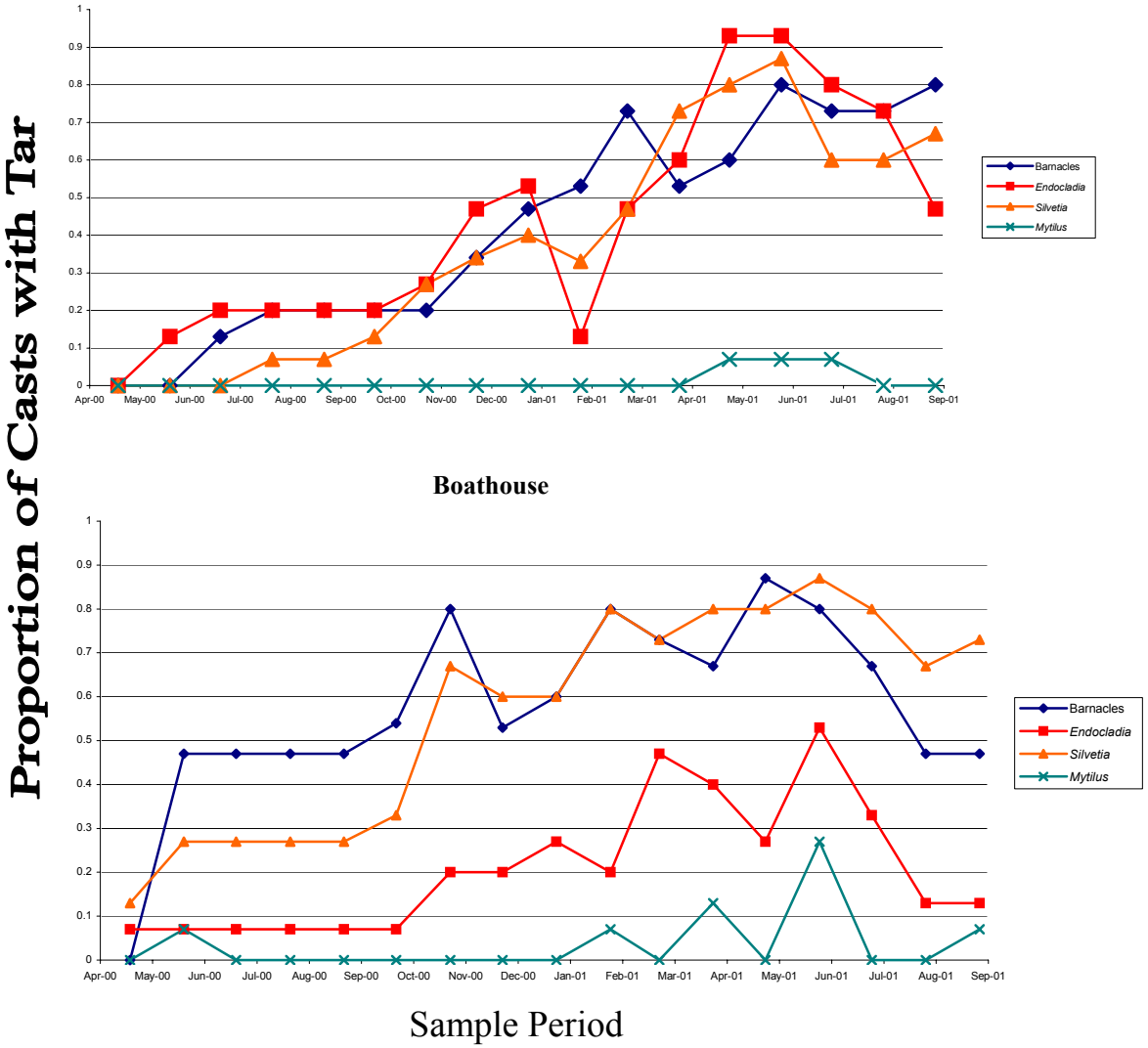


Figure 1. The Proportion of casts in 4 zones that have accumulated tar during May 2000 thru August 2001.

Progress during 2002-2003

Analyses and writing culminated in a DRAFT final report, which was submitted in Feburary 2003, and the final report, which was submitted in May 2003. In addition, a manuscript stemming from this research was published during the 2002-2003 fiscal year.

Inventory of Rocky Intertidal Resources in San Luis Obispo and Northern Santa Barbara Counties

Principal Investigator: Peter Raimondi, Department of Biology, University of California Santa Cruz, CA 95064

Background

The purpose of the Shoreline Inventory Project is to provide baseline information on the rocky intertidal plants and animals along the central and southern California coast. Information on coastal biota in these areas would be essential in the event of an oil spill or other major impact. In addition, the monitoring studies yield important data on population dynamics on a local and regional scale which can be utilized for more effective resource management as well as provide fundamental ecological knowledge about the dynamics of the systems. The rocky intertidal surveys of five sites in Northern Santa Barbara County (NSB) represent a continuation of previous semi-annual monitoring conducted for the Minerals Management Service from 1992 to 1998. Five additional sites were established in 1995 for San Luis Obispo County (SLO). The combination of previous and current year surveys in the two counties has resulted in a total of 15 samples for NSB sites, and 8 samples for SLO sites.

The sampling protocol focuses on target species or assemblages. Permanent photoplots are established in assemblages such as barnacles, mussels, anemones, turfweed, and rockweed. Cover of the major taxa is determined by point-contact photographic analysis. Permanent plots are also established for large motile species such as owl limpets, black abalone, and seastars. Line transects are used to estimate the cover of surfgrass. A video overview and field notes are used to describe general conditions at the site and to document the distribution and abundance of organisms not found within the photoplots.

Summary of Research

Progress during 1999-2000

The project has undergone some changes in personnel over the past year, with a new postdoctoral researcher, Todd Minchinton, taking over the main portion of the research.

The overall objective of this research is to provide an empirical basis for judging the utility of pre-impact monitoring programs to estimate accurately the consequences of impacts to rocky intertidal assemblages along the southern and central coasts of California. The set of data used to address this objective was derived from the "Inventory of rocky intertidal resources" monitoring program funded by the Minerals Management Service for about the last decade. Three main objectives were formulated based on the overall objective.

The first objective is to determine the spatial and temporal patterns in the structure of targeted assemblages of species (e.g., mussels, macroalgae, abalone) monitored at all 25 sites constituting the inventory. These patterns have now been documented and results show that there is considerable variation in the spatial and temporal patterns of abundance of many species. Nevertheless, some species showed seasonal, annual, and longer-term trends in

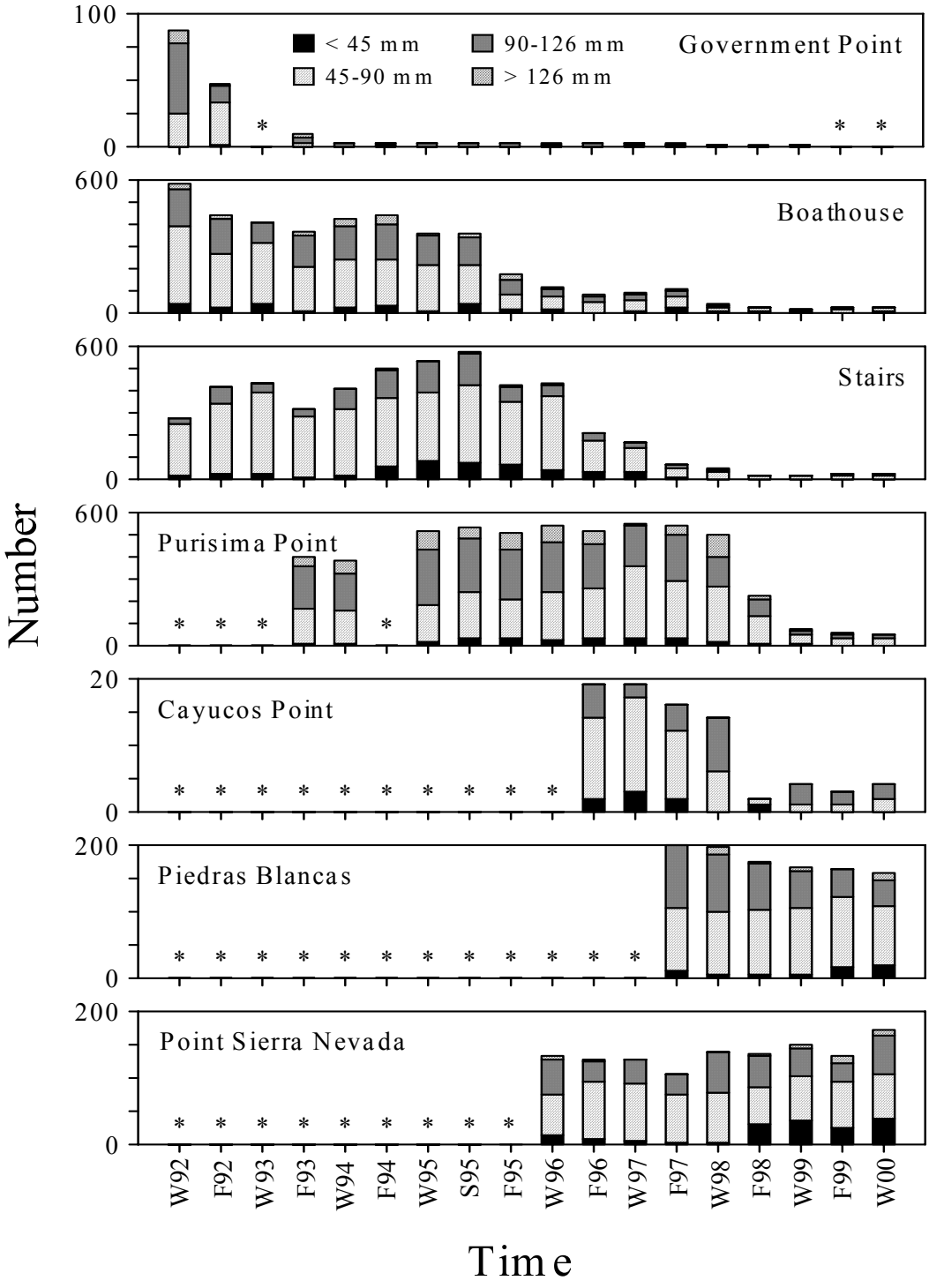
abundance. These trends are best exemplified by the data for the black abalone *Haliotis cracherodii*, which also present one of the significant findings of the study thus far.

Along the coast of southern and central California, black abalone have suffered massive die-offs since the mid 1980s. Mortality has been attributed to a fatal condition called "withering disease". Results of our assessment of the spatial and temporal patterns of abundance of black abalone from data collected at multiple sites along the southern to central California coast indicate a sequential decline in abundance from north to south over the past eight years. The figure below shows the number of black abalone in permanent plots at four sites (Government Point, Boathouse, Stairs, Purisima Point) established in 1992-93 and another three sites (Cayucos Point, Piedras Blancas, Point Sierra Nevada) established in 1996-97. Withering syndrome and mass mortalities of abalone were observed at the five most southern sites, but not at the two most northern sites (Piedras Blancas, Point Sierra Nevada). Moreover, results indicate that mortality was independent of abalone size. Rates of northward spread were variable among years and rates of decline were variable among sites. Nevertheless, faster rates appear to be related to elevated sea surface temperatures associated with El Niño warming events. For example, rates of decline at Boathouse and Stairs, which occurred in non-El Niño years, were slower than those at Purisima Point and Cayucos Point, which occurred during the 1997-98 El Niño event. These patterns of decline are consistent with the idea that withering syndrome is caused by the transmission of an infectious pathogen from southern to northern populations, with the rate of transmission accelerated during times of elevated sea surface temperatures.

The second objective of this research is to determine whether there should be any modification to the sampling regime employed at the various sites. One way we are answering this question is by simulating various levels of impact to the abundance of a particular species (e.g., a 50% reduction) at a particular site and doing statistical analyses (e.g., power analyses) to determine whether this impact can be detected given the varation in abundance of that species at non-impacted sites. At least for black abalone, the current pre-impact monitoring program appears to adequately assess impacts due to withering syndrome. Analyses on the entire suite of key species is ongoing. These research activities have resulted in the development of another research project. We have been recently contracted to evaluate the adequacy of the long-term, rocky intertidal monitoring program on the Channel Islands in southern California by the methods developed in this project. This will give us the opportunity to compare the results from two separate and independent programs of long-term monitoring of rocky intertidal assemblages. Ultimately, we would like to assess whether the data collected by the monitoring programs can be used to predict the structure of rocky intertidal communities at previously unsampled sites. This third objective of the research is currently in the planning stages.

Research Presentations

These findings were presented in greater detail at the 13th Annual UC Toxic Substances Research & Teaching Program Research Symposium in San Diego, California in April, 2000.



Progress during 2000-2001

The majority of the work for the Shoreline Inventory Project in San Luis Obispo (SLO) and Northern Santa Barbara (NSB) Counties during the first quarter focused on scoring photographic slides and entering these percent cover data, along with field data collected

during the previous quarter into computer files. Although no statistical analyses were performed, these data have been incorporated into graphs that allow us to observe dynamics in species abundances. Comprehensive statistical analyses are done every 3 years and results are discussed and included in a formal 3-year report to the Minerals Management Service.

On July 1st & 2nd, and 5th-7th, SLO and NSB sites were visited in order to collect data for an ongoing barnacle recruitment study.

Currently, we are planning and preparing for the upcoming sampling trips, which will take place in October and November.

During the second quarter of the 2001-2002 fiscal year the 10 study sites in San Luis Obispo (SLO) and Northern Santa Barbara (NSB) Counties were sampled for the 11th and 18th semi-annual surveys respectively. In addition, data were compiled and analyzed for a presentation given at the December 2000 PISCO (Partnership for the Interdisciplinary Studies of Coastal Oceans) meeting in Corvalis, Oregon. Principal component analyses of photoplot species data revealed that sites clearly divided into two groups: those north of Pt. Conception and those south of this biogeographic barrier. In addition, these analyses showed that many sites experienced severe changes in species composition following the 1997/98 El Niño storms. These types of patterns can only be seen in long-term monitoring data sets.

Progress during 2001-2002

This project was transferred to the Coastal Marine Institute and funded by Minerals Management Service in first quarter of fiscal year 2001-2002. The following text has been taken from the Coastal Marine Institute's annual report.

This report summarizes the accomplishments of the Inventory of Rocky Intertidal Resources for San Luis Obispo and Northern Santa Barbara Counties from July 2001 to July 2002. The purpose of the Shoreline Inventory Project is to provide baseline information on the rocky intertidal plants and animals along the central and southern California coast. Information on coastal biota in these areas would be essential in the event of an oil spill or other major impact. In addition, the monitoring studies yield important data on population dynamics on a local and regional scale which can be utilized for more effective resource management as well as provide fundamental ecological knowledge about the dynamics of the systems. The rocky intertidal surveys of five sites in Northern Santa Barbara County (NSB) represent a continuation of previous semi-annual monitoring conducted for the Minerals Management Service from 1992 to 2001. Five additional sites were established in 1995 for San Luis Obispo County (SLO). A sixth site at which only black abalone and owl limpets are monitored was recently added in SLO County. The combination of previous and current year surveys in the two counties has resulted in a total of 21 samples for NSB sites, and 14 samples for SLO sites (with the exception of the newly added sixth site).

The sampling protocol focuses on target species or assemblages. Permanent photoplots are established in assemblages such as barnacles, mussels, anemones, turfweed, and rockweed. Cover of the major taxa is determined by point-contact photographic analysis for all plots

except barnacles, which are scored in the field to allow samplers to distinguish *Chthamalus* spp. from *Balanus glandula*. Counts of mobile invertebrates occurring within the barnacle, mussel, *Endocladia, Mastocarpus, Silvetia*, and *Hesperophycus* photoplots are also done in the field. Additional permanent plots are established for large motile species such as owl limpets, black abalone, and seastars. Line transects are used to estimate the cover of surfgrass. Photographic overviews and field notes are used to describe general conditions at the site and to document the distribution and abundance of organisms not found within the photoplots.

One drawback of this protocol is that observations made within our plots cannot be extended to the site as a whole (because they are fixed). To alleviate this problem, we have begun to do comprehensive surveys in conjunction with the normal monitoring. The comprehensive surveys are funded through separate awards, but are mentioned here because of their close ties to our established monitoring work. These surveys are done at each site on a less frequent basis (approximately every 3 years). They incorporate a permanent, 30m transect that runs parallel to shore above the organisms in the high zone. Eleven transects are laid out perpendicular to this "baseline" transect at each 3m mark, starting at 0. Transects are then sampled using a point intercept method in which the organism or substrate occurring directly under each point is recorded as well as the two closest species. Point spacing varies according to transect length. These surveys allow us to: 1) monitor overall diversity at each site, 2) determine site-wide abundance for various species, 3) assess the vertical distribution of species within each site and 4) detect long-term temporal changes in diversity, abundance and distribution of species.

Table 1 summarizes the field activities of this past fall and spring for both counties. Data for all sites have been entered and analyzed for all work completed through spring 2002.

Table 1: Summary of Rocky Intertidal Field Activities for San Luis Obispo and Northern Santa Barbara Counties.

Dates	**County**	**Activity**
11/14-11/17	Northern Santa Barbara	Fall 2001 sample
11/29-12/2	San Luis Obispo	Fall 2001 sample
3/11-3/13	San Luis Obispo	Spring 2001 sample
3/23-3/28	San Luis Obispo and Northern Santa Barbara	Spring 2001 sample
3/24	San Luis Obispo	Set up new *Lottia* site at Rancho Marino UC Reserve

A species by species summary of the results of the past year's monitoring follows. The summaries are broken into 3 sections: Photoplot Invertebrates, Photoplot Algae and Surfgrass, and Motile Invertebrates.

Photoplot Invertebrates

Anemones, (*Anthopleura elegantissima*), were sampled at only one NSB site, and showed similar percent cover as compared to previous years. Barnacle cover (*Chthamalus* spp. & *Balanus glandula*) has been decreasing over time at five of the eight monitored sites, but experienced a slight recovery at three sites (Pt. Sierra Nevada, Cayucos and Boat House) during the past year. Cover at two sites (Occulto and Stairs) remained extremely low. At Occulto the barnacle zone has shifted up in tidal height, and "barnacle" plots are now dominated by algae and mussels. Barnacles at Stairs have been steadily declining over time due to a lack of recruitment of new individuals into the site. In SP01 we began to sample the barnacle plots in the field in order to distinguish between *Chthamalus* and *Balanus*, since this is impossible to do using slides. Only three sites were found to contain *Balanus*. Government Pt. and Hazards were nearly equally split in cover of *Chthamalus* and *Balanus*, while Cayucos was largely dominated by *Chthamalus*. The gooseneck barnacle, *Pollicipes polymerus*, has experienced almost no change in percent cover over time at the one NSB site where it is sampled. Mussel cover (*Mytilus californianus*) declined at five of the eight sites where they are sampled. Shell Beach experienced the most drastic decline (over 50%) during the F98/SP99 sampling period, but cover has since remained stable.

Photoplot Algae and Surfgrass

Cover of the rockweed, *Silvetia compressa* (formally *Pelvetia compressa*), typically exhibits a strong seasonal fluctuation (higher in the fall, lower in the spring), at nearly all sites. However, this pattern did not hold for the 2001-2002 sampling period for SLO sites. *Silvetia* cover did not change much between the F01 and SP02 sampling periods at these sites. *Silvetia* declined in cover at five of the seven sites where it is sampled. This decline was most pronounced at Stairs (an NSB site), where cover has gone from over 90% to less than 20%. Another species of rockweed, *Hesperophycus harveyanus*, has declined in cover at Pt. Sierra Nevada, the northernmost SLO site, from an initial 90% to less than 20%. *Hesperophycus* cover at another SLO site, Cayucos, experienced an initial sharp decline, but appeared to level off after SP97, and even showed a slight increase over the past three year sampling period. Cover of the high intertidal turfweed, *Endocladia muricata*, has fluctuated seasonally over time (up to 40% higher in spring than in fall) but has also declined over time at four of the seven sites where it is sampled. *Endocladia* in plots at two of these sites has been gradually replaced by other species (*Silvetia* at Boat House and mussels at Occulto). The red alga, *Mastocarpus papillatus*, was higher in cover in the fall than the spring at one SLO site. A decreasing trend was observed over time at both sites where *Mastocarpus* was sampled. Cover of *Mazzaella* spp., another red alga, appeared to be relatively stable over time, with no substantial change in the F01/SP02 sampling period. Surfgrass cover (*Phyllospadix* spp.) remained high over time at all sites except Stairs (NSB), where plots were decimated by the 1997/98 El Niño storms. However, a slow but steady recovery of surfgrass occurred at this site over the period following this destructive event, and cover is now at nearly 1/2 of its initial value. All sites except Cayucos (SLO) experienced slight seasonal fluctuations, with higher cover in the fall than the spring. Surfgrass transects at Cayucos are located within permanent pools, so it makes sense that there would be no seasonal differences in cover at this

site. Surfgrass transects were established at Hazards in F01, but could not be re-sampled in SP02 because they remained underwater at low tide.

Motile Invertebrates

Seastar numbers have fluctuated at most sites over time, and counts for the F01/SP02 samples did not appear to be abnormally high or low at any site. Numbers of the owl limpet, *Lottia gigantea*, were stable at all sites except Cayucos, where a sharp decline that began in SP00 continued into the F01/SP02 sampling period. The mean size of *Lottia* remained fairly constant at all sites except Hazards, where animals were found to be larger on average than in previous years. The fatal condition termed "withering syndrome" has caused drastic declines in black abalone (*Haliotis cracherodii*) populations as far north as Cayucos (SLO). Recovery of these decimated populations is unlikely as recruitment is thought to be very localized and the remaining individuals at these sites are probably too sparsely distributed to allow for successful spawning. Although evidence of withering syndrome was seen at Rancho Marino (the SLO site just north of Cayucos) in SP00, numbers have not declined as rapidly as expected. Abalone numbers at Piedras Blancas, just upcoast of Rancho Marino, were stable while those at the northernmost site (Pt. Sierra Nevada) continued to increase slightly. This increase was attributed to recruitment of black abalone into our plots prior to the F00 sample.

A somewhat recent addition to the sampling protocol are counts of the small mobile invertebrates that occur within our photoplots. Species targeted in these plots include *Tegula funebralis*, *Acanthina* spp., *Nucella emarginata*, *N. canaliculata*, *Ocenebra circumtexta, Lepidochitona harwegii*, 3 species of *Pagurus*, and various limpets. *Tegula* was the most abundant mobile invertebrate found in the photoplots, particularly at the SLO sites, where it was found in all plot types. *Nucella* were the most commonly found animal in mussel plots at all sites except Shell Beach and Cayucos. *Nucella* could also be found in other plot types in lower numbers. *Acanthina*, which are known to feed on barnacles, were found in barnacle plots, but were actually most common in *Silvetia* plots. *Lepidochitona* were also most common under *Silvetia*, which is though to provide refuge from desiccation for these chitons, but like *Nucella* they could be found in other plot types in lesser abundance. *Ocenebra* were rare or absent from most sites except in the mussel plots at Shell Beach, and the *Pelvetia* plots at Cayucos. Limpets were common in all plot types.

In conclusion, the long term monitoring of intertidal sites in NSB and SLO Counties (and other areas not mentioned in this report) has allowed us to document many aspects of intertidal community structure that had previously not been shown to exist on a large scale. These findings include: 1) Zone shifts, where a species "band" moves (generally up) or expands in tidal height and replaces another species "band" (e.g. *Silvetia* replacing *Endocladia*), 2) Differential community responses to disturbance (e.g. El Niño storm damage and recovery, community response to an oil spill), 3) Systematic spreading of a disease and the resulting changes in communities, 4) Short and long term variability in species abundance, and 5) Variability and to some extent the scale of recruitment events.

Inventory of Rocky Intertidal Resources in Southern Santa Barbara and Ventura Counties

Principal Investigator: Richard F. Ambrose, Department of Environmental Health Sciences, University of California, Box 951772, Los Angeles, CA 90095-1772

Summary of Research

Research progress 1999-2000

This year marks the second report period for which the inventory of Ventura County rocky intertidal monitoring program was supported by MMS funding. In addition to the two established Ventura County sites, four southern Santa Barbara County sites are still being monitored by the UCLA group (Pete Raimondi's portion of the Inventory Program, at UC Santa Cruz, is responsible for the four northern Santa Barbara County sites.) Under the current arrangement, our UCLA group collects and enters the data for the southern Santa Barbara sites, but then the data files are sent to the UCSC group for data analysis. The Orange County sites are monitored and managed entirely by Steve Murray's group at Cal State Fullerton, and their report is presented separately.

During the third quarter of the 1999-2000 fiscal year, all monitoring sites were sampled as scheduled. During the Fall 1999 sampling there were no problems with data collection and the sampling efforts went smoothly. Sampling during the Spring 2000 low tide series occurred during a period of heavy swells and a few of the sites could not be finished on the first sampling day. All of those sites were eventually completed within the Spring sampling season, however. In addition to the normal eight sites, an additional site was developed this quarter at Point Fermin in San Pedro on the Palos Verdes Peninsula. This site was established in collaboration with the Cabrillo Marine Aquarium, and is located in the Cabrillo Marine Reserve. The rocky intertidal begins just upcoast of the Cabrillo State Beach. There is a steep sandstone cliff that extends toward the intertidal. A footpath skirts this cliff face with access from the beach. This is deemed dangerous and is the justification for a proposed boardwalk to allow visitors, including the disabled, access to the rocky intertidal. Due to the potential increase in foot traffic at the site as a result of this boardwalk, Aquarium staff were interested in establishing a monitoring program at this site. On October 26, 1999 we met onsite with Susanne Lawrenz-Miller and other Aquarium personnel to survey and set up a monitoring site consistent with our inventory program. We established sets of five *Chthamalus* barnacle plots, *Mytilus* mussel plots, and *Sylvetia* (=*Pelvetia*) plots, and three 10 meter surfgrass (*Phyllospadix*) transects. No barnacle recruitment plates or clearings were established at this site. The site was then revisited for its initial sampling on November 24, 1999, during which the Aquarium personnel were trained on sampling procedures and use of equipment so that they may do future sampling independently. As of the Spring, 2000 sampling, the aquarium personnel had yet to purchase their own sampling equipment and were, otherwise, not ready to sample the site independently. We will need to help them for at least one more sampling season if not two.

Table 1. Sampling schedule for Fall 1998 and Spring 1999.

Location	Date	Researchers	Comments
Little Harbor	Oct 8	J.Engle, S.Lee, J. Wible, M. Buttner, F.Starkey	UCSB, Hopkins, and Catalina Conservency help
Bird Rock	Oct 9	J.Engle, S.Lee, M.E.Dunaway, J.Wible, M.Buttner	UCSB, MMS, and Hopkins help
Carpinteria	Oct 24	S.Lee, M.McCrary, H. Leedy, M. Pierson	MMS help
Alegria	Oct 25	S.Lee, M.E. Dunaway, S. Morton	MMS, SB County help
Point Fermin	Oct 26 & Nov 24	S.Lee, S. Bergquist, S. Lawrenz-Miller, E. Mastro, L. Chilton, S. Vogel	Site creation and initial sampling at Point Fermin with Cabrillo Marine Aquarium personnel help
White's Point	Nov 7	S.Lee S. Luce, R. Sepulveda	SCMI help
Coal Oil Point	Nov 8	S.Lee, S. Morton	SB County help
Old Stairs	Nov 9	S.Lee, S.Luce, S.Bergquist, J.Smith, K.Johnston	UCLA personnel only
Paradise Cove	Nov 21	S.Lee, Sh.Lee, S.Bergquist, J.Smith	UCLA personnel only
Mussel Shoals	Nov 22	S.Lee, S.Anghera, M.Myers, C.Ching, K.Gazzaniga	UCLA and UCSB personnel
Arroyo Hondo	Nov 23	S.Lee, Sh.Lee, S.Bergquist, S.Morton	SB County help
Old Stairs	March 6 & March 17	S.Lee B.Hajduczek, E.Ramirez	UCLA personnel only – had to revisit site because of big swells on first sampling day
Coal Oil Point	March 14 & March 19	S.Lee, S.Morton, B.Hajduczek, J.Smith	SB County help – had to revisit site because of a film winding problem
Alegria	March 15	S.Lee, S.Morton, B.Hajduczek, S.Bergquist	SB County help
Carpinteria	March 16	S.Lee, S.Morton, B.Hajduczek, S.Bergquist	SB County help
Paradise Cove	March 17	S.Lee, S.Bergquist, S.Luce, B. Hajduczek	UCLA personnel only
Mussel Shoals	March 18	S.Lee, S.Bergquist, J.Smith, B.Hajduczek	UCLA personnel only
Arroyo Hondo	March 19	S.Lee, S.Anghera, M.Anghera, S.Morton, B.Hajduczek, J.Smith	UCSB and SB County help
Point Fermin	March 20 & April 14	S.Lee, S.Lawrenz-Miller, E.Mastro, B.Hajduczez	Cabrillo Marine Aquarium help – had to revisit site because of big swells on first sampling day
White's Point	April 14	S.Lee, B.Hajduczek	UCLA personnel only
Bird Rock	May 11	J.Engle, D.Richards, J.Altstatt, S.Allen, J.Wible, E.Erikson	J.Engle and UCSB group, no UCLA personnel
Little Harbor	May 12	J.Engle, D.Richards, J.Altstatt, S.Allen, F. Starkey	J.Engle and UCSB group, no UCLA personnel

The Fall 1999 and most of the Spring slides have been scored, and the respective data have been entered into the computer files. The only exception are the slides and data for the two Catalina Island sites, Little Harbor and Bird Rock. Jack Engle's group collected the data

during a late spring sampling trip, but has yet to send the slides and data sheets to the UCLA group for scoring and management. For the rest of the sites, the data up to and including the Spring 2000 season have been graphed and are included below.

We have continued to monitor barnacle recruitment at most of our intertidal sites. In addition to the *in situ* measurements and recruitment plates that we exchange during our normal spring and fall sampling, we are also revisiting the sites in the summer months to collect additional barnacle data. We have been getting close to 100% recovery of the recruitment plates each season. The exception is Carpinteria, which has very soft mudstone substrate that doesn't hold the masonery anchors very well. We have been losing one or two plates each season. After collecting the old plates from the sites, we have been sending the plates and data sheets to the UCSC group, who has been maintaining the barnacle recruitment database.

In the early morning hours of April 9, a gasoline tanker truck crashed on the Hwy 101 freeway and spilled at least 1900 gallons of gasoline that drained through an old culvert to the ocean, just south of our Mussel Shoals site. On April 13, we visited the site to survey our intertidal monitoring site for damage due to the spill. While significant visible effects of the gas were seen in the area immediately surrounding the input, no evidence of direct impacts were seen at our monitoring site, which lies 200-300 m upcoast. The extent of the spill's impact was clearly recognized by the "burning" of the ephemeral algae communities on boulders. Normally green *Ulva* and *Enteromorpha* algae became bleached with a near-complete disintegration of their thalli. In many places, distinct divisions could be seen in the algae between affected and non-affected areas. In other areas, especially in the lower portions of rip rap downcoast of the spill, mussels were found gaping and clearly dead, and barcnacles were found dead as well. Some dead snails and crabs were found, but most of these had already been removed by cleanup crews. Most of the damage appeared minor or ephemeral. It was unlikely that any evidence of the spill could be detected in our monitoring site upcoast, so we did not repeat any of the normal surveys. We took numerous still photo shots and pans within the immediate area of the spill. These slides have been developed, but no further analysis has been made to date.

The recent decision to replace the video surveys with still photo surveys was implemented during the Fall 1999 sampling season and continued in Spring 2000. Using our new Nikon camera, we experimented with different methods until we came up with what we believe to be a good procedure for gathering photo survey information in a quick and effective way at the sites. We decided to use all of the video reference points that were indicated in the most recent video protocol compiled by Dr. Engle for consistency with the previous video footage. Standing at one of those reference points, the photographer uses a handheld field compass to locate magnetic north. That position is used as the center of the first field of view with the camera set at its widest focal distance (35mm on the variable focus lens). The top of the viewfinder (the viewable area, not the viewfinder's indicator marks) is held level even with the horizon. This is best found by looking first out to sea, and then extending that horizon line along the shore. Once the first picture is taken, the photographer takes a mental note of a terrain feature at extreme right edge of the viewfinder and then moves the camera clockwise and level until that feature is at the left edge of the new view. This process is continued until the entire 360-degree pan is complete. Photo surveys of this nature were taken at all of the

sites on 35mm-slide film, and these were later developed, organized and labeled. We recently received our new Sony digital video camera, which we will also use to document sites as needed for oil spill documentation.

Also this year, we received a new computer to serve as a workstation for the manipulation and storage of photographic images for the inventory project. To this computer we attached the new slide scanner, which includes a bulk loader, and a newly obtained CD-RW drive that can write CDs to hold the digitized photographs from our surveys. After some time was spent becoming familiar with the equipment, we started scanning both the photographic survey images as well as the photoplot images from the Fall 1999 sampling season. We purchased a software program that joins our 360 pans into a continuous image. During the course of this past year, we have scanned in the entire backlog of photoplot images since the inception of the project, and these have been stored and archived on CD media, copies of which have been distributed to the different groups involved in the project. In addition, we have scanned a considerable portion of the UCSC group's photoplot and photosurvey slides in using our bulk loader.

Future Plans

In a recent meeting of the PI's, the decision was made to repeat the "One-Time" surveys at all of the sites and to view them as comprehensive surveys that will be repeated occasionally, perhaps at 5-year intervals. The UCSC and UCSB groups have begun resampling the northern sites this spring, including Alegria. It is our intention to comprehensively resample the remainder of the LA, Ventura, and Southern Santa Barbara County sites this upcoming fall or winter. We also plan to coordinate our sampling the Dr. Murray's group at CSUF. This will require a considerable amount of increased planning, personnel and equipment over and above our normal sampling efforts.

Research progress 2000-2001

This project was transferred to the Coastal Marine Institute (CMI) and funded by Minerals Management Service in first quarter of fiscal year 2001-2002. Please refer to the CMI 2000-2002 Annual Report and the CMI 2002-2003 Annual Report for research updates and complete sets of graphs from the 1999-2000, 2000-2001, 2001-2002, and 2002-2003 fiscal years.

The Role of Knowledge in the Public's Trust in Science about Offshore Oil and Gas Development (Study Name: *Design for a Time Series Study of a NIMBY Response*)

Principal Investigator: **Eric R. A. N. Smith**, Department of Political Science, University of California, Santa Barbara, CA 93106-9420

Project Objective

The goal of this project is to design a set of public opinion surveys and news media content analysis methods in preparation for a time series analysis of NIMBY responses to proposed offshore oil development projects along the Santa Barbara coast in California. Current oil-lease holders are considering a number of new drilling projects. This project will prepare a set of methods to study the public's reaction to the debate surrounding these proposed projects.

Background

Whenever a neighborhood or community group objects to a local development, someone suggests that the objections are part of a NIMBY, or "Not in My Backyard" pattern of responses. NIMBY behavior has been responsible for slowing or blocking a wide variety of government and industry proposals—including offshore oil developments. In some cases, such as housing developments, NIMBY resistance is motivated by people's preferences about the quality of life in their communities. In other cases, NIMBY resistance is motivated by people's perceptions of risks associated with the developments. In some of these cases, critics allege, the fears are irrational because they are based on misinformation. That is, people are said to fear hazards that have extremely small probabilities of occurring. Offshore oil development is one area in which exaggerated perceptions of risks may influence public opinion, and therefore government and industry decisions.

Despite the prominent role of NIMBY influence on many government and industry decisions, researchers have not yet developed a full understanding of it. Although there is a substantial literature on risk perceptions, relatively little of it examines risk perceptions in the context of actual NIMBY behavior, and none it has examined the development of a NIMBY response over an extended period of time. That is, no investigator has yet used a series of public opinion surveys to explore how people's knowledge, risk perceptions, policy preferences, and behavior change over time during the course of a public debate about proposed development such as a new offshore oil platform. This study is developing a research design to do just that.

The core of the design will be a series of public opinion surveys extending for a period of five years so that we can measure change over time. A baseline survey—the 1998 Offshore Oil Drilling and Energy Policy Survey, funded by the University of California's Toxic Substances Research and Teaching Program—has already been conducted. Subsequent surveys will measure the public's knowledge of oil development in general and the proposed projects in particular, as well as the public's perceptions of various risks associated with the projects, including both risks to people and to the environment. In addition, the surveys will measure people's preferences about the projects and the extent to which they act on their preferences

by writing letters, attending meetings, and engaging in other forms of political activity. Finally, the surveys will measure a variety of variables that various theories suggest may explain people's knowledge, perceptions of risk, preferences, and activism.

In order to explain the public's response to the drilling project, we will also study the sources from which the public receives information or persuasive communications—that is, the news media, industry advocates, and political activists. These efforts will include a content analysis study of local newspapers, television news, and radio as well as an effort to obtain and analyze any direct mail or other communications from the oil industry or advocates on either side of the conflict. Measuring these communications will allow us to test theories explaining changes in the public's knowledge, opinions, and behavior over time.

Summary of Research

Research progress 1999-2000

Initial efforts focused on developing a set of content analysis methods for monitoring newspaper coverage of oil drilling and other oil-related issues. The news media are most people's primary sources of information on the world. To understand how people form opinions on issues such as oil development, we must first understand their sources of information.

Two types of content analysis measures have been developed. The first focuses on information about oil development and the oil industry; the second on the availability of comparative risk assessment information. For the oil industry, we have developed a coding scheme and are now collecting data so that we can test and refine the measure. This measure categorizes newspaper stories about oil according to the ways in which they should influence public opinion. For example, one category consists of stories about real or potential accidents that threaten people or the environment because those stories all hypothetically influence public in the same manner—they tend to make people anti-oil development. A second category consists of stories about gasoline price hikes because those stories may make people slightly more disposed toward additional oil drilling.

For the comparative risk assessment analysis, we developed a coding scheme to allow us to discover what sorts of information people receive about potential causes of death. The original intent was to measure both the extent of risk information related to the oil industry and the extent to which the information allowed readers to compare various risks. We sought to discover, for example, how much information people could learn about the likelihood of getting cancer from various sources—including the oil industry. To do this, we cast our net widely, and attempted to code all information in any story that indicated a potential cause of death.

Using the *Los Angeles Times*, by reputation one of the nation's most comprehensive newspapers, we developed and refined a set of measures of various types of risk information. Our categories included, for example, stories about simple events (e.g., cancer deaths) which could be used by readers to estimate probabilities, and stories about scientific studies which directly presented risk estimates.

Our initial data indicate a surprising finding. Although there are literally hundreds of newspaper stories that include information about death events, there is remarkably little information about either actual probabilities of death from any given cause or comparative risk probabilities. These findings are surprising because the academic literature on risk perceptions assumes that people can learn about actual risks posed by various hazards. Researchers who claim that people behave "irrationally" when they fear hazards that are highly improbable implicitly assume that people either know or can find out what the risks are. Yet that information is almost completely lacking in the *Los Angeles Times* and one must presume in other newspapers as well. If risk information is not available to the public, there is no basis for claiming irrationality. Given the surprising nature of our findings, we have prepared an article based on these data, which we will submit shortly.

A second area of progress in the questionnaire development has been in testing alternative theories of attitude formation using the 1998 Offshore Oil Drilling and Energy Policy Survey. Although a single survey cannot fully test theories of change over time, it does allow preliminary examination of how well alternative theories explain attitudes. The analysis showed that a set of questions measuring egalitarianism worked well, a parallel set measuring individualism worked in one case, and a set measuring postmaterialism did not work at all. These findings, presented in a paper delivered at the World Association of Public Opinion Research, allow us to omit the postmaterialism questions from the questionnaire.

Research summary 2000-2001

In the first quarter, we continued to analyze the data from a March 1998 public opinion survey to test a model of how people form opinions toward potentially risky environmental technologies such as offshore oil drilling and nuclear power. The central model in this work combines the insights of Mary Douglas and Aaron Wildavsky's cultural theory and John Zaller's Receive-Accept-Sample model of public opinion formation. Refining the model is critical to designing the questionnaire for the time series study.

The paper we presented at the World Association of Public Opinion Research conference in May, "The Role of Knowledge in Attitudes toward Risky Environmental Technologies," was revised and submitted to a journal for publication. We have not yet received a response.

Based on the analysis of the March 1998 survey data, we have continued to refine the survey instrument. One focus of research has been on the role of trust. Loss of trust in institutions and the experts associated with them is one of the most commonly proposed explanations for the failure of people to believe expert risk assessments and accept technologies such as offshore oil drilling. The argument is that if people do not trust the government, big business, university scientists, or other sources of expertise, then they will reject the experts' assurances that risks are minimal and that they have no reason to worry. Some scholars further claim that trust in experts has declined in the last forty years and that the U.S. is becoming a less trusting society. The lack of trust, according to this reasoning, explains why many Americans remain afraid of nuclear power plants, high-power electric transmission lines, offshore oil drilling, and other potential risks.

In a recent book, Howard Margolis raised doubts about the role of trust and distrust in risk assessments. Margolis suggested that the causal path may actually be in the in opposite direction. Once a person has decided that something is dangerous, he or she will distrust any so-called expert who says otherwise. That is, distrust may be *caused by* exaggerated fears, rather than being a cause of them. Margolis produced no direct evidence to support his claim; nevertheless, his argument is certainly plausible.

We began examining the relationship between trust in experts and attitudes toward offshore oil drilling using our survey data and two-stage, least squares regression methods. Our initial findings suggest that attitudes toward oil drilling cause trust in government, oil industry, and environmental group experts—as Margolis predicted. Trust in government experts however, may have some effect on attitudes. If these findings hold up, they will suggest that the trust questions about advocacy groups be revised or dropped from the questionnaire being designed.

Finally, we worked on the zip-code based coding scheme to measure the proximity of potential survey respondents in the San Luis Obispo, Santa Barbara, and Ventura counties to oil drilling or refining facilities, and a similar measure of whether oil drilling or refining facilities are in the viewshed of potential respondents. This coding scheme will be designed to work in geographical information systems (GIS) software. This work progressed slowly because of the complications in GIS software.

In the second quarter of the 2000-2001 fiscal year, we focused on analysis of a March 1998 data set to help select questions for the questionnaire. The goal of the analysis was to determine whether we should include a battery of questions on trust in experts. In previous studies, many investigators have argued that the trend of declining trust in government and industries has caused people to distrust government and industry experts. Consequently, when experts offer the public assurances that potentially risky environmental technologies are actually safe, the public ignores them. That is, the lack of trust is one cause of exaggerated perceptions of risk. However, in a recent study Howard Margolis argued that the causal direction is actually from risk perception to trust. When people fear a technology, they distrust experts who maintain that the technology is safe. In order to investigate the causal relationship between trust and risk perceptions, we estimated a two-stage, least-squares regression model with trust in government, oil industry, or environmental group experts and support for oil drilling as the endogenous variables. We found that attitudes toward oil drilling causes trust, but trust does not cause attitudes. In the case of trust in government experts, the regression coefficient came close to statistical significance at $p < .05$, but did not attain it.

The results of this investigation are presented in "Trust in Experts: A Cause of Attitudes or a Consequence?" This paper has been submitted to MMS for review prior to submission to a journal.

Research summary 2001-2002

Project Objective

The goal of this project was to conduct a series of preliminary analyses in order to help design a set of public opinion surveys and news media content analysis methods for a study of NIMBY responses to proposed offshore oil development projects along the California coast. A number of new drilling projects will be announced soon by current oil-lease holders. These proposals offer an opportunity to study the public's reaction.

Theory

One way to describe this project would be to say that in large part it is an application and testing of the "Receive-Accept-Sample," or RAS, model of opinion formation. Although this model has received a great deal of attention from public opinion scholars, it has not been used by researchers investigating risk perception, risk communication, NIMBYs, or attitudes regarding offshore oil drilling. The preliminary studies reported here and the overall project test the RAS model in the context of attitudes toward offshore oil drilling. We begin, therefore, with a discussion of the RAS model.

The Receive-Accept-Sample Model of Opinion Formation

Our approach to understanding the public's reaction to potentially risky technologies begins with a focus on the role of the public's knowledge. How much people know about potential hazards plays a critical—and poorly understood—role in their perceptions of risk. A few studies suggest that risk perceptions depend on information, but most studies point to the conclusion that deeply held values, cultural orientations, and other factors govern risk perceptions, and that knowledge about potential hazards has little or no influence.

John Zaller's (1992) "Receive-Accept-Sample" (RAS) model of opinion formation focuses on the critical role of political awareness and knowledge in the communication and persuasion process. The basic propositions of the RAS model are: (1) exposure to mass communication messages increases with political knowledge; (2) among those who have been exposed, acceptance of the message increases with knowledge if the message agrees with the person's values or "predispositions"; and (3) among those who have been exposed, acceptance of the message decreases with knowledge if the message is contrary to the person's predispositions. So acceptance of a persuasive, controversial message depends on the individual's political knowledge and on whether the message agrees or disagrees with the listener's predispositions. This has been described in previous studies as the "expertise interaction hypothesis."

In concrete terms, people who don't pay attention to politics will not be influenced by claims that offshore oil drilling is risky because they are not likely to hear those claims. Among those who do pay attention, pro-environmental people will be likely to believe the claims and pro-development people will be likely to reject them because of their prior beliefs. The people most likely to be persuaded by messages are those who have intermediate levels of knowledge and attention to politics. They pay enough attention to politics so that they hear

some messages, but they don't know enough to recognize whether the messages are consistent with their prior beliefs.

Five measures of people's basic values were examined as possible predispositions in this project—egalitarianism, individualism, postmaterialism, liberal-conservative ideology, and party identification. Each of these measures has been identified as a likely cause of pro-environmental attitudes in previous research. The predisposition that yielded the strongest results throughout this study is egalitarianism, the belief that material goods should be distributed more equally both within the U.S. and among nations.

Findings

We tested the RAS model in several ways using a 1998 public opinion survey of California adults. We found expertise interactions in three important areas: (1) in people's attitudes of support or opposition to offshore oil drilling; (2) in people's trust in scientists working for the government, the oil industry, or environmental groups; and (3) in people's confidence in claims by university scientists that offshore oil drilling was either safer or riskier than previously believed.

With respect to attitudes toward offshore oil drilling, we found that the strongest opponents were those who were well informed and who were strong egalitarians, while the strongest supporters were those who were well informed but who rejected egalitarianism. These findings held up under a variety of controls in multiple regression models. Moreover, egalitarianism, knowledge, and their interaction explained attitudes toward offshore oil drilling far better than any of the "standard" variables used to explain environmental attitudes in previous research.

To examine people's trust in scientists working for the government, the oil industry, and environmental groups, a two-stage, least squares regression model was estimated. The model allowed us to disentangle the causal effects in the relationship between trust in experts and attitudes toward oil drilling. Loss of trust in institutions and the experts associated with them is one of the most commonly proposed explanations for the failure of people to believe expert risk assessments and accept technologies such as offshore oil drilling. The argument is that if people do not trust the government, big business, university scientists, or other sources of expertise, then they will reject the experts' assurances that risks are minimal and that they have no reason to worry. Recently, however, it has been suggested that the causal path might run in the opposite direction. That is, once a person has decided that something is dangerous, he or she may distrust any so-called expert who says otherwise. That is, distrust may be *caused by* exaggerated fears, rather than being a cause of them.

We found that attitudes toward oil drilling cause which set of experts' people choose to believe. Drilling supporters are most likely to believe oil industry scientists, while drilling opponents are most likely to believe environmental group scientists. Trust in environmental group and oil industry experts, in contrast, has no impact on attitudes at all. There is some marginal evidence, however, that trust in government experts may influence people's opinions—a potentially important finding from MMS's point of view. We also found that the

expertise interaction with egalitarianism and knowledge was again a prominent cause of attitudes.

In our third analysis of survey data, we used an experiment embedded in our 1998 survey to examine people's confidence in claims by university scientists that offshore oil drilling was either safer or riskier than previously believed. We found that people choose to believe scientists based on the content of the scientists' reports. People had confidence in the scientists when the scientists supported their prior beliefs, but not when the scientists reports contradicted their beliefs. Greater education and knowledge did not make people more likely to believe scientists. Instead, as the RAS model predicts, greater education and knowledge makes people more likely to accept findings that agree with their predispositions and reject those that do not.

The final part of this project was a content analysis of the *Los Angeles Times* for the period April 1 to September 30, 1997. The original intent was to provide a baseline analysis of the information in the *Times* that would allow readers to estimate risks from a variety of threats, including any potential hazards associated with oil development. Contrary to our expectations, we found almost no detailed risk information on any subject. Although the *Times* is one of the most thorough newspapers in the United States, it did not offer its readers any systematic evidence that would allow them to evaluate risks from oil development or any other subject.

The results discussed here are being used to help design a questionnaire and set of content analysis instruments for the next phase of this project. The results are also described more fully in the final study report, *The Role of Knowledge in the Public's Trust in Science about Offshore Oil and Gas Development,* which was submitted to the MMS in October 2001.

Application of genetic techniques for use in restoration of surfgrass (Phyllospadix torreyi)

Principal Investigators: Scott A. Hodges, Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara, CA 93106-9610 **Douglas S. Bush**, Marine Science Institute and **Daniel C. Reed**, Marine Science Institute, University of California, Santa Barbara, CA 93106-6150

Research Objectives

Our first objective is to describe the mating system in *Phyllospadix torreyi*. Surfgrass is dioecious; however, the sex ratio of plants is strongly female biased. Female plants outnumber male plants by more than ten to one at most of our sites; at some sites males were never observed. Despite this apparent shortage of male flowers, most female flowers produce fruit. For successful fruit set to occur under these conditions, female flowers must either receive pollen from distant males, or produce fruit asexually. Asexual cloning via apomixis (the production of an embryo from an ovule without fertilization) is common in many plants, especially grasses. Determining whether apomixis is common in surfgrass is important if restoration is to depend on outplanting seeds or seedlings obtained from natural populations. The reason for this is that the genetic diversity and sex ratio of populations dominated by cloning would be very different from those in populations where pollination is prevalent. In particular, genetic diversity of cloning populations would be lower and the proportion of females would be much higher than in populations that reproduce sexually.

Our second objective is to determine the amount of genetic diversity within and among local populations of surfgrass. Previous work has shown that restored seagrass populations with lower genetic diversity do not perform as well as natural populations. Specifically, restored populations of eelgrass (*Zostera marina*) in southern California have lower genetic diversity than natural populations. Inbreeding depression, which is a common occurrence in populations with lower genetic diversity, has been shown to produce reduced seed set in *Zostera*. The issue of lowered genetic diversity is relevant to surfgrass management, because genetic diversity of locally-restored populations might be lower than in natural ones. Higher genetic diversity provides the potential for populations to cope with changing environmental conditions, as well as an increased capacity to occupy heterogeneous environments. Furthermore, if surfgrass populations are genetically differentiated then local adaptation may have occurred and thus restoration with germplasm from nearby sites may be most successful. Surfgrass populations occupy environments that change on a variety of temporal and spatial scales, such as climate change due (for instance) to ENSO, as well as daily and seasonal tidal fluctuations, inundation with sand, etc. Lastly, increased genetic diversity (within an individual) also has been associated with increased fitness across a wide range of species.

Summary of Research

Research progress 1999-2000

In our last annual report, we detailed our work on developing AFLP technology for the genetic analysis of surfgrass populations. At that time, we were using radioactively labeled primers and X-ray film to detect DNA fragments. Since that time, we have now aquired an

automated, non-radioactive system. We now label primers with fluorescent tags and detect DNA fragments with a LiCor automated DNA sequencing machine. This system has greatly increased our ability to assay samples.

1) *Levels of genetic diversity in surfgrass populations*. We have used AFLPs, a DNA fingerprinting technique, to estimate the extent of clonality and the overall genetic diversity of six surfgrass populations. The populations we studied are in areas that are impacted by oil and gas activities off the coast of Santa Barbara. We found high levels of genetic diversity in each of the six populations; we identified more than 50 variable AFLP markers, and individuals within populations differed from each other, on average, at 5 to 20% of these variable AFLP markers.

Our data also indicate that clonal propagation occurs only over limited distances. We found that genets (genetically identical plants) typically did not extend beyond one or two meters at most. When sampled along transects in the intertidal the proportion of shoots identified as clones decreased from approximately 60 % to zero as sampling interval increased from 20 cm to 50 m. In other words, shoots separated by as little as 20 cm were genetically distinct in over 40% of our samples, and only 17% of shoots separated by 8 m were identified as clones. No clones were detected in samples collected greater than 8 m apart. These data indicate that at least in the intertidal zone surfgrass populations are not comprised of a few large-sized, spatially extensive clones but rather that they consist of many relatively small-sized, genetically distinct plants. Together with the fact that rhizomes of *P. torreyi* cannot be fragmented and re-established naturally, these data further suggest that outcrossing and seedling recruitment must be important for establishing and maintaining the genetic structure of surfgrass populations. Comparable data are lacking for the subtidal and the extent to which clone size (and thus genetic diversity) vary with depth and disturbance regime await further investigation.

A third important result of our studies on genetic diversity is that surfgrass populations that we sampled were all genetically distinct from each other. Phylogenetic analysis of the AFLP data groups individuals within a population together but separates individuals from different populations. The two closest mainland populations (Shoreline and Lompoc Landing which are separated by about 100 km) were clearly separated by the analysis. The distances separating island populations were generally less than those on the mainland (i.e., about 50 km) yet they too were distinguished from each other in the analysis. The island samples are, of course, separated by open ocean rather than shoreline which may decrease the distance where differentiation may occur compared with contiguous coastline. In any case, these data indicate that gene flow between populations along a shoreline can be restricted over distances as little as 100 km leading to genetic differentiation and, possibly, local adaptation. Additional analyses with greater spatial resolution are needed to refine the spatial scale over which local surfgrass populations are genetically differentiated.

2) *Relative contribution of apomixis (cloning) vs. outcrossing to the breeding system*. Along the Santa Barbara coast, *Phyllospadix* produces abundant seeds even in populations where males are rare or apparently absent. This, together with our initial assumption that *Phyllospadix* has low genetic diversity, led us to hypothesize that seed production might occur through apomixis (cloning) rather than through outcrossing. To determine if apomixis occurs,

we compared DNA fingerprints from mother/seedling pairs in two populations, one where the frequency of flowering males is rare (Females: Males, 13:1) and one where they are common (Females: Males, 1:0.95). Our results clearly show that even in the population where males are rare, i.e. at Shoreline, seedlings are genetically distinct from their mother as we found no instance where the DNA fingerprint of the mother matched that of the seed. Apomixis, therefore, does not occur in *Phyllospadix* at any detectable level and seeds are produced sexually. Because *Phyllospadix* is dioecious, the seed produced must be the result of outcrossing.

The results of these studies of the genetics of seed production corroborate those described above that show high levels of genetic diversity within surfgrass populations. Furthermore, they lend strong support to the hypothesis that seedling recruitment is important for establishing and maintaining the genetic structure of surfgrass populations.

3) *Identifying genetic markers linked to gender determination*. Strong female-biased sex ratios have long been reported for *Phyllospadix torreyi* (Dudley 1893). Because the causes and consequences of this skewed gender bias are not fully understood (Williams 1995), the prudent course of action for restoration is to maintain the natural ratio and distribution of male and female plants. It is important to note, however, that the reported sex ratios in *P. torreyi* have been based on observations of flowering, which may not be an accurate depiction of the relative abundance of male and female plants. Many individuals in a population fail to flower in any given year and determining the primary distribution of the sexes using vegetative morphology cannot accurately be done. Because of the need to know the relative abundance and distribution of the sexes for restoration, we sought to identify genetic markers that are linked to gender determination. We screened for gender-specific markers by pooling DNA from known (flowering) males or females of several populations. By using AFLP analysis on these pools, we can determine if a single individual in the pool has a particular marker (data not shown). In this way we are able to rapidly screen a large number of individuals and populations for potential gender-specific markers. We screened three male and three female pools for 32 AFLP primer pairs and identified 25 markers that appeared in all of the pools of one sex but not the other. We have identified 23 potential male markers and 2 potential female markers using this method. The predominance of male markers is consistent with the existence of an XY system of sex-determination like that of humans and a number of plant species (Dellaporta and Calderon-Urrea 1993). In these systems only males possess the Y chromosome and all individuals possess at least one copy of an X chromosome, thus genetic markers on the Y chromosome are sex specific and restricted to males.

Research presentations

Brian Counterman presented the results of his investigation of chloroplast DNA variation in a poster at the annual Toxics Substances Research and Teaching symposium in San Diego.

Undergraduate Personnel

Brian Counterman conducted a senior project where he investigated chloroplast DNA (cpDNA) variation in surfgrass. For this project, he PCR amplified and then sequenced a number of individuals to look for sequence variation. In addtion, Brian worked on the main

portion of the grant by isolating DNA and learning the AFLP technology to study genetic variation. Chris Adams started working in our laboratory this past year. He has worked on the isolation of DNA samples from surfgrass and has begun learning how to conduct AFLP analyses.

Research progress 2000-2001

We have been focusing our efforts on our analysis of genetic diversity within and among populations of surfgrass. We have completed AFLP fingerprints, using six different primer pairs, on all of these samples. Currently, we are scoring these gels and have begun some preliminary analyses. We have found about 30 variable bands among samples across populations and therefore we expect to have nearly 200 variable bands to determine population differentiation. Thus far we have found genetic evidence for clonality on a limited scale. Clones appear to occur on a spatial scale on the order of 1-2 meters at most. In addition, we have found a great deal of variation within and among populations of surfgrass. Preliminary analyses based on a subset of our data indicate that populations are genetically differentiated from one another on the spatial scale of about 50 km. We have also begun to analyze our samples to determine the mating system of surfgrass. We have analyzed one population to date and found that all seeds were produced through sexual reproduction and not apomixis.

We have also been conducting genetic analyses to identify molecular markers for gender. So far we have screened approximately 70 Randomly Amplified Polymorphic DNA (RAPD) primers for sets of males and females. From these analyses we have identified one possible marker for gender. This marker has only been found in males thus far and never in females. However, not all males possess this marker making it of limited value for our purposes. We plan to determine if these patterns occur in larger samples and if so, we will then try several techniques to convert this marker into a consistent marker for gender.

Research progress 2001-2002

This project was transferred to the Coastal Marine Institute and was funded by the Minerals Management Service since the first quarter of the 2001-2002 fiscal year. Please refer to the CMI 2000-2002 Annual Report and the CMI 2002-2003 Annual Report for research updates from the 2001-2002 and 2002-2003 fiscal years.

Early Development of Fouling Communities on Offshore Oil Platforms

Principal Investigators: Henry M. Page and **Jenifer E. Dugan,** Marine Science Institute, University of California, Santa Barbara, CA 93106-6150
Graduate Student: Jason Bram

Background

Offshore oil platforms provide hard attachment sites for an array of sessile animal species, including barnacles, mussels, scallops, tunicates, bryozoans, and sea anemones. In an otherwise soft-bottom environment these platforms provide habitat for a diverse community of invertebrates that otherwise would not exist there. In addition, the sessile invertebrate community provides habitat and food for many small mobile invertebrates, such as gammaridean and caprellid amphipods, as well as for larger invertebrates and fishes. In general, previous studies of platform invertebrate communities have been descriptive in nature, with little investigation of the processes that influence development and structure of this community. We are quantifying the role of selected physical and biological factors in the rate of accumulation and structure of the invertebrate community on two platforms in the Santa Barbara Channel.

Using platforms "Houchin" and "Hogan" (Pacific Operators Offshore), we are: (1) quantifying changes in biomass and community composition on these structures over time following maintenance cleaning, (2) using experimentally scraped surfaces and plates to evaluate the effects of time from disturbance, time-of-year, and depth on the early development of the invertebrate community; this includes testing the models of facilitation and inhibition in order to better understand the effect of the presence of a species on community development, (3) determining relationships between the species composition, biomass, and thickness of the fouling community and rates of faunal litterfall to the benthos, and (4) quantifying the growth of organisms of economic and biological importance. Our research will contribute to decisions regarding platform cleaning and maintenance operations and the design of platform structures.

Summary of Research

Research progress 1999-2000

We are measuring the accumulation of biomass (as dry weight) at three depths (6 m, 12 m, and 18 m) on vertical support members (n=4 members) using three techniques: (1) samples obtained from ceramic tiles placed on Platform Houchin and subsequently exposed for various intervals (2-month, 4-month, 6-month, 12-month, 24-month), and (2) samples obtained from the destructive sampling of experimental plots (20x20 cm) on the support members at 2-month, 4-month, 6-month, and 12-month intervals. For the latter samples, each quadrat is scraped and vacuumed to remove settled invertebrates from the plot. Our third technique estimates the biomass of the organisms settling on more structurally complex settlement surfaces (plastic mesh tuffys), which are deployed and collected monthly. The tiles and tuffys are attached by cable ties to a PVC frame reinforced with rebar, which was attached to each vertical support member with cable ties. The experimental plots are located

just below the frames on the support members. The percent cover of dominant organisms on the tiles is determined in the laboratory using point contact methods. The percent cover of dominant organisms in the experimental plots will be determined from photographs taken with a digital camera and image analysis software. The tiles are also photographed after their retrieval. We have initiated the image analysis of the photographic record and will begin formal analyses during the next 3 months.

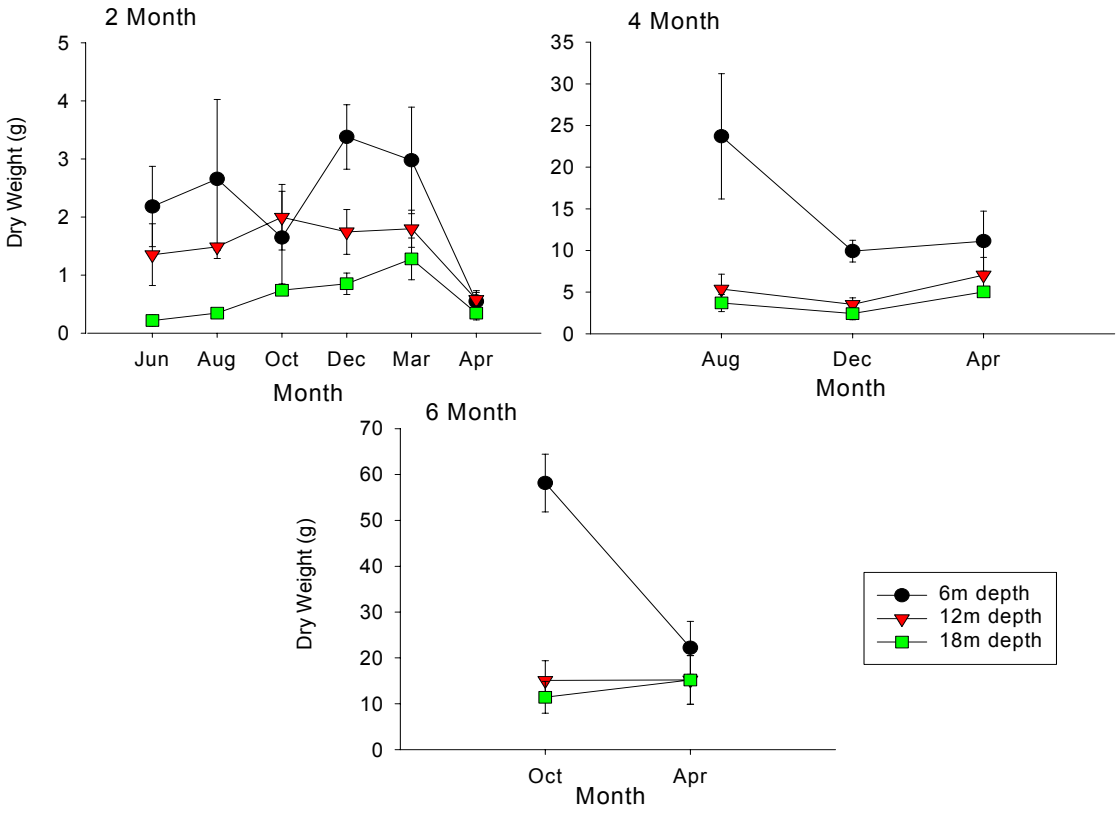


Figure 1. Comparison of biomass accumulation on tiles from Platform Houchin exposed for intervals of 2, 4, or 6 months. (x± 1SE, n= 4 tiles).

A general pattern found on all of the experimental surfaces (tiles, tuffys, scraped areas) is illustrated in Figure 1: biomass decreases with depth at all time periods between disturbances, with the 6 m depth having a much greater biomass accumulation than the deeper depths. In addition, Figure 1 shows temporal variation in biomass accumulation with the lowest values in April. Also evident is the much greater biomass as time between disturbances is increased, with over 20 times the biomass at the 6-month disturbance time at 6 m compared to the 2-month disturbance time at the same depth. It is interesting to note that mussel recruitment has been extremely low on these surfaces when compared to other studies on platforms in the Santa Barbara Channel (data not shown).

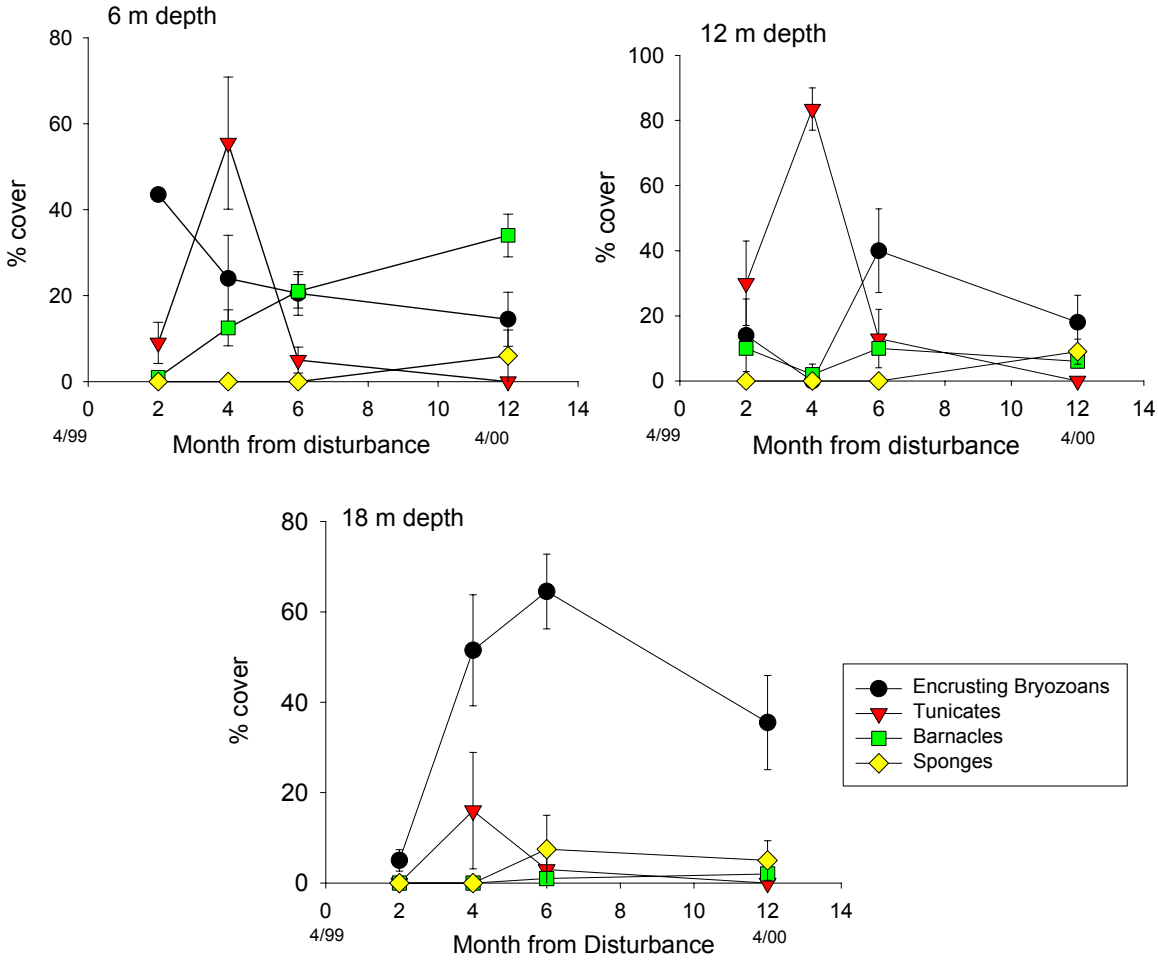


Figure 2. Changes in percent cover of selected invertebrate taxa over time on ceramic tiles at Platform Houchin at depths of 6, 12, and 18 m (x± 1SE, n=4 tiles).

Community composition on the tiles changes over time and among depths (Fig. 2). For example, at a depth of 6 m, encrusting bryozoans dominate early, followed by a gradual decrease in the cover of this taxa and an increase in the cover of tunicates. However, the cover of tunicates decreases to 0% after 12 months. Barnacles show a continual increase in percent cover, and sponges slowly begin to become part of the assemblage after 12 months. At the 12 m depth, the tunicates dominate early, with a large increase in cover after 4 months of exposure time. However, the cover of tunicates at this depth decreases to 0% after 12 months. At the 18 m depth, the community takes longer to develop, with little coverage from any group of organisms after 2 months. Both the tunicates and encrusting bryozoans show an increase in cover after 4 months, with the bryozoans being dominant.

We are also estimating the rates and composition of faunal litterfall from the invertebrate community using circular plastic hoops with attached mesh bags as "traps". The faunal litterfall traps are located on Platform Hogan at a depth of 18 m (n=8 traps). On average, we

have collected approximately 200 g/trap of litterfall monthly. *Mytilus galloprovincialis* is the dominant component of these samples to date. We are also measuring the thickness of and photographing the invertebrate community at Platform Hogan, quarterly at depths from 6 m to 18 m. The thickness and cover of the invertebrate community has generally increased over time at all depths.

To compare relative flow among depths we have attached clod cards to each PVC frame at each depth (n=12). Early data suggest that water flow is lower at deeper depths, a result that corresponds with our observations of a lower biomass and invertebrate species richness, although more samples will be taken.

To examine the effects of dominant space occupying species on the early development of the invertebrate community we are conducting removal experiments using the anemone, *Anthopleura elegantissima,* and the mussels, *Mytilus californianus* and *M. galloprovincialis*. Experimental removals were initiated in April and data will be collected through the next year, using a digital camera. We predict that mussels or other species will colonize plots in which the anemones are removed more rapidly than control plots, if anemones consume or otherwise interfere with settling larvae. Similar predictions can be made for the mussel removal plots, which we predict will have other species colonizing these areas more rapidly than control plots with mussels present.

To quantify temporal and spatial variation in commercially important and dominant organisms on the platforms we measure the sizes of all mussels, scallops, urchins and crabs and barnacles collected. These measurements will allow us to compare the growth rates of selected species over time and at different depths.

Over the next year we will continue to deploy, retrieve, and measure invertebrates from the tiles, the tuffys, and the experimental plots. Video photoplots will be analyzed, and sampling will continue as described above. The litterfall will be collected monthly. The thickness of the invertebrate community will will be measured quarterly. Video data from the removal experiments will be collected and analyzed and flow data will be collected. Continued sampling and analysis of the data will provide greater insight into the factors that influence the early development of the invertebrate communities on offshore oil platforms.

Research Progress 2000-2001

We continued to measure spatial and temporal patterns in development of the invertebrate community at depths of 6, 12, and 18 m on Platform Houchin. Invertebrates were sampled on two types of settlement surfaces (tiles, tuffys) attached to frames and on conductor pipes. Tiles were retrieved after a 2 or 4-month exposure time at all depths in August. Tuffys were retrieved monthly at all depths. Permanently marked 20 cm x 20 cm quadrats on conductor pipes at Houchin, scraped at intervals of 2, 4, 6, and 12 months, were photographed in July and September. Vacuum samples from these 2, 4, 6, and 12-month treatments were collected at all depths in July and 2-month treatments were collected in September. Removal experiments using the anemone, *Anthopleura elegantissima,* and the mussel, *Mytilus californianus,* were monitored monthly at a depth of 9 m. Faunal litterfall traps, deployed at a

depth of 18 m, were monitored monthly at Hogan. Planktonic larval collection and clod card deployment at 6, 12, and 18 m was initiated in July, and continued monthly.

For the tiles and vacuum samples, biomass varied significantly among exposure times and depths. For the 2-month and 4-month exposure periods on the tiles, mean dry biomass increased with exposure time and decreased with depth. For the 2-month, 4-month, 6-month, and 12-month exposure periods on the vacuum samples, mean dry biomass also increased with exposure time and decreased with depth.

On average, 167 g of animal biomass was collected monthly from each faunal litterfall trap, with a high of 212 g in August and a low of 119 g in September. Mussels, (*Mytilus galloprovincialis)* comprised most of the faunal litterfall by weight.

Clod cards, used to determine relative flow between the depths, indicated that the flow at the 6 m depth was significantly greater than the flow at the deeper depths in all months.

Research Progress 2001-2002

During the first quarter, we continued to measure spatial and temporal patterns in development of the invertebrate community at depths of 6, 12, and 18 m on Platform Houchin. Permanently marked 20 cm x 20 cm quadrats on conductor pipes at Houchin, scraped at intervals of 2, 4, 6, and 12 months, were photographed in August. Vacuum samples from the 2, 4, 6, and 12-month treatments were collected at all depths in August. Biomass of the experimentally scraped plots varied significantly among exposure times (2, 4, 6 and 12 months) and depths. Mean biomass decreased with depth and increased with exposure time for all treatments and was significantly greater at the 6 m depth than at the 12 and 18 m depths for all exposure times.

The plumose anemone, *Metridium senile*, an abundant member of the invertebrate community on offshore oil platforms, may be an important competitor for space. To investigate the role that this anemone plays in the development of the platform invertebrate community, we initiated an anemone removal experiment at Platform Houchin in September. Anemones are removed from randomly selected artificial surfaces (ceramic tiles attached to PVC frames) at depths of 6, 12, and 18 m and allowed to accumulate naturally on other artificial surfaces at the same depths. We will measure biomass and the percent cover of the taxa present among treatments.

We continued to analyze data on species composition and percent cover of invertebrates that colonized ceramic tiles (15x15 cm) exposed for various time intervals (2, 4, 6, 12, 24 months) at depths of 6, 12, and 18 m at Platform Houchin from April 1999 to April 2001. Patterns of accumulation of biomass on the ceramic tiles were similar to those observed in the experimentally scraped plots (see above). Analyses of variance and subsequent post hoc tests on the mean biomass and percent cover of selected taxa present on the ceramic tiles showed that biomass was significantly greater at the 6 m depth than at the two deeper depths. Mean biomass also significantly increased with exposure time across all depths and varied significantly among dates of initial tile immersion. Invertebrate community development and

the percent cover of selected taxa on the tiles also varied significantly over time, among depths, and among dates of initial tile immersion.

In August, faunal litterfall was collected and measured from traps deployed at a depth of 18 m at Platform Hogan. The average biomass of faunal litterfall found in August (1151.25 g) was the greatest amount observed to date (two years). It was approximately three times that observed during the previous August (2000) and ~35% higher than the preceding month (July, 2001). Mussels, (*Mytilus galloprovincialis)* comprised most of the faunal litterfall by weight.

During the second and third quarters of the 2000-2001 fiscal year, we continued data analysis on the species composition, biomass and percent cover of invertebrates that colonized ceramic tiles (15x15 cm) exposed for various time intervals (2, 4, 6, 12, 24 months) at depths of 6, 12, and 18 m at Platform Houchin. We also continued data analysis on the percent cover and biomass of invertebrates that colonized experimentally scraped 20 cm x 20 cm quadrats on conductor pipes and plastic mesh tuffys at depths of 6, 12, and 18 m at Platform Houchin from April 1999 to April 2001. The removal experiment using the anemone, *Metridium senile,* was monitored at Houchin at depths of 6, 12, and 18 m.

Preliminary analysis shows that biomass on both the experimental surfaces and the surface of the platform itself increased significantly over time at all depths, and varied among depths. Biomass was significantly greater at the 6 m depth than at the two deeper depths. Additionally, there was a greater rate of biomass accumulation in the second year of the study at all depths. The amount of biomass on these surfaces also varied with the time of year. Percent cover of selected taxa on the tiles varied significantly over time, among depths, and among dates of initial exposure of the surface, and between the two years of the study, with the greatest temporal effects evident at the 6 m depth. The successional sequence in the appearance and cover of taxa over time was strongly influenced by depth and year. For example, in year one, compound tunicates and encrusting bryozoans had the greatest cover in both the 2 month and 4 month exposure time at all depths, while in year two, compound tunicates were the sole dominant taxon at the 2 month interval at the 6 m and 12 m depths, and were co-dominant with encrusting bryozoans at the 18 m depth. At the 4 month interval, barnacles were dominant at the 6 m depth. The longer exposure times showed these differences between depths and years as well. For example, in year one at the 12 month exposure time, barnacles were dominant at the 6 m depth, encrusting bryozoans, barnacles, and sponges were dominant at the 12 m depth, and encrusting bryozoans were dominant at the 18 m depth. In year two for the 12 month exposure period, barnacles and sponges were both dominant at the 6 m and 12 m depths, while barnacles, sponges, and encrusting bryozoans were dominant at the 18 m depth.

Preliminary analyses of barnacle size distributions on the experimental surfaces indicates that growth rate was significantly more rapid at shallower depths. In addition, growth rate was significantly more rapid in year one compared with year two at all depths. Barnacles were significantly more abundant in year two than year one at all depths and for all exposure times.

Biomass on both the experimental surfaces and the surface of the platform itself increased significantly over time at all depths, and varied among depths. Biomass was significantly

greater at the 6 m depth than at the two deeper depths. Additionally, there was a greater rate of biomass accumulation in year two at all depths. Biomass on these surfaces also varied with the time of year.

A talk on the results of this study was given at the Western Society of Naturalists conference in November. A master's thesis and a manuscript on these results are both in preparation.

Research Progress 2002-2003

We are continuing to test whether selected early successional species inhibit, enhance, or have no effect, on the composition and rate of development of the invertebrate assemblage using field experiments at Platform Houchin. We are experimentally manipulating the abundance of three invertebrate taxa (barnacles, encrusting bryozoans, and colonial tunicates) that are important as early colonizers on ceramic tiles placed on Platform Houchin at three depths (6 m, 12 m, and 18 m). Each treatment involves the monthly removal of one taxon from the tile. These taxa were chosen based on their presence early in the successional sequences observed in 1999–2001. Preliminary observations suggest that encrusting bryozoans and colonial tunicates compete for primary space; encrusting bryozoans occur at a high % cover on tiles when colonial tunicates are removed while colonial tunicates occur at a high % cover when encrusting bryozoans are removed. Barnacles have continued to occur in low cover on all tiles.

We continued statistical analyses and interpretation of our results on species composition, biomass and percent cover of invertebrates that colonized tiles (15x15 cm) exposed for various time intervals (2, 4, 6, 12, 24 months) at depths of 6, 12, and 18 m at Platform Houchin. We also continued analyses of our results on the percent cover and biomass of invertebrates that colonized experimentally scraped 20 cm x 20 cm quadrats on conductor pipes and plastic mesh tuffys at depths of 6, 12, and 18 m at Platform Houchin from April 1999 to April 2001.

Percent cover of selected taxa on the tiles varied significantly over time, among depths, among dates of initial exposure of the surface, and between the two years of the study, with the greatest temporal effects evident at the 6 m depth. The cover of different invertebrate taxa over time was strongly influenced by depth and year. For example, barnacles accounted for 34% cover on the tiles after 12 months of exposure at the 6 m depth in 1999-2000. At the 12 and 18 m depths for this same treatment, barnacles occurred at 9% and 2% covers, respectively. In 2000-2001, the cover of barnacles was 66% after 12 months of exposure at 6 m, and at the 12 and 18 m depths, the cover of barnacles was 27% and 25%, respectively. The statistical analysis of our results on density and size of barnacles that colonized tiles (15x15 cm) exposed for various time intervals (2, 4, 6, 12, 24 months) at depths of 6, 12, and 18 m at Platform Houchin continued through the reporting period.

Biomass on both the experimental surfaces and the surface of the platform itself increased significantly over time at all depths, and varied among depths, with a greater rate of biomass accumulation at the 6 m depth than at the two deeper depths. There was also a greater rate of

biomass accumulation in 2000-2001 at all depths on all surfaces. In addition, there was significantly greater biomass accumulation on the tiles than on the scraped platform surfaces.

During the reporting period, an extensive literature review was undertaken. Figures for a manuscript and master's thesis are in preparation.

The Political Economy of the Rigs to Reef Option for Decommissioning Oil and Gas Structures

Principal Investigators: Michael Vincent McGinnis, Marine Science Insitute, University of California, Santa Barbara, CA 93106-6150 **Linda Fernandez**, Department of Environmental Sciences, University of California, Riverside, CA 92521 and **Caroline Pomeroy**, Institute for Marine Sciences, University of California, Santa Cruz, CA 95060

Background

Scholars have examined the political dimensions of oil and gas leasing, exploration and production associated with the Outer Continental Shelf (OCS) in the three primary OCS REGIONS, the Gulf of Mexico, Alaska and California. The history of OCS oil and gas development varies greatly from one region to another. Researchers have uncovered critical differences among OCS oil and gas regions, due to their particular legal, technological, and socio-economic contexts. As a result, the local and regional politics of OCS oil and gas development varies among these regions. OCS oil and gas development is contingent upon socio-cultural factors endemic to particular places, regions and localities and not just related to the presence of OCS oil and gas reserves, governments' willingness to create opportunities for the development of oil and gas, or the availability of modern technologies to develop oil and gas.

California has entered a new era of OCS oil and gas activity. The decommissioning of offshore oil and gas facilities is rapidly becoming an issue of public concern. Since 1998, government and private interests have been proposing various options to complete removal, including "rigs-to-reefs". The importance of socio-economic, legal and political factors notwithstanding, the implications of the rigs-to-reefs option and other decommissioning alternatives have received little systematic consideration by social scientists.

This study addressed three primary questions: (1) what are the potential costs and benefits of various options to decommission California OCS oil and gas structures? (2) what is the policy history of state artificial reef and rigs-to-reefs programs in the Gulf of Mexico (as a point of comparison with California)? and (3) what is the history of California's artificial reef program, and how does it fit into the current policy debate over rigs-to-reefs as an alternative to complete removal of platforms slated for decommissioning?

Summary of Research

Research progress 1999-2000

California's particular social reality and ecological concerns will shape the politics of decommissioning policy-making. Because of the stark differences between the California setting and that of the Gulf of Mexico, we propose that California policymakers should not use the Gulf state programs as a blueprint for the development of a rigs-to-reef program.

(1) *The potential costs and benefits of various options to decommissioning of California OCS oil and gas structures*

The National Research Council (1985) estimated that the cumulative costs for removal of all platforms in the OCS could total $2.9 billion by 2005 and $9.9 billion by 2020. More recently, the GAO (1994) estimated total decommissioning costs at $4.4 billion. The GAO (1994) review of offshore structure removal operations concluded that the MMS needs to better understand the risk of ecosystem damage posed by certain decommissioning practices, such as the use of explosives as a removal technique.

We analyzed three alternatives for decommissioning oil platforms: "Complete Removal", "Partial Removal" (i.e., removing the platform from one marine location to another) and "Leave in Place". We identified variables that are associated with the costs and benefits of these three alternatives. We also determined monetary values to quantify these costs and benefits, then compared those costs and benefits of each alternative within and across categories. We found that there are a range of values associated with each alternative, suggesting that they can be compared relatively, with low and high bounds of the ranges enabling the ranking of alternatives. The range for Partial Removal has an upper bound that makes accounting for two sites (original platform site and site where rig is transported to) less attractive than the Complete Removal and Leave in Place alternatives. The overlap of ranges for Complete Removal versus Leave in Place means it is more likely that each platform should be considered individually in order to derive more specific estimates of costs and benefits to weigh alternatives. However, economies of scale from grouping platforms together for Complete Removal can be considered by accounting for spreading the costs from the engineering and planning, mobilization and demobilization, and platform and structural removal across several platforms.

Since this part of the study is an objective information document, we do not rank alternatives. Instead, our results identify the factors associated with decommissioning alternatives, especially for platforms standing in varied water depths that often exceed the depth of platforms that have been decommissioned in other geographic areas such as the Gulf of Mexico.

One category of interest that is not quantified here is liability. The oil producer retains all liability for the platform and wells under each of the decommissioning options. Liability for accidents during lease clearance and abandonment is a cost to contend with in terms of personal injury, property damage and environmental damages for the Complete Removal alternative. The platform can still cost the operators long after ceasing oil production. Platforms can become top-heavy from biofouling growth that supports fisheries habitat; this can cause them to topple, and possibly cause ecological damage, personal injury or property damage. Moreover, for both the Partial Removal and Leave in Place alternatives, liability for any recreational or fishing accident that might occur constitutes an additional cost. This lingering liability suggests that platform operators need to reserve financial resources to cover these potential costs.

The potential costs of liability with the Leave in Place or Partial Removal alternatives call into question the logic of pending legislation in California, Senate Bill 241 (Alpert). SB 241 outlines a voluntary program whereby platform operators would yield to a portion of cost savings from partially removing or leaving a platform in place to support fisheries mitigation projects. SB 241 does not release operators from liability, and could reduce the incentives for platform operators to pursue the rigs-to-reef option.

(2) *The policy history of state artificial reef and rigs-to-reefs programs in the Gulf of Mexico*

This part of the study had two goals: a) to describe the historical development of the rigs-to-reefs alternative to Complete Removal in the Gulf of Mexico, and b) to characterize the general administration and operation of Gulf states' rigs-to-reef programs.

In the early 1980s, the Department of the Interior joined with the president of the National Ocean Industries Association to form the Recreational Environmental Enhancement for Fishing in the Seas (REEFS) task force. The task force was composed of fishery representatives, private industry and resource agencies primarily in the Gulf of Mexico region. Its goal was to create a strategy that would lead to the creation of a national rigs-to-reef policy, plan and program. Commercial and sport fishing industries lobbied state and federal government for an act that would accomplish this goal.

In late 1984 President Reagan signed the National Fishing Enhancement Act (NFEA). The NFEA does not apply to the decommissioning of California's OCS oil and gas structures (i.e., oil and gas structures in federal waters off California). The NFEA: 1) recognized social and economic values in developing artificial reefs, 2) established national standards for artificial reef development, 3) called for creation of a National Artificial Reef Plan under leadership of the Department of Commerce, and 4) established a reef permitting system under the US Army Corps of Engineers that limits the liability of participants in the program.

Although the law encourages the development of artificial reefs, it authorizes no direct appropriations for administration, planning, construction, enforcement, monitoring, or research on artificial reefs. States and regions have had to develop programs with scarce resources. The NFEA was enabling legislation that allowed Gulf states to develop and implement rigs-to-reef programs. State programs have been developed out of existing artificial reef programs. For example, in June 1986, Louisiana enacted legislation (Act 100--The Louisiana Fishing Enhancement Act) authorizing a state-directed rigs-to-reef program. The program is administered by the Louisiana Department of Wildlife and Fisheries and conducted jointly with staff from Louisiana State University. This section describes several examples of local and state rigs-to-reef programs and their administrative operation. From 1987-1995, of the over 941 platforms removed from Louisiana and Texas waters, 90 platforms or approximately 10% were transformed into artificial reefs.

(3) *The history of California's artificial reef program and the current policy debate over a rigs-to-reef option to complete removal*

SB 241, California's pending "rigs-to-reefs" legislation, would establish a state rigs-to-reef program closely tied to the state's artificial reef program. SB 241 cites the rigs' potential value as fish attraction and production sites, and would extend the Department's artificial reef management authority to federal waters.

Although the California Department of Fish and Game (CDFG) began a program of artificial reef research and development in 1958, legislation providing for the formal establishment of the program and allocation of (limited) personnel and financial resources did not occur until 1985. CDFG initiated its program of artificial reef development in the late 1950s in the interest of enhancing nearshore sport fishing opportunities in southern California. Using donated materials (due to a lack of funding), the Department oversaw the construction of several artificial reefs (e.g., at Paradise Cove in Northern Santa Monica Bay and Redondo Beach). CDFG biologists used these reefs to test the effectiveness of such structures in attracting fish; the study showed aggregation of fishes at both reef sites. This success led to a program to investigate the cost-effectiveness and practicality of different reef materials using aseries of "replication reefs" in Santa Monica Bay. These studies determined that quarry rock was the most effective material (Lewis and McKee 1989:3).

From the late 1960s through 1980, little systematic study was done on these or newly placed reefs. In 1980, however, CDFG began a major program of artificial reef construction and research in connection with Southern California Edison's required mitigation for the negative impacts of warm water discharge on coastal kelp beds. That mitigation plan included a 6-year cooperative project with CDFG for the construction of Pendleton Artificial Reef (in northern San Diego County) and studies to evaluate the reef's potential for enhancing marine resources (Lewis and McKee 1989:3). Although it was clear that the reefs attracted fish, there were concerns this could lead to increased local fishing pressure and resultant negative effects on populations. Next the program turned to an emphasis on designs that would promote production (by augmenting shelter and forage), as well as attraction. Research has shown that high relief, open structures serve best to attract fish, and better enable fishery exploitation, while low relief, complex structured reefs provide better nurseries and afford more diverse assemblages of fish and other organisms. As a CDFG biologist noted, a drawback to rigs as reefs is that they are high relief, which works against survival of young-of-the-year fish, suggesting they may not be a source of production but rather simply an attraction site.

Artificial reef construction thus became one aspect of CDFG's Nearshore Sportfish Habitat Enhancement Program for restoring or enhancing sportfish habitat along the southern California coastline (Lewis and McKee 1989:1). The program's objective is to maintain sportfishing success in the face of the cumulative effects of increasing fishing pressure as well as negative impacts on the nearshore ecosystem (Lewis and McKee 1989:1). It is supported, in part, by Dingell-Johnson/Wallop-Breaux Federal Aid in Sport Fish Restoration Act Funds.

Although CDFG is charged with managing the state's artificial reefs and the program, several other agencies play a role in the pre-construction permitting process. Siting artificial reefs in

California waters requires a (federal) permit for ocean dumping from the U.S. Army Corp of Engineers, a coastal development permit from the California Coastal Commission (CCC), and a lease from the State Lands Commission (SLC) for activity on submerged state lands. In waters outside the three-mile state jurisdiction, an SLC permit is not required, but the CCC must issue a consistency finding before the Corps of Engineers will issue a permit. Other agencies that may be involved in the process include the U.S. Coast guard (for navigation), and the U.S. Environmental Protection Agency may require an environmental impact statement showing no negative impact.

At present, there are some 36 artificial reefs consisting of hundreds of modules off the coast of California, but resources to support monitoring these sites and the state's program more generally are quite limited. Three CDFG personnel are assigned to the program, part-time. There are no funds available for building new reefs, so materials for any new construction come from demolition projects or other donations. The Department maintains a keen interest, however, in building several large reefs. Meanwhile, CDFG periodically monitors and continues to augment two artificial reefs outside of state waters. These reefs were permitted prior to any public discussion about CDFG's role in a rigs-to-reef program. When CDFG lawyers started looking at rigs-to-reefs, they informed CDFG personnel that they have no legal standing beyond California state waters, with the exception of the two above-mentioned reefs.

Research Progress 2000-2001

Analyses and writing culminated in a Final Report, which was submitted in March 2001. In addition, a manuscript stemming from this research was submitted to the journal of *Policy Studies Review.*

RESEARCH PRODUCTIVITY

PAPERS PUBLISHED

Ambrose, R.F., S.F. Lee, and S. Bergquist. 2002. Sediment disposal site rocky intertidal monitoring studies: Santa Monica to Malibu Coastline. Report to the State of California Department of Transportation District 7. (With Addendum: Data and Field Notes.)

Forde, S.E. 2002. Modelling the effects of an oil spill on open populations of intertidal invertebrates. *Journal of Applied Ecology* **39**: 595-604.

Holbrook, S.J., Ambrose, R.F., Botsford, L., Carr, M.H., Raimondi, P.T., and M.J. Tegner. 2000. Ecological Issues Related to Decommissioning of California's Offshore Production Platforms. A Report to the University of California Marine Council by The Select Scientific Advisory Committee on Decommissioning, University of California.

Holbrook, S.J., Reed, D.C., Hansen, K., et al. 2000. Spatial and temporal patterns of predation on seeds of the surfgrass *Phyllospadix torreyi*. *Mar. Biol.* **136** (4): 739-747.

Hamdoun, A.M., Griffin, F.J., and G.N. Cherr. 2002. Tolerance to biodegraded crude oil in marine invertebrate embryos and larvae is associated with expression of a multixenobiotic resistance transporter. *Aquat. Toxicol.* **61** (1-2): 127-140.

Lika, K and R.M. Nisbet. 2000. A dynamic energy budget model based on partioning of net production. *Journal of Mathematical Biology*, **41**: 361-386.

*McGinnis, M.V. 1997. An analysis of the role of ecological science in offshore continental shelf abandonment policy. In: *Proceedings of California and the World Ocean '97*, Organized and sponsored by Coastal Zone Foundation and Resources Agency of California. 9 pp.

Miller, A.W. and R.F. Ambrose. 2000. Sampling patchy distributions: Comparison of different sampling designs in rocky intertidal habitats. *Marine Ecology Progress Series* **196**: 1-14.

Muller, E.B. and R.M. Nisbet. 2000. Survival and production in variable resource environments. *Bulletin of Mathematical Biology,* **62**: 1163-1189.

Muller, E.B., Nisbet, R.M., Kooijman, S.A.L.M., Elser, J.J., and E. McCauley. 2001. Stoichiometric food quality and herbivore dynamics. *Ecology Letters* **4**(6): 519-529.

Nisbet, R.M., Muller, E.B., Lika, K. and S.A.L.M. Kooijman. 2000. From molecules to ecosystems through dynamic energy budget models. *Journal of Animal Ecology,* **69**: 913-926.

Osenberg, C.W., St. Mary, C.M., Wilson, J.A., and W.J. Lindberg. 2002. A quantitative framework to evaluate the attraction-production controversy, with application to marine ornamental fisheries. *ICES Journal of Marine Science* **59**: 214-221 Suppl. S.

*Osenberg, C.W., Sarnelle, O., Cooper, S.D., and R.D. Holt. 1999. Resolving ecological questions through meta-analysis: goals, metrics and models. *Ecology* **80**:1105-1117.

*Page, H.M., Dugan, J.E., Dugan, D., and J. Richards. 1999. Effects of an offshore oil platform on the distribution and abundance of commercially important crab species. *Marine Ecology Progress Series* **185**: 47-57.

Raimondi, P.T., Forde, S.E., Delph, L.F., and C.M. Lively. 2000. Processes structuring communities: evidence for trait-mediated indirect effects through induced polymorphisms. *OIKOS* **91**(2): 353-361.

Raimondi, P.T., Wilson, C.M., Ambrose, R.F., Engle, J.M., and T.E. Minchinton. 2002. Continued declines of black abalone along the coast of California: are mass mortalities related to El Nino events? *Mar Ecol-Prog Ser* **242**: 143-152.

*Reed, D.C., and R.J. Lewis. 1994. Effects of an oil and gas production effluent on the colonization potential of giant kelp (*Macrocystis pyrifera)* zoospores. *Marine Biology* **119**: 277-283.

*Reed, D.C., Lewis, R.J., and M. Anghera. 1994. Effects of an oil and gas production effluent on the colonization potential of giant kelp (*Macrocystis pyrifera)* zoospores. *Marine Biology* **120**: 26-31.

Reed, D.C., Raimondi, P.T., Carr, M.H., and L. Goldwasser. 2000. The role of dispersal and disturbance in determining spatial heterogeneity in sedentary organisms. *Ecology* **81** (7): 2011-2026.

Seeber, L. and C.C. Sorlien. 2000. Listric thrusts in the western Transverse Ranges, California. *Geological Society of America Bulletin.* **112** (7): 1067-1079.

Smith, E.R.A.N. 2002. Energy, the environment, and public opinion. Boulder, Colorado: Rowman and Littlefield.

Smith, E.R.A.N. and M. Marquez. 2000. The Other Side of the NIMBY Syndrome. *Society & Natural Resources* **13**: 273-80.

*Sorlien, C.C., Kamerling, M.J., and D. Mayerson. 1999. Block rotation and termination of the Hosgri strike-slip fault, California, from three-dimensional map restoration. *Geology* **27** (11): 1039-1042.

Stewart-Oaten, A. 2001a. Impact assessment. Encyclopedia of Environmetrics. (Wiley 2001).

Stewart-Oaten, A. 2001b. Pseudoreplication. Encyclopedia of Environmetrics. (Wiley 2001).

Stewart-Oaten, A. and J. R. Bence. 2001. Temporal and spatial variation in environmental impact assessment. *Ecological Monographs* **71**: 305-339.

Syms, C. and M. H. Carr. 2001. Marine protected areas: evaluating MPA effectiveness in an uncertain world. 30 pages. Available at Marinet: North American Commission for Environmental Cooperation site: http://www.orchestrabycrossdraw.com/30/Posting.cfm?2B07183C303E151A01097F505D546A

Wilson, J.A., C.W. Osenberg, C.M. St. Mary, C.A. Watson, and W.J. Lindberg. 2002. Artificial reefs, the attraction-production issue, and density-dependence in marine ornamental fishes. *Aquarium Sciences and Conservation* **3**: 95-105.

* Papers published before 2000 not included in previous annual reports

IN PRESS

Bram, J., H.M. Page and J. Dugan. Temporal and depth effects on the early development of fouling assemblages on an offshore oil platform (in preparation).

Flegal, A.R., Rivera-Duarte, I., and S. Sañudo-Wilhelmy. Silver contamination in aquatic environments. *Review in Environmental Chemistry and Toxicology* (in press).

Luengen, A.C., Friedman, C.S., Raimondi, P.T., and A.R. Flegal. Evaluation of immune responses as indicators of contamination in San Francisco Bay, CA; Development of a novel phagocytosis and phagocytic index method for mussels. Aquatic Toxicology. *Marine Environmental Research* (in press).

Muller, E.B. and R.M. Nisbet. Sublethal effects of toxicants: a dynamic energy budget modeling approach compared to experimental results (in preparation).

MMS REPORTS

Cherr, G.N. and F.J. Griffin. Effects of Biologically Degraded Oil on Marine Invertebrates and Vertebrate Embryos and Larvae. *MMS OCS Study* **2001-048**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number**:** 14-35-0001-30761. 14 pages.

Engle, J. Rocky Intertidal Resource Dynamics at Point Loma, San Diego County, California. *MMS OCS Study* **2001-016**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number: 14-35-0001-30758. 78 pages.

Flegal, A.R. Characterization and Fate of Produced Water in Shallow Water. *MMS OCS Study* **99-0020**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Numbers: 14-35-0001-30471 and 14-35-0001-30761. 58 pages.

Lick, W.J. Risk Analysis. *MMS OCS Study* **2003-015**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number**:** 14-35-0001-30471. 18 pages.

Lick, W.J. Resuspension, Flocculation, and Transport of Drilling Muds and Fine-grained Sediments. *MMS OCS Study* **2003-016**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number**:** 14-35-0001-30471. 146 pages.

McGinnis, M.V., Fernandez, L., and C. Pomeroy. The Politics, Economics, and Ecology of Decommissioning Offshore Oil and Gas Structures. *MMS OCS Study* **2001-006**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number: 14-35-0001-30761. 98 pages.

Murray, S.N., Ambrose, R.F., and M.N. Dethier. Methods for Performing Monitoring, Impact and Ecological Studies on Rocky Shores (Evaluating the Impact of Oil Spills on Southern California Rocky Intertidal Populations and Communities: Development of a Handbook). *MMS OCS Study* **2001-070**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number: 14-35-0001-30761. 210 pages.

Nisbet, R.M. and E.B. Muller. Sublethal Effects of Toxicants on Organisms: A Modeling Approach with Dynamic Energy Budgets. *MMS OCS Study* **2001-043**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number**:** 14-35-0001-30761 and 14-35-0001-30758. 164 pages.

Osenberg, C.W. and R.J. Schmitt. Ecological Responses to, and Recovery From, Produced Water Discharge: Application of a BACIPS Assessment Design (Compiles: Study I – Effects of Produced Water on Demographic Rates; Study II – Spatial Scale of Produced Water Impacts as Indicated by Plume Dynamics and Biological Field Assays; and Study III – Environmental Recovery Following Cessation of a Produced Water Discharge). *MMS OCS Study* **99-0061**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number: 14-35-0001-30761. 82 pages.

Osenberg, C.W. Long-term Monitoring of Biological Parameters at a Proposed Produced Water Discharge: Application of a BACIPS Assessment Design (Compiles: Study I – Ecological Effects of Chronic Exposure to Produced Water: A Field Test; and Study II – Environmental Effects of Produced Water: A BACIP Field Assessment). *MMS OCS Study* **99-0062**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Numbers: 14-35-0001-30471 and 14-35-0001-30761. 52 pages.

Reed, D.C., Ebeling, A.W. and M. Neushul. Potential biogenic habitat alteration by OCS Activities: Adverse effects to early life-stages of giant kelp from chronic disturbance. *MMS OCS Study* **2003-017**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number**:** 14-35-0001-30471. 38 pages.

Roe, C.A., Raimondi, P.T., and S.E. Forde. Variability in the accumulation and persistence of tar in four intertidal communities along the central and southern California coast. *MMS OCS Study* **2003-033**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number: 14-35-0001-30761. 44 pages.

Smith, Eric R.A.N. 2003. The Role of Knowledge in the Public's Trust in Science about Offshore Oil and Gas Development (Study – A Design for a Time Series Study of a NIMBY Response). *MMS OCS Study* **2002-0051**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number: 14-35-0001-30761. 69 pages.

Sorlien, C.C. and M.J. Kamerling. Structural Evolution of the Hosgri-Pirisima-Lompoc fault system, Santa Maria basin, California, from 3-D map restoration: Economic and earthquake hazard implications. *MMS OCS Study*. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number: 14-35-0001-3047.

Stewart-Oaten, Allan. Using Before-After-Control-Impact in Environmental Assessment: Purpose, Theoretical Basis, and Practical Problems (Compiles: Study Ia – Environmental Assessment: Statistical Description of Variable Effects on Fluctuating Populations; Study 1b – Continuation of Study 1a; and Study II – Adding Biology to BACI: Exploring the Use of Functional Groups, Trophic Relationships, and Multiple, Ecologically Similar Comparison Sites in Choosing Models and Estimating Effects Impacts Analysis). *MMS OCS Study* **2003-035.** Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Numbers: 14-35-0001-30471 & 14-35-0001-30761. 116 pages.

Woolley, J.T. and J.T. Lima. Mitigating the Impact of Offshore Oil Development. *MMS OCS Study* **2003-014**. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Numbers 14-35-0001-30471. 133 pages.

RESEARCH PRESENTATIONS

Bram, J., H.M. Page and J. Dugan. 2000. Early development of subtidal invertebrate assemblages on offshore oil platforms in the Santa Barbara Channel. Western Society of Naturalists, Monterey Bay, California, December 2000.

Bram, J., H.M. Page and J. Dugan. 2001. Early development of subtidal invertebrate assemblages on offshore oil platforms in the Santa Barbara Channel. Western Society of Naturalists, Ventura, California, November 2001.

Carr, M.H. and C. Syms. 2001. Building linkages for marine protected areas in North America II: A workshop of the North American Marine Protected Areas Network. NOAA Marine Protected Areas Science Institute, Monterey, California, May 2001.

*Carr, M.H., P. Raimondi, C. Syms. 1999. Effectiveness of Marine Reserve: Approaches to Evaluation and Need for Adaptive Management. Invited Symposium talk at the 80th Annual Meeting of the Western Society of Naturalists, Monterey, California, December, 1999.

Counterman, B., Hodges, S.A., Bush, D.S., and D.C. 2000. Investigation of chloroplast DNA variation in *surfgrass (Phyllospadix torreyi)*. 13th annual Toxics Substances Research and Teaching symposium, San Diego, California, April 2000.

Forde, S.E. 2000. Assessing the individual and population level effects of a disturbance using a dynamic state variable model. Ecological Society of America Meetings, Snowbird, UT.

*Lima, J. 1995. The life cycle of a land use planning agency in California: Santa Barbara County and offshore energy development. Southern Political Science Association Annual Meeting.

*Lima, J. 1996. The design of environmental impact mitigation measures. 73rd Annual Metting of the Alabama Academy of Science Meeting.

Osenberg, C.W. 2002. Marine protected areas: a critique of current assessment approaches. International Workshop: *Restoring and Sustaining Diversity of Tropical Pacific Coral Reef Fish*. Mo'orea, French Polynesia. April 2002 (invited).

Osenberg, C.W. and C.M. St. Mary. 2002. Marine reserves: a tentative and cautionary evaluation of a powerful tool. Annual meeting of the Florida Chapter of the American Fisheries Society. Brooksville, FL. February 2002 (invited).

Osenberg, C.W., St. Mary, C.M., and B. Bolker. 2002. Assessing the efficacy of ecosystem management and marine reserves: the need for new approaches. The Fourth Mote International Symposium in Fisheries Ecology: *Confronting Tradeoffs in the Ecosystem Approach to Fisheries Management*, Sarasota, Florida, November 2002.

*Osenberg, C.W., St. Mary, C.M., Wilson, J.A., and W.J. Lindberg. 1999. A quantitative framework to evaluate the attraction-production controversy, with application to marine ornamental fisheries. Seventh International Conference on Artificial Reefs and Related Aquatic Habitats. Sanremo, Italy, October 1999.

Roe, C.A and Raimondi, P.T. 2001. Variability in the accumulation and persistence of tar in four intertidal zones. Western Society of Naturalists Meetings, Ventura, CA.

Smith, Eric R. A. N. 2002. Recent Trends in Public Opinion toward Offshore Oil Development. Report to the Minerals Management Service, U.S. Department of the Interior, December, 2002.

*Wilson, J.A., C.W. Osenberg, C.M. St. Mary, C.A. Watson, and W.J. Lindberg. 1999. Artificial reefs, the attraction-production issue, and density-dependence in marine ornamental fishes. First International Conference on Marine Ornamentals. Kailua - Kona, Hawaii, November 1999.

Wilson, J.A., C.W. Osenberg, C.M. St. Mary, C.A. Watson, and W.J. Lindberg. 2000. Artificial reefs, the attraction-production issue, and density-dependence in coral reef fishes. Annual meeting of the American Society of Ichthyologists and Herpetologists, La Paz, Mexico, June 2000.

Wilson, J.A., C.W. Osenberg, C.M. St. Mary, C.A. Watson, and W.J. Lindberg. 2001. Artificial reefs, the attraction-production issue, and density-dependence in coral reef fishes. Larry McEdward Memorial Symposium. Gainsville, FL., December 2001. (invited).

* Research presentations given before 2000 not included in previous annual reports

PERSONNEL FUNDED

TRAINEES AND STAFF FUNDED BY THE SOUTHERN CALIFORNIA EDUCATIONAL INITIATIVE

1999-2000

Name	Status	Supervisor
Adams, Chris	Undergraduate	Hodges
Aherne, Darren	Undergraduate	Page/Dugan
Altstatt, Jessica	Laboratory Technician	Engle
Anghera, Michele	Post Graduate	Reed
Anghera, Michelle	Graduate	Ambrose
Aumack, Craig	Undergraduate	Page/Dugan
Bills, Jena	Undergraduate	Page/Dugan
Bonesh, James	Graduate	Osenberg
Bram, Jason	Graduate	Page/Dugan
Clark, Scott	Undergraduate	Page/Dugan
Countermain, Brian	Undergraduate	Bush/Hodges
Dugan, Dan	Graduate	Page/Dugan
Faist, Chris	Undergraduate	Page/Dugan
Farrar, David	Laboratory Technician	Engle
Forde, Samantha	Graduate	Raimondi
Golden, Bill	Lab Assistant	Page/Dugan
Hamdoun, Amro	Graduate	Cherr
Henry, Michael	Undergraduate	Page/Dugan
Hibbard-Robbins, Thea	Post Graduate	Griffin
Hitz, Sam	Undergraduate	McGinnis/Fernandez
Holley, Wendy	Administrative Assistant	Williamson
Hubbard, David	Staff Research Associate	Engle
Knope, Matt	Lab Assistant	Page/Dugan
Lee, Steven	Staff Research Associate	Ambrose
Machula, Jana	Post Graduate	Griffin
Mardian, Brent	Undergraduate	Page/Dugan
Martin, Daniel L.	Staff Research Associate	Engle
Milne, Nicole	Undergraduate	Page/Dugan
Minchinton, Todd	Post Graduate	Raimondi
Miyagishima, Juliet	Undergraduate	Smith
Navarro, Carla	Undergraduate	Page/Dugan
Pinckard, Deanna	Undergraduate	Page/Dugan
Redlin, Jenny	Undergraduate	Page/Dugan
Reese, Doug	Research Assistant	McGinnis/Fernarndez
Roe, Christy	Laboratory Technician	Raimondi
Scott, Matt	Undergraduate	Page/Dugan
Snyder, Mark	Asst. Research Biochemist	Cherr
Taylor, Cynthia	Laboratory Technician	Engle
Vines, Carol	Graduate/Post Doctoral	Cherr
Watson, Jordan	Undergraduate	Page/Dugan
Williamson, Bonnie	Program Manager	Schmitt
Wilson, Jacqueline	Graduate	Osenberg
Wilson, Melissa	Staff Research Associate	Raimondi
Wolcott, Bryce	Undergraduate	Page/Dugan

2000-2001

Name	Status	Supervisior
Adams, Chris	Undergraduate	Hodges
Anghera, Michele	Post Graduate	Reed
Bram, Jason	Graduate	Page/Dugan
Conway-Cranos, Tish	Laboratory Technician	Raimondi
Countermain, Brian	Undergraduate	Bush/Hodges
Forde, Samantha	Graduate	Raimondi
Kendall, Alison	Laboratory Technician	Raimondi
Kusic, Kristen	Laboratory Technician	Raimondi
Lee, Steven	Staff Research Associate	Ambrose
Livingston, Haven	Laboratory Technician	Raimondi
Minchinton, Todd	Post Graduate	Raimondi
Moran, Sharese	Undergraduate	Carr
Roe, Christy	Laboratory Technician	Raimondi
Royer, Chantell	Undergraduate	Carr
Shinen, Jenna	Undergraduate	Carr
Stier, Jeannie	Undergraduate	Carr
Hansen, Dan	Graduate	Carr
Williams, Meagan	Laboratory Technician	Raimondi
Williamson, Bonnie	Program Manager	Schmitt
Wilson, Jacqueline	Graduate	Osenberg
Wilson, Melissa	Staff Research Associate	Raimondi
Vonesh, James	Graduate	Osenberg

2001-2002

Name	Status	Supervisior
Adams, Chris	Undergraduate	Hodges
Anghera, Michele	Post Graduate	Reed
Bram, Jason	Graduate	Page/Dugan
Conway-Cranos, Tish	Laboratory Technician	Raimondi
Countermain, Brian	Undergraduate	Bush/Hodges
Forde, Samantha	Graduate	Raimondi
Kendall, Alison	Laboratory Technician	Raimondi
Kusic, Kristen	Laboratory Technician	Raimondi
Lee, Steven	Staff Research Associate	Ambrose
Mardian, Brent	Laboratory Technician	Page/Dugan
Moran, Sharese	Undergraduate	Carr
Roe, Christy	Laboratory Technician	Raimondi
Royer, Chantell	Undergraduate	Carr
Shinen, Jenna	Undergraduate	Carr
Williams, Meagan	Laboratory Technician	Raimondi
Williamson, Bonnie	Program Manager	Schmitt
Wilson, Melissa	Staff Research Associate	Raimondi

2002-2003

Name	Status	Supervisior
Bram, Jason	Graduate	Page/Dugan
Roe, Christy	Laboratory Technician	Raimondi
Wilson, Melissa	Staff Research Associate	Raimondi
Willis, Alan	Laboratory Technician	Page/Dugan

CURRICULUM VITAE

Richard Ambrose 81
Douglas Bush 83
Mark H. Carr 85
Gary N. Cherr 87
Jenifer Dugan 89
Linda Fernandez 91
Fred J. Griffin 92
Richard M. Higashi 94
Scott Hodges 96
Sally H. Holbrook 98
Michael V. McGinnis 100
Craig W. Osenberg 102
H. Mark Page 104
Carolyn Pomeroy 105
Peter T. Raimondi 107
Daniel C. Reed 109
Russell J. Schmitt 111
Eric R.A.N. Smith 113

RICHARD AMBROSE

Environmental Science and Engineering Program
Department of Environmental Health Sciences
University of California
Los Angeles, CA

Projects: *Evaluating the Impact of Oil Spills on Southern California Rocky Intertidal Populations and Communities: Development of a Handbook*
Inventory of Rocky Intertidal Resources in Southern Santa Barbara, Ventura and Los Angeles Counties

Education:

B.S.	University of California, Irvine	1975
Ph.D.	University of California, Los Angeles	1982

Positions:

1992-present	Associate Professor, Environmental Science and Engineering Program, Department of Environmental Health Sciences, University of California, Los Angeles
1991-present	Associate Research Biologist, Marine Science Institute, University of California, Santa Barbara
1985-1991	Assistant Research Biologist, Marine Science Institute, University of California, Santa Barbara
1983-1984	Postdoctoral Fellow, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C., Canada
1982	Visiting Lecturer, Department of Biology, University of California, Los Angeles
1976-1981	Teaching Assistant, Department of Biology, University of California, Los Angeles

Major Research Interests:

- Restoration ecology, especially for coastal marine and estuarine environments
- Development and scientific evaluation of mitigation techniques
- Long-term ecological monitoring
- Development of habitat valuation techniques
- Ecology of artificial and natural reefs
- Ecology of Coastal wetlands and estuaries
- Marine ecology
- Interface between environmental biology and resource management policy

Selected Publications:

Page, H. M., Schroeter, S., Reed, D. C., Ambrose, R. F., Callaway, J., and J. Dixon. Variation in the distribution and abundance of salt marsh vegetation associated with elevation and height of tidal inundation. *Bulletin of the Southern California Academy of Sciences* (in press).

Vance, R.R., R.F. Ambrose, S.S. Anderson, S. MacNeil, T. McPherson, I. Beers and T.W. Keeney. Effects of sewage sludge on the growth of potted salt marsh plants exposed to natural tidal inundation. *Restoration Ecology* (in press)

Shuman, C. S. and R. F. Ambrose. A comparison of remote sensing and ground-based methods for monitoring wetland restoration success. *Restoration Ecology* (in press).

Stein, E.D. and R. F. Ambrose. Cumulative impacts of Section 404 Clean Water Act permitting on the riparian habitat of the Santa Margarita, CA watershed. *Wetlands* (in press)

Forrester, G. E., Fredericks, B. I., Gerdeman, D., Evans, B., Steele, M. A., Zayed, K., Schweitzer, L. E., Suffet, I. H., Vance, R. R., and R. F. Ambrose. 2003. Correspondence between field-measured growth rates of fish from several California estuaries and the inferred toxicity of multiple sediment contaminants. *Marine Environmental Research* **56**: 423-442.

Moeller, A., MacNeil, S. D., Ambrose, R. F., and S. S. Que Hee. 2003. Elements in fish of Malibu Creek and Malibu Lagoon nearLos Angeles, California. *Marine Pollution Bulletin* **46**: 424-429.

Raimondi PT, Wilson CM, Ambrose RF, Engle JM, Minchinton TE. 2002. Continued declines of black abalone along the coast of California: are mass mortalities related to El Nino events? Mar Ecol-Prog Ser 242: 143-152.

Sudol, M.F. and R.F. Ambrose. 2002. The US Clean Water Act and habitat replacement: Evaluation of mitigation sites in Orange County, California. *Environmental Management* **30**: 727-734.

Boyer, K.E., P. Fong, R.R. Vance and R.F. Ambrose. 2001. *Salicornia virginica* in a Southern California salt marsh: seasonal patterns and a nutrient enrichment experiment. *Wetlands* **21** (3): 315-326.

Cohen, T., S.S. Que Hee and R.F. Ambrose. 2001. Comparison of trace metal concentrations in fish and invertebrates in three Southern California wetlands. *Marine Pollution Bulletin* **42**: 224-232.

Downs TJ, Ambrose RF. 2001. Syntropic ecotoxicology: A heuristic model for understanding the vulnerability of ecological systems to stress. *Ecosyst Health* **7**(4): 266-283.

Moeller, A, Ambrose, RF, Hee, SSQ. 2001. A comparison of techniques for preparing fish fillet for ICP-AES multi-elemental analysis and the microwave digestion of whole fish. *Food Addit Contam* **18** (1): 19-29.

Stein, E.D. and R.F. Ambrose. 2001. Landscape-scale analysis and management of cumulative impacts to riparian ecosystems: past, present and future. *Journal of American Water Resources Association* **37**(6): 1597-1614.

Ambrose, R.F. 2000. Wetland mitigation in the United States: Assessing the success of mitigation policies. *Wetlands* (Australia) **19**: 1-27.

Ambrose, R.F. and D.J Meffert. 1999. Fish-assemblage dynamics in Malibu Lagoon, a small, hydrologically altered estuary in southern California. *Wetlands* **19**: 327-340.

Lafferty, K., C. Swift and R.F. Ambrose. 1999. Extirpation and recovery of local populations of the endangered tidewater goby, *Eucyclogobius newberryi*. *Conservation Biology* **13**: 1447-1453.

Stein, E.D. and R. F. Ambrose. 1998. A rapid impact assessment method for use in a regulatory context. *Wetlands* **18**: 379-392.

Ambrose, R.F. 1997. Ecological value in restored coastal ecosystems. Pp. 67-86 in: *Saving the Seas: Values, Scientists, and International Governance,* L.A. Brooks and S.D. VanDeveer, eds. Maryland Sea Grant College, College Park, MD.

Dunaway, M.E., R.F. Ambrose, J. Campbell, J.M. Engle, M. Hill, Z. Hymanson, and D. Richards. 1997. Establishing a Southern California rocky intertidal monitoring network. Pp. 1278-1294. in: *California and the World Ocean '97,* O.T. Magoon, H. Converse, B. Baird, and M. Miller-Henson, eds. American Society of Civil Engineers, Reston, Virginia.

Engle, J.M., R.F. Ambrose, and P.T. Raimondi. 1997. Synopsis of the Interagency Rocky Intertidal Monitory Network Workshop. Final Report, OCS Study MMS 97-0012. U.S. Minerals Management Service, Pacific OCS Region. 18p.

Palmer, M.A., N.L. Poff, and R.F. Ambrose. 1997. Ecological theory and community restoration ecology. *Restoration Ecology* **5:** 291-300.

DOUGLAS BUSH
Marine Science Institute
University of California
Santa Barbara, CA

Project: *Application of Genetic Techniques for use in Restoration of Surfgrass (Phyllospadix torreyi)*

Education:

B.A.	Botany, University of Hawaii	1974
M.S.	Plant Physiology, UC Berkeley	1979
Ph.D.	Plant Physiology, UC Berkeley	1983
Postdoctoral	Botany, UC Berkeley	1984 – 1989

Positions:

1998-Present	Associate Research Biologist, Marine Science Institute, UC Santa Barbara
1998-Present	Adjunct Associate Professor, Dept. Ecology, Evolution, & Marine Biology, UC Santa Barbara
1990-1997	Assistant/Associate Professor, Rutgers University, Dept. of Biological Sciences
1989-1990	Assistant Research Botanist, UC Berkeley, Dept. of Botany
1984-1989	Postdoctoral Associate, UC Berkeley, Dept. of Botany
1979-1983	Research Associate, UC Berkeley, Dept. of Plant and Soil Biology
1977-1979	Statistician, UC Berkeley, Dept. of Plant and Soil Biology

Research Interest:

Genetics of natural plant populations, Evolutionary Genetics, Plant cell biology, cell calcium and transduction of hormonal signals. Membrane transport events induced by plant growth regulators. Programmed cell death.

Awards:

Henry Rutgers Fellow, 1990
EMBO Workshop Fellowship, Patch Clamp Techniques, Göttingen, West Germany, 1987
Presidents Fellowship, University of California, Berkeley, 1980-1981

Selected Publications:

Rodriguez, M.T. and D.S. Bush. 1999. Gibberellin-induced cell death in the wheat aleurone. *Plant Physiology* (submitted).

Silverman, P., Assiahmah, A., and D.S. Bush. 1998. Cytokinin action in root hairs of *Medicago sativa*. *Planta* **205**: 25-31.

Subbaiah, C., Bush, D.S., and M. Sachs. 1998. Mitochondria contribution to the anoxic Ca^{2+} signal in maize suspension-cultured sells. *Plant Physiology* **118**: 759-771.

Thompson, M.D., Bush, D.S., and L.E. Bello. 1997. Possible Wilson's disease: A case presentation. *Arch Clin Neuropsych* **12**(4): 416-416.

Bush, D.S. 1996. Effects of gibberellic acid and environmental factors on cytosolic calcium in wheat aleurone cells. *Planta*. **199**: 89-99.

Kuo, A., Cappellutti, S., Cervantes-Cervantes, M., Rodriquez, M., and D.S. Bush. 1996. Okadaic acid, a protein phosphatase inhibitor, blocks calcium changes, gene expression and cell death induced by gibberellin in wheat aleurone. *The Plant Cell* **8**: 259-269.

Rodriguez, M.T. and D.S. Bush. 1996. Programmed cell death and hormonal responses in wheat aleurone cells. *Mol Biol Cell* **7**: 2015-2015 Suppl. S.

Silverman, F.P. and D.S. Bush. 1996. Membrane transport and cytokinin action in alfalfa root hairs. *Mol Biol Cell* **7**: 1761-1761 Suppl. S.

Bush, D.S. 1995. Calcium regulation in plant cells and its role in signaling. *Annu. Rev. Plant Physiology. Plant Molecular Biology* **46**: 95-122.

Bush, D.S. and T. Wang. 1995. Diversity of calcium efflux transporters in wheat aleurone cells. *Planta*. **197**:19-30.

Cervantes-Cervantes, M., Cappelluti, S.J., and D.S. Bush. 1995. Identification of Plant Ca^{2+} Transport Proteins by Complementation in Yeast. *Plant Physiol* **108**(2): 37-37 Suppl. S.

Silverman, P., Assiamah, A.A., and D.S. Bush. 1995. Cytokinin Action in Medicago-Sativa Root Hairs. *Plant Physiol* **108**(2): 46-46 Suppl. S.

Subbaiah, C., Bush, D.S., and M. Sachs. 1994. Elevation of cytosolic calcium precedes anoxic gene expression in maize suspension-cultured cells. *The Plant Cell* **6**:1747-1762.

Bush, D.S. 1993. Regulation of cytosolic calcium in plants. *Plant Physiology* **103**: 7-13.

Bush, D.S., Biswas, A.K., and R.L. Jones. 1993. Hormonal regulation of Ca^{2+}-transport in the endomembrane system of the barley aleurone. *Planta* **189**: 507-515.

Bush, D.S. 1992. The role of Ca^{2+} in the action of GA in the barley aleurone. In: CM Karssen, LC Van Loon, and D Vreugdenhil, eds. "Progress in plant growth regulation: Proceedings of the 14th International conference on plant growth substances, Amsterdam, 21-26 July, 1991." pp. 96-104. Kluwer Academic Pub., Dordrecht, The Netherlands.

Drøbak, B.K., Bush, D.S., Jones, R.L., Dawson, A.P., and I.B. Ferguson. 1992. Analysis of calcium involvement in host-pathogen interactions. In: Gurr, S.J., M.J. McPherson, and D.J. Bowles eds. "Molecular Plant Pathology: A Practical Approach". Vol. II, pp. 159-194. IRL Press at Oxford University Press, Cambridge.

Arnalte, M.E., Cornejo, M.J., Bush, D.S., and R.L. Jones. 1991. The effect of gibberellic acid on the lipid composition of barley aleurone protoplasts. *Plant Science* **77**: 223-232.

Bush, D.S., Sticher, L., and R.L. Jones. 1991. Gibberellic acid-regulated α-amylase synthesis and calcium transport in the endoplasmic reticulum of barley aleurone cells. In: "Gibberellins: Tokyo 1989". pp. 106-113.

Jones, R.L. and D.S. Bush. 1991. Gibberellic acid and abscisic acid regulate the level of a BiP cognate in the endoplasmic reticulum of barely aleurone cells. *Plant Physiology* **97**: 456-459.

Jones, R.L., Sticher, L., and D.S. Bush. 1991. Secretion of hydrolases from cereal aleurone cells. In: Hawes, C., J. Coleman and D. Evans, eds. "Endocytosis, Exocytosis and Vesicle Traffic in Plants", Cambridge University Press, Cambridge.

Bush, D.S. and R.L. Jones. 1990. Hormonal Regulation of Ca^{2+} transport in microsomal vesicles isolated from barley aleurone layers. Calcium in plant growth and development. Leonard and Hepler eds. *American Society of Plant Physiologists* **4**: 60-65.

Bush, D.S. and R.L. Jones. 1990. Measuring intracellular Ca^{2+} levels in plant cells using the fluorescent probes, indo-1 and fura-2: progress and prospects. *Plant Physiology* **93**: 841-845.

DuPont, F.M., Bush, D.S., Windle, J.J., and R.L. Jones. 1990. Calcium and proton transport in membrane vesicles from barley roots. *Plant Physiol.* **94**: 179-188.

Hillmer, S., Bush, D.S., Robinson, D.G., Zingen-Sell, I., and R.L. Jones. 1990. Endomembrane structure and function in barley aleurone protoplasts. *Eur. J. Cell Biol.* **52**: 169-173.

MARK H. CARR
Department of Biology
University of California
Santa Cruz, CA

Projects: *Detecting Ecological Impacts: Effects of Taxonomic Aggregation in the Before-After/Control-Impact Paired Series Design*

Education	B.A.	Biology, University of California, Santa Cruz	1976
	M.S.	San Francisco State University	1983
	Ph.D.	University of California, Santa Barbara	1991

Positions:	1997-present	Assistant Professor III, Department of Biology, University of California, Santa Cruz, CA.
	1994-1997	Assistant Research Biologist IV, Deputy Director, SCEI and CMI, Marine Science Institute, University of California, Santa Barbara, CA.
	1993-94	Lecturer, Department of Zoology, Oregon State University
	1992-94	Post-doctoral Research Associate, Department of Zoology, Oregon State University
	1984-1991	Graduate Research Assistant, Department of Biological Sciences, University of California, Santa Barbara
	1981-1983	Research Technician, California Institute of Technology

Distinctions:	1989	Outstanding Student Paper Award, Western Society of Naturalists
	1988	EPRI Fellowship, Sport Fishing Institute
	1987	Joseph Drown Fellowship, University of Southern California, Oceanographic Associates

Research Interests: Population and community ecology of marine reef fishes. Application of behavioral and ecological research to marine fisheries and conservation problems.

Selected Publications:

Carr, M.H. and C. Syms. "Recruitment: the replenishment of demersal fish populations" chapter *In:* Allen, L. (ed.) *The Ecology of California Marine Fishes*. U.C. Press. (in press)

Carr, M.H., Neigel, J.E., Estes, J.A., Andelman, S.J., Warner, R.R., and J.L. Largier. Comparing marine and terrestrial ecosystems: implications for principles of reserve design in coastal marine ecosystems. *Ecological Applications* (in press)

Shanks, A.L., Grantham, B., and M.H. Carr. Propagule dispersal distance and the size and spacing of marine reserves. *Ecological Applications* (in press)

Anderson, T.W., Bartels, C.T., Hixon, M.A., Bartels, E., Carr, M.H., and J.M. Shenker. 2002. Current flow and catch efficiency in sampling settlement-stage larvae of coral-reef fishes. *Fishery Bulletin* **100**: 404-413.

Carr, M.H. and C. Syms. 2002. Marine reserves in the Monterey Bay National Marine Sanctuary: what we do and don't know. Pp. 51-72 *In*: Starr, R.M., M.H. Carr, J. Caselle, J.A. Estes, C. Pomeroy, C. Syms, D, VenTresca, and M.M. Yoklavich. A review of the ecological effectiveness of subtidal marine reserves in Central California. Part I: Synopsis of scientific investigations. A Report to the Monterey Bay National Marine Sanctuary.

Carr, M.H., Anderson, T.W., and M.A. Hixon. 2002. Biodiversity, population regulation, and the stability of coral-reef fish communities. *Proceedings of the National Academy of Sciences* **99**: 11241-11245.

Starr, R.M., Carr, M.H., Caselle, J., Estes, J.A., Pomeroy, C., Syms, C., VenTresca, D., and M.M. Yoklavich. 2002. A review of the ecological effectiveness of subtidal marine reserves in Central California. Part II: Summary of existing marine reserves in Central California and their potential benefits. A Report to the Monterey Bay National Marine Sanctuary.12 pp.

Steele, M.A., Malone, J.C., Findlay, A.M., Carr, M.H., and G.E. Forrester. 2002. A simple method for estimating larval supply in reef fishes and a preliminary test of population limitation by larval delivery in the kelp bass, *Paralabrax clathratus*. *Marine Ecology Progress Series* **235**: 195-203.

Syms, C. and M.H. Carr. 2002. International Clearinghouse for MPA Effectiveness Measures: a Conceptual Design. Report prepared for the North American Commission for Environmental Cooperation.

Carr, M.H. 2000. Marine protected areas: challenges and opportunities for understanding and conserving coastal marine ecosystems. *Environmental Conservation* **27**: 106-109.

Carr, M.H. and A.A. Ammann. 2000. Contrasting effects of La Nina and El Nino on recruitment of juvenile rockfishes. Ecosystem Observations, Monterey Bay National Marine Sanctuary: 11-12.

Holbrook, S.J., Ambrose, R.F., Botsford, L., Carr, M.H., Raimondi, P.T., and M.J. Tegner. 2000. Ecological Issues Related to Decommissioning of California's Offshore Production Platforms. A Report to the University of California Marine Council by The Select Scientific Advisory Committee on Decommissioning, University of California.

Reed, D.C., Raimondi, P.T., Carr, M.H., and L. Goldwasser. 2000. The role of dispersal and disturbance in determining spatial heterogeneity in sedentary kelp-forest organisms. *Ecology* **81**: 2011-2026.

Carr, M.H. and P.T. Raimondi. 1999. Marine protected areas as a precautionary approach to management. *California Cooperative Oceanic Fisheries Investigations Reports* **40**: 71-76.

Murray, S.N., Ambrose, R.F., Bohnsack, J.A., Botsford, L.W., and M.H. Carr. 1999. No-take reserve networks: sustaining fishery populations and marine ecosystems. *Fisheries* **24**: 11-25

Allison, G., Lubchenco, J., and M.H. Carr. 1998. Marine reserves are necessary but not sufficient for marine conservation. *Ecological Applications* **8**: S79-S92.

Anderson, T.W. and M.H. Carr. 1998. BINCKE: A highly efficient net for collecting reef-associated fishes. *Environmental Biology of Fishes* **51**: 111-115.

Carr, M.H. 1998. Effects of spatial structure on the relationship between larval supply, habitat availability and recruitment of reef fishes. pp. 215-218 *In:* Jones, G.P., Doherty, P.J., Mapstone, B.D., and Howlett, L. (eds.) *ReeFish '95: Recruitment and Population Dynamics of Coral Reef Fishes*. CRC Reef Research Centre, Townsville, Australia, 297 pp.

Carr, M.H. and P.T. Raimondi. 1998. Concepts relevant to the design and evaluation of harvest reserves. *In*: Proceedings of the Marine Harvest Refugia for West Coast Rockfish: A Workshop. M. Yoklavich, ed. *NOAA-NMFS Technical Memo* SWFC-255, pp. 27-31.

Carr, M.H., Hourigan, T., Ito, D., McArdle, D., Morgan, L., Palsson, W., Parrish, R., Ralston, S., Reilly, P., Sladek, J., and R. Starr. 1998. "Working group on design considerations" pp. 143-148 *In:* M.M. Yoklavich (ed.) Marine Harvest Refugia for West Coast Rockfish: A Workshop. *NOAA/NMFS Technical Memo* SWFC-255.

Caley, M.J., Carr, M.H., Hixon, M.A., Hughes, T.P., Jones, G.P., and B.A. Menge. 1997. Recruitment and the population dynamics of open marine populations. *Annual Review of Ecology and Systematics* **27**: 477-500.

Carr, M.H. and M.A. Hixon. 1997. Artificial reefs: the importance of comparisons with natural reefs. *Fisheries* **22**: 28-33.

GARY N. CHERR
University of California, Davis
Bodega Marine Laboratory
Bodega Bay, CA

Project: *Effects of Biologically Degraded Oil on Marine Invertebrate and Vertebrate Embryos and Larvae*

Education:	B.A.	Biology, Sonoma State University	1979
	Ph.D.	Zoology, University of California, Davis	1984

Positions:	1995-present	Lecturer, Division of Biological Sciences, University of California, Davis
	1995-present	Adjunct Associate Professor, Sonoma State University
	1994-present	Associate Research Biologist III, Bodega Marine Laboratory, University of California, Davis
	1990-1994	Assistant Research Biologist IV, Bodega Marine Laboratory, University of California, Davis
	1988-90	Assistant Research Biologist III, Bodega Marine Laboratory, University of California, Davis
	1986-88	Assistant Research Biologist II, Bodega Marine Laboratory, University of California, Davis
	1984-86	Postdoctoral Fellow, National Institute of Health, Department of Obstetrics & Gynecology, School of Medicine, University of California, Davis

Distinctions:	1984	National Institute of Health Postdoctoral Fellowship, Reproductive Training Grant
	1983	Best Student Paper Award, Annual American Fisheries Society Meeting

Research Interests: Dr. Cherr's laboratory investigates cell functioning during fertilization and early development in marine and estuarine organisms, and the effects of pollutants and environmental stressors. The systems utilized in the laboratory include gametes and embryos from algae, molluscs, echinoderms, and fishes. Since these systems exhibit temporally and mechanistically distinct cellular events during development, they can be used to discern the mode of action of pollutants at the subcellular levels. A major emphasis is placed on the effects of pollutants on cytoskeletal dynamics, intracellular ion activities, and cell-extracellular matrix interactions during fertilization and development. The laboratory is also involved in isolation and identification of pollutants in complex mixtures and investigates structure/function relationships of the pollutants using the above biological systems. Dr. Cherr is Chair of the State of Washington Biomonitoring Science Advisory Board, and is on the State of California's Marine Bioassay Protocol Review Committee.

Selected Publications:

Yudin, A.I., G.N. Cherr, C.A. VandeVoort, and J.W. Overstreet. 1998. Rearrangement of the PH-20 protein on the surface of macaque spermatozoa following exposure to anti-PH-20 antibodies or binding to zona. *Molecular Reproduction and Development* **50:**207-220.

Clegg, J.S., K.R. Uhlinger, S.A. Jackson, G.N. Cherr, E. Rifkin, and C.S. Friedman. 1998. Induced thermotolerance and the heat shock protein-70 family in the Pacific oyster, *Crassostrea gigas. Molecular Marine Biology and Biotechnology* **7:**21-30.

Griffin F.J., M.C. Pillai, C.A. Vines, R. Yanagimachi, and G.N. Cherr. 1998. Effects of salinity on sperm motility, fertilization, and development in the Pacific herring, *Clupea pallasi. Biological Bulletin* **194:**25-35.

Middaugh, D.P., M.W. Shelton, C.L. McKenney Jr., G.N. Cherr, P.J. Chapman, and L.A. Courtney. 1998. Preliminary observations on responses of embryonic and larval Pacific herring, *Clupea pallasi,* to neutral fraction biodegradation products of weathered Alaska North Slope Oil. *Archives Environmental Contamination and Toxicology* **34:**188-196.

Cherr, G.N. 1998. The use of developing organisms for assessing contamination in the marine environment. In: *Effects of Multiple Impacts on Ecosystems*, J.J. Cech, B.W. Wilson and D.C. Crosby, eds. Lewis Publishers, Chelsea, MI.

Shamseldin, A.A., J.S. Clegg, C.S. Friedman, G.N. Cherr, and M.C. Pillai. 1997. Induced thermotolerance in the Pacific oyster, *Crassostrea gigas. Journal of Shellfish Research,* **16:**487-491.

Garman, G.D., G.N. Cherr, and S.L. Anderson. 1997. Developmental abnormalities and DNA-protein crosslink induction in sea urchin embryos exposed to metals. *Aquatic Toxicology* **39**:247-265.

Meyers, A.S., A.I. Yudin, G.N Cherr, C.A. Vandevoort, D.G. Myles, P. Primakoff, and J.W. Overstreet. 1997. Hyaluronidase activity of macaque sperm assessed by an *in vitro* cumulus penetration assay. *Molecular Reproduction and Development* **46**:392-400.

Pillai, M.C., H. Blethrow, R.M. Higashi, C.A. Vines, and G.N. Cherr. 1997. Inhibition of the sea urchin sperm acrosome reaction by a lignin-derived macromolecule. *Aquatic Toxicology* **37**:139-156.

Cherr, G.N., S.A. Meyers, A.I. Yudin, C.A. VandeVoort, D.G. Myles, P. Primakoff, and J.W. Overstreet. 1996. The PH-20 protein in cynomolgus macaque spermatozoa: Identification of two different forms exhibiting hyaluronidase activity. *Developmental Biology* **175**:142-153.

Griffin, F.J., C. Vines, M.C. Pillai, R. Yanagimachi, and G.N. Cherr. 1996. Sperm Motility Initiation Factor (SMIF) is a minor component of the Pacific herring egg chorion. *Development, Growth*, *and Differentiation* **38**:193-202.

Olin, K.A., G.N. Cherr, E. Rifkin, and C.L. Keen. 1996. The effects of some redox-active and reactive aldehydes on DNA-protein cross-links *in vitro. Toxicology* **110**:1-8.

Spagenberg, J.M. and G.N. Cherr. 1996. Developmental effects of barium in a marine bivalve (*Mytilus californianus*). *Environmental Toxicology and Chemistry* **15**:1769-1774.

Garman, G.D., M.C. Pillai, L.J. Goff, and G.N. Cherr. 1995. Nuclear events during early development in *Macrocystis pyrifera* gametophytes and the temporal effects of a marine contaminant. *Marine Biology* **121**:355-362.

Garman, G.D., M.C. Pillai, and G.N. Cherr. 1994. Inhibition of cellular events during algal gametophyte development: Effects of select metals and an aqueous petroleum waste. *Aquatic Toxicology* **28**:127-144.

Pillai, M.C., R. Yanagimachi, and G.N. Cherr. 1994. *In vivo* and *in vitro* initiation of sperm motility using fresh and cryopreserved gametes from Pacific herring, *Clupea pallasi*. *Journal of Experimental Zoology* **269**:62-68.

Cherr, G.N., T.W-M. Fan, M.C. Pillai, T. Shields, and R.M. Higashi. 1993. Electrophoretic separation, characterization, and quantification of biologically active lignin derived macromolecules. *Analytical Biochemistry* **214**:521-527.

Fan, T.W-M., R.M. Higashi, G.N. Cherr, and M.C. Pillai. 1992. Use of noninvasive NMR spectroscopy and imaging for assessing produced water effects on mussel reproduction. Pp. 403-414 in: *Produced Water: Technological / Environmental Issues and Solutions*, J.P. Ray and F.R. Englehardt, eds. Plenum Press, New York.

JENIFER E. DUGAN
Marine Science Institute
University of California
Santa Barbara, CA

Project: *Early Development of Fouling Communities on Offshore Oil Platforms*

Education:

A.A.	Liberal Arts, De Anza Junior College, Cupertino, CA	1977
B.A.	Aquatic Biology, University of California, Santa Barbara	1980
Ph.D.	Biology, University of California, Santa Barbara	1990

Positions:

1995-present	Assistant Research Biologist, Marine Science Institute, University of California, Santa Barbara
1990-95	Postdoctoral Researcher, Marine Science Institute, University of California, Santa Barbara
1994	Postdoctoral Fellow, Department of Marine Science, University of Otago, New Zealand
1993	Postdoctoral Fellow, Department of Zoology, University of Port Elizabeth, Republic of South Africa
1988-93	Marine Biologist, Cooperative Park Science Unit, University of California, Davis, Channel Islands National Park, Ventura, CA

Selected Publications:

Dugan, J.E. and D. Hubbard. Southern New Zealand Beaches. In: Natural History of Southern New Zealand. Darby, J. and W. Harrex (eds.) University of Otago Press and the Otago Museum, Dunedin, New Zealand. (in press)

Dugan, J.E., Hubbard, D.M., McCrary, M., and M. Pierson. 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. *Estuar. Coastl. Shelf Sci*. **56** (in press)

Hubbard, D.M., and J.E. Dugan. 2003. Shorebird use of an exposed sandy beach in southern California. *Estuar. Coastl. Shelf Sci*. **56** (in press)

Lastra, M., Dugan, J.E., and D.M. Hubbard. 2002. Burrowing and swash behavior of the Pacific mole crab, *Hippa pacifica* (Anomura, Hippidae) on tropical sandy beaches. *J. Crust. Biol*. **22**: 53-58.

Dugan, J.E., Hubbard, D.M., and M. Lastra. 2000. Burrowing abilities and swash behavior of three crabs, *Emerita analoga* Stimpson, *Blepharipoda occidentalis* Randall and *Lepidopa californica* Efford (Anomura, Hippoidea), of exposed sandy beaches. *J. Exp. Mar. Biol. Ecol*. **255**(2): 229-245.

Dugan, J.E., Hubbard, D.M., Engle, J.M., Martin, D.L., Richards, D.M., Davis, G.E., Lafferty, K.D., and R.F. Ambrose. 2000. Macrofauna communities of exposed sandy beaches on the Southern California mainland and Channel Islands. Fifth California Islands Symposium, OCS Study, MMS 99-0038: 339-346.

Jaramillo, E., Dugan, J., and H. Contreras. 2000. Abundance, tidal movement, population structure and burrowing rate of Emerita analoga (Anomura, Hippidae) at a dissipative and a reflective sandy beach in south central Chile. *Mar Ecol-P S Z N I* **21**(2): 113-127 AUG 2000

Barron, M.G., Podrabsky, T., Ogle, R.S., Dugan, J.E., *et al*. 1999. Sensitivity of the sand crab *Emerita analoga* to a weathered oil. *Bull. Environmental Contamination & Toxicology* **62**: 469-475.

Dugan, J.E. and A. McLachlan. 1999. An assessment of longshore movement in *Donax serra*: Röding (Bivalvia: Donacidae) on an exposed sandy beach. *J. Exp. Mar. Bio. Ecol.* **234**: 111-124.

Page, H.M., Dugan, J.E., Dugan, D.S., and J. Richards. 1999. Effects of an offshore oil platform on the distribution and abundance of commercially important crab species. *Mar. Ecol. Prog. Ser.* **185**: 47-57.

Dugan, J.E., Hubbard, D.M., and A.M. Wenner. 1998. A catalog of the sandy beaches of San Luis Obispo and Santa Barbara Counties. Report prepared for Minerals Management Service, Camarillo, CA.

Dugan, J.E., Hubbard, D.M., and A.M. Wenner. 1998. A physical characterization of the sandy beaches of San Luis Obispo and Santa Barbara Counties. Prepared for Minerals Management Service, Camarillo, CA.

McLachlan, A., Dugan, J., Defeo, O., Ansell, A., Hubbard, D., Jaramillo, E., and P. Penchaszadeh. 1997. Beach clam fisheries. *Ocean. Mar. Biol. Ann. Rev.* **34**: 163-232.

Dugan, J.E. and D.M. Hubbard. 1996. Local variation in populations of the sand crab. *Emerita analoga* (Stimpson) on sandy beaches in southern California. *Revista Chilena de Historia Natural* **69**: 579-588.

Dugan, J.E., Hubbard, D.M., and H.M. Page. 1995. Scaling population density to body size: tests in two soft sediment intertidal communities. *J. Coast. Res.* **11**: 849-857.

Jamarillo, E., McLachlan, A., and J. Dugan. 1995. Total sample area and estimate of species richness in exposed sandy beaches. *Mar. Ecol. Prog. Ser.* **119**: 311-314.

McLachlan, A., Jamarillo, E., Defeo, O., Dugan, J.E., DeRuyck, A., and P. Coetzee. 1995. Adaptations of bivalves to different beach types. *J. Exp. Mar. Biol. Ecol.* **187**: 147-160. .

Dugan, J.E., Hubbard, D.M., and A.M. Wenner. 1994. Geographic variation in life history in populations of the sand crab, *Emerita analoga* (Stimpson), on the California coast: relationships to environmental variables. *J. Exp. Mar. Bio. Ecol.* **181**: 255-278.

Dugan, J.E. and G.E. Davis. 1993. Applications of fishery refugia to coastal fishery management. *Can. J. Fish. Aquat. Sci*. **50**: 2029-2042.

Dugan, J.E. and G.E. Davis. 1993. Introduction to the international symposium on fishery refugia. *Can. J. Fish. Aquat. Sci*. **50**: 1991-1992.

Wenner, A.M., Dugan, J.E., and D.M. Hubbard. 1993. Sand crab population biology on the California Islands and mainland. Pp. 335-348 in: *Third California Islands Symposium, Recent Advances in Research on the California Islands,* F.G. Hochberg, ed. Santa Barbara Museum of Natural History, CA.

Page, H.M., Dugan, J.E., and D.M. Hubbard. 1992. Comparative effects of two infaunal bivalves on an epibenthic microalgal community. *J. Exp. Mar. Biol. Ecol.* **157**: 247-262.

Davis, E.G., Jameson, S., and J.E. Dugan. 1991. Potential benefits of harvest refugia in Channel Islands National Park and Channel Islands National Marine Sanctuary. Pp. 2962-2972 in: *Coastal Zone '91: Proceedings of the 7th Symposium on Coastal and Ocean Management*, O. Magoon, H. Converse, V. Tippie, L. Tobin and D. Clark, eds. Long Beach, CA.

Dugan, J.E., Wenner, A.M., and D.M. Hubbard. 1991. Geographic variation in the reproductive biology of the sand crab, *Emerita analoga* (Stimpson), on the California coast. *J. Exp. Mar. Biol. Ecol*. **150**: 63-81.

Wenner, A.M., Dugan, J.E., and H. Wells. 1991. Estimating egg production in multibrooding populations. In: *Egg Production. Crustacean Issues Vol. 7,* A. Wenner and A. Kuris, ed. Balkema, Netherlands.

Dugan, J.E. 1990. *Geographic and temporal variation in the life history, growth, and reproductive biology of the sand crab, Emerita analoga (Stimpson)*. Ph.D. Dissertation. University of California, Santa Barbara. 329p.

LINDA FERNANDEZ
Donald Bren School of Environmental Science and Management
University of California
Santa Barbara, CA

Project: *The Political Economy of the Rigs-to-Reef Option for Decommissioning of Offshore Oil and Gas Structures*

Education:

Ph.D.	Agricultural and Resource Economics, UC Berkeley	1996
M.S.	Agricultural and Resource Economics, Univ. of Hawaii	1989
B.S.	International Agricultural Development, UC Davis	1985

Positions:

1997-Present	Visiting Assistant Professor, School of Environmental Science and Management, UC Santa Barbara
1996-1997	Lecturer, School of Environmental Science and Management, UC Santa Barbara
1993-1996	Graduate Research Associate, Dept. of Agricultural and Resource Economics, UC Berkeley
1987-1988	Graduate Research Assistant, Water Resources Research Center and East-West Center, University of Hawaii, Honolulu.

Professional Positions:

1989-1993	Environmental Scientist, U.S. Environmental Protection Agency, Region IX, Water Management Division, San Francisco.

Grants and Awards:

University of California Toxic Substances Program, Grant for 1998
Institute on Global Conflict and Cooperation, UC San Diego, Grant for 1997-1998
Institute of Industrial Relations, UC Berkeley, Grant for 1995-1996
College of Natural Resources, UC Berkeley, Grant for 1994-1995
U.S. Environmental Protection Agency, Region IX, Grant for 1993-1994
UC Berkeley Graduate Division Fellowship, 1991-1993

Selected Publications:

Fernandez, L. and L. Karp. 1998. Restoring wetlands through wetlands mitigation banks. *Environmental and Resource Economics* **12**:323-344.

Fernandez, L. 1997. Estimation of wastewater treatment objectives through maximum entropy. *Journal of Environmental Economics and Management* **32**:293-308.

Fernandez, L. 1997. An application of entropy estimation to public wastewater management. *Advances in Econometrics* Vol. 12.

Fernandez, L. and D. Zilberman. 1997. Trade Liberalization and the Environment in the Pacific Basin: Coordinated Approaches to Trade and Environmental Policy. Economic Development and Cooperation in the Pacific Basin: Trade, Investment, and Environmental Issues, H. Lee and D. Roland-Holst, eds. Cambridge University Press, New York.

Fernandez, L. 1991. Demonstration of pesticide best management practices for controlling nonpoint source pollution in the Monterey Bay watershed. Proceedings from the Seventh Symposium on Coastal and Ocean Management. Long Beach, CA.

Fernandez, L. 1991. Environmental and economic feasibility of water supply alternatives in Hawaii and California-desalination, water marketing, and conservation. Proceeding from the Seventh Symposium on Coastal and Ocean Management. Long Beach, CA.

FRED J. GRIFFIN
Division of Biological Sciences
University of California
Davis, CA

Project: *Effects of Biologically Degraded Oil on Marine Invertebrate and Vertebrate Embryos and Larvae*

Education:	B.S.	Agricultural Business Management, University of California, Davis	1970
	B.A., M.A.	Biology, Sonoma State University	1981
	Ph.D.	Zoology, University of California, Davis	1987

Positions:	1996-present	Lecturer, Division of Biological Sciences, University of California, Davis
	1994-present	Assistant Research Biologist II, University of California, Davis
	1986-1994	Staff Research Associate, University of California, Davis, Bodega Marine Laboratory
	1981-1985	Research Assistant/Teaching Assistant, University of California, Davis

Selected Publications:

Baldwin, J.B., F.J. Griffin, and W.H. Clark, Jr. 1999. Immunological characterization of the acrosomal filament in the marine shrimp *Sicyonia ingentis*. *Zygote* **6**:329-339.

Griffin, F.J., J.D. Baldwin, T.-I. Chen, and W.H. Clark, Jr. 1999. The composition and functions of the sperm acrosome reaction in Penaeoidean shrimp. *J. Reprod. Dev.* **44**:8.

Griffin, F.J., M.C. Pillai, C.A. Vines, J. Kääriä.T. Hibbard-Robbins, R. Yanagimachi, and G.N. Cherr. 1998. Effects of salinity on sperm motility fertilization, and development in the Pacific herring, *Clupea pallasi. Biol. Bull.* **194:**25-35.

Wang, S.W., F.J. Griffin, and W.H. Clark. 1997. Cell-cell association directed mitotic spindle orientation in the early development of the marine shrimp *Sicyonia ingentis*. *Development* **124**:773-780.

Griffin, F.J., C.A. Vines, M.C. Pillai, R. Yanagimachi, and G.N. Cherr. 1996. Sperm motility initiation factor (SMIF) is a minor component of the Pacific herring egg chorion. *Development, Growth & Differentiation* **38**:193-202.

Clark, W.H., Jr., F.J. Griffin, and A.H. Wikramanayake. 1994. Pre-fusion events of sperm-oocyte interactions in the marine shrimp, *Sicyonia ingentis. Sem. Dev. Biol*. **5:**225-231.

Clark, W.H., Jr. and F.J. Griffin. 1993. Acquisition and manipulation of Penaeoidean gametes. Pp. 133-152 in: *Handbook of Techniques for Crustacean Aquaculture*, J. McVew, ed. Second Edition., Vol. 1, CRC Press, Boca Raton.

Wikramanayake, A.., K. R. Uhlinger, F.J. Griffin, and W.H. Clark., Jr. 1992. Sperm of the shrimp *Sicyonia ingentis* undergo a bi-phasic capacitation accompanied by morphological changes. *Dev. Growth & Diff* **34**.:347-355.

Keller, R., F.J. Griffin, and W.H. Clark, Jr. 1991. *Gastrulation: Movements, Patterns and Molecules,* Bodega Marine Laboratory, Marine Sciences Series 3. Plenum Press, New York.

Clark, W.H., Jr., T.I. Chen, M.C. Pillai, K. Uhlinger, J. Shoffner-Mcgee, and F.J. Griffin. 1991. The biology of gamete activation and fertilization in *Sicyonia ingentis* (Penaeoidea); present knowledge and future direction. *Bull. Inst. Zool., Academia Sinica* **16:**553-571.

Pillai, M.C., F.J. Griffin, and W.H. Clark, Jr. 1990. Post spawning changes in the extracellular matrices in the eggs of *Sicyonia ingentis*. Pp. 201-207 in: *Advances in Invertebrate Reproduction*, M. Hoshi and O. Yamashita, eds. Vol. 5. Elsevier Science Publishers.

Griffin, F.J. and W.H. Clark, Jr. 1990. Induction of acrosomal filament formation in the sperm of *Sicyonia ingentis. J. Exp. Zool*. **254**:296-304.

Clark, W.H., Jr., A. Yudin, J.W. Lynn, F.J. Griffin, and M.C. Pillai. 1990. Jelly formation in penaeoidean shrimp eggs. *Biol. Bull.* **178**:295-299.

Chen, T.I., F.J. Griffin, L. Crowe, and W.H. Clark, Jr. 1990. The anterior granule in the sperm of the shrimp *Sicyonia ingentis. J. Cell Biol*. 111, 113a.

Pillai, M.C., F.J. Griffin, and W.H. Clark, Jr. 1989. Pre and post spawning alterations of the extracellular matrices in the eggs of Sicyonia ingentis. *Fifth International Congress of Invertebrate Reproduction.*

RICHARD M. HIGASHI
Crocker Nuclear Laboratory
University of California, Davis
Davis, CA 95616

Project: *Effects of Biologically Degraded Oil on Marine Invertebrate and Vertebrate Embryos and Larvae*

Education:	B.S.	Chemistry, University of Hawaii	1977
	Ph.D.	Agricultural & Environmental Chemistry, University of California, Davis	1987
Positions:	1996-present	Assistant/Associate Faculty Research Chemist, Crocker Nuclear Laboratory/Center for Health and Environment, University of California, Davis	
	1989-1996	Assistant Research Chemist, Bodega Marine Laboratory, University of California, Davis	
	1987-1989	Postdoctoral Research Chemist, Bodega Marine Laboratory, University of California, Davis	

Selected Publications:

Fan, T.W-M., S.J. Teh, D.E. Hinton, and R.M. Higashi. 2002. Selenium biotransformations into proteinaceous forms by foodweb organisms of selenium-laden drainage waters in California. *Aquat Toxicol* **57** (1-2): 65-84.

Fan, T.W-M., A.N. Lane, M. Shenker, J.P. Bartley, D. Crowley, and R.M. Higashi. 2001. Comprehensive chemical profiling of gramineous plant root exudates using high-resolution NMR and MS. *Phytochemistry* **57** (2): 209-221.

Fan, T.W-M. and R.M. Higashi. 2000. Se biogeochemistry, ecotoxicology, and bioremediation. *Abstr Pap Am Chem S* **219**: 174-IEC Part 1.

Fan, T.W-M., F. Baraud, and R.M. Higashi. 2000. Heavy metal bioavailability and sequestration by plants via interaction of plant root exudate and soil humic ligands. *Abstr Pap Am Chem S* **220**: 314-ENVR Part 1.

Fan, T.W-M., R.M. Higashi, and A.N. Lane. 2000. Characterization of peptidic structures in a chelator-treated soil humate by solution-state multinuclear two-dimensional NMR with FTIR and pyrolysis-GCMS. *Abstr Pap Am Chem S* **220**: 326-ENVR Part 1.

Fan, T.W-M., R.M. Higashi, and A.N. Lane. 2000. Chemical characterization of a chelator-treated soil humate by solution-state multinuclear two-dimensional NMR with FTIR and pyrolysis-GCMS. *Environ Sci Technol* **34** (9): 1636-1646.

James, T.A., R.M. Higashi, and T.W-M. Fan. 2000. Interaction between contaminant metal mobility and soil fertility manipulated by organic amendments. *Abstr Pap Am Chem S* **220**: 10-FERT Part 1.

Baraud, F., T.W-M. Fan, and R.M. Higashi. 1999. Transition metals' bioavalability to wheat: Interactions with cadmium and soil humates. *Abstr Pap Am Chem S* **218**: 41-NUCL Part 1.

Fan, T.W-M., A.N. Lane, and R.M. Higashi. 1999. Structure analysis of soil humates by liquid-state, multinuclear, and multidimensional NMR. *Abstr Pap Am Chem S* **218**: 14-GEOC Part 1.

Fan, T.W-M., M. Shenker, R.M. Higashi, D.E. Crowley, and A.N. Lane. 1999. Rhizosphere mobilization of heavy metals via plant root exudation. *Abstr Pap Am Chem S* **217**: 043-BIOT Part 1.

Fan, T.W-M., R.M. Higashi, and A.N. Lane. 1999. Heavy metal uptake and sequestration via plant chelator production. *Abstr Pap Am Chem S* **218**: 42-NUCL Part 1.

Higashi, R.M., T.W-M. Fan, and A.N. Lane. 1999. Ternary interactions of biogenic ligands and Cd(II) with humic substances, with implications for metal ion bioavailability. *Abstr Pap Am Chem S* **217**: 018-GEOC Part 1.

Schultz, L.F., R.M. Higashi, T.W-M. Fan, and T.M. Young. 1999. Soil organic matter structural considerations in the sorption and bioavailability of phenanthrene. *Abstr Pap Am Chem S* **217**: 030-GEOC Part 1.

Schultz, L.F., T.M. Young, and R.M. Higashi. 1999. Sorption-desorption behavior of phenanthrene elucidated by pyrolysis-gas chromatography-mass spectrometry studies of soil organic matter. *Environ Toxicol Chem* **18** (8): 1710-1719.

Fan, T.W-M., A.N. Lane, D. Martens, and R.M. Higashi. 1998. Synthesis and structure characterization of selenium metabolites. *Analyst* **123**:875-884.

Fan, T.W-M., R.M. Higashi, and A.N. Lane. 1998. Biotransformations of selenium oxyanion by filamentous cyanophyte-dominated mat cultured from agricultural drainage waters. *Environmental Science & Technology* **32**:3185-3193.

Higashi, R.M., T.W-M. Fan, and A.N. Lane. 1998. Association of desferrioxamine with humic substances and their interaction with cadmium(II) as studied by pyrolysis gas chromatography mass spectrometry and nuclear magnetic resonance spectroscopy. *Analyst* **123**:911-918.

Cherr, G.N., T.W-M. Fan, M.C. Pillai, T. Shields, and R.M. Higashi. 1997. Electrophoretic separation, characterization, and quantification of biologically active lignin-derived macromolecules. *Analytical Biochemistry* **214**:521-527.

Fan, T.W-M., A.N. Lane, and R.M. Higashi. 1997. Selenium biotransformations by a euryhaline microalga isolated from a saline evaporation pond. *Environmental Science & Technology* **31**:569-576.

Fan, T.W-M., A.N. Lane, J. Pedler, D. Crowley, and R.M. Higashi. 1997. Comprehensive analysis of organic ligands in whole root exudate using nuclear magnetic resonance and gas chromatography-mass spectrometry. *Analytical Biochemistry* **251**:57-68

Fan, T.W-M., R.M. Higashi, T.A. Frenkiel, and A.N. Lane. 1997. Anaerobic nitrate and ammonium metabolism in flood-tolerant rice coleoptiles. *Journal of Experimental Botany* **48**:1655-1666.

Marschner, P. D.E. Crowley, and R.M. Higashi. 1997. Root exudation and physiological status of a root-colonizing fluorescent pseudomonad in mycorrhizal and non-mycorrhizal pepper (*Capsicum annuum* L). *Plant and Soil* **189**:11-20.

Pillai, M.C., H. Blethrow, R.M. Higashi, C.A. Vines, CA, and G.N. Cherr. 1997. Inhibition of the sea urchin sperm acrosome reaction by a lignin-derived macromolecule. *Aquatic Toxicology* **37**:139-156.

Colmer, T.D., T.W-M. Fan, A. Läuchli, and R.M. Higashi. 1996. Interactive effects of salinity, nitrogen and sulphur on the organic solutes in *Spartina alterniflora* leaf blades. *Journal of Experimental Botany* **47**:369-375.

Colmer, T.D., T.W-M. Fan, R.M. Higashi, and A. Läuchli. 1996. Interactive effects of Ca2+ and NaCl salinity on the ionic relations and proline accumulation in the primary root tip of sorghum bicolor. *Physiologia Plantarum* **97**:421-424.

Läuchli, A., T.D. Colmer, T.W-M. Fan, and R.M. Higashi. 1994. Solute regulation by calcium in salt-stressed plants. *NATO Advanced Research Workshop Series: Molecular and Cellular Mechanisms of Stress Tolerance in Plants*. J.H. Cherry, ed. Springer-Verlag, Berlin. pp. 443-461.

SCOTT HODGES
Department of Ecology, Evolution and Marine Biology
University of California
Santa Barbara, CA

Project: *Application of Genetic Techniques for use in Restoration of Surfgrass (Phyllospadix torreyi)*

Education:

B.A.	Botany and Biology, University of California, Berkeley	1983
Ph.D.	Botany, University of California, Berkeley	1990

Positions:

1995 - present	Assistant Professor, Dept. of Ecology, Evolution and Marine Biology, UCSB
1993 - 1995	Postdoctoral Associate, Depts. of Botany and Genetics, Univ. of Georgia, Athens, GA
1992	Research Associate, Dept. of Genetics, University of Georgia, Athens, GA
1991	Visiting Assistant Professor of Biology, Barnard College, Columbia Univ. New York, NY
1983-1990	Research Associate, Research Associate, Teaching Assistantship at UC Berkeley

Awards and Honors:

1998	UCSB nominee for Packard Fellowship
1997	Regents' Junior Faculty Fellowship
1996	Regents' Junior Faculty Fellowship
1994	Menzel Award, Genetics Section, Botanical Society of America
1988	Distinguished Instructor, University of California, Berkeley
1987-88	Regents Fellowship, University of California, Berkeley

Selected Publications:

Taylor, D.L., Bruns, T.D., Szaro, T.M., and S.A. Hodges. 2003. Divergence in mycorrhizal specialization within *Hexalectris spicata* (Orchidaceae), a non-photosynthetic desert orchid. *American Journal of Botany* (in press).

Hodges, S.A., Whittall, J.B., Fulton, M., and J.Y. Yang. 2002. Genetics of floral traits influencing reproductive isolation between *Aquilegia Formosa* and *A. pubescens*. *American Naturalist* **159**: S51-S60.

Bushakra, J.M., Hodges, S.A., Cooper, J.B., and D.D. Kaska. 1999. The extent of clonality and genetic diversity in the Santa Cruz Island Ironwood *Lyonothamnus floribundus*. *Molecular Ecology* **8**: 471-476 (cover photo).

Fulton, M. and S.A. Hodges. 1999. Floral isolation between *Aquilegia formosa* and *A. pubescens. Proceedings of the Royal Society of London, Series B* **266**: 2247-2252

Baker, H.G., Baker, I., and S.A. Hodges. 1998. Sugar composition of nectars and fruits consumed by birds and bats in the tropics and subtropics. *Biotropica* **30**: 559-586.

Hodges, SA. 1997. A rapid adaptive radiation via a key innovation in *Aquilegia*. Molecular evolution and adaptive radiations. pg. 391-405. Eds. T. Givinish and K. Sytsma. Cambridge University Press, Cambridge.

Hodges, SA. 1997. Floral nectar spurs and diversification. *International Journal of Plant Sciences* **158**: S81-S88.

Carney, S.E., Hodges, S.A., and M.L. Arnold. 1996. Effects of differential pollen-tube growth on hybridization in the Louisiana irises. *Evolution* **47**: 1432-1445.

Emms, S.K., Hodges, S.A., and M.L. Arnold. 1996. Pollen-tube competition, siring success and consistent asymmetric hybridization in the Louisiana irises. *Evolution* **50**: 2201-2206.

Hodges, S.A., Burke, J., and M.L. Arnold. 1996. Natural formation of iris hybrids: experimental evidence on the establishment of hybrid zones. *Evolution* **47**: 2504-2509

Arnold, M.L. and S.A. Hodges. 1995. Are natural hybrids fit or unfit relative to their parents? *Trends in Ecology and Evolution* **10**: 67-70.

Arnold, M.L. and S.A. Hodges. 1995. The fitness of Hybrids - A response to Day and Schluter. Trends in Ecology and *Evolution* **10**: 289.

Hodges, S.A. 1995. The influence of nectar production on hawkmoth behavior, self pollination and seed production in *Mirabilis multiflora* (Nyctaginaceae). *American Journal of Botany* **82**: 197-229.

Hodges, S.A. and M.L. Arnold. 1995. Spurring plant diversification: Are floral nectar spurs a key evolutionary innovation? *Proceedings of the Royal Society of London, Series B* **262**: 343-348.

Hodges, S.A. and M.L. Arnold 1994. Columbines: a geographically wide-spread species flock. *Proceedings of the National Academy of Sciences, USA* **91**: 5129-5132.

Hodges, S.A. and M.L. Arnold. 1994. Floral and ecological isolation between *Aquilegia formosa* and *A. pubescens*. *Proceedings of the National Academy of Sciences, USA* **91**: 2493-2496.

Hodges, S.A. 1993. Consistent interplant variation in nectar characteristics of *Mirabilis multiflora*. *Ecology* **74**: 542-548.

Hodges, S.A. 1987. Some preliminary observations on hawkmoth pollination of *Oenothera caespitosa* and *Mirabilis multiflora*. pages. 244-249 In: C. A. Hall and V. Doyle- Jones, eds., Plant Biology of Eastern California. Natural History of the White-Inyo Range Symposium, Vol. 2. University of California, White Mountain Research Station, Los Angeles, California.

SALLY J. HOLBROOK
Department of Biological Sciences
University of California
Santa Barbara, CA

Project: *Detecting Ecological Impacts: Effects of Taxonomic Aggregation in the Before-After/Control-Impact Paired Series Design*

Education:	B.A.	Biology, Smith College	1970
	Ph.D.	Zoology, University of California, Berkeley	1975

Positions:	1987-present	Professor, Department of Biological Sciences, University of California, Santa Barbara
	1981-87	Associate Professor, Department of Biological Sciences, University of California, Santa Barbara
	1975-81	Assistant Professor, Department of Biological Sciences, University of California, Santa Barbara

Selected Publications:

Bull, J. S., Reed, D. C., and S. J. Holbrook. An experimental evaluation of different methods of restoring *Phyllospadix torreyi* (Surfgrass) (submitted).

Holbrook, S. J. and R. J. Schmitt. Population dynamics of a damselfish: effects of a competitor that also is an indirect mutualist (submitted).

Holbrook, S. J. and R. J. Schmitt. Ecological performance of a tropical anemone: benefits of hosting anemonefish (submitted).

Schmitt, R. J. and S. J. Holbrook. Mutualism can mediate competition and promote coexistence (submitted).

Bernardi, G., Holbrook, S.J., Schmitt, R.J. and Crane, N.L. Long-distance dispersal in an edge population of the coral reef three-spot damselfish *Dascyllus trimaculatus*. *Marine Biology* (in press).

Holbrook, S.J. and R. J. Schmitt. 2003. Spatial and temporal variation in mortality of newly settled damselfish: patterns, causes and co-variation with settlement. *Oecologia* **135**: 532-541.

Bernardi, G., Holbrook, S.J., Schmitt, R.J., Crane, N.L., and E. DeMartini. 2002. Species boundaries, populations, and color morphs in the coral reef three-spot damselfish (*Dascyllus trimaculatus*) species-complex. *Proceedings of the Royal Society of London B* **269**(1491): 599-605.

Bolker, B.M., St.Mary, C.M., Osenberg, C.W., Schmitt, R.J., and S.J. Holbrook. 2002. Management at a different scale: marine ornamentals and local processes. *Bulletin of Marine Science* **70**:733-748.

Brooks, A.J., Schmitt, R.J. and S.J. Holbrook. 2002. Declines in regional fish populations: have species responded similarly to environmental change? *Marine and Freshwater Research* **53**(2): 189-198.

Holbrook, S.J. and R.J. Schmitt. 2002. Competition for shelter space causes density-dependent mortality in damselfishes. *Ecology* **83**: 2855-2868.

Holbrook, S.J., Brooks, A., and R.J. Schmitt. 2002. Predictability of fish assemblages on coral patch reefs. *Marine and Freshwater Research* **53**(2): 181-188.

Holbrook S.J., Brooks, A.J., and R.J. Schmitt. 2002. Variation in structural attributes of patch-forming corals and in patterns of abundance of associated fishes. *Mar Freshwater Res* **53**(7): 1045-1053.

Holbrook, S.J., Reed, D.C., and J.S. Bull. 2002. Survival experiments with outplanted seedlings of surfgrass (Phyllospadix torreyi) to enhance establishment on artificial structures. *ICES J. Mar. Sci.* **59**: S350-S355 Suppl. S.

Osenberg, C.W., St.Mary, C.M., Schmitt, R.J., Holbrook, S.J., Chesson, P., and B. Byrne. 2002. Rethinking ecological inference: density-dependence in reef fishes. *Ecology Letters* **5**(6): 715-721.

Schmitt, R.J. and S.J. Holbrook. 2002. Correlates of spatial variation in settlement of two tropical damselfishes. *Marine and Freshwater Research* **53**(2): 329-337.

Schmitt, R.J. and S.J. Holbrook. 2002. Spatial variation in concurrent settlement of three damselfishes: relationships with near-field current flow. Oecologia **131**: 391-401.

Bernardi, G., Holbrook, S.J., and R.J. Schmitt. 2001. Gene flow in the coral reef three-spot dascyllus, *Dascyllus trimaculatus*, at three spatial scales. *Marine Biology* **138**: 457-465

Holbrook, S.J., Forrester, G.E., and R.J. Schmitt. 2000. Spatial patterns in abundance of a damselfish reflect availability of suitable habitat. *Oecologia* **122**(1): 109-120.

Holbrook, S.J., Reed, D.C., Hansen, K., et al. 2000. Spatial and temporal patterns of predation on seeds of the surfgrass *Phyllospadix torreyi*. *Mar. Biol.* **136**(4): 739-747.

Schmitt, R.J. and S.J. Holbrook. 2000. Habitat-limited recruitment of coral reef damselfish. *Ecology* **81**(12): 3479-3494.

Blanchette, C.A., Worcester, S., Reed, D., and S.J. Holbrook. 1999. Algal morphology, flow and spatially variable recruitment of surfgrass, *Phyllospadix torreyi*. *Marine Ecology Progress Series* **184**: 119-128.

Holbrook, S.J. and R.J. Schmitt. 1999. I*n situ* nocturnal observations of reef fishes using infrared video. In: Proc. 5th Indo-Pac. Fish Conf., Nouméa, 1997 (Séret B. & J.-Y. Sire, eds), pp. 805-812. Paris: Soc. Fr. Ichtyol.

Holbrook, S.J., Forrester, G.E., and R.J. Schmitt. 1999. Spatial patterns in abundance of a damselfish reflect availability of suitable habitat. *Oecologia*.

Schmitt, R.J. and S.J. Holbrook. 1999. Mortality of juvenile damselfish: implications for assessing processes that determine abundance. *Ecology* **80**: 35-50.

Schmitt, R.J. and S.J. Holbrook. 1999. Settlement and recruitment of three damselfish species: larval delivery and competition for shelter space. *Oecologia* **118**: 76-86.

Schmitt, R.J. and S.J. Holbrook. 1999. Temporal patterns of settlement of three species of damselfish of the genus *Dascyllus* (Pomacentridae) in the coral reefs of French Polynesia. In: Proc. 5th Indo-Pac. Fish Conf., Nouméa, 1997 (Séret B. & J.-Y. Sire, eds), pp. 537-551. Paris: Soc. Fr. Ichtyol.

Schmitt, R.J., Holbrook, S.J., and C.W. Osenberg. 1999. Quantifying the effects of multiple processes on local abundance: A cohort approach for open populations. *Ecology Letters* **2**: 294-303.

Holbrook, S.J. and R.J. Schmitt. 1998. Have field experiments aided in the understanding of abundance and dynamics of reef fishes? Pp. 152-169 in: *Issues and Perspectives in Experimental Ecology*, W.J. Resetarits and J. Bernado eds. Oxford University Press.

Reed, D.C., Holbrook, S.J., Solomon, E., and M. Anghera. 1998. Studies on germination and root development in the surfgrass *Phyllospadix torreyi*: Implications for habitat restoration. *Aquatic Botany* **62**: 71-80.

Holbrook, S.J. and R.J. Schmitt. 1997. Settlement patterns and process in a coral reef damselfish: *in situ* nocturnal observations using infrared video. *Proceedings of the VIIIth International Coral Reef symposium* **2:** 1143-1148.

MICHAEL V. McGINNIS
Marine Science Institute
University of California
Santa Barbara, CA

Project: *The Political Economy of the Rigs-to-Reef Option for Decommissioning of Offshore Oil and Gas Structures*

Education:	B.A.	Political Science, University of California, Los Angeles	1985
	M.A.	Political Science, University of California, Santa Barbara	1988
	Ph.D.	Political Science, University of California, Santa Barbara	1993

Positions:	1996-present	Co-Director and Founder, The Center for Bioregional Conflict Resolution, Santa Cruz, California
	1995-present	Research Political Scientist, Ocean and Coastal Policy Center, Marine Science Institute, University of California, Santa Barbara
	1994	Lecturer, Department of Political Science, University of California, Santa Barbara
	1992-94	Visiting Assistant Professor, Department of Political Science, University of Oregon
	1992-94	Research Associate, Institute for Sustainable Environment, Department of Planning and Public Policy
	1991	Technical Consultant, Santa Barbara County Energy Division
	1990	Lecturer, Department of Political Science, University of California, Santa Barbara

Selected Publications:

Woolley, J.T., McGinnis, M.V., and J. Kellner. 2002. The California watershed movement: Science and the politics of place. *Nat. Resour. J.* **42**(1): 133-183.

Woolley, J.T. and M.V. McGinnis. 2000. The conflicting discourses of restoration. *Soc. Natur. Resour.* **13**(4): 339-357.

McGinnis, M.V. 1999. *Bioregionalism: The Tug and Pull of Place*. London, New York: Routledge. 231 p.

McGinnis, M.V. 1999. Making the watershed connection. *Policy Stud. J.* **27**(3): 497-501.

McGinnis, M.V., Woolley, J., and J. Gamman. 1999. Bioregional conflict resolution: Rebuilding community in watershed planning and organizing. *Environmental Management* **24**: 1-12.

Woolley, J.T. and M.V. McGinnis. 1999. The politics of watershed policymaking. *Policy Stud. J.* **27**(3): 578-594.

McGinnis, M.V. 1997. An analysis of the role of ecological science in offshore continental shelf abandonment policy. In: *Proceedings of California and the World Ocean '97*, Organized and sponsored by Coastal Zone Foundation and Resources Agency of California. 9 pp.

McGinnis, M.V. 1996. Deep ecology and the foundations of restorations. *Inquiry: An Interdisciplinary Journal of Philosophy* **39**: 203-217.

McGinnis, M.V. 1996. Perceptions and restoration ecology: A comparison of restoration discourses. *Inquiry: An Interdisciplinary Journal of Philosophy.*

McGinnis, M.V. 1995. Bioregional organization: A constitution of home place. *Human Ecology Review* **2**: 72-84.

McGinnis, M.V. 1995. On the verge of collapse: The Columbia River system, wild salmon and the Northwest Power Planning Council. *Natural Resources Journal* **35**: 520-552.

McGinnis, M.V. 1994. Collective bads: The case of low-level radioactive waste compacts. *Natural Resources Journal* **34**: 563-588.

McGinnis, M.V. 1994. Myth, nature and the bureaucratic experience. *Environmental Ethics* **16**: 425-434.

McGinnis, M.V. 1994. The politics of restocking vs. restoring salmon in the Columbia River Basin. *Restoration Ecology* **2**: 1-7.

McGinnis, M.V. 1993. Low-level radioactive waste compacts: Cases in the illogic of collective action. In: *Problems and Prospects for Nuclear Waste Disposal Policy,* E.B. Herzik and A. Mushkatel, eds. Greenwood Press, CT.

McGinnis, M.V. and J.T. Lima. 1993. California ocean use conflict management--An assessment of two integrating approaches. Pp. 705-722 in: *International Perspective on Coastal and Ocean Space Utilization,* P.M. Griffman and J. Fawcett, eds. University of Southern California Sea Grant, CA.

McGinnis, M.V. and W. Cohan. 1992. Ecology and international studies. Pp. 245-267 in: *Revealing the World: An Interdisciplinary Reader in International Studies,* D Lieberman and M. Gurtow, eds. Kendall/Hunt Publ. Co.

McGinnis, M.V. 1991. San Luis Obispo's measure A--check or checkmate? Pp. 119-119 in: *The California Coastal Zone Experience,* G.W. Domurat and T.H. Wakeman, eds. American Society of Civil Engineers, NY, NY.

McGinnis, M.V. 1990. *The multiple uses of the ocean and coastal zone offshore California*. California Sea Grant Publication, Working Paper P-T-51. California Sea Grant College Program, CA.

CRAIG W. OSENBERG
Department of Zoology
University of Florida
Gainesville, FL

Project: *Detecting Ecological Impacts: Effects of Taxonomic Aggregation in the Before-After/Control-Impact Paired Series Design*

Education:	B.A.	Biology, University of California, Santa Barbara (*summa cum laude*)	1980
	Ph.D.	Ecology, Michigan State University	1988

Positions:	1998-present	Associate Professor, Department of Zoology, University of Florida
	1995-1998	Assistant Professor, Department of Zoology, University of Florida
	1991-1995	Assistant Professor, Department of Integrative Biology, University of California, Berkeley (on leave without pay, 1991-92, 1995-96)
	1989-1996	Assistant Research Biologist, Marine Science Institute, University of California, Santa Barbara
	1988-1993	Research Associate, Kellogg Biological Station, Michigan State University
	1988-1992	Lecturer, Department of Biological Sciences, University of California, Santa Barbara
	1988-1991	Post-graduate Research Biologist, Marine Science Institute, University of California, Santa Barbara

Distinctions:	1987	Kellogg Biological Station Scholarship Award
	1985-1986	MSU College of Natural Sciences Fellowship
	1982-1985	National Science Foundation Predoctoral Fellowship

Research Interests: Size and stage-structured interactions, and their implications for population dynamics and community patterns. The roles of predation and food limitation in aquatic ecosystems. Quantification of effect size (and interaction strength) and its variation among organisms and environments. The design and implementation of whole ecosystem experiments and environmental assessment studies.

Selected Publications:

Osenberg, C.W., C.M. St. Mary, J.A. Wilson, and W.J. Lindberg. A quantitative framework to evaluate the attraction-production controversy, with application to marine ornamental fisheries. *ICES Journal of Marine Science.*

Wilson, J.A., C.W. Osenberg, C.M. St. Mary, C.A. Watson, and W.J. Lindberg. Artificial reefs, the attraction-production issue, and density-dependence in marine ornamental fishes. *Aquarium Sciences and Conservation.*

St. Mary, C.M., C.W. Osenberg, T.K. Frazer, and W.J. Lindberg. 2000. Stage structure, density dependence, and the efficacy of marine reserves. *Bulletin of Marine Sciences.*

Scheiner, S.M., S B. Cox, M. Willig, G.G. Mittelbach, C.W. Osenberg, and M. Kaspari. 2000. Species richness, species-area curves, and Simpson's paradox. *Evolutionary Ecology Research.*

Gough, L., C.W. Osenberg, K.L. Gross, and S.L. Collins. 2000. Fertilization effects on species density and primary productivity in herbaceous plant communities. *Oikos* **89**:428-439.

Huckins, C.J.F., C.W. Osenberg, G.G. Mittelbach. 2000. Consequences of introducing species beyond their native range: an example with sunfishes. *Ecological Applications* **10**:612-625.

Wilson, W.G. C.W. Osenberg, R.J. Schmitt and R. Nisbet. 1999. Complementary foraging behavior allows coexistence of two grazers. *Ecology* **80**:2358-2372.

Schmitt, R.J., S.J. Holbrook, and C.W. Osenberg. 1999. Quantifying the effects of multiple processes on local abundance: a cohort approach for open populations. *Ecology Letters* **2**:294-303.

Osenberg, C.W., O. Sarnelle, D.E. Goldberg. 1999. Meta-analysis in ecology: concepts, statistics, and applications. *Ecology* **80**:1103-1104.

Downing, J., C.W. Osenberg, and O. Sarnelle. 1999. Meta-analysis of marine nutrient-enrichment experiments: variation in the magnitude of nutrient limitation. *Ecology* **80**:1157-1167.

Osenberg, C.W., O. Sarnelle, S.D. Cooper, and R.D. Holt. 1999. Resolving ecological questions through meta-analysis: goals, metrics and models. *Ecology* **80**:1105-1117.

Mittelbach, G.G., C.W. Osenberg, and P. Wainwright. 1999. Variation in feeding morphology between pumkinseed populations: phenotypic plasticity or evolution? *Evolutionary Ecology Research* **1**:111-128.

Osenberg, C.W. and C.M. St Mary. 1998. Meta-analysis: synthesis or statistical subjugation? *Integrative Biology: Issues, News and Reviews* **1**:37-41. (Invited and reviewed by editor)

Moeller, R.E., R.G. Wetzel, C.W. Osenberg. 1998. Concordance of phosphorus limitation in lakes: Bacterioplankton, phytoplankton, epiphyte-snail consumers, and rooted macrophytes. Pp. 318-325 in: *The Structuring Role of Submersed Macrophytes in Lakes,* E. Jeppesen, M. Søndergaard, M. D Søndergaard, and K. Christoffersen eds. Springer-Verlag, Berlin.

Osenberg, C.W., O. Sarnelle, and S.D. Cooper. 1997. Effect size in ecological experiments: in the application f biological models in meta-analysis. *American Naturalist* **15**:798-812.

Steichen, D.J., Jr., S.J. Holbrook, and C.W. Osenberg. 1996. The response of benthic and demersal macrofauna to organic enrichment at a natural oil seep. *Marine Ecology Progress Series* **138**:71-82.

Ambrose, R.F., R.J. Schmitt, and C.W. Osenberg. 1996. Predicted and observed environmental impacts: can we foretell ecological change? Pp. 343-367 in: *Detecting Ecological Impacts: Concepts and Applications in Coastal Habitats*, R.J. Schmitt and C.W. Osenberg, eds. Academic Press, San Diego, CA.

Osenberg, C.W. and R.J. Schmitt. 1996. Detecting ecological impacts caused by human activities. Pp. 3-17 in: *Detecting Ecological Impacts: Concepts and Applications in Coastal Habitats*, R.J. Schmitt and C.W. Osenberg, eds. Academic Press, San Diego, CA.

Osenberg, C.W., R.J. Schmitt, S.J. Holbrook, K.E. Abu-Saba, and A.R. Flegal. 1996. Detection of environmental impacts: natural variability, effect size, and power analysis. Pp. 83-108 in: *Detecting Ecological Impacts: Concepts and Applications in Coastal Habitats*, R.J. Schmitt and C.W. Osenberg, eds. Academic Press, San Diego, CA. [Republication of Osenberg *et al.* 1994, *Ecological Applications* **4**:16-30.]

Schmitt, R.J. and C.W. Osenberg (editors and contributing authors). 1996. *Detecting Ecological Impacts: Concepts and Applications in Coastal Marine Habitats*. Academic Press, San Diego, CA. 401p.

Schmitt, R.J., C.W. Osenberg, W.J. Douros, and J. Chesson. 1996. The art and science of administrative environmental impact assessment. Pp. 279-291 in: *Detecting Ecological Impacts: Concepts and Applications in Coastal Habitats*, R.J. Schmitt and C.W. Osenberg, eds. Academic Press, San Diego, CA.

Mittelbach, G.G., A.M. Turner, D.J. Hall, J.E. Rettig, and C.W. Osenberg. 1995. Perturbation and resilience: a long-term whole-lake study of predator extinction and reintroduction. *Ecology* **76**:2347-2360.

H. MARK PAGE
Marine Science Institute
University of California
Santa Barbara, CA

Project: *Early Development of Fouling Communities on Offshore Oil Platforms*

Education:

B.S.	University of Southern California	1973
M.A.	University of California, Santa Barbara	1977
Ph.D.	University of California, Santa Barbara	1984

Positions:

1985-present	Assistant Research Biologist, Marine Science Institute, University of California, Santa Barbara
1984-1998	Lecturer in Summer Session, Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara
1994-1997	Instructor, Department of Biological Sciences, Santa Barbara City College
1983-1985	Postgraduate Research Biologist, Marine Science Institute, University of California, Santa Barbara

Selected Publications:

Galindo-Bect, M. S., E. P. Glenn, H. M. Page, L. A. Galindo-Bect, J. M. Hernandez-Ayon, R. L. Petty, and J. Garcia-Hernandez. Analysis of peneid shrimp landings in the northern Gulf of California in relation to Colorado River discharge. *Fishery Bulletin*, in press

Page, H.M., J. E. Dugan, D. Dugan, and J. Richards. 1999. Effects of an offshore oil platform on the distribution and abundance of commercially important crab species. *Marine Ecology Progress Series* **185**:47-57.

Page, H.M. 1997. Importance of vascular plant and algal production to macroinvertebrate consumers in a southern California salt marsh. *Estuarine, Coastal and Shelf Science* **45**:823-834.

Page, H.M. Variation in the natural abundance of ^{15}N in the halophyte, *Salicornia virginica*, associated with ground water subsidies of nitrogen in a southern California salt marsh. *Oecologia* **104**:181-188.

Page, H.M., R.L. Petty, and D.E. Meade. 1995. Influence of watershed run-off on nutrient dynamics in a southern California salt marsh. *Estuarine, Coastal and Shelf Science* **41**:163-180.

Dugan, J.E., D.M. Hubbard, and H.M. Page. 1995. Scaling population density to body size: tests in two soft sediment intertidal communities. *Journal of Coastal Research* **11**:849-857.

Page, H.M., J.E. Dugan, and D.M. Hubbard. 1992. Comparative effects of infaunal bivalves on an epibenthic microalgal community. *Journal of Experimental Marine Biology and Ecology* **157**:247-262.

Page, H.M., A. Fiala-Medioni, C.R. Fisher, and J.J. Childress. 1990. Experimental evidence for filter-feeding by the hydrothermal vent mussel, *Bathymodiolus thermophilus*. *Deep-Sea Research* **38**:1455-1461.

Page, H.M., C.R. Fisher, and J.J. Childress. 1990. The role of filter-feeding in the nutritional biology of a deep sea mussel with methanotrophic symbionts. *Marine Biology* **104**:251-257.

Page, H.M. and D.M. Hubbard. 1987. Temporal and spatial patterns of growth in mussels, *Mytilus edulis*, on an offshore platform: relationships to water temperature and food availability. *Journal of Experimental Marine Biology and Ecology* **111**:159-179.

Page, H.M. 1986. Differences in population structure and growth rate of the stalked barnacle, *Pollicipes polymerus* between a rocky headland and an offshore oil platform. *Marine Ecology Progress Series* **29**:157-164.

CAROLYN POMEROY
Institute of Marine Science
University of California
Santa Cruz, CA

Project: *The Political Economy of the Rigs-to-Reef Option for Decommissioning of Offshore Oil and Gas Structures*

Education:

B.A.	Yale University, Southeast Asian Studies	1985
M.A.	University of Miami, Rosenstiel School of Marine and Atmospheric Science Marine Affairs	1989
Ph.D.	Texas A&M University, Wildlife & Fisheries Sciences	1993

Positions:

1995-present	Assistant Research Scientist, Institute of Marine Sciences, UCSC
1998-present	Lecturer, Ocean Sciences Board, UCSC
1995-96	Lecturer, California State University, Monterey Bay
1993-95	Visiting Scientist, Workshop in Political Theory & Policy Analysis, Indiana University
1994	Lecturer, School of Public and Environmental Affairs, Indiana University

Research experience and interests:

Local institutions for common pool resource management; cooperative management of local fisheries; territorial use rights in fisheries (Big Sur, CA; Lake Chapala, Mexico; Quintana Roo, Mexico; Skagit System Cooperative, Washington)

Social identity and cooperation in the commons (Lake Chapala, Mexico; Skagit System Cooperative, Washington)

Marine resource conflicts and conflict resolution (Lake Chapala, Mexico; Quintana Roo, Mexico; Santa Barbara Channel, CA; Skagit System Cooperative, Washington; Southeast Asian artisanal fisheries)

Social and economic organization of fisheries; social and economic impact assessment, for fishery management, mitigation of fish contamination, and offshore oil platform decommissioning (California market squid; Mare Island Naval Shipyard and Vallejo, CA; Santa Barbara Channel, CA)

Management of coastal and marine protected areas (Miami, FL; Half Moon Caye, Belize; Big Creek, CA, coastal CA)

Honors and awards:

1997	Most Innovative Poster, Sanctuary Currents '97, Santa Cruz, CA
1994	Grant-in-Aid, Research and the University Graduate School, Indiana University
1993	Travel Research Grant, Workshop in Political Theory & Policy Analysis, Indiana University
	Graduate Program, Texas A&M University
	Enhancement Fund Grant
1992	Exploration Fund Grant-in-Aid, Explorers Club
	F.T. Griswold Scholarship, Pan American Round Tables of Texas
1991	SEASPACE Scholarship, Houston Underwater Club
	Grant-in-Aid of Research, Sigma Xi
1990-91	Gamma Sigma Delta, Agriculture Honor Society
1989	International Enhancement Grant, Texas A&M University
	Regent's Fellowship, Texas A&M University
1987	Rosenstiel Fellowship, University of Miami

Selected Publications:

Pomeroy, C. in press. Social considerations for marine resource management: Evidence from Big Creek Ecological Reserve. *California Cooperative Oceanic Fisheries Investigation*s *Reports* 40.

Pomeroy, C. and J. Beck. in press. An experiment in fisheries co-management: Preliminary evidence from Big Creek. *Society and Natural Resources.*

Pomeroy, C. and M. FitzSimmons. 1998. Information needs for effective management of the California market squid fishery: The role of social science research. *California Cooperative Oceanic Fisheries Investigation*s *Reports* **39**:108-114.

Bailey, C., and C. Pomeroy. 1996. Resource dependency and community stability in coastal fishing communities of Southeast Asia. *Society and Natural Resources* **9**:191-199.

Pomeroy, C. 1995. Review of *Ecological Identity* by Mitchell Thomashow. *Journal of Political Ecology* **2**:47-51.

Pomeroy, C. 1994. Obstacles to institutional development in the fishery of Lake Chapala, Mexico. Pp. 17-41 in *Folk Management in the World's Fisheries*, C.L. Dyer and J.R. McGoodwin, eds. Niwot, CO: University Press of Colorado.

PETER T. RAIMONDI
Department of Biology
University of California
Santa Cruz, CA

Projects: *Variability in the accumulation and persistence of tar in four intertidal communities along the central and southern California coast*
Inventory of Rocky Intertidal Resources in San Luis Obispo and Northern Santa Barbara Counties

Education:	B.A.	Philosophy, Northern Arizona University	1976
	Ph.D.	Biology, University of California, Santa Barbara	1988

Positions:	1996-present	Assistant Professor, Department of Biology, University of California, Santa Cruz
	1992-1996	Assistant Research Biologist, Marine Science Institute, University of California, Santa Barbara
	1991-1992	Post-doctoral Research Biologist, Marine Science Institute, University of California, Santa Barbara
	1989-1991	Research Fellow, Australian Research Council Fellowship, University of Melbourne, Department of Zoology
	1988-1989	Research Fellow, University of Melbourne Research Fellowship
	1987-1988	Post-doctoral Researcher, University of California, Santa Barbara
	1986-1990	Environmental Consultant, Marine Review Committee

Distinctions:	1976	President's Scholarship for Academic Excellence. Northern Arizona University
	1981-82	Dean's Award for Academic Excellence, University of Arizona
	1984	Sigma Xi Grant-in-Aid of Research
	1986	University of California Patent Fund
	1987-88	Office of Naval Research Postdoctoral Fellowship
	1988-89	University of Melbourne Research Fellowship
	1989-91	Australian Research Council Fellowship

Selected Publications:

Carr M.H., and P.T. Raimondi. 1999. Marine protected areas as a precautionary approach to management. CALCOFI reports.

Reed D.C., M.H. Carr, L. Goldwasser, and P.T. Raimondi. Role of dispersal potential in determining the spatial structure of an assemblage of sedentary marine organisms. *Ecology*. In press.

Carr, M.H. and P.T. Raimondi. Concepts relevant to the design and evaluation of harvest reserves. Proceedings of workshop on rockfish refugia.

Raimondi, P.T. and S. Forde. Processes structuring communities: evidence for trait mediated interactions through induced polymorphisms. *Ecology*. In press.

Raimondi, P.T. and A.N.C. Morse. Complex larval behavior and the vertical distribution and orientation of *Agaricia humilis* (Scleractinia). *Ecology*.

Raimondi, P.T., A.M. Barnett, and P.R. Krause. 1997. The effects of drilling muds on marine invertebrate larvae and adults. *Environmental Toxicology and Chemistry* **16**:1218-1228.

Alltstatt, J.A., R.F. Ambrose, J.M. Engle, P.L. Haaker, K.D. Lafferty, and P.T. Raimondi. 1996. Recent declines of black abalone *Haliotis cracherodii* on the mainland coast of central California. *Marine Ecology Progress Series* **142**:185-192.

Keough, M.J. and P.T. Raimondi. 1996. Responses of settling invertebrate larvae to bioorganic films: Effects of large-scale variation in films. *J. Exp. Mar. Biol. Ecology* **207**:59-78.

Raimondi, P.T. and D. Reed. 1996. Determining the spatial extent of ecological impacts caused by local anthropogenic disturbances in coastal marine habitats. Pp. 179-198 in: *Detecting Ecological Impacts: Concepts and Applications in Coastal Habitat*s, R.J. Schmitt and C.W. Osenberg, eds. Academic Press, San Diego, CA.

Keough, M.J. and P.T. Raimondi. 1995. Responses of settling invertebrate larvae to microbial films, II: Effects of different types of films. *Marine Ecology Progress Series* **185**:235-253.

Morse, D.E., A. Morse, N. Hooker, and P.T. Raimondi. 1994. Morphogen-based chemical flypaper for Agaricia humilis larvae. *Biological Bulletin* **186**:172-181.

Lively, C.M., P.T. Raimondi, and L.F. Delph. 1993. Intertidal community structure: space-time interactions in the Northern Gulf of California. *Ecology* **74**:162-173.

Raimondi, P.T. and R.J. Schmitt. 1992. Effects of produced water on settlement of larvae: field tests using red abalone. Pp. 415-430 in: *Produced Water: Technological/Environmental Issues and Solutions,* J.P. Ray and F.R. Engelhardt, eds. Plenum Press, NY.

Raimondi, P.T. 1992. Adult plasticity and rapid larval evolution in a recently isolated barnacle population. *Biological Bulletin* **182**:210-220.

Keough, M.J. and P.T. Raimondi. 1992. Robustness of estimates of recruitment rates for sessile marine invertebrates. Recruitment Workshop Proceedings. *Australian Society of Fisheries Biologists*.

Raimondi, P.T. 1991 The settlement of *Chthamalus anisopoma* largely determines its adult distribution. *Oecologia* **85**:349-360.

Raimondi, P.T. and J.E. Martin. 1991. Evidence that mating group size affects allocation of reproductive resources in a simultaneous hermaphrodite. *American Naturalist* **138**:1206-1217.

Raimondi, P.T. 1990. Patterns, mechanisms, and consequences of variability in settlement and recruitment in an intertidal barnacle. *Ecological Monographs* **60**:283-309.

Raimondi, P.T. and M.J. Keough. 1990. Behavioral variability in marine larvae. *Aust. J. Ecology* **15**:427-437.

Raimondi, P.T. 1988. Rock type affects settlement, recruitment, and zonation of the barnacle *Chthamalus anisopoma* (Pilsbry). *Journal of Experimental Marine Biology and Ecology* **123**:253-267.

Raimondi, P.T. 1988. Settlement cues and determination of the vertical limit of an intertidal barnacle. *Ecology* **69**:400-407.

DANIEL C. REED
Marine Science Institute
University of California
Santa Barbara, CA

Project: *Application of Genetic Techniques for use in Restoration of Surfgrass (Phyllospadix torreyi)*

Education:	B.A.	Moss Landing Marine Laboratories and San Francisco State University	1978
	M.A.	Moss Landing Marine Laboratories and San Francisco State University	1981
	Ph.D.	University of California, Santa Barbara	1989
Positions:	1994-present	Associate Research Biologist, Marine Science Institute, University of California, Santa Barbara	
	1989-94	Assistant Research Biologist, Marine Science Institute, University of California, Santa Barbara	
	1990	Biological Consultant, Woodward-Clyde Consultants	
	1987-90	Biological Consultant, Marine Review Committee	
	1988-89	Biological Consultant, Michael Brandman Associates	
	1986-87	Biological Consultant, Chambers Consultants	
Distinctions:	1989	Lancaster Award for Outstanding Dissertation, University of California, Santa Barbara	
	1984	Antarctic Service Medal of the United States of America, National Science Foundation	

Selected Publications:

Bull, J. S., Reed, D. C., and S. J. Holbrook. An experimental evaluation of different methods of restoring *Phyllospadix torreyi* (Surfgrass) (submitted).

Page, H. M., Schroeter, S., Reed, D.C., Ambrose, R. F., Callaway, J., and J. Dixon. Variation in the distribution and abundance of salt marsh vegetation associated with elevation and height of tidal inundation. *Bulletin of the Southern California Academy of Sciences* (in press).

Gaylord, B., Reed, D.C., Raimondi, P.T., Washburn, L., and S.R. McLean. 2002. A physically based model of macroalgal spore dispersal in the wave and current-dominated nearshore. *Ecology* **83**(5): 1239-1251.

Holbrook, S.J., Reed, D.C., and J.S. Bull. 2002. Survival experiments with outplanted seedlings of surfgrass (Phyllospadix torreyi) to enhance establishment on artificial structures. *Ices J Mar Sci* **59**: S350-S355 Suppl. S.

Schroeter, S.C., Reed, D.C., Kushner, D.J., Estes, J.A., and D.S. Ono. 2001. The use of marine reserves in evaluating the dive fishery for the warty sea cucumber (Parastichopus parvimensis) in California, USA. *Can J Fish Aquat Sci* **58**(9): 1773-1781.

Holbrook, S.J., Reed, D.C., Hansen, K., and C.A. Blanchette. 2000. Spatial and temporal patterns of predation on seeds of surfgrass, *Phyllospadix torreyi*. *Mar Biol* **136**(4): 739-747.

Reed, D.C., Raimondi, P.T., Carr, M.H., and L. Goldwasser. 2000. The role of dispersal and disturbance in determining spatial heterogeneity in sedentary kelp-forest organisms. *Ecology* **81**(7): 2011-2026.

Blanchette, C.A., Worcester, S., Reed, D., and S.J. Holbrook. 1999. Algal morphology, flow and spatially variable recruitment of surfgrass, *Phyllospadix torreyi*. *Marine Ecology Progress Series* **184**: 119-128.

Reed, D.C., Brzezinski, M.A., Coury, D.A., Graham, W.M., and R.L. Petty. 1999. Neutral lipids in macroalgal spores and their role in swimming. *Marine Biology* **133**: 737-744

Reed, D.C., Holbrook, S.J., Solomon, E., and M. Anghera. 1998. Studies on germination and root development in the surfgrass *Phyllospadix torreyi*: Implications for habitat restoration. *Aquatic Botany* **62**: 71-80.

Reed, D.C., Anderson, T.W., Ebeling, A.W., and M. Anghera. 1997. Role of reproductive synchrony in the colonization potential of kelp. *Ecology* **78**: 2443-2457.

Canestro, D., Raimondi, P.T., Reed, D.C., Schmitt, R.J., and S.J. Holbrook. 1996. A study of methods and techniques for detecting ecological impacts. Pp. 53-67 in*: Methods and techniques of underwater research*, *Proceedings of the American Academy of Underwater Scientists symposium*. AAUS, Nahant, MA.

Raimondi, P.T. and D. Reed. 1996. Determining the spatial extent of ecological impacts caused by local anthropogenic disturbances in coastal marine habitats. Pp. 179-198 in: *Detecting Ecological Impacts: Conceptual Issues and Applications in Coastal Marine Habitat,* R.J. Schmitt and C.W. Osenberg, eds. Academic Press, San Diego, CA.

Reed, D.C., Ebeling, A.W., Anderson, T.W., and M. Anghera. 1996. Differential reproductive responses to fluctuating resources in two seaweeds with different reproductive strategies. *Ecology* **77**: 300-316.

Ambrose, R.F., Boland, J., Murdoch, W.W., Raimondi, P.T., and D.C. Reed. 1995. The San Onofre nuclear generating station mitigation reef: monitoring issues. Pp. 587-592 in: *Proceedings from the International Conference on Ecological System Enhancement Technology for Aquatic Environments*. Japan International Marine Science and Technology Federation, Tokyo.

Reed, D.C. 1994. Giant forests of the sea. *The World and I* **July**: 202-207.

Reed, D.C. and R.J. Lewis. 1994. Effects of an oil and gas production effluent on the colonization potential of giant kelp (*Macrocystis pyrifera*) zoospores. *Marine Biology* **119**: 277-283.

Reed, D.C., Lewis, R.J., and M. Anghera. 1994. Effects of an open coast oil production outfall on patterns of giant kelp (*Macrocystis pyrifera*) recruitment. *Marine Biology* **120**: 26-31.

Brzezinski, M, Reed, D.C., and C.D. Amsler. 1993. Neutral lipids as major storage products in *Macrocystis pyrifera*. *J. Phycology* **29**: 16-23.

Carr, M.H. and D.C. Reed. 1993. Conceptual issues relevant to marine harvest refuges: examples from temperate marine fishes. *Can. J. Fish. Aquat. Sci.* **50**: 2019-2028.

Amsler, C.D., Reed, D.C., and M. Neushul. 1992. The microclimate inhabited by algal propagules. *British Phycological Journal* **27**: 253-270.

Carr, M.H. and D.C. Reed. 1992. Harvest refuges and their potential for enhancing reef fisheries in southern California. Pp. 63-68 in: *Perspectives on the Marine Environment,* P.M. Grifman and S.E. Yoder, Eds. Sea Grant Program, University of California, Los Angeles.

Neushel, M., Amsler, C.D., Reed, D.C., and R.J. Lewis. 1992. The introduction of marine plants for aquacultural purposes. Pp. 103-138 in: *Movement and dispersal of biotic agents into aquatic ecosystems*, A. Rosenfield, ed. Maryland Sea Grant College, College Park, MD.

Reed, D.C., Amsler, C.D., and A.W. Ebeling. 1992. Dispersal in kelps: factors affecting spore swimming and competency. *Ecology* **73**: 1577-1585.

Reed, D.C., Neushul, M., and A.W. Ebeling. 1991. The role of density on gametophyte growth and reproduction in the kelps *Macrocystis pyrifera* and *Pterygophora californica*. *J. Phycol*. **27**: 361-366.

RUSSELL J. SCHMITT
Department of Ecology, Evolution and Marine Biology and
Coastal Research Center, Marine Science Institute
University of California
Santa Barbara, CA

Education:	B.A.	Environmental Biology, University of Colorado	1972
	M.S.	Marine Science, University of the Pacific	1975
	Ph.D.	Biology, University of California, Los Angeles	1979

Positions:	1995-present	Professor, Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara
	1994-present	Program Director, Coastal Marine Institute, University of California, Santa Barbara
	1991-present	Program Director, Coastal Toxicology Program, UC Toxic Substances Research and Teaching Program
	1989-present	Program Director, Southern California Educational Initiative, University of California, Santa Barbara
	1987-present	Director, Coastal Research Center, Marine Science Institute, University of California, Santa Barbara
	1993-1995	Associate Professor, Department of Biology and Environmental Studies Program, University of California, Santa Barbara
	1987-1992	Associate Research Biologist, Marine Science Institute, University of California, Santa Barbara
	1981-1987	Assistant Research Biologist, Marine Science Institute, University of California, Santa Barbara

Distinctions:	1989	George Mercer Award for 1989, Ecological Society of America (best published research in field of Ecology by a scientist under age 40; Awarded for "Indirect interactions between prey: apparent competition, predator aggregation and habitat selection," *Ecology* **68**:1887-1897)

Selected Publications:

Schmitt, R.J. and S.J. Holbrook. Habitat-limited recruitment of coral reef damselfish. Submitted manuscript.

Bernardi, G., Holbrook, S.J., Schmitt, R.J., Crane, N.L., and E. DeMartini. 2002. Species boundaries, populations and colour morphs in the coral reef three-spot damselfish (Dascyllus trimaculatus) species complex. *P Roy Soc Lond B Bio* **269**(1491): 599-605.

Bolker, B.M., St Mary, C.M., Osenberg, C.W., Schmitt, R.J., and S.J. Holbrook. 2002. Management at a different scale: Marine ornamentals and local processes. *B Mar Sci* **70**(2): 733-748.

Brooks, A.J., Schmitt, R.J., and S.J. Holbrook. 2002. Declines in regional fish populations: have species responded similarly to environmental change? *Mar Freshwater Res* **53**(2): 189-198.

Holbrook, S.J. and R.J. Schmitt. 2002. Competition for shelter space causes density-dependent predation mortality in damselfishes. *Ecology* **83**(10): 2855-2868.

Holbrook, S.J., Brooks, A.J., and R.J. Schmitt. 2002. Predictability of fish assemblages on coral patch reefs. *Mar Freshwater Res* **53**(2): 181-188.

Holbrook, S.J., Brooks, A.J., and R.J. Schmitt. 2002. Variation in structural attributes of patch-forming corals and in patterns of abundance of associated fishes. *Mar Freshwater Res* **53**(7): 1045-1053.

Osenberg, C.W., St Mary, C.M., Schmitt, R.J., Holbrook, S.J., Chesson, P., and B. Byrne. 2002. Rethinking ecological inference: density dependence in reef fishes. *Ecol Lett* **5**(6): 715-721.

Schmitt, R.J. and S.J. Holbrook. 2002. Correlates of spatial variation in settlement of two tropical damselfishes. *Mar Freshwater Res* **53**(2): 329-337.

Schmitt, R.J. and S.J. Holbrook. 2002. Spatial variation in concurrent settlement of three damselfishes: relationships with near-field current flow. *Oecologia* **13**(3): 391-401.

Bernardi, G., Holbrook, S.J., and R.J. Schmitt. 2001. Gene flow at three spatial scales in a coral reef fish, the three-spot dascyllus, Dascyllus trimaculatus. *Mar Biol* **138**(3): 457-465.

Buko, A.M., Beckner, C., Hepp, D., Helias, N., Zhu, F., Nemcek, T., Schmitt, R.J., and J. Hochlowski. 2001. Stability testing of chemical diversity in liquid DMSO storage. *Abstr Pap Am Chem S* **222**: 210-ANYL Part 1.

Schmitt, R.J. and S.J. Holbrook. 2001. Habitat-limited recruitment of coral reef damselfish. *Ecology* **81**(12): 3479-3494.

Holbrook, S.J., Forrester, G.E., and R.J. Schmitt. 2000. Spatial patterns in abundance of a damselfish reflect availability of suitable habitat. *Oecologia* **122**(1): 109-120.

Holbrook, S.J. and R.J. Schmitt. 1999. *In Situ* Nocturnal Observations of Reef Fishes Using Infrared Video. Pp. 805-812 in Proc. 5th Indo-Pacific Fish Conf., Noumea, 1997. B Seret and J-Y Sire, eds. Paris: Soc. Fr. Ichtyol.

Schmitt, R.J. and S.J. Holbrook. 1999. Mortality of juvenile damselfish: implications for assessing processes that determine abundance. *Ecology* **80**: 35-50.

Schmitt, R.J. and S.J. Holbrook. 1999. Settlement and recruitment of three damselfish species: larval delivery and competition for shelter space. *Oecologia* **118**: 76-86.

Schmitt, R.J. and S.J. Holbrook. 1999. Temporal patterns of settlement of three species of damselfish of the genus *Dascyllus* (Pomacentridae) in the coral reefs of French Polynesia. Pp. 537-551 *in* Proc. 5th Indo-Pacific Fish Conf., Noumea, 1997. B Seret and J-Y Sire, eds. Paris: Soc. Fr. Ichtyol.

Schmitt, R.J., Holbrook, S.J., and C.W. Osenberg. 1999. Quantifying the effects of multiple processes on local abundance: A cohort approach for open populations. *Ecology Letters* **2**: 294-303.

Wilson, W.G., Osenberg, C.W., Schmitt, R.J., and R.M. Nisbet. 1999. Complementary foraging behaviors allow coexistence of two consumers. *Ecology* **80**(7): 2358-2372.

Holbrook, S.J. and R.J. Schmitt. 1998. Have field experiments aided in the understanding of abundance and dynamics of reef fishes? Pp. 152-169 in: *Issues and Perspectives in Experimental Ecology*, W.J. Resetarits and J. Bernado eds. Oxford University Press.

Holbrook, S.J. and R.J. Schmitt. 1997. Settlement patterns and process in a coral reef damselfish: *in situ* nocturnal observations using infrared video. *Proceedings of the VIIIth International Coral Reef Symposiums* **2**: 1143-1148.

Holbrook, S.J., Schmitt, R.J., and J.A. Stephens Jr. 1997. Changes in an assemblage of temperate reef fishes associated with a climate shift. *Ecological Applications* **7**: 1299-1310.

Ambrose, R.F., Schmitt, R.J., and C.W. Osenberg. 1996. Predicted and observed environmental impacts: can we foretell ecological change? Pp. 345-369 in: *Detecting Ecological Impacts: Concepts and Applications in Coastal Habitats*, R.J. Schmitt and C.W. Osenberg, eds. Academic Press, San Diego, CA.

ERIC R.A.N. SMITH
Department of Political Science
University of California
Santa Barbara, CA

Project: *The Role of Knowledge in the Public's Trust in Science about Offshore Oil and Gas Development*

Education:	A.B.	University of California, Berkeley	1975
	M.A.	University of California, Berkeley	1976
	Ph.D.	University of California, Berkeley	1982

Positions:	1990-present	Associate Professor, Department of Political Science, University of California, Santa Barbara
	1986-90	Assistant Professor, Department of Political Science, University of California, Santa Barbara
	1982-86	Assistant Professor, Department of Political Science, Columbia University
	1982	Lecturer in Politics, Brandeis University

Selected Publications:

Smith, Eric R.A.N. 2003. The Role of Knowledge in the Public's Trust in Science about Offshore Oil and Gas Development. MMS OCS Study 2002-0051. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number 14-35-0001-30761. 69 pages.

Smith, E.R.A.N. 2002. *Energy, the Environment, and Public Opinion*. Boulder, CO: Roman & Littlefield.

Smith, E.R.A.N. and R.L. Fox. 2001. The Electoral Fortunes of Women Candidates for Congress. *Political Research Quarterly* **54**: 205-21.

Smith, E.R.A.N., Squire, P., Lindsay, J.M., and C.R. Covington. 2001. *Dynamics of Democracy*, 3rd edition. St. Paul, MN: Atomic Dog.

Smith, E.R.A.N. 2000. Democratic Values vs. Environmentalism? In: *The Culture Wars by Other Means* Richard Ellis and Fred Thompson. University of British Columbia, Centre for Business and Government.

Smith, E.R.A.N. and M. Marquez. 2000. The Other Side of the NIMBY Syndrome. *Society & Natural Resources* **13**: 273-80.

Fox, R.L. and E.R.A.N. Smith. 1998. The role of candidate sex in voter decision-making. *Political Psychology* **19**: 405-419.

Smith, E.R.A.N. 1998. How Political Activists See Offshore Oil Development: An In-depth Investigation of Attitudes on Energy Development. MMS OCS Study 98-0042. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number 14-35-0001-30761. 195 pages.

Smith, ERAN. 1997. Book Review: What Americans know about politics and why it matters, by M.X.D. Carpini, S. Keeter. *Political Science Quarterly* **112**: 314-315.

Smith, E.R.A.N. 1996. Book Review: Public opinion in America - moods, cycles and swings, by J.A. Stimson. *Critical Review* **10**: 95-105.

Smith, E.R.A.N. 1996. Book Review: The changing American mind - how and why American public opinion changed between 1960 and 1988, by W.G. Mayer. *Critical Review* **10**: 95-105.

Smith, E.R.A.N. 1996. Book Review: The rational public - fifty years of trends in American policy preferences, by B. Page and R. Shapiro. *Critical Review* **10**: 95-105.

Smith, E.R.A.N. 1996. Book Review: The two majorities - the issue context of modern American politics, by B.E. Shafer and W.J.M. Claggett. *American Political Science Review* **90**: 438-439.

Squire, P. and E.R.A.N. Smith. 1996. A further examination of challenger quality in Senate elections. *Legislative Studies Quarterly*. **421**: 235-248.

Herrera, R., Epperlein, T., and E.R.A.N. Smith. 1995. The stability of congressional roll-call indexes. *Political Research Quarterly* **48**: 403-416.

Smith, E.R.A.N. and S.R. Garcia. 1995. Evolving California opinion on offshore oil development. *Ocean and Coastal Management* **26**: 41-56.

Squire, P., Smith, E.R.A.N., Lindsay, J. and C. Covington. 1995. *Dynamics of Democracy*. Brown-Bennchmark, Madison, Wisconsin. 596p.

Smith, E.R.A.N. 1992. Changes in the Public's political sophistication. In: *Controversies in Voting Behavior, 3rd edition*, R.G. Niemi and H.F. Weisberg, eds. Congressional Quarterly Press, Washington, D.C. (reprinted from *The Unchanging American Voter*).

Smith, E.R.A.N., Herrera, R., and C.L. Herrera. 1992. Public opinion and congressional representation. *Public Opinion Quarterly* **56**: 185-205.

Smith, E.R.A.N. and P. Squire. 1990. The effects of prestige names in question wording. *Public Opinion Quarterly* **54**: 97-116.

Smith, E.R.A.N., Herrera, R., and C.L. Herrera. 1990. The measurement characteristics of congressional roll call indexes. *Legislative Studies Quarterly* **15**: 283-295.

Smith, E.R.A.N. 1989. *The Unchanging American Voter*. The University of California Press, Berkeley, CA.

Smith, E.R.A.N. and P. Squire. 1988. The effect of partisan information on voters in non-partisan election. *J. Politics* **50**: 169-79.

Smith, E.R.A.N. and P. Squire. 1987. Direct election of the president and the power of the states. *Western Political Quarterly* **40**: 29-44.

Smith, E.R.A.N. and P. Squire. 1987. State and National Politics in the Intermountain West. In: *The Politics of Realignment: Partisan Change in the Intermountain West*. Peter Galderisi *et al*., eds. Westview Press, Boulder, CO.

Smith, E.R.A.N. and P. Squire. 1984. Repeat challengers in congressional elections. *American Politics Quarterly* **12**: 51-70.

Tannenbaue, P., L. Kostrich, E.R.A.N. Smith and M. Berg. 1983. *Turned-on television and turned off voters: Policy options for election projections*. Sage Publications, Beverly Hills, CA.