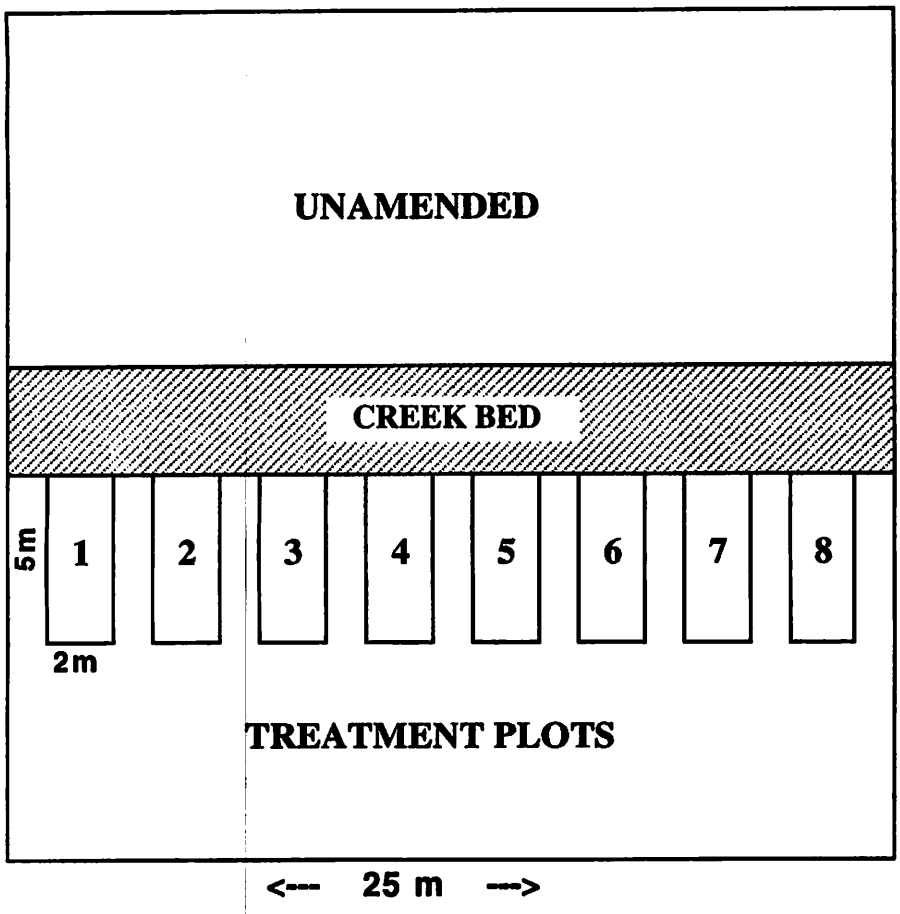

Figure 2. Sample layout of organic amendments within a block at the Crown Point Mitigation Site. The sequence of treatments within each block was randomized so that the sequence is different in each of the six blocks. *Spartina* transplants were from the Northern Wildlife Preserve, Tecolote Creek, and the San Diego River flood-control channel. Ø = no treatment.

mortality, greatest mean stem length, highest number of seed-bearing stems, greatest mean area occupied per plug (an indicator of vegetative spreading), and greatest estimated biomass (all ANOVA results $p < .0001$ $df = 5$). Conversely, blocks F and G were "poor" sites for *S. foliosa* transplants, with highest mortality, minimal seed production, and lowest above-ground biomass.

Soil amendments had some effect on plant mortality when plots within individual blocks were compared; however, between blocks no consistent trends were associated with treatment. Even when blocks of similar soil characteristics were pooled (mud = C, D, and E; sand = A, F, and G), organic treatments had no consistent effect on plant mortality. Total stem height, a nondestructive indication of above-ground plant biomass, was significantly greater ($P = 0.034$, $df = 4$) in the rototilled planted controls than in the nonrototilled planted controls, suggesting that rototilling was beneficial to plant growth. Plants in the kelp and milorganite treatment plots attained the highest total stem height.

No effects of elevation or transplant source were observed in September 1996. The dramatic block effects on the plant parameters are related to spatial variability in the size distribution of soil particles and associated content of organic matter characteristic at the Crown Point site. Regression analyses indicate positive correlation of total stem height (log-transformed September 1996 data) with percentages of silt and clay (<63 µm) and percentage of organic matter (arcsin-transformed April 1996 data; Figures 5A and 5B).

Zostera and *Salicornia* Habitat Recruitment

In an effort to obtain a clearer understanding of the controls on succession in restored habitats, the recruitment of plants and fauna, and changes in sediment properties within the naturally colonized *Zostera* and *Salicornia* habitats were initially monitored in July and August of 1996. *Zostera* vegetated and

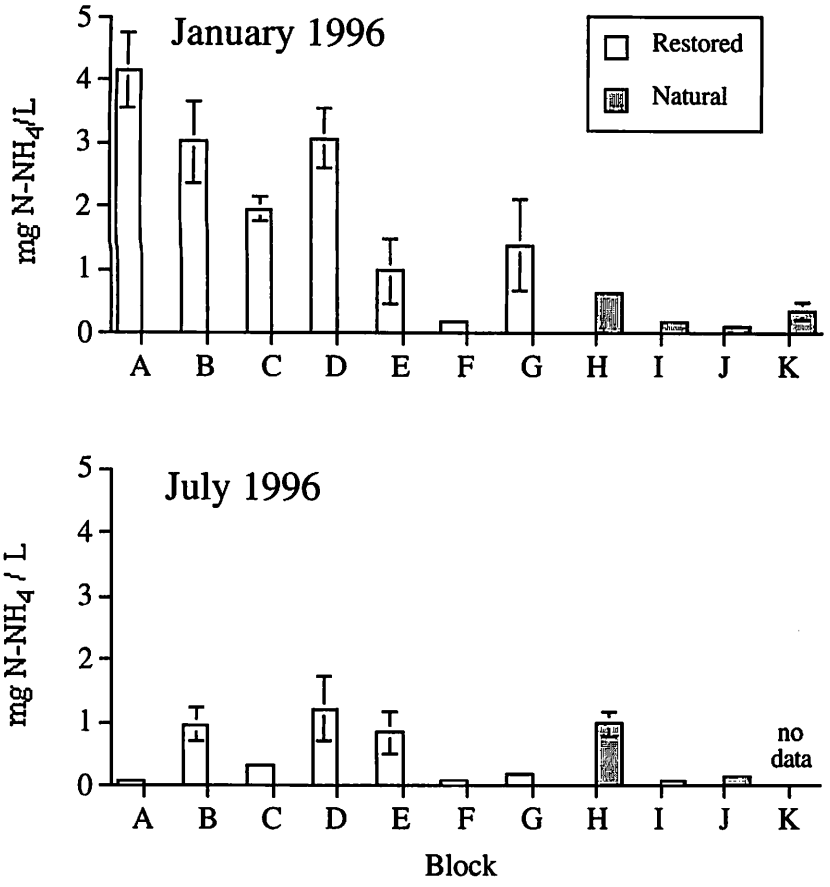

Figure 3. Mean (± SE) ammonium concentration (mg $N\text{-}NH_4/l$) in each plot of the Crown Point Mitigation Site (restored marsh) and the Northern Wildlife Preserve (natural marsh) in January (A) and July (B) 1996. Comparisons of restored vs. natural marshes: A, January 1996: $P = .034$, $t_9 = 2.49$; B, July 1996; $P = .7$, $t_8 = .36$.

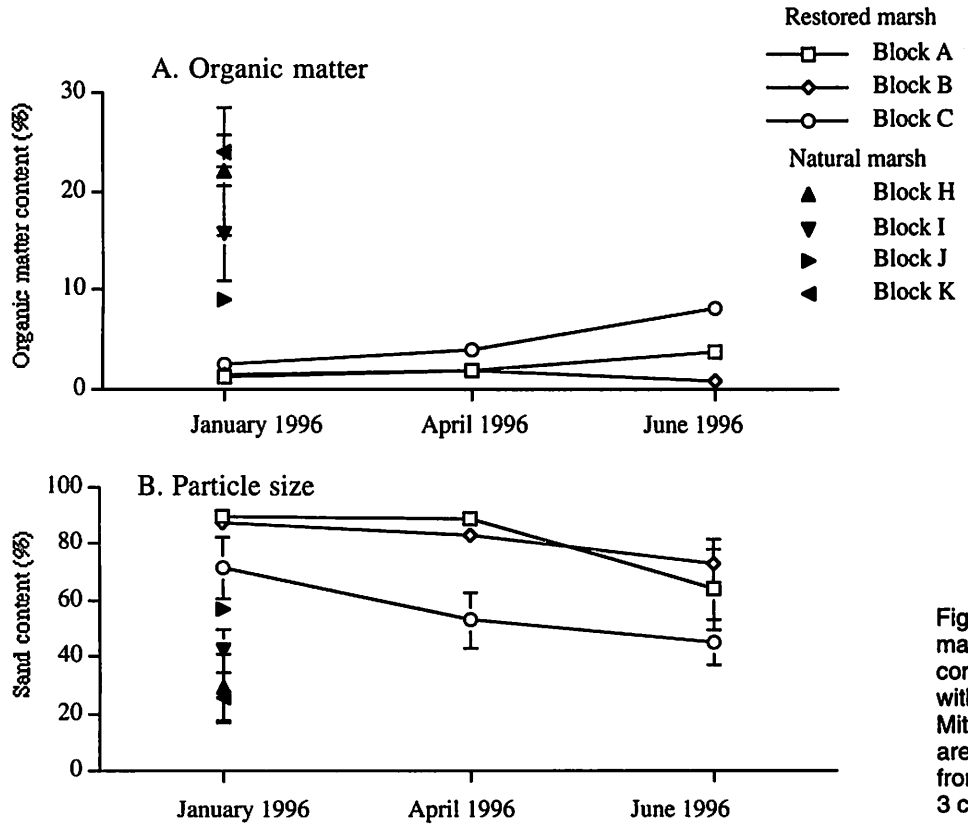

Figure 4. Mean (± SE) percent organic matter content (A) and percent sand content (B) in three blocks (A, B, C) within the restored marsh (Crown Point Mitigation Site). Included for comparison are the four natural marsh blocks (H–K) from the Northern Wildlife Preserve. n = 3 cores 18 cm^2 x 6 cm deep.

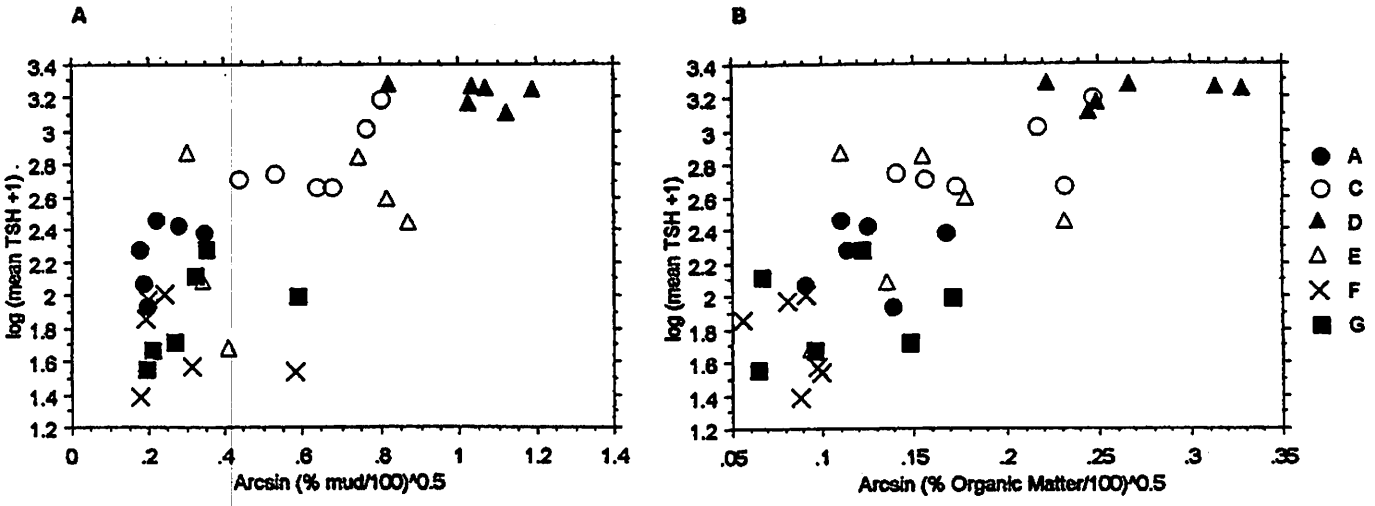

Figure 5. Scattergrams, data split by block: total stem height (TSH) per transplant plug, one mean value for each plot (six per block, log-transformed September 1996 data) against mean percentage of mud (A) defined as silt and clay (arcsin-transformed April 1996 data) and mean percentage of organic matter (B) (arcsin-transformed April 1996 data).

unvegetated low-intertidal habitat, and high-, low- and zero-density *Salicornia* habitats (Figure 1) were sampled for sediment properties, infaunal and epifaunal densities and composition, and vegetation biomass. Although this research will track the succession of these communities as the restored marsh develops, this funding covered only part of the first sampling.

Sediments. Sediments in the restored *Zostera* and *Salicornia* habitats tended to have lower amounts of organic matter and coarser particles than those in the natural areas. Salinities were lower and less variable in vegetated than in unvegetated areas. In the restored *Salicornia* marsh, salinity increased with decreased plant cover (66 ± 7 parts per thousand [ppt] in the high-, 77 ± 6 ppt in the low-, and 87 ± 8 ppt in the zero-density habitats). Plant densities were similar or slightly lower in the restored marsh than in the natural marsh, and overall plant cover was much more extensive (large, contiguous patches) in the natural than in the restored marsh.

Epifauna and biogenic structures. Epifauna and biogenic structures were surveyed in the *Salicornia* areas. No epifauna were found in the restored marsh, and only *Cerithidea californica* (California horn snail) were found in the natural marsh. *Cerithidea* densities were highest in the low-density *Salicornia* area and lowest in the unvegetated area. Grapsid crab burrows were observed in the natural marsh only, and we found no relationship to plant densities. Smaller burrows (0.2–1 cm in diameter) were on average higher and more variable in the restored marsh than in the natural marsh. Insects were observed in some of the burrows of both marshes, and juvenile crabs were also observed in the natural marsh burrows.

Macrofauna. Species richness normalized to number of individuals (rarefaction analysis) was higher in the vegetated *Zostera* habitats than in the unvegetated habitats, and the natural area had higher species richness than did the restored area (Figure 6A). These results are expected on the basis of the literature (Orth, 1977; Homziak et al., 1982). The opposite was true of the natural and restored *Salicornia* habitats, where species richness decreased with increased plant density, and the natural marsh had similar (low- and high-density areas) or lower (unvegetated area) richness than did the restored area (Figure 6B). Again, this finding is contrary to what has been reported in the literature for salt marsh plants (Lana and Guiss, 1992).

Macrofaunal densities were similar or higher in the natural marsh habitats than in the restored habitats. In the natural *Zostera* habitat, densities were higher in the unvegetated areas than in the vegetated areas. The opposite was true of the restored area, where higher macrofaunal densities were found in the vegetated areas (Figure 6C). Similarly, the highest densities in the natural *Salicornia* habitat were found in the high-density plant areas (Figure 6D). This trend of higher faunal densities being associated with vegetation follows what is reported in the literature (Orth, 1977; Lana and Guiss, 1992). All macrofaunal densities in the restored *Salicornia* area were similar and low (0.5 ± 0.2 to 0.6 ± 0.4 individuals per 18-cm^2 core; Figure 6D).

The natural marsh had higher numbers and proportions of oligochaetes than did the restored marsh in both the *Zostera* and *Salicornia* habitats. Tubificid oligochaetes dominated the natural *Zostera* habitat, whereas enchytraeid and tubificid oligochaetes dominated the natural *Salicornia* habitat. This difference probably occured because

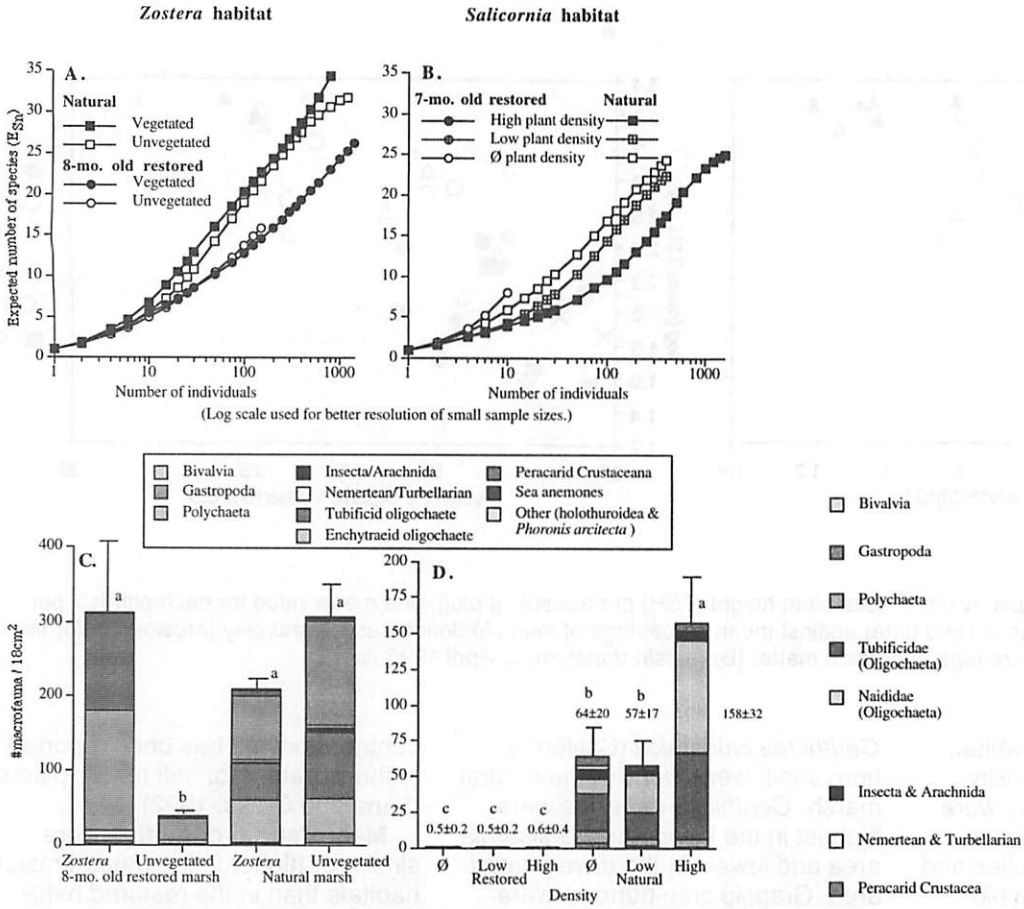

Figure 6. Species richness expressed with rarefaction curves (A and B) and mean ± SE density of macrofauna (C and D) from the *Zostera*-vegetated and unvegetated (A and C) and *Salicornia* high-, low-, and zero-density (B and D) restored and natural areas in Mission Bay. Species richness data are pooled from 18-cm^2 cores taken within each area during July and August 1996. n = 5 *Zostera* habitat, n = 15 restored zero- and low-density, n = 5 restored high-density, and n = 10 natural *Salicornia* marsh cores taken within the *Salicornia* habitat. Different letters indicate significance *a posteriori t* test, $P = .05$.

oligochaetes are direct developers and therefore slow to disperse. Pera-carid crustaceans are also direct developers, yet they accounted for a large percentage of the restored marsh fauna. They were probably recruited as adults by rafting in to the restored marsh on their own or on clumps of algae or plant material. Anemones were the other dominant macrofauna in the restored marsh. The patches of *Zostera* provided substrate for the anemones in a creek that is submerged most of the time. Anemones, peracarid crustaceans, and the exotic mussel, *Musculista senhousia*, were all observed on clumps of algae floating in the restored marsh creek.

Major Conclusions

Major conclusions are as follows:

1. Variations in elevation and soil properties inherent to the site (rather than manipulations by restorers) control growth and survival of transplanted *Spartina*.
2. The success of vascular plant vegetation may eventually influence both soil parameters and development of faunal assemblages.
3. After 9 months, the restored and natural marshes showed differences in soil, vegetation and faunal parameters.

Accomplishments and Benefits

This funding supported the collection, processing and data collation of the April 1996 sediment samples and partial collection of infaunal, epifaunal, vegetation, and other sediment data from the Crown Point Mitigation Site and adjacent Northern Wildlife Preserve during June, September, and December 1996. These collections have provided data essential to all researchers and students at the University of California, San Diego. Results will be incorporated into four graduate student research projects and provided preliminary information for a research proposal subsequently funded by Sea Grant.

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Culture of Black Abalone, *Haliotis cracherodii*, for Pathologic, Aquaculture, and Restoration Studies

Humboldt State University
R/F-7PD
1996–97

Timothy J. Mulligan, Helen L.Mulligan, Susan McBride, and Patricia Clinton

Black abalone, *Haliotis cracherodii*, are one of six seasonally spawning species of abalone found along the California coast (Hahn, 1989). They inhabit rocky intertidal areas from Baja California, Mexico to southern Oregon (Cox, 1962). The spawning season has been well documented for populations from Pacific Grove (Boolootian et al., 1962), Point Dume (Leighton and Boolootian, 1963) and Monterey, California (Webber and Geise, 1969). These studies indicate that *H. cracherodii* is a strongly seasonal spawner, with reproduction occurring between June and December. Black abalone for this study were collected during July 1996 from Año Nuevo Island, San Mateo County, California, approximately 60 miles north of the northern most population previously studied, and in September 1996, from Sobranes Point, Monterey County, California.

Gravid adults were detected by using a visual, macroscopic gonad index (Ebert and Houk, 1984; Uki and Kikuchi, 1984). Visual gonadal indexing is a subjective process in which gonads are examined by pushing the foot of the abalone away from the right side of the shell and exposing the conical gonad. The criteria used to establish the gonad index values were as follows:

0: Undeveloped. Sex cannot be determined.

1: Immature. Patches of gametogenic material visible, usually as strands of color over parts of the digestive gland.

2: Mature. Entire digestive gland covered by a sheath of gametogenic material but the gonad does not extend beyond the shell and is not rounded at the apex.

3: Ripe. As in criterion 2 but the gonad extends beyond the shell and the apex is rounded.

Gonads of female *H. cracherodii* are a bright, blue-green or green; males have yellow or cream-colored testes. Because of the limited number of *H. cracherodii* we were permitted to collect, visual determination of the reproductive condition was the sole method used during this project. This visual method has limitations, because the gametogenic material may form a thin layer around a large digestive gland or a thick layer around a small digestive gland (Hahn, 1981). Given this limitation, we attempted to choose *H. cracherodii* most suitable for spawn induction.

Between June 2 and June 4, 1996, we examined 26 *H. cracherodii* at Sobranes Point and Año Nuevo Island. Four females were mature (Table 1). During July 1996, two collecting trips were made to Año Nuevo Island, one on July 2 and one on July 30. A total of 20 adult *H. cracherodii* were collected and transported to the Humboldt State University Telonicher Marine Laboratory in Trinidad, California. One of the 10 females was mature; 9 were immature. Five of the males were mature. This finding was not a dramatic change from observations in June, but on the basis of historical data on the strong seasonal spawning cycle of *H. cracherodii*, we expected the abalone to become more gravid under laboratory conditions. In September 1996 and February 1997, an additional 120 *H. cracherodii* were collected at Sobranes Point, Monterey, California.

Male and female abalone were separated into four tanks. One group of each sex was held in ambient, flowing seawater at 10–15° C and another in heated seawater at 15–16° C. Algal foods were continually available to all animals.

We completed 18 spawn inductions between September 1996 and November 1997 (Table 2). The first two spawn trials were done with red abalone, *H. rufescens*, a species routinely spawned at the Telonicher Marine Laboratory for bioassy tests and mariculture classes. Larvae were successfully cultured and settled. Throughout the experiments, *H. rufescens* was used as a control to ensure that procedures

Table 1. Reproduction of *Hallotis cracherodii* visually examined at Sobranes Point, Año Nuevo Island, and Pigeon Point at low tides between June 2 and June 4, 1996

Location	Females		Males		Shell Length	
	Gonad Index	No.	Gonad Index	No.	Mean	SD
Sobranes Point	2 1	4 4	1	7	56.0	14
Año Nuevo Island	1	5	1	5	124.6	20.4
Pigeon Point	2	2	1	2	132.0	7.9

Note: Gonad index was subjectively determined and classified into four levels (0–3; see text for details).

Table 2. Spawn induction of *Haliotis cracherodii* September 1996–November 1997

Spawn No.	Date	Species	Method	No. of Males	No. of Females	Dessication	Start Time	Spawn Time	Temperature (°C)	Duration (h)
1:96	September 10	HR	1	2	2	1 h	0840	1110 (M)	15	3
2:96	September 20	HR	2	2	2	1 h	0825	1030 (M) 1130 (F)	17	3.5
3:96	October 1	HC	2	2	2	2 h	0810	Unsuccessful	19	22
4:96	October 7	HC	3	2	3	6	2350	Unsuccessful	18	12
		HR		2	4	1		Unsuccessful		12
5:96	October 11	HC	3	3	0	25 min	0755	Unsuccessful	18	9
6:96	October 14	HC	4	2	0	3 h	0803	1345 (F)	17	7
		HR		2	0	1 h	0803	1100(M)	17	7
7:96	October 18	HC	4	2	3	3 h	0800	Unsuccessful	—	6
		HR		1	2	1 h	0800	1100 (M)	15	6
8:96	October 25	HC	4	2	4	1 h	0800	1330 (M)	19	6.5
							1100	1419 (F)	19	6.5
		HR		2	2	1 h	0800	1100 (M and F)	15	6.5
9:96	October 26	HC	4	2	3	3 h	0830	1300 (F)	16	4.5
							0830	1135 (F)	17	4.5
10:96	October 29	HC	4	2	4	3 h	0855	Unsuccessful	16	6
		HR		3	0	1 h	0855	1205 (M)		6
11:96	November 1	HC	4	2	1	None	0850	1519 (F)	15	7
		HR		2	1	None	0850	Unsuccessful		7
12:96	November 30	HC	4	2	3	None	0930	Unsuccessful		7
		HR		2	1	None	1230	1600 (M)	15	7
1:97	January 25	HC	4	1	1	6 h	1605	Unsuccessful		32.5
		HC		1	1	12 h	2205	Unsuccessful		32.5
		HR		2	0	None	1905	2220	15	?
2:97	January 31	HC	4	1	1	18 h	0750	Unsuccessful		38
		HC		0	1	None	0745	1400 (F)	17	38
3:97	March 19	HC	4	4	3	None	0840	Unsuccessful	17	6
4:97	September 13	HC	3	6	6	1 h	0730	1420 (F)	18	3
		HR		2	2			1100 (M,F)		
5:97	September 20	HC	4	5	5	1 h	0900	Unsuccessful	19	6
		HR		2	2			1200 (M,F)		
6:97	November 9	HC	5	5	5	None	1030	Unsuccessful	22	2.5

Note: Methods include 1, hydrogen perioxide buffered with TRIS plus flow through ultraviolet-irradiated seawater; 2, hydrogen peroxide plus TRIS; 3, ultraviolet-irradiated seawater at 180–200 ml/min; 4, ultraviolet-irradiated seawater at 80–120 ml/min; 5, heated seawater at 22 °C. HR = *Halitotis rufescens;* HC = *Haliotis cracherodii*; M = male; F = female.

used for spawn induction were functioning correctly.

No synchronous spawns of *H. cracherodii* were achieved. We postulate that (1) the abalone from Año Nuevo Island may have reached reproductive condition and spawned between July 2 and July 30, 1996; (2) this population of large *H. cracherodii* may require more than 1 year to become reproductively mature; and (3) transport and husbandry of the *H. cracherodii* may have interrupted gonadal development. We do not know if the first postulated event occurred. Histologic examination of the gonads would have been necessary to determine if the abalone were spent or were still increasing in gamete production. Regarding the second posulated event, nonspawning populations of *H. rufescens* (Young and DeMartini, 1970), *H. iris* and *H. australis* (Poore, 1973), and *H. midae* (Newman, 1967) have been found. In these populations, little or no change in gonad index was seen during sampling periods of 2 years, indicating that the two groups of *H. cracherodii* may have been collected during a nonspawning year. As for the third posulated event, the abalone adapted to the laboratory conditions quickly. After approximately 1 week, they were feeding heavily on *Laminaria farlowii, Alaria marginata, Gigartina* spp., *Iridea* spp., and *Nereocystis luetkeana*. The abalone were fed in excess throughout the experiment. However, between December and February, only *N. luetkeana* was available for feed. The gametogenic cycle may have been interrupted, but feeding and growth continued (Table 3).

On one occasion, October 25, 1996, a male and a female *H. cracherodii* spawned. However, the male released sperm 1.5 hours after the eggs had been broadcast, and subsequent fertilization was not successful. Research has shown that fertilization rates in *H. rufescens* and *H. discus hannai* decrease from greater than 90% to less than 20% within 2 hours after release (Ebert and Hamilton, 1983; Uki and Kikuchi, 1984).

On three occasions, including spawn 8:96 (Table 2), female *H. cracherodii* released eggs. Eggs were measured by using a micrometer. Egg diameter was 180–190 μm, slightly smaller than eggs of *H. rufescens, H. iris, H. discus, H. sieboldi*, and *H. gigantea* but similar in size to eggs of *H. tuberculata, H. rubra, H. sorenseni*, and *H. canariensis* (Harrison and Grant, 1971; Leighton, 1974; Ino, 1966; Hiyashi, 1980; Pena, 1986).

Individual *H. cracherodii* that were successfully induced to spawn responded to ultraviolet-irradiated seawater flowing at 80–120 ml/min for 6.5–7 hours at 15–17° C. In our experiments, *H. cracherodii* did not respond to the hydrogen peroxide method of spawn induction commonly used successfully with several other abalone species, including *H. rufescens, H. fulgens, H. corrugata, H. tuberculata, H. iris,* and *H. canariensis* (Hiyashi, 1980; Leighton and Lewis, 1982; Pena, 1986: Tong et al., 1987).

Artificial spawn induction was the first step in attempting to culture *H. cracherodii*. Induction of spawning is not completely understood, and several exogenous and endogenous factors have been proposed for its control. They include temperature change, exposure to air, photoperiod, lunar cycle, release of gametes from other abalone, and some combination of these (Boolootian et al., 1962; Giorgi and DeMartini, 1977; Morse, 1984).

Because there is no published scientific literature on spawn induction or culture of *H. cracherodii*, and because ours is the first study we know of that attempts to develop methods for culturing black abalone, we suggest the following protocol for broodstock conditioning and spawn induction of *H. cracherodii*:

1. Test photoperiod over a 1-year period: natural, long day length, short day length.
2. Test recently developed, prepared diets and algal diets as a method of improving reproductive condition.
3. Hold abalone outdoors as well as indoors to determine if lunar cycles influence gametogenesis or spawn induction.
4. Record barometric pressure daily.
5. Replicate tidal cycles in the *H. cracherodii* tanks.

With our current black abalone population at the marine laboratory, we plan to continue broodstock conditioning and spawn induction through the summer of 1997. The black abalone have adjusted to laboratory conditions, feed consistently, and are healthy. However, the mechanisms that regulate gametogenesis are one of the most important aspects in the culture of any organism. At this point we do not understand and we cannot control the reproductive development of *H. cracherodii* in our laboratory. Further refinements of our system and tests of photoperiod and diet combined with replication of tidal cycles may yield a procedure to complete the reproductive cycle of *H. cracherodii* under controlled laboratory conditions. Our experience with *H. cracherodii* indicate

Table 3. Length and weight of *Haliotis cracherodii* collected from Año Nuevo Island, San Mateo County, and Sobranes Point, Monterey County, California

Date	Site	Shell Length (mm)	Whole Live Weight (g)	Sample Size
September 26, 1996	SB	52.4 ± 9.1	23.7 ± 17.5	10
March 19, 1997	SB	56.4 ± 9.6	29.7 ± 12.5	10
July 30, 1996	ANI	126.7 ± 16.0	470 ± 177	20
July 30, 1997	ANI	129.9 ± 12.8	529 ± 202	19

Note: SB = Sobranes Point; ANI = Año Nuevo Island.

that this species can be added to the list of haliotids from around the world that do not spawn each year and may also have considerable variablility of spawning periods among sites.

Accomplishments

Three successful spawnings of black abalone occurred with one of our defined spawn induction methods. We have determined the time required (6.5–7 hours), temperature (15–17° C), and flow rate (80–120 ml/min) of seawater past three ultraviolet bulbs that will successfully induce black abalone to spawn.

Patty Clinton, the Sea Grant trainee, was successful in the husbandry of the black abalone broodstock. Abalone were fed brown and red macroalgae.

Benefits

The director of the Año Nuevo State Reserve permitted collection of black abalone on Año Nuevo Island. He was provided with length and weight data of all abalone, information important to the reserve. California Department of Fish and Game shellfish pathologist, Dr. C. Friedman, supported this work. She will benefit if we are successful in spawn induction and larval rearing of black abalone in the extended project period. All black abalone from this project were provided to Dr. Friedman for her pathological research.

Cooperating Organizations

Año Nuevo State Reserve
California Department of Fish and Game
California Sea Grant Extension Service
Eureka Oxygen
Humboldt State University
Point Reyes Bird Observatory

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Regulation of Gonadal Maturation in Penaeid Shrimp

California State University, Fresno
R/A-1PD
1995–96

Brian Tsukimura

Shrimp aquaculture is hampered by lack of information on the basic physiology of gonadal development and by the inability to regulate the production of viable eggs. In this project, we addressed regulation of the synthesis of yolk protein in shrimp and developed an enzyme-linked immunosorbent assay (ELISA) and a Western blot procedure to quantitate levels of hemolymph in yolk proteins. These tests were used to assay potentially biologically active compounds that stimulate synthesis of yolk protein. The penaeoidean shrimp *Sicyonia ingentis* is an excellent model for studies of the main physiologic regulatory mechanisms of vitellogenesis. Much of the reproductive cycle of *S. ingentis* had been defined before this study (see review by Clark et al., 1991).

During this funding period, we characterized the *S. ingentis* yolk protein vitellin. In column chromatography studies, vitellin eluted as a 322-kD protein. In other studies, we found that vitellin is composed of three major subunits with molecular weights of 182, 91, and 85 kD (Bender and Tsukimura, unpublished findings). Molecular weights for vitellin from other shrimp have been described. The sizes of vitellin for *Penaeus vannamei* and *P. semisulcatus* are 289 kD and 283 kD, respectively (Tom et al., 1992). Larger vitellins have been found in *P. japonicus* (500 kD, Vazquez-Boucard and Ceccaldi, 1986) and *P. monodon* (492 kD, Chang et al., 1993). The size of *S. ingentis* vitellin is within the range of molecular weights found in other Penaeoidae. Preliminary examination of vitellogenin, the hemolymph-borne precursor of vitel-lin, indicates that vitellogenin separates differently on gel electrophoresis. It is well established that vitellogenin and vitellin from many crustaceans have similar electrophoretic and immunologic properties (Kerr, 1969; Fyffe and O'Conner, 1974; Croisille et al., 1974). Thus, we can detect vitellogenin in hemo-lymph by using antibodies to vitellin (Bender, 1996).

The isolated and purified vitellin of *S. ingentis* was used to prepare an antibody to the protein. Western blot assays showed that the antibody binds only to vitellin bands under native and denaturing conditions. A single band was immunoreactive in hemolymph that corresponded to the 322-kD protein vitellogenin. No immunoreactivity was detected in males.

The antibody to vitellin was also used to develop a two-step ELISA, which we used to measure the levels of vitellogenin in hemolymph (Bender and Tsukimura, 1995). Briefly, with this assay, we can detect vitellin at concentrations of 0.3–300 ng (Figure 1). We found that when the competition reaction occurred in separate tubes, rather than in the ELISA plate wells, the sensitivity of the assay was at least 10-fold higher.

To characterize the ELISA, we used serial dilutions (1:50–1:3200) of hemolymph from reproductively active females. The results confirmed the large range of concentrations that can be detected with the ELISA (Figure 2). Serial dilutions (1:50–1:3200) of hemolymph from males showed no changes in optical density, suggesting the absence of immunoreactive material in these samples (Figure 2). With this assay, we can measure low levels of vitellogenin in hemolymph and use quantities as low as 10 ml of hemolymph.

To verify that the ELISA was insensitive to changes in hemolymph concentrations, we used serial

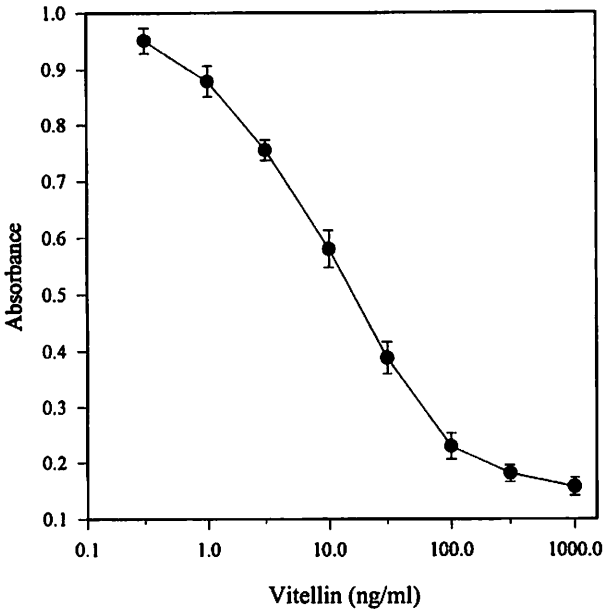

Figure 1. Enzyme-linked immunosorbent assay standard curve of vitellin from *Sicyonia ingentis*. The effective range of this assay is 0.3–300 ng.

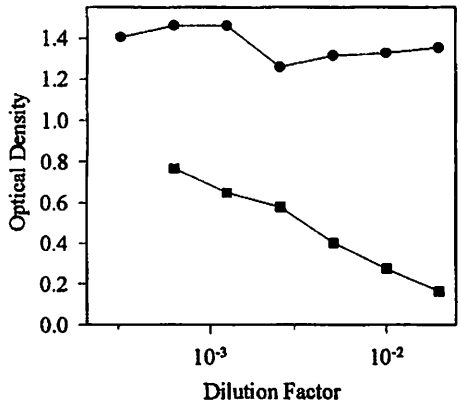

Figure 2. Enzyme-linked immunosorbent assays of serial dilutions of hemolymph from male (●—●) and female (■—■) *Sicyonia ingentis*.

dilutions (1:50–1:25,600) of vitellogenin (from reproductively active females). Hemolymph from males was added to each competition reaction to maintain hemolymph concentrations at a 1:50 dilution. The values obtained with this dilution set indicated that hemolymph components do not interfere with the competition reaction (Figure 3).

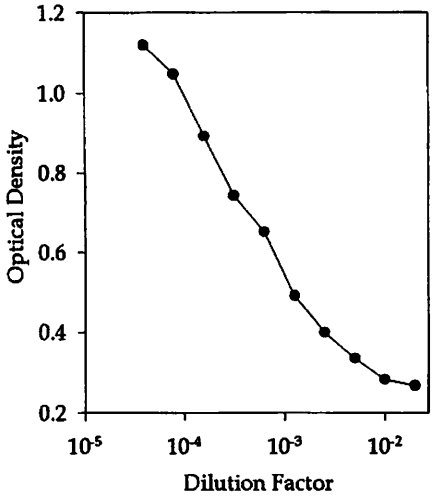

Figure 3. Enzyme-linked immunosorbent assays of serial dilution of hemolymph from vitellogenic female *Sicyonia ingentis*. The concentration of hemolymph was kept constant by adding hemolymph from males.

During the reproductively inactive period (December through June), we used the ELISA to monitor levels of vitellogenin in sexually quiescent females exposed to summer daylight conditions (14 hours of light and 10 hours of dark). These animals were housed in light chambers at the Bodega Marine Laboratory (courtesy of Dr. E. Chang). Over 11 days, levels of vitellogenin in females remained undetectable in four animals and slowly increased to more than 2 mg/ml in two others (Figure 4a).

A number of studies have attempted to determine hormones and other biological compounds that stimulate vitellogenesis in various decapod crustaceans. These data suggest that the stimulatory effects of biological compounds are, at best, inconsistent among the various decapods. Unfortunately, the primary bioassay used in many of the early studies was spawning. This type of bioassay makes it difficult to determine whether the injected compound affects the organism directly or indirectly. Thus, success in determining effective biological compounds has been limited. Discovery of vertebrate-type steroids in many invertebrates prompted investigators to inject steroids into shrimp to ascertain the effects of these compounds. For example, in vitro incubations with 17b-estradiol modestly stimulated synthesis of yolk protein (Quackenbush, 1992) but had no effect on the diameter of oocytes (Tsukimura and Kamemoto, 1991). Injections of 17b-estradiol into *P. esculatus* (Koskela et al., 1992), *S. ingentis* (Figure 4b), or the lobster *Homarus americanus* (Tsukimura et al., unpublished findings) had no effect.

Injections of progesterone into penaeid shrimp produced spawning in various penaeid species (Kulkarni et al., 1979; Yano, 1985). Similarly, in vitro treatment with progesterone stimulated yolk synthesis (Quackenbush, 1992). However, injections of progesterone had no effect in sexually quiescent *S. ingentis* (Figure 4c) or in female *H. americanus* (Tsukimura et al., unpublished findings).

Additionally, in vitro application of progesterone had no effect on the diameter of oocytes (Tsukimura and Kamemoto, 1991). Injections of 17α-hydroxyprogesterone stimulated vitellogenesis (Nagabhushanam et al., 1980; Yano, 1987), and in vitro incubations with this steroid significantly increased oocyte diameters (Tsukimura and Kamemoto, 1991). However, no change in oocyte diameter or ovarian index was observed with injections into *P. esculentus* (Koskela et al., 1992). Similarly, injections of 17α-hydroxyprogesterone had no effect on the hemolymph levels of vitellogenin in the lobster *H. americanus* (Tsukimura et al., unpublished findings). Thus, the role of vertebrate steroids in the vitellogenesis of decapod crustaceans remains unclear. Our initial study examined the effect of injections of steroid hormones on sexually quiescent female *S. ingentis* (Bender and Tsukimura, unpublished findings). The discrepancies between the results of these studies may be explained by the different maturation stages of the oocytes used in each study.

Accomplishments

We characterized the yolk protein vitellin of *S. ingentis*. We created an antibody to vitellin and used the antibody to develop an ELISA that can be used to detect yolk proteins in the hemolymph of *S. ingentis*. This ELISA can now be used to assay a variety of biological compounds that may increase the rate of synthesis of yolk protein.

Benefits

Dr. Mark Snyder, University of California, Davis, has requested the use of our antibody to vitellin to study *S. ingentis*. Our laboratory will continue to use the ELISA to assay the effects of biological and pharmacologic compounds on the synthesis of yolk proteins in shrimp. The antibody can also be used to screen cDNA libraries for the mRNA sequences that encode for the yolk protein precursor, vitellogenin.

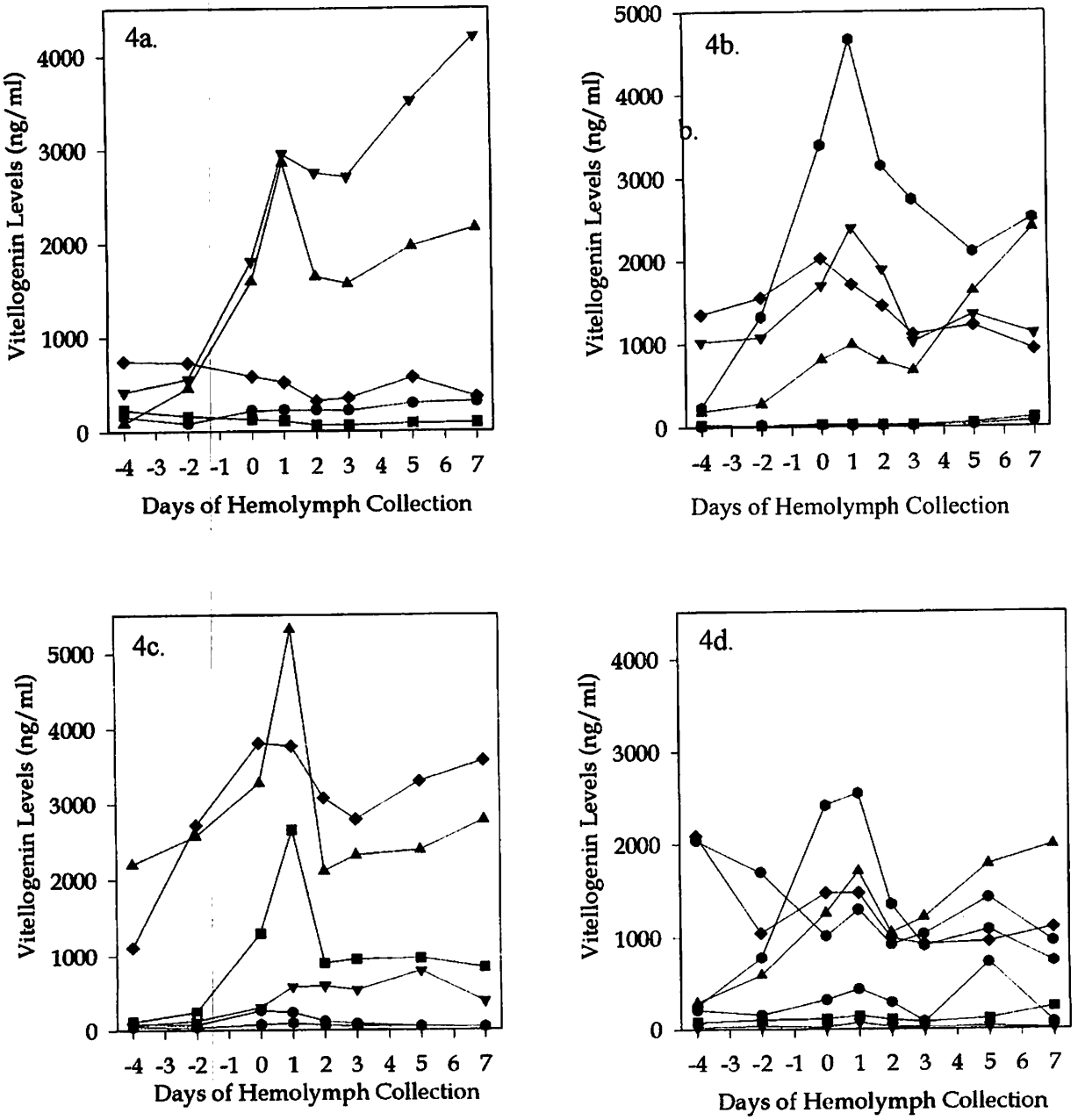

Figure 4. Concentrations of vitellogenin in hemolymph from *Sicyonia ingentis*. Each symbol represents a different animal in each treatment group: a, controls; b, estradiol; c, progesterone; d, 17α-hydroxyprogesterone. 1 microgram of each compound was injected into the ventral sinus of females on days 0, 1, and 2. Controls received saline injections.

Cooperating Organizations
Bodega Marine Laboratory

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Abstract

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Distribution, Diet, and Species Interaction of the Green Crab, *Carcinus maenas*, in Humboldt Bay, California

Humboldt State University
R/F-9PD
1996

David G. Hankin

Exotic species, introduced through ballast water into bays and estuaries in the United States, have caused substantial alteration of native estuarine fauna throughout the country. One such invading species is the European green crab, *Carcinus maenas*. The green crab has become established in San Francisco, Tomales, and Bodega bays (Cohen et al., 1995; Grosholz and Ruiz, 1995) and in June 1995 was found in Humboldt Bay (by Sea Grant trainee T. Miller). The green crab is a voracious predator with a broad diet, with an emphasis on bivalve mollusks, polychaetes, and small crustaceans. Introduced populations are thought to be responsible for substantial declines in the abundance of bivalves, including some of commercial importance. *Cancer* crabs constitute a large part of green crab's diet (Ropes, 1968; Elner, 1981), and in laboratory studies green crabs have consumed Dungeness crabs up to the size of the green crabs (Grosholz and Ruiz, 1995). The green crab may have adverse predatory effects on at least the following important fishery resources of the northern arm of Humboldt Bay, Arcata Bay: (1) juvenile oysters (*Crassostera gigas*) reared by commercial on-bottom culture; (2) juvenile rock crabs (several species of *Cancer*), which reside in large numbers on oyster beds; and (3) juvenile Dungeness crabs (*Cancer magister*).

In view of the apparent impact of green crabs on other native benthic communities, we proposed to study the extent of green crab colonization in Arcata Bay, the northern limit of their current western North American range. Our overall project goals were to (1) establish the extent of distribution of green crabs by studying their occurrence, sex and size frequency, and reproductive success and (2) study interspecific interactions between green crabs and native *Cancer* species of Arcata Bay by analyzing their stomach contents and by conducting laboratory feeding experiments with oyster seed with all species to determine feeding rates and critical prey size.

We did field sampling designed to assess distribution of green crab in Arcata Bay for the period June through September 1996. With cooperation from Coast Seafoods, Eureka, California, we set and pulled 50 modified minnow traps and 6 collapsible lobster traps along with 150–200 Coast Seafoods crab traps in selected sites with newly planted oyster seeds (Figure 1). The oyster beds that were sampled are divided into five separate regions within Arcata Bay: Bird Island, Sand Island, Gunther Island, East Bay, and Mad River Slough. On each of the five sampling occasions, all traps were baited with various rock fish or flatfish carcasses and allowed to soak for at least 48 hours before retrieval.

Crab species found inside the traps were identified, measured, and sexed for all minnow and lobster traps and for one Coast Seafoods crab trap for every bed sampled (Table 1). No green crabs were captured on the sampling dates, and none were reported seen in the traps of Coast Seafoods on the company's weekly trapping excursions. With the lack of green crab samples on the oyster beds of Arcata Bay, we set modified minnow traps and sampled by foot several locations around Mad River Slough. Searching along riprap yielded three molt casts of green crab (August 9 and 12, 1996), but no live specimens were collected.

We proposed to analyze stomach contents to determine predation on oysters and assess dietary overlap between the green crab and native *Cancer* species. Stomach analyses were not done on any crabs because of the lack of green crab samples. Laboratory feeding experiments proposed to determine feeding rates and critical oyster size were also not done because no green crab samples were available.

Benefits

Amy Gibson and Joe Ysselstein, seniors in the Department of Biology, Humboldt State University, used parts of the methods, traps, and sampling locations proposed in the study for conducting their senior project.

Cooperating Organizations

Coast Seafoods, Inc., Eureka, California
California Sea Grant Marine Advisory Extension Service, Eureka, California

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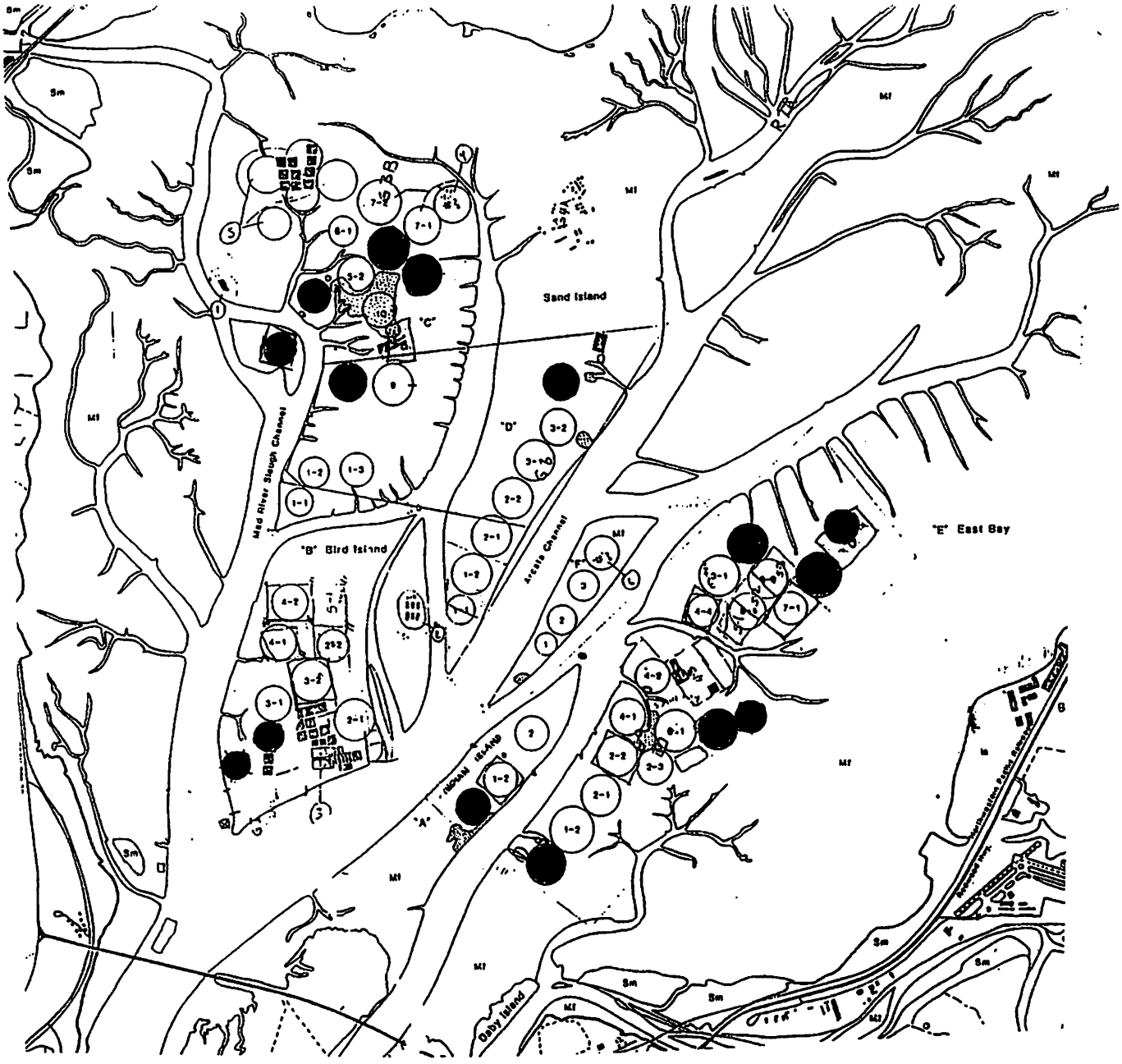

Figure 1. Map of Coast Seafoods' oyster beds and selected sites with newly (within 1 year) planted oyster seeds within Arcata Bay, Humboldt Bay.

Table 1. Sampling Information on Crab Species Found Inside Traps June Through September 1996

Date	Sampling Sites Within Arcata Bay	No. of Traps	No. and Carapace Width (mm)			
			Brown Rock Crab (*Cancer antennarius*)		Red Rock Crab (*Cancer productus*)	
			Male	Female	Male	Female
6/21/96	Bird Island	2	7 (64.0–85.3)	1 (107.6)	10 (88.7–145.0)	2 (102.4–121.0)
	Sand Island	3	2 (79.0–85.8)	1 (80.2)	5 (68.6–124.2)	1 (53.0)
	Gunther Island	1			4 (113.0–146.7)	3 (83.8–89.0)
	East Bay	6	2 (67.3–67.7)	5 (63.5–69.7)	16 (96.0–134.3)	2 (53.0–137.1)
	Mad River Slough	12	9 (58.3–82.0)	7 (50.3–68.8)	9 (50.4–120.5)	1 (73.9)
7/5/96	Bird Island	1			2 (83.6–109.2)	2 (78.2–89.5)
	Sand Island	1	2 (69.4–96.0)			
	Gunther Island	3			10 (50.8–127.4)	
	East Bay	4	15 (67.0–81.8)	5 (58.0–73.0)	19 (66.2–165.7)	5 (71.0–134.3)
	Mad River Slough	5	6 (63.0–88.0)	2 (60.4–63.0)	15 (56.8–131.5)	2 (63.2–65.8)
7/26/96	Sand Island	1			1 (59.0)	
	Gunther Island	1	4 (75.7–89.8)	2 (56.2–81.0)	9 (88.8–148.3)	
	East Bay	8	8 (46.0–87.4)	16 (56.2–81.0)	15 (66.2–97.2)	1 (66.6)
	Mad River Slough	9	17 (50.7–92.7)	9 (51.0–75.2)	19 (60.8–112.7)	5 (58.6–75.9)
8/16/96	Bird Island	1				1 (78.4)
	Gunther Island	1			1 (122.2)	
	East Bay	6	3 (64.2–74.3)		14 (72.0–103.7)	4 (60.5–117.3)
	Mad River Slough	1			2 (46.1–59.7)	
9/27/96	Bird Island	1	1 (73.9)		1 (68.2)	
	Sand Island	2	1 (58.6)		1 (67.8)	
	East Bay	3	5 (74.5–83.0)	1 (51.0)	3 (63.0–118.2)	4 (86.4–93.3)
	Mad River Slough	6	3 (33.4–73.4)	2 (50.2–74.7)	5 (63.0–103.8)	

Genetic Analysis of Year-Class Formation in Shortbelly Rockfish, *Sebastes jordani*

San Francisco State University
R/F-23-3PD
1994–95

Ralph J. Larson, Cristián Orrego, and Richard W. Julian

Marine populations are typically affected by the vagaries of larval survival. However, although the effects of such factors as food and drift on larval survival have been widely addressed, the spatial and temporal features of year-class formation are not yet clearly understood. Is a good year class the result of good survival among all the progeny produced in a reproductive season, and a poor year class the result of poor survival among all the progeny? Or is the survival of progeny produced at different times and places unequal, complicating the relationship between environmental conditions and year-class strength? The issue of spatial and temporal variation in larval survival is not new. For example, Lasker (1978) showed that spatial patchiness in the food supply can influence larval survival, and Cushing (1975, 1982) introduced the concept of temporal match-mismatch of reproduction with appropriate environmental conditions for larval survival. Recently, genetic data have also suggested that spatial and temporal variation can influence both year-class strength and population structure.

Although many marine populations are characterized by genetic homogeneity on macrogeographic scales of 10s to 100s of kilometers (Winans, 1980; Graves et al., 1984; Seeb and Gunderson, 1988; Shulman and Bermingham, 1995), slight but significant levels of genetic heterogeneity can be found on microgeographic scales of 10s of kilometers or less (Johnson and Black, 1982, 1984; Watts et al., 1990; Johnson et al., 1993; Hedgecock et al., 1994). Large-scale genetic heterogeneity may be due to gene flow through planktonic dispersal, but the smaller scale heterogeneity may be due to yearly variation in the genetic composition of successful recruits. Hedgecock (1994a, 1994b) proposed the "sweepstakes-chance matching hypothesis" to explain such micro-scale heterogeneity. According to this hypothesis, most spawners do not produce surviving offspring, because the reproductive activity of the spawners is not matched in space and time to the most optimal oceanographic conditions during a given season. As a result, the surviving year class is produced by only a small minority of adults that spawned within restricted temporal and spatial oceanographic windows that offered good conditions for larval survival and subsequent recruitment. This situation leads to a loss of genetic variation, because these restricted windows act as population bottlenecks.

One testable prediction of Hedgecock's hypothesis is that a cohort of new recruits should show less genetic diversity than does the adult population. In order to test this prediction, the genetic composition of adults, larvae, and juveniles must be analyzed. The Tiburon Laboratory of the National Marine Fisheries Service conducted a unique sampling survey of the entire pelagic stage of shortbelly rockfish (*Sebastes jordani*) during 1994 that allowed such a test of the sweepstakes-chance matching hypothesis. The purpose of this study was to determine whether the genetic variability of the 1994 year class of shortbelly rockfish declined in a way that was consistent with Hedgecock's hypothesis.

Samples of the pelagic stages of shortbelly rockfish off the central California coast were collected in three types of surveys carried out between January and June 1994 (Figure 1). Samples of early-stage larvae were obtained by means of bongo nets from January through May near Pioneer and Ascension canyons, sites of the two major spawning aggregations of shortbelly rockfish off central California. Samples of late-stage larvae and early-stage juveniles were obtained by means of MocNess gear during March along eight transects between Point Reyes and Monterey. Samples of pelagic juveniles were collected in a midwater trawl survey carried out in May and June from Point Reyes to Monterey. For our study, a sample of adults from the Ascension and Pioneer canyon areas was also obtained from the National Marine Fisheries Service.

The larvae collected with bongo nets near Pioneer and Ascension canyons tended to be small (Figure 2). Nearly all were less than 7 mm standard length, and the average size of 5.41 mm was near the hatching length of shortbelly rockfish (Matarese et al., 1989). These larvae were present throughout the sampling period, reflecting the extended spawning season of shortbelly rockfish, but were most abundant in February through March, the peak of spawning. Because these larvae were so small, we consider them genetically representative of the part of the adult population that actually spawned.

The fish collected in the March MocNess survey were larger than those obtained in the bongo tows, bridging the larval-juvenile transition (Figure 2). Although most of the shortbelly rockfish collected in this survey were in the northern part of the study area, they were neither abundant nor concentrated. Instead, small catches were scattered over a large area (Figure 3).

The catches of pelagic juveniles in the May–June midwater-trawl survey were smaller than those of many other years, indicating that the 1994 year class of shortbelly rockfish was poor (Woodbury,

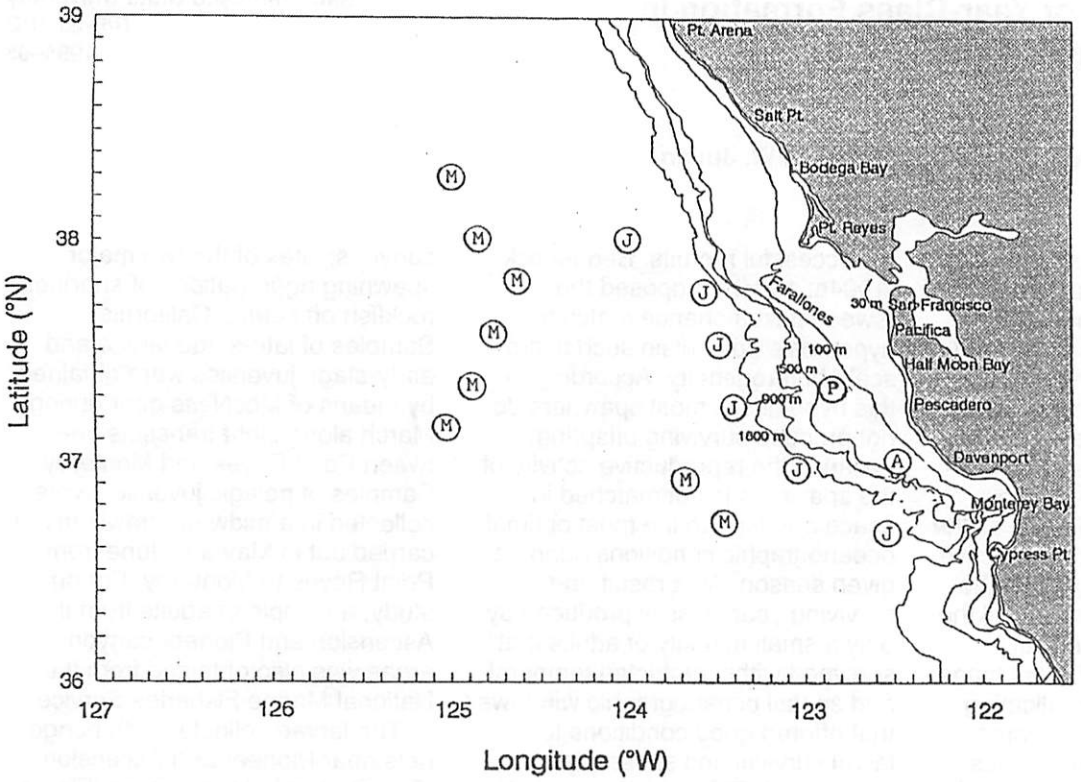

Figure I. Distribution of sampling surveys conducted by the Tiburon Laboratory, National Marine Fisheries Service, during 1994. A and P denote the location of bongo surveys off Ascension and Pioneer canyons, respectively, in January–May. M indicates the maximum distance offshore of MocNess transects carried out in March. J indicates the maximum distance offshore of midwater-trawl transects carried out in May–June. Modified from Sakuma et al., 1995.

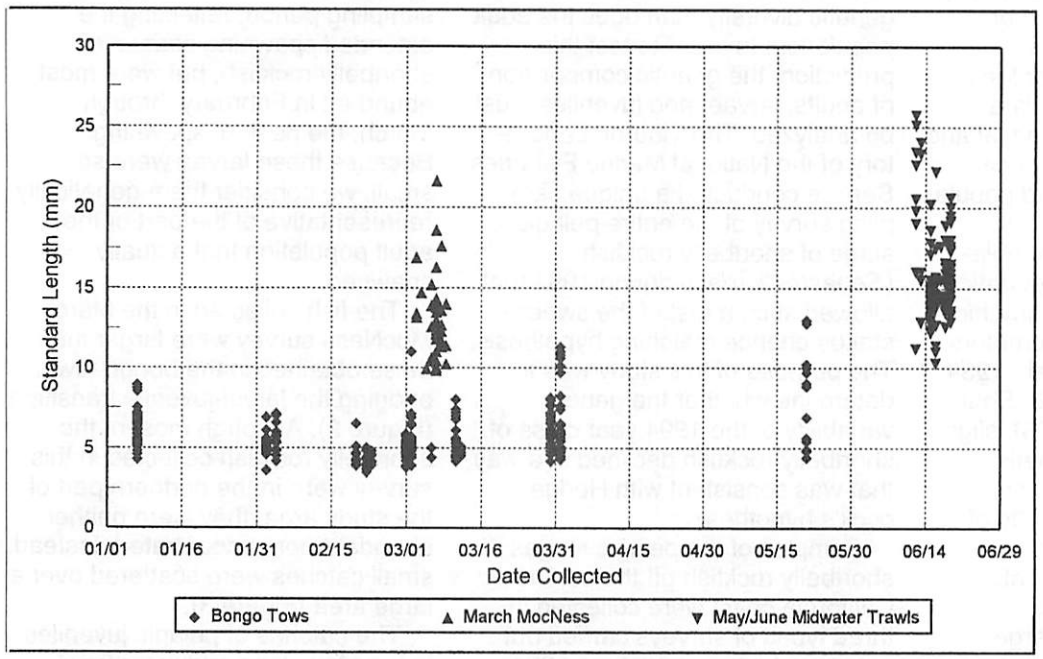

Figure 2. Standard lengths of shortbelly rockfish sampled in bongo, MocNess, and midwater-trawl surveys in 1994.

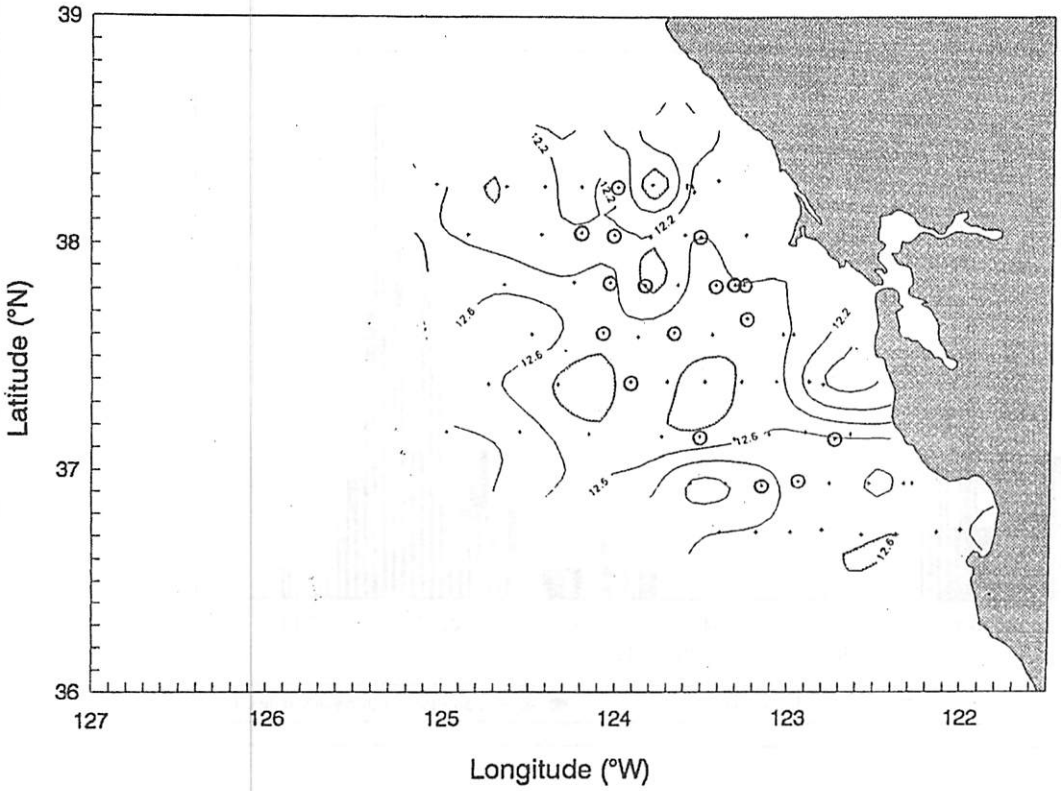

Figure 3. Catches of late-stage larvae or early-stage juvenile shortbelly rockfish in the MocNess survey in March 1994. Plus signs indicate sampling locations, and circled plus signs indicate locations at which shortbelly rockfish were caught. An average of 3.45 shortbelly rockfish were caught per trawl. Contour lines indicate temperature (°C) at 30 m. Modified from Sakuma et al., 1995.

1995). In addition, the juveniles were shorter (Figure 2) than those of years with larger catches and were born late in the year, long after the peak of spawning in shortbelly rockfish (Figure 4). It appears that, like other poor years for shortbelly rockfish (Lenarz et al., 1995), few of the larvae born earlier in the year survived to become juveniles. Unlike the catches of late-stage larvae and early-stage juveniles in March, however, the catches of juveniles in June were concentrated (Figure 5). Most of the region, including the Pioneer-Ascension area, yielded small catches of juveniles. Larger catches occurred off southern Monterey Bay and especially off the Farallon Islands (Figure 5). (Later, we distinguish between the abundant catches of juveniles off the Farallon Islands and the sparse catches of juveniles off Pioneer and Ascension canyons. We did not have access to any of the juveniles collected off Monterey Bay).

Genetic analysis of adults, larvae, MocNess larvae and juveniles was carried out at the Conservation Genetics Laboratory, San Francisco State University. The D-loop region of mitochondrial DNA was extracted and then amplified by using a polymerase chain reaction. Haplotypes were identified by using denaturing gradient gel electrophoresis (Saiki et al., 1988; Kocher et al., 1989; Myers et al., 1989; Abrams and Stanton, 1992). The genetic diversity and genetic differentiation of different parts of the sample (adults, larvae, early- and late-stage juveniles, and other subsets of the population) were estimated by using Nei's H and G statistics, respectively (Nei, 1983; Chakraborty and Leimar, 1987). The significance of differences in haplotype frequencies between different sets of specimens was calculated by using Monte Carlo chi-square contingency test simulations (Roff and Bentzen, 1989). Among the 405 fish assayed (30 adults, 199 young larvae, and 176 late-stage larvae and juveniles), 14 distinct haplotypes were scored. Direct nucleotide sequencing confirmed the differences in the base pairs of the haplotypes. Two haplotypes were predominant; the remaining 12 haplotypes occurred in about 26% of the individuals.

Adults and young larvae showed the highest level of genetic diversity ($H = 0.6844$ and $H = 0.7355$, respectively) of all the life stages sampled (Table 1). The March MocNess larvae and juveniles had a somewhat lower level of genetic diversity ($H = 0.6211$), and the juveniles collected in the May–June (June) midwater-trawl had the lowest level ($H = 0.5887$). Within the midwater-trawl juveniles, those from the aggregation off the Farallon Islands had an even lower level of diversity ($H = 0.5532$). Adults, young larvae, and March larvae and juveniles did not differ significantly in haplotype

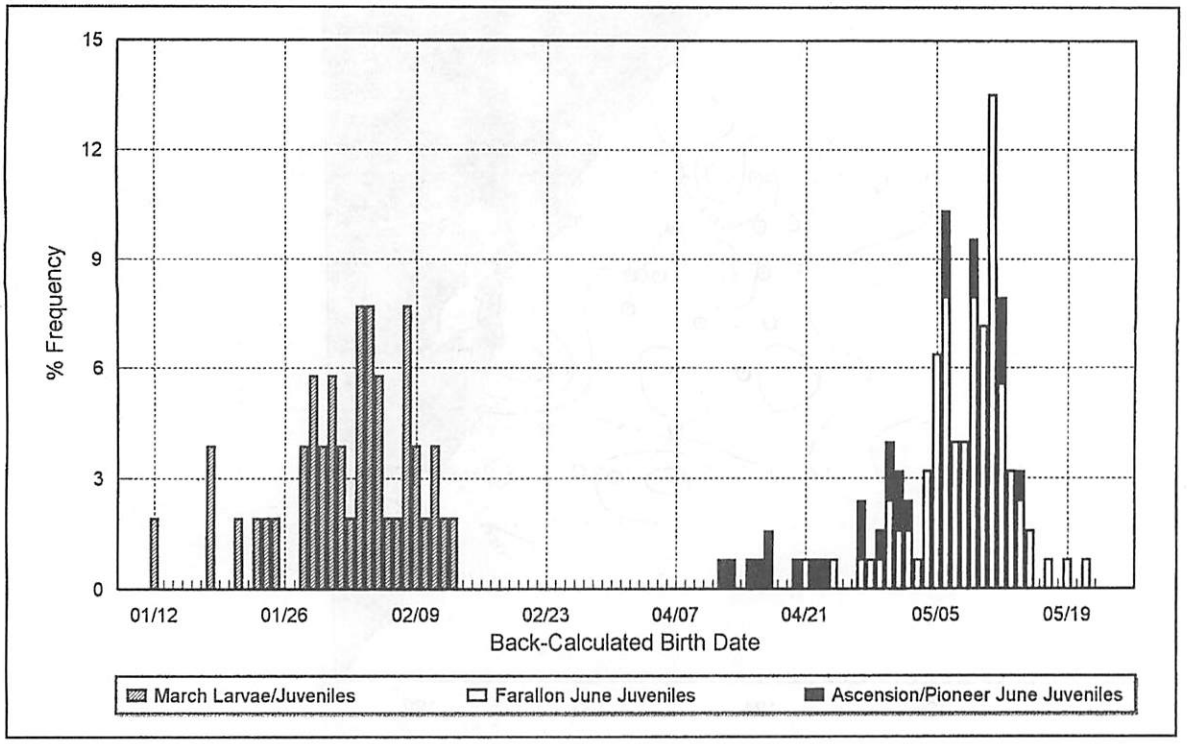

Figure 4. Frequency of back-calculated birthdates of pelagic shortbelly rockfish collected in MocNess trawls in March, midwater trawls in May–June from the Ascension-Pioneer canyon area, and midwater trawls in May–June from the Farallon Islands area, all in 1994. Birth dates were estimated from lengths according to the equation age = –65.33 + 89.511 * log (standard length), as determined by D. Woodbury (National Marine Fisheries Service, Tiburon Laboratory) from examination of daily increments on the otoliths of 40 pelagic juveniles captured in 1994.

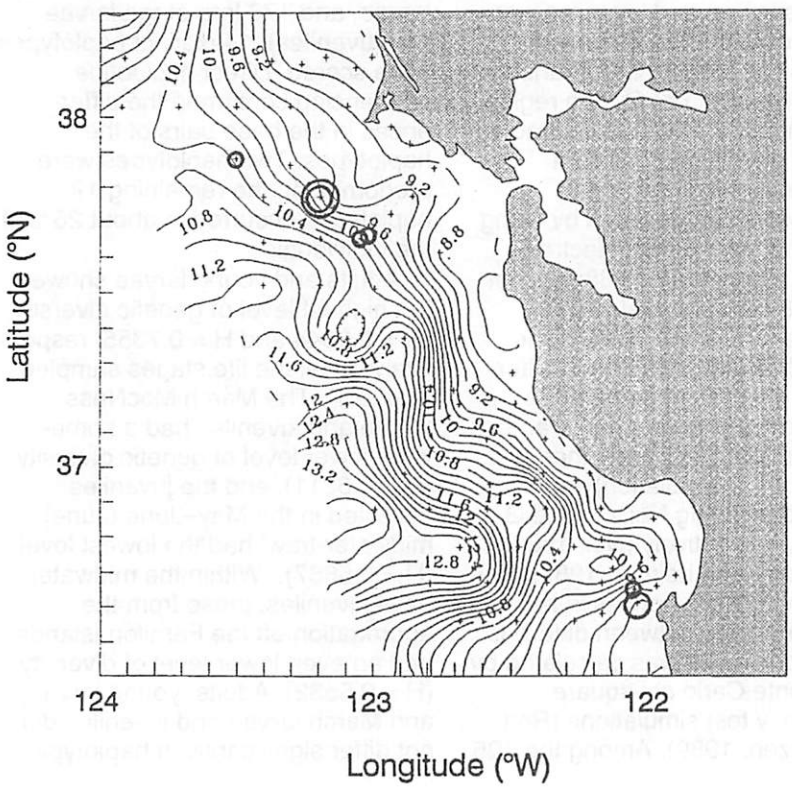

Figure 5. Distribution of large catches of juvenile shortbelly rockfish in midwater-trawl surveys in May–June 1994. Plus signs indicate station locations. Circles are approximately proportional to the number of fish caught, the smallest circles indicate approximately 100 fish per trawl. The single large circle indicates 407 fish per trawl, and the large double circle indicates 565 fish per trawl. Contour lines denote temperature (°C) at 30 m. Modified from Sakuma et al., 1995.

Table 1. Genetic Diversity Within Samples (Nei's H Statistic: Diagonal) and Genetic Differentiation Between Samples (Nei's G_{ST}: Off Diagonal) for Different Pelagic Stages of Shortbelly Rockfish

	Adults[1]	Larvae[2]	March Juveniles[3]	Total June Juveniles[4]	Farallon June Juveniles[5]
Adults	**0.6844**				
Larvae	0.0070	**0.7355**			
March Juveniles	0.0148	0.0161	**0.6211**		
Total June Juveniles	0.0549*	0.0447*	0.0247	**0.5887**	
Farallon Juveniles	0.0677**	0.0572**	0.0316*	—	**0.5532**

[1]Adults obtained from the Ascension and Pioneer canyon areas.
[2]Young larvae obtained from the Ascension and Pioneer canyon areas.
[3]Late-stage larvae and early-stage juveniles obtained with MocNess gear throughout the study area in March.
[4]Juveniles obtained by midwater trawl in May–June throughout the study area.
[5]Juveniles obtained in May and June from an area of concentrated abundance off the Farallon Islands.
*$p < .10$ for Monte Carlo chi-square contingency tests for differences in haplotype frequencies.
**$p < .05$ for Monte Carlo chi-square contingency tests for differences in haplotype frequencies.

frequencies, exhibiting genetic differentiation (G_{ST}) levels of 0.0070 to 0.0161 (Table 2). The juveniles collected in the midwater-trawl had higher levels of genetic differentiation than did adults, young larvae, and MocNess larvae and juveniles (ranging from 0.0247 to 0.0549), and the differences in haplotype frequencies were significant at the 0.10 level for midwater-trawl juveniles vs. both adults and young larvae (Table 1). The aggregation of juveniles at the Farallon Islands was even more distinct (with G_{ST} levels ranging from 0.0316 to 0.0677). Haplotype frequencies of these juveniles differed significantly from those of adults and young larvae at the 0.05 level and from MocNess samples at the 0.10 level (Table 1). Therefore, the genetic data support the sweepstakes-chance matching hypothesis: levels of genetic diversity were lower for later-stage pelagic juveniles, and their haplotype frequencies differed from those of adults and most of the earlier stages. The aggregation at the Farallon Islands was particularly distinct.

The genetic distinctiveness of the pelagic juveniles was not caused by seasonal variation in the genetic composition of spawning. Larvae collected in each of three periods (early season: January and early February; middle season: late February and early March; and late season: middle March, April, and May) had similar levels of genetic diversity, low levels of genetic

Table 2. Genetic Diversity Within Samples (Nei's H Statistic: Diagonal) and Genetic Differentiation Between Samples (Nei's G_{ST} Off Diagonal) for Adults of Shortbelly Rockfish and Larvae Obtained at Different Times During the Reproductive Season

	Adults[1]	January–February Larvae[2]	February–March Larvae[3]	April–May Larvae[4]
Adults	**0.6844**			
January–February Larvae	0.0079	**0.7009**		
February–March Larvae	0.0211	0.0161	**0.7281**	
April–May Larvae	0.0081	0.0034	0.0181	**0.6814**

[1]Adults obtained from the Ascension and Pioneer canyon areas.
[2]Larvae obtained in early collections made during January and February.
[3]Larvae obtained during the middle of the reproductive season, February–March.
[4]Larvae obtained late in the reproductive season, April–May.
Note: None of the Monte Carlo chi-square contingency tests for differences in haplotype frequencies were significant at $p < .10$.

differentiation from adults, and low levels of genetic differentiation from each other (Table 2). Because the larvae were mostly quite young, and therefore representative of the adults that spawned them, it appears that a large, random, sample of adults spawned throughout the reproductive season and that the distinct genetic composition of June juveniles was not due to spawning by a unique part of the adult population. In addition, the lack of any significant differences in haplotype frequencies between the MocNess larvae and juveniles (which were most abundant in the northern part of the study area) and either adults or larvae (which were obtained in the southern part of the study area) suggests that little spatial differentiation of haplotypes occurred at this scale.

The spatial and genetic patterns of shortbelly rockfish indicate how the 1994 year class may have been formed. The shortbelly rockfish collected in the March MocNess survey were widely scattered and never particularly abundant, whereas those collected in the May–June midwater-trawl survey were highly aggregated. The relatively high levels of genetic diversity, low levels of genetic differentiation, and scattered distribution of MocNess samples suggest that these fish were the random individual survivors of a variety of patches of larvae that, in general, had high mortality. In contrast, the aggregated distribution, low level of genetic diversity, and high level of genetic differentiation of the juvenile shortbelly rockfish in samples from the Farallon Islands region suggest that these individuals were all the result of good survival of a limited subsample of the larvae produced that year, perhaps even one or a few patches of larvae. Similar contrasts existed even within the midwater-trawl juveniles. Although the fish from the Farallons were aggregated and had relatively low levels of genetic diversity, juveniles from the Ascension and Pioneer regions were scattered and never abundant and had higher levels of genetic diversity and lower levels of genetic differentiation than did adults and larvae, much like the March MocNess individuals. This finding again suggests that these fish were the random survivors of different patches of larvae. These observations suggest that the preponderance of juveniles that survived the pelagic stage in 1994 (those in the aggregation near the Farallon Islands) were the result of unusually good survival of a small part of the adult spawn.

The temporal and, to some extent, the spatial distribution of surviving shortbelly rockfish in the 1994 year class appears to be correlated with changes in oceanography. Ainley et al. (1993) found that year-class strength in shortbelly rockfish is usually poor when upwelling during February and March is either extremely weak or extremely strong. Weak upwelling most likely does not produce adequate food supplies in upwelling fronts. In addition, nearshore transport appears to coincide with weak upwelling indices and may result in high mortality of larvae and juveniles because of predation in the nearshore environment. Strong upwelling most likely advects larvae too far offshore for subsequent recruitment. The strongest year classes, however, are correlated with moderate upwelling activity (Ainley et al., 1993) which appears to produce both the food-rich conditions at the upwelling fronts and the transport mechanism that bring the larval patches to these fronts.

In 1994, upwelling was weak early in the season (Figure 6). The spring transition to predominantly upwelling-driven conditions did not occur until mid to late March (Figure 6), and the conductivity-temperature-depth data taken during the March MocNess survey (Figure 3) show little evidence of upwelling activity and few fronts within the study region. These observations are consistent with the low survival of larvae born early in the season. However, upwelling became stronger later in the season (Figure 6), perhaps leading to greater primary production, the existence of fronts (Figure 5), and greater survival of larvae. The surviving juveniles from the midwater-trawl survey were born early in May, whereas in years of greater year-class strength, the bulk of surviving juveniles were born earlier in the year, during the peak of spawning. The survival of only late-born individuals in 1994 may be related to the delayed onset of upwelling. The spatial distribution of surviving juveniles may also be related to the spatial distribution of upwelling, although our data are not as strong in this regard. Upwelling was concentrated, as it usually is, off Point Reyes and Año Nuevo. The concentrations of juveniles in frontal regions off Point Reyes and in southern Monterey Bay (Figure 5) suggest associations with these features, whereas the scattered distribution of juveniles off Ascension and Pioneer canyons may have been linked to an intrusion of warm, less productive water.

In conclusion, the 1994 year class showed a lower degree of genetic diversity than did the adult and spawning populations. This reduction occurred after parturition of the larvae, but before the pelagic juvenile stage. The spatial distribution of surviving juveniles and their reduced genetic diversity suggest that the surviving year class was the result of good survival in only a few larval patches that became entrained in the favorable conditions within upwelling fronts. This reduction by random bottleneck events was consistent with the sweepstakes-chance matching hypothesis. Furthermore, although the more common haplotypes may dominate the genetic composition of year class, certain uncommon haplotypes were disproportionately common in the late-stage pelagic juveniles. In other years, different uncommon haplotypes may characterize the cohort, depending on which larvae were entrained within favorable conditions. As a result, year classes may be characterized by this "genetic signature."

To the extent that they are representative of years other than 1994, our findings have important implications for fisheries management. First, they imply that the adults actually contributing to a year

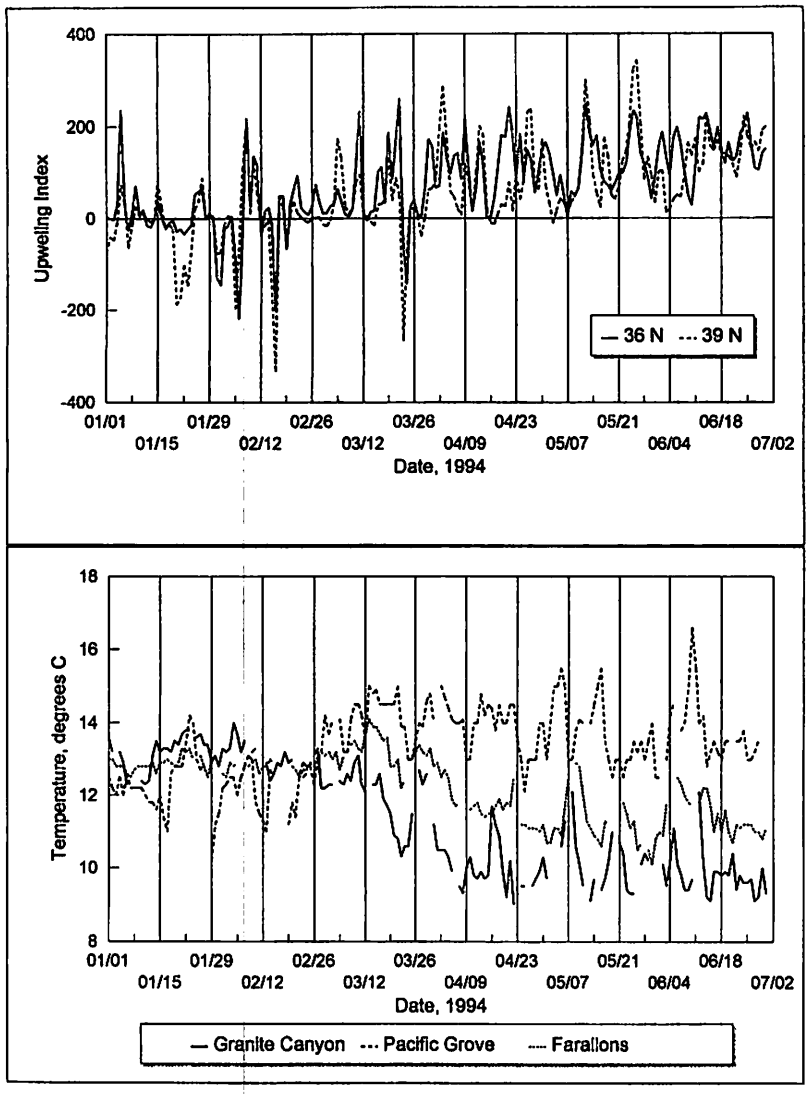

Figure 6. Bakun's upwelling index (upper panel) and shore temperatures (lower panel) in January–July 1994.

class may be a small fraction of the entire spawning stock. Furthermore, different parts of the adult population may be successful each year. Current management practice in rockfish seeks to preserve a minimal "spawning biomass per recruit" in a population (Pacific Fisheries Management Council, 1996). Our results suggest that successful management should recognize that the geographic source of successful recruits may differ from year to year and should act to preserve minimal spawning stock sizes over the entire geographic range of a stock. Second, the potential of having a year class "tagged" with a preexisting genetic signature may enable fisheries biologists and managers to track cohorts after the fish have entered the fishery. Genetic markers such as those used in this study may be powerful tools for gathering previously unobtainable information on the population dynamics of many marine species.

Accomplishments

Our research is the first, to our knowledge, to demonstrate that a decline in genetic diversity can occur during the pelagic stage in a marine fish. By combining our genetic data with data on oceanography and the geographical distributions of pelagic larvae and juveniles, we have provided evidence that the surviving members of this class of shortbelly rockfish were the offspring of a small portion of the adult population, which had encountered good conditions for survival. This scientific advancement is the major accomplishment of our project.

Benefits

Our project has applications for fishery and environmental management. If the time and place of good conditions for larval survival vary from year to year, it will be important in resource management to recognize that all portions of the geographic range of a stock must be conserved. If the geographic range of a stock becomes reduced, then the chances of offspring encountering good conditions for survival become reduced. Colleagues at the National Marine Fisheries Service have taken our research into consideration in the development of management plans for groundfish.

Cooperating Organizations

Conservation Genetics Laboratory, Department of Biology, San Francisco State University

National Marine Fisheries Service, Southwest Fisheries Science Center, Tiburon Laboratory

Rainey Fund, American Society of Ichthyologists and Herpetologists

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Presentations

Julian, R.W. and R.J. Larson. Genetic analysis of year-class formation in shortbelly rockfish (*Sebastes jordarni*). Presented at the annual meeting of the Western Society of Naturalists, January 1996.

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The Effect of Releasing Treated Wastewater on Blooms of Nuisance Algae in Southern California Estuaries

University of California, Los Angeles
R/C-15PD
1996–97

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The objective of this research project is to determine whether releases of treated wastewater will trigger "nuisance" blooms of macroalgae in Southern California estuaries. Releases of tertiary treated wastewater during the wet season are scheduled to begin this year in Upper Newport Bay, Orange County, California. Upper Newport Bay is one of the largest remaining wetlands in Southern California and has a history of nuisance algal blooms. To determine the ecologic effects of the release of proposed wastewater, we have begun quarterly field surveys of the bay to document prerelease conditions of nutrient levels and algal biomass. Data from these field surveys are being coupled with a series of microcosm experiments that test the effects on algal biomass of nutrient enrichment and increased estuarine flushing due to the input of fresh water. The purpose is to determine causative links between these factors and algal blooms.

This project can be divided into two parts: field monitoring and experimental microcosms. The primary goals of our field-monitoring program were to (1) quantify algal blooms in the field and correlate growth and accumulation of biomass with environmental conditions and (2) develop monitoring methods to assess the effects on field populations.

The objectives of the experimental microcosm phase of this project were to (1) determine the relative importance of nitrogen and phosphorus enrichment in regulating biomass and species composition of algal blooms and (2) test whether enhanced estuarine flushing due to greater input of fresh water will increase or decrease the rate of growth and accumulation of biomass of algal blooms.

Progress to Date

During the past year, we have successfully developed techniques to quantify algal biomass in the field and have begun to analyze these data for correlations with input of nutrients into Upper Newport Bay. During four quarterly sampling periods in the bay, we measured nutrient levels of the water column, sediments (Figures 1 and 2), and algal tissue at eight sites. In addition, we have obtained data on both the magnitude and species composition of algal blooms in the bay (Figure 3). Our data capture the seasonal shift of the algal community in Upper Newport Bay from the winter season, in which benthic diatoms dominate primary productivity, through the spring *Enteromorpha* bloom and document the increasing dominance of *Ulva* as the summer progresses. Data on nutrients in the water indicate that this estuary is highly eutrophic, with levels of nitrate in the water column as high as 828 μM (Figure 4). Our data on nutrient levels in the water column and sediment strongly suggest that macroalgae in the bay may be phosphorus limited during several months of the year. Consequently, we plan to repeat our microcosm experiment of nitrogen and phosphorus limitations during the wet season to investigate this possibility. We have developed an effective monitoring program in Upper Newport Bay that is yielding data on nutrient dynamics and macroalgal biomass in the system. During the past year, we have obtained a baseline data set of these parameters that we can now compare with data obtained in the coming years to measure any effects the upcoming release of wastewater has on algal blooms and on the nutrient status of the bay.

The experimental microcosm phase of this project has proceeded well. We have successfully developed the techniques required to collect and maintain microcosms drawn from our field sites, and both the experiments on nitrogen and phosphorus limitation and flushing rate have been completed. The data set obtained from these experiments is complex, and we are analyzing it. Our initial analysis indicates that macroalgal biomass in the microcosms was nitrogen limited during this experiment. Field data indicate that phosphorus limitation of macroalgae in Upper Newport Bay also becomes important at certain times of year, so we will be repeating this experiment to test for seasonal effects. To clarify the effects of both the nutrient component and the increased flow due to the release of wastewater, we will follow our flushing-rate experiment with a dose-response trial in which the amount of microcosm turnover will be constant, but the nutrients in the incoming water will be varied. The information that these experiments yield on causative links between algal biomass and various levels of nutrient loads and flushing rates will dramatically increase our understanding of eutrophication and bloom dynamics in Southern California estuarine systems.

In addition to the field surveys and microcosm experiments, we have used a newly developed (Fong et al., unpublished findings) bioassay system as an alternative method of measuring nutrient enrichment. This technique involves deploying mesh bags containing nutrient-starved *Enteromorpha* tissue at our study sites. After 1 week of exposure to ambient nutrient levels, the samples are collected and the nutrient levels of the tissue are measured. The

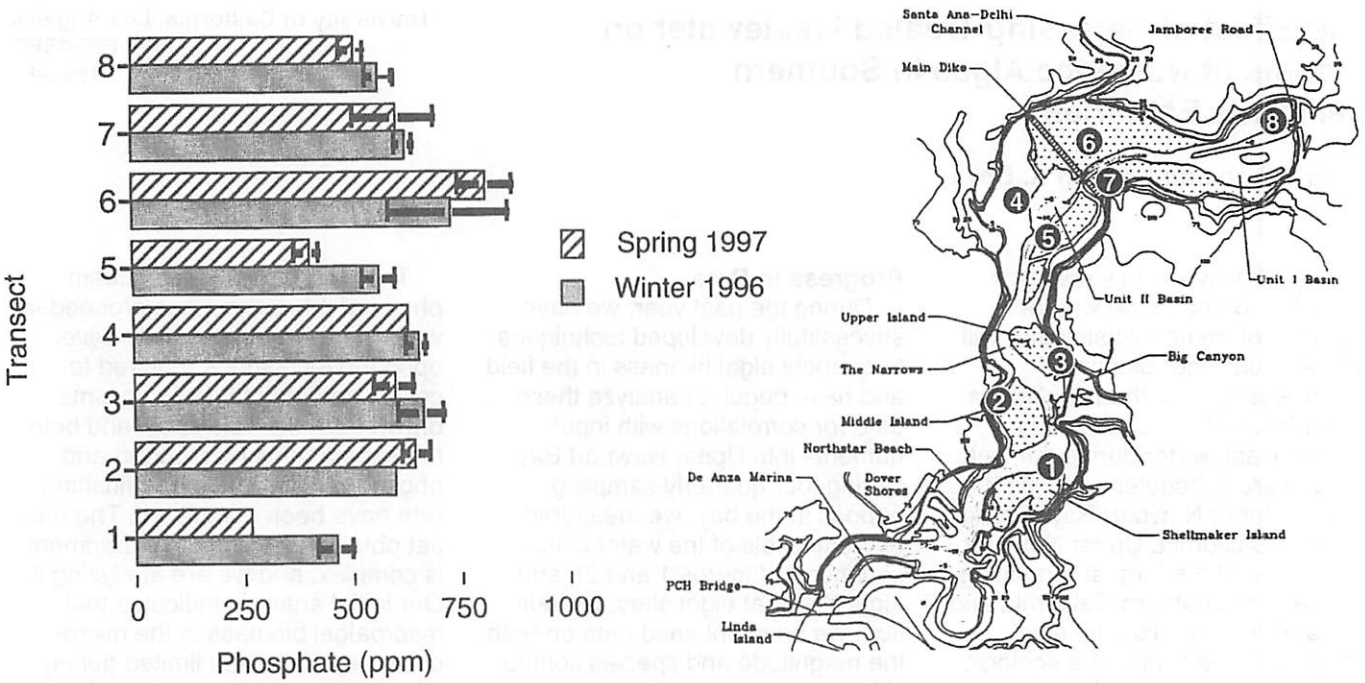

Figure 1. Seasonal variation in sediment phosphate, Upper Newport Bay, California. Numbers highlighted on the map correspond to transect numbers on the *y*-axis of the graph.

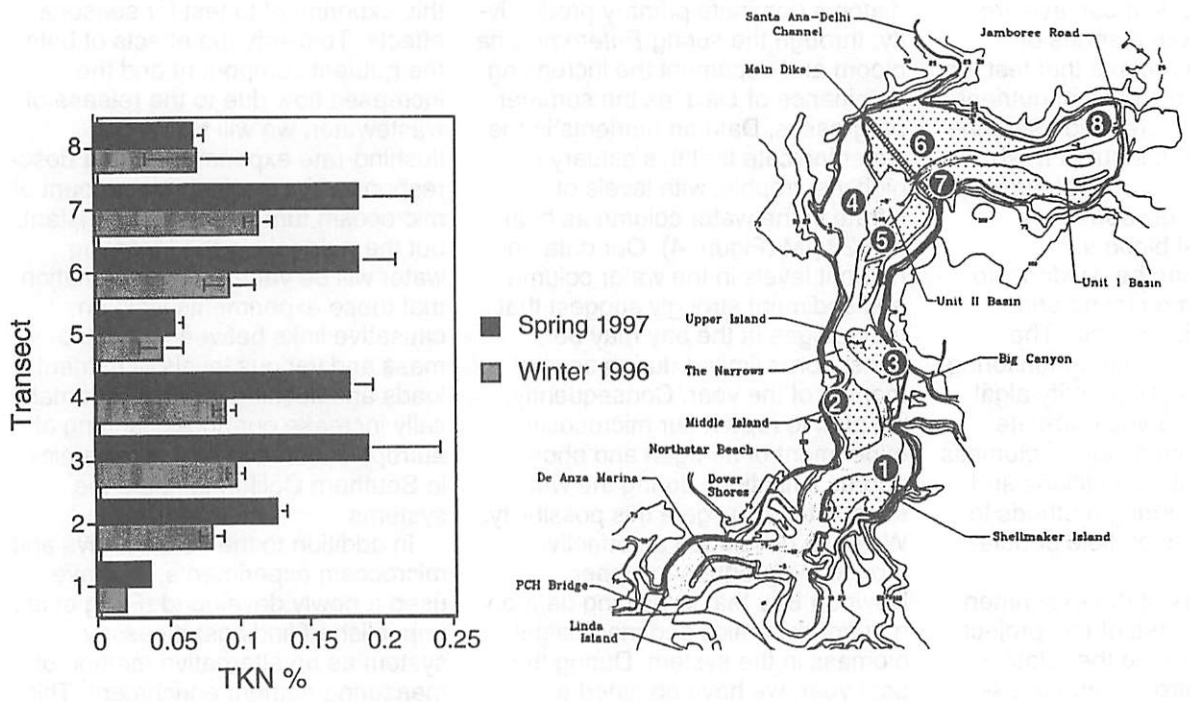

Figure 2. Variation in sediment total Kjeldahl nitrogen (TKN) from winter 1996 to spring 1997 in Upper Newport Bay, California. Numbers highlighted on the map correspond to transect numbers on the *y*-axis of the graph.

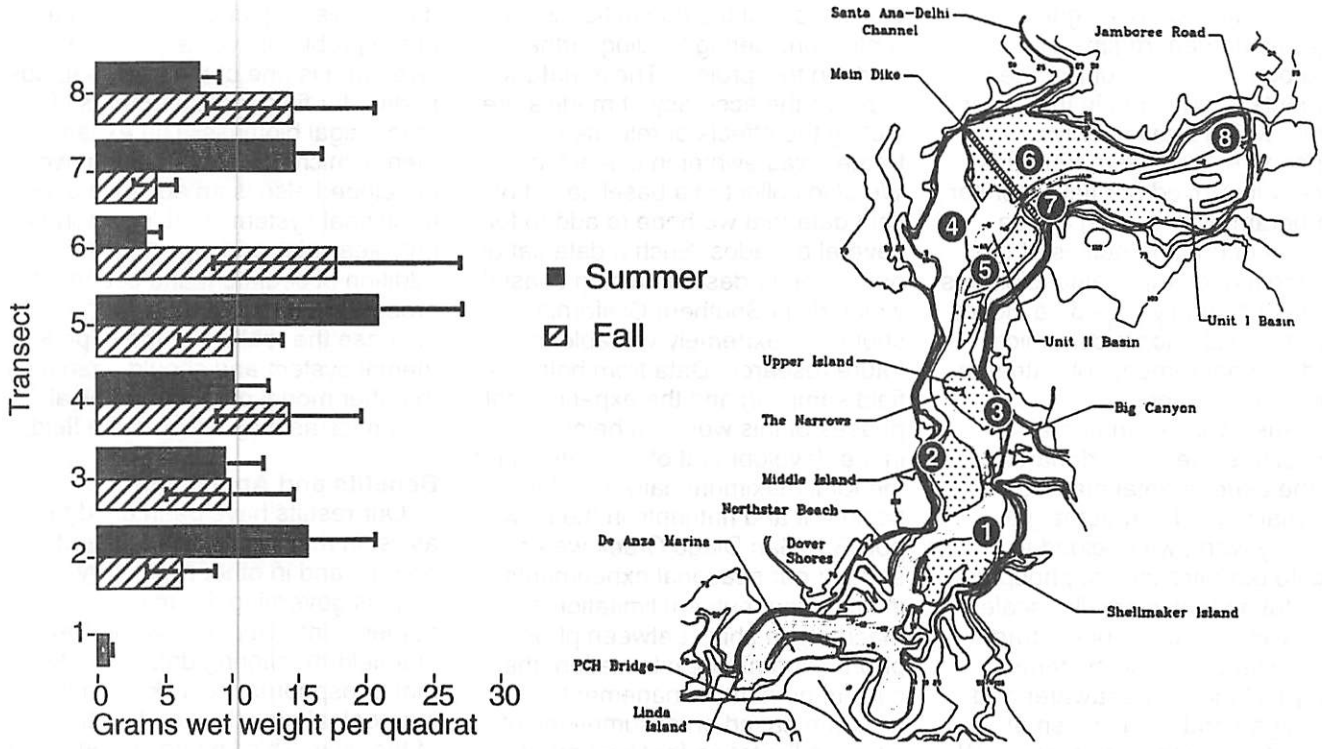

Figure 3. Seasonal variation in macroalgal biomass, 1996–1997 in Upper Newport Bay, California. No values are presented for winter and spring because the biomass present at these sampling times was insufficient for collecting.

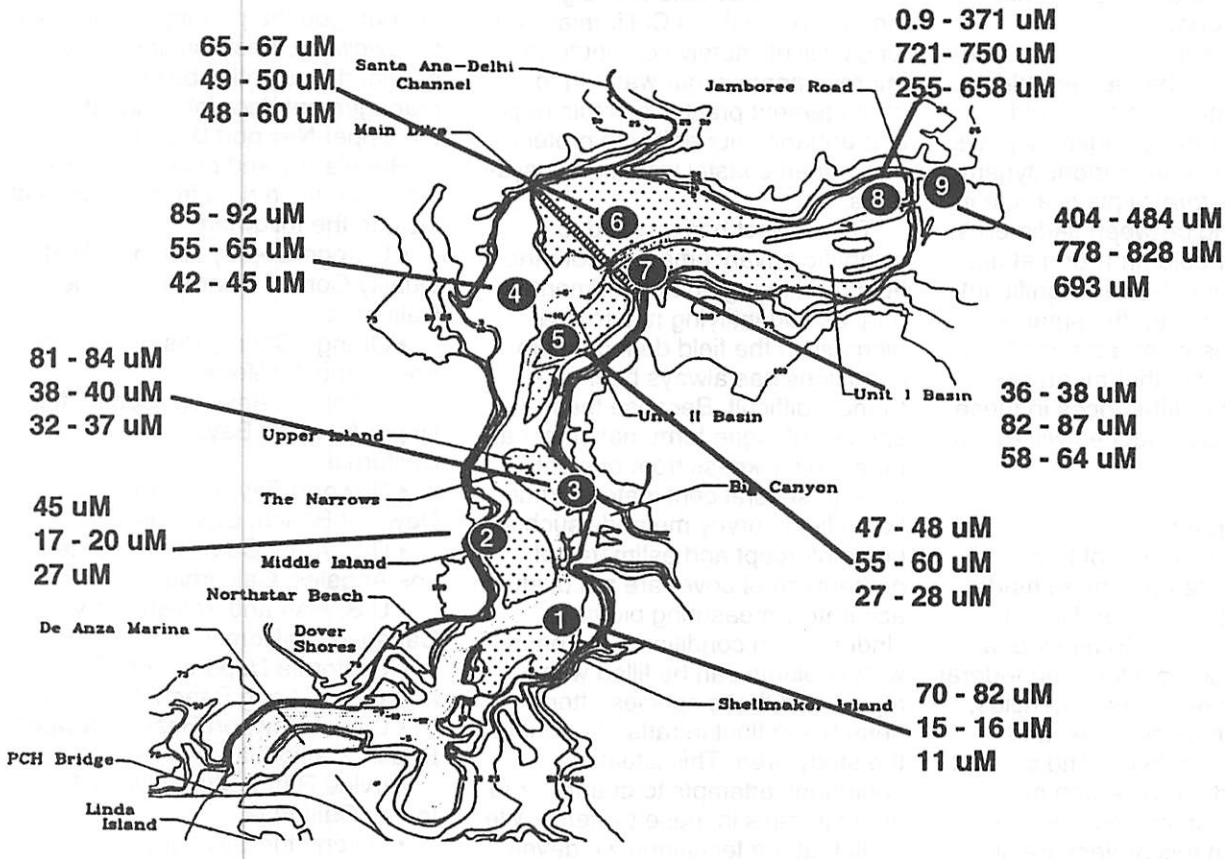

Figure 4. Seasonal range of nitrate (μM) in the water column, 1996–1997, Upper Newport Bay, California. Top values are for winter; middle values for spring; and bottom values for summer.

nutrient content of this algal tissue integrates nutrient regime at a site over a period of time, unlike measurements of nutrients in the water column, which provide only a "snapshot" in time. Data from this bioassay improved our field-monitoring program by providing a measurement of nutrient pulses at the scale most relevant to algal biomass and may ultimately provide a closer correlation with bloom dynamics than do measurements of nutrients in the water column.

Because our experimental microcosm system is a departure from the experimental methods traditionally used in macroalgal laboratory work, we decided to replicate our nitrogen vs. phosphorus limitation trial in smaller scale microcosms, comparable to traditional systems. These systems usually include only seawater and macroalgae and are fairly small—200 ml of seawater in this case. We modified this system by increasing the size of our microcosms to 3.78 l in volume and including sediment and the gastropod *Cerithidea californica* in each microcosm. We think that these changes enable us to more realistically model field conditions, because sediment plays an important role in nutrient dynamics and *C. californica* plays a role in nutrient cycling between sediments and the water column (Fong et al., 1997). Our data showed significant differences between the smaller scale microcosms and our system, and we anticipate that an article highlighting the differences in these experimental approaches will evolve from this project.

Accomplishments

From the beginning of this project, our data have been made available to the Newport Beach Technical Advisory Committee, a panel composed of state and federal resource and regulatory agencies, private industry, scientists, and citizen representatives. The committee has found our research extremely useful in its decision making. Data from this project are so applicable to its management decisions that the committee is currently considering funding further work on this project. These data will improve the accuracy of models predicting the effects of releases of treated wastewater in this estuary. We also collected a baseline set of field data that we hope to add to for several decades. Such a data set on one of the largest remaining coastal wetlands in Southern California should be extremely valuable to future research. Data from both the field sampling and the experimental phases of this work are being used in the development of regulations for the total maximum daily load for sediment and nutrients in the Newport Bay/San Diego Creek watershed. If our seasonal experiments indicate that nutrient limitation of macroalgae shifts between phosphorus and nitrogen limitation, the current nutrient management program based on assumptions of nitrogen limitation for Newport may be revised. An increased understanding of these nutrient dynamics and their interactions with algal blooms in Southern Californian wetlands will ultimately contribute to improvements in our watershed management practices in this region and enhance our ability to protect threatened coastal wetland ecosystems.

This project has also led to scientific advancement in both the field-monitoring and experimental phases. Quantifying macroalgal biomass in the field during bloom conditions has always been extremely difficult. Because these species of algae form mats that can range in thickness from one cell-layer to several centimeters, traditional field-survey methods such as point-intercept and estimates of percentage of cover are not useful in accurately measuring biomass. Under bloom conditions, the entire water column can be filled with algae, and these species often detach and float in rafts throughout the study area. This situation confounds attempts to quantify and map biomass in these systems. We think that the technique we developed for quantifying algal biomass during this project overcomes many of the problems typically encountered and is one of the best methods to date for field measurements of macroalgal biomass. The experimental microcosm system that we developed also is an advance over traditional systems that incorporate only seawater and algae. Our addition of sediment and sediment-processing gastropods helps increase the realism of the experimental system and should enable us to better model nutrient and algal dynamics as they occur in the field.

Benefits and Applications

Our results have been used to assist in making decisions about permits and in other regulatory actions governing the release of nutrients into Upper Newport Bay. Our field-monitoring data indicate that phosphorus most likely limits macroalgal growth at certain times of the year. This finding is significant because no limit on phosphorus is currently mandated for the release of wastewater. Our data have encouraged the permitting agencies to review this decision and have provided a scientific basis for management decisions that affect the Upper Newport Bay estuary.

Regulatory and private agencies that have used data from this project include the following:

- Orange County Regional Water Quality Control Board, Riverside, California
- Orange County Water District, Santa Ana, California
- Technical Advisory Committee, Upper Newport Bay, Irvine, California
- Newport Bay Advisory Council, Newport Beach, California
- U.S. Army Corps of Engineers, Los Angeles, California
- U.S. Fish and Wildlife Service, Carlsbad, California
- California Department of Fish and Game, Long Beach, California
- City of Newport Beach, Newport Beach, California
- Irvine Ranch Water District, Irvine, California
- Defend the Bay, Newport Beach, California

• Various landowners and concerned citizens

Cooperating Organizations

California Department of Fish and Game
Irvine Ranch Water District
Orange County Regional Water Quality Control Board
Orange County Water District
U.S. Army Corps of Engineers Regulatory Division

Publications

Fong, P., J.S. Desmond, and J.B. Zedler. 1997. The effect of a horn snail on *Ulva expansa* (Chlorophyta): Consumer or facilitator of growth? *J. Phycology* 33:353–359.

Presentations

Boyle, K.A. Nutrient dynamics in a heavily modified Southern California estuary: Responses of the algal community to treated wastewater release. Presented at the 14th annual International Conference of the Estuarine Research Federation, Providence, Rhode Island, October 1997.

Fong, P. Developing an indicator of nutrient enrichment in coastal estuaries and lagoons using tissue nitrogen content of the opportunistic alga, *Enteromorpha intestinalis*. Presented at the 14th annual International Conference of the Estuarine Research Federation, Providence, Rhode Island, October 1997.

Kamer, K. The effect of an herbivorous estuarine amphipod on *Enteromorpha intestinalis* and *Ulva expansa*. Presented at the 14th annual International Conference of the Estuarine Research Federation, Providence, Rhode Island, October 1997.

A Management Plan for the Bahamian Gorgonian, *Pseudopterogorgia elisabethae*

State University of New York at Buffalo
R/MP-12PD
1996–97

Howard R. Lasker, Mary Alice Coffroth, and Shellene Hurley-Leslie

Pseudopterogorgia elisabethae is a moderately common gorgonian of coral reefs throughout the Caribbean. Sea Grant-funded research by W. Fenical and his colleagues during the past 15 years has led to the identification of a class of natural products, pseudopterosins, that have anti-inflammatory and analgesic properties. The extract from *P. elisabethae* is used as a topical agent in cosmetics, and samples of *P. elisabethae* are being collected in the Bahamas under a permit issued by the Bahamas Department of Fisheries. However, neither the effects of the harvest on the species nor the abundance of the resource is known. We proposed a pilot program for an examination of *P. elisabethae* population biology to develop those data necessary for a management plan. The goals of the study were to (1) determine the annual reproductive cycle and the timing of spawning of *P. elisabethae*, (2) use DNA fingerprint analysis to determine whether *P. elisabethae* dispersal is philopatric, and (3) develop a research plan designed to produce a management plan for the species.

Status of the Fishery

Harvest of *P. elisabethae* began in 1994. Collection intensity is high in some locations, with harvests of up to 105,000 colonies from a single 0.5 × 0.5-mile area (H. Higgs, personal communication). Annual harvests have been as great as 16,000 lb (7273 kg; W. Fenical, personal communication), which is equivalent to more than 1 million colonies. In an effort not to destroy the populations, the collectors currently crop colonies above the base, leaving one set of branchlets. This procedure probably allows many colonies to recover, and we have observed colonies with several years of growth after an initial harvest.

Distribution

Table 1 is a summary of transects conducted at sites that were selected because of the presence of *P. elisabethae*. Variance:mean ratios suggest that *P. elisabethae* has a clumped distribution at some sites from the Bahamas.

Reproduction

Like all gorgonians studied to date, *P. elisabethae* is gonochoric. Unlike most gorgonians, it surface broods planulae before their release to the environment. Planulae remain on colonies up to several days and appear to be neutrally buoyant when wave or current action strips them from colonies. Several reports of variation in spawning time suggest either a broad and diffuse reproductive synchronization or population-level differences in reproduction. Higgs (personal communication) reports that *P. elisabethae* colonies at Cross Harbour (Abacos) contain larvae in June rather than in January as do colonies at other sites. We observed that colonies did not spawn in January 1997 at San Salvador at the same time that populations near Grand Bahama were spawning, and we observed spawning in colonies in December 1997, whereas more northerly populations spawned in November.

Population Structure

In January 1997, we collected colonies from groups of colonies along five 10-m transects at San Salvador. The relatedness of colonies was compared within and between transects by using minisatellite DNA fingerprinting. The techniques followed those of Coffroth et al. (1992), and fingerprints were prepared by using the endonuclease *HaeIII* and the oligonucleotide probe $(GGAT)_4$. Figure 1 shows the results of one within-transect comparison. Colonies along the transect were located in two groups, one at the end of the transect, as evident from the positions indicated in Figure 1A. In the genetic analysis, six of the eight colonies from meter 10 fell within the same cluster. Colonies from the other end of the transect (meters 1–3) tended to fall in two distinct clusters. Similarities between colonies from meter 1 and meter 10 had an average value of 0.14, whereas those from within meters 1 and 10 had averages of 0.20 and 0.21, respectively. Averaging similarities of colonies within smaller distances yields slightly greater similarities, but once colonies more than 6 m apart are included in the average, mean similarity steadily declines.

Table 1. Abundance of *P. elisabethae* at Three Localities in the Bahamas

Location	Density (per 10 m²)	Standard Deviation	Variance: Mean Ratio
Sweetings Cay	7.00	0.90	0.51
Little San Salvador	10.50	1.50	0.21
San Salvador	14.33	6.57	3.02

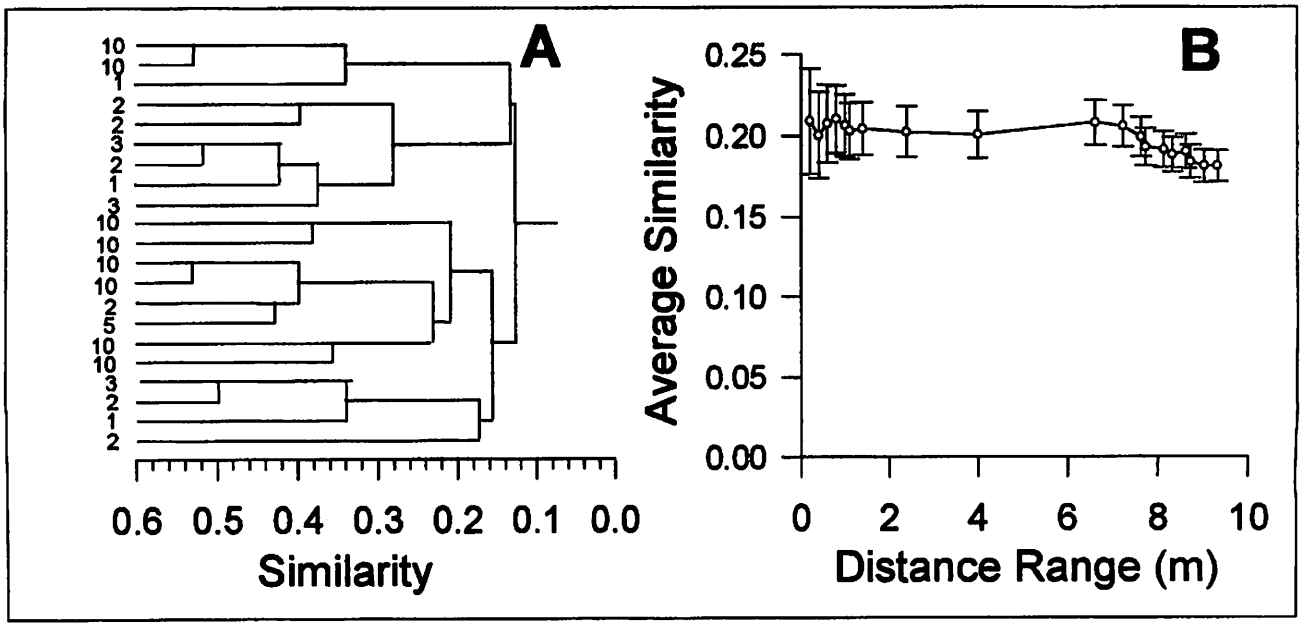

Figure 1. Relatedness of *Pseudopterogorgia elisabethae* colonies from a transect at Sweetings Cay, Bahamas. **A**, Dendrogram of UPGMA cluster analysis based on proportion of shared bands. Number on the left indicates position of the colony on the 10 m-long transect. **B**, Average similarity of colonies found within different distances of each other (± SE)

The data suggest that there is population structure on a scale of about 5–6 m. However, the presence of colonies within clusters that were quite dissimilar also suggests gene flow that homogenizes the population. This finding indicates that over timescales of generations, some dispersal occurs. However dispersal might lead to slow recolonization, and limited dispersal may inhibit recovery of harvested populations if large (kilometer scale) sections of reef are cleared. Evidence for larger scale effects of limited dispersal will be evident in population structure but will require analysis of different components of the DNA, such as randomly amplified polymorphic DNA, or microsatellite analyses. Fingerprint analyses of a group of colonies collected on two transects on reefs at San Salvador Islands are consistent with the philopatric dispersal of some larvae overlaid on a pattern of more distant dispersal.

Benefits

The Bahamas Department of Fisheries is in the process of promulgating harvest regulations for *P. elisabethae* and has been provided with those data which we have available. Our currently funded Sea Grant biotechnologic research is a direct outgrowth of this project and will supply the detailed data essential to the development of a management plan.

References

Coffroth, M.A., H.R. Lasker, M.E. Diamond, J.A. Bruenn, et al. 1992. DNA fingerprints of a gorgonian coral: A method for detecting clonal structure in a vegetative species. *Mar. Biol.* 114:317–325.

Expansion of California's Golden Seas to All Tri-County Elementary Schools

California Seafood Council, Santa Barbara
R/E-25-9PD
1997

Diane Pleschner

Introduction

Educating children, as well as their parents, about the local fishing industry through programs like California's Golden Seas is important to the future of our commercial fishing industry and marine ecology. The goal of California's Golden Seas is to promote understanding of the ocean and the multiple use of its resources, as well as to foster support for fishers and enhance the value of their catch.

The California's Golden Seas kit educates children and their parents about the importance of the ocean as a food source, the health benefits of eating seafood, and the importance of the local fishing industry as food providers. It stresses the multiple-use concept and the fact that resources are both usable and renewable.

The California's Golden Seas education program is integral to increasing public awareness of, and appreciation for, the working marine environment, as well as promoting consumption of the local catch for our local fishing industry. The program also works to enhance consumer confidence in the quality of the local catch and further promotes the importance of protecting the ocean to ensure a sustainable supply of California seafood.

Each California's Golden Seas educational packet consists of the following five elements:

- California's Golden Seas Activity Guide, a 185-page guide for teachers with 27 lessons and take-home handouts for elementary school-age children. The lessons cover marine ecology, fishing gear types, health benefits of seafood, seafood handling, food safety, the economics of fishing decisions, and other related topics. Individual lessons have clear educational objectives ranging from creating an understanding of the marine environment and environmental issues to understanding the nutritional value and health benefits of seafoods. The lessons/activities conform to the curriculum framework of the California State Board of Education for science, math, social science, language arts, health and the visual and performing arts. They are grouped to match the interests and learning abilities of 9-, 10-, and 11-year old children.
- Three videos: "Gone Fishin'" (45 minutes) illustrates how fishers make their catches and demonstrates six major gear types; "GrowSeries: Seafood" (35 minutes, coproduced with the California Department of Education) illustrates the path of seafood from ocean to market; "Protecting the Ocean" (7.2 minutes) depicts fishers working to keep the ocean clean.
- California's Golden Seas Riddle Book (story booklet about a fishing family includes riddles, word search, crossword puzzle). Each kit contains 27 copies of this take-home workbook for children.
- California seafood stickers (featuring top species harvested in California and fishing boats). Each of these kits contains 27 sets of 20 stickers.
- California's Golden Seas full-color poster illustrates major species and fishing gears by area (also used as a board game).

Project Results

The goals and objectives of this project were to reproduce 250 complete sets of the California's Golden Seas Activity Kit and to distribute them to all public grade school districts in the Tri-County area, including San Luis Obispo, Santa Barbara and Ventura Counties. Accordingly, an estimated 7,000 Tri-County elementary school-age children and their parents were provided the opportunity to increase their knowledge and appreciation about the marine environment through the California's Golden Seas materials provided by the California Seafood Council (CSC).

All components of the Golden Seas kits were reproduced, assembled and mailed to principals of the elementary schools identified on a list developed for the project. A direct-mail announcement to each school preceded the mailing of the kits. All kits were mailed in time to celebrate "October is National Seafood Month" in 1997. The following school districts were included in the mailings accomplished through this project: Atascadero United School District (SD), Cambria Union SD, Cayucos Elementary SD, Lucia Mar Unified SD, Paso Robles Union SD, Pleasant Valley Joint Union SD, San Luis Coastal Unified SD, San Miguel Joint Union SD, Shandon Joint Unified SD, Templeton Unified SD, Ballard Elementary SD, Blochman Union SD, Buellton Union SD, Carpinteria Unified SD, Casmalia Elementary SD, Cold Spring Elementary SD, College Elementary SD, Cuyama Joint Unified SD, Goleta Union SD, Guadalupe Elementary SD, Hope Elementary SD, Lompoc Unified SD, Los Alamos Elementary SD, Los Olivos Elementary SD, Santa Barbara Elementary SD, Santa Maria-Bonita Elementary SD, Solvang Elementary SD, Vista Del Mar Union SD, Briggs Elementary SD, Conejo Valley Unified SD, Fillmore Unified SD, Huemene Elementary SD, Mesa Union SD, Moorpark Unified SD, Mupu Elementary SD, Oak Park Unified SD, Ocean View Elementary SD, Ojai Unified SD, Oxnard Elementary SD, Pleasant Valley Elementary SD, Rio Elementary SD,

Santa Clara Elementary SD, Santa Paula Elementary SD, Simi Valley Unified SD, Somis Union SD, and Ventura Unified SD.

Following distribution of the kits, CSC staff contacted the principal of each school by telephone to ascertain that the kit had arrived and that teachers had been made aware of its availability. The CSC received positive responses from most schools contacted; principals reported that kits had been placed in school libraries and teachers had been notified. In further follow-up, a substantial number of teachers reported that they were using or planning to use the materials in their ocean education units. Positive to very positive comments were received by nearly all teachers who reported using the Golden Seas materials.

Accomplishments and Benefits

The goal of the California's Golden Seas Activity Kit is to promote understanding of the ocean and the multiple use of its resources, as well as to foster support for fishers and enhance the value of their catch.

By reproducing and distributing 250 activity kits to all public grade schools throughout the Counties of San Luis Obispo, Santa Barbara, and Ventura, the CSC has increased the knowledge of approximately 7,000 Tri-County children and their parents, helping them to better understand the productivity of the ocean and the role of fishers as food providers.

Cooperating Organizations

Santa Barbara County Fisheries Enhancement Fund

Developing Community Partnerships to Introduce Urban Youth to the Marine Environment

University of California, Los Angeles
R/E-24-7PD
1997

William Hamner and Charles Kopczak

Between June 30 and August 28, 1997, 405 children from local Boys and Girls Clubs participated in experiential marine science education programs at the UCLA Ocean Discovery Center (ODC) on the Santa Monica Pier. Participants ranged in age from 6 to 17 and came from clubs in Santa Monica, Lennox, Los Angeles, Carson, Long Beach, and Pomona. Two groups from the Santa Monica YMCA also participated.

The programs provided a guided discovery and a hands-on experience to the young visitors before going on ocean-fishing trips. Children were introduced to the biological, oceanographic, and environmental conditions of Santa Monica Bay during a brief lecture, slide show, and video in the ODC's Santa Monica Bay room. The lessons presented here were then reinforced when the children were allowed to discover some of the plants and animals that are found in Santa Monica Bay and displayed at the ODC. Children were challenged to select four organisms and discover as much information about them as possible by interacting with the ODC docents. Following this discovery period, children then received firsthand experience of the human impact on Santa Monica Bay during a guided beach cleanup activity led by the docents.

Finally, as a reward for their efforts, Pacific Park, the new amusement park on the Santa Monica Pier, donated wristbands that allowed the children to enjoy free park rides.

By utilizing the resources of the University of California, Los Angeles ODC, these children learned more about the marine environment that many of them were seeing for the first time. This, in turn, provided access to the university to these children. By forming a critical local partnership with the Santa Monica Boys and Girls Club and, by extension, other Boys and Girls Clubs in Southern California, the outreach capabilities of the ODC were increased.

Results

Valuable information was gathered during the first year of this 2-year pilot study. The staff of the Santa Monica Boys and Girls Club handled scheduling of all trips to the ODC. This procedure was adopted to take advantage of the preexisting connection between local Boys and Girls Clubs. From a practical standpoint, however, it resulted in a scheduling problem that effectively eliminated the planned evaluation portion of the program. While children were to take a simple pre- and post-test to assess the efficacy of the program, in reality no evaluations were possible. It seems clear, in retrospect, that had scheduling been handled by ODC staff, many of these problems would have been eliminated. In many cases groups arrived 30 to 80 minutes late with no warning from the scheduled groups. Lacking contact numbers it was impossible for ODC staff to check on the status of these groups. As a policy, ODC volunteers are released if groups do not arrive within 45 minutes of the scheduled start time and no notification has been given. Thus many of the late groups had less than the optimal number of docents available for their learning experience. However, there were no instances where a group was denied access to a program.

A number of young visitors participated in the educational programs more than once, which tended to decrease their attention span. While they certainly may have gained more knowledge of the marine environment, it had the practical effect of reducing the total number of children that were able to participate in the program. As with the scheduling, these repeat visits often caught ODC staff unawares.

Both of these problems could be alleviated in year 2 of the project by having all scheduling occur at the ODC. The ODC staff successfully scheduled over 380 school field trips during the 1996–97 school year. For 1997–98, ODC scheduling procedures have been further refined to include more thorough confirmation and an advanced billing system. This experience would make it quite simple for the ODC to handle the smaller number of groups represented by this program. It would have the added benefit of providing ODC staff with confirmation of scheduled trips and contact numbers that could be used in the event of late arrivals.

Accomplishments

The program educated 405 children from local Boys and Girls Clubs about the marine environment of the Santa Monica Bay and the human impact on the bay. These children left with a better understanding of the relationship between the plants and animals that live in the bay and human activities that can alter their habitat. While it is not possible to measure long-term behavioral changes that may occur, participating children were introduced to a variety of ways that could have a direct and positive impact on the marine environment by changing some simple behavioral patterns. It is hoped that these changes can also be passed along to siblings, friends, and parents.

Conclusion

In general, we feel this marine education program was a success, and with a few small modifications it

can be improved. From this initial effort, expansion of the program is also easily achieved. In addition to Boys and Girls Clubs, children at local YMCA's, Santa Monica Police Activity League and other local summer programs could easily be included, thus expanding the opportunities for more children to learn about the local marine environment.

California Sea Grant College System produced a brochure on Ocean Sportfishing in Southern California that was used as part of the program and has further been distributed to other visitors to the ODC.

Cooperating Organizations
California Sea Grant College System
Pacific Park Santa Monica Pier

Education

Education

California Sea Grant's commitment to education is evident in the projects it supports for students at all levels.

The Trainee Program

Research projects supported by the California Sea Grant College System generally include at least one graduate student trainee. The students work alongside university scientists and engineers in stimulating research environments, while working on or completing graduate degrees. These young scientists and engineers will be responsible for maintaining the high quality of U.S. marine research in the future.

Isaacs Scholarship

The thirteenth John D. Isaacs Memorial Sea Grant Scholarship was awarded in 1994 to Lulu Wen-Luh Wang then a graduate of Alhambra High School. Wang conducted a three-year study of the taxonomy of brittle stars—frequently used as indicator species in pollution studies. Wang is presently a senior at Pomona College. The 1995 scholarship went to Kimberly Johnson of Canyon High School, Anaheim. Johnson sought to delineate the Palos Verdes Hills fault offshore in three dimensions, using a high-resolution system that could give both low frequency and high energy pulses. Johnson is presently a junior at Stanford University. The winner of the 1996 scholarship was Misty Rose Borja of Long Beach Polytechnic High School who studied the defense mechanisms of sea slugs. Borja is now a sophomore at California State University, Long Beach. Shane Sevey, the 1997 winner, was a senior at Fort Bragg High School. His project tested a variety of supplemental diets on red sea urchins with the aim of increasing both the quantity and quality of their roe. Sevey is currently in his freshman year at the College of the Redwoods, Eureka.

The $10,000 award, allocated over a four-year period, recognizes the research excellence of California high school seniors and encourages students to continue their marine education at California colleges and universities. The winner is selected from other marine-related projects at the annual California State Science Fair.

California Sea Grant State Fellowship Program

This program provides a unique educational opportunity for graduate students who are interested in both marine resources and policy decisions that affect those resources. The program matches highly motivated and qualified graduate student with "hosts" in the California state government or in state agencies for a nine-month paid fellowship. In 1994–95, there were three fellows: Stephen Clark from UC Davis worked with the State Regional Quality Control Board; Christopher Davis from San Diego State University worked with the Senate Committee on Natural Resources and Wildlife, as did Christopher Potter from the University of San Francisco. In 1995–96, there were three fellows: Phillip Giovanni of UC Davis worked with the Joint Committee on Fisheries and Aquaculture; Chris Parta of the University of San Diego, worked with the Subcommittee for River Protection and Restoration; and Richard Green of UC Santa Barbara worked with the Monterey Bay National Marine Sanctuary. In 1996–97, Michele Jacobi of Moss Landing Marine Laboratories worked with the Monterey Bay National Marine Sanctuary, and Keith Casey of UC Davis worked with the California Regional Water Quality Control Board.

Continuing Projects

Sea Grant Extension Program

The work of the California Sea Grant Extension Program is presently organized into four major program areas. These areas and the approximate percent of total program effort for each program area are Marine Fisheries, 27%; Seafood Technology, 13%; Coastal Resources, 28%, and Aquaculture, 12%. Selection of these four primary topics was based on the following criteria: availability of subject matter expertise within the Sea Grant Extension Program; existence of a strong research base within the University of California or within other universities, colleges, or agencies; identified national, regional, state, and local needs and priorities; and probability of having a significant impact on solving identified problems. The remainder of time is devoted to professional development, program planning, administration, and public service activities.

Marine Fisheries

Innovative Fisheries Management Techniques. Marine Fisheries Specialist Chris Dewees continued to advise the fishing industry, agencies, fishery scientists, and others about the status and effects of individual transferable quotas. Papers were published on ITQs in Canada and New Zealand. He also participated in the activities of the ICES international ITQ study group and provided information to the National Academy of Sciences ITQ study. Presentations were given to numerous groups including the American Fisheries Society and American Institute of Fishery Research Biologists. Dewees also assisted the California Department of Fish and Game (CDFG) with development of limited entry policies.

Deborah McArdle provided research results on sea cucumber biology with CDFG, industry, and policy makers during negotiations on establishing a limited-entry fishery management plan for that fishery. Her efforts led to species-specific permits that will make fishery monitoring and population dynamics work more useful.

Rick Starr worked with West Coast researchers to study species-habitat associations of rockfishes. He used submersibles to run visual belt transects of rocky habitats. Using direct observations and videotapes, he determined habitats used by different fish species. Starr provided submersible expertise on a research cruise with Mary Yoklavich of NMFS. He also assisted Dr. Milton Love (UCSB) in his efforts to evaluate oil drilling rigs as habitat for rockfishes. Data from observations were entered into database, statistical, and GIS programs and analyzed. These data will be used by researchers from the Pacific states and Canada to define habitat requirements for rockfish species.

Starr published a paper that compared hydroacoustic and submersible estimates of fish abundance on rocky banks and presented the results at the World Fisheries Congress in Brisbane. He chaired a session on in situ techniques at the 1996 Western Groundfish Conference. The results of his work will enable fishery managers to improve stock assessments of rockfishes. Starr also published a paper describing the use of hydroacoustics to estimate squid distribution and abundance as well as a paper that compared fishery logbook data with NMFS research cruise data.

McArdle and Starr organized sessions and presented papers on marine protected areas and harvest refugia at the California and the World Ocean '97 Conference. They also presented papers on MPAs at international meetings on marine conservation and reserves. McArdle completed a major book on California's Marine Protected Areas which, for the first time, organizes and explains the diverse array of 104 MPAs in California.

Jim Waldvogel continued to focus on anadromous fisheries issues by serving as a technical advisor to the Klamath Management Zone Coalition and a technical representative to the Klamath River Task Force. Waldvogel also chaired the Smith River Advisory Council and wrote successful proposals to establish cross-state (California and Oregon) Smith River watershed coordinator and endangered species positions. These positions were funded by For the Sake of Salmon.

Advisors McBride and Waldvogel completed their project on the age and size composition, reproductive characteristics, and diet of California halibut in Humboldt Bay. A large fishery (primarily recreational) has developed in recent years. Jennifer Bloeser will complete her master's thesis at Humboldt State based on data from this project. A related halibut tagging and genetics project with Paul Olin continued with 400 halibut tagged by anglers and 3% return rate to date.

Dewees, Olin, emeritus advisor John Richards, McArdle and Starr all wrote and presented papers at the Resources Agency's California and the World Ocean Conference. In addition, Dewees gave the Conference closing speech which summarized major themes across the 280 papers. The National Sea Grant Office supplied funding to bring in marine policy graduate students from UC Davis and the University of Washington to track the major conference themes.

McBride, Paul Olin and McArdle gave papers at the Live Aquatics

1996 conference on handling, shipping, and conservation issues related to the rapidly growing market for live seafood.

McBride chaired the Punta Gorda Marine Ecological Reserve Advisory Committee which reviewed proposals and made recommendations on research related to the marine reserves research program. Committee comments were submitted to CDFG.

Nearshore Dive Fisheries. SGEP staff continued to be an integral part of the Sea Grant College Program's kelp bed initiative by identifying research needs, helping researchers, industry and managers develop coordinated projects, conducting demonstration projects, and by extending new information. These activities led to several new Sea Grant research projects focused on kelp bed resources.

Marine Advisor McArdle provided the commercial fishing industry with current information on harvest refugia. She began an educational program on MPAs with Santa Barbara area fishers. Her new *California Marine Protected Areas* book was a useful tool in this effort.

Dewees and McBride continued to serve on the CDFG Director's Sea Urchin Advisory Committee and provided research-based information to the Committee to help it with management policy deliberations. Dewees worked on helping the committee improve its methods for requesting and judging research proposals.

Marine Advisors and Dewees assisted CDFG and others by facilitating a series of meetings related to the potential closure of the red abalone fishery south of San Francisco. Their facilitation skills and nonadvocacy approach were helpful on the highly controversial topic.

Chris Dewees co-authored two papers on red sea urchin ecology and management with graduate student Laura Rogers-Bennett.

Salmonid Resource Enhancement. Staff Research Associate Leon Davies and Dewees continued to work with the Springrun Chinook Salmon Work Group made up of fishers, farmers, landowners, forest managers, irrigation districts, environmental organizations and resource agencies. Ten work group meetings were organized, which led to improved habitat actions and improved returns of spawners, and have made endangered species listing unnecessary to date. Improvements include removal of blockages, riparian zone habitat improvement, increased and well-timed water flows, improved monitoring of fish migrations, increased community awareness, and increased funding for habitat improvement. Funding for the project has come from the California Commercial Salmon Stamp Program and the National Fish and Wildlife Foundation.

Waldvogel was appointed as the Del Norte county representative to the Coastal Salmon Initiative (CSI) and served until this initiative failed in late 1996. Waldvogel was also involved with the Oregon Governor's Watershed Enhancement Board and local Curry County watershed councils to develop the successful Oregon Coastal Salmon Restoration Initiative. Waldvogel continued to serve as a technical advisor to several Curry County watershed enhancement councils and as chairman of the Smith River Advisory Council. Waldvogel organized workshops and public meetings on endangered species listings for salmonids and worked closely with the county and others on fishery issues related to proposed gravel extraction.

Cassell obtained $30,000 for a high school student watershed monitoring program in San Mateo county from the Pilarcitos Watershed Restoration Trust Fund. Half Moon Bay High School students will assess the status of steelhead and coho salmon habitat to determine the effectiveness of ongoing stream restoration activities. In addition, Cassell began an education program with coastal landowners and land managers about salmonids and the Endangered Species Act. She produced a slide show and publication which was used in a series of eight workshops. Funding was provided by the Renewable Resources Extension Act Program.

Salmonid Management Studies. Waldvogel completed the 17th year of a 20-year chinook salmon escapement study on Mill Creek (Smith River). The fishery data collected have provided a long-term database for the proposed and actual ESA listings of coho salmon and chinook salmon coastwide in the Pacific Northwest.

Waldvogel's recently completed 10-year study of adult steelhead trout on the Winchuck River was used as a major database for the proposed listing of Klamath Province steelhead as threatened or endangered. Waldvogel also completed the sixth consecutive year of analyzing adult chinook returns to Rowdy Creek Hatchery (Smith River) for age and growth. In cooperation with Rellim Redwood Company, Waldvogel completed a fourth year of juvenile salmonid outmigration data collection. These Mill Creek data will be coordinated with ongoing long-term adult chinook escapement data.

Waldvogel organized and conducted a volunteer steelhead sampling project on the Smith River. Samplers documented the return of marked adult steelhead from Rowdy Creek Hatchery in the sport fishery and provided a database for hatchery/natural steelhead ratios in the Smith River.

Fisheries Outreach and Education. Waldvogel co-organized the Klamath River Restoration Conference with 240 attendees participating in technical session discussion panels and field trips.

Cassell initiated a project, in cooperation with the Pacific Coast Federation of Fishermen's Association and the Half Moon Bay Fishermen's Marketing Association, to develop a series of interpretive signs about central California fisheries to educate tourists at Pillar Point Harbor.

Starr helped design Monterey Bay Aquarium's new commercial fishing exhibit which will be experienced by approximately three million people by 2000.

Increased fuel efficiency lowers harvesting costs and increases profitability for fishermen. The SGEP provided information on the

California Energy Extension Service low interest loan program and fuel saving technologies.

Susan McBride continued to collaborate with the Salmon Restoration Federation in its Fishery Resource Conservation Education Network Project. A resource reference directory of educators, agencies, private organizations and individuals involved in fisheries restoration is now on the Internet through the Resources Agency CERES Homepage, http://ceres.ca.gov/cra/ocean.

Information available to fishermen through computer technology has increased dramatically and rapidly. McArdle trained fishermen and developed a California Fisheries Homepage which was placed on the Internet, http://www.sb.net/mcardle.

Seafood Technology

Seafood Safety. Robert Price served on the steering committee for the Seafood HACCP Alliance, chaired the Alliance's committee to develop a compendium of approved processes and controls, and cochaired a committee to develop educational materials for allied industries and the public. He gave presentations during three-day seafood HACCP train-the-trainer courses. Price also gave HACCP presentations to the seafood industry and regulatory agency personnel in California.

Pamela Tom coordinated and arranged for nine statewide locations for two nationally transmitted satellite down-link conferences on Developing HACCP Plans, and a Legal Assessment of the FDA's new HACCP regulation. Marine Advisors McBride and Cassell assisted with local coordination of these down-link conferences.

Price conducted a Better Process Control School (BPCS) for food canners in Bangkok and assisted in a second BPCS in Huahin, Thailand. Price also conducted a three-day workshop on food canning in Chonburi, Thailand. Additional presentations on seafood safety were given to the Sacramento City Unified School District Nutrition Services Department staff and at the Oregon State University Surimi Technology School.

Price authored and co-authored numerous publications and articles on seafood safety. Price and Tom responded to telephone and written information requests on this topic.

Marine Advisor Cassell organized an informal working group with several San Francisco Bay area home economists to discuss issues related to subsistence fisheries and seafood contamination in the San Francisco Bay area, and potential coordinated education projects focusing on consumers of bay seafood. A survey was developed to evaluate "subsistence" seafood consumption in San Francisco, San Mateo, Santa Clara, Alameda, and San Joaquin Counties. Cassell also continued to coordinate activities in this area with staff from the Department of Health Services and other agencies and groups interested in seafood contamination issues through the Fish Contamination Outreach Task Force.

Price and Tom continued to update and expand a seafood database on a World Wide Web server on the Department of Food Science and Technology's computer network. The Webserver can be accessed at http://www-seafood.ucdavis.edu and contains information on federal seafood guidelines and regulations, seafood publications, upcoming seafood meetings, Seafood HACCP Alliance activities, seafood organizations, and seafood images.

Price and Tom continue to provide seafood technology information worldwide via an automatic interactive discussion group on the Internet. Currently, about 630 people from the U.S. and 40 other countries have subscribed to this discussion group.

Seafood Quality Improvement. Price and Tom completed a project reviewing rapid methods for detecting pathogenic bacteria, viruses, and marine toxins.

Coastal Resources

Geographic Information Systems (GIS) in Coastal Resource Planning. Rick Starr provided technical advice and information about the use of GIS to help identify and solve central California coastal resource management problems. Starr also helped researchers in the Monterey Bay region develop GIS tools for several projects and assisted the new California State University, Monterey Bay, in designing a GIS service center. An intern completed GIS programs for resource restoration projects, GIS workshops, and Rowdy Creek stream data analysis for Del Norte county groups.

Coordination of Monterey Bay National Marine Sanctuary Management Plans. The numerous governmental and nongovernmental organizations involved are attempting to clarify agency water policy, eliminate duplication of agency regulations, and design positive educational and incentive programs to improve water quality in the Central California coastal region. Starr received a grant to coordinate the efforts of the multiagency Water Quality Protection Plan for the Monterey Bay National Marine Sanctuary. Starr hired Dr. Holly Price, who identified locations and sources of water quality problems in the watersheds that drain into the Sanctuary. She also developed draft policies and action plans related to urban runoff and nonpoint source pollution for the cities and counties adjacent to the Sanctuary.

Starr helped coordinate other federal, state, and local management policies that are related to the new Monterey Bay National Marine Sanctuary. He serves on three advisory panels for the Sanctuary. In addition, he also served as chair of the Elkhorn Slough National Estuarine Research Reserve Advisory Committee.

Marine Protected Areas. McArdle and assistant Cindy Schneider obtained and entered information into a computer database for 104 California Marine Protected Areas (MPAs). The database includes information on MPA classification type, county, geographic region, date established, responsible agencies, official regulations

and official boundaries. McArdle also placed maps and descriptions of each MPA into a GIS database and published a guide to California MPAs.

McArdle and Starr created a California Marine Protected Areas Network (CMPAN) Electronic mail list server. The purpose of CMPAN is to enable researchers, nongovernmental agencies, resource managers, industry representatives and extension personnel to receive, share, and discuss MPA-related information as it becomes available. McArdle and Starr have provided CMPAN subscribers with the latest information on research, meetings, book reviews, and bibliographies, as well as information on state, national and international topics.

McArdle and Starr organized a session and presented papers on Marine Protected Areas for the California and World Oceans Conference in San Diego. Starr was an invited speaker at an international conference on the design and monitoring of MPAs, and McArdle made a presentation at an international symposium on protected area management.

Morro Bay National and State Estuary Management Plan. McArdle formed a Morro Bay Management Plan Research Needs Work Group which has begun to update the existing Morro Bay Scientific Research Bibliography. This will provide a central information source which will be made available through libraries, computer disk, and the Internet. In an effort to facilitate information exchange among the Morro Bay Management Plan Administrative Council, the work groups, and other stakeholders, McArdle organized a research needs workshop.

Introduced Marine and Freshwater Species in California. Cassell and Olin hosted a marine exotic species research needs workshop. The workshop brought together academics, government agency staff, and others interested in nonindigenous species issues for the first time in California. Cassell received funding from the US Fish and Wildlife Service to initiate a pilot project to educate boaters in the 12 county San Francisco Bay-Delta region about zebra mussels. The project involves development of a brochure and other outreach materials, as well as sponsoring educational presentations for boaters in the area. The project also involves a survey to assess transport of recreational boats between California and the Midwest (the current infestation zone of the mussel). Cassell and Olin continued to coordinate with the informal California state agency task force on zebra mussels. In addition, they worked with a group of state and federal agency representatives to establish and organize an initial meeting for the Western Regional Panel on Aquatic Nuisance Species.

National Marine Sanctuary Resource Education. Starr helped make a film about gray whales for Pandion Enterprises Wildlife Photographers and the Corporation for Public Broadcasting (PBS). The film describes the biology and habitat requirements of gray whales. Starr also helped make a film about sea otters that is used in the Monterey Bay Aquarium.

Coastal Waterfront Economic Revitalization. Advisors McBride and Jodi Cassell cooperated with Oregon Sea Grant Specialist Fred Smith and Washington Sea Grant Specialist Bob Goodwin to facilitate the Pacific Coast Congress of Harbor Masters and Port Managers Waterfront Workshop. Seventy harbor masters and port managers discussed the fourteen projects selected by the City of Eureka for initial design and implementation. The work groups identified key issues and made suggestions based on their experiences. The results of this experimental training session were used by the Eureka Harbor Commission.

McBride also worked with The Fishermen's Dock and Building Group to develop a proposal to redevelop a 30,000 square foot historical warehouse on the Eureka Waterfront. The proposal links the working waterfront with visitors and takes advantage of the region's history of fishing, timber, agriculture, and Victorian architecture.

McBride's waterfront revitalization group completed their activities when the project they had been working on was privatized. Local and out-of-town businesses are preparing designs and implementation plans for the waterfront project. McBride gave a presentation on her work with this group at a session of the Coastal Society. McBride collaborated with a local nonprofit and developed a one day teachers' workshop on Coastal Dune Ecology. McBride worked with the North Coast Water Quality Control Board staff and numerous local agencies, individuals, and organizations to identify water quality issues and develop goals.

Coastal and Marine Tourism and Recreation. Advisor Cassell initiated contact with a number of government agencies, groups, and individuals involved in coastal and marine tourism and recreation issues in California and other Pacific States to assess the potential and need for California Sea Grant to undertake coastal tourism projects. She worked with Bruce DeYoung of Oregon State University Cooperative Extension to distribute a booklet on the use of low power radio for interpretive programs in coastal areas to San Mateo coastal Chambers of Commerce. Cassell served as UC coordinator for the 1996 Congress of Marine Tourism and Recreation.

Coastal Hazards. Advisor McBride worked with Oregon Sea Grant Specialist Jim Good, Washington Sea Grant Specialist Bob Goodwin, and representatives from numerous state and federal agencies to plan, organize, and publicize a regional, three-day conference on "Coastal Earthquakes and Tsunamis and Reducing the Risks." Approximately 160 people attended and developed an action plan for long-range coastal land use planning in the region.

McBride is a member of the Multiagency Tsunami Mitigation Work Group organized by the state OES office. This work group formed following the 1995 Cascadia Subduction Zone Conference and is part of a regional group, the Cascadia Regional Earthquake Work Group. Members include representatives from state and national parks, county

and state OES personnel, California Department of Mines and Geology, the Bureau of Land Management , and Humboldt State University. The committee's work has resulted in endorsement of tsunami signs and logos by California, Oregon, and Washington.

Reducing Boating Impacts on Water and Sediment Quality. Leigh Johnson and Program Representatives Erika McCoy and Clay Clifton prepared pamphlets for boaters and boat maintenance services, as well as a manual for marina managers and an annotated bibliography on preventing pollution from marinas and recreational boating. Johnson, McCoy, and Clifton cooperated with Marine Advisors Cassell, Starr, and Olin, the San Diego Dockmasters Group and the Association of Monterey Bay Area Governments to conduct pollution prevention workshops in San Diego, Moss Landing and San Francisco. Johnson also spoke to representatives of 17 clubs at the San Diego Association of Yacht Clubs. Johnson completed service on the California Technical Advisory Committee for boating NPS and presented its educational recommendations to the State Water Resources Control Board.

Johnson cooperated with the California Coastal Commission to found the California Clean Boating Network (CCBN) on which advisors Cassell, Olin, and Starr also serve. It includes 51 representatives of federal, state and local agencies, Sea Grant Extension Program and environmental organizations that conduct educational programs on pollution prevention for marinas and recreational boating.

San Diego Bay Water Quality. Johnson represented the Sea Grant Director at the San Diego Interagency Water Quality Panel meetings and chaired the Panel's Communication and Education comprehensive planning committee. Johnson encouraged the San Diego Supercomputer Center to submit a proposal to develop a hydrologic model of San Diego Bay and arranged a meeting that led to joint funding by California Sea Grant and Scripps Institution of Oceanography. The research is part of a larger project to coordinate San Diego Bay environmental data, which is the first to utilize Supercomputer technology for analyzing environmental data collected with different protocols.

Sonoma and Marin County Water Quality. As a member of the Tomales Bay Shellfish Technical Advisory Committee, Olin helped to identify potential pollution sources in the watershed and design a study to determine their actual impacts. Working with Cooperative Extension dairy and livestock advisors, Olin coordinated two workshops for resource managers to develop consensus on water quality goals and monitoring programs for agricultural users in coastal watersheds. This was followed with four workshops for agricultural landowners to educate them about water quality concerns, agricultural impacts, best management practices to reduce pollution from ranching operations, and monitoring programs to document changes in water quality. Olin also authored a fact sheet on water quality for agricultural landowners.

Olin also served as a member of the Marin County Wildlife and Fisheries Advisory Committee which recommends projects to the Board of Supervisors, and subsequently administers projects for habitat enhancement and public education. Water quality and fish habitat are a primary focus of the committee.

The Value of Preserving Estuaries. Susan McBride and representatives from the Coastal Land Trust developed a slide show featuring three of the eight small coastal estuaries in Mendocino County. The three estuaries were used to demonstrate variations in biodiversity in a fully, partially, and undeveloped estuary, sedimentation, habitat use, erosion, and pollution issues were also addressed.

Susan McBride served on the steering committee and collaborated with local, state, and federal agencies, and nonprofit fishery and watershed restoration groups for the Humboldt Bay Symposium. McBride solicited papers for the technical poster session, moderated a panel discussion on bay uses and issues, provided administrative support and gave a presentation on aquaculture in Humboldt Bay.

Aquaculture

Aquaculture Public Service. Marine Advisor McBride organized a workshop for sea urchin processors, divers, and researchers on the urchin fishery, aquaculture potential and enhancement trials. At the workshop Olin presented information based on his research on urchin gonad enhancement. McBride continues to serve on the Research Subcommittee of the Western Regional Aquaculture Consortium Technical Committee. Olin responded to requests for information on aquaculture and pond management. He made presentations to the California Aquaculture Association covering his work with the Department of Fish and Game and researchers at the Bodega Marine Lab to determine causes for oyster mortalities in Tomales Bay. McBride and Olin lectured to high school, community college, and university classes on aquaculture; in addition, McBride taught a mariculture course at Humboldt State University. McBride also gave a presentation on oyster and trout culture to a group of Indonesian academic and government officials.

Abalone Culture and the Third International Abalone Symposium. McBride completed symposium planning, reviewed abstracts and developed the final program for the Third International Abalone Symposium held in Monterey in 1997. Advisor Paul Olin, in cooperation with commercial growers, is continuing research to evaluate artificial diets for the production of abalone. Olin is also working with commercial growers to evaluate methods to reduce impacts of sabellid worms on abalone growth. McBride and a student intern developed protocols for spawning black abalone.

Water Quality and Oyster Farming. Olin is working with shellfish growers collecting water quality data to identify variables associated with oyster mortalities. He made plans to secure a popula-

tion of oysters from Tasmania to evaluate these stocks for resistance. Olin and researchers at the Bodega Marine Lab have determined that environmental toxins, adverse water quality, or pathogens do not appear to be associated with mortalities. Some tissue irritation has been observed that suggests a toxic phytoplankton may be involved. Working with a phycology class at Sonoma State University, a comprehensive phytoplankton survey was conducted in the spring of 1997. No toxic phytoplankton were identified and no mortalities were observed during this time. Researchers at the Bodega Marine Lab have identified heat shock proteins produced in oysters subjected to heat stress. Oysters with these proteins exhibit an induced thermotolerance, and in preliminary field trials heat-shocked oyster survival was 20% greater than controls.

A great deal of public concern exists about the safety of consuming raw oysters. Most cases of illness associated with oyster consumption result from temperature abuse prior to consumption. Olin produced a leaflet on post-purchase handling of oysters to educate consumers about safety issues and proper handling. The flyer is distributed at oyster farms where live oysters are sold.

Olin worked with the Tomales Bay Shellfish Technical Advisory Committee in conducting a study to monitor water quality in the Bay and identify pollution sources. Four workshops were held for rural landowners to discuss water quality variables, monitoring programs and management practices to reduce agricultural pollutants, and lectures were given at high schools and in-service trainings on water quality and aquaculture.

Red Sea Urchin Gonad Enhancement. Marine Advisors Olin and McBride conducted feeding trials with red sea urchins to test the feasibility of fattening urchins in tanks. McBride presented her results at the annual meeting of the World Aquaculture Society, while Olin made presentations at a sea urchin workshop in Bodega Bay and at a shellfish growers workshop in Seattle.

Communications

California, which is now home to over 33 million people, 80 percent of whom live in coastal areas, stretches for more than 1,000 miles along the Pacific.

Not surprisingly, the state has developed a strong academic tradition in marine science. From modest turn-of-the century beginnings in San Diego under a University of California professor from Berkeley, marine research in the University of California has developed into the world's largest and most diverse academic program in ocean science and technology.

Today, on all eight general campuses of the University, marine studies are integrated into many departments. And on five of these campuses—Berkeley, Davis, Santa Barbara, Santa Cruz, and San Diego (i.e., the Scripps Institution of Oceanography)—there are also units devoted solely to marine studies.

In addition, there are strong marine science curricula at a number of private universities, including Stanford University, and at several of the California State University (CSU) campuses, including Humboldt State University, San Diego State University, and Moss Landing Marine Laboratories (sponsored by a consortium of CSU campuses).

In California, Sea Grant began in 1968 with an award to Scripps Institution of Oceanography. By the following year, the National Sea Grant Program was supporting separate projects as well at San Diego State University and UC Santa Barbara. Ultimately, in order to achieve greater coordination and reduce administrative expenses, programs at the various University of California and California State University systems consolidated into the University of California Sea Grant Program. In 1973, this program was designated a Sea Grant College, "for sustained excellence in research, education, and public service dedicated to wise use of America's marine resources."

Today, the California Sea Grant College System is the largest in the national network, with a reputation for supporting strong, cutting-edge research in marine science and technology. In the period 1994–97, the program supported 83 major research projects, plus rapid response projects as well, in the general areas of Coastal Ocean Research, Aquaculture, Fisheries, New Marine Products, Ocean Engineering and Instrumentation, and Marine Affairs. The projects are selected on the basis of competitive proposals.

In addition to research, the California Sea Grant College System has an active extension component and a range of educational programs, chief among which is graduate training through its trainee program.

Communications Objectives

The Communications Program of the California Sea Grant College System plays an essential role in disseminating information about the activities and accomplishments of the program and in promoting communications among a variety of audiences involved in marine resource management, conservation, and development.

Located at the Program's administrative headquarters at UC San Diego, the Communications Office has these major goals:

Goal 1. To increase program recognition and support by informing key audiences and users about the activities and accomplishments of the state, regional, and national Sea Grant programs.

Goal 2. To educate key audiences and users about critical marine resource issues.

Goal 3. To support the communications needs of program management, thereby contributing to Sea Grant's visibility and effectiveness.

Audiences include resource managers, legislators, scientists, commercial fishermen, seafood processors, and other industry representatives, educators, and members of the public. The communications staff works closely with media and produces news releases, brochures, and publications of various types. It also distributes information produced by Sea Grant-sponsored researchers in the form of journal reprints for information about Sea Grant research and other marine science issues each year.

Operations

Mechanisms for information gathering. Perhaps the single most valuable formal mechanism that the Communications Office has for gathering information is the Annual Progress Report, requested of each project leader. The Annual Progress Report has three components: (1) a questionnaire, (2) a technical narrative report, and (3) a trainee report.

The questionnaire asks project leaders about results-to-date in light of project goals and objectives, practical applications of their work, media contacts, publications to date, cooperating organizations, international contacts, and so on. This document is used in a variety of ways. Here are just three:

The questionnaire alerts the communications manager to accomplishments that should be followed up and reported to the media or to federal or state agencies;

It helps track what media coverage a project has received, either

as a result of program efforts, or those of the project leader and his or her university public affairs office;

It provides lists of published articles, books, and conference presentations that result from Sea Grant-funded projects. This ensures that the Sea Grant publications inventory and archives are kept as complete and up-to-date as possible.

Another important component of the Annual Progress Report is the technical narrative. Reports of completed projects are published in the *Biennial Report of Completed Projects*. This publication not only describes overall project accomplishments, but also provides a forum in which project leaders can discuss difficulties encountered, project modifications, public benefits, and so on. The Biennial Report contains lists of cooperating organizations and also a complete list of publications resulting from the project.

Management of information. In order to encourage project leaders to report their publications to the program (and appropriately acknowledge Sea Grant support), the Communications office pays for 100 journal article reprints, 50 of which go to the author and 50 of which the program keeps for mandatory and other distributions.

In any given year, the research projects funded by California Sea Grant result in the publication of as many as 40 to 60 specialized articles in refereed journals, plus other publications such as theses and dissertations, technical reports, and conference papers. The fact that California Sea Grant scientists have the highest publication record in the network has ramifications throughout the area of information management and dissemination and necessitates having a full-time information specialist.

The information specialist has responsibility for maintaining records in publications, for filing and distributing publications, and for filling requests. Specifically the information specialist:

(a) Maintains a cumulative, computerized inventory of Sea Grant publications dating back to 1968. There are at present 2,957 entries in this system.

(b) Maintains a physical archive of these publications, which also includes those produced by Extension specialists and advisors;

(c) Maintains a sophisticated computerized database of 4,200 names and addresses organized into 120 specialized groups. This database allows California Sea Grant to achieve highly targeted mailings—for example, to state legislators or to members of the Pacific Fishery Management Council or to high school teachers in Santa Barbara County. Much of the information specialist's efforts go into list maintenance;

(d) Maintains a "library" of journals, newsletters, and brochures that the program receives from other sources;

(e) Tallies the number of publications received and distributed each month, and enters this information into the computer. A spreadsheet produced from these data details monthly distribution and request counts by type of publication. At the end of each quarter, a report is generated consisting of the spreadsheet with monthly and year-to-date totals, an initial distribution analysis for publications received during the quarter, year-to-date totals of initial distributions, and a page of distribution notes commenting on noteworthy requests and distributions during the period. A listing showing how many times each publication was requested and/or distributed each month during the quarter is also included.

The information specialist also has a critical role in information dissemination: (a) handles distributions of reprints, announcements, news releases, and California Sea Grant series publications, and fulfills all mandatory distribution requirements, including those for Extension materials; (b) answers all phone, mail, and "walk-in" requests for general and specific information and fills all orders; (c) twice yearly compiles and distributes Publications Lists containing newly received publications resulting from Sea Grant research. Each mailing goes to approximately 1,500 persons.

From1994–97, the information specialist distributed reprints of 120 journal articles, 6 papers from published conference proceedings, publications in the California Sea Grant series, and miscellaneous publications, for a total of 210 different items, or 16,900 pieces. Publication announcements, news releases, awards announcements, and newsletters brought the number of pieces distributed to 115,757.

The information specialist also maintains a library of reprints and books from which to fill both specific and general requests for information. In 1994–97, there were 2,926 individual requests for information or publications, bringing the total number of pieces distributed to 131,110.

Information Dissemination

Once information on marine issues or program accomplishments has been gathered, the communications manager, acting in consultation with the program director, decides on appropriate methods for disseminating it. There are a number of communications vehicles that are used routinely and are thus identified in this document as "core" publications. These are the Program Directory, Summary Report, and the Biennial Report of Completed Projects. In addition, conference summaries and proceedings, technical and working papers, specialized publications, a bimonthly newsletter (*Sea Grant In Brief*) news releases, and announcements are regular products of the Communications Office.

Cover design is usually done by freelancers or by the design department at the University of California, San Diego, under the direction of the communications manager. Word processing, typesetting, and page preparation and layout are done in-house by the desktop publishing specialist using Microsoft Word,

Pagemaker, Photoshop, and Freehand. Printing is either done by the University or by outside vendors on the basis of solicited bids in accordance with University policy.

The following publications in the Sea Grant reference and technical series were produced by the Communications Office from 1994–97.

Program Directory 1993–1995. 1994. 32 pages. The Directory presents brief descriptions of each current research project in lay terms with emphasis on the objectives and potential applicability of the research.

Environmental Applications of Marine Biotechnology. Brad Tebo, Scripps Institution of Oceanography, editor. 1995. 32 pages. A workshop sponsored by the California Sea Grant College System at Scripps Institution of Oceanography, August 2, 1994, to explore the application of marine biotechnology to environmental issues. The goal of the meeting was to bring agency representatives, researchers, and potential users together to explore how marine biology-based systems can be exploited for environmental assessment, monitoring, remediation and restoration, and pollution prevention.

Program Directory 1995–1997. 1995. 28 pages.

Tidal Wetland Restoration: A Scientific Perspective and Southern California Focus. Joy Zedler (principal author), San Diego State University. 1996. 136 pages. The objective in producing this publication was to document lessons from wetland restoration efforts in California that have relevance to similar efforts elsewhere on the Pacific Coast. The publication describes some of the problems that constrain wetland restoration and recommends the use of adaptive management techniques as a way to improve planning and accelerate the development of ecosystems.

Patterns in the Ocean: Ocean Processes and Marine Population Dynamics. Andrew Bakun, Food and Agriculture Organization (FAO), United Nations. 1996. 339 pages. The objective of this publication was to provide fisheries scientists and resource managers with current understanding of both the physical and biological processes affecting fish production and to apply this knowledge to explain large-scale fluctuations in fish populations worldwide. The publication (which was produced in conjunction with the Centro de Investigaciones Biológicas del Noroeste in La Paz, Mexico) is virtually unique in bridging the gap between physical oceanography and fisheries biology.

Sea Grant in California: Developing and Protecting Our Marine Resources. 1996. 36 pages. The *Summary Report* serves the program's need for a general, easily comprehensible introduction to the program; it is directed to the broadest possible audience. The publication, which is in magazine format and includes photographs, provides readers with a broad understanding of marine issues and Sea Grant's contribution to meeting them.

Biennial Report of Completed Projects. 1996. This publication includes final reports of Sea Grant-funded research projects. It provides wide dissemination of research results to technical and scientific audiences, as well as a historical record of program accomplishments.

California Marine Protected Areas. Deborah A. McArdle, California Sea Grant Marine Extension Advisor. 1997. 282 pages. There are presently over 100 marine protected areas such as sanctuaries and reserves in California. These include a wide variety of both habitat types and designations, and represent different levels of protection. The aim of this publication was to provide resource managers, scientists, and resource users such as fishermen with the first comprehensive overview of the state's marine protected areas, including the locations, regulations, management objectives, and resources of these areas. It includes uniform maps of California's marine protected areas produced on a geographical information system at the University of California, Santa Barbara.

Ocean Sportfishing in Southern California. 1997. 4 pages. This short publication was developed by the Communications Office in collaboration with the UC Los Angeles Ocean Discovery Center and the California Department of Fish and Game (CDF&G). Its aim was to provide an instructional component to the deep-sea fishing experiences provided to inner-city grade school students by the Santa Monica Boys and Girls Clubs and Los Tiberones (CDF&G). The publication illustrates marine fish that the youngsters are likely to catch and briefly discusses some of the ways catch is regulated in order to protect fish stocks. In addition, the Communications Manager prepared pre- and post-test materials to be used in conjunction with the publication.

Program Directory 1997–1999. 1997. 28 pages.

Taxonomy of Economic Seaweeds: With Reference to Some Pacific Species. (Volume VI), Isabella A. Abbott, University of Hawaii, editor. 1997. 230 pages. The identity of and relationships between major groups of Pacific seaweeds remains largely unknown, a fact that inhibits commercial exploitation of this important resource. This series of publications utilizes the expertise of a small (and diminishing) population of experts around the Pacific Rim to elucidate the taxonomy of economically important Pacific seaweeds. It contributes to the understanding of marine biodiversity and enhances the potential commercial utilization of algal resources.

The first volume in this series received the Blue Pencil Award from the National Association of Government Communicators, and the series has received excellent reviews in the Plant Science Bulletin, NAGA, and The ICLARM Quarterly. The workshop, whose results are documented in this volume, was hosted by Hokkaido University in Sapporo, Japan in July 1991. The series of publications has a wide international audience; multiple copies are frequently ordered from Japan, for example.

Publications in this series are produced with special supplementary funding from the California State Environmental License Fund.

Identification and Management of the Exotic Sabellid Pest in California Cultured Abalone, Carolyn S. Culver, et al. 1997. 36 pages. The abalone aquaculture industry of California was dealt a sharp blow when a shell-inhabiting parasitic worm native to South Africa was inadvertently introduced to cultured stocks in the late 1980s. The previously unknown parasitic polychaete, member of a group collectively known as sabellids or ("fan worms"), does not affect the abalone's meat, but so damages the shell that the abalone's growth slows or virtually ceases. Though the industry has learned to manage the pest, concerns over its impact and its potential spread, even to the environment, have become widespread. This publication addresses the sabellid's life history and ways in which it spreads, the kinds of shell damage it causes, methods for detection, susceptibility of other native marine species to infestation, and recommendations for preventing its spread, both within culture facilities and in the wild.

California Sea Grant will be publishing *Fishery Resources of the Monterey Bay National Marine Sanctuary* by Sea Grant Marine Advisor, Richard M. Starr. This book examines the status of fisheries in the Monterey Bay region of central California where close to 200 species of fishes and invertebrates are harvested in commercial and recreational fisheries. The status of each fishery—and, by extension, the health of fish populations—is influenced by numerous social, economic, environmental, and biological variables. Starr's book provides a comprehensive description of important species, environmental factors affecting fish populations, and the issues challenging fisheries resource management in today's world.

Other planned publications by the program include *Make Every Day a Clean Boating Day,* is a full-color poster outlining environmentally sound practices for recreational boaters prepared by Sea Grant Marine Advisor Leigh Taylor Johnson. This poster will highlight potential pollution problems stemming from such activities as boat and deck washing, painting, varnishing, engine maintenance, and waste production. The targeted distribution is to marinas, yacht clubs, and boatyards throughout the state.

Taxonomy of Economic Seaweeds: With Reference to Some Pacific Species is the result of a workshop hosted by Kasetsart University, Bangkok, Thailand in May 1997. This will be the seventh volume in the series.

Public Relations and Publicity

Public relations activities designed to publicize the activities and achievements of California Sea Grant take a number of forms. These include: contact with the broadcast and print media and with public affairs officers at other universities; news releases and tip sheets; attendance at work-shops, conferences, and special functions; preparation of speeches and testimony; and publication of a bimonthly newsletter, brochures, and announcements.

The Communications staff maintains a list of broadcast, print and electronic media contacts throughout the country to contact via mailings, tip sheets, and phone. They have participated with the national media specialist for the National Sea Grant College Program in compiling an "experts" guide, which was distributed nationally.

The staff produce a bimonthly, single page newsletter, *Sea Grant In Brief,* to maintain program visibility with a number of key contact groups, such as government officials and industry personnel, and to inform these audiences in an encapsulated way about Sea Grant activities. This newsletter is also sent to members of the news media, who have used it for story ideas.

The electronic bulletin board *ProfNet* provides highly directed responses to reporters and writers who issue requests for information for stories they are developing. This allows staff to respond with timely and detailed information to newspaper, television, and radio reporters on a regular basis.

The California Sea Grant website disseminates information on the Communications Program. Publication lists, current project information, Marine Advisory Service contacts, announcements, scholarship and fellowship forms, information, and filing deadlines, are presented on these pages.

The staff also maintain photograph and slide files to fill media requests and use in publications and presentations describing California Sea Grant.

Article Placement

Newspapers and journals featuring the activities of Sea Grant scientists that resulted from staff efforts include: Los Angeles Times, San Diego Union-Tribune, Aquaculture News, Pacific Coast Aquaculture, Chemical and Engineering News, BioScience, Journal of Natural Products, Journal of the American Medical Association (JAMA), San Diego Business Journal, Aquaculture Magazine, MTS Currents, Pacific Fishing, California Geology, Sea Technology, Sportfishing, Santa Cruz Sentinel, Newsletter of the California Fisheries and Seafood Institute, Santa Barbara News Press, and National Fisherman.

Staff also worked with the Sea Grant Extension Program to develop a special issue of *California Agriculture*, which is published by the Division of Agriculture and Natural Resources of the University of California.

Also, during the period 1994–97, the staff was successful in sponsoring and placing an article using a freelance writer: "Enhanced Drifter Fleet Advances Investigation of Coastal Pollution," *MTS Currents*, July/August 1995.

Speeches and Testimony

The following testimony, speeches, and slide shows were prepared by the Communications staff for presentation by the Program Director, Dr. James Sullivan:

Testimony to the State Legislature's Joint Committee on Fisheries and Aquaculture, Sacramento,

California, 1996;

Presentation to the California Fisheries and Seafood Institute, San Francisco, California, 1996;

Presentation to National Sea Grant College Program site visit committee, 1996;

Testimony to the U.S. House of Representatives, Washington, D.C., 1997;

Speech to the Third International Abalone Symposium, Monterey, California, 1997.

Worked with the Office of the Secretary of Resources, State of California, to promote an international conference on the state's marine agenda—"California and the World Ocean '97." Also organized California Sea Grant's exhibition at the conference.

National Sea Grant Programwide Activities

The following activities were performed in collaboration with colleagues in the National Sea Grant College network or in support of state and/or national program objectives:

Collaborated with the National Sea Grant Media Office in organizing special media briefings on marine biotechnology for reporters attending the 1996 meeting of the National Association of Science Writers and the American Association for the Advancement of Science in Baltimore, Maryland, and later in Seattle, Washington.

Wrote articles on marine biotechnology and aquaculture for the first annual report of the National Sea Grant College Program;

Cooperated in the development of a Pacific Sea Grant Communicators' session on Communicating with Coastal Audiences for the 1996 Coastal Society of America meeting in Seattle.

Appendices

Officials and Administrators

Regents of the University of California

Regents Ex Officio

Pete Wilson
Governor of California

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Lieutenant Governor

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