OCS Study
MMS 2006-048

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## Final Technical Summary

## Final Study Report

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Authors

**Hunter S. Lenihan**
**Andrew J. Brooks**
**Principal Investigators**

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Coastal Marine Institute
Marine Science Institute
University of California
Santa Barbara, CA 93106

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# FINAL TECHNICAL SUMMARY

**STUDY TITLE**: Relative importance of POCS oil platforms on the regional population dynamics of reef fishes in the Eastern Santa Barbara Channel

**REPORT TITLE**: Relative contribution of POCS oil platforms to regional population dynamics of a model reef fish, the blackeye goby *Rhinogobiops nicholsii*, in the Eastern Santa Barbara Channel

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**ADDRESS**: Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, CA 93106-6150

**PRINCIPAL INVESTIGATORS**: Hunter S. Lenihan and Andrew J. Brooks

**ADDRESSES:** Bren School of Environmental Science and Management, University of California, Santa Barbara, CA 93106-5131; Marine Science Institute, University of California, Santa Barbara, CA 93106

**BACKGROUND**:

Determining the effect of each decommissioning alternative on the regional production of reef-associated fish species is the primary ecological question concerning the decommissioning of the POCS offshore oil platforms (Holbrook et al. 2000). Surveys of the 27 platforms in California waters reveal that they harbor rich but highly variable assemblages of reef-associated fishes and invertebrates (Love et al. 1999; Page et al. 1999). However, the total habitat area provided by platforms is relatively small in relation to the regional availability of natural reef habitat thus suggesting that platforms may have little influence on population dynamics at regional scales. Nevertheless, platforms may negatively influence the regional population dynamics if they attract individuals from more suitable habitat, or they may enhance populations in areas that have relatively little natural habitat and where the structures have positive influences on demographic processes, including individual growth, reproduction, and survival. Regional stocks of most reef-associated species are composed of local populations that are linked together through the dispersal of larvae and/or the migration of adults or juveniles (Lipcius et al. 1997; Lenihan et al. 2001). Oil platforms most likely enhance regional population abundance by acting as (1) self-maintained local populations, or (2) source populations that continually supply individuals to less-productive sink populations.

**OBJECTIVES**:

Our objectives were to test whether POCS oil platforms in the Eastern Santa Barbara Channel influence the regional population abundance of a model reef fish, the blackeye goby *Rhinogobiops nicholsii*, through examination of the relative contribution of one POCS oil platform, OP Gina, and natural rocky reefs. We examined the population demographics of the blackeye goby because this species is the most common demersal fish found on oil platforms (Carr et al. 1999), provides the best model species to examine population dynamics, and as a very common, small benthic species plays an important role in reef food webs as both a predator on zooplankton and benthic invertebrates (e.g., amphipods, isopods, and polychaete worms) and prey to rockfish, kelp bass, and other groundfish species. Blackeye goby utilize a limited amount of benthic habitat, have limited migratory behavior as adults, closely guard non-cryptic nests, and produce eggs that can be used to quantify fecundity. Therefore, it was possible to quantify key demographic features (reproductive output, recruitment, deaths, immigration, and emigration) necessary to relative contributions to regional population dynamics as they may vary on POCS oil platforms and natural rocky reef habitat.

If oil platforms influence the population dynamics of a fish species on a regional scale, this effect can be accurately estimated for blackeye goby in the Eastern Santa Barbara Channel (ESBC). This species inhabit most of the 13 oil platforms in the area (Carr et al. 1999). There are also relatively few local natural reefs in the ESBC within the normal range of movement of adult blackeye goby, or that are hydrographically connected with local oil platforms (Harms and Winant 1998). Consequently, populations of goby inhabiting ESBC platforms are either self-maintained on individual or proximal platforms, or are subsidized by, or subsidize natural reefs through limited immigration/emigration. They can also be connected through larval transport as blackeye goby has pelagic larvae that spend a relatively short time in the water column during dispersal. Therefore, identifying connectivity between local populations of blackeye goby will entail understanding hydrographic connectivity between habitats, larval transport processes, and adult/juvenile migration (Hench et al. 2001).

Understanding the population dynamics of blackeye goby on ESBC POCS oil platforms and natural reefs, and estimating whether platforms influence regional population dynamics through supply of "excess production", are a means of estimating the relative contribution of oil platforms and natural rocky reefs. It also provides the means of executing the three major research objectives proposed by Holbrook et al (2000): (1) assessing the quality of platforms as reef habitat, (2) estimating connectivity between local populations, and (3) modeling effects on the regional population of maintaining, moving, removing, or topping the oil rigs. Our specific objectives were to (1) quantify population demographic processes (abundance, growth rates, births, mortality, immigration, and emigration) of blackeye goby through sampling using scuba;

and (2) assess the relative contribution of an oil platform and natural reefs as a means of estimating the influence of platforms on the regional population dynamics of a reef fish.

**DESCRIPTION**:

**Overview:** Between May 2003 and November 2004, we made 90 total trips to oil platform Gina in the eastern Santa Barabara Channel and three natural rocky reef control sites at Santa Cruz Island, Orizaba Reef, Chief Reef, and Potato Reef. At each site we measured the following life history parameters of the blackeye goby (*Rhinogobiops nicholsii*), egg production, recruitment, abundance of adults, and population size structure. Additionally, we conducted tethering experiments to estimate mortality from predation, and a tag-recapture study to track mortality and immigration and emigration of individuals from the study areas. Finally, we collected individuals from all sites and removed otoliths (sagittae and lapillae) for size-at-age and microchemical analyses. The methods employed for each of these procedures is described in detail below.

We examined the population dynamics of blackeye gobies at four locations, POCS oil platform Gina (OP Gina) and three natural, subtidal rocky reefs located on Santa Cruz Island (SCI). We selected OP Gina as our oil platform treatment because it is the only platform located at a water depth (31 m) at which scuba divers can dive to the seafloor and work for acceptable lengths of time (>10 min) safely. The seafloor around all other platforms in the SB Channel is too deep for diving, even with Nitrox gas. Natural reefs were selected on SCI because they were the reefs that were nearest to OP Gina, were located at similar water depths (20-30 m), and were inhabited by blackeye goby.

**Demographic study:** Our first objective in the field was to identify the most abundant benthic fish species at OP Gina. We counted the total numbers of individuals of all species encountered on four transects (30 m long x 2 m wide) placed around OP Gina in June, July, and August 2003. We also counted on the same dates all fishes located in the water column (from the seafloor to the surface) within the footprint of the platform from the bottom to the surface of the water on the same dates. We found the blackeye goby was by far the most abundant species at OP Gina. Survey dives made during the same period at SCI confirmed that this species was also one of the most abundant species at our control sites. Therefore, we concentrated our effort throughout the project on this species. We had initially planned to study a surf perch species and the painted greenling but saw only a few individuals at all sites, and had substantial difficulty in capturing them in preliminary fish tagging trials.

To test whether the abundance of gobies varied between OP Gina and natural reef control sites, divers counted the abundance of adults, juveniles, and young-of-the-year (YOY) along four replicate transects (30 m x 2 m) placed along the reef/sand interface at each site. Our counts of YOY provided an estimate of goby recruitment. Transect counts were made in September, October, and November 2003, and January and June 2004.

**Population structure, immigration, and emigration:** We conducted monthly tagging of blackeye goby at each site during September, October, and November 2003, and January 2004 to test whether rates of population size structure, mortality, survival, immigration, and emigration varied among natural reefs and OP Gina. Gobies were captured by divers, brought to the surface, measured, and tagged with a small subcutaneous injection of latex paint placed near the dorsal fin. Gobies were then released in the general area (within 2-5 meters) from which they were caught. Divers remained with the gobies upon release and chased away potential predators until the gobies regained awareness of their surroundings and exhibited what appeared to be normal behavior, mainly using the shelly bottom as refuge. A different color tag was applied each month, and colors were easily visible and distinguishable underwater at all our sites.

Surveys for tagged fish were conducted September, October, November, and December 2003, and January, June, and July 2004. Length-frequency data recorded during tagging were used to construct adult population structure histograms for each site. Estimates of mortality, growth, immigration, and emigration are generated from the number of individuals tagged and recovered at each site during each sampling period.

**Fecundity:** To test whether fecundity of blackeye gobies varied among natural reefs and OP Gina, we estimated the total number of eggs produced by individual fishes from each site. In April 2004, we collected egg masses of our target species from platform Gina (n=15), Chief Reef (n=11), Orizaba Reef (n=11), and from two depths at Potato Reef (n=11 from 20 m, and n=11 from 30 m). This species deposit egg masses on the undersides of small boulders and/or shell fragments, which allowed for collection of entire egg clutches from an individual female. Eggs were collected by divers who non-destructively flipped loose pieces of material on the seafloor that appeared to be guarded by an adult goby. Samples were then placed in a cooler filled with seawater and returned immediately to flow-through seawater aquaria at the UC Santa Barbara's Marine Science Institute. Estimates of egg mass area, egg density, and total number of eggs per clutch (fecundity) were then determined for each location. We examined each egg mass for data yielding a mean density of eggs (eggs/cm$^2$) and total number of eggs, which was calculated by multiplying the area of an egg mass by the mean density.

**Predation mortality of blackeye goby:** To test whether rates of predation on gobies varied among natural reefs and OP Gina, we conducted a tethering experiment in which live, adult blackeye gobies were attached to lines and their fate was followed by divers. We deployed three replicate lines (33 m long) to which we tethered 10 gobies (10 gobies x 3 replicate lines = 30 total gobies per site). The long-lines were placed along our "permanent" survey transects. We conducted this experiment at the conclusion of our study from 10-17 July 2004 to avoid impacts to our study area). After long-lines were deployed and inspected, gobies were captured and brought to the surface as described above (*Tagging*). Gobies were measured and hooked through the base of the dorsal fin with a small, barbed live-bait type fish hook connected to 1 m of 4lb monofilament with a size 7 (15 lb) snap swivel attached to the other end. The diver then released the goby from the plastic bottle and noted the loop location and bottle number of each fish. Gobies were tethered to the long-lines and sampled by divers after 1 hour. Tethered individuals were scored as "goby present", "hook only present", or "snapped". Predators hooked on the goby lines were recorded and released. To address the possibility that "hook only present" individuals may have shaken off the hook without being preyed upon, we ran a control study at in which divers monitored the longlines continually. The depths at our study sites were prohibitive to prolonged bottom times, and so this study was conducted at Naples reef off of Santa Barbara, CA, at a depth of 12 meters.

**Age and Growth estimates:** To test whether growth rates of blackeye goby varied among natural reefs and OP Gina, we collected 60 individuals from each site and dissected the saggitae and lappillae (otoliths) for age-at-size and microchemical analyses. The collection process was as described above (*Tagging*) with the exception that fish were measured and then placed in ethanol immediately upon capture. Weight-length measurements were made from the 60 fish sacrificed for otiliths. Weights were taken prior to the removal of otoliths but after they were stored in 70% ETOH for 1-2 weeks.

**Mircochemistry of otoliths:** We have yet to conduct this additional aspect of our study because we seek additional funding for the relatively expensive and time consuming analysis.

**Population modeling:** We are in the process of modeling the population dynamics of blackeye goby and providing predictions for the regional-scale impacts of the five proposed decommissioning methods. We will undertake and complete our modeling component when we complete preparation of our population demographics paper.

**Summary:** We expect that we will generate a total of four publications from our study: (1) a population demographics paper comparing a POCS oil platform and natural reef populations of blackeye goby, (2) a regional population dynamics modeling paper, (3) and age-growth analysis, and (4) potentially a paper that reports use of otolith microchemistry to analyze temporal patterns of habitat utilization by populations of gobies inhabiting POCS Gina and natural rocky reef control sites.

## SIGNIFICANT CONCLUSIONS:

We assembled a thorough and spatially and temporally comprehensive field-based demographic data set of blackeye goby populations OP Gina and three natural rocky reefs located on the north shore Santa Cruz Island in the ESBC. The natural reefs we used were those located closest in space to OP Gina that also were inhabited by the blackeye goby. Our results provide information that can be used to estimate the relative contribution of goby populations from OP Gina and the natural reefs to the regional population pool of this species.

We found that abundance did not differ among the oil platform and natural reefs; that recruitment was slightly lower at OP Gina than at natural reefs, that the size structure of the population was greater at Op Gina than natural reefs; that the differences in size structure may be explained by reduced predation mortality; that fecundity may be relatively low OP Gina OP, but that fish may live longer and therefore produce more population output over the long-term.

Our general finding is that populations of blackeye goby at OP Gina do not make a substantial contribution to the regional stock of blackeye goby, indicating that OP Gina’s removal, or modification based on other decommissioning strategies, would have little effect on the regional abundance and population dynamics of this species. Because this species is found on many other POCS oil platforms in the ESBC, our findings are relevant to decommissioning strategies in general. We predict that removal or in-situ modification of a platform will not have an important influence on regional populations of this model benthic species. OP Gina is not an important population source or sink. Therefore we also predict that (1) if the platforms were to remain in place it would not have a negative impact on the regional populations of blackeye goby, and (2) that OP Gina should be not considered a potential marine reserve based on this ecologically relevant species.

## STUDY PRODUCTS:

### Published work

Lenihan, H.S., A.J. Brooks, and M.C. Kay. *In preparation*. Relative contribution of POCS oil platforms to regional population dynamics of a model reef fish, the blackeye goby *Rhinogobiops nicholsii*, in the Eastern Santa Barbara Channel. *Target*: Ecological Applications.

A.J. Brooks, H.S. Lenihan, and M.C. Kay. *In preparation*. Age and growth of the blackeye goby *Rhinogobiops nicholsii*, in the Eastern Santa Barbara Channel. Target: Environmental Biology of Fishes.

### Presentations

H.S. Lenihan, A. Brooks, and M.C. Kay. 2005. Relative Importance of POCS Oil Platforms on the Population Dynamics of Reef Fishes in the Eastern Santa Barbara Channel. Bren School, UCSB. October, 2005.

H.S. Lenihan. 2005. Population ecology and problem solving in the marine environment. Bren School, UCSB. December 2005.

H.S. Lenihan. 2006. Population source-sink dynamics and POCS oil platform decommissioning. March, 2006.

# FINAL STUDY REPORT

## Relative contribution of POCS oil platforms to regional population dynamics of a model reef fish, the blackeye goby *Rhinogobiops nicholsii*, in the Eastern Santa Barbara Channel

Hunter S. Lenihan and Matthew C. Kay
Bren School of Environmental Science and Management, University of California, Santa Barbara, CA 93106-5131

Andrew J. Brooks
Marine Science Institute, University of California, Santa Barbara, CA 93106

9 July 2006

## INTRODUCTION

Ecological impact assessment has advanced in recent years due the integration of powerful ecological tools, including BACIPS impact analyses, oceanographic modeling to track population connectivity and manipulative experiments borrowed from marine field and population ecologists (Connell 1960; Schmitt and Holbrook 1996). Population ecology has made an especially important contribution because the models and analytical methods used to explore dynamical and often complex process regulating populations are also well suited to assessing impacts of human activities (Schmitt and Osenberg 1996). Here we address a pressing applied question concerning temperate latitude reef fishes and the management of Pacific Offshore-Continental Shelf (POCS) oil platforms in southern California. The effective management of oil platforms is critical to the ecosystems in which they operate because they are artificial reefs that are both a source of marine pollution and physical disturbance, and habitat for many marine species. By employing a quantitatively rich population biological approach, we not only generate ideas relevant for oil platform management, but also provide a general model for conducting field-based ecological assessments at a regional spatial scale.

Substantial debate surrounds the future of POCS oil platforms, especially concerning how they should be decommissioned once they have reached the end of their productive lifetimes. Five potential methods are under consideration, leaving as they are, removing them completely, leaving them in place but cutting off top 30 m so that they are not a navigational hazard, toppling them in place, and disposing of them elsewhere, including into deep water. Determining the effects of decommissioning alternatives on the regional production of reef-associated fish species is a primary ecological question concerning future management of the POCS offshore oil platforms (Holbrook et al. 2000). Evidence has amassed indicating platforms are inhabited by many marine organisms including economically valuable rockfishes and other groundfishes. These data have ignited debate concerning the most environmentally and economically appropriate options for decommissioning. Many consider high biological production of platforms as justification for avoiding the expenditure of large sums of industry resources necessary for decommissioning. Others argue that the industry is responsible for removing the structures no matter the cost because that was a condition of the original lease policy. Holbrook et al. (2000) suggest that decisions on decommission should be made based at least in part on the best information concerning the ecological impacts of various decommissioning strategies.

Little question remains as to whether POCS platforms are productive. Surveys of the 27 platforms in California waters reveal that they harbor rich but highly variable assemblages of reef-associated fishes and invertebrates (Love et al. 1999; Page et al. 1999). However, Holbrook et al. (200)) suggest that high productivity on individual platforms does not necessary translate into high productivity and ecological enhancement at the regional or ecosystem level. They point out that the total habitat area provided by platforms is relatively small in relation to the regional availability of natural reef habitat thus suggesting that platforms may contributed very little to the regional abundance and distribution of marine organisms. Platforms also may negatively influence the regional population dynamics of a species if they attract individuals from more suitable habitat and, as a result, lead to significant reductions in demographic processes such as recruitment, growth, survival, or reproductive output. As platforms provide little reef habitat relative to natural reefs, significant negative impacts at a regional scale are unlikely, unless the platforms act as major population sinks. In contrast, platforms may enhance populations in areas that have relatively little natural habitat and where the structures have positive influences on demographic processes. Regional stocks of most reef-associated species are composed of local populations that are linked together through the dispersal of larvae and/or the migration of adults or juveniles (e.g., Lipcius et al. 1997; Lenihan et al. 2001). Oil platforms most likely enhance regional population abundances to some degree by acting as (1) self-maintained local populations, and/or (2) source populations that supply individuals to other populations within the region. Thus, the ecologically relevant question is not whether platforms act as sources or sinks, but rather what is the relative contribution to regional populations in terms of numbers or biomass of individuals produced by populations associated with oil platforms when compared with the contribution made by populations associated with areas of natural habitat.

We examined the population dynamics of a model reef fish, the blackeye goby (*Rhinogobiops nicholsii*), that commonly is found on both natural reefs and platforms. By estimating the demographic rates of populations on natural reef and an oil platform, we generate the information necessary to estimate the relative contribution of POCS oil platforms and natural rocky reefs at a regional scale. We also lay the grounds for quantitatively assessing the potential effects of the various decommissioning strategies and provide the data necessary for a meaningful ecological risk assessment model of future POCS platform management options. Here we provide the first step in that process, a rigorous examination of the population demographics of a model reef fish on one POCS oil platforms, Gina (OP Gina), located in the eastern Santa Barbara Channel (ESBC) and a nearby set of natural rocky reefs located on Santa Cruz Island (Figure 1).

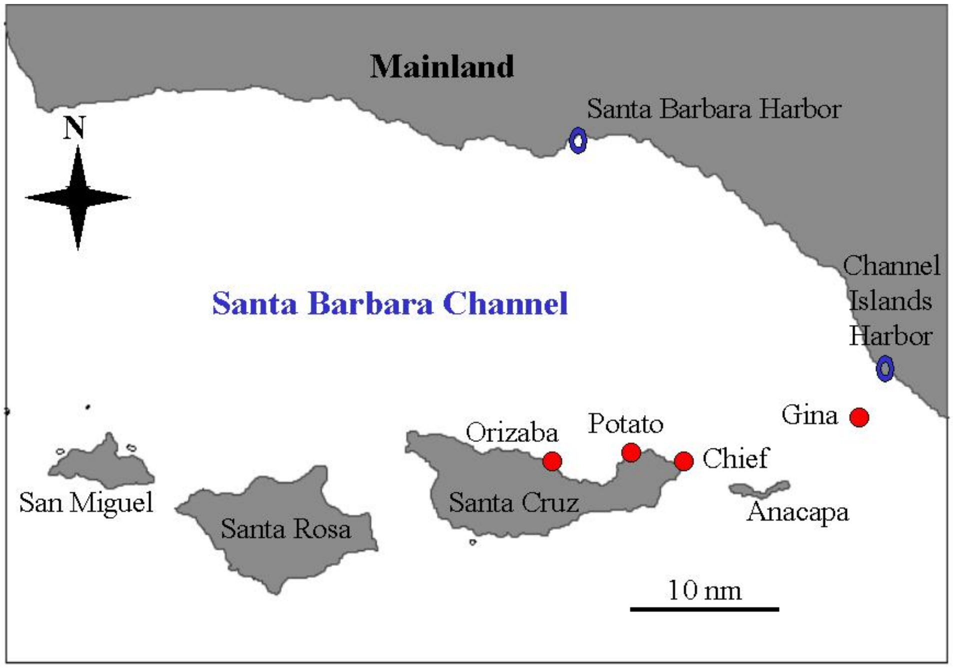



**Figure 1.** Site map of study locations, POCS Oil Platform Gina (OP Gina), and three natural subtidal rocky reefs on Santa Cruz Island.

We selected the blackeye goby as our model reef fish because it is one of the most common species on platforms (Carr et al. 1999), is a good species with which to examine population dynamics, and as a very common benthic species plays an important role in reef food webs as both a predator on zooplankton and benthic invertebrates (e.g., amphipods, isopods, and polychaete worms) and prey for larger rockfish and other groundfish species. Blackeye gobies are a territorial benthic species, have limited migratory behavior as adults, closely guard non-cryptic nests, and produce benthic egg masses that can be used to quantify fecundity. Therefore, it is possible to quantify some of the key demographic features (reproductive output, recruitment, deaths, immigration, and emigration) necessary to identify population dynamics as they may vary on POCS oil platforms and natural rocky reef habitat (Steel 2001). Blackeye gobies are found in water depths to 150 m in the Santa Barbara Channel, including the base of POCS oil platform (OP Gina); the only platforms that is located in a water depth (30 m) that is accessible to scuba divers for long enough periods of time to conduct meaningful population ecological research.

The study reported here is the first step in exploring source-sink population dynamics among platforms and natural reefs (Holt 1985; Pulliam 1988; Crowder et al. 2000). Understanding the population dynamics of the blackeye goby on ESBC POCS oil platforms and local reefs, and estimating whether platforms influence regional population dynamics through supply of "excess production", are also means of executing the three major research objectives proposed by Holbrook et al (2000): (1) assessing the quality of platforms as reef habitat, (2) estimating connectivity between local populations, and (3) modeling effects on the regional population of maintaining, moving, removing, or topping the oil rigs.

Our specific objectives were to quantify the demographic contributions (abundance, growth rates, births, mortality, immigration, and emigration) of the blackeye goby on POCS oil platform Gina and three natural rocky reefs in the ESBC through sampling using scuba. We will use the models to estimate the influence of platforms on regional population dynamics, and estimate the effects of maintaining, moving, removing or topping the platforms using sensitivity analyses.

## METHODS AND MATERIALS

Between May 2003 and November 2004, we made a total of 90 trips to oil platform Gina in the eastern Santa Barbara Channel and three natural, rocky reef control sites at Santa Cruz Island; Orizaba Reef, Chief Reef, and Potato Reef. At each site, we measured the following life history parameters of the blackeye goby, egg production, recruitment, abundance of adults, and population size structure. Additionally, we conducted tethering experiments to estimate mortality from predation, and a tag-recapture study to track mortality and immigration and emigration of individuals from the study areas. Finally, we collected individuals from all sites and removed otoliths (sagittae and lapillae) for size-at-age and micro-chemical analyses. The methods employed for each of these procedures is described in detail below.

### Site Descriptions

We examined the population dynamics of blackeye gobies at four locations, POCS oil platform Gina and three natural, subtidal rocky reefs located on Santa Cruz Island. We selected OP Gina as our oil platform treatment because it is the only platform located at a water depth (31 m) at which scuba divers can safely dive to the seafloor and work for acceptable lengths of time (>10 min). Natural reefs were selected on SCI based on their proximity to OP Gina, similar water depths (20-30 m), and the occurrence of populations of the blackeye goby.

**POCS Oil Platform Gina**

OP Gina (34$^{O}$ 07' N; 119$^{O}$ 16' W) is located approximately 6.5 km offshore from the entrance to Channel Islands Harbor in Oxnard, California. Compared with other oil platforms in the Santa Barbara Channel, the seafloor footprint of OP Gina is relatively small (~30 m x 40 m) and located in shallow water (~31 m deep). Primary space on the support pilings is dominated by the mussel *Mytilus californianus*, and the scallop *Crassoderma giganteum*, barnacle *Balanus nubilus*, and anenome *Corynactis californica* are also common. Fish species that we commonly observed associated with the platform's structural members include (in decreasing order of abundance): kelp bass (*Paralabrax clathratus*), cabezon (*Scorpaenichthys marmatus*), painted greenling (*Oxylebius pictus*), pile surfperch (*Damalichthys vacca*), rubberlip surfperch (*Damalichthys toxotes*) and ocean whitefish (*Caulolatilus princeps*).

The seafloor directly beneath OP Gina is covered by a large shell mound composed of live and dead mussels (*M. californianus*) that have accumulated since the platform's installation in 1980. The "shell mound" reaches a high point ~ 2 m tall (i.e., ~29 m beneath the sea surface) near the center of the OP Gina footprint, and gradually tapers into the surrounding sandy seafloor in ~31 m water depth. The mound is generally circular in shape, 50-60 m in diameter, and there is 100% cover of mussel shells directly below OP Gina. The percent cover of shells decreases rapidly so that there are only a few scattered shells on the sandy substrate only 6-8 m away beyond the platforms foot print. The shell reef supports large populations of the sea stars (*Pisaster* spp. and *Asterina miniata*), octopus (*Octopus bimaculatus*), crabs, and small infuanal organisms including polycheate worms and amphipods. We observed several fish species associated with this unique reef habitat, including (in decreasing order of abundance) blackeye goby (*R. nicholsii*), cabezon (*S. marmatus*), painted greenling (*O. pictus*), C-O turbot (*Plueronichthys coenosus*), fingeheads (*Neoclinus* spp.), and recruits and young-of-the-year (YOY) of numberous species of rockfish (*Sebastes* spp.). We conducted our work with *R. nicholsii* at the shell mound/sand interface along the eastern side of OP Gina.

**Control Sites- Natural Rocky Reefs at Santa Cruz Island**

Control sites were selected to mimic the physical and biological characteristics of OP Gina, especially in terms of water depth, total area and quality of blackeye goby habitat, physical structure, the relative isolation in space from other reefs, and proximity to platform Gina, as well as the composition and structure of fish and invertebrate assemblages. We intensively surveyed the coastlines of the mainland, Anacapa Island, and Santa Cruz Island before selecting our control sites. The three sites at Santa Cruz Island exhibited the highest level of biological and physical similarity to OP Gina.

The three sites we selected, Chief, Potato and Orizaba reefs, were submerged rocky reefs associated with submerged pinnacles (Chief and Potato) and an islet (Orizaba) located north shore of Santa Cruz Island (Figure 1). Each reef was surrounded by sandy seafloor such that there was no corridor of rocky habitat linking the reefs to other reefs onshore on Santa Cruz

Island. We conducted all surveys and experiments at the interface of the seaward edge of each reef and the sandy seafloor at water depths from 20-30 m. All locations were at least 40 m away from other goby or rocky reef habitat (Table 1).

**Table 1**. Site characteristics for Gina and three control sites at Santa Cruz Island.

| Site Name | GPS Position | Water depth | Highest vertical point | Distance to shore | Conspicuous / unique benthic features |
|---|---|---|---|---|---|
| OP Gina | $34^{O}$ 07' N<br>$119^{O}$ 16' W | 30.5 m<br>(100') | Above surface | 6.5 km<br>(3.6 nm) | Shell mound |
| Chief Reef | $34^{O}$ 02.555' N<br>$119^{O}$ 31.855' W | 19.8 m<br>(65') | 8.5 m<br>(28') | 100 m | Uneven rocky bottom, little mussel shell present, abundant *Ophiothrix spiculata, Muricea spp.* |
| Potato | $34^{O}$ 02.945' N<br>$119^{O}$ 35.880' W | 27.7 m<br>(91') | 4.3 m<br>(14') | 170 m | Steep vertical walls, mussel shell present |
| Orizaba | $34^{O}$ 02.880' N<br>$119^{O}$ 43.353' W | 19.8 m<br>(65') | Above surface | 40 m | Steep vertical walls, mussel shell present |

Invertebrate assemblages at each control site were similar to each other and typical of the Santa Barbara Channel. Fish that we commonly observed at sampling locations at each site included (in order of decreasing abundance), Blackeye goby (*R. nicholsii*), California sheephead (*Semicossyphus pulcher*), kelp bass (*P. clathratus*), pile surfperch (*D. vacca*), black surfperch (*Embiotica jacksoni*) rockfish (*Sebastes* spp.), cabezon (*S. marmatus*) and ocean whitefish (*C. princeps*). Other species common to the region were present but occurred higher in the water column or were seen much less regularly.

Despite their similarities, the control sites were unique in several important ways. The reef/sand interface at Chief Reef contained isolated, small (~0.1-1.0 $m^3$) boulders on the sandy seafloor, and this area supported extremely high densities of the brittle stars *Ophiothrix spiculata*. Neither feature was present at Potato or Orizaba Reefs. Potato Reef was physically the most similar to Platform Gina due to its depth, steep walls, and the high density of mussel distributed on the seafloor (see below).

We accessed all sites using a 22' UCSB research vessel that was launched from Santa Barbara (SCI sites) or Channel Islands Harbor (OP Gina). At SCI sites, we anchored at prerecorded GPS locations (Table 1). At OP Gina divers were deployed from an unanchored ("live") boat. Divers descended the anchor line/platform pilings and located permanent buoys that marked sampling locations at each site.

### Abundance and recruitment

Our first objective in the field was to identify the most abundant benthic fish species at OP Gina. We estimated the total numbers of individuals of all species encountered on four transects (30 m long x 2 m wide) placed haphazardly around OP Gina in June, July, and August 2003. We also counted on the same dates all fishes located in the water column (from the seafloor to the surface) within the foot print of the platform from the bottom to the surface of the water. We found the blackeye goby was by far the most abundant species at OP Gina. Survey dives made during the same period at SCI confirmed that blackeye gobies were also one of the most abundant species at our control sites. Therefore, we concentrated our effort throughout the project on this species. We had initially planned to study a surf perch species and the painted greenling but saw only a few individuals at all sites, and had substantial difficulty in capturing them in preliminary fish tagging trials.

To test whether the abundance of gobies varied between OP Gina and natural reef control sites, divers estimated the abundance of adults, juveniles, and young-of-the-year (YOY) along four replicate transects (30 m x 2 m) placed along the reef/sand interface at each site. Our counts of YOY provided an estimate of goby recruitment. Transect counts were made in September, October, and November 2003, and January and June 2004. On each transect, two divers attached a transect line to a fixed marker and spooled the tape out as they swam along the interface. Each diver recorded all *R. nicholsii* encountered in a 30 m x 1 m swath. Data from both divers on a single transect were later pooled to form 1 replicate. This procedure was repeated at each site along fixed markers deployed to ensure that the same areas were sampled through time ("permanent" transects). Gobies smaller than 1.5 cm were recorded as YOY, and thus considered recruits.

**Population structure, immigration, and emigration**

We conducted monthly tagging of blackeye goby at each site during September, October, and November 2003, and January 2004 to test whether rates of mortality, survival, immigration, and emigration varied among natural reefs and OP Gina. At each site, divers used aquarium dip nets to capture individual gobies that were then transferred to larger holding pens on the seafloor. Holding pens were constructed of 1/16" nylon mesh (Memphis Net & Twine) fitted with internal wire frames (1 per pen) that were circular and measured 28 cm diameter x 15 cm tall. These frames protected captured gobies from abrasion and impacts associated with transport.

When ascending, divers attached the holding pens to the bottom of a weighted line that hung from the boat at a depth of 8 m. This allowed the swim bladders of the captured gobies to equilibrate as divers surfaced and entered the boat. After 10-20 minutes at 8 m, the gobies were retrieved, removed from the pens, and placed in a 48 L cooler filled with fresh seawater. The cooler was partially drained and refilled with fresh seawater every 10-15 minutes throughout the tagging process.

All gobies brought to the surface were measured and tagged with a small subcutaneous injection of latex paint placed near the dorsal fin. We used *Liquitex*® brand acrylic paint injected through a 1 ml tuberculin slip-tip syringe fitted with a 30G1/2 *Precisionglide*® needle (Becton, Dickinson, and Company). Individuals were handled in aquarium dip nets during tagging and returned immediately to the cooler. When all fish in the cooler were tagged, they were placed in the holding pens and returned to the seafloor by divers. Gobies were released in the general area (within 2-5 meters) from which they were caught. Divers remained with the gobies upon release and chased away potential predators until the gobies regained awareness of their surroundings and exhibited what appeared to be normal behavior, mainly using the shelly bottom as refuge. A different color tag was applied each month, and colors were easily visible and distinguishable underwater at all our sites.

Surveys for tagged fish were conducted September, October, November, and December 2003, and January, June, and July 2004. Surveys were conducted within 3-7 days after tagging at a given site, and methods used were the same as those used to estimate abundance. Additionally, we searched areas immediately adjacent and further outside of our permanent transects to sample for movement/emigration of individuals from our study transects. Length-frequency data recorded during tagging were used to construct adult population structure histograms for each site. Estimates of mortality, growth, immigration, and emigration are generated from the number of individuals tagged and recovered at each site during each sampling period.

**Fecundity**

To test whether fecundity of blackeye gobies varied among natural reefs and OP Gina, we estimated the total number of eggs produced by individual fishes from each site. In April 2004, we collected egg masses of blackeye gobies from platform Gina (n=15), Chief Reef (n=11), Orizaba Reef (n=11), and from two depths at Potato Reef (n=11 from 20 m, and n=11 from 30 m). This species deposits egg masses on the undersides of small boulders and/or shell fragments that allowed for collection of entire egg clutches from an individual female. Males guard the egg masses. Eggs were collected at OP Gina from mussel shells, but egg masses from the Santa Cruz Island sites were found on shells of mussel shells, scallop (*Crassoderma giganteu) shells*, and small boulders.

Eggs were collected by divers who non-destructively flipped loose pieces of material on the seafloor that appeared to be guarded by an adult goby. Egg masses deposited entirely on collectable substrata were placed in individually labeled *Ziploc*® bags and brought to the surface. Once on the boat, samples were placed in a cooler filled with seawater and returned immediately to flow-through seawater aquaria at the UC Santa Barbara’s Marine Science Institute.

Estimates of egg mass area, egg density, and total number of eggs per clutch (fecundity) were determined as follows. Each egg mass (attached to substratum) was placed in a 1L finger bowl with the egg mass facing upwards. An acetate paper tracing of the egg mass was cut to fit the shape of the mass. This tracing was then weighed against an acetate standard of known weight and area to calculate egg mass area. Next, an acetate paper square of known area ($1cm^2$) was placed haphazardly within the egg mass and all eggs within the square were counted through a dissecting microscope. Four such replicate counts were made for each egg mass, thus yielding a mean density of eggs ($eggs/cm^2$). Total number of eggs was calculated by multiplying the area of an egg mass by the mean density.

**Predation mortality of blackeye goby**

To test whether rates of predation on gobies varied among natural reefs and OP Gina, we conducted a tethering experiment in which live, adult blackeye gobies were attached to lines and their fates followed by divers. We deployed three replicate lines (33 m long) to which we tethered 10 gobies (10 gobies x 3 replicate lines = 30 total gobies per site). Long-lines were constructed of 100 lb monofilament line with small loops spaced every 3 m. The long-lines were placed along our “permanent” survey transects. We conducted this experiment at the conclusion of our study from 10-17 July 2004 to avoid impacts to our study area). Long-lines were deployed along sets of 0.5 m tall risers that lifted the lines off the seafloor in an effort to limit goby entanglement.

After long-lines were deployed and inspected, gobies were captured and brought to the surface as described above (*Tagging*). Gobies were measured and hooked through the base of the dorsal fin with a small, barbed live-bait type fish hook connected to 1 m of 4lb monofilament with a size 7 (15 lb) snap swivel attached to the other end. Each hooked goby was then placed into an individually labeled ½ liter plastic wide-mouth bottle such that the 4 lb monofilament trailed through a slit in the top of the bottle. The remaining <1 meter of 4lb monofilament and snap swivel were wrapped around a rubber stopper and attached to the outside of the bottle with a rubber band, and the bottle was returned to the cooler.

When all gobies were hooked and ready for deployment, divers descended to the long-lines with the plastic bottle/goby assemblies. At each loop in the long-line, a diver first unspooled the 4lb monofilament and attached the snap swivel to the loop. The diver then released the goby from the plastic bottle and noted the loop location and bottle number of each fish. Gobies were tethered to the long-lines and sampled by divers after 1 hour. Tethered individuals were scored as "goby present", "hook only present", or "snapped". Predators hooked on the goby lines were recorded and released.

To address the possibility that "hook only present" individuals may have shaken off the hook without being preyed upon, we conducted a control study in which divers monitored the longlines continually. The depths at our study sites prohibited prolonged bottom times, and so this study was conducted at Naples reef off of Santa Barbara, CA, in a depth of 12 meters.

**Age and Growth estimates**

To test whether growth rates of blackeye gobies varied among natural reefs and OP Gina, we collected 60 individuals from each site and dissected the saggitae and lappillae (otoliths) for age-at-size and microchemical analyses. The collection process was as described above (*Tagging*) with the exception that fish were measured and then placed in ethanol immediately upon capture. At one site, fish were weighed prior to being placed in ethanol, and were re-weighed after 1 week exposure to ethanol. The difference in weights was used to correct for wet weights. Fish which were placed in ethanol prior to being weighed. Ageing of the otoliths has proven problematic to date and we developing an avenue for microchemical analyses. Weight-length measurements were made from the 60 fish sacrificed for otoliths. Weights were taken prior to the removal of otoliths but after they were stored in 70% ETOH for 1-2 weeks.

## RESULTS

**Population abundance on OP Gina and natural reefs at Santa Cruz Island**

Adult blackeye goby, *Rhinogobiops nicholsii*, were the most abundant fishes observed on benthic transects at OP Gina and all natural rocky reef sites located at Anacapa and Santa Cruz Islands (Figure 1) in June, July, August 2003 (Figures 2, 4, and 6). At OP Gina, blackeye gobies were located on the seafloor only, usually associated with mussel shell habitat, and were not found in the water column or on the platform structure (Figures 3, 5, and 7). Blackeye gobies were seen on the rocky faces of vertical reefs above the soft-sediment seafloor at the three natural control sites, Chief Reef, Potato Reef, and Orizaba Reefs, but only occasionally and in very low numbers. At Chief reef, gobies were observed in the water displaying mating behavior and occasionally feeding on zooplankton. Other fishes that were regularly observed at all sites, pile surfperch (*Damalichthys vacca*), rubberlip surfperch (*Damalichthys toxotes*), and cabezon (*Scorpaenichthys marmatus*), were found on both benthic habitat and in the water column. The painted greenling *Oxylebius pictus* was the second most commonly found fish after blackeye gobies (Figures 2-7), and like the balckeye goby, was found only on the bottom habitat. Cabezon was observed in relatively high numbers on the support structures of OP Gina, often males guarding egg masses.

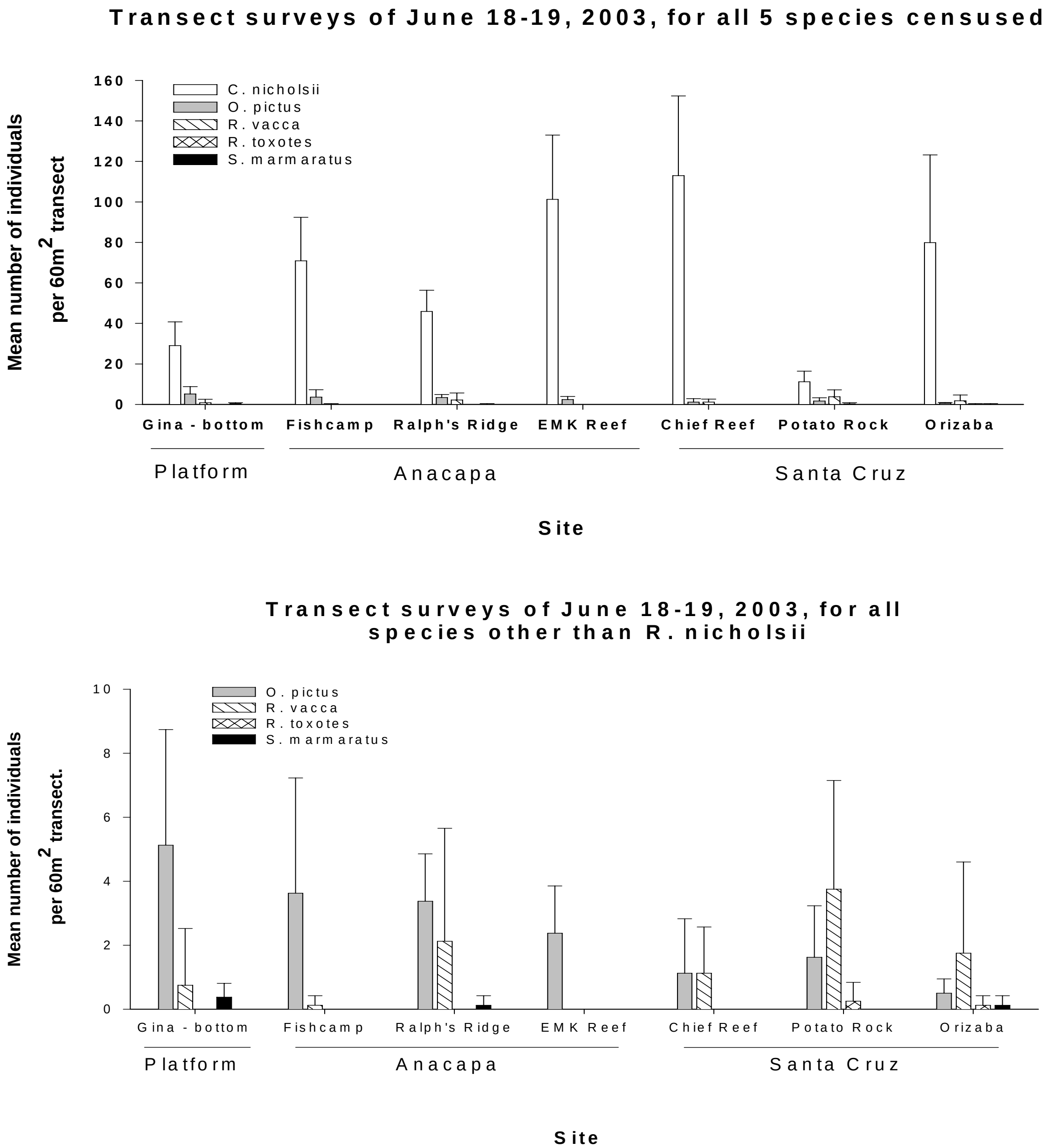



**Figure 2.** Abundance of fishes at POCS oil platform Gina (OP Gina) and natural rocky reefs at Anacapa and Santa Cruz Islands in June 2003. Data are means and 95% CI from four replicate 30 m x 2 m transect counts collected by divers from each site. C. nicholsii is the former name for R. nicholsii, the blackeye goby.

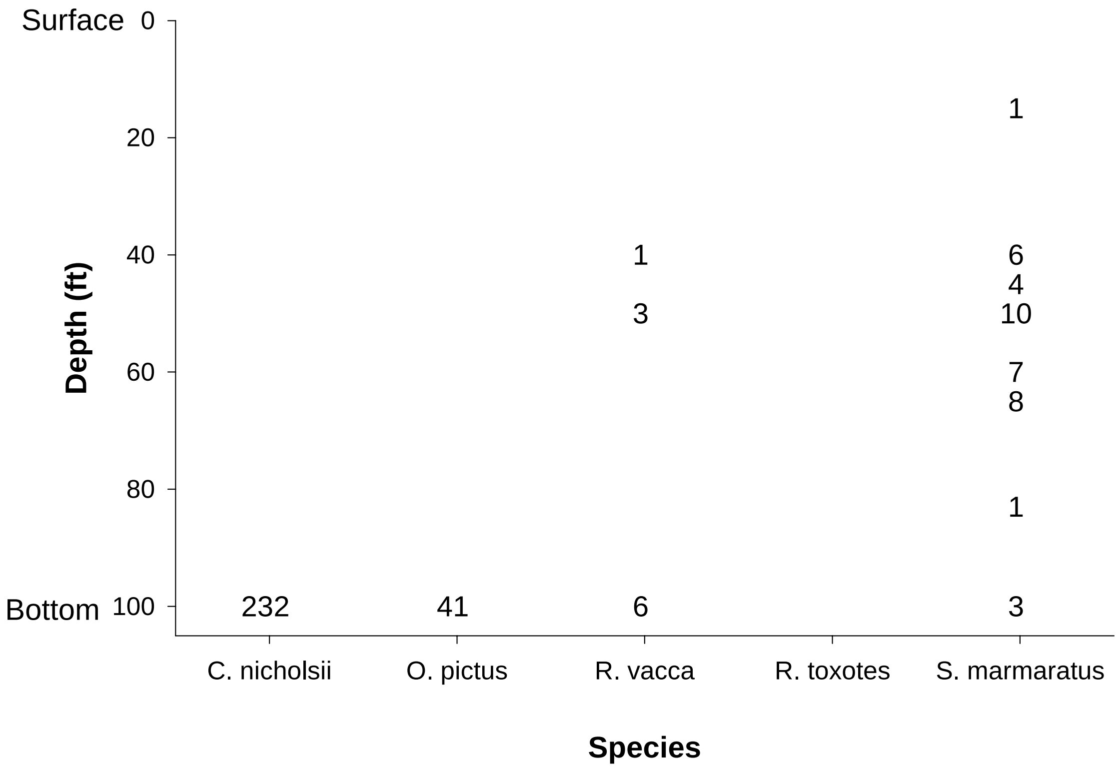
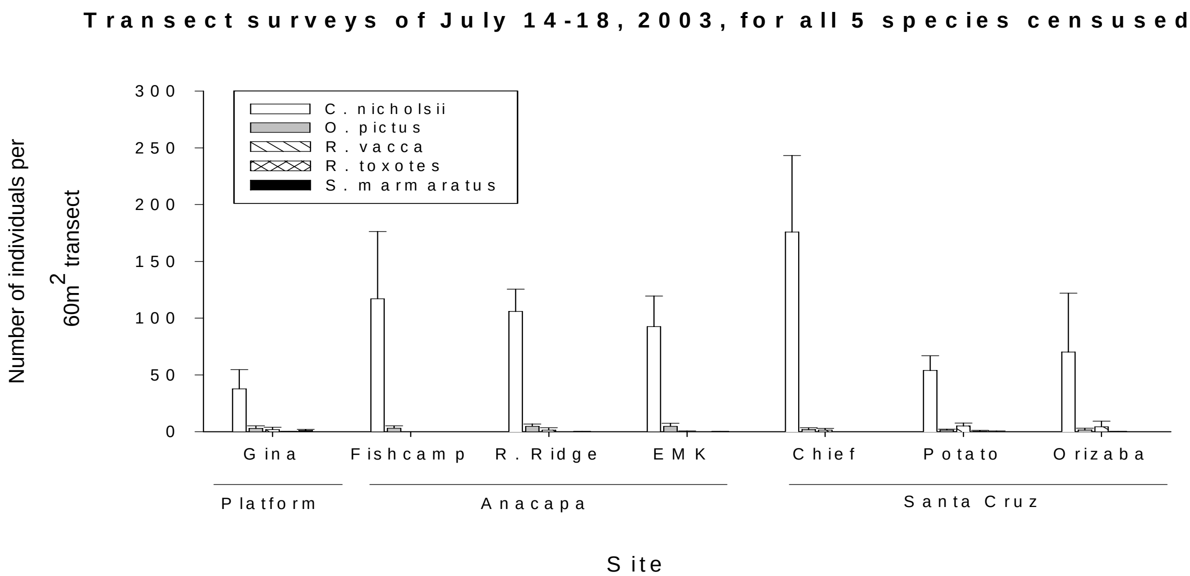



**Figure 3.** Total number and vertical distribution of fishes observed beneath OP Gina on 14 June 2003. Data from bottom transect (31m depth) are included. Each number represents the total number of individuals of all species recorded at that depth. *C. nicholsii* is the former name of *R. nicholsii*, the blackeye goby.



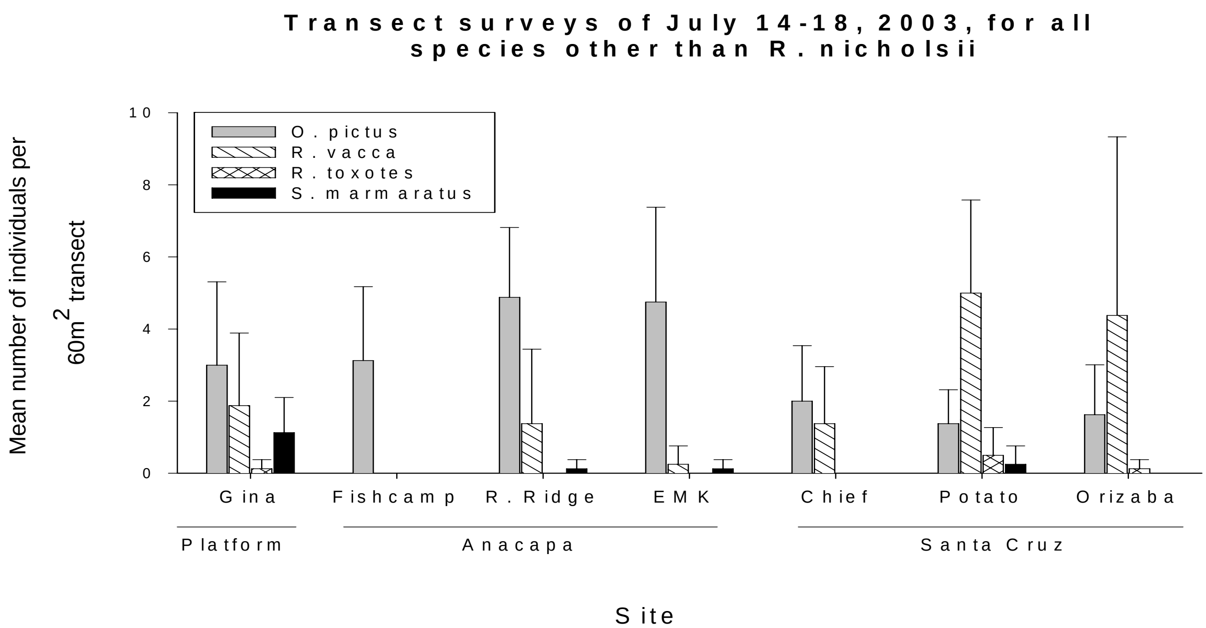




**Figure 4.** Abundance of fishes at POCS oil platform Gina (OP Gina) and natural rocky reefs at Anacapa and Santa Cruz Islands in July 2003. Data are means and 95% CI from four replicate 30 m x 2 m transect counts collected by divers from each site. *C. nicholsii* is the former name of *R. nicholsii*.

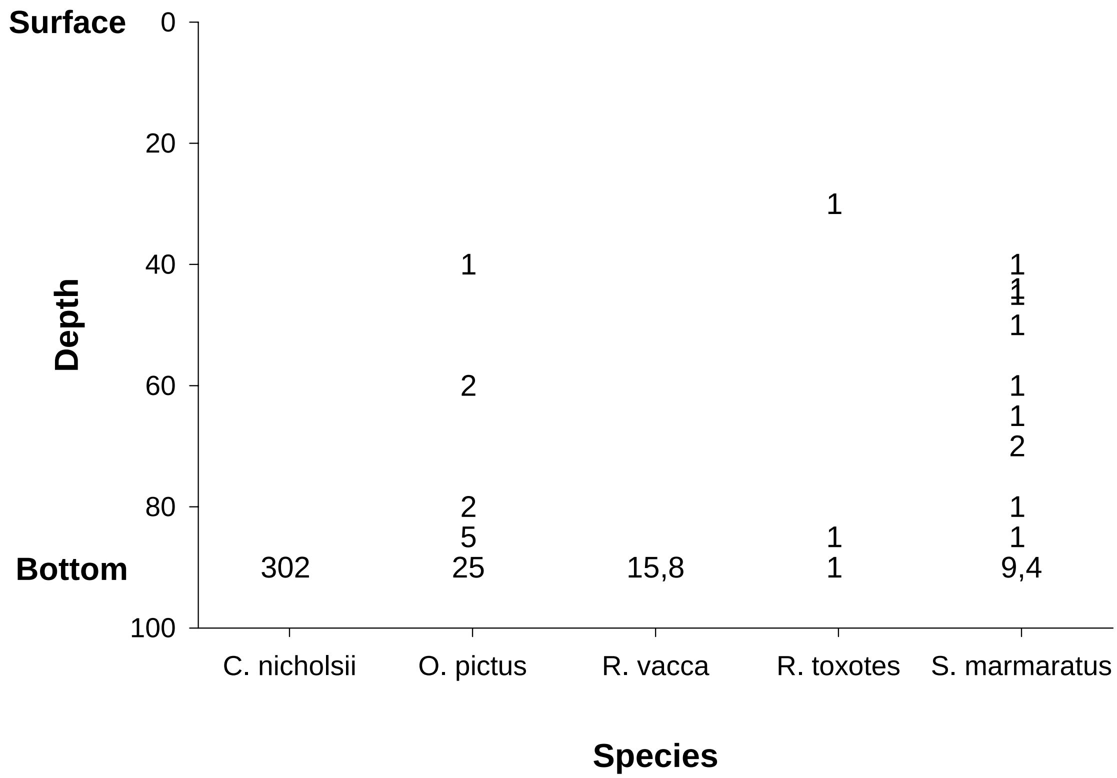
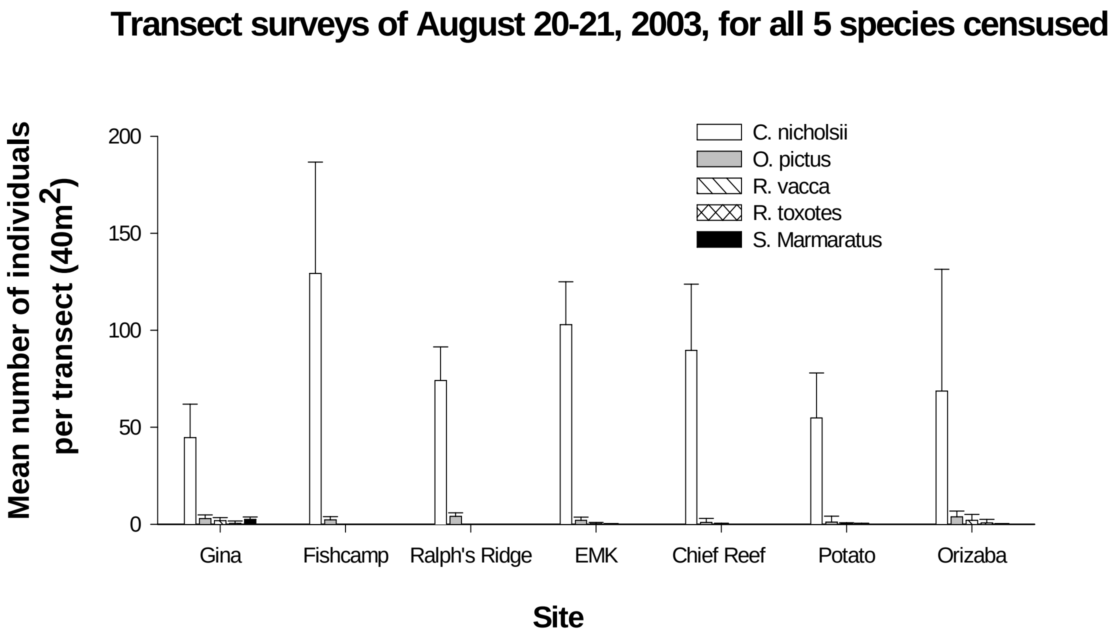



**Figure 5.** Total number and vertical distribution of fishes observed beneath OP Gina on 17 July 2003. Data from bottom transect (31m depth) are included. Each number represents the total number of individuals of all species recorded at that depth. Number after commas are counts made at the same depths but counted by divers when conducting bottom transects (i.e. looking upwards). *R. nicholsii* was initially *C. nicholsii*.



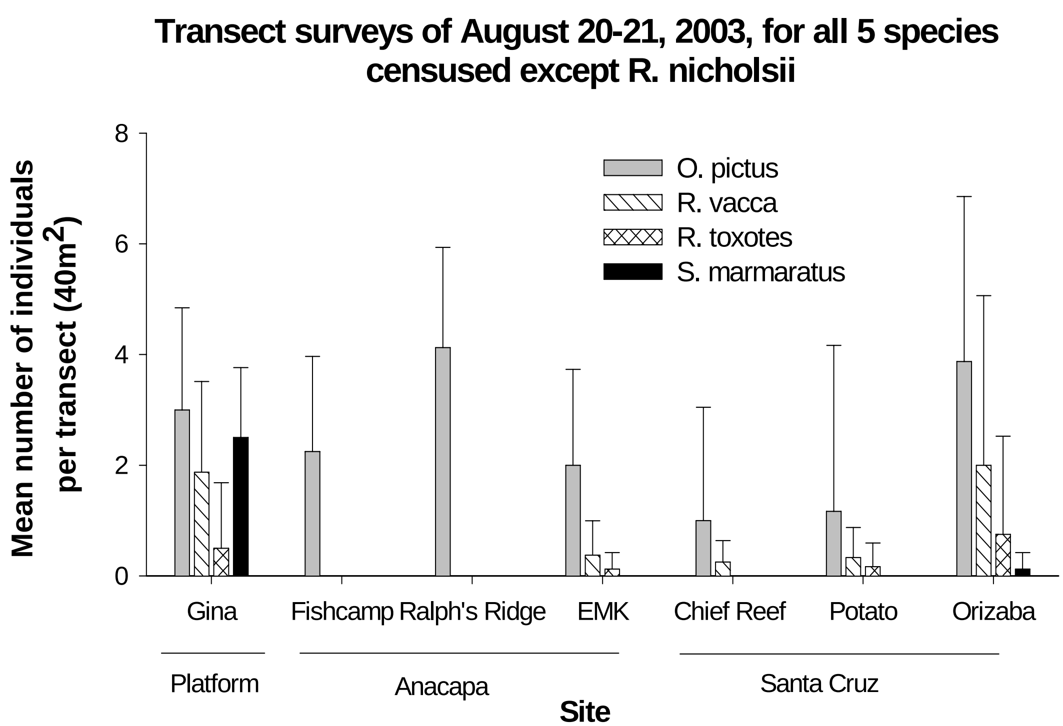




**Figure 6.** Abundance of fishes at POCS oil platform Gina (OP Gina) and natural rocky reefs at Anacapa and Santa Cruz Islands in August 2003. Data are means and 95% CI from four replicate 30m x 2m transect counts collected by divers from each site. *C. nicholsii* was the former name of *R. nicholsii*, the blackeye goby.

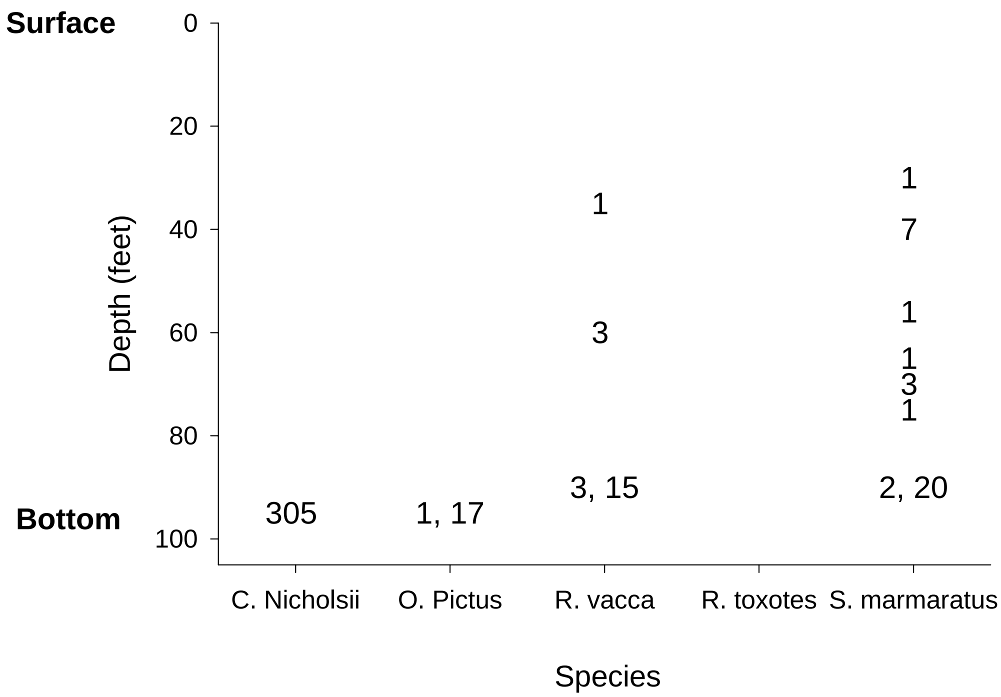



**Figure 7.** Total number and vertical distribution of fishes observed beneath OP Gina on 30 August 2003. Data from bottom transect (31m depth) are included. Each number represents the total number of individuals of all species recorded at that depth. Number after commas are counts made at the same depths but counted by divers when conducting bottom transects (i.e. looking upwards).

In June 2003, there were significantly higher densities of blackeye gobies at Chief Reef than at Potato Reef-90' and OP Gina, and greater numbers at Orizaba Reef than at Potato Reef-90' (Figure 2). There were no significant differences among other locations during June 2003. In July 2003, there were greater numbers of blackeye gobies at Chief Reef than at other locations, and no difference in goby density among any other stations (Figure 4). In August 2004, there were generally higher densities of blackeye gobies at all stations than during June and July, but there were no significant differences among locations (Figure 6).

**Recruitment**

In 2004, we examined recruitment during March-September, months in which blackeye gobies have been reported to recruit (e.g., Love 1999). Recruitment did not occur or was at very low levels March through June, when steadily increasing recruitment began. Recruitment reached maximum levels in late July-early August (Figure 8). There was no significant difference among locations for any time period, due mainly to high variation within sites and thus low power to detect differences. However, there was a trend towards lower recruitment at OP Gina than at natural reefs, across all sampling dates.

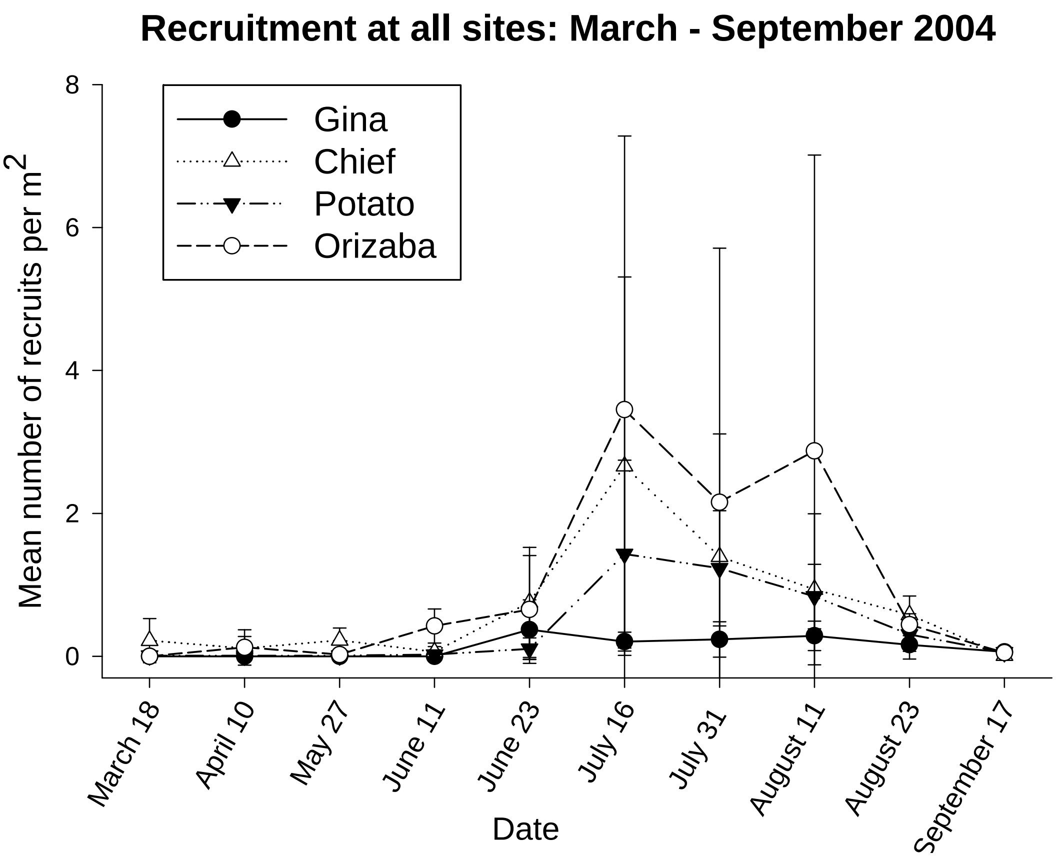



**Figure 8.** Recruitment per unit area of habitat of *R. nicholsii* measured March-September 2004 at OP Gina and the three natural rocky reefs at Santa Cruz Island. Data are means and 95% CI from four replicate 30 m x 2 m transects. Visual counts were made by divers.

**Population structure, immigration, and emigration**

We were able to tag a relatively high number of blackeye goby at all sites in September, October, and November 2003, and January 2004 (Tables 2-5). The number of gobies tagged at OP Gina was less than at other sites in 2003 (Figure 9) because goby density was lower than reef sites and there was often more shell material in which fish were able to escape and hide, thereby making them more difficult for divers to catch. By December 2004, we were highly efficient at tagging gobies at all stations. We sampled transects for tagged gobies in December 2003, and January, June, and July 2004 and found relatively high rates of tag returns at all sites, except for OP Gina in December 2003, when we found very low numbers of fishes tagged in September. Low numbers of returns of blue (i.e., September) tagged fish during this period may have resulted from very low light levels and the resulting difficulty in identifying the blue tags.

**Table 2.** Total number of blackeye gobies tagged in the study, and the number of tags and proportion of individuals tagged recovered in December 2003.

| Site | Total # tags applied | | | | # of tags recovered December 2003 | | | | Proportion recovered | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Blue* | *Yellow* | *Orange* | Total | *Blue* | *Yellow* | *Orange* | Total | *Blue* | *Yellow* | *Orange* |
| **Chief Reef** | 80 | 120 | 100 | 300 | 5 | 19 | 18 | 42 | 0.06 | 0.16 | 0.18 |
| **Potato Reef** | 81 | 120 | 85 | 286 | 19 | 29 | 30 | 78 | 0.23 | 0.24 | 0.35 |
| **Orizaba Reef** | 125 | 130 | 161 | 416 | 5 | 36 | 41 | 82 | 0.04 | 0.28 | 0.25 |
| **OP Gina** | 43 | 47 | 63 | 153 | 1 | 11 | 15 | 26 | 0.02 | 0.23 | 0.24 |

Blue = September 2003 Yellow = October 2003 Orange = November 2003

**Table 3.** Total number of blackeye gobies tagged in the study, and the number of tags and proportion of individuals tagged recovered in January 2004.

| Site | Total # tags applied | | | | | # of tags recovered Janaury 2004 | | | | | Proportion recovered | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Blue*** | ***Yellow*** | ***Orange*** | ***Green*** | **Total** | ***Blue*** | ***Yellow*** | ***Orange*** | ***Green*** | **Total** | ***Blue*** | ***Yellow*** | ***Orange*** | ***Green*** |
| **Chief Reef** | 80 | 120 | 100 | 147 | 447 | 2 | 4 | 22 | 20 | 48 | 0.03 | 0.03 | 0.22 | 0.14 |
| **Potato Reef** | 81 | 120 | 85 | 109 | 395 | 10 | 27 | 26 | 33 | 96 | 0.12 | 0.23 | 0.31 | 0.30 |
| **Orizaba Reef** | 125 | 130 | 161 | 154 | 570 | 3 | 18 | 33 | 44 | 98 | 0.02 | 0.14 | 0.20 | 0.29 |
| **OP Gina** | 43 | 47 | 63 | 91 | 244 | 2 | 17 | 24 | 35 | 78 | 0.05 | 0.36 | 0.38 | 0.38 |

Blue = September 2003 Yellow = October 2003 Orange = November 2003 Green = January 2004

**Table 4.** Total number of blackeye gobies tagged in the study, and the number of tags and proportion of individuals tagged recovered in June 2004.

| Site | Total # tags applied | | | | | # of tags recovered June 2004 | | | | | Proportion recovered | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Blue*** | ***Yellow*** | ***Orange*** | ***Green*** | **Total** | ***Blue*** | ***Yellow*** | ***Orange*** | ***Green*** | **Total** | ***Blue*** | ***Yellow*** | ***Orange*** | ***Green*** |
| **Chief Reef** | 80 | 120 | 100 | 147 | 447 | 0 | 7 | 6 | 14 | 27 | 0 | 0.06 | 0.06 | 0.10 |
| **Potato Reef** | 81 | 120 | 85 | 109 | 395 | 3 | 10 | 1 | 10 | 24 | 0.04 | 0.08 | 0.01 | 0.09 |
| **Orizaba Reef** | 125 | 130 | 161 | 154 | 570 | 1 | 11 | 7 | 22 | 41 | 0.01 | 0.08 | 0.04 | 0.14 |
| **OP Gina** | 43 | 47 | 63 | 91 | 244 | 1 | 7 | 10 | 10 | 28 | 0.02 | 0.15 | 0.16 | 0.11 |

Blue = September 2003 Yellow = October 2003 Orange = November 2003 Green = January 2004

**Table 5**. Total number of blackeye gobies tagged in the study, and the number of tags and proportion of individuals tagged recovered in July 2004.

| Site | Total # tags applied | | | | | # of tags recovered July 2004 | | | | | Proportion recovered | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Blue*** | ***Yellow*** | ***Orange*** | ***Green*** | **Total** | ***Blue*** | ***Yellow*** | ***Orange*** | ***Green*** | **Total** | ***Blue*** | ***Yellow*** | ***Orange*** | ***Green*** |
| **Chief Reef** | 80 | 120 | 100 | 147 | 447 | 0 | 2 | 2 | 13 | 17 | 0 | 0.02 | 0.02 | 0.09 |
| **Potato Reef** | 81 | 120 | 85 | 109 | 395 | 5 | 15 | 8 | 14 | 42 | 0.06 | 0.13 | 0.09 | 0.13 |
| **Orizaba Reef** | 125 | 130 | 161 | 154 | 570 | 2 | 10 | 4 | 19 | 35 | 0.02 | 0.08 | 0.02 | 0.12 |
| **OP Gina** | 43 | 47 | 63 | 91 | 244 | 0 | 7 | 9 | 13 | 29 | 0 | 0.15 | 0.14 | 0.14 |

Blue = September 2003 Yellow = October 2003 Orange = November 2003 Green = January 2004

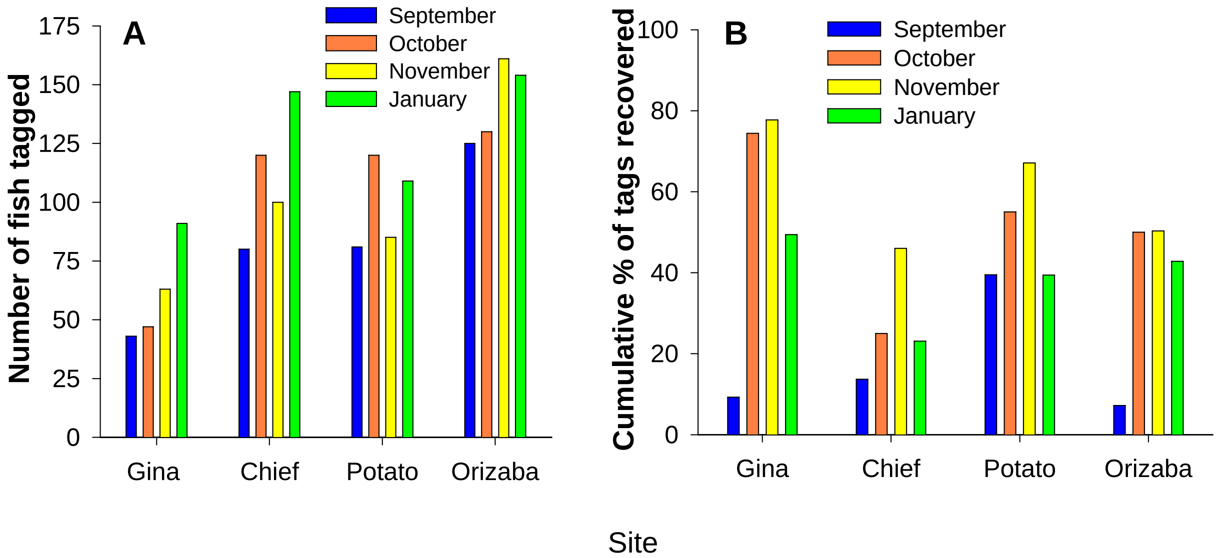



**Figure 9.** Total number of blackeye goby, *R. nicholsii*, tagged from September 2003 to January 2004, the cumulative numbers of tags recovered during censuses conducted from December 2003 to July 2004 at OP Gina and three natural rocky reefs sites at Santa Cruz Island.

Analysis of the size structure of populations at our sampling sites collected from tagged fishes indicated that a higher proportion of the population at OP Gina contained relatively large fishes compared with all natural reef sites (Figure 10-13; G-test, $P<0.05$). There was no significant difference in size structure among reef sites (G-test, $P>0.056$). Larger fish at OP Gina may result from a number of factors, including higher survivorship and faster growth rates, which we plan to explore via population modeling. One potential factor, reduced predation mortality at OP Gina, was explored with a manipulative experiment described below.

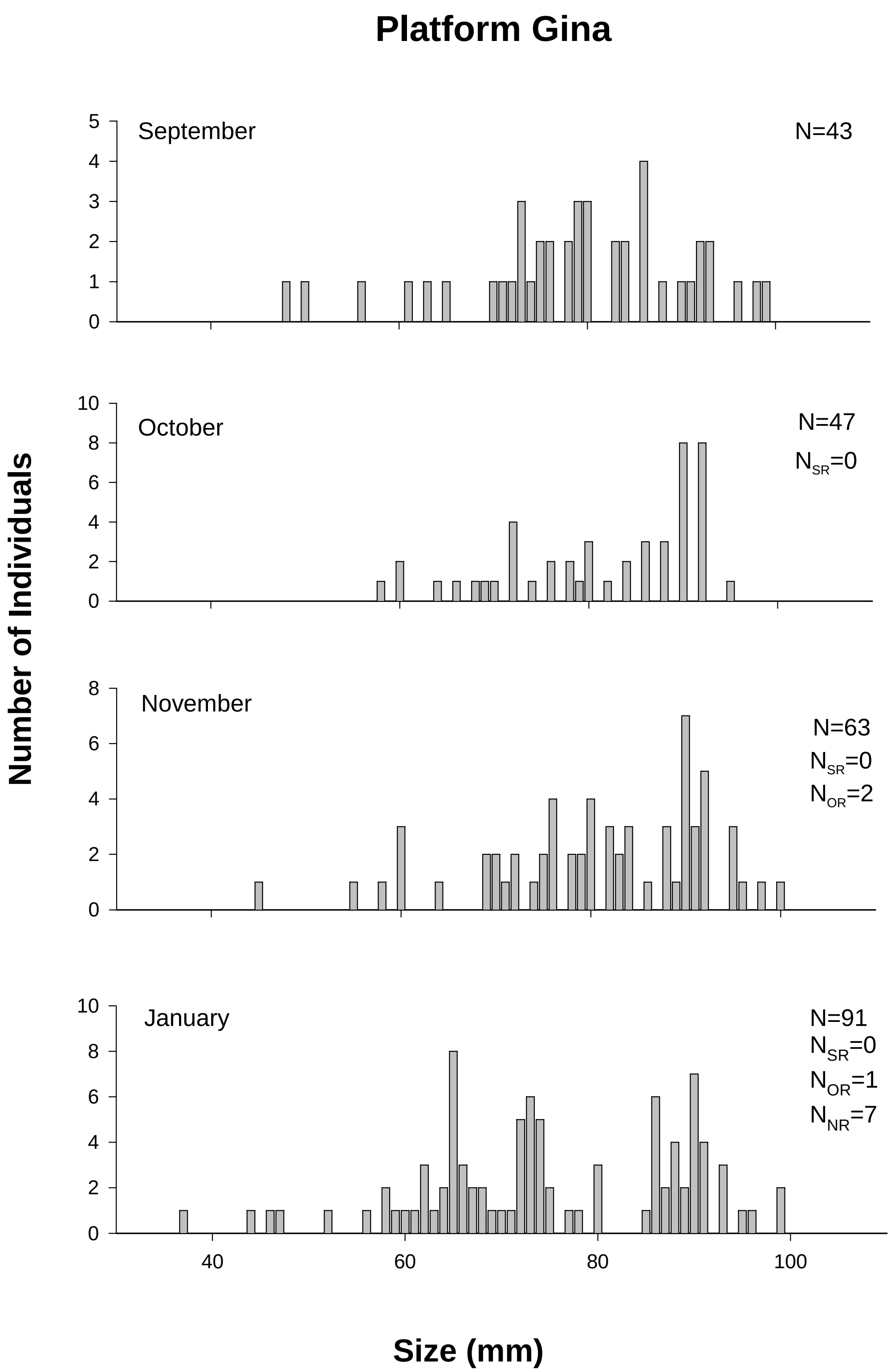



**Figure 10.** The size-frequency distribution of blackeye goby at OP Gina collected from fish tagged September 2003 to January 2004. SR= September tag returns; OR= October tag returns; and NR= November tag returns.

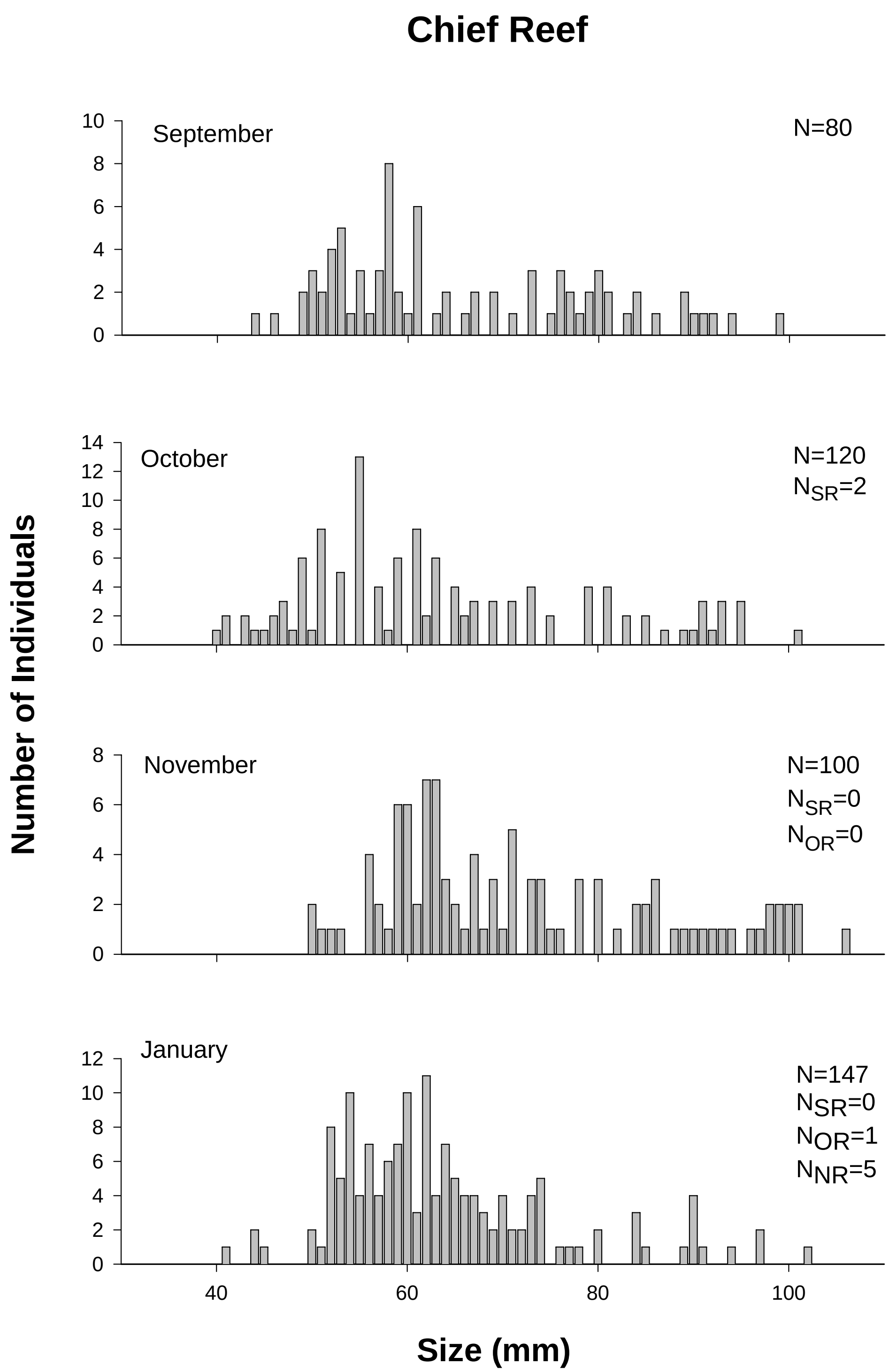



**Figure 11.** The size-frequency distribution of blackeye goby at Chief Reef (SCI) collected from fish tagged September 2003 to January 2004. SR= September tag returns; OR= October tag returns; and NR= November tag returns.

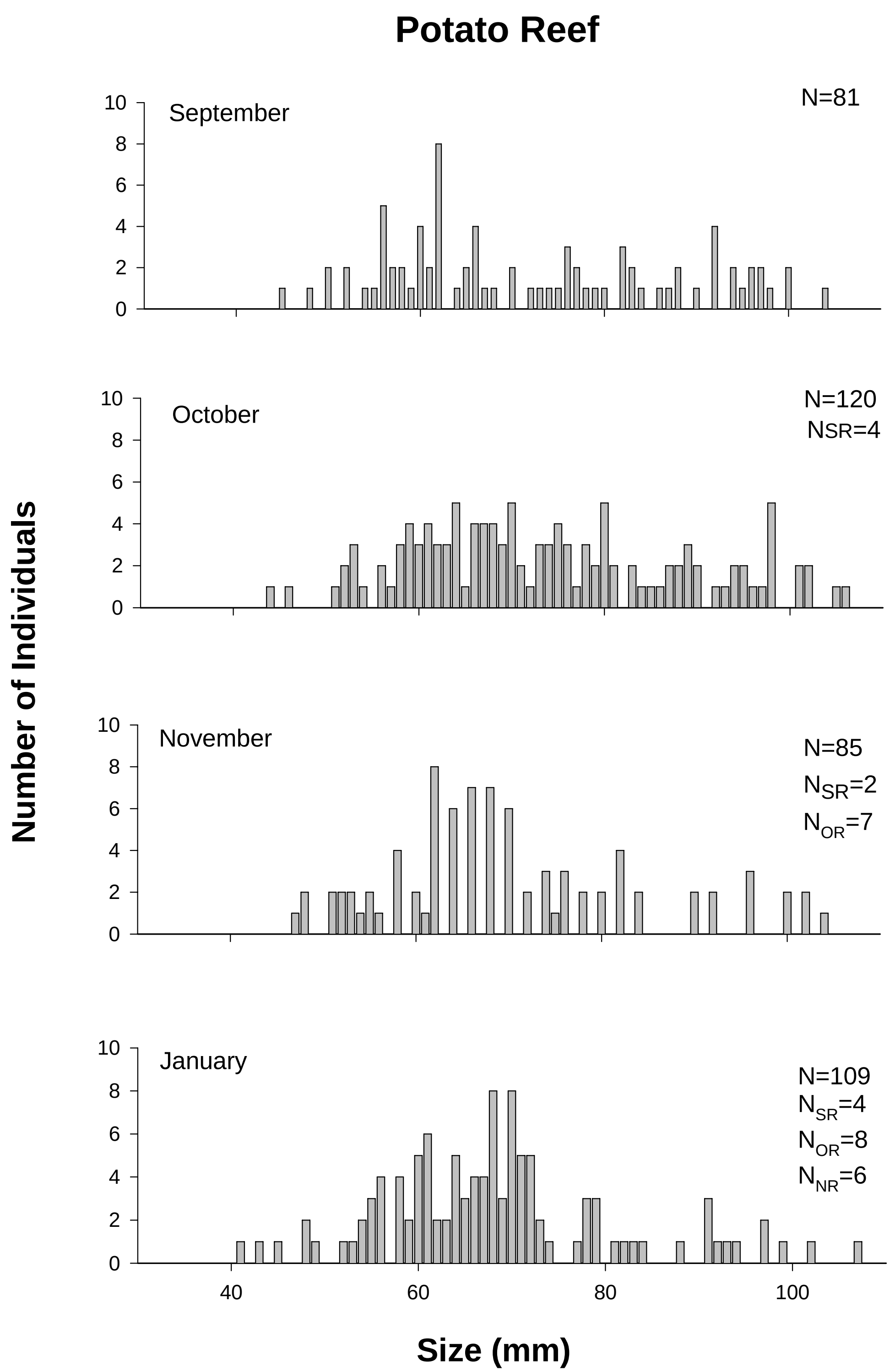



**Figure 12.** The size-frequency distribution of blackeye goby at Potato Reef (SCI) collected from fish tagged September 2003 to January 2004. SR= September tag returns; OR= October tag returns; and NR= November tag returns.

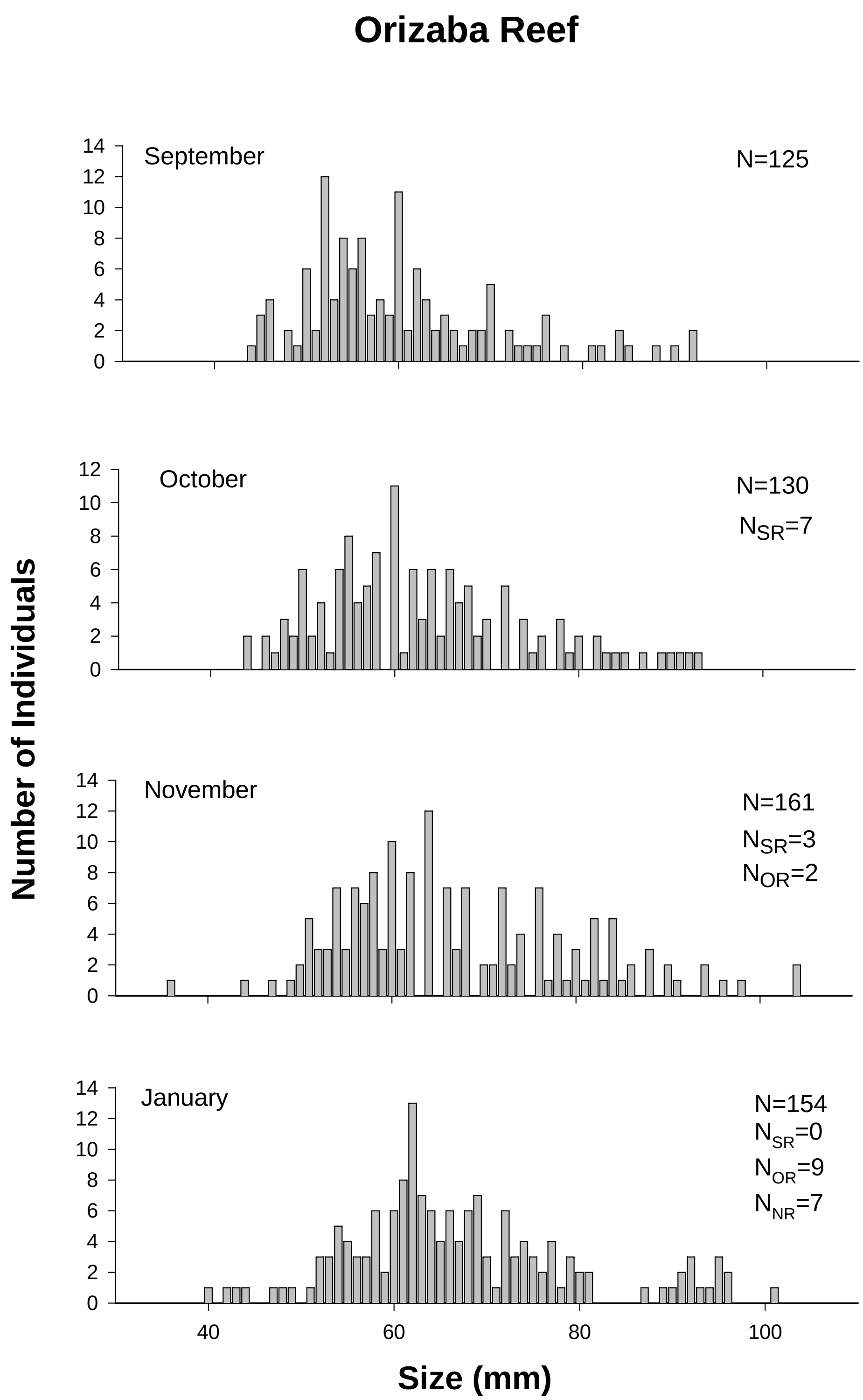



**Figure 13.** The size-frequency distribution of blackeye goby at Orizaba Reef (SCI) collected from fish tagged September 2003 to January 2004. SR= September tag returns; OR= October tag returns; and NR= November tag returns.

Results of the tag-and-recovery experiment indicate that rates of survival at both OP Gina and all rocky reefs sites were relatively high (Tables 2-5), or alternatively that rates of emigration at all sites was relatively low. Because each site was located substantial distances away from even the closest ref sites inhabited by gobies (see Methods), and during frequent surveys at the those sites we never saw tagged individuals, we think that immigration and emigration rates were generally very low and, that variation through time in the numbers of tagged fishes from each tagging is a good means of estimating mortality rates. However, the tagging method prevented us from definitively assessing whether immigration and emigration of adults and juveniles occurred among sites. The tagging data thus indicate that mortality rates of blackeye goby were lower at OP Gina than at natural rocky reefs, and that there was relatively little difference in mortality rates among the natural reef sites. The rate of tag returns declined substantially between January and June-July 2004, a pattern probably caused by a series of intense storms that occurred during winter February-March 2004. In a subsequent paper, we will use tagging data in a population dynamic model to more thoroughly estimate rates of mortality, survival, and movement among reefs and OP Gina.

Our tagging effort also provided the first comprehensive information concerning length-biomass relationships. Data from fish collected across all tagging periods indicate a tight relationship between the two variables for all sites in our study (Figures 14-15). These data will provide others working with this species with the means to estimate biomass through length measurements. We found no apparent difference in length-biomass relationships between populations at OP Gina and natural reefs.

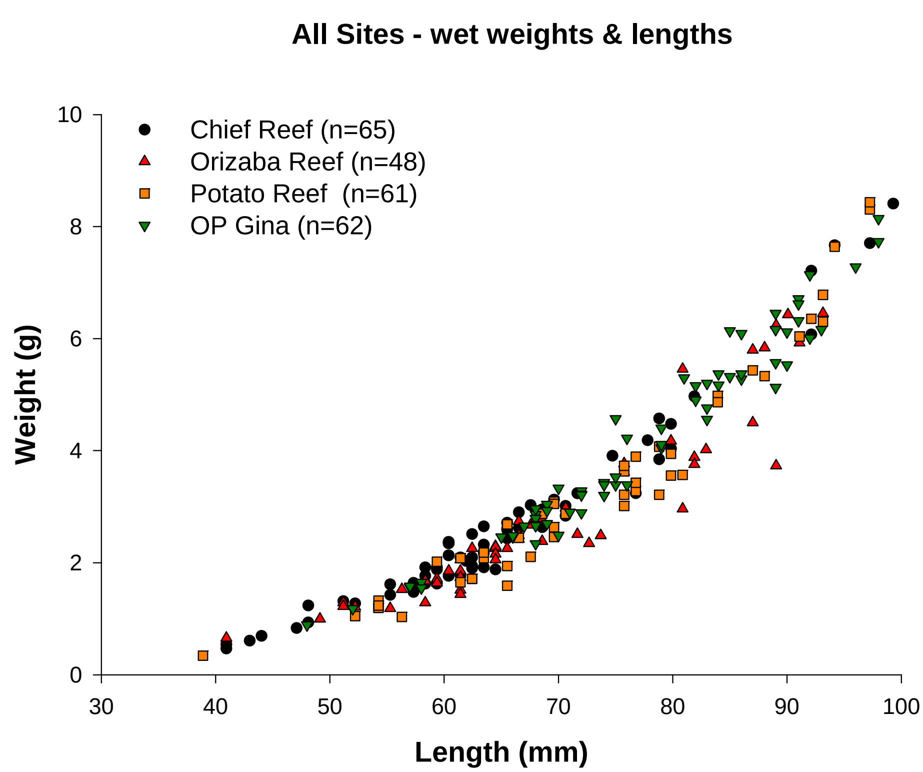



**Figure 14.** Weight-length relationships for blackeye goby at all locations. Data are from wet weights of gobies (see Methods section for details).

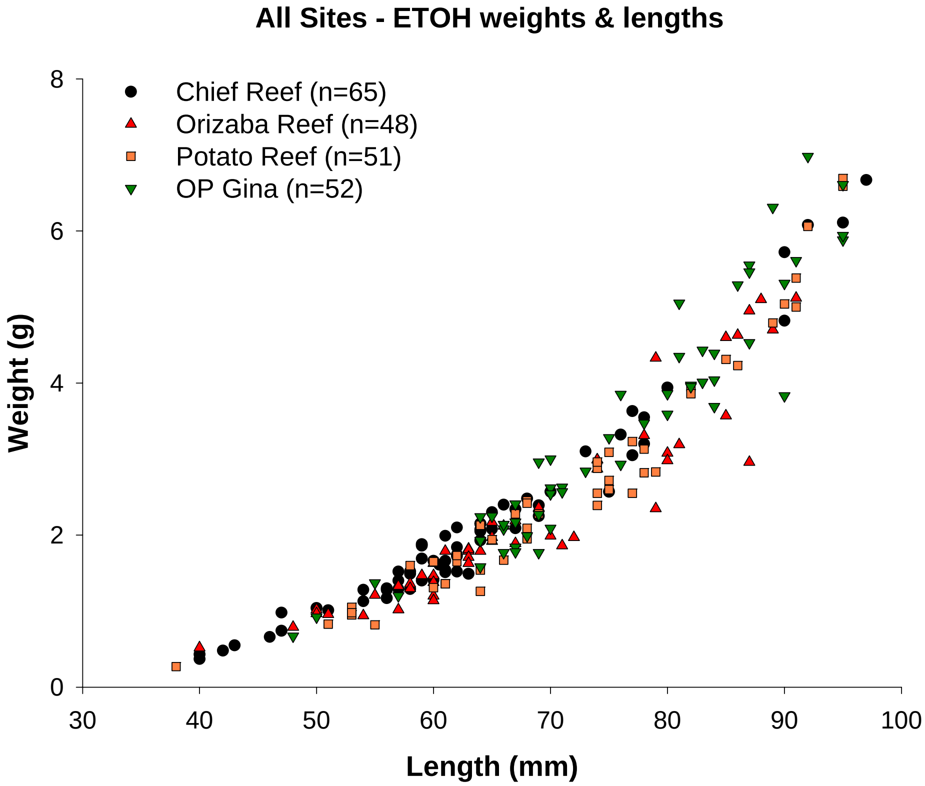



**Figure 15.** Weight-length relationships for blackeye goby at all locations. Data are from gobies from 70% ETOH (see Methods section for details).

## Fecundity

We estimated variation in fecundity among goby populations located at OP Gina and natural rocky reefs at Santa Cruz Island by quantifying and comparing various metrics associated with egg masses collected at each site in April 2004, which is when we observed the highest abundance of male gobies displaying nest guarding behavior. Potato Reef (both at 60' and 90' water depths) had a significantly higher number of eggs per clutch than the other sites (Figure 16). There were no significant differences in total egg counts at the other sites. Relatively high egg counts at Potato Reef were caused by both larger mean areas of egg masses and higher egg densities per clutch than at other sites (Figure 17). Although there were no significant differences among sites in the latter two parameters, there were trends for higher values at Potato Reef versus all other sites. The relationship between egg density and clutch size in area are illustrated in Figure 18.

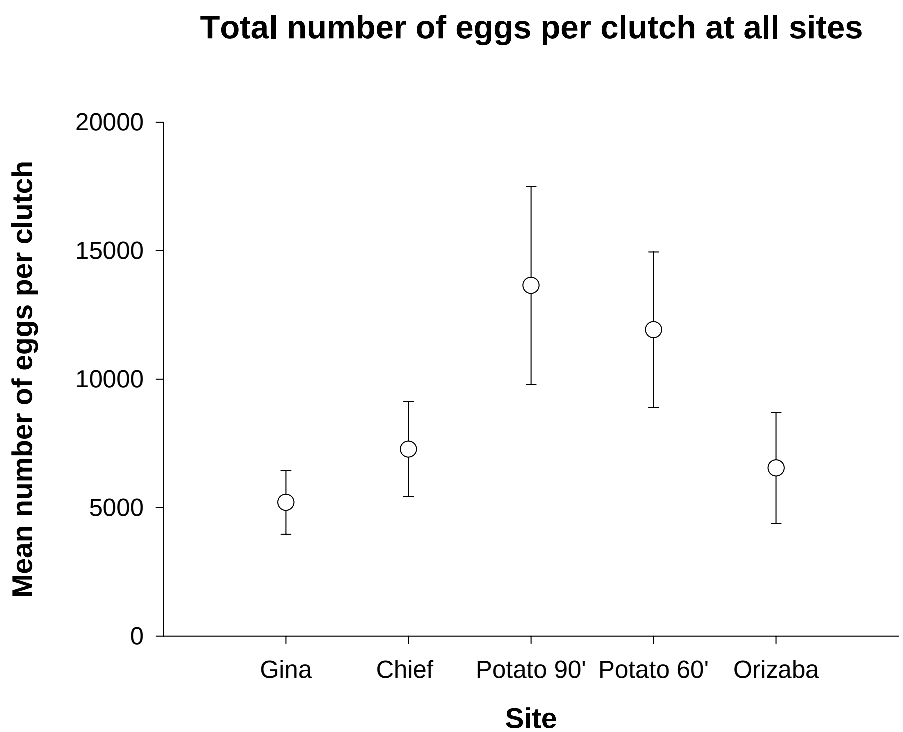



**Figure 16**. Mean (+ 95% CI) number of eggs per clutch at all sites. The number of clutches at each site varied: OP Gina, N= 15 clutches; all other sites, N= 11. Data were collected April 2004.

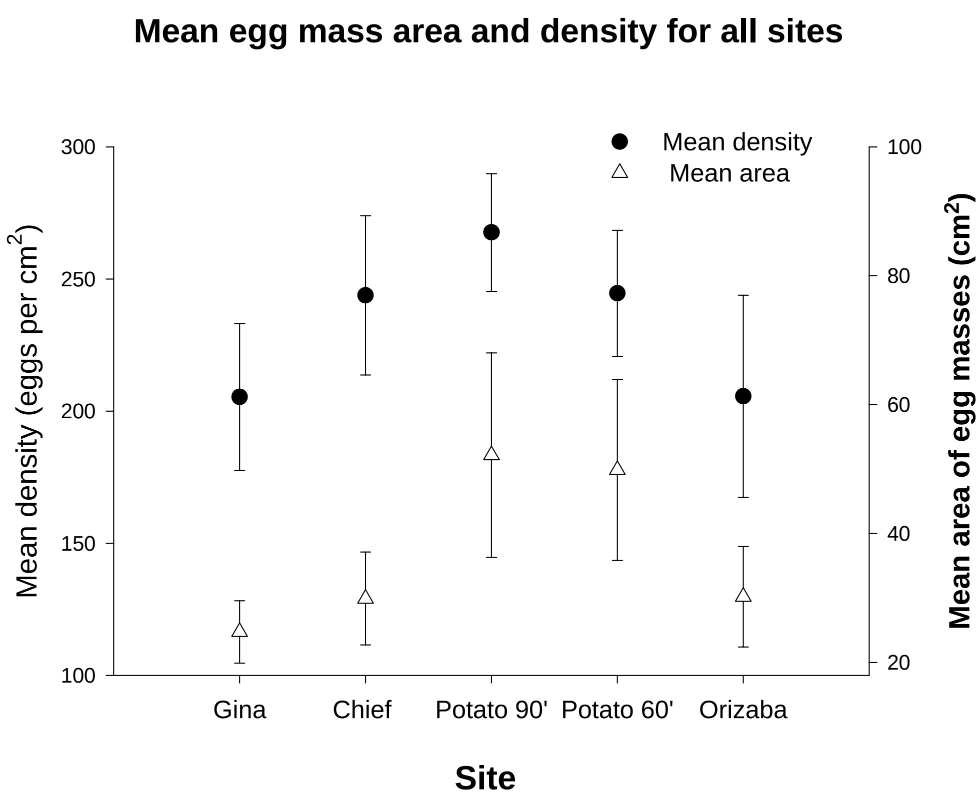



**Figure 17.** Mean (+ 95% CI) area and density of egg masses at OP Gina and natural rocky reef sites on Santa Cruz Island. Data were collected in April 2004.

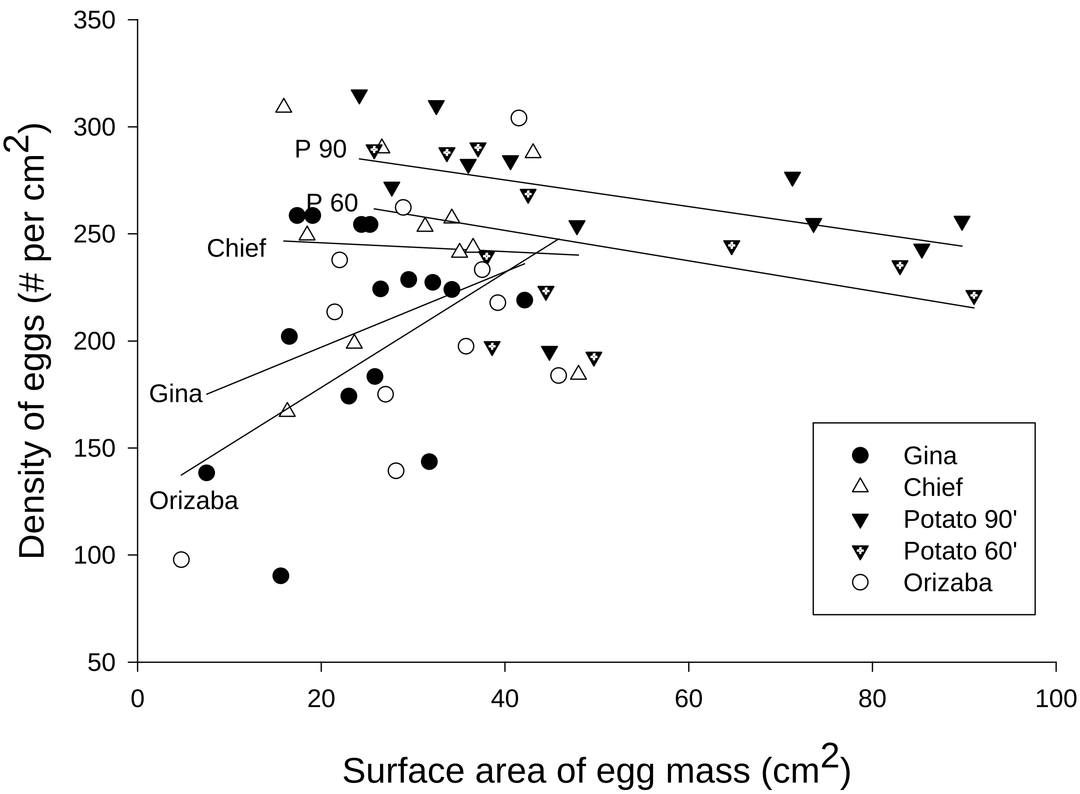



**Figure 18.** Relationship between egg density and surface area of eggs in egg masses from all sites examined. Eggs were collected in April 2004.

**Predation mortality of blackeye goby**

The tethering of blackeye gobies to longlines and monitoring of their fate was used to test whether predation on gobies differed among OP Gina and natural rocky reefs. This experiment was conducted because we found populations of gobies at OP Gina contained a higher proportion of larger fishes than other stations, thereby indicating survivorship was highest at OP Gina. In contrast, of course, growth rates might have been higher at OP Gina than other stations.

The tethering method we used had four possible outcomes, three with missing fish, snapped lines, empty hooks, or snapped lines in which we also found empty hooks nearby on the seafloor, and, the fourth outcome, gobies still hooked (see Methods for details). To test which of these outcomes represented a predation event, we conducted an experiment on Naples Reef on the mainland coast (see Methods for details). Results from this experiment indicate with a moderate-high level of certainty (~50-77%) that snapped lines, empty hooks, and snapped lines with empty hooks were caused by predation and not escapement (Tables 6-7). These results provide us with guarded confidence that results from our actual tethering experiment are valid (see below).

**Table 6**: Tethering control for treatments with empty hooks ("predation" vs "escape").

| Fates of hooks/gobies | T = 40 minutes | | T = 60 minutes | |
|---|---|---|---|---|
| | **Mean** | **95%** | **Mean** | **95%** |
| Snapped | 0.66 | 1.43 | 1.33 | 1.43 |
| Live | 3.00 | 2.48 | 0.66 | 1.43 |
| Empty | 1.33 | 1.43 | 3.00 | 2.48 |
| Empty due to: | | | | |
| predation (confirmed) | 0.66 | 1.43 | 1.33 | 1.43 |
| escape (confirmed) | 0.00 | 0.00 | 0.00 | 0.00 |
| unknown | 0.66 | 1.43 | 1.66 | 1.43 |
| % of *all* hooks empty due to possible escape | 13.3% | - | 33.3% | - |
| % of *empty* hooks due to possible escape | 50.0% | - | 55.3% | - |

**Table 7**: Tethering control for treatments with empty hooks ("predation" vs "escape").

| Fates of hooks/gobies | T = 40 minutes | T = 60 minutes |
|---|---|---|
| Snapped | 2 | 4 |
| Live | 9 | 2 |
| Empty | 4 | 9 |
| Empty due to: | | |
| predation (confirmed) | 2 | 4 |
| escape (confirmed) | 0 | 0 |
| unknown | 2 | 5 |
| % of *all* hooks empty due to possible escape | 13.3% | 33.3% |
| % of *empty* hooks due to possible escape | 50.0% | 55.5% |

Results from the tethering experiment conducted at OP Gina and natural reef sites indicated that rates of predation on gobies, by the fishes that we observed attacking goby or found hooked to our lines with gobies in their stomachs (e.g., gopher and olive rockfishes), did not differ between OP Gina and all the natural reef sites (Figure 19). However, there was a statistically non-significant trend (based on the overlap of 95% confidence level error bars in Figure 19) towards higher survivorship at OP Gina relative to natural reefs. Those fish that we estimate were probably preyed upon (i.e., those on lines "snapped" and "snapped and empty hooks") were mostly of medium length (Figure 20). In contrast, empty hooks were those that tethered relatively large gobies.

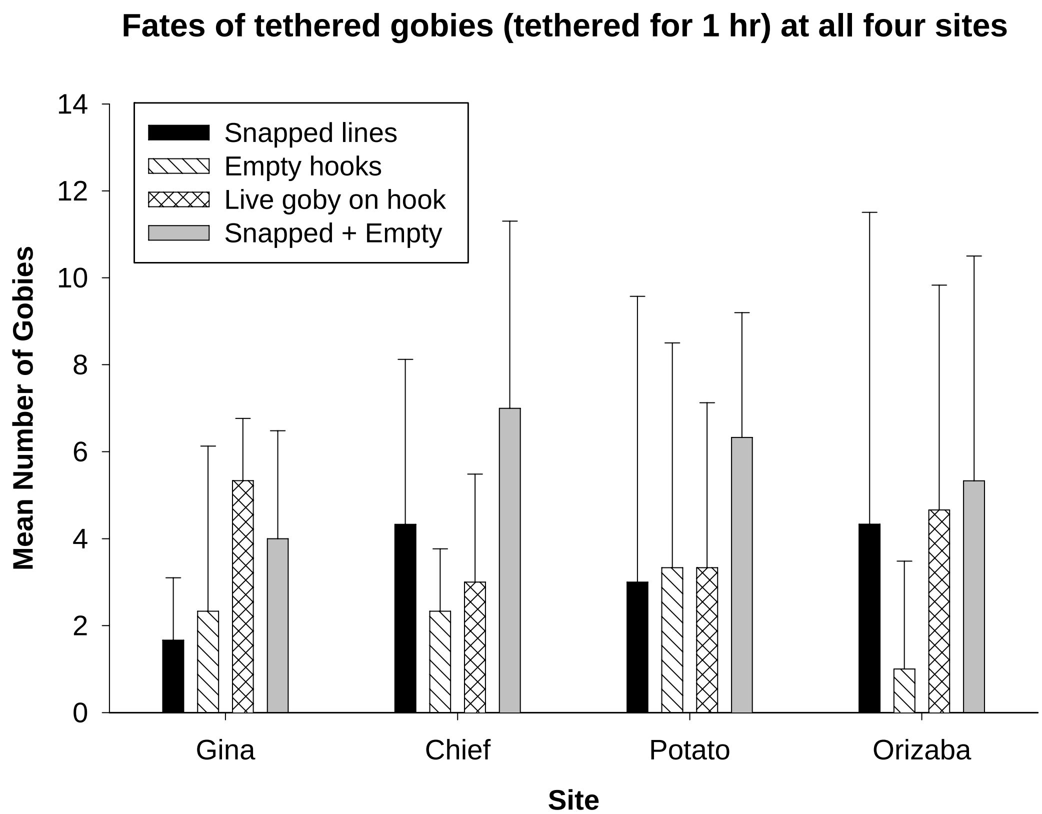



**Figure 19**. Fates of gobies tethered to lines at all sites. Data are means + 95% Confidence Intervals (CI). The tethering experiment was conducted 10-17 July 2004.

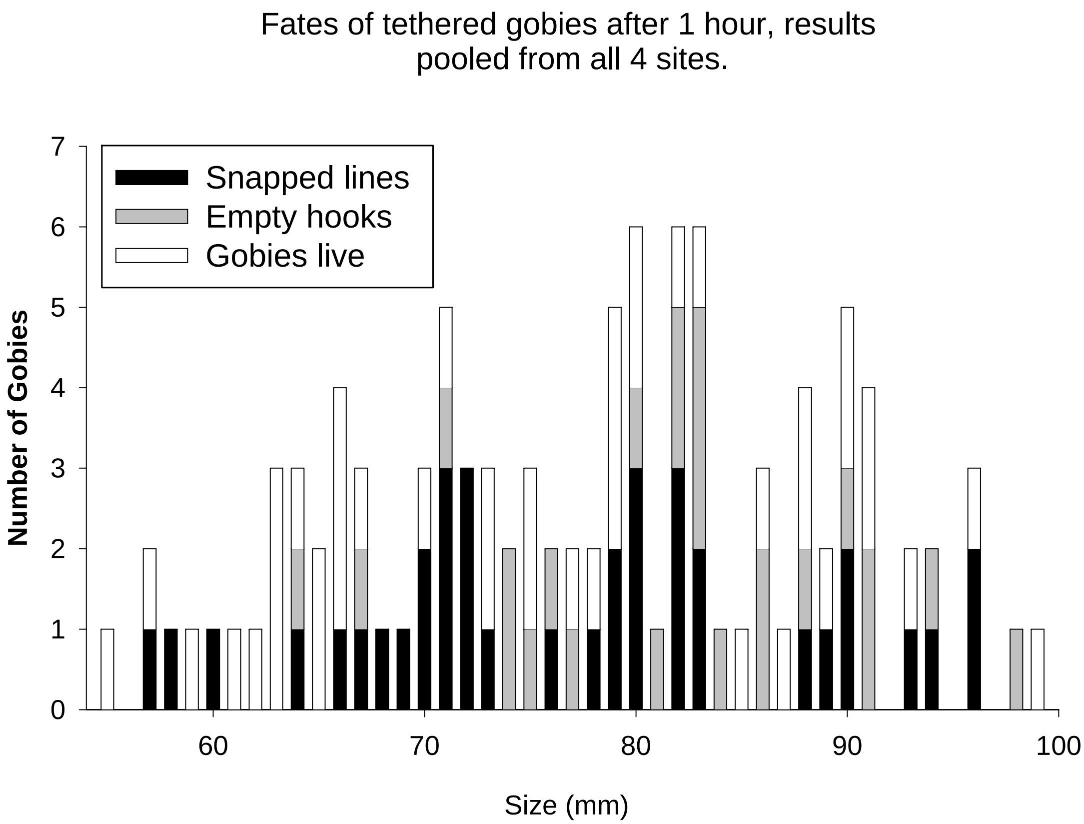



**Figure 20.** The length frequency of gobies tethered on lines to test predation risk. Data are from three treatments, lines which were found snapped, and therefore likely a sign of gobies being eaten by rockfish or other groundfish (e.g., cabezon and lingcod); lines with empty hooks, from which gobies could have escaped or were eaten; and live gobies that remained tethered after 1 hr. Data are pooled from all four sites, OP Gina, Chief Reef, Orizaba Reef, and two locations (water depths) at Potato Reef (60 and 90 feet).

### Age and Growth estimates

We are in the process of analyzing age and growth data. We found that patterns of growth via rings or demarcations in blackeye goby otoliths are very difficult to identify. However, we are developing a statistical model based on sampling populations of visual microscope counts of potential growth rings taken by different observers as a means of estimating age classes. If successful we will be able to age and therefore estimate growth rates in goby populations and OP Gina and our natural reef sites. We think the method we are developing will also generate a publication that can be used by others to estimate growth patterns in otoliths that are difficult to read.

## DISCUSSION

We assembled a thorough spatially and temporally comprehensive field-based demographic data set of blackeye goby populations inhabiting OP Gina and three natural rocky reefs located on the north shore Santa Cruz Island in the ESBC. The natural reefs we used were those located closest in space to OP Gina that were inhabited by the blackeye goby. Our results provide information that can be used to estimate the relative contribution of goby populations from OP Gina and the natural reefs to the regional population pool of this species. In general, we found that OP Gina does not represent a critical population source of blackeye gobies to the region. We also found that OP Gina does not represent a population sink. These findings have a major implication; that during consideration of decommissioning alternatives, the level of potential localized population loss at OP Gina should not be a major factor influencing management decisions. Removal of OP Gina should not have an important influence on regional blackeye goby populations, and were it to be left in place, it should not cause a decrease in population abundances at a regional scale.

Although there were no statistically significant differences in blackeye goby abundance between OP Gina and natural reefs, nor among reef sites, there was a trend towards lower abundance at OP Gina versus natural reefs sites. This was somewhat surprising because we found a relatively large of amount of favored goby habitat, mainly mussel shells, at OP Gina. In addition, results form other demographic measurements, especially trends toward lower mortality via predation, and potentially higher growth rates at OP Gina versus natural reefs are mechanisms that should contribute to higher abundance at Op Gina. These results may be explained by several factors, including higher mortality rates caused by some other factor than predation, including intraspecific density dependent interactions within a potentially habitat limited environment. We found little evidence for relatively high emigration based on our tagging data.

Another factor that may help to explain the trends toward relatively low abundance at OP Gina was that this site had a trend towards lower input rates via recruitment than the natural reef sites. Recruitment levels in March-September did not vary statistically but here was a trend towards relatively low levels at OP Gina. We measured recruitment as the relatively abundance of YOY blackeye gobies counted by divers along transects. There is the possibility that we underestimated recruitment at OP Gina relative to other sites because the study area was deep and dark, and the bottom was covered with excellent refuges gobies to hide within. However, we think it is more likely that recruitment rates are lower at Op Gina because the platform is relatively isolated from other populations that could supply larvae.

The mean size of individual gobies was significantly higher at OP Gina than at natural reef sites. There were no significant differences among control reef sites. These data indicate that there is a larger proportion of large fish in the OP Gina population than at other sites. Large fish at OP Gina are probably due to faster growth rates, greater survivorship to older age classes, or a combination of both factors. We tested whether mortality caused by predation varied among sites as a way to determining whether survivorship was greater at OP Gina than natural reefs. Results from our experiment indicate a trend toward reduced predation mortality at Op Gina. This was likely caused by relatively low abundance at OP Gina of kelp bass that were by far the most voracious predators on blackeye gobies at control reef sites. The other important goby predator, cabezon, is found at relatively high levels at Op Gina, but mainly inhabited the supporting structure of the platform located above the bottom where no gobies were found. Therefore, reduced relatively low levels of predation at OP Gina may explain larger size structure of that population relative to natural reef sites. We are in the process of analyzing age and growth data from goby otoliths, the results of which should help us further explain the variation in size structure.

We fond that several proxies for fecundity of blackeye goby, based on various measurements of egg clutches laid and guarded by gobies, varied between OP Gina and reef control sites. Egg clutches were smaller and had lower egg densities at Op Gina than at natural reef sites, indicating that populations on OP Gina may generate less per capita output than populations on natural reefs. Based on differences in standardized abundances as each site, these data indicate OP Gina populations may have less total output.

Our study provides an example of how population ecological tools and data can be used to address a complex applied problem, in this case the relative contribution of POCS oil platforms to regional population dynamics of a reef fish relative to the contribution made by natural reefs. This approach has been used often in terrestrial wildlife management and well as marine fisheries and mammal management and conservation. Our study provides one of the few examples where a thorough demographic survey has been subsidized by specific experimental evidence in a marine ecological field assessment (see Schmitt and Osenberg 1996 for other examples). This approach is valuable for the management of POCS oil platforms that are both extensive in their size and environmental impact but also situated in environmental conditions that make examination of the their ecological value and contributions difficult to quantify, especially at regional scales. We plan to use the data generated from this study to conduct generalized population dynamic models that can be used to explore the general effects of ESBC platforms on regional stocks of the blackeye goby, and to predict the impact of the five decommissioning alternatives.

## ACKNOWLEDGEMENTS

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## LITERATURE CITED


Crowder, L.B. et al. 2000. Source-sink population dynamics and the problem of siting marine reserves. *Bulletin of Marine Science* **66**: 799-820.

Harms, S. and C. D. Winant. 1998. Characteristic patterns of the circulation in the Santa Barbara Channel. *Journal of Geophysical Research* **103**: 3041-3065.

Hench, J. L., B. O. Blanton, and R. A. Luettich, Jr. 2001. Lateral dynamic analysis and classification of barotropic tidal inlets. *Continental Shelf Research*, in press.

Holbrook, S. J., R. F. Ambrose, L. Botsford, M. H. Carr, P.T. Raimondi, and M. J. Tegner. 2000. Ecological issues related to decommissioning of California's offshore production platforms. Report to the University of California Marine Council. The Select Committee on Decommissioning, University of California.

Holt, R. D. 1985. Population dynamics in two-patch environments: some anomalous consequences of an optimal habitat distribution. *Theoretical Population Biology* **28**: 181-208.

Lenihan, H.S., C.H. Peterson, J.E. Byers, J.H. Grabowski, G.W. Thayer, and D.R. Colby. 2001. Cascading of habitat degradation: oyster reefs invaded by refugee fishes escaping stress. *Ecological Applications* **11**: 764-782.

Lipcius, R. et al. 1997. Hydrodynamic decoupling of recruitment, habitat quality, and adult abundance in the Caribbean spiny-lobster: source-sink dynamics? *Marine and Freshwater Research* **48**: 807-815.

Love, M. S., J. Caselle, and L. Snook. 2000. Fish assemblages around seven oil platforms in the Santa Barbara Channel area. *Fishery Bulletin* **98**: 96-117.

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

Pulliam, H. R. 1988. Sources, sinks, and population regulation. *American Naturalist* **132**: 652-661.

Schmitt, R.J. and C. W. Osenberg. 1996. Detecting Ecological Impacts: Concepts & Applications in Coastal Habitats. Academic Press.

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**The Minerals Management Service Mission**

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.