Title

Fisheries Habitat: Recruitment, Growth, and Survival of Coastal Fishes on an Experimental Artificial Reef

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Publication Date

2004-04-15

Final Year Narrative: California Sea Grant Project Number R/F-188
Dates: 3/1/01–2/29/04

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Introduction

Currently, many fisheries are under severe pressure from anthropogenic impacts, including over-fishing and habitat degradation. Several approaches have been developed to ameliorate such impacts, including the reduction of catch quotas, implementation of marine reserves, and habitat enhancement. Artificial reefs, as supplemental habitat to coastal systems, often has been used under the premise that additional habitat will increase production of coastal fishes, thereby increasing fish stocks. Several criticisms have been leveled at artificial reefs as a tool in habitat enhancement for a failure to (1) decouple attraction and production in assessing the contributions of artificial reefs, (2) evaluate regional production on artificial and natural reefs, (3) construct artificial reefs to be similar in habitat to natural reefs, (4) replicate artificial reefs for rigorous experimentation and statistical analysis, and (5) consider process-oriented studies at more appropriate spatial scales.

Coincident with efforts directed towards habitat enhancement, information on how reef structure, size, and topographic complexity influence the distribution, abundance, and dynamics of fish populations is critical if artificial reefs are to provide essential fish habitat in managing near-shore fisheries and in mitigating losses of suitable habitat at natural reefs. Relevant data on the relationships between the demography of fish populations and the habitats in which they reside are lacking or poorly known for most reef-associated species. To provide essential information on the design of artificial reefs from which management decisions are based, studies are needed to examine the effects of reef structure and topographic complexity on reef fish assemblages.

Our goal was to quantify recruitment (input of young-of-year fish), growth, and survival of near-shore fish populations to a replicated, large-scale experimental artificial reef. Unlike the inherent variation in habitat features present on natural reefs, artificial reefs can be constructed to examine specific habitat characteristics. Our aim was to provide information that would allow resource managers to better assess the role of habitat in management of near-shore fisheries and to critically evaluate habitat enhancement and

restoration requirements in mitigating losses of habitat. Our focus was directed towards two main studies: that habitat type and structure influence (1) recruitment success of reef fishes that settle to the experimental reef, and (2) production of reef fishes.

Study System

The California Coastal Commission (CCC) required Southern California Edison (SCE) to construct an artificial reef large enough to replace a minimum of 150 acres (60.7 ha) of kelp forest habitat as partial mitigation for losses of kelp-bed resources (kelp, invertebrates, and fishes) caused by operation of the San Onofre Nuclear Generating Station (SONGS). A five-year experimental phase, now in its last year of study, was inititated to determine the types of substratum and the configurations that provide adequate conditions for establishing and sustaining giant kelp and other reef-associated species. At an unprecedented spatial scale, over 22 acres (9.1 ha) of hard substrate was deposited within a 2.5 km long x 0.5 km wide area north of SONGS in Fall 1999 to form the San Clemente Artificial Reef (SCAR; Fig. 1). Seven replicate modules of eight reef designs exist, with two types of substrate (quarry rock and recycled concrete), three levels of substrate coverage (17%, 34%, and 67% hard substrate [vs. soft bottom]), and two levels of kelp abundance (with and without transplanted kelp on 34% level of substrate coverage), totaling 56 reef modules, each module 0.4 acres in size. This system presented a unique opportunity to examine recruitment success and fish production at an experimental reef that addressed the many criticisms of past artificial reefs. We employed the use of the quarry rock modules in the three designated coverages of hard substratum: 17%, 34% (without transplanted kelp), and 67%, using three modules in each of the seven blocks (= 21 modules).

Objectives

After preliminary work to examine the feasibility of our proposal objectives, we divided our efforts into the following three tasks: (1) quantify recruitment success of several reef fishes among treatments of habitat structure, (2) estimate fish production on the experimental reef as a function of habitat structure, and (3) determine the degree of correspondence in spatial variation using an index of settlement and recruitment of the kelp bass, *Paralabrax clathratus*.

Approaches and Results

Patterns of habitat-dependent recruitment success. We conducted surveys from 2001 to 2004 to record the densities of young-of-year fishes at SCAR over three recruitment periods. For each survey, a series of transects was conducted to examine the number of recruits in the kelp canopy, midwater, and bottom strata of modules. Each survey was performed with SCUBA by swimming four fixed transect lines along the bottom at distances of 5 m, 15 m, 25 m and 35 m from the northwest corner of each reef. Two transects in the midwater region and two in the kelp canopy were also completed. Along each transect, young-of-year recruits along with their major predators (the kelp bass *Paralabrax clathratus* and the barred sand bass *Paralabrax nebulifer* > 15 cm TL) were

counted, with their size estimated visually. Transect dimensions were 2 m wide x 2 m high x 40 m long for censusing most fishes in all strata. Cryptic species were censused on the bottom while swimming back along the same fixed transect lines, using smaller transect dimensions of 1 m wide x 40 m long. Each transect took approximately 5 min to swim by two experienced divers and were performed between 0900 and 1500 h on each day of the census. Densities for recruits (no. per volume or surface area) were calculated from counts recorded at each reef module.

Species-specific patterns of recruitment to treatments of habitat structure at SCAR were observed. Patterns of recruitment for the California sheephead showed a unique pattern of higher densities observed at medium coverage of rocky habitat, and these results are reported, along with those of the blackeye goby, in a paper that is in press with Marine Ecology Progress Series (Fig. 2). In a subsequent paper, we will report on differential recruitment of several other species, including the blacksmith, senorita, black surfperch, kelp bass. Patterns of recruitment for species that are kelp-associated will be analyzed using kelp density as a covariate with the main treatments of habitat structure.

Fish production and habitat structure. The focus of this work was to determine how fish production may vary between treatments of habitat structure at SCAR and compare these estimates with natural reefs. We used young-of-year black surfperch as a model for fish production because they are abundant on the reefs, they grow quickly as juveniles, they exhibit high habitat fidelity and thus are likely to remain on modules in which they were born (surfperches are livebearers that produce well-developed young that reside immediately in habitat and do not undergo planktonic dispersal), and they feed on reef-based resources. Up to six young-of-year fish were collected from two treatments of quarry rock (17%and 67%) from all seven blocks, for a total of 14 modules. Several young-of-year black surfperch also were collected at Barn Kelp, a natural reef. Using otoliths (fish earbones), the number and width of daily growth rings on an otolith (lapillus) will be measured using digital image analysis software (Image Pro 4.1)The distance or width between these rings reflects the growth rate of fish; faster-growing fish are expected to have a greater width between rings, because these fish are depositing organic material at a greater rate. The number of rings will give an estimate of age in days, since these fish lay daily rings (we are conducting otolith validation experiments to establish that rings are laid daily). By knowing the relationship between fish length and otolith radius or total area, the weight of a fish at a particular interval can be calcated by hindcasting the size of the otolith at a particular period, applying the length of fish expected based on otolith size, and then converting length to weight using a length-weight regression. In this manner, total change in biomass can be calculated on a reef and standardized to a particular time period (change in somatic biomass per unit time). We are in the process of examining otoliths for this purpose and also using surrogate measures of growth rate such as gut fullness and resource availability on the reef.

Kelp bass settlement and recruitment. A prevalent question in the recruitment of fishes is whether larval supply, habitat, or post-settlement processes cause variation in recruitment success and if so, the relative importance of such processes. We examined these factors in the kelp bass, *Paralabrax clathratus*. For three summers, we set out a

number of buoyed lines with plastic mesh devices, known to "collect" settlement-stage kelp bass in southern California. We monitored the number of settlers of kelp bass weekly for 3-4 months each year as an index of input of kelp bass to the experimental reef. We also examined the number of recruits observed on the reef in the fall, and the density of kelp as habitat as a likely variable in recruitment success.

Unfortunately, despite considerable effort, kelp bass were found only in reasonable numbers in 2001. We received few or no kelp bass in the settlement collectors in 2002 and 2003. In interacting with other reef fish ecologists who were monitoring settlement of kelp bass and rockfishes in southern and central California over this period, they also found poor or no recruitment of their target species. This apparent recruitment failure may have been widespread, and there may be a note on this phenomenon in collaboration with other researchers.

Figure Legends

1. (a) Diagram of experimental reef system located near San Clemente, California. Filled squares denote the 21 reefs used in the present study. (b) Representation of habitat coverage (low, medium, high) for three reefs in each of seven blocks.

2. (a) *Semicossyphus pulcher* and (b) *Rhinogobiops nicholsii*. Recruitment success (mean densities [+ SE] of recruits in late fall 2001 and 2002) for the California sheephead (no. / 100 m^3) and the blackeye goby (no. / 100 m^2) in treatments of low, medium, and high habitat coverage; n = 6 reefs for each bar. Zero values indicate that no recruits of the California sheephead were recorded on reefs in 2002.

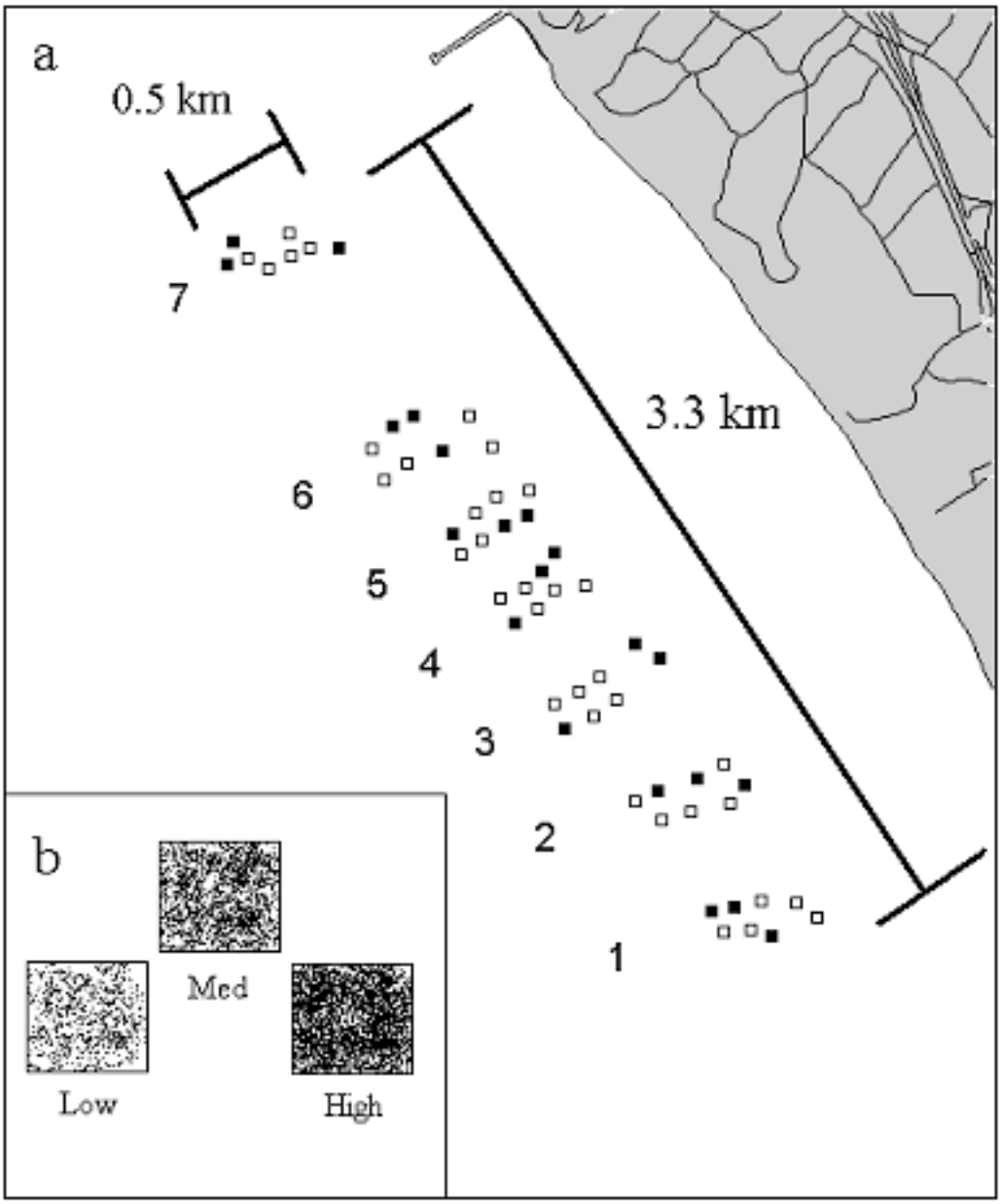

Figure 1

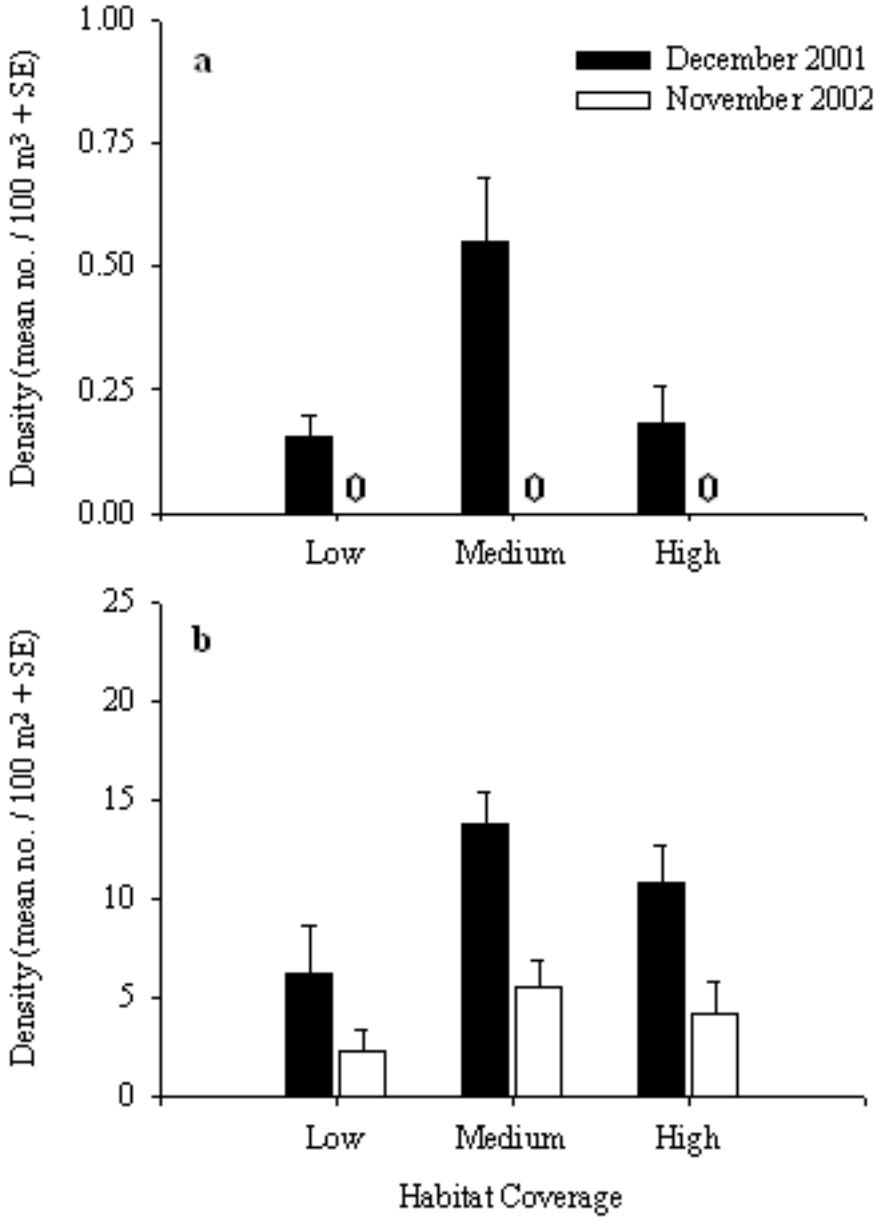
a
December 2001
November 2002
Density (mean no. / 100 m³ + SE)
1.00
0.75
0.50
0.25
0.00
0
0
0
Low
Medium
High
b
Density (mean no. / 100 m² + SE)
25
20
15
10
5
0
Low
Medium
High
Habitat Coverage

Figure 2