**BRAZILIAN ARCHIVES OF
BIOLOGY AND TECHNOLOGY**

A N   I N T E R N A T I O N A L   J O U R N A L

Spatial Partition of Artificial Structures by Fish at the Surroundings of the Conservation Unit - *Parque Estadual da Ilha Anchieta*, SP, Brazil

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ABSTRACT

The aim of this work was to study the spatial partition dynamics of fish at artificial structures. Holed structured concrete blocks were used to construct eight identical artificial structures and disposed between 3m-6m depths. Installation was made in two steps during 1996 (May/June and November/December) and daily observations were carried out during 30 consecutive days SCUBA diving. The artificial reef areas were used in discriminated ways by the fish community and was most probably influenced by several factor, mainly biotic. The results of the Krustal-Wallis test led to the refutation of the hypothesis that the artificial structure spaces were shared and randomly used by fish.

Key words: Fish community, artificial reefs, space partition, coastal area, Brazil, conservation unit

INTRODUCTION

Artificial reefs are human made structures and may be billed with an infinity of natural or artificial materials (Bohnsack, 1991), considered mainly security, specially toxicity (Grove et al., 1991). These purposefully deployed objects intend to influence physical, biological or socio-economic process related to living resources (Seaman, Jr. and Jensen, 2000). These habitats function as shelters against predators, feeding and reproduction areas for fish (Bohnsack and Sutherland, 1985). The artificial reefs may, if correctly employed, constitute an important tool to enhance environmental complexity for human benefit (Bohnsack, 1991). They may furnish opportunity to enhance live natural resource and maintain local biodiversity, apart from functioning as a live laboratory. They can also be devoted to restore damaged areas, since their transformer function of relatively unproductive areas in to productive ecosystems are well documented in literature (Bortone, 1998; Jensen et al., 1994).

Ecological processes that occur at artificial structures, are not yet well understood (Bohnsack et al., 1991, Bortone et al., 1988, 1994). Lack of controlled scientific studies on artificial habitats ecology at world level is reported by Bohnsack and Sutherland (1985) and Seaman (1996). This lacuna creates a problem on the discussions of artificial environments uses as management technique, including area mitigation that suffers environment damages (Seaman and Sprague, 1991). Ecology knowledge of natural reefs can add

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to comprehension of artificial reefs in the literature of Sale (1991).

The aim of this work was to study the dynamic of the fish community at artificial structures settled at a cove (*Enseada das Palmas*), concerning space use, during the first installation month on two reefs batteries, viewing to test the following hypothesis: "*fish share and use space randomly at artificial structures* ".

MATERIAL AND METHODS

Construction and installment
A total of eight identical sets of artificial structures were constructed and settled on the substratum, each one formed by 36 concrete blocks measuring 160 cm long x 60 cm wide x 60 cm high. For a better stability, each structure iron angle bars were set and tied up with steel wires. The architecture of the artificial structures was adapted from Walsh (1985) model. The three floors of all reefs were uniformed, *i.e.*, structures architecture was planned for specific form, height, profile, holes size and general dimension with the aim of disponibilizing equitative spaces.

The artificial structures were installed directly on the unconsolidated substrate and displayed parallel to the rocky shore, near the biggest rocky shore of *Praia Grande*, in the *Enseada das Palmas*, between 3m and 6m depth, in two stages. The first stage started in May 1996, when four artificial structures (E) were laid down, named as E1, E2, E3 and E4, and the group was nominated **Battery 1**. In the second stage, initiated in November 1996, four others were displayed (E5, E6, E7 and E8), denominated **Battery 2**. The artificial reefs positions followed a random pattern, obeying a 50m minimum distance from the nearest rocky shore and 20m between replicas (Seaman and Sprague, 1991).

Data acquisition
The visual stationary census technique described by Bohnsack and Bannerot (1986) was adapted to obtain biotic data. Observations took place during diurnal period between 9:00h and 16:00h, daily for 30 consecutive days for Battery 1 and another 30 days for Battery 2.

Biotic data was obtained by SCUBA diving for which the two largest flanks of each structure were elected, stipulating a 5' time observation period for each flank. A total of 20' daily observations were dedicated for each structure, summing 4800' actual data taking for both periods. To allow fish community stabilization, due to the arrival of the diver to the reefs, and before the beginning of each observation session, a 3' to 5' time interval was conceded and this time interval was not considered in the observations. This time interstice adopted was similar to that used by Bohnsack and Bannerot (1986) and Bortone et al. (1989, 1991), data were recorded on plastic slates.

During diving observation, fishes were identified, counted and their localization was recorded in relation to the artificial structures. Fishes were visually identified taking advantage of the preterit existent regional fish knowledge, mainly Cunningham, 1983, 1986, 1994, Cunningham and Saul, 1995. Humann (1994), Figueiredo and Menezes (1978, 1980) and Menezes and Figueiredo (1980, 1985) were also used for identification. When necessary, specimens that raised identification doubt, were collected for further laboratory examination.

Classification of individuals spatial positioning was made registering their horizontal and vertical locations, in relation to the artificial structures, as followed explained: *Horizontal location* → R = fish spotted from the own artificial reef until 10cm distance from it, R1 = distance > 10cm until 1m of the artificial reef and R>1 = distance > 1m of the reef, and *Vertical location* → S = on the substrate, P1 = height equivalent to the 1st floor of the artificial reef (until 20cm), P2 = height equivalent to the 2nd floor of the reef (> 20cm until 40cm), P3 = height equivalent to the 3 rd floor of the reef (> 40cm until 60cm), TR = top of the artificial reef (> 60cm up to 1m) and W>1 = height > 1m up to the surface.

Data analyses
It was stipulated to nominate as component the specimens that were not possible to identify to species level. Trophic group classification criteria of Lowe McConnell (1999), Choat and Bellwood (1991) and Moyle and Cech (2000), with some adaptations, were utilized. Species and components were grouped into three trophic categories: (1) omnivorous; (2) piscivorous (including crustacean and fish eaters); (3) herbivorous (including planctivorous). Specie/components were also categorized as pelagic or demersals based on fish position in the water column and substrate. The hypothesis of the present study was tested, applying Kruskal –

Wallis method, using a *p>0.05* significance level and Brower et al. (1998) and Zar (1999) methodology to calculate it.

RESULTS

This field work was conducted at the *Enseada das Palmas* (23°32' S - 45°04' W) of the Conservation Unit (*Parque Estadual da Ilha Anchieta)*, localized at the northern shore of São Paulo State. The artificial structures were installed near the largest rocky shore of *Praia Grande* (Fig.1).
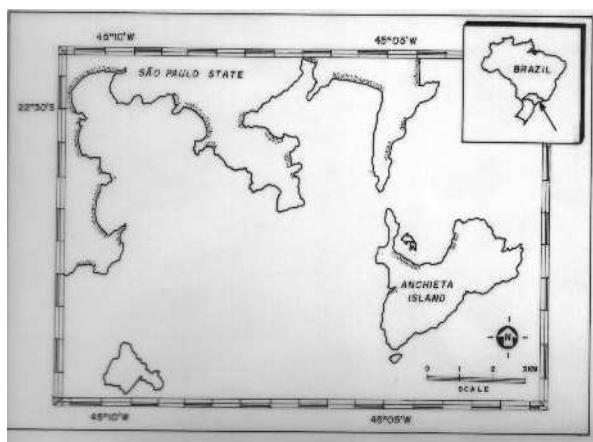
Figure 1 - Map of artificial reefs location.

The *Parque Estadual da Ilha Anchieta* revealed to be a considerably adequate area to develop this project mainly due to two aspects: (a) good preterit historical knowledge of the regional fish fundamental aspect to visual identification of species, and (b) the safety of the artificial structures, proportionate by the fact that the Park area is constantly inspected. Other reasons that motivated the choice of this spot to undertake the present work were the location of the Park near the North Research Base of the *Instituto Oceanográfico* of the *Universidade de São Paulo* (IOUSP) that supplied logistic support and the neighborhood of the Atlantic Forest one of the most important Brazilian biomes.

Considering the two-month observations on Batteries 1 and 2, a total of 19 species/components were registered and a minimum of 758 individuals counted, apart from the more then 1000 estimated very small fishes. These individuals formed a school and could not be identified or individually counted.

Table 1 - List of families, species and components at the artificial reefs

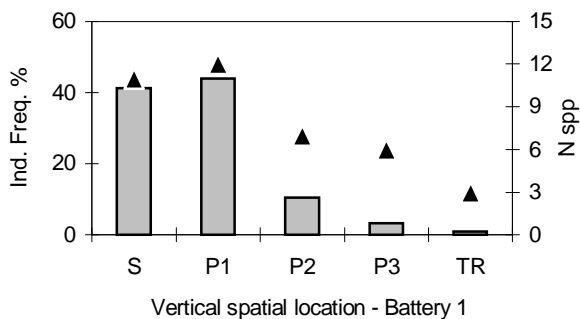| Families	Species/Componentes
Synodontidae	*Synodus foetens*
Fistulariidae	*Fistularia tabacaria*
Serranidae	*Epinephelus morio*
Carangidae	*Chloroscombreus crysurus*
Lutjanidae	*Lutjanus analis*
	Lutjanus synagris
Gerreidae	*Diapterus rhombeus*
	Eucinostomus sp
Haemulidae	*Anisotremus virginicus*
	Haemulon aurolineatum
	Haemulon steindachneri
Sparidae	*Calamus penna*
	Diplodus argenteus
Mullidae	*Pseudupeneus maculatus*
Chaetodontidae	*Chaetodon striatus*
Scaridae	*Scarus* sp
Bleniidae	
Acanthuridae	*Acanthurus baianus*
Pleuronectidae	

BATTERY 1 - MAY/JUNE 1996

The analysis of horizontal space occupation showed that the artificial reef areas, denominated R and R1 nearest surroundings, were the ones with larger numbers of components, 12 in each of these areas as well as of individuals, respectively, 51.13% and 40.73%, summing up 91.86% of the abundance (Fig. 2).
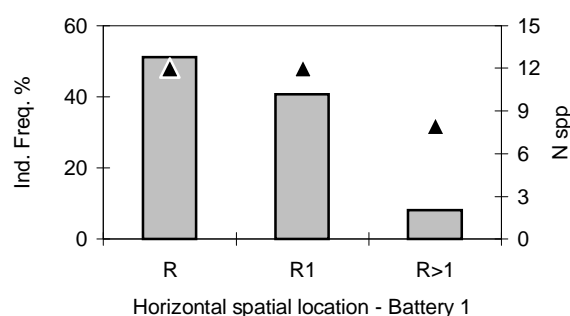
Figure 2 - Horizontal spatial location - Battery 1 - relative frequency of individuals (Ind. Freq. % ■) and absolute frequency of components (N spp ▲) at artificial reefs during May/June, Ubatuba/SP.

Environments R and R1 were occupied by the fishes during all days of observation. Environment R>1 was occupied in just 44.44% of the days. Pleronectidae, Blenniidae, *D. argenteus* and *L. analis* were observed exclusively on R and *A. virginicus* on R1. No component was exclusive to R>1. Vertically, 44.02% of the individuals were observed highly corresponding to the artificial reef first floor (P1) and 41.25% on the substrate (S). Thus, during the first month of observations after the artificial reef installment, these two floors combined held 85.09% of the abundance. The highest register of components also occurred in these environments, respectively, 12 and 11 (Fig. 3).
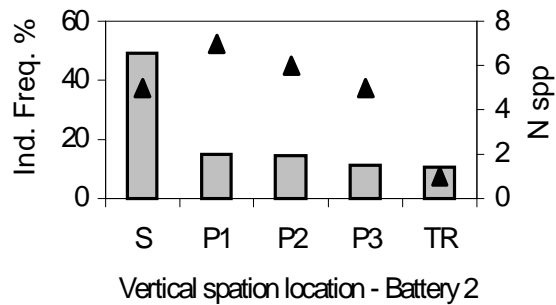
evaluation of the individuals frequency of occurrence, showed that R area was occupied during 84.21% of the days of observation, area R1 in 57.87% and R>1 in 10.52% of the days. *C. striatus*, *A. bahianus*, *L. analis*, *E. morio*, *L. synagris and* Blenniidae representants were exclusively observed in area R, and on the other areas there were no exclusive components.

Figure 4 - Horizontal spatial location - Battery 2 - relative frequency of individuals (Ind. Freq. % ☐) and absolute frequency of components (N spp ▲) at artificial reefs during November/December, Ubatuba/SP.

Figure 3 - Vertical spatial location - Battery 1 - relative frequency of individuals (Ind. Freq. % ☐) and absolute frequency of components (N spp ▲) at artificial reefs during May/ June, Ubatuba/SP.

With regard to vertical analysis, individuals were seen on S during all sampling days (100%), on P1 in 96.29% of the days, on P2 in 70.37%, on P3 in 37.03% and on TR in 14.81% of the days. Pleuronectidae and *S. foetens* representants were exclusive of S, and *F. tabacaria*, *D. argenteus, A. virginicus* and *L. analis* of P1. The other locations did not shelter exclusive components.
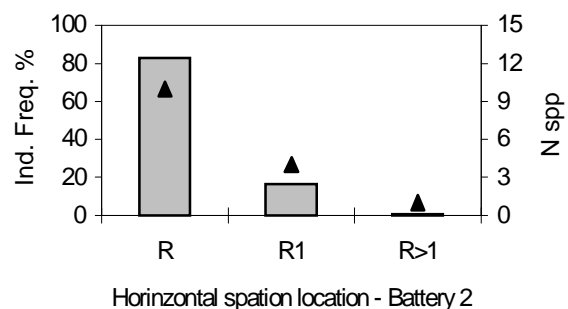
BATTERY 2 - NOVEMBER/DECEMBER 1996

Battery number 2 was also surveyed during 30 consecutive days between November and December, 1996. The horizontal occupation evaluation evidenced that the R area of the artificial reef supported the highest individual numerical abundance (82.69%) as well as of components (10) (Fig. 4). The horizontal

The vertical partition evolution of floors showed that the substrate (S) was the environment with the highest number of individuals, corresponding to 49.04% of the total abundance and P1 the one with most components number (7) (Fig. 5), following the same tendency observed in the previous evaluation (May/June - Battery 1).

Figure 5 - Vertical spatial location - Battery 2 - relative frequency of individuals (Ind. Freq. % ☐) and absolute frequency of components (N spp ▲) at artificial reefs during November/December, Ubatuba/SP.

Individuals were present and observed on S floor in all surveys (100%), on P1 and P2 floors in 42.10%, on P3 in 26.31% and on TR in 10.52% days of observation. Pleuronectidae were exclusive of S and *L. synagris* of P1. The other floors did not have exclusive components.

Comparing the existing spatial partition between the two artificial structures Batteries 1 and 2, it was observed that:

- Horizontally: R area was the most explores by fish. there was no 100% frequency of occurrence in any reef area during the period of November/December (Battery 2).
- Vertically: P1 floor was the one with the highest number of components, and of individuals in May/June, but S was where, in November/December, occurred the biggest abundance of individuals. The TR floor was the least used by the fishes, and no component was registered in W>1. Occurrence frequency on S floor was maximum for both batteries and this environment was the most frequented and TR the least.
- Horizontally, Blenniidae and *L. analis* were exclusive to R area and vertically Pleuronectidae to S.
- Omnivorous were outstanding on R and P1.
- All species, except *C. cryssurus*, presented benthonic habits.

DISCUSSION

A first level of evaluation includes descriptions and that of fish assemblages provides the database essential to make time series comparisons and a following level could include temporal/spatial comparisons and colonization processes. High majority of fishes, found on reefs belong to advanced families (Choat and Bellwood, 1991) and this pattern was also detected in this work. Less advanced orders representants may in addition occur, such as lizard fish and cornet fish and were also present.

Comparisons of abundance values with other reefs data have to be very coshious due to the fact that several factors may have influenced final counting and overshadowed possible enhancement of number of fishes in the study area. The benthic behaviour of almost the entire fish assemblage was expected and similar to literature findings as the provided habitat privileged this category.

The established fish associations at the reef denoted that the cavities, holes designs as well as overall design of the reef benefited mostly demersal species and their behavior. The deployment of the artificial reefs units, right angled to the prevailing currents provided shelter to the fishes as also mentioned by Dean (1983).

There is considerable evidence that reef fish compete for shelter holes as refuges from predation (Sale, 1991). On a global scale, the geographical scarcity of natural reefs is an obvious limiting factor (Bohnsack, 1991) and shelter provided by habitat is likely the dominant factor limiting populations (Pickering and Whitmarsh, 1996).

The depth deployments location was very adequate as it was proper to allow large diving observation periods. According to Bombace et al. (1994) shallow inshore waters do not seem to affect species diversity of resident reef fish, but the exchange and mixing of waters, mixing of sedimentary nutrients and river runoff area highly productive. These authors also mentioned that these characteristics have the potential to enhance the effectiveness of artificial reef in terms of productivity.

The large gap (60m) between reef units has been shown by Frazer and Lindberg (1994) to possibly influence fish association and similar situation was found in this study. It revealed that the artificial reefs were an extension of the existing habitats, with benefits for fish recruitment. Shelter and territory are pivotal for species that present non-gregarious behavior. More than half showed solitary behavior. Apart from shelter behavior, adaptations play an important role reducing individuals threat and schools of very small sized *Haemulon* were observed at the reef. Since natural and artificial reefs are patchy habitats and reef fishes are generally sedentary, the only significant recruitment to local fish populations comes from the settlement of planktonic larvae. Local factors determining the settlement characteristics could play an important role in structuring the assemblages of fish.

The intensity of settlement of fish is variable during and between seasons. An explanation for seasonal cycles of settlement is that it reflects the varying breeding capabilities of adults. Daily fluctuations also occr as well as inshore movements. The magnitude of settlements is

extremely variable over time and the individuals that settle must have the ability to determine shelter availability, number of predators and food supply. Ecklund (1996) continues saying that occupants select their habitats and change with age so the reefs of this work might have contributed to shelter in the small holes a considerable number of relatively small individuals. Eckland (1996) states that, in some cases reduction of predation of reef residents is made possible by the provision of shelter and Bohnsack (1989, 1991) reinforces saying that it is one of the main mechanisms by which na artificial reef can operate.

Predation may have an important role in structuring the fish assemblage, as a post-settlement process. Predation structures prey assemblages by altering abundance of species so affecting distribution and perhaps the local diversity. Evidences were found that the artificial reefs functioned as recruitment and survival areas for young and small fishes, attracted predators and probably the total area production might not have increased.

Jensen et al. (1994) reported an unequal species colonization of vertical and horizontal surfaces and faunal species dominating the vertical and algae on the latter but did not make special attention to fishes. In this work it was detected that horizontally there was a higher occupation of the reef itself but when vertical analysis was carried out, the lowest floors were where there were largest occupation.

Fishes did not share and use the environment of artificial reefs randomly , different areas of the reefs were occupied in significantly different ways so the results refute the tested hypothesis.

ACKNOWLEDGEMENTS

RESUMO

Este trabalho é parte integrante de um projeto maior realizado pelo Laboratório ECOPEX/IOUSP. Foi desenvolvido nos entornos do Parque Estadual da Ilha Anchieta, Ubatuba, litoral norte de São Paulo, com o objetivo de estudar a dinâmica de repartição espacial dos peixes em estruturas artificiais e de testar a hipótese "os peixes repartem e utilizam aleatoriamente o espaço das estruturas artificiais". Utilizando-se blocos de concreto vazados, foram construídas e colocadas entre 3m - 6m, oito estruturas artificias idênticas. A instalação foi feita em duas etapas durante o ano de 1996 (Maio/Junho e Novembro/Dezembro) e as observações efetuadas diariamente durante 30 dias consecutivos usando equipamento de mergulho autônomo. A ictiofauna utilizou de forma diferenciada as áreas dos recifes artificiais, influenciada provavelmente por vários fatores, principalmente bióticos. Os resultados do teste de Kruskal-Wallis levaram a refutar a hipótese desse estudo.

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