Structural Complexity and Fish Biomass at Seven Artificial Reefs of the Campeche Bank, Mexico

Biomasa Peces y Complejidad Estructural en Siete Arrecifes Artificiales del Banco de Campeche, México

Structurelle Biomasse de Complexité et de Poissons à Sept Récifs Artificiels de la Banque de Campeche, Mexique

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ABSTRACT

Artificial reefs are structures deposited on the seabed in order to create new habitat for flora and fauna, the composition and structure of the fish community is positively influenced by the complexity of artificial habitat. Structural complexity was determined in seven sunken barges becoming artificial reefs, where biomass of their fish communities was estimated. It was found that more structurally complex structures showed better development of benthic flora and fauna. Two complex reefs are able to withstand a high biomass despite that their structures are essentially different. Biomass was estimate by the 23 most abundant species of fish in the seven reefs examined. The maximum biomass was found in one reef, with 285 g/m^2; two reefs presented intermediate biomass values (183 and 163 g/m^2), and the remaining reefs exhibited lower biomass values. The *species Lutjanus griseus, Megalops atlanticus*, *Selene vomer, Lutjanus jocu* and *Chaetodipterus faber*, contribute with 80% of total biomass. Species important for fisheries belong to the families *Carangidae, Ephippidae* and *Haemulidae*, being the most abundant in most of the reefs studied; the rest of the families are represented by 10 species in which stand out appreciated for their market value, *Lutjanidae* and *Carangidae*.

KEY WORDS: Artificial reef, fish community, biomass, habitat structure, Mexico

INTRODUCTION

Artificial reefs are structures deposited on the seabed to impact physical and biological processes (Seaman 2000). By concentrating high fish abundance, they are used as a tool for restoration of natural resources (Duffy 1985, Hueckel et al. 1989, Ambrose, 1994). However, the fact that they are producers of biomass (biomass/time), or just as fish attractors that may be used for fishery exploitation purposes (Grossman, et al. 1997, Lindberg 1997), is a topic still under intense debate.

Aspects to be considered to evaluate the role of artificial reefs in the natural environment enhancing recruitment of many species is affected by the dimensions of the artificial systems; these reefs enhance survival of recruits and increase in the number of organisms. It has been suggested that as fish production increases, the complexity of the associated reef community is higher too. Therefore, this may lead to an increase in fishing mortality of important stocks due to the concentrating action of artificial systems, which could somehow affect populations that otherwise could naturally be more disperse, thus causing negative effects on the role of artificial systems, with higher impact on *K* strategists, this is, species with low rates of reproduction and growth (Hixon 1998, Peterson et al. 2003). Based on these considerations, this study aims to determine the structural complexity of seven artificial reefs and estimate the biomass of the fish community inhabiting them.

METHODS

Visual censuses in four 10-meter long by 5-meter wide transects (50m^2), were made, covering an area of 200 m^2. Conspicuous and cryptic reef fish species were recorded (Bohnsack et al. 1986). Fauna at each site was accounted for in five size ranges: 1 - 10 cm 11 - 20 cm, 21 - 30 cm, 31 - 40 cm, and higher than 41 cm. Species important for fisheries were also accounted.

Estimating Biomass

Density values (Ind/m^2) between artificial reefs were used for estimate biomass (g/m^2). Biomass per species-site was obtained from the product of the density obtained by the average weight, were estimated using the equation by Marks and Klomp (2003): ,

$$B = a * L^b$$

where: B = biomass, L = average length observed a and b are constants of the weight-length relationship.

RESULTS

Dimensions of each structure influence the complexity of the biological community, these structures which are under particular oceanographic and biological conditions for colonization. In Figure 1, four scenarios with different complexity are defined and are conditioning the species present and their abundance. Two artificial reefs are structures that displayed higher complexity (large vessels with plenty of space and larger area); 60% of the species were observed in both reefs, showing the highest diversity and abundance compared to the rest of the structures examined.

Two structures with medium complexity are found under similar oceanographic conditions and their surface is very similar; consequently, 50% of the species they contain are the same. Three other reefs have low structural condition due to their sizes; their structures are scattered on the ground and provide little habitat for the colonization. This factor constrains their ability to withstand higher biomass. Finally, one reef presented very adverse conditions for colonization (high sedimentation) of benthic species and is small as compared to the other reefs.

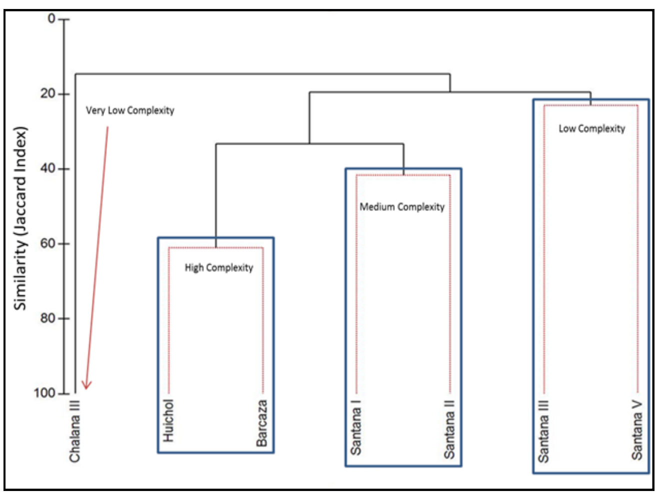

Figure1. Types of biological complexity (high complexity, medium complexity, low complexity, and very low complexity). Grouping was made using data on species richness and abundance. The cluster represents a Q type matrix, transformed in Presence/Absence (P/A) and using the Jaccard similarity index with p = 0.05.

Species Richness

In one of the reefs, known as the Barcaza, 43 fish species were recorded; the highest structural complexity and high level of colonization of corals, algae and mollusks were found. In three other artificial reefs, named Huichol, Santana I and Santana III, intermediate levels of richness were found. Finally, in the artificial reef known as Chalana III, the reef community showed the lowest richness and structural complexity (Figure 2).

Abundance by Reefs

On the Barcaza, the species *Haemulon striatum*, *Scarus croicensis* and *Sphyraena barracuda*, were the most abundant; the first two are associated to coralline substratum. The Huichol is the second reef structure in size and complexity; here *Selene vomer* is the most abundant species, out of 29 others species of fish making up the community, nine of which represent 94% of total abundance. Here, juvenile *Haemulon carbonarium* form dense schools and most species are pelagic reef dwellers. Four other have similar specific composition of small pelagic. One of these showed the highest abundance and a cast of more complex species; these differences consist primarily of species associated to areas with higher benthic coverage, where most species concentrate. The development of benthic community seems to have a direct relationship with fish composition and density. In the Santana´s an opposite condition is observed, where the number of species and abundance was lower. Where the benthic coverage is higher, the equitability increases, and in contrast, when the benthic organisms colonize small areas, dominance is higher. In Chalana III and Santana I, 72% of species richness is made up with only nine species, in the Santana II, five species represent 91% of abundance; in Santana III, eight species 90% and finally, in the Santana V, four species account for 81% of the total fish abundance (Figure 3).

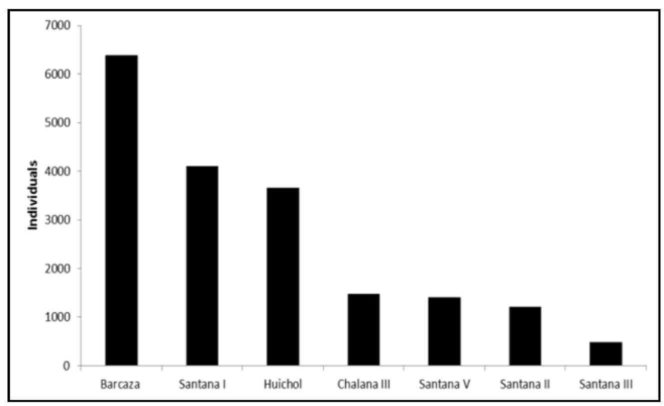

Figure 3. Fish abundance per artificial reef.

Biomass

Biomass of the 23 most abundant fish in the 7 artificial reefs studied. The site with the maximum value is the Barcaza (285 g/m^2). The reefs Santana I and Huichol have intermediate biomass values (183 and 163g/m^2, respectively). The Chalana III and Santana's V, II and III have the lowest biomass values (Figure 4). The commercial species *Lutjanus griseus, Megalops atlanticus, Selene vomer, Chaetodipterus faber* and *Lutjanus jocu*, contribute with 80% of total biomass.

The species with commercial importance belong to five families; of these, Carangidae and Lutjanidae are the most important and abundant in most of the reefs studied. Other families of fish are represented by just one or two species (Figures 5 and 6).

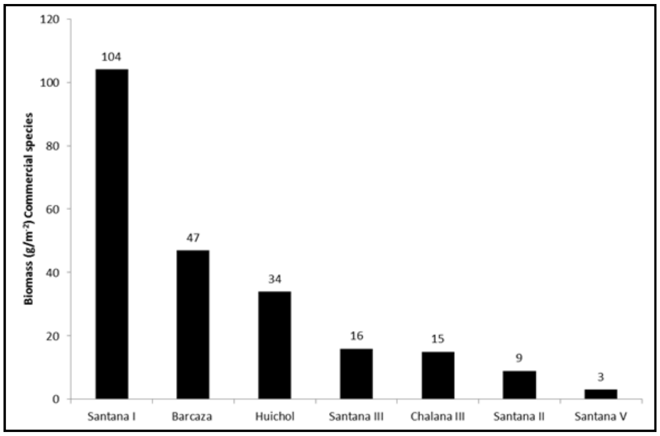

Figure 5. Biomass of the species with commercial importance per artificial reef.

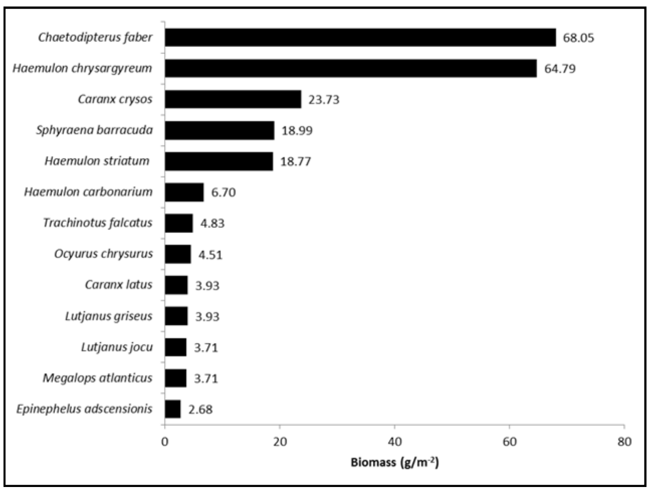

Figure 6. Biomass per species important for fisheries.

DISCUSSION

According to Peterson et al. (2003), artificial reefs play a role of both concentration and production, increasing fish biomass. He states that in some cases, the absence of fishing pressure, allows a net increase in fish production.

Fish species of the genus *Stegastes* and *Pomacanthus* are influenced by benthic associations, while the fish in turn are prey for larger fish such as species of the genus *Lutjanu*s. It is noteworthy that, certainly in the absence of artificial structures studied, an ecosystem of desertic sandy bottoms, the abundance of fish would display much lower density as compared to the observed in artificial reefs (Zieman 1989). *Chaetodipterus faber* was the most abundant species with the widest distribution in the study area. The 17 most abundant species are mainly fish and zoo benthos eaters, all coral reef residents, being the herbivore species less abundant.

Species richness was higher in those reefs with greater structural complexity and higher volume, besides being in apparently more favorable oceanographic conditions, like currents providing food, oxygen, carbonates for growth of corals and algae, and higher luminosity (Baynes and Szmant 1989, Scarborough and Kendall 1994, Rogers 1990, Rooker et al. 1997). Diversity of these artificial systems ranges between 1 to 3 bits/Ind., being the lowest for those structures with unfavorable conditions for growth of benthic fauna (Santana´s I, II and V). The exception to this pattern was the Santana III, where its high diversity surpasses that of those more complex structures with better conditions. This may be induced by the low dominance of all species found on the reef, giving the highest diversity values. The effect of increased diversity is just the combined effect of lower dominance, as found in Santana III (Rooker et al. 1997).

In the reefs with higher structural complexity (Barcaza and Huichol) the highest concentration of fish of all sizes and species mainly resident fish was found. They are reef fish which seem to have direct connection to the benthic fauna. In the Barcaza, with higher structural complexity, high biological richness and many niches were observed. Consolidation of structures for long time under suitable conditions allows the organization of a more complex community diversifying ecological roles, as it was observed in the case of the genus *Stegastes, Thalassoma,* and *Chormis*, which are species forming cleaning stations where species of carangids and barracuda (*Sphyraena*) are the beneficiaries of this symbiosis. This phenomenon could be a good indicator of the maturity reached by the community in these artificial systems (Menni 1983).

CONCLUSION

Structures with higher surface complexity and structure of habitat, plus a longer deposition time, had higher biomass and abundance of fish fauna and higher potential to be used for fisheries. It was also observed that the oceanographic conditions strongly influence the level of biological colonization on each reef. The structures studied are far from the coast and from ecosystems that may provide recruits for colonization. Even so, the development of associated flora and fauna is certainly important, demonstrating the true function of these systems under similar conditions. If these artificial reefs would not be in the area, a bare ground with sandy bottom and very low species diversity would be there.

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