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Research Article

Influence of a shipwreck on a nearshore-reef fish assemblages off the coast of Rio de Janeiro, Brazil

Eduardo Barros Fagundes-Netto[1,2], Luiz Ricardo Gaelzer[1], Ricardo Coutinho[1,2] & Ilana R. Zalmon[2]
[1]Instituto de Estudos do Mar Almirante Paulo Moreira, Departamento de Oceanografia
Rua Kioto 253, 28930-000, Arraial do Cabo, RJ, Brazil
[2]Universidade Estadual do Norte Fluminense, Av. Alberto Lamego 2000, 28013-602
Campos dos Goytacazes, RJ, Brazil

ABSTRACT. The effect of the *Orion* shipwreck on fish assemblage distribution near the reef was studied to the northeast of Rio de Janeiro with six different fishing gears: gillnets, mid-water longlines, circular traps, rectangular traps, vertical longlines, and bottom trawling. The study consisted of a pre-monitoring survey four months before the shipwreck in the area (A) and in two control areas (B and C). After 36 months, a total of 56 species were caught in the *Orion* reef area, 49 in control area B and 59 in control area C. The similarity analysis, considering the number of fish caught during the nine surveys in the three study areas, clustered the pre-monitoring and first post-settlement surveys of the three sites. This occurred due to the low number of fish captured and the dominance of *Trichiurus lepturus* and *Lagocephalus laevigatus*. These results differed from all the other studies in the three areas due to the co-dominance of *Ctenosciaena gracilicirrhus* and *Stephanolepis hispidus*. Such spatial similarity shows the low influence of the *Orion* reef in the area after three years. Biomass values were 15% higher in the *Orion* reef area than in the control areas, representing an increase of up to 1.2 times in wet weight. The increment of fish communities is still insufficient for proposing sustainable fishery activity in the shipwreck area. The monitoring time (32 months) after the sinking of the *Orion* may be considered too short to assure that the wreckage had reached its maturity as an artificial reef, either as a fish attractor or producer.

Keywords: shipwreck, artificial reef, monitoring, management, fish assemblage, southern Brazil.

Influencia de un buque sumergido sobre agregaciones de peces asociados a un arrecife somero de la costa nordeste de Rio de Janeiro, Brasil

RESUMEN. El efecto del buque sumergido *Orión* sobre la distribución de las comunidades de peces próximas al arrecife fue estudiado en el noreste de Rio de Janeiro utilizándose seis artes de pesca: red de enmalle, palangre pelágico, trampas circulares, trampas rectangulares, palangres y red de arrastre de fondo. El estudio consistió en una investigación premonitoreo, cuatro meses antes del naufragio en el área (A) y en dos áreas control (B y C). Después de 36 meses, 56 especies fueron capturadas en el arrecife *Orión*, 49 en el área control B y 59 en el control C. Los análisis de similitud considerando el número de peces capturados durante las nueve campañas en las tres áreas de estudio, agruparon las campañas de premonitoreo y la primera de pos-asentamiento, en las tres localidades, debido a la baja captura de individuos y a la dominancia de *Trichiurus lepturus* y *Lagocephalus laevigatus*. Estos resultados fueron distintos en todas las otras investigaciones en las tres localidades, debido a la codominancia de *Ctenosciaena gracilicirrhus* y *Stephanolepis hispidus*. Esta similitud espacial muestra la baja influencia del arrecife *Orión* en el área después de tres años. Los valores de biomasa fueron 15% mayores en la área del arrecife *Orión* que en las áreas control, representando un aumento de hasta 1,2 veces en peso húmedo. El aumento de las comunidades de peces en el área es todavía insuficiente para proponer la actividad pesquera sustentable en la región del naufragio. El periodo de monitoreo (32 meses), despues del asentamiento del *Orión*, puede ser considerado corto para asegurar que el naufragio, tenga legado a su madurez como arrecife artificial, como atractivo o productor de peces.

Palabras clave: naufragio, arrecife artificial, monitoreo, manejo, comunidad de peces, sur de Brasil.

Corresponding author: Eduardo Fagundes-Netto (eb-netto@uol.com.br)

INTRODUCTION

The use of decommissioned marine ships as artificial reefs for fisheries or conservation is a common practice in many coastal countries (Jensen *et al.*, 2000; Love *et al*., 2006) and increased fishing yield can be obtained almost immediately after the installation of artificial structures (Seaman & Jensen, 2000).

Despite of the increased use as artificial reefs, studies comparing fish assemblages on shipwrecks and natural reefs are still scarce (Arena *et al*., 2007). According to Rilov & Benayahu (2000), one should take into consideration that complex vertical artificial structures do not necessarily imitate the natural environment, but can establish their own community, which is influenced by the spatial orientation and complexity of the structure.

Abandoned ships have been settled since 1935 (Stone, 1985) to promote the success of tourism and commercial fishing (Seaman & Jensen, 2000). Walker *et al.* (2007) pointed out that artificial reefs including shipwrecks are characterized by different ecological interactions. Epibenthic communities provide food resources for consumers and act as a secondary habitat for other benthic invertebrates, increasing the complexity of the habitat including shelter for fish (Moura *et al*., 2007; Nicoletti *et al*., 2007).

Wreckage of ships, accidentally or planned, are known among fishers as abundant areas for fish species which live there, or ground for feeding and spawning activities (Supongpan, 2004). The latter aspect has led over the last decade to a refinement of the historical view of reefs as simple attractors (Seaman & Jensen, 2000). The biodiversity and great biomass of fish and invertebrates in deliberate sinking ships, and the replacement of less selective fishing practices to more conservative gears in these habitats have highlighted the potential for the controlled use of the seafloor (Silva, 2001).

Given the shortage of new opportunities for fishery resources in coastal areas of Rio de Janeiro state, the Brazilian oil and gas company (Petrobras) and the Brazilian Navy established an artificial reef project based on the decommissioning of the hydrographic ship *Orion*, expecting to create potential habitats for different marine species.

This study aimed to evaluate the influence of the *Orion* shipwreck on the composition and structure of the associated fish assemblages on the northeast coast of Rio de Janeiro, assuming that it enhances fish assemblage's densities and biomass contributing for the artisanal fishing yield.

MATERIALS AND METHODS

Study area

The shallow platform in the northeast region of Rio de Janeiro is characterized mainly by sandy and muddy substrate. This part of the coast is used for trawling and longline by the fishing fleets of the states of Rio de Janeiro, São Paulo and Santa Catarina (Paiva, 1997).

The hydrographic ship *Orion* (45 m long, 6.5 m wide and 9 m height) after decommissioned went through a diagnosis process to subsidize the cleaning steps and to prepare the steel hull before the sinking in November 2003 (Fig. 1). The hull was sunk near the coast of Quissamã (22°20'S, 041°25'W) in the northeastern state of Rio de Janeiro, at 30 m depth and 8.4 nm (around 15 km) from the coast.

Besides the *Orion* reef site, the study was carried out in two control areas (B: 22°17'S, 41°25'W; C: 22°20'S, 41°22'W), both of them distant 2.6 nm (4.7 km) from the *Orion* reef and 3.5 nm (6.6 km) apart from each other. Given the scarcity of natural rocky substrate in the region, the distances among the three areas were pre-defined according to the depth (20 to 30 m), sediment type (sand and/or mud) and absence of elevations (Fig. 2).

Abiotic data

The current velocity during the monitoring period was determined by an Aanderaa RCM-7 (Recording Current Meter) kept 5 m away from the bottom. Water samples for nutrient analysis and temperature were collected in triplicate at 0, 5, 10, 15, 20 and 25 m during the monitoring surveys in the three study areas with a 1.5 L Nansen bottle sampling and an inversion

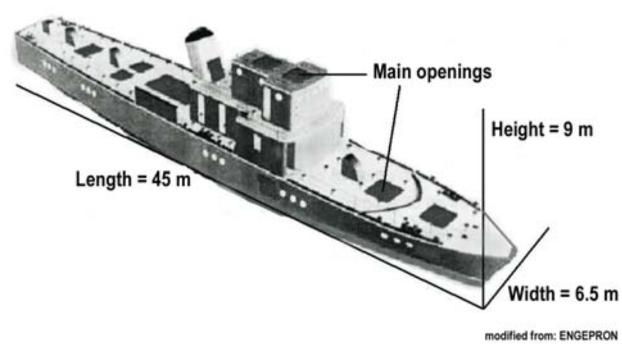

Figure 1. Digitalized image of the hydrographic ship *Orion* showing the hull dimensions and the openings for fish and water circulation.

Figura 1. Imagen digitalizada del buque hidrográfico *Orión* indicando las dimensiones del casco y las aperturas hechas para la circulación del agua y de los peces.

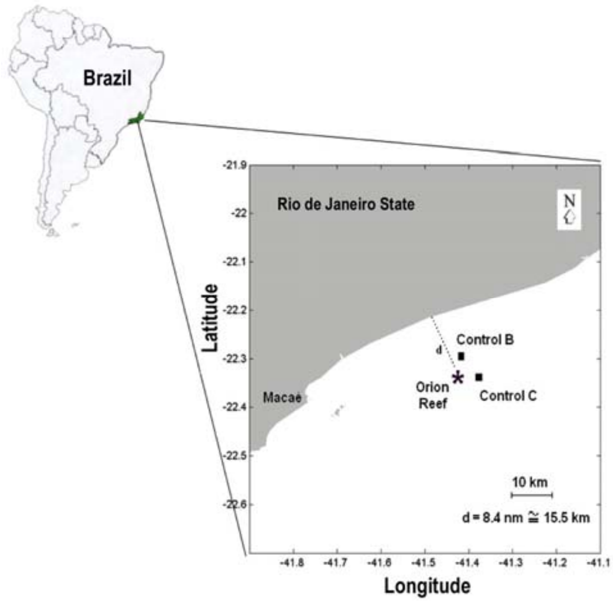

Figure 2. Study area indicating the location of the *Orion* reef and the controls B and C. d: distance from the coast.

Figura 2. Área de estudio indicando la localización del arrecife *Orión*, áreas control B y C. d: distancia de la costa.

thermometer attached. Dissolved oxygen was determined using the Winkler method described by Strickland & Parsons (1972) and salinity through an Autosal Guildeline 8400B m. Nitrite, nitrate, ammonia-N and orthophosphate concentrations were determined according to Strickland & Parsons (1972).

Sampling design

Fish monitoring program in the *Orion* reef area (A) and in two controls (B and C) consisted of a pre-monitoring survey (AP, BP and CP) conducted in July 2003, four months before the hull sinking, followed by eight monitoring surveys in each area (AI, BI and CI, to, AVIII, BVIII and CVIII) 2, 4, 7, 10, 13, 16, 28 and 32 months after the sinking. Six different types of fishing gears (gillnet, mid-water longline, circular traps, rectangular traps, vertical longline and bottom trawling) were used simultaneously in each area. The gears were launched as near as possible of the *Orion* shipwreck (average distance ~100 m) and of the center of the two control areas, depending on the oceanographic conditions as wind and current directions during the surveys. The immersion time for the gears was variable (Table 1) depending on the predation effect over the fish species caught by each gear.

Fish assemblage's analysis

Fish assemblages in the three areas (*Orion* reef, control B and control C) on the nine surveys (one pre-monitoring and eight after the sinking) was characterized for species composition, richness, abundance and frequency of occurrence of fish caught with the six gears. The catch per unit effort (CPUE) was calculated as total weight from each gear separately in the three study areas. Fishes were identified (Figueiredo & Menezes, 1978, 1980; Menezes & Figueiredo, 1980, 1985; Cervigón, 1993), measured as total length and total weight and also characterized according to the position in the water column. The length-weight relationships (LWR) for the most abundant species in the three areas were expressed by the equation: $Wt = a\ Lt^b$ (Pauly, 1980).

The significance of differences of species richness between surveys in each area was assessed by a one-way analysis of variance (ANOVA), followed by a Tukey test for multiple comparisons of averages. The data was tested as for normality using the Kolmogorov-Smirnov test (Zar, 1984).

Fish assemblages' analysis among the *Orion* reef and control areas in the pre-and post-settlement surveys included a cluster analysis (UPGMA) and a MDS ordination, using the Bray-Curtis similarity coefficient, including the species that occurred in number $\geq$ 10 individuals in at least one sampled area or survey, and the more frequent ones (FO $\geq$ 65%) in each area. The adequacy of the configuration of the samples in the MDS ordination was obtained from the stress value. The ANOSIM permutation test (one-way) assessed the significance of differences between the pre-defined groups from the cluster analysis. The procedure of percentage of similarities SIMPER identified the species contribution within and between groups (Clarke & Warwick, 2001). Data analysis was performed with the software PRIMER 6.

The relationship among the environmental variables and the species abundance was investigated by a Canonical Correspondence Analysis (CCA) (Ter Braak, 1986) using the software MVSP (Multi-Variate Statistical Package) 5.1. The species selected were the same of the cluster and MDS analysis, using their biomass values (wet weight) with the data Log (10) transformed. Monte Carlo permutation test (CANOCO 4.0) using the downweighting rare species routine was used to test the abiotic variable effect over the fish assemblages. The environmental variables included temperature, salinity, dissolved oxygen, nitrite, nitrate, ammonia and phosphate values registered in each area during the nine surveys.

RESULTS

Correntometry

The average magnitude of currents near the *Orion* reef ranged from 4.8 to 13.2 cm s^{-1} presenting lower

Table 1. Characteristics of the fishing gears: number, size, immersion time and baits (fish: *Auxis thazard*, squid: *Loligo plei*) in the three study areas.

Tabla 1. Características de las artes de pesca: número, tamaño, tiempo de inmersión y carnadas (pez: *Auxis thazard*, calamar: *Loligo plei*) en las tres áreas de estudio.

Fishing gear	Number of gears	Characteristics of the gears	Time of immersion	Bait
Gillnet	1	Length 200 m Height 05 m	4 h	No bait
Midwater longline	1	150 hooks Size 11/0	3 h	Fish and squid
Circular trap	6	Base 1.0 m Mouth 0.3 m	7 h	Fish
Rectangular trap	4	1.6 m x 0.8 m	7 h	Fish
Vertical longline	2	30 hooks Size 11/0	3 h	Squid
Bottom trawl	1	Mouth 10 m Length 10 m	30 min	No bait

range of values but not significantly different ($P > 0.05$) in relation to the control areas B (6.1 to 20.4 cm s^{-1}) and C (6.4 to 15.1 cm s^{-1}).

Physical and chemical parameters and nutrients

In the three study areas, the temperature ranged from 20° to 23°C, salinity from 35 to 36, dissolved oxygen from 4.0 to 6.0 mL L^{-1}, phosphate from 0.2 to 0.6 µmol L^{-1} and nitrate from 0.2 to 2.7 µmol L^{-1}. Nitrite levels ranged from 0.1 to 0.5 µmol L^{-1} on the *Orion* reef, from 0.01 to 0.6 µmol L^{-1} on control B and 0.04 to 0.4 µmol L^{-1} on control C; ammonia ranged from 0.5 to 2.4 µmol L^{-1} on *Orion* reef, from 0.9 to 1.5 µmol L^{-1} on control B and 0.8 to 2.1 µmol L^{-1} on control C. Temporal variations after sinking occurred near the reef with mean values higher in the 1st survey (ammonia), 3rd (temperature), 4th (salinity, DO, nitrite, nitrate and phosphate) and 5th (DO and nitrite) (Table 2).

Fish assemblages

The fish composition and abundance in the studied areas were similar. In the *Orion* reef, 1789 specimens were captured with a total biomass of 311 kg throughout the study. Fish assemblages were composed of 56 species belonging to 48 genera and 30 families; 11 species (14%) were exclusive to this area. Regarding their position in the water column, 31 species were demersal (55%), 12 bentho-pelagic (21%), 6 pelagic (11%) and 7 benthic (12%). *Trichiurus lepturus* and *Dules auriga* (89%) were the most frequent species in this reef area (Table 3).

At control B, 1820 specimens were captured totaling 279 kg throughout the study. Fish assemblages were composed of 49 species belonging to 45 genera and 28 families; 7 species (14%) were exclusive of this area. Regarding their position in the water column, 27 species were demersal (55%), 10 bentho-pelagic (20%), 8 pelagic (16%) and 4 benthic (8%). *Trichiurus lepturus* (100%), *D. auriga, Lagocephalus laevigatus, Z. brevirostris* and *P. brasiliensis* (67%) were the most frequent species at control B (Table 3).

At control C, 1796 specimens were captured totaling 267 kg throughout the study. Fish assemblages were composed of 59 species belonging to 54 genera and 36 families; 10 species (17%) were exclusive of this area. Regarding their position in the water column, 31 species were demersal (53%), 13 bentho-pelagic (22%), 9 pelagic (15%) and 6 benthic (10%). *D. auriga* (100%), *Pagrus pagrus* (89%) were the most frequent species at control C (Table 3).

Although spatial and temporal variation in fish abundance was observed during the study period, these differences didn't show a clear distribution pattern (Fig. 3). At *Orion* reef and control B, the number of individuals was higher in the third and sixth surveys, corresponding to 46 and 71 kg in the reef and 38 and 26 kg in control B, respectively (Fig. 3). At control C, the number of individuals was higher in the third and fifth surveys, corresponding to 62 and 31 kg, respectively. The species that contributed with more than 70% of the captures in number of individuals were *Dactylopterus volitans, Ctenosciaena gracili-*

Table 2. Mean values for the physical and chemical parameters and nutrients in the *Orion* reef area. Highest values are in bold.

Tabla 2. Valores medios de los parámetros físicos, químicos y nutrientes en el arrecife del área *Orión*. Los mayores valores se indican en negrita.

Months after sinking	Surwey	Temperature (°C)	Salinity	O_2 (mL L^{-1})	NO_2 (µmol L^{-1})	NO_3 (µmol L^{-1})	NH_4 (µmol L^{-1})	PO_4 (µmol L^{-1})
2	I	21.7	35.67	4.67	0.09	0.30	**2.41**	0.33
4	II	21.6	35.39	4.82	0.20	1.55	1.25	0.34
7	III	**22.5**	35.76	5.04	0.17	0.66	0.54	0.28
10	IV	20.5	**36.01**	**5.66**	**0.42**	**2.73**	1.27	**0.51**
13	V	20.2	35.68	**5.60**	**0.49**	2.09	1.20	0.28
16	VI	20.0	35.79	5.13	0.24	0.98	1.40	0.40
28	VII	21.8	35.76	4.47	0.24	1.14	2.28	0.45
32	VIII	21.3	35.68	4.96	0.33	1.01	1.80	0.48

Table 3. List of species according to family and species composition, specie code, position in the water column (PWC) (D: demersal, BP: bentho-pelagic P: pelagic, B: benthic) and frequency of occurrence (FO%) by area (*Orion* reef, Control B and Control C) and total.

Tabla 3. Lista de especies por familia, composición de especies, código de especie, posición en la columna de agua (PWC) (D: demersales, BP: béntico-pelágico, P: pelágico, B: bentónico) y frecuencia de ocurrencia (FO%) por área (arrecife *Orión*, Control B y Control C) y total.

Family	Species composition	Species code	PWC	FO% Orion reef	FO% Control B	FO% Control C	FO% Total
Lamnidae	*Isurus oxyrinchus*	Isox	P	0	0	11	4
Carcharhinidae	*Rhizoprionodon porosus*	Rhpo	D	33	56	67	52
Squatinidae	*Squatina argentina*	Sqar	D	11	0	33	15
Rhinobatidae	*Zapteryx brevirostris*	Zabr	D	56	67	44	56
Rhinobatidae	*Rhinobatus horkelli*	Rhho	D	22	22	22	22
Rhinobatidae	*Rhinobatus percellens*	Rhpe	D	0	11	11	7
Rajidae	*Rioraja agassizi*	Riag	D	44	33	44	41
Rajidae	*Atlantoraja castelnaui*	Atca	D	11	11	22	15
Rajidae	*Psammobatis extenta*	Psex	D	11	0	22	11
Rajidae	*Raja platana*	Rapl	D	0	0	11	4
Narcinidae	*Narcine brasiliensis*	Nabr	D	11	11	22	15
Narcinidae	*Discopyge tschudii*	Dits	D	0	0	11	4
Dasyatidae	*Dasyatis say*	Dasa	D	33	0	44	26
Dasyatidae	*Dasyatis guttata*	Dagu	D	11	0	0	4
Myliobatidae	*Myliobatis freminvillei*	Myfr	BP	11	11	11	11
Rhinopteridae	*Rhinoptera bonasus*	Rhbo	BP	0	11	0	4
Elopidae	*Elops saurus*	Elsa	BP	0	0	11	4
Congridae	*Ariosoma opisthophthalma*	Arop	D	0	11	0	4
Ophichthidae	*Ophichthus gomesii*	Opgo	D	44	0	56	33
Pristigasteridae	*Pellona harroweri*	Peha	P	33	11	11	19
Clupeidae	*Chirocentrodon bleekerianus*	Chbl	P	0	11	33	15
Clupeidae	*Harengula clupeola*	Hacl	P	11	11	11	11
Clupeidae	*Odontognathus mucronatus*	Odmu	P	11	0	22	11
Ariidae	*Genidens genidens*	Gege	D	0	33	22	19
Phycidae	*Urophycis brasiliensis*	Urbr	D	22	0	11	11
Batrachoididae	*Porichthys porosissimus*	Popo	D	78	44	44	56
Triglidae	*Prionotus punctatus*	Prpu	D	33	11	67	37
Dactylopteridae	*Dactylopterus volitans*	Davo	B	78	33	56	56
Serranidae	*Dules auriga*	Duau	BP	89	67	100	85

Family	Species composition	Species code	PWC	FO% Orion reef	FO% Control B	FO% Control C	FO% Total
Serranidae	*Diplectrum formosum*	Difo	BP	11	0	0	4
Echeneididae	*Echeneis naucrates*	Ecna	P	44	22	22	30
Carangidae	*Trachinotus carolinus*	Trca	P	0	11	22	11
Carangidae	*Caranx latus*	Cala	P	11	0	0	4
Carangidae	*Chloroscombrus chrysurus*	Chch	P	0	11	0	4
Carangidae	*Oligoplites saliens*	Olsa	BP	11	0	0	4
Carangidae	*Parona signata*	Pasi	D	0	11	0	4
Carangidae	*Selene setapinnis*	Sese	BP	11	0	0	4
Carangidae	*Trachurus lathami*	Trla	P	11	0	0	4
Gerreidae	*Diapterus olisthostomus*	Diol	BP	0	0	11	4
Haemulidae	*Orthopristis ruber*	Orru	D	67	44	56	56
Haemulidae	*Conodon nobilis*	Cono	BP	22	22	22	22
Haemulidae	*Boridia grossidens*	Bogr	BP	0	11	0	4
Sparidae	*Pagrus pagrus*	Papa	BP	56	22	89	56
Sciaenidae	*Ctenosciaena gracilicirrhus*	Ctgr	D	78	56	78	70
Sciaenidae	*Paralonchurus brasiliensis*	Pabr	D	44	67	78	63
Sciaenidae	*Micropogonias furnieri*	Mifu	D	33	56	44	44
Sciaenidae	*Cynoscion microlepidotus*	Cymi	D	33	33	22	30
Sciaenidae	*Cynoscion striatus*	Cyst	D	33	22	33	30
Sciaenidae	*Isopisthus parvipinnis*	Ispa	D	11	22	33	22
Sciaenidae	*Umbrina canosai*	Umca	D	11	22	33	22
Sciaenidae	*Cynoscion jamaicensis*	Cyja	D	11	22	11	15
Sciaenidae	*Menticirrhus americanus*	Meam	D	11	11	22	15
Sciaenidae	*Stellifer rastrifer*	Stra	D	11	22	11	15
Sciaenidae	*Stellifer brasiliensis*	Stbr	D	11	22	0	11
Sciaenidae	*Cynoscion virescens*	Cyvi	D	11	0	0	4
Sciaenidae	*Larimus breviceps*	Labr	D	0	11	0	4
Sciaenidae	*Menticirrhus littoralis*	Meli	D	11	0	0	4
Ephippididae	*Chaetodipterus faber*	Chfa	BP	0	0	11	4
Percophidae	*Percophis brasiliensis*	Pebr	D	11	0	11	7
Mugiloididae	*Pinguipes brasilianus*	Pibr	BP	0	0	11	4
Trichiuridae	*Trichiurus lepturus*	Trle	BP	89	100	67	85
Scombridae	*Euthynnus alleteratus*	Eual	P	0	11	11	7
Scombridae	*Sarda sarda*	Sasa	P	0	0	22	7
Scombridae	*Auxis thazard*	Auth	P	0	11	0	4
Stromateidae	*Peprilus paru*	Pepa	BP	56	22	44	41
Bothidae	*Bothus ocellatus*	Booc	B	11	0	0	4
Paralichthydae	*Paralichthys patagonicus*	Papat	B	56	33	33	41
Paralichthydae	*Etropus longimanus*	Etlo	B	22	22	44	30
Paralichthydae	*Etropus crossotus*	Etcr	B	0	0	11	4
Cynoglossidae	*Symphurus tesselatus*	Syte	B	11	11	33	19
Cynoglossidae	*Symphurus jenynsi*	Syje	B	11	0	0	4
Cynoglossidae	*Symphurus kyaropterygium*	Syky	B	0	0	11	4
Cynoglossidae	*Symphurus* sp.	Sysp	B	11	0	0	4
Balistidae	*Balistes capriscus*	Baca	BP	11	11	22	15
Monacanthidae	*Stephanolepis hispidus*	Sthi	D	78	56	78	70
Tetraodontidae	*Lagocephalus laevigatus*	Lalae	BP	44	67	44	52
Tetraodontidae	*Sphoeroides spengleri*	Spsp	BP	11	0	11	7
Diodontidae	*Cyclichthys spinosus*	Cysp	D	22	22	22	22

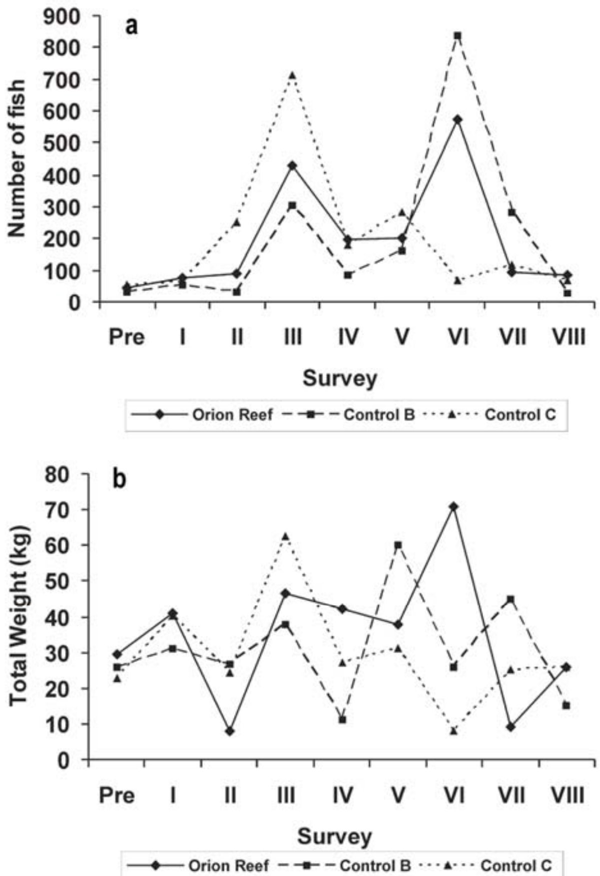

Figure 3. a) Total fish number, and b) weight at *Orion* reef, control B and control C on the nine monitored surveys (01 pre-settlement and 08 post-settlement).

Figura 3. a) Número total de peces, y b) peso total en el arrecife *Orión*, áreas control B y control C en los nueve monitoreos (01 pre-hundimiento y 08 pos-hundimiento).

cirrhus, Stephanolepis hispidus, Trichiurus lepturus, accounting for 40% of the total biomass in all three areas. *T. lepturus, Lagocephalus laevigatus* and *Rhizoprionodon porosus* were the species that showed the highest contribution in weight.

Considering all surveys, fish biomass values were 15% higher on the *Orion* reef area than on the control ones, representing an increase of 1.2 times in wet weight.

The growth parameters values of the LWR are presented for the most abundant species in number of individuals at the *Orion* reef and controls B and C (Table 4) (Fig. 4). The *t* test (ANOVA-Univariate test of significance) results for the growth parameters of each species among the three areas did not show significant statistical differences (ANOVA, $P > 0.05$).

The CPUE in the three study areas through the six fishing gears didn't show a clear pattern that could be associated to the influence of the *Orion* reef or even to temporal variations (Fig. 5). Significant spatial differences were registered only with the circular trap between controls ($P = 0.03$; $F = 3.59$; df = 2). All the other fishing gears showed similar variations ($P > 0.05$).

The cluster analysis including the nine surveys in the three study areas showed two main groups. Group 1 with 20% similarity included the pre-monitoring survey and the 1st post-settlement survey in the three areas, due to the low number of fish captured and the co-dominance of *Trichiurus lepturus* and *Lagocephalus laevigatus* at this initial time. Group 2 had 25% similarity and included the other surveys of the three areas, due to the co-dominance of *Ctenosciaena gracilicirrhus* and *Stephanolepis hispidus*. The isolation of control B on the 2nd survey from all other samples reflected the predominance of *Stelifer rastrifer* in control B area during this monitoring period. It is noteworthy that the subgroups generally linked the three areas of a given survey (Fig. 6) showing their similarity. The MDS ordination with a stress value of 0.16 represented the large group formed in the cluster analysis, which basically included the three areas from the II to VIII post-settlement surveys, and confirmed the low influence of the shipwreck among the three studied areas (Fig. 6).

The similarity analysis ANOSIM didn't show a significant difference between groups 1 and 2 from the cluster analysis ($R = 0.627$; $P > 0.1$). The SIMPER analysis identified the species that most contributed to similarity within and between those groups. Group 1 had an average similarity of 32% with *T. lepturus* responsible for about 60% of this value. Group 2 showed a similarity of 20% and the main contributors were *C. gracilicirrhus* (34%) and *S. hispidus* (22%). The dissimilarity between the two main groups was 92% and the species that most contributed to this difference were *C. gracilicirrhus* (17%), *D. volitans* (16%) and *S. hispidus* (15%).

The CCA including the environmental parameters and species biomass values on each survey resulted on a correlation value of 21%. The first canonical axis explained 11% of the total variance. The species *Trachurus lathami* (Trla), *Porichthys porosissimus* (Popo), *Symphurus tesselatus* (Syte) and *Cynoscion striatus* (Cyst) showed higher biomass values associated with higher levels of NH_4 in summer surveys I, II, V, VI and VII. *Conodon nobilis* (Cono), *Pellona harroweri* (Peha) and *Cynoscion microlepidotus* (Cymi) were associated with lower levels of NH_4 and higher levels of O_2, temperature and NO_3 during winter surveys of pre-monitoring, III

Table 4. LWR growth parameters a, b, r (regression coefficient) and k (condition factor) of *Dactylopterus volitans, Stephanolepis hispidus, Ctenosciaena gracilicirrhus* and *Trichiurus lepturus* by area (*Orion* reef, control B and control C).

Tabla 4. Parámetros de crecimiento: a, b, r (coeficiente de regresión) y k (factor de condición) de *Dactylopterus volitans, Stephanolepis hispidus, Ctenosciaena gracilicirrhus* y *Trichiurus lepturus* por área (arrecife *Orión*, control B y control C).

Species	Area	LWR growth parameters			
		a	b	k	r
D. volitans	Orion reef	3.00E-04	2.4565	1.00030	0.7718
	Control B	3.00E-05	2.8182	1.00003	0.9103
	Control C	2.00E-05	2.8425	1.00002	0.9821
S. hispidus	Orion reef	2.00E-05	2.9214	1.00002	0.9746
	Control B	4.00E-05	2.7812	1.00004	0.9584
	Control C	3.00E-05	2.9275	1.00003	0.9630
C. gracilicirrhus	Orion reef	2.00E-05	2.9715	1.00002	0.9697
	Control B	7.00E-06	3.1565	1.00001	0.9615
	Control C	3.00E-06	3.3387	1.00000	0.9756
T. lepturus	Orion reef	3.00E-06	2.8172	1.00000	0.9621
	Control B	8.00E-08	3.3105	1.00000	0.9906
	Control C	6.00E-08	3.3468	1.00000	0.9916

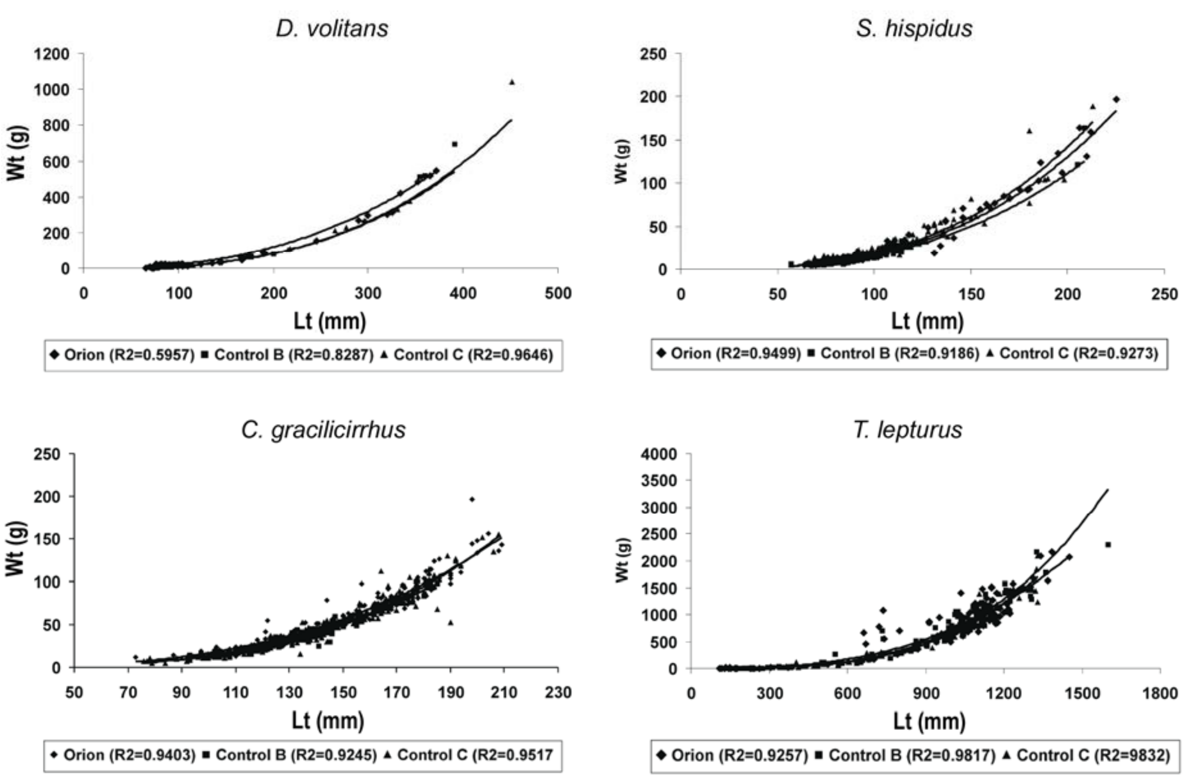

Figure 4. Total length (Lt, mm) *vs* total weight (Wt, g) of *Dactylopterus volitans, Stephanolepis hispidus, Ctenosciaena gracilicirrhus* and *Trichiurus lepturus* in the *Orion* reef and control B and C.

Figura 4. Longitud total (Lt, mm) *vs* peso total (Wt, g) de *Dactylopterus volitans, Stephanolepis hispidus, Ctenosciaena gracilicirrhus* y *Trichiurus lepturus* en el arrecife *Orión* y en las áreas controles B y C.

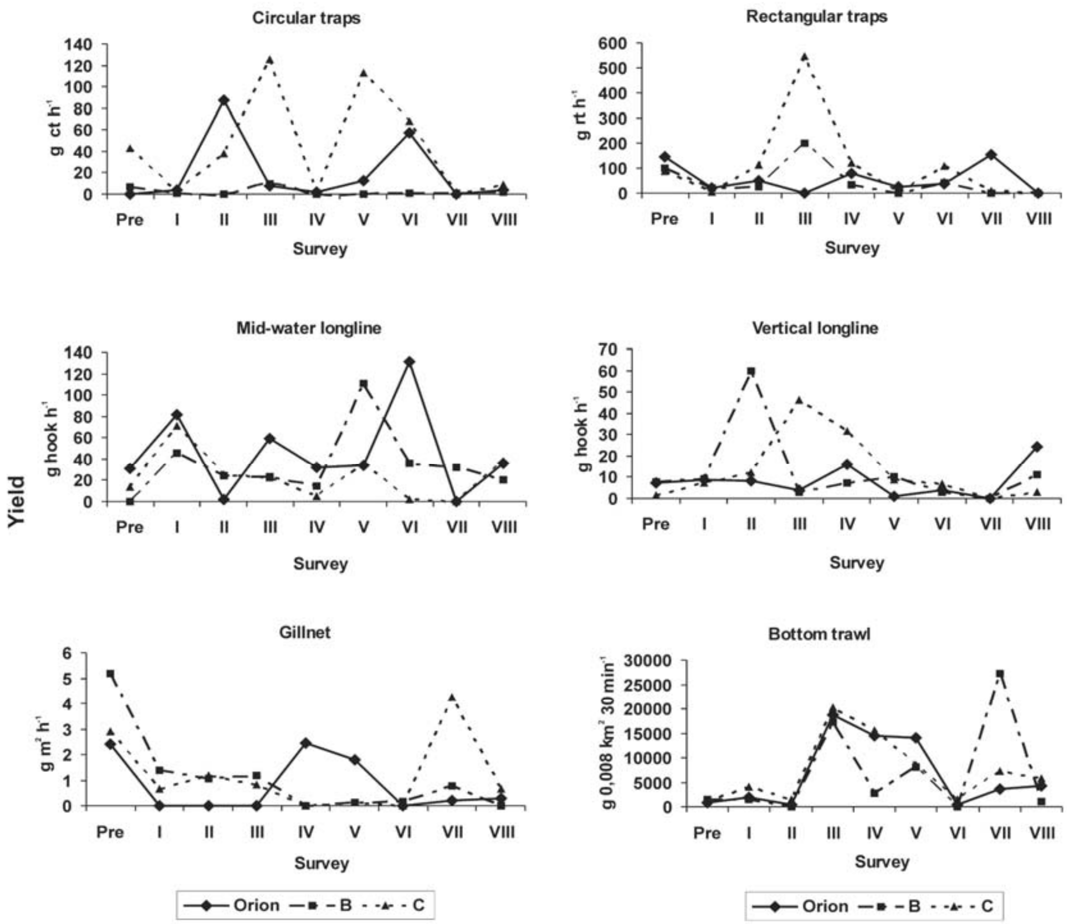

Figure 5. Catch per unit effort (CPUE) at the three study areas (*Orion* reef, control B and control C) on the pre-monitoring and the eight surveys for each fishing gear.

Figura 5. Captura por unidad de esfuerzo (CPUE) en las tres áreas de estudio (arrecife *Orión*, control B y control C) durante el pre-monitoreo y ocho campañas después del hundimiento para cada arte de pesca.

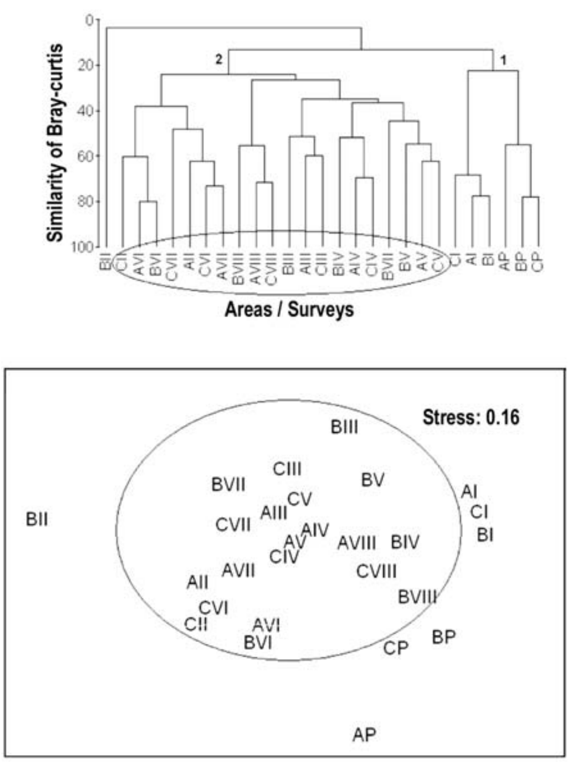

Figure 6. Cluster analysis (UPGMA) and MDS ordination (Bray-Curtis similarity coefficient), included the nine surveys in the three study areas (A: *Orion* reef, B and C: controls, P: pre-monitoring and I to VIII: monitoring surveys), considering the 23 species with > 10 individuals in at least one of the areas.

Figura 6. Análisis de agrupamiento (UPGMA) y ordenación MDS (coeficiente de similaridad Bray-Curtis) incluyendo las nueve campañs en las tres áreas de estudio (A: arrecife *Orión*, B y C: controles, P: pre-monitoreo y I a VIII: monitoreos). Se consideraron las 23 especies más representativas de peces.

and IV. The second canonical axis explained 10% of the total variance. The species *S. rastrifer* (Stra) and *C. nobilis* (Cono) showed higher biomass values associated with warmer temperatures during winter surveys of pre-monitoring, III and IV (Fig. 7). We highlight the pre-monitoring survey in the three areas AP, BP, CP, which were related to higher temperatures and the first survey after the ship sinking AI, BI, CI associated with higher levels of NH_4.

The Monte Carlo permutation test revealed significant differences (P = 0.005) for the fish assemblages' distribution in relation to the samples and abiotic variables. The two axes explained 17% (eigenvalue = 0.50) and 7.2% (eigenvalue = 0.21) of the fish assemblages (total inertia of the biotic data = 2.95).

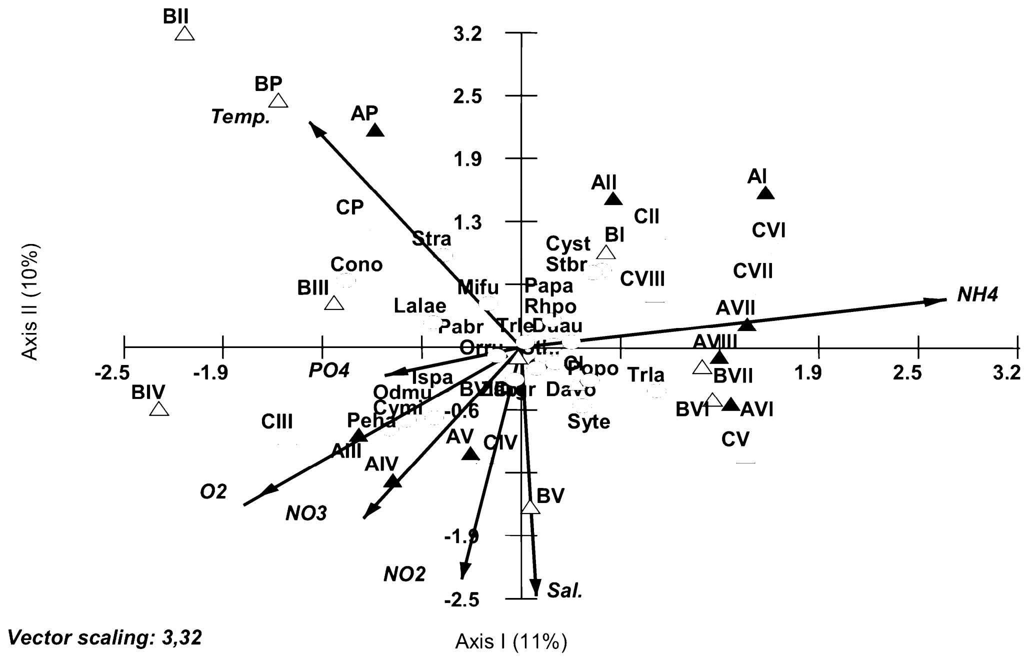

Figure 7. Canonical correspondence analysis. Factorial diagram showing the most abundant species in biomass and most frequent (65%) in the surveys (P: pre-monitoring and I to VIII: post-monitoring). Environmental parameters: temperature, salinity, dissolved oxygen, nitrite, nitrate, ammonia and phosphate on the *Orion* reef (area A) and control areas B and C. Species code on Table 2.

Figura 7. Análisis de correspondencia canónica: diagrama factorial mostrando las especies más abundantes en biomasa y más frecuentes (65%) en las campañas (P: pre-monitoreo y de I a VIII: pos-monitoreo). Factores ambientales: temperatura, salinidad, oxígeno disuelto, nitrito, nitrato, amonio y fosfato en el arrecife *Orión* (área A) y áreas control B y C. Código de especies en Tabla 2.

DISCUSSION

The marine currents in the area of the *Orion* reef are driven by weather and mesoscale oceanographic processes modulated by the tides, making difficult to establish a typical direction or even a more frequent one for the region, since they vary with the weather at the measurements (Candella *pers. comm.*). In the three study areas, the local currents did not differ significantly in intensity or direction over time (intra-area) and space (inter-areas) to reflect corresponding changes in fish abundance and distribution. Considering the current intensities, they had magnitudes up to five times higher when compared to the study of Lindquist & Pietrafesa (1989) nearby a shipwreck in North Carolina, which also showed no significant differences in relation to the current effect on fish assemblages. Even to a recreational proposal, the shipwreck does not support a diving tourism due to the strong bottom currents and the water turbidity.

Over the 36 months of study we did not observe differences with respect to the nutrient concentrations (nitrite, nitrate, ammonia-N and orthophosphate) in the *Orion* reef and in the control areas. This can be attributed to the homogeneity on local hydrological conditions, which are under the influence of coastal and tropical waters. Temporal variations were observed in the *Orion* reef for nitrite, nitrate, phosphate in the 4th and 5th surveys in relation to the pre and first monitoring. Thus, similarity among the three areas reinforces the environment homogeneity related to the water masses, since the reef and the controls are all located on open water. The influence of environmental variables over the fish community associated with artificial reefs on the Brazilian coast are limited to studies at the northern coast of Rio de Janeiro, an area under the influence of Paraiba do Sul river (Godoy *et al.*, 2002; Zalmon *et al*., 2002).

The attractive potential of artificial reef structures to cartilaginous and finfish on the northern of Rio de Janeiro was evaluated by Faria *et al*. (2001) and Gomes *et al*. (2001, 2004). They found that among four shark species, only *Rhizoprionodon lalandii* increased in the reef area. However, *R. porosus* was similar in number and weight in the reef and control areas about 500 m distant. According to our results, among the three shark species that surrounded the *Orion* reef, only *R. porosus* occurred near the shipwreck and control areas, although it was more frequent and abundant on the latter. This distribution pattern suggests that until now, the *Orion* reef did not represent an attractive potential for this specie. This differential behavior probably resulted from the greater complexity and dispersed spatial distribution of the experimental structures used by Faria *et al*. (2001) compared to the *Orion* reef.

In relation to the finfish distribution, the results of our study compared with those of Gomes *et al*. (2001), revealed a co-occurrence of nine species between their artificial reefs and the *Orion* reef. In both studies, these species also occurred in control areas except for *Caranx latus*, which was exclusive of the *Orion* reef. The occurrence of another 10 species only in the shipwreck area was probably due to the increase of food supply around the wreck promoting a temporary attraction effect of these species.

Santos & Monteiro (1997, 1998) and Santos *et al.* (2005) pointed out that artificial reefs and surrounding areas support a great diversity of species that are distributed according to food availability or associated with sand or mud bottoms, where their benthic preys live. These observations corroborate with our results where the fish distribution on the *Orion* reef, according to the position in the water column were represented by 55% demersal species, 21% bentho-pelagic, 12% benthic and 11% pelagic. Our results suggest that the influence of the wreck is not yet well defined, given the number of exclusive species in the control areas (N = 7 in control B and N = 12 in control C) and their respective habits (demersal, bentho-pelagic, pelagic and benthic), not allowing a characterization of the behavior and distribution of these species in relation to the *Orion* shipwreck.

Comparing the total biomass in the three areas, we found that the values were 15% higher on the *Orion* reef than on the control ones, which represent an increase of 1.2 times in wet weight. These results can be compared, although not yet conclusively, to those obtained by Santos & Monteiro (1997, 1998) who observed an increase in biomass from 1.1 to 2.3 times in artificial reef areas when compared with control ones. They concluded that the reefs represent a useful management tool that contributes to the increased value of artisanal fisheries in the region. It is worth pointing out however that this increase on biomass would be greater if the benthic fish inside the *Orion* reef could be assessed.

The fish sampling associated with artificial reefs do not have a single target species, due to the non-selective capture methods employed and the occurrence of several species susceptible to the fishing gears. In our study the use of six different types of fishing gears simultaneously in each study area per survey allowed a complete assessment of the local fish assemblages. Gillnets, mid-water and vertical longlines are suitable gears for catching pelagic species, which migrate in the water column. Different types of traps (circular and rectangular) and the bottom trawl usually catch demersal and benthic species. In this work, CPUE results with the different fishing gears showed no significant differences ($P \geq 0.05$) among the shipwreck area and the control ones, except for the circular traps ($P \geq 0.03$; F = 3.59; df = 2) between the controls, suggesting that the species were evenly distributed.

All these methods operate at a relative distance from the artificial reefs. In our study the average distance (~100 m) from the shipwreck promotes a global description of the associated reef fish assemblages catching resident and also transient species, which occurs in the artisanal and commercial fisheries landings. In the northern coast of Rio de Janeiro, Gomes *et al*. (2001) and Santos *et al.* (2010) assessed the fish assemblages' sorting different sets of gillnets at a mean distance of 50 m from the artificial structures. Santos *et al.* (2010) indicated that artificial reefs are a promising management tools to artisanal fisheries in that area, depending on the target species and the fishing distance from the reefs (maximum of 300 m on their study). Also, Ryu (1995) states that the influence of artificial reefs on the fish assemblages can reach 300 m distant. However, in our study, even with a maximum distance of 300 m, it was not observed a real influence of the shipwreck on the associated fish assemblages, especially when comparing the results of both control areas.

According to Bortone *et al.* (2000), fish assemblages´ assessments in artificial reefs employ destructive sampling methods with different fishing gears and/or non-destructive conservative observations, ranging from technical underwater visual census methods to remote sensing using hydroacoustic equipment. Sampling methods using destructive sampling gears as gillnets were used by Santos & Monteiro (1998, 1999); Fabi *et al.* (1999); Vicente *et al.* (2008) and Santos *et al.* (2010) to assess the influence area and the spatial distribution of fish surrounding large and small artificial structures. According to them, the use of this fishing gear is ideal because of its efficiency and widespread use by fishermen in the region coupled with its effectiveness in capturing in deeper and/or less visible waters. Besides, it was possible to get biological data as feeding habits, growth parameters and reproduction stages from the studied species. The LWR results for the most abundant and most frequent ones caught in each area showed that *Stephanolepis hispidus, Ctenosciaena gracilicirrhus* and *Dactylopterus volitans* were mostly juveniles. However, the growth parameters of these representative species didn't show significant differences among the areas, indicating a lower attraction of adult fish by the *Orion* reef. Considering the lack of information on the fish biology of the artisanal and commercial species caught in the area, these data will be useful for future considerations on the influence of the shipwreck in the fish assemblages.

Despite the numerous studies on artificial reefs, the controversy over the question of attraction *vs*. production persists because the studies need to be conducted over larger scales of time (> 2 yrs) and space (km), so that the artificial reefs impacts could be statistically distinguished from natural variations (Bohnsack *et al.*, 1997). The authors found that many studies concluded that high fish densities around offshore structures are an evidence of increased production. But, according to Hixon & Beets (1993); Bohnsack *et al*. (1994) and Eklund (1996), such evidence is demonstrated mainly by the increase of young fish directly associated with the artificial structures.

As observed in this study, the fish community on a Mediterranean artificial reef (Recasens *et al.*, 2006) presented similar species composition and relative fish abundance when compared to natural areas. Fish assemblages associated to shipwrecks is a unique situation, since the species might be using food resources and habitat with features unavailable in natural reefs and especially when the artificial habitat is far from hard bottoms (Arena *et al*., 2007).

The temporal variation in the colonization process of the fish community associated with the *Orion* reef showed the same pattern as in the two control areas, highlighting the similarity of the pre and first monitoring surveys due to the dominance of *T. lepturus*, and distinguished the subsequent surveys with the co-dominance of *C. gracilicirrhus* and *S. hispidus*. Fish assemblages similarity observed in the three study areas in all the surveys suggest a seasonal variation of the local ichthyofauna, reinforcing the hypothesis that the *Orion* reef is still not influencing the associated fish assemblages after almost three years.

During the fish assemblages monitoring near the *Orion* reef and control areas, there was no evidence of any effect on the local species composition and abundance. These results do not support the idea that decommissioned ships can generate benefits for the protection and maintenance of marine organisms associated with these artificial structures. However, it should be noted that a more complete assessment of a shipwreck effect on the fish assemblages should be longer (Danovaro *et al*., 2002).

The monitoring time of 32 months after the *Orion* sinking may still be considered short to assume that the wreckage had reached its maturity as an artificial reef (*sensu* Charbonnel *et al.*, 2002; Stephens & Pondella, 2002), either as a fish attractor or producer.

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