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Quantitative Biological Assessment of a Newly Installed Artificial Reef in Yenne, Senegal

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Hiroaki Terashima, Masashi Sato, Hiroyuki Kawasaki, and Djiby Thiam (2007) Quantitative biological assessment of a newly installed artificial reef in Yenne, Senegal. *Zoological Studies* **46**(1): 69-82. An artificial reef project was initiated in the coastal area of Yenne Village on the central coast of Senegal in June 2004 in response to a strong demand for coastal fisheries management and resource conservation in Senegal. The artificial reef consisted of 400 gabions and 75 concrete cubes installed in a 570 m^2 area. We used a modified point-stationary census method with video analysis to quantify fish abundance over a summer and winter season. The results showed a strong tendency for fish aggregation around the artificial reef, while fish aggregation was negligible at the control site. Estimated fish biomass at the artificial reef increased from 0 to 1.7 tn only 1 mo after construction of the artificial reef. The biomass then decreased to around 300 kg in winter. The total fish biomass significantly differed over time ($H = 11.674$, $p < 0.05$). At the control site, the biomass was very low in July 2004 (0.8 ± 0.3 kg), and this trend was maintained throughout the study period. This is the 1st study to quantify fish abundances on an artificial reef in the West African region. Such information is important for assessing the effectiveness of artificial reefs in enhancing marine resources in habitat-limited coastal areas. http://zoolstud.sinica.edu.tw/Journals/46.1/69.pdf

Key words: Artificial reef, Visual census, Quantitative assessment, Senegal.

Fishing is one of the staple industries in Senegal. However, after a maximum catch record of 450,000 tn of fish in 1997, there has been a gradual decline in fishery production, and the catch record in 2001 was 380,000 tn (Gueye et al. 2003). Small-scale artisanal fisheries which contribute 87% to national fisheries production is almost completely unregulated due to the traditional view of natural sea resources being one's own property. This situation is viewed with concern by the Senegal authorities as overexploitation of fisheries resources in the coastal region could lead to their depletion. Therefore, it was decided to seriously enforce fishery regulations and also to sustainably manage the fishery resources of Senegal. For example, to prevent further depletion of the already declining coastal fisheries resources, small-scale fishermen are now being given incentives to modernize their equipment and gear so that they can access more-distant fishing grounds (Dahou et al. 2001).

The demand for the introduction of artificial reefs in coastal zones has been growing in the fisheries sector, as artificial reefs are known to be effective in providing habitat to a multitude of marine organisms, including a variety of fish species (Bohnsack 1989, Ito and Terashima 2004). In Japan, artificial reefs have been used to enhance marine habitat for fisheries over a long period of time (e.g., Mottet 1985, Stone et al. 1991, Nakamura 1991, Grove et al. 1994), as a result of which, it has developed expertise in their

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Zoological Studies **46**(1): 69-82 (2007)

implementation and management. (e.g., Sato 1984, JCFPA 2000). The Japanese Overseas Fisheries Consultant Association (OFCA) initiated an experimental artificial reef project in 2001 in the coastal zone of Bargney, a fishing village in Senegal. The project objective was to promote the enhancement and management of marine habitat resources; however, its effectiveness had previously only qualitatively been assessed (OFCA 2004). In 2004, we installed an artificial reef in Yenne, a coastal village south of Dakar and used visual census techniques to quantitatively assess the efficacy of the artificial reef structure.

Various types of visual census techniques have been used for quantitatively assessing marine organisms aggregating around artificial reef (e.g., Bortone and Bohnsack 1991, Borton and Kimmel 1991, Borton et al. 2000). Moreover, some studies have used the latest technologies such as remotely operated vehicles (ROVs), stereo cameras, and echo sounders to quantitatively estimate the effectiveness of artificial reefs to avoid biases associated with visual census methodologies (e.g., Okamoto 1989 1991, Wilson et al. 1991, Takahashi et al. 2005). In the present study, we chose a visual census methodology to estimate fish abundances to quantitatively assess the efficacy of the artificial reef in the coastal zone of Yenne because it is inexpensive and can be replicated over time by researchers in developing countries for the sustained monitoring of artificial reefs. It is important to monitor fluctuations in fish abundances around artificial reefs so that their effectiveness can be assessed for informed

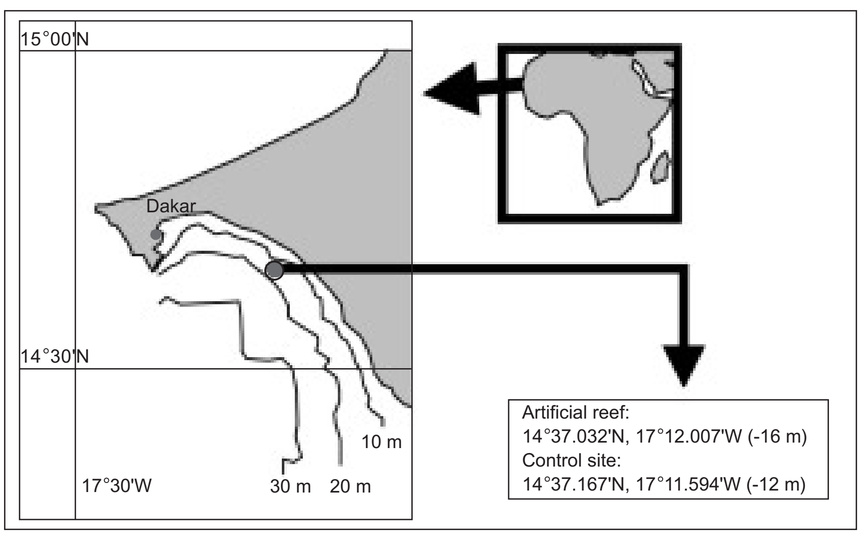

Fig. 1. Location of sampling sites at off Yenne, 30 km far from Dakar.

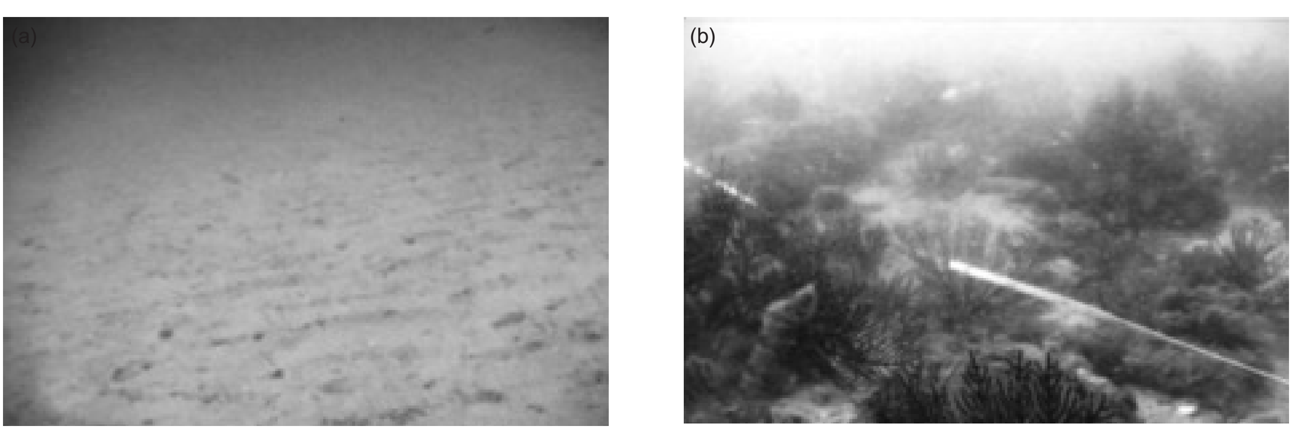

Fig. 2. Bottom topography of artificial reef site (a) and control site (b).

resource management.

In this study, our main objective was to collect biological data using a modified visual census technique for monitoring temporal changes in fish abundances around a newly installed artificial reef structure in a habitat-limited area. This is the first attempt to collect quantitative data over time on an artificial reef in tropical West Africa.

MATERIALS AND METHODS

Study site

The artificial reef was installed at Yenne (14°37.032'N, 17°12.007'W), about 30 km from Dakar, Senegal (Fig. 1). The bottom topography of the site is flat and consists mainly of sand with water depths averaging 16 m. A control site was identified after a survey of various fishing grounds in the region, and the one closest to the artificial reef site was selected for logistical reasons. This site was approximately 500 m from the artificial reef structure (14°37.167'N, 17°11.594'W), and water depths averaged 12 m. The area was about 600 m^2 (60 x 10 m), and the bottom topography is mainly a monotonous flat rock stratum which is partly covered with sand with sparsely distributed gorgonians and soft corals (Fig. 2). After installation, we measured the area covered by the artificial structure (570 m^2) and made a schematic diagram of the reef (Fig. 3).

Artificial reef structure

The artificial reef consisted of 75 concrete cubic blocks (75 x 75 x 75 cm) weighing approximately 170 kg and 400 gabions, each of which consisted of 5 or 6 stones enclosed in plastic-coated wire sheets and weighing approximately 20 kg. These blocks and gabions were made by fishermen in the area and were carried on a raft made of metal drums and wooden boards to the chosen site by 7 or 8 fishermen. We chose cheap materi-

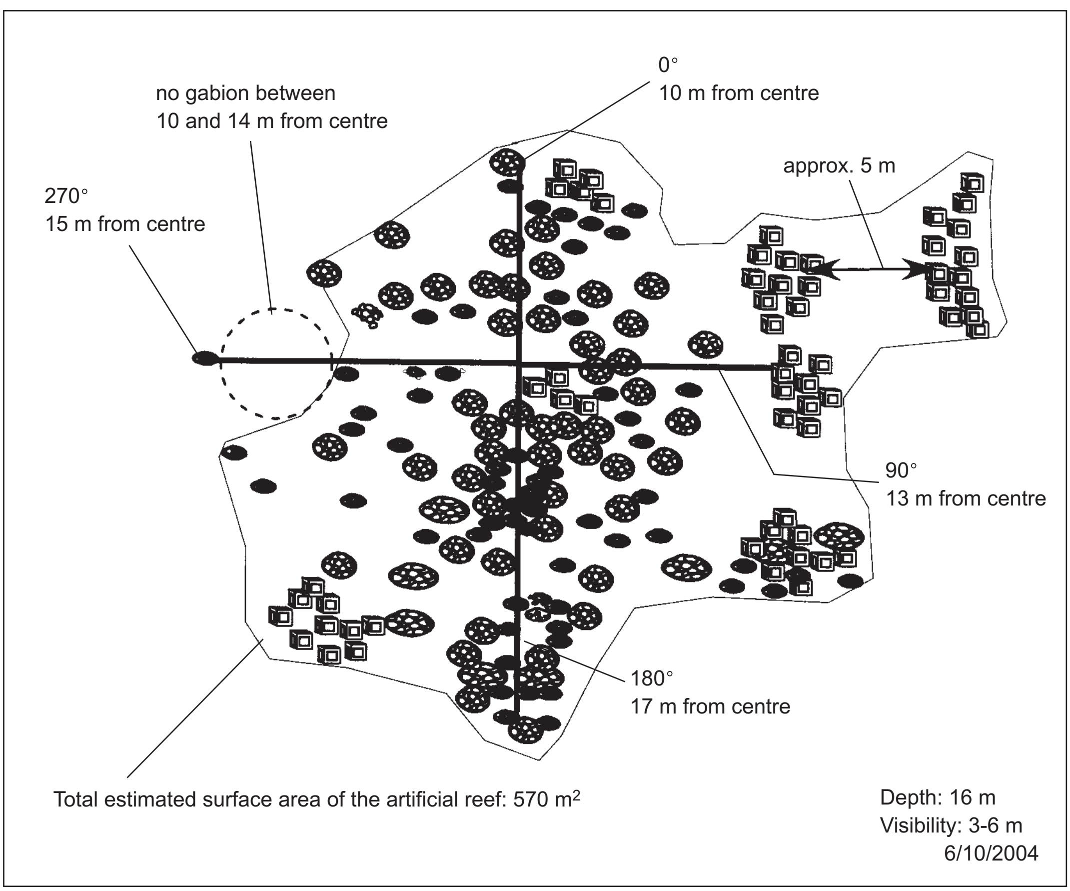

Fig. 3. Schematic diagram of artificial reef consist of 75 concrete cubes (75 cm x 75 cm x 75 cm, 170 kg) and 400 gabions (five to six natural stones, approx. 20 kg).

als for constructing the artificial structures and designed it so the fishermen could easily handle them. Installation of the artificial reef lasted from Aug. to the beginning of Sept. 2004. After installation, we measured the area covered by the artificial structure (570 m^2) and made a schematic diagram of the reef.

Sampling dates

We collected biological data on the artificial reef and the control site on 28 July 2004 before installation, on 8 and 9 Sept. just after installation and on 6 Oct., 1 mo after installation of the artificial reef. Then surveys were repeated on 18, 20, and

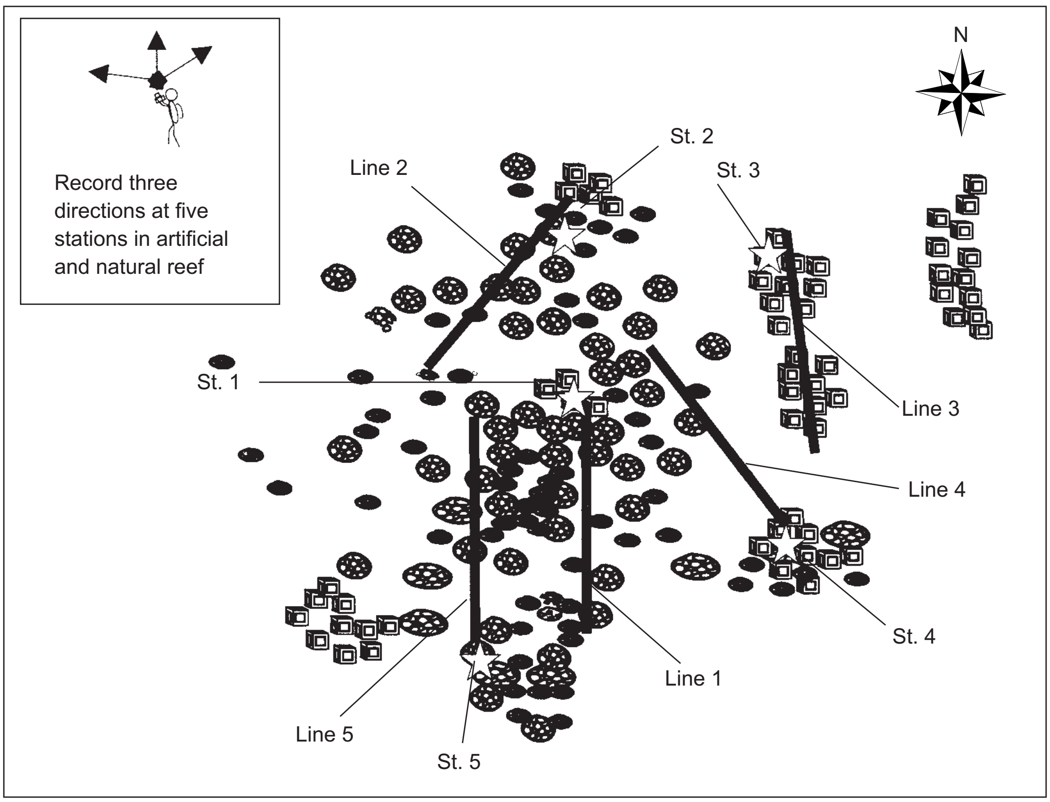

Fig. 4. Sampling stations with overlaid belt transect within each station.

Table 1. Sampling dates with depths, water temperatures and visibility records

Artificial Reef	28th July	8th Sept.	9th Sept.	6th Oct.	18th Feb.	20th Feb.	21st Feb.
Dive time	11:31-11:49	11:56-13:26	11:59-14:14	11:41-14:10	11:07-11:58	10:47-11:52	11:31-12:32
Depth	15.8 m	15.8 m	15.8 m	15.8 m	15.8 m	15.8 m	15.5 m
Water temperature: Surface	28°C	30°C	30°C	29°C	15°C	15°C	16°C
Water temperature: Bottom	27°C	29°C	29°C	26°C	15°C	15°C	15°C
Visibility	2.0 m	3.8 m	4.5 m	5.8 m	4.2 m	3.2 m	3.2 m

Control Site (Natural reef)	28th July	8th Sept.	9th Sept.	6th Oct.	18th Feb.	20th Feb.	21st Feb.
Dive time	12:16-12:33	13:40-14:00	14:30-14:46	12:16-12:33	13:03-13:37	12:18-13:02	13:05-13:58
Depth	12.2 m	12.2 m	12.2 m	12.2 m	13.7 m	12.2 m	12.1 m
Water temperature: Surface	28°C	30°C	30°C	28°C	15°C	15°C	16°C
Water temperature: Bottom	27°C	29°C	29°C	27°C	15°C	15°C	15°C
Visibility	2.0 m	3.0 m	4.0 m	5.2 m	4.2 m	3.2 m	3.0 m

21 Feb., approximately 6 mo later. In situ water temperature was measured during the surveys (Table 1). A dataset of sea surface temperatures was obtained from National Oceanic and Atmospheric Administration, USA (NOAA) for the period Mar. 2004 to Feb. 2005.

Survey methods

The biological surveys were designed to have minimal requirements for sophisticated equipment so that they could easily be implemented by local researchers. We established 5 sampling stations at both natural and artificial reefs and laid down 1 transect line randomly within each sampling station. At the artificial reef, we chose areas with either blocks or gabions or both before placing the transect lines within such areas (Fig. 4). Fish surveys were carried out by a visual census using the belt transect method (English et al. 1990) for demersal fish (Fig. 5) and the point stationary method (Bohnsack and Bannerot 1986) for pelagic fish (Fig. 6) within each station.

If large schools of fish were found, we used a modified point stationary method with video analysis. The method consisted of taking photographs with an underwater camera with a known underwater angle of view. Photographs were taken at 3 angles within each sampling station (3 angles x 5 sampling stations = 15 photographs). We then counted the number of fish in each photograph. We also measured the distance from the camera to visual references in the photograph to estimate the volume in the photograph and then estimated the density of fish within the sampled area. (Fig. 7). We then calculated the volume of fish aggregating around the reef by multiplying the area by a height of 1 m (which was the distribution range of fish aggregations above the gabions and blocks within the area). Henceforth the biomass is expressed as total biomass within the reef.

The body weight of each species at the artificial reef and control site corresponding to the length was calculated by length-to-weight conversion formulae (Bohnsack and Harper 1988, Froese and Pauly 1998). We collected samples of those species for which conversion formulae were not available and calculated the parameters or used formulae based on similarly shaped species (Bortone et al. 2000). We then estimated the biomass of each species according to the following formula:

Biomass = Estimated total number of fish x Body weight;

where the Estimated total number of fish is (Average number of fish ± S.E.)/unit volume x Research area, and Body weight was estimated by the length-weight equations.

However, if only a few individuals or schools were observed on a transect line, we did not extrapolate the data to the entire survey area but instead considered it a single dataset.

Statistical analysis

To examine temporal patterns in total fish biomass, the mean amount of total biomass was compared between months using the Kruskal-Wallis non-parametric test. We could not analyze the data with parametric tests because the data were non-normal and heterogeneous after verification with Bartlett's and Kolmogorov-Smirnov test for goodness of fit, and transformation did not improve

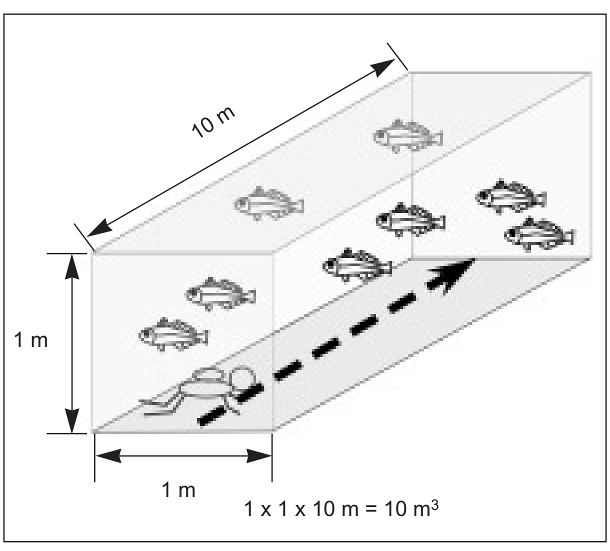

Fig. 5. Belt transect method.

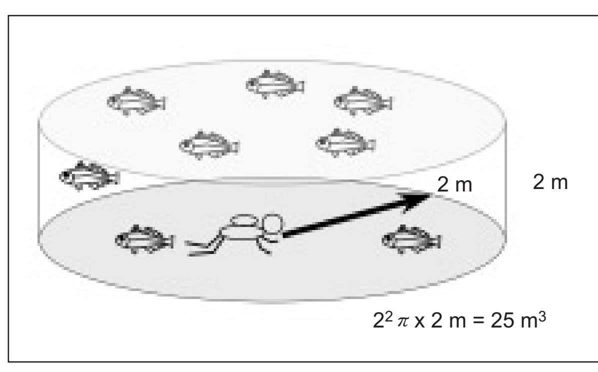

Fig. 6. Point stationary method.

the heterogeneity of the variances. When significant differences were detected between the means after the Kruskal-Wallis test, a nonparametric Tukey-type multiple comparison test was used to determine which of the mean groupings significantly differed (Zar 1999). All values are expressed as the mean ± 1 standard error (SE).

RESULTS

The sea surface temperature data obtained from NOAA showed a seasonal trend with the highest temperature being recorded in Sept. (29°C) and the lowest in Feb. (15°C). Similar results were obtained with the in situ recordings (Fig. 8).

The average size and average number ± SE of individuals of various fish species for each sampling date around the artificial reef and control site are shown in tables 2 and 3, respectively.

The observed number of species around the artificial reef dramatically increased after installation of the artificial structure, from 1 to 9 species, then to 14 or 15 species after 1 mo until the winter season (6 mo later). In contrast, the number of species did not change noticeably at the control site (with the number of species ranging 0 to 3 throughout the period). The species composition slightly differed between the summer and winter samplings. The 6 species of *Diplodus bellottii* (Steindachner, 1882), *Epinephelus costae*

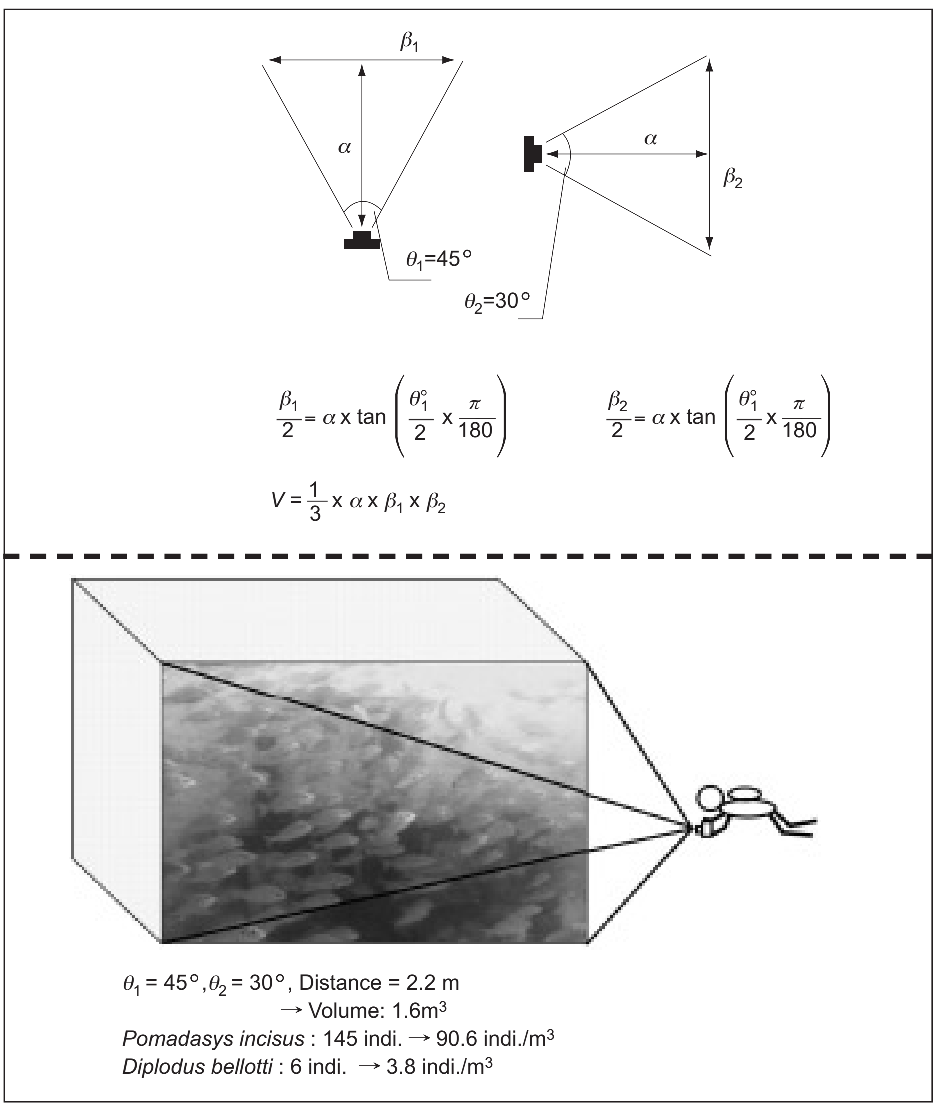

Fig. 7. Calculation for volume estimation with example (bottom side).

(Steindachner, 1878), *Plectorhinchus mediterraneus* (Guichenot, 1850), *Pomadasys incisus* (Bowdich, 1825), *Trachurus trecae* Cadenat, 1950, and *Decapterus punctatus* (Cuvier, 1829) were found to be dominant at the artificial reef during each survey (Fig. 9, Table 2). At the control site, *D. bellottii* was dominant, although the observed numbers were considerably smaller than those at the artificial reef site.

Fluctuations of the estimated biomass (kg) within the reef (570 m^3 at the artificial reef and 600 m^3 at the control site) for these 6 dominant species are shown in figure 10. After installation of the artificial structure, the biomass of *D. bellottii* (Fig.10a) dramatically increased to 47 ± 6 (on 8 Sept. 2004) and 50 ± 6 kg (on 9 Sept. 2004), reaching a maximum of 111 ± 10 kg after 1 mo (on 6 Oct. 2004), then decreasing to 9 ± 2 (on 18 Feb. 2005), 11 ± 3 (on 20 Feb. 2005), and 9 ± 6 kg (on 21 Feb. 2005) in winter. In contrast, only a few individuals of *D. bellottii* were observed at the control site from July to Oct. 2004 (with an estimated biomass of 0.1 ± 0.1 kg through the period) but in Feb. 2005, the number of individuals slightly increased (with an estimated biomass of 2 ± 1 kg on 18 Feb., 11 ± 3 kg on 20 Feb., and 3 ± 2 kg on 21 Feb. 2005). In addition, the biomass of *P. incisus* (Fig. 10b) increased to 16 ± 6 (on 8 Sept. 2005.) and 17 ± 6

Table 2. Fishes observed around artificial reef with averaged size (cm) / averaged number ± S.E. of individuals on each sampling date

	28 July 2004		8 Sept. 2004	9 Sept. 2004	6 Oct. 2004	18 Feb. 2005	20 Feb. 2005	21 Feb. 2005
Acanthurus monroviae	-		30cm	22 ± 9	30cm / 30 ± 18	5cm / 1 ± 0	30cm / 2 ± 0	30cm / 1 ± 0
Batrachoides liberiensi	-		-	-	20cm / 1 ± 0	20cm / 1 ± 0	20cm / 1 ± 0	-
Bodianus speciosus	-		-	-	-	25cm / 3 ± 0	25cm / 1 ± 0	25cm / 2 ± 0
Caranx sp.	-		-	-	30cm / 4 ± 0	-	-	-
Chaetodon hoefleri	-		-	-	-	15cm / 3 ± 0	15cm / 4 ± 0	15cm / 2 ± 0
Dasyatis sp.	40cm / 1 ± 0		-	-	-	-	-	-
Decapterus punctatus	-		-	-	9cm / 6650 ± 4824	-	-	-
Diplodus bellottii	-		13cm / 2736 ± 335	13cm / 2904 ± 334	13cm / 6422 ± 577	15cm / 285 ± 63	15cm / 369 ± 102	15cm / 285 ± 114
Diplodus puntazzo	-		-	-	-	23cm / 114 ± 51	23cm / 251 ± 34	23cm / 467 ± 274
Diplodus vulgaris	-		-	-	-	23cm / 80 ± 29	23cm / 125 ± 34	23cm / 114 ± 0
Epinephelus aeneus	-		40cm / 1 ± 0	40cm / 1 ± 0	40cm / 1 ± 0	40cm / 1 ± 0	40cm / 2 ± 0	40cm / 2 ± 0
Epinephelus costae	-	installation of artificial reef	-	-	25cm / 353 ± 103	25cm / 68 ± 23	25cm / 91 ± 23	25cm / 91 ± 29
Labridae sp.	-		25cm / 1 ± 0	25cm / 1 ± 0	-	-	-	-
Mugil sp.	-		-	-	30cm / 11 ± 0	-	-	-
Parapristipoma octolineatum	-		-	-	-	15cm / 3 ± 0	15cm / 4 ± 0	15cm / 2 ± 0
Plectorhinchus mediterraneus	-		-	-	25cm / 9 ± 0	23cm / 695 ± 175	23cm / 513 ± 228	23cm / 661 ± 234
Pomadasys incisus	-		18cm / 132 ± 45	18cm / 144 ± 77	13cm / 17100 ± 1096	13cm / 1349 ± 181	13cm / 1197 ± 136	13cm / 1311 ± 342
Pseudupeneus prayensis	-		4cm / 389 ± 131	4cm / 504 ± 150	15cm / 980 ± 240	10cm / 160 ± 97	10cm / 262 ± 120	10cm / 365 ± 234
Serranus scriba	-		30cm / 1 ± 0	30cm / 1 ± 0	-	20cm / 2 ± 0	18cm / 3 ± 0	18cm / 3 ± 0
Sphoeroides marmoratus	-		5cm / 173 ± 46	5cm / 216 ± 75	5cm / 125 ± 033	5cm / 34 ± 11	5cm / 46 ± 23	5cm / 46 ± 023
Trachinotus ovatus	-		-	-	30cm / 8 ± 0	-	-	-
Trachurus trecae	-		12 cm	12 cm	12 cm	-	-	-
			5712 ± 2689	6456 ± 3990	12464 ± 4552			
observed species number	1		9	9	14	15	15	14

Table 3. Fishes observed around control site (natural reef) with averaged size (cm) / averaged number ± S.E. of individuals on each sampling date

	28 July 2004	8 Sept. 2004	9 Sept. 2004	6 Oct. 2004	18 Feb. 2005	20 Feb. 2005	21 Feb. 2005
Batrachoides liberiensi	0	-	-	-	20 cm / 1 ± 0	20 cm / 1 ± 0	20 cm / 1 ± 0
Diplodus bellottii	10 cm / 22 ± 9	-	-	13 cm / 7 ± 7	15 cm / 68 ± 46	15 cm / 137 ± 91	15 cm / 103 ± 68
Epinephelus costae	0	-	-	-	20 cm / 2 ± 0	20 cm / 2 ± 0	20 cm / 1 ± 0
Pseudupeneus pyayensis	5 cm / 22 ± 9	-	-	-	-	-	-
observed species number	2	0	0	1	3	3	3

kg (on 9 Sept. 2005.) after installation of the artificial reef, reaching a maximum of 894 (57 kg on 6 Oct. 2004 and decreasing to 71 ± 9 (on 18 Feb. 2005), 63 ± 7 (on 20 Feb. 2005), and 69 ± 18 kg (on 21 Feb. 2005) in winter. However, this species was not observed at the control site. *Epinephelus costae* (Fig. 10c) only began to aggregate around the artificial reef 1 mo after its installation; its biomass on 6 Oct. 2004 was 55 ± 16 kg and by Feb. 2005, its biomass had decreased to 11 ± 4 - 14 ± 4 kg. We observed only 1 individual of *E*. *costae* at the control site (with an estimated biomass of < 200 g). *Plectorhinchus mediterraneus* (Fig. 10d) was not observed over the summer after installation of the artificial reef; however, in winter its estimated biomass was 143 ± 36, 105 ± 47, and 141 ± 105 kg on 18, 20, and 21 Feb. 2005, respectively. *Plectorhinchus mediterraneus* was not observed at the control site. The 2 species of the Carangidae, *T*. *trecae* (Fig. 10e) and *D*. *punctatus* (Fig. 10f) were observed at the artificial reef site only in summer 2004. In fact, large schools of *T*. *trecae* aggregated near the artificial reef from Sept. to Oct. 2004 (131 ± 62 kg on 8 Sept., 148 ± 92 kg on 9 Sept., and 286 ± 105 kg on 6 Oct. 2004), while *D. punctatus* (30 ± 22 kg) was only observed on 6

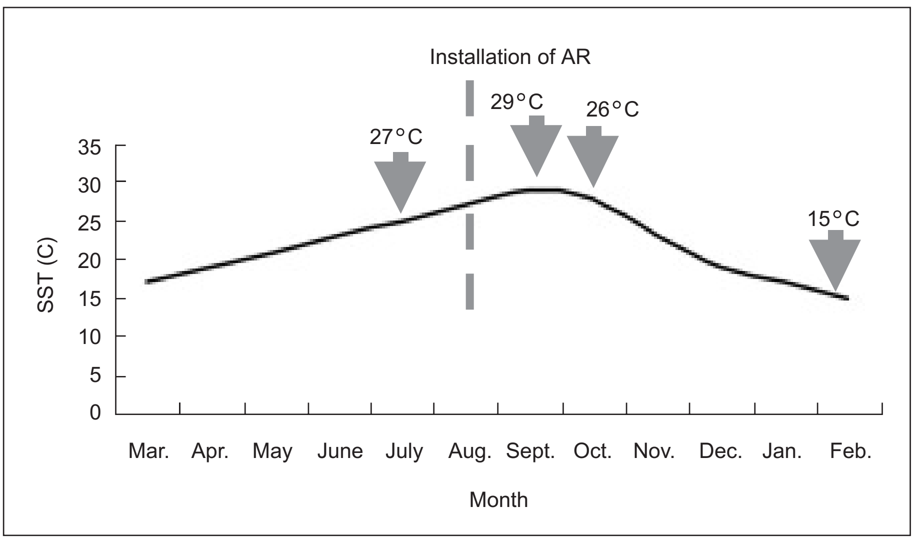

Fig. 8. Monthly mean sea surface temperature (SST) in Senegal as from Mar. 2004 (source: NOAA) with *in situ* bottom water temperatures. Arrows indicate sampling months.

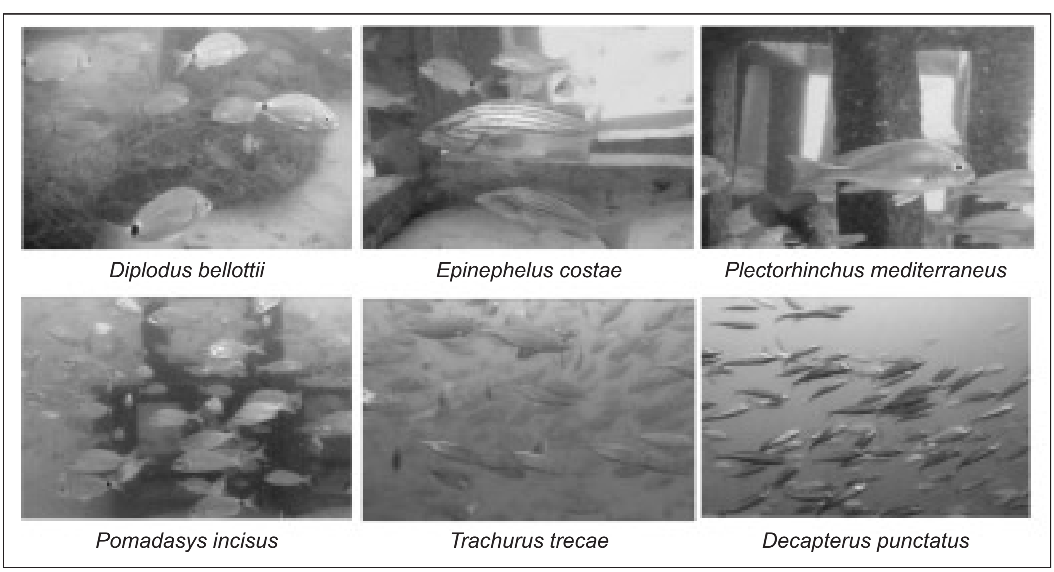

Fig. 9. The most common species observed at the artificial reef.

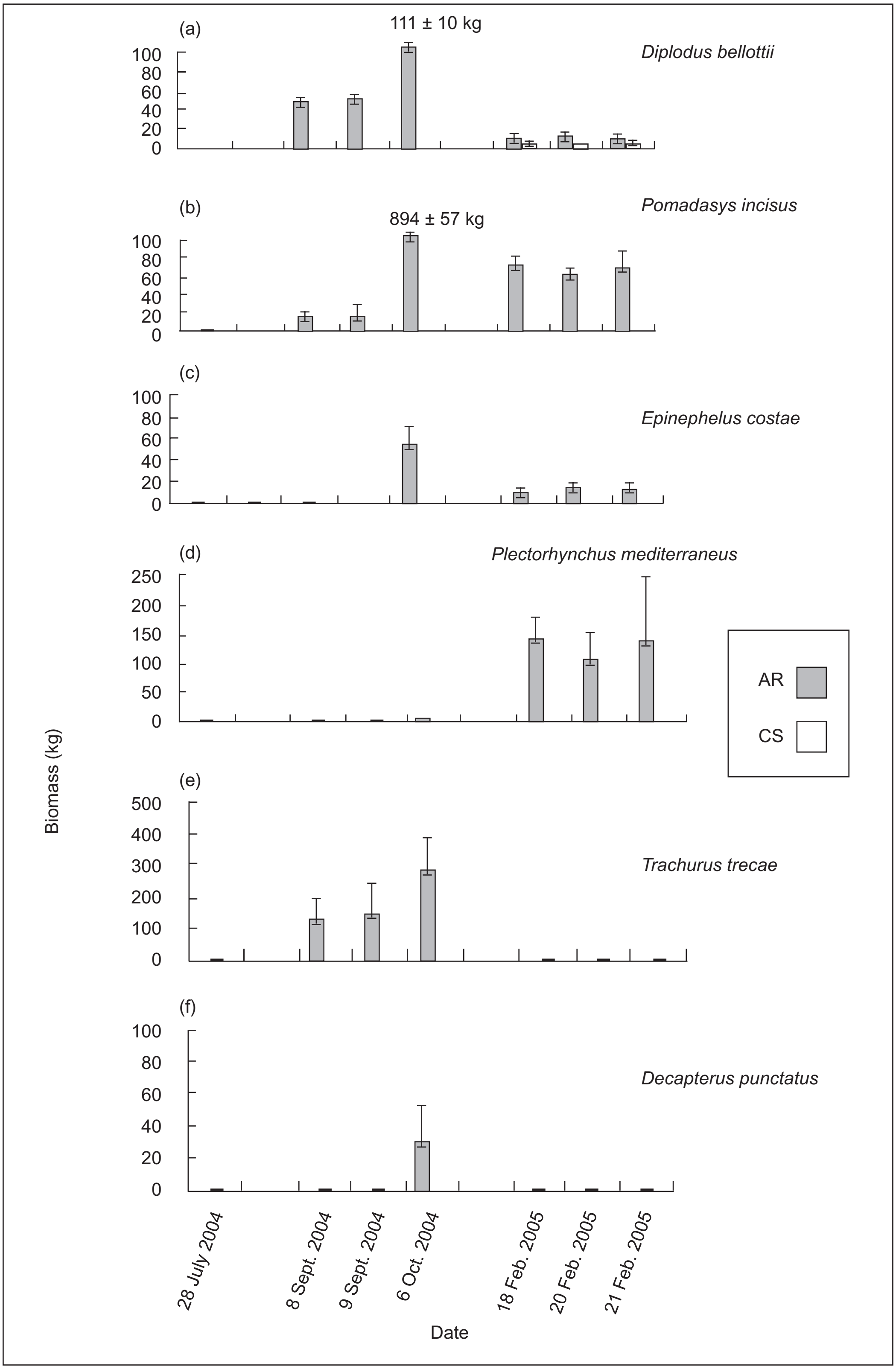

Fig. 10. Change of the estimated biomass (average kg ± S.E.) over the sampling period for six dominant species (AR: Artificial reef, CS: Control site). Biomass was used as indicator of abundance of fish aggregating around reefs.

Oct. 2004. Neither species was observed in winter 2005. The total biomasses of fish around the artificial reef site and control site are shown in figure 11.

Biomass was low in July 2004 before installation of the artificial reef and increased to about 200 kg just after installation. Biomass then increased sharply to 1.7 tons in Oct. and decreased to ca. 300 kg in Feb. 2005, the latter being slightly higher than the estimated biomass of the previous year. The total fish biomass significantly differed over time (H = 11.674, $p < 0.05$). A nonparametric Tukey-type multiple comparison test detected significant differences ($p < 0.05$) between July and Sept. 2004, July and Oct. 2004, July 2004 and Feb. 2005, Sept. and Oct. 2004, and Oct. 2004 and Feb. 2005. At the control site, the biomass was very low in July 2004 (0.8 ± 0.3 kg), and this trend continued throughout the study period. We did not statistically compare the biomass between the artificial reef and control site as the data had very large heterogeneous variances due to the sharp contrast in the estimated biomass between both reef sites (to avoid type 1 or type 2 errors). Moreover, graphical representation of the data clearly showed the pattern between the artificial reef and control site (Figs. 10, 11).

DISCUSSION

Changing fish abundances over time

Fish biomass significantly increased after installation of the artificial reef at our study site. Although hardly any fish species were observed prior to installation of the artificial reef, huge schools of *D. bellottii* aggregated soon after its installation. This study showed that the average size of individuals was 13 cm in total length and could be categorized as being 2 yrs old (Mennes 1985). Its common length has been reported to be 15 cm in previous studies (e.g., Bauchot and Hureau 1986). Other species, such as *P. incisus* and *T. trecae* which also immediately moved into the artificial reef area, had average sizes of 18 and 12 cm, respectively. The common length of the former has been reported to be 25 cm (Roux 1990), and the usual yearling size of the latter is 13-15 cm (CECAF 1978). These early occupants could therefore be categorized as being young or semi-adults in terms of their life histories. Fish colonization may be initiated by the settlement of pelagic larvae or by immigration of juveniles or adults (Bohnsack et al. 1991). The observed colonization pattern in this study probably followed the latter scenario. A previous study showed that colonization of a tropical coral reef area was initiated by juveniles (Russell et al. 1974), whereas another study reported that most fish colonization was by adult and sub-adult individuals in a temperate area (Gascon and Miller 1981). Such reported differences in recruitment patterns may be specific to tropical and temperate regions (Bohnsack et al. 1991). However, in the present study, fish colonization seemed to have followed the temperate zone pattern although the study site is in a tropical area. This might have been related to the addi-

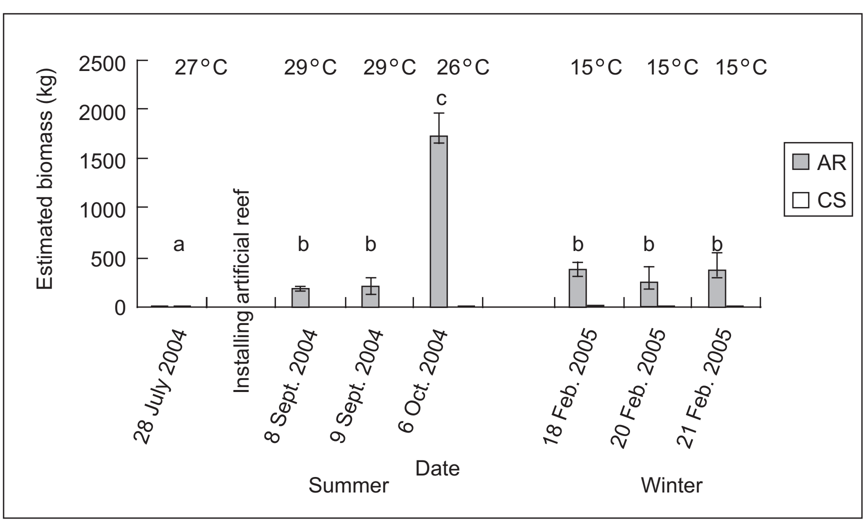

Fig. 11. Change in fish biomass on artificial reef (AR) and control site (CS) over season. *In situ* water temperature is indicated on the upper axis of the bar chart. Lower case letters show membership to groups identified by Tukey type nonparametric multiple comparisons ($p < 0.05$).

tional structural complexity of the study site created by the newly installed artificial reef rather than climatic conditions associated with latitudinal differences.

The biomass of most dominant species, except *P. mediterraneus*, increased to a maximum 1 mo after installation of the artificial reef in summer and then decreased in winter, with the exception of *P. incisus* and *E. costae*, whose biomass did not significantly change until Sept. On the other hand, large schools of *P. mediterraneus* aggregated around the artificial reef only in winter, while 2 species of Carangidae, *T. trecae* and *D. punctatus*, were absent from the artificial reef in winter. Changes in fish species composition around the artificial reef can be attributed to seasonal trends in water temperature (Ogawa 1984). For example, in a study of fish assemblages around an artificial reef in Brazil, it was observed that the assemblage peaked in summer (Godoy et al. 2002). Similarly, Fabi et al. (2002) recorded the lowest fish catch in winter to spring at an artificial reef installed in the northern Adriatic Sea. Over our study period, the water temperature varied from 29 (summer) to 15°C (winter) and such large disparity in water temperature could be 1 explanation for the observed changes in species composition in this study. However, there is a need for more-complete seasonal data on fish aggregating patterns to conclusively confirm this trend.

Differences in the fish biomass between the artificial reef and control site. There were highly significant differences in fish biomass between the artificial reef and control site in this study. While fish biomass remained consistently low at the control site over the study period, it showed considerable fluctuations at the artificial reef. Similarly, other studies have reported considerable differences in fish abundances and biomass between artificial and natural reefs although the species composition did not differ (Bohnsack et al. 1991). This could be due to the habitat availability provided by artificial structures (e.g., Randall 1963, Ambrose and Swarbrick 1989, DeMartini et al. 1989, Beets and Hixon 1994). For example, fish biomass was 11 times greater at an artificial reef than neighboring natural reefs in St. John, US Virgin Is. due to the grunts and snappers that used the artificial structure as shelter during the daytime (Randall 1963). Furthermore, in a study of the habitat structure of fish in a coral reef region, it was shown that the availability of preferable habitats for common reef fishes is strongly correlated to the complexity (Abelson and Shlesinger 2002, Charbonnel et al. 2002, Sherman et al. 2002, Kawasaki et al. 2003). Most coastal areas of the tropical west coast of Africa are mainly sandy or muddy with sparsely distributed rocky bottoms. Natural reefs in the vicinity of our study site, including the artificial reef site and control site, had a flat topography, mostly with sandy bottoms and relatively few rocks and crevices that could provide refuge to fish. The paucity of habitat diversity could be a limiting factor to the survival of demersal fish. It has been suggested that under habitat limitations, an increase in habitat will directly increase population abundances (Bohnsack et al. 1991), hence deployment of artificial reefs will not only augment fish abundances but will also increase habitats in habitat-limited areas.

Moreover, artificial reefs can be used for rehabilitating areas degraded by natural disturbances and anthropogenic impacts (Pratt 1994, Rilov and Benayahu 2000). Several studies have shown that artificial reefs promote recruitment and growth of juvenile fish in a way similar to natural reefs (Ogden and Ebersole 1981, Bohnsack and Sutherland 1985, Gorham and Alevizon 1989, Caley 1993, Tupper and Hunte 1998, Rilov and Benayahu 2000, Leis et al 2002). Hence, the installation of an artificial reef in habitat-limited areas such as our study site on the west coast of Africa will likely contribute to increased fish biomass. Long-term data are certainly needed to confirm this.

Survey techniques

It is important to implement monitoring techniques that are suitable to a given region so that these may be easily adopted by local researchers and volunteers (Halusky et al. 1993). In developing countries faced with budgetary limitations and skilled human resources, survey techniques should be realistic and applicable to local conditions. Moreover, it is generally difficult to collect quantitative data for reef fish assemblages by divers without proper training because of fish diversity and mobility (Russell et al. 1978). Visual census techniques for estimating reef fish abundances rely on the skill of the diver, and the precision of the data may be affected by in situ conditions and a diver's knowledge of the target region. Therefore, Parker Jr. et al. (1994) suggested that video transects are more appropriate to quantitatively assess reef fish abundances. However, such methods are tedious and time consuming and may not be appropriate for use in developing nations where the main objective at times is to rapidly collect biological information around installed artificial structures. Such common exigencies and scientific interest have conflicted many times in the past. Furthermore, there is a need for repeatable nondestructive survey techniques that can be used in already established or proposed marine protected areas in developing countries. The modified point stationary method with video analysis in the present study enabled us to count large numbers of individuals in fish schools with photographic images. This modified visual census technique is relatively inexpensive and simple and can be easily adopted by local researchers and volunteers. Simplified survey techniques are promising as data can easily be acquired and analyzed for assessing fish aggregations around artificial structures. Such information is important to administrators and local communities for determining the effectiveness of artificial reefs in habitat-limited areas. In addition, it is indispensable to establish community-based advisory groups comprised of stakeholders such as fishers, local researchers, and government officials to properly manage artificial reef areas (Wilson et al. 1992). We strongly believe that such groups can provide management with relevant information for the sustainable utilization of artificial reefs.

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