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PRELIMINARY RESULTS OF HATCHERY-REARED SEABREAMS RELEASED AT ARTIFICIAL REEFS OFF THE ALGARVE COAST (SOUTHERN PORTUGAL): A PILOT STUDY

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ABSTRACT

In 2001 a pilot project of fish restocking began using reared juveniles of two native species: the white seabream (*Diplodus sargus* Linnaeus, 1758) and the gilthead seabream (*Sparus aurata* Linnaeus, 1758). Between 2001 and 2004 more than 13,600 juveniles of different sizes (over 7500 white seabreams and 6100 gilthead seabreams) were tagged (FLOY T-Bar anchor FD94) and released on the artificial reef areas, to evaluate the efficiency of restocking. The preliminary results of this ongoing study based on caught fish show that the number of days at liberty ranged from 1 to 340, while the distance traveled ranged from 0 to 67 nmi. However, the mean dispersal distance was < 11 nmi from the release location. A behavioral deficit of the reared seabreams in the use of refuges and feeding was observed during the first week after release. However, thereafter gut content analysis suggested that the reared specimens were able to search for food and feed on the available prey. These results suggest that restocking associated with artificial reefs may be used as an additional tool within an integrated coastal management plan aimed at the enhancement of locally important artisanal fisheries.

Numerous attempts are underway worldwide to augment the natural supply of fish by various means, ranging from aquaculture to various fisheries-enhancement systems (Munro and Bell, 1997). According to Leber et al. (2004), in recent years 33 developing countries have reported the stocking of 59 marine or coastal species. Nonetheless, most of the hatchery-based programs for fisheries enhancement have failed (Bohnsack, 1996), the exception being Japanese experiments with red seabream (*Pagrus major* Temminck and Schlegel, 1843) and Japanese flounder (*Paralichthys olivaceus* Temminck and Schlegel, 1846) (Fushimi, 2001). Most of these releases were made into limited habitats such as coastal lagoons, fjords, and estuaries (McEachron et al., 1995). The causes of such failures have been reviewed by D'Anna et al. (2004) and attributed to a wide range of issues.

The gilthead (*Sparus aurata* Linnaeus, 1758) and white (*Diplodus sargus* Linnaeus, 1758) seabreams are two commercially important species in southern European countries, where catches have declined in the last two decades (FAO, 2004). In the Algarve coast (southern Portugal) the landings of the white seabream decreased from 200.3 to 75.2 t between 1987 and 2004, while the gilthead seabream has shown some stability, with mean annual landings of 72 t (data source: National Fisheries Database). These species are mainly targeted by small-scale and recreational fisheries. Aspects of their biology and ecology are well known (Arias, 1980; Rosecchi, 1985; Gordoa and Moli, 1997; Vigliola and Harmelin-Vivien, 2001), and both are successfully bred and reared up to the age of about 1 yr. However, in the case of *D. sargus* growth rates are slower, making the rearing process inappropriate for intensive aquaculture (Abellan et al., 1994), and thus economically unprofitable.

The present study, carried out in coastal Algarve, is the first attempt to enhance local marine fisheries by means of restocking. Presently, the enhancement of local fisheries has been based mostly on a program of artificial reef deployment, which began in 1990 (Santos and Monteiro, 1997, 1998). Currently, the Algarve artificial reef complex consists of seven large systems, which cover a total area of 43.5 km^2, and use more than 20,500 concrete blocks with a total volume > 100,000 m^3 (Santos and Monteiro, 2001). The white seabream is a common species in these artificial reefs (Santos and Gaspar, 2002), while the gilthead seabream is rare, although it is common in the neighboring sandy areas.

Here we report preliminary results of release experiments using two species of hatchery-reared seabreams, aimed at evaluating the potential usefulness of hatchery-released species within an integrated coastal management plan for enhancing locally important artisanal fisheries. In particular, the objectives are to evaluate: (i) the ability of hatchery-reared young seabreams to adapt to the wild, and (ii) fish dispersion after release at the artificial reefs.

Material and Methods

Study Site.—The artificial reef systems of Olhão and Faro/Ancão are located off the Ria Formosa (Algarve, south Portugal), a highly productive ecosystem that acts as a nursery, supplying the most important fish stocks of the coastal waters (Monteiro et al., 1987, 1990), while the Vilamoura artificial reef system is located slightly to the west (see Fig. 1). The artificial reef systems were deployed between 1990 and 2004, 2.5–4.8 km offshore, on flat sandy or sandy/muddy bottoms. A few scattered patches of natural bedrock were recorded on the bottom of the Vilamoura and Faro/Ancão areas. Each artificial reef system consists of between 7 and 52 assemblages of 35 concrete cubic units (2.7 m^3 each) and between 5 and 18 groups of four large concrete structures (174 m^3 each; for details see Santos and Monteiro, 2001).

Tag and Release.—The released specimens were hatched and reared at IPIMAR's aquaculture facility in Olhão, starting from a wild parent stock caught in the area. The seabreams were tagged using dart style tags (T-anchor Bar FD-94 and FF-94, from "Floy Tag"), following the procedure suggested by Parker et al. (1990). Between November 2001 and July 2004, 14 batches of fish of different sizes were tagged and released (7520 white seabreams and 6102 gilthead seabreams; see Table 1 for details). The percentage of mortality due to tagging and/or handling was negligible (< 0.5%).

Release procedures were selected to minimize stress on the fish. Fish release occurred at the Olhão, Faro or Vilamoura artificial reef systems at one of the reef sets (assemblages of 35 concrete cubic units, see Fig. 1)

Data Collection.—Fish returns presented here were recorded for almost 3 yrs (from November 2001 until September 2004). Visual censuses, which allowed the estimation of fish density (no. fish m^{-3}), were carried out by a SCUBA diver at the Faro/Ancão artificial reef system, for batches of *D. sargus* released in September 2002 and May 2003. The visual censuses extended for a 3-mo period, at different time intervals (1, 3, 5, 8, 15, and approximately 30, 45, 60, and 90 d after release). Three artificial reef sets were sampled each time. Overall, 81 fish counts were made using the stationary point count method developed by Bohnsack and Bannerot (1986).

Underwater photography and video recording, together with observations made during visual census, provided qualitative information on the spatial distribution and on the behavior of released seabreams on the artificial reefs.

Returns from recreational and professional fishermen were used to estimate fish dispersion. Information requested from the fishermen included: date of capture, location, fishing gear used, fish size, and weight. Fish returned by fishermen were measured by research staff

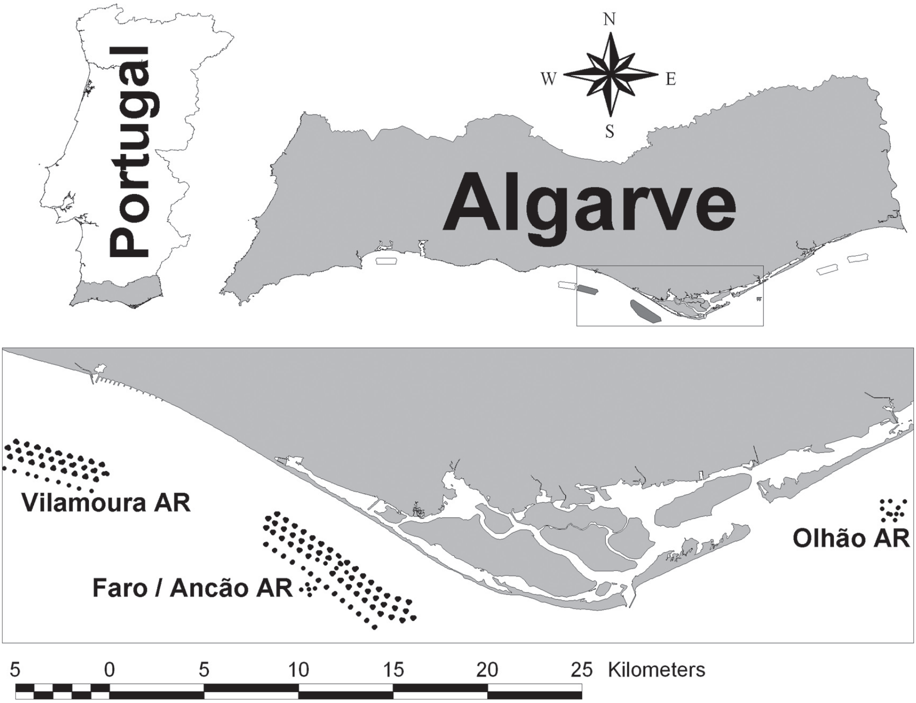

Figure 1. Geographical location of the Algarve coast (Southern Portugal), with particular emphasis on the study sites (dark grey areas in box) and the artificial reefs (ARs).

and when the fishermen did not want the fish for their own consumption, an analysis of the digestive system was carried out. Items present in the digestive system (including stomach and intestine) of *D. sargus* were analyzed and identified to the lowest possible level.

Data Analysis.—Exponential models were fitted to the mean abundance over time using:

$$Abundance\left(N_t\right) = a_n e^{-b_n t}$$

where *Abundance* (N_t) is the density of fish in number over time, a_n is the intercept, b_n is the parameters defining the rate of decrease, and t is time after release (number of days). In order to compare the results from the summer and spring experiments in terms of fish abundance, data were log transformed [log(1+x)] and the Student's t test was used to compare slopes (Zar, 1996).

Results

Visual Census on Artificial Reefs.—In total, 1456 white seabreams were counted on the Faro/Ancão artificial reef system over the two periods. The highest abundances were registered immediately after release, and decreased rapidly within the first week. The last *D. sargus* were observed 30 d after release in both experiments. The estimated slopes of the models for the two experiments were not significantly different (t = 0.0006, P < 0.01), and thus a curve was fitted to the pooled data (Fig. 2). There was a rapid decrease in abundance of *D. sargus* over time.

Table 1. Summarized characteristics of the 14 batches of fish released and respective return data. SD = standard deviation, nmi = nautical miles, and FL = fork length.

	Sparus aurata	*Diplodus sargus*
Total number of fish released	6,102	7,520
Number of batches	7	7
Minimum fish size (cm, FL)	10.5	11.6
Mean fish size ± SD (cm, FL)	19.0 ± 2.8	16.5 ± 2.6
Maximum fish size (cm, FL)	34.5	23.3
Minimum fish weight (g)	24	34
Mean fish weight ± SD (g)	170.9 ± 92.4	151.2 ± 64.5
Maximum weight (g)	1,006	416
Total weight of released fish (kg)	1,014.9	1,136.5
Total number of fish returned	378	337
Total percentage of returns	6.2%	4.5%
Maximum days at sea	287	340
Minimum dispersal distance [nmi (d)]	0 (163)	0.5 (49)
Mean dispersal distance ± SD nmi	6.3 ± 8.4	10.4 ± 9.1
Maximum dispersal distance [nmi (d)]	65 (199)	67 (42)
Percentage of fish captured at < 5 nmi	65.1%	27.1%
Percentage of fish captured at < 10 nmi	77.2%	46.8%
Percentage of fish captured at < 20 nmi	90.6%	80.6%

During the visual census, namely within the first 3 d after release, divers observed a behavioral deficit of the white seabream in the use of the artificial reef refuges. The fish formed schools, swimming around the modules as they usually do while in the rearing tanks and showed no attempt to hide within the modules in the presence of divers or natural predators, such as large sea bass (*Dicentrarchus labrax* Linnaeus, 1758) or European conger eel (*Conger conger* Linnaeus, 1758). Also, during the first week the fish did not forage on the modules as wild fish usually do. However, after about 10 d, small groups of two or three tagged fish were observed, together with other species of the same genus (*Diplodus annularis* Linnaeus, 1758; *Diplodus bellottii* Steindachner, 1882; and *Diplodus vulgaris* Geoffroy Saint-Hilaire, 1817) moving, foraging, and hiding among the artificial reefs modules.

Digestive System Contents.—A total of 17 *D. sargus* specimens was returned by fishermen, which allowed the analysis of their digestive system contents. Fish caught within the first 8 d after release (eight specimens, with a mean size of 19.6 cm) had empty digestive systems. By 11 d after release all the specimens (n = 9, mean size of 19.9 cm) had items in their digestive system.

Prey included algae, bryozoans, gastropods, crustaceans, and fish remains. Among these the most frequent items were crustaceans, namely brachyuran crabs.

Fish Returns.—Of the 13,622 released fish, 337 *D. sargus* and 378 *S. aurata* were returned, for an overall catch rate of 5.2%. The percentage of returns per batch ranged from 0.2% to 8.6% and 2.8% to 11.2%, for the white and gilthead seabreams, respectively. The overall return rate for the white seabream was 4.5%, while for the gilthead seabream it was 6.2% (Table 1). The maximum days at liberty observed were 287 and 340 for the gilthead and white seabream, respectively. Both species had similar maximum dispersal ranges, although *D. sargus* reached the maximum distance in much less time. On the other hand, this species had lower catch rates closer to the

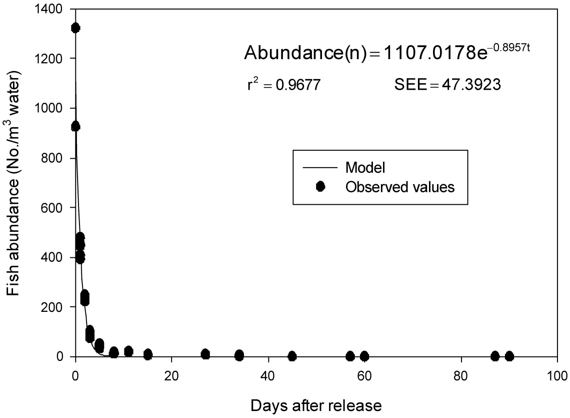

Figure 2. Progression of the density of the hatched-reared *Diplodus sargus* released at the artificial reefs (points) and fitted model (line). Nt is the density of specimens (No. fish m^{-3}) and SEE is the standard error of the estimated curve.

artificial reefs and a higher mean dispersal distance than the gilthead seabream (see Table 1 for details).

Discussion

Our observations highlight the fact that during the first days after release the fish maintained their schooling behavior. This behavior of reared species has been previously reported by Kudoh et al. (1999) for the red seabream (*Pagrus major*) in Japan and by D'Anna et al. (2004) for *D. sargus* in Sicily. The latter authors also reported that the white seabream do not flee into reef holes or crevices, forage, and are not are afraid of potential predators. The same reaction was also reported to us by spear fishermen who observed our tagged specimens (L. Sousa and F. Reis, pers. comm.). As suggested by D'Anna et al. (2004), this behavioral deficit is probably linked to the long time in captivity, with no chance to experience other habitats. Moreover, the fact that during the first days we observed them swimming in large groups could be also a consequence of their lack of natural behavior, or as mentioned by Macpherson (1998), the gregarious habit of the juveniles. These results are consistent with the opinion of others who believe that reared specimens once released in the open sea, are not able to perceive environmental stimuli useful for their settlement, and are not able to exploit available food resources (Olla et al., 1994). Thus, it is clear that such behaviors might have negative effects on the survival of released individuals (D'Anna et al., 2004). However, this might not necessarily compromise the success of the restocking experiments. In fact, our in situ observations and preliminary gut content analysis confirmed that only 11 d after release all fish (which were larger than 19.5 cm FL) had ingested some food items.

The low number of fish analyzed does not allow for robust conclusions regarding prey composition, but it was interesting to notice that the primary prey was brachyuran crabs, which are not used as bait. These findings indicate that *D. sargus* reared in captivity has the instinct and ability to feed on hard shelled active organisms, which are commonly found in the diet of wild white seabreams (F. Leitão, IPIMAR, unpubl. data).

Wild specimens of *D. sargus* have been constantly observed on the Algarve artificial reefs, while the occurrence of *S. aurata* on these structures has been occasional. However, the tagged seabreams left the reef rather early to move towards shallower coastal waters. A similar behavior was reported for *D. sargus* tagged and released on artificial reefs in the Gulf of Castellammare (D'Anna et al., 2004) and for *S. aurata* tagged and released in the Gulf of Cadiz (SE Spain; Sánchez-Lamadrid, 2002). This behavior is most likely due to ecological factors other than substratum type or reef features. Ongoing studies on the contribution of the Algarve artificial reefs to the diet of *D. sargus* (F. Leitão, IPIMAR, unpubl. data) suggest that at least food and shelter are not limiting factors for this species. Preference by *D. sargus* for shallower waters could be due to a search for adjacent artificial habitats such as breakwaters and harbors, which are particularly suitable for the settlement and growth of juveniles and pre-adults fishes (D'Anna et al., 2004). In fact, a considerable portion of the captured white seabreams occurred in such areas, where the availability of numerous holes and crevices of different dimensions, in shallow and sheltered waters, may be an important factor for the fish settlement. These findings are consistent with studies carried out on wild white seabream, where specific habitats are used by the early stages of the life cycle of *D. sargus* (Biagi et al., 1998; Macpherson, 1998).

In contrast to the white seabream, more than three quarters of gilthead seabream released were captured within 10 nmi of the release site, suggesting that although gilthead seabream also move to shallower waters, they tend to disperse less than the white seabream. The primary prey in the diet of wild *Sparus aurata* are mollusks, particularly bivalves (Arias, 1980; Rosecchi, 1985). Thus it is possible that the gilthead seabream move to shallower feeding grounds, namely juvenile bivalves beds, which occur near the coast at < 10 m deep (M.B. Gaspar, IPIMAR, pers. comm.). The low reef dependence of this species is also supported by the fact that during our regular underwater observations (M.N. Santos, IPIMAR, unpubl. data) we did not regularly observe wild gilthead seabreams around the artificial reefs.

Our preliminary results suggest that hatchery-reared young white seabreams, although showing an initial behavior deficit regarding predator avoidance, are able to feed on live prey after a short period. Thus, white seabream may adapt to the wild successfully. On the other hand, specimens of both species released at the artificial reefs do not remain inside the artificial structures for a long period, but their dispersal is mostly limited to neighboring areas (< 11 nmi). These results suggest that both species might be adequate for restocking at the regional level and that fish restocking may be used as an additional tool within an integrated management plan for local fisheries enhancement. However, these results should be regarded as preliminary, since several important aspects such as growth, mortality, and habitat selection must be further investigated.

Acknowledgments

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