

Fish communities associated with FADs*

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SUMMARY: Two groups of six fish aggregating devices (FADs) were deployed at two locations off the eastern coast of Majorca (Western Mediterranean). Samples were obtained fortnightly throughout a two-year period by means of hauls performed with an experimental purse seine. Two control areas were established to check the aggregation efficiency of the FADs. A total of 16 families and 26 species of fishes were recorded beneath FADs. Pelagic fishes, largely *Trachurus picturatus*, *T. mediterraneus*, *T. trachurus*, *Naucrates ductor*, *Seriola dumerili* and *Coryphaena hippurus*, dominated the fauna. The total fish abundance, number of species and length range of the species confirmed that the FAD community was significantly related to season (recruitment period), resulting in a sequential fish colonisation of the FADs during the study period. Some of the species were present only during a particular period, such as *Trachurus* spp. in spring and summer. Other species, although evident for a longer period, were more occasional in catches (*Schedophilus ovalis*, *Balistes carolinensis* and *Polyprion americanus*), and some others were also present in small quantities. Diversity and equitability of the fish community associated with FADs were higher in summer than in winter. Many species were more abundant around FADs than in open water controls. The species that showed the most distinct recruitment phase beneath the FADs were *N. ductor*, *S. ovalis*, *Trachurus* spp., *P. americanus*, *S. dumerili*, *C. hippurus* and *B. carolinensis*. FADs can be considered nursery structures for many pelagic and demersal species, thus having an effect on the redistribution of juveniles. In the deployment of artificial structures as aggregators for fishing purposes one should consider the patchiness and seasonal characteristics of these communities as well as the redistribution aspect for fishery management.

Key words: FADs, fish assemblages, seasonality, juvenile fish, western Mediterranean.

INTRODUCTION

Associations of fishes with flotsam have been widely reported in the literature (Gooding and Magnuson, 1967; Hunter and Mitchell, 1967; Dooley, 1972; Safran and Omori, 1990; Druce and Kingsford, 1995) from subtropical and temperate waters. However, few data are available on the Mediterranean (Relini *et al.*, 1994; Massutí and Reñones, 1994) and little is known on medium-term processes operating

on fish communities associated with floating objects, with the exception of a few studies (Kingsford, 1992, 1993). Thigmotaxis in fish (the attraction to a solid object) (Ibrahim *et al.*, 1996) has been exploited by fishermen in many seas (Yabe and Mori, 1950; Kojima, 1956; Galea, 1961; Kihara, 1981; Massutí and Morales-Nin, 1991). This aggregating behaviour is a consequence of many factors acting on the individuals, and several mechanisms have been suggested to explain the association of fishes with floating objects. Four of the more accepted mechanisms are: shelter from predators, food supply, schooling companions

*Received November 25, 1997. Accepted February 2, 1999.

and substrate for species undergoing a change from a pelagic to other modes of existence (Gooding and Magnuson, 1967; Hunter and Mitchell, 1967; Wickham *et al.*, 1973; Wickham and Russell, 1974; Matsumoto *et al.*, 1981; Brock, 1985; Rountree, 1989; Fonteneau, 1993).

In the waters around the island of Majorca (Western Mediterranean) (Fig. 1), from late August to early December a small scale fishery based on the use of Fish Aggregating Devices (FADs) for dolphinfish (*Coryphaena hippurus* Linnaeus, 1758) takes place. The gear used in the fishery is a surrounding net without a purse seine with an average length of 180 m and height of 16 m (Massutí and Morales-Nin, 1991). During the fishing season the fish community associated with FADs is composed mainly of juveniles of *C. hippurus*, *Naucrates ductor* (Linnaeus, 1758), *Seriola dumerili* (Risso, 1810), and to a lesser degree *Balistes carolinensis* Gmelin, 1788 and *Polyprion americanus* (Schneider, 1801) (Massutí and Reñones, 1994). The need to describe and forecast the seasonal pattern of the fish community living beneath flotsam, in addition to the lack of data in the area during the months when the fishery does not take place, led us to conduct a continuous and prolonged sampling exercise for a two-years period. Two open water control areas were established to test for the aggregation behaviour of the species.

Previously, little experimental research has been undertaken to understand the function of FADs in pelagic and more oceanic waters as aggregators of fish schools on a temporal scale. Some of these studies have been based on visual counts of fishes, but this is not sufficient to gain an insight into the biology of the species (eg. size, maturity). Consequently, in this work fish catches were preferred as a means of assessing the influence of FADs on fish in the epipelagic environment. This paper focuses on the description of the faunal composition, abundance and seasonality of fishes associated with FADs in the western Mediterranean in order to explain their residence time under the FADs area.

MATERIALS AND METHODS

Sampling strategy

Two groups of FADs were moored in waters off the east coast of Majorca (Western Mediterranean) in front of Portocolom harbour to study fishes asso-

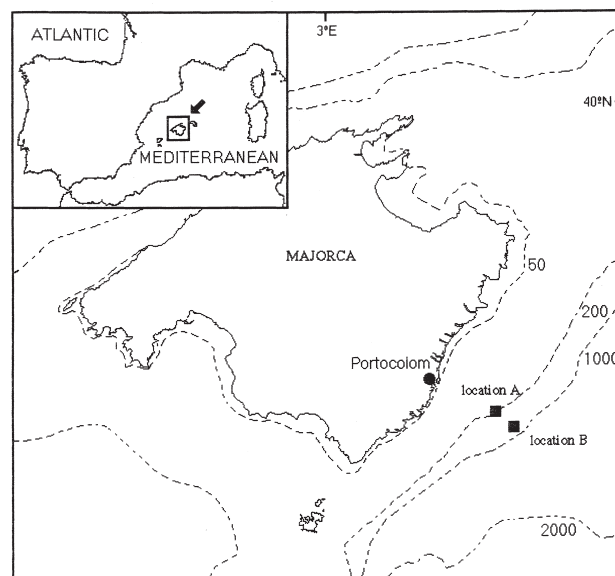


FIG. 1. – Map of the sampling area showing the locations (A and B) where the two groups of FADs were moored (black squares).

ciated with them (Fig. 1). Each group of FADs was composed of three floating artefacts with a surface of 40x70 cm and a height of 25 cm made of wood, polystyrene, bush branches and palm leaves tied to the underwater part to increase the efficiency of fish concentration (Rountree, 1989). The FAD design was very similar to the typical fish aggregation devices employed by the local fishermen in the exploitation of the dolphinfish fishery.

Two different locations were considered. The first group of 3 FADs was moored at co-ordinates 39°21'N 03°24'E over the 200m isobath and at a distance of 4 nautical miles from the coast. The other group of 3 FADs was moored 7 nautical miles from the shoreline at co-ordinates 39°19'N 03°18'E over the 800m isobath (Fig. 1). The distance between each FAD was approximately 0.1-0.2 nautical miles. Two zones without flotsam, separated one nautical mile from each group of FADs and at the same depth, were taken as controls.

The Portocolom area is characterised by a narrow continental shelf and a steep slope, reaching a depth of 1000 m in less than 10 nautical miles from the shoreline. This zone is dominated by the circulation pattern of the Algerian basin, which depends mainly on the mesoscale patterns associated with the Algerian current, giving rise to cyclonic gyres that can affect the south-eastern coast of Majorca.

A traditional Majorcan vessel (Ilaüt) (9m, 100HP and 8GRT), engaged in the Portocolom small-scale dolphinfish fishery, was used for the sampling. An experimental purse seine with a cod-end mesh size

of 2 mm was designed in order to sample the whole length range and species composition of the populations (Massutí *et al.*, 1999). This net was similar to the commercial one used in the dolphinfish fishery (Massutí and Morales-Nin, 1991), although with a purse line and smaller dimensions (around 110m in length and 14m in height) (Massutí *et al.*, 1999). As inferred from the dolphinfish fishery catches (Lleonart *et al.*, 1999), fish abundance seemed to be maximal at dawn, so catches were undertaken at this time, thus emulating the dolphinfish fishery to increase the catch efficiency and to prevent fishes escaping from the net.

Seasonal variability was studied by sampling each group of FADs with a fortnightly periodicity, whenever possible according to weather conditions, over a two-year period. However, bad weather and the long-liners fishing for swordfish (*Xiphias gladius* Linnaeus, 1758) operating in the same waters caused the loss and damage of many experimental FADs. Therefore, they had to be renewed and moored several times, thus causing discontinuities in the sampling. A total of 133 hauls were performed on 38 sampling dates from May 1995 to January 1996, and from May 1996 to February 1997.

In every sampling date a minimum of one haul was performed at each FAD group and at each control station. To characterise the total catch of the fish community, as well as the individuals of some species, observations under the FADs from the deck were also taken into account.

The total catch and the species composition by weight and number were determined. Also, the length frequency, sex and maturity stage and other biological parameters were recorded in the laboratory.

Data analysis

The ecological parameters, abundance, species richness (S), Shannon-Weaver diversity index (H') and evenness (J') for the species caught beneath FADs were determined separately for the two locations without considering the control stations. The non-parametric Mann-Whitney U test was applied to examine differences between seasons for each location, since normality assumptions were not met (Zar, 1996). Catches from the two groups of FADs were considered together for the following calculations: frequency of appearance, size range and average number of individuals in a shoal.

The variation of species composition with time was tested using a multivariate analysis of the abun-

dance of catches per day and location. A correspondence analysis was preferred because of the large variation in species composition, and also because of the high degree of variance. The Lawi statistical programme (J. Lleonart, Institut de Ciències del Mar, Barcelona, unpublished) was used in the analysis. Only species appearing to be closely associated with FADs, obtained by the comparison with control data and on the basis of their frequency of appearance, were considered for the analysis. From the abundance data, samples with less than 2 species were rejected. Correspondence analysis was performed on a 38 abundance data x 9 species matrix.

RESULTS

During the study period a total of 12865 fishes were sampled, comprised of a total of 30 species belonging to 18 families (Table 1). By far the most frequently observed family was Carangidae with 5 species, but also present were Scombridae (4 species), Centrolophidae (2 species), and Coryphaenidae, Serranidae and Balistidae (1 species). In the control stations, Centranchidae, Clupeidae, Mullidae, Myctophidae, among others, were more abundant. Of the 30 species encountered, 18 were caught only beneath FADs, 8 both at FADs and in the control areas, and 4 only at the control stations. Average densities of fishes were higher around FADs than at control stations (Table 1). For the species caught exclusively under the FADs, nine may be representative of this community since they never appeared in the open water controls and their mean density value was higher than 0.1 indiv/FAD. These species were *N. ductor*, *Schedophilus ovalis* (Valenciennes, in Cuv. Val., 1833), *B. carolinensis*, *Trachurus picturatus* (Bowdich, 1825), *T. trachurus* (Linnaeus, 1758), *T. mediterraneus* (Steindachner, 1863), *P. americanus*, *S. dumerili* and *C. hippurus*, whereas the others were juveniles of pelagic and demersal species. On the other hand, the most abundant species encountered in control areas were *Sardinella aurita* Valenciennes, 1847, *Centranchus cirrus* Rafinesque, 1810 and *Mullus surmuletus* Linnaeus, 1758 (Table 1). However, small, compact schools of *M. surmuletus* juveniles were observed accompanying shoals of *Trachurus* spp. in association with the FAD.

Changes in species composition during the study period indicated a strong seasonality (Fig. 2). The number of species associated with FADs was signif-

TABLE 1. – Species mean density (n. individuals/FADs) per location (standard deviation in brackets). Total n. of fish:12865

| Family | Species | Location A | | Location B | |
|------------------|---|---------------|----------------|----------------|----------------|
| | | FADs (n=34) | Control(n= 11) | FADs (n= 31) | Control(n= 10) |
| Clupeidae | <i>Sardinella aurita</i> Valenciennes, 1847 | 0.65 (3.60) | 1.18 (3.92) | 0.25 (1.38) | 7.60 (22.01) |
| Engraulidae | <i>Engraulis encrasicolus</i> (Linnaeus, 1758) | 0.02 (0.11) | — | 0.01 (0.06) | — |
| Myctophidae | <i>Ceratocopelus maderensis</i> (Lowe, 1839) | 0.01 (0.06) | — | — | 0.50 (1.58) |
| | <i>Lampanyctus pusillus</i> (Johnson, 1890) | — | 0.09 (0.30) | — | — |
| Scomberesocidae | <i>Scomberesox saurus</i> (Walbaum, 1792) | — | 0.18 (0.60) | 0.03 (0.11) | 0.20 (0.63) |
| Macroramphosidae | <i>Macroramphosus scolopax</i> (Linnaeus, 1758) | 0.03 (0.17) | — | 0.05 (0.24) | — |
| Gadidae | <i>Phycis blennoides</i> (Brünnich, 1768) | — | — | — | 0.10 (0.32) |
| Serranidae | <i>Polyprion americanus</i> (Schneider, 1801) | 0.09 (0.26) | — | 0.17 (0.38) | — |
| Carangidae | <i>Naucrates ductor</i> (Linnaeus, 1758) | 4.60 (11.19) | — | 7.72 (22.98) | — |
| | <i>Seriola dumerili</i> (Risso, 1810) | 0.49 (1.48) | — | 4.17 (15.08) | — |
| | <i>Trachurus mediterraneus</i> (Steindachner, 1863) | 0.24 (0.96) | — | 0.93 (2.93) | — |
| | <i>Trachurus picturatus</i> (Bowdich, 1825) | 31.56 (98.98) | — | 85.54 (246.72) | — |
| Coryphaenidae | <i>Trachurus trachurus</i> (Linnaeus, 1758) | 0.41 (1.67) | — | 0.92 (4.44) | — |
| | <i>Coryphaena hippurus</i> Linnaeus, 1758 | 1.70 (5.55) | — | 2.52 (5.12) | — |
| Mullidae | <i>Mullus surmuletus</i> Linnaeus, 1758 | 0.24 (0.81) | 0.18 (0.60) | 0.46 (2.33) | 0.60 (1.90) |
| Sparidae | <i>Boops boops</i> (Linnaeus, 1758) | — | — | — | 0.10 (0.32) |
| | <i>Pagellus bogaraveo</i> (Brünnich, 1768) | — | — | 0.01 (0.06) | — |
| Pomacentridae | <i>Chromis chromis</i> (Linnaeus, 1758) | 0.01 (0.06) | — | — | — |
| Centracanthidae | <i>Centracanthus cirrus</i> Rafinesque, 1810 | 0.41 (1.40) | 0.55 (1.81) | 0.25 (0.92) | 15.80 (40.45) |
| Scombridae | <i>Auxis rochei</i> (Risso, 1810) | 0.09 (0.46) | — | — | 0.40 (1.26) |
| | <i>Scomber scombrus</i> (Linnaeus, 1758) | — | — | 0.01 (0.06) | — |
| | <i>Thunnus alalunga</i> (Bonnaterre, 1788) | 0.08 (0.46) | 0.09 (0.30) | — | — |
| | <i>Thunnus thynnus</i> (Linnaeus, 1758) | 0.01 (0.06) | — | 0.02 (0.08) | — |
| Blenniidae | <i>Parablennius sanguinolentus</i> (Pallas, 1811) | 0.01 (0.06) | — | — | — |
| | <i>Parablennius tentacularis</i> (Brünnich, 1768) | 0.06 (0.29) | — | 0.01 (0.06) | 0.50 (1.58) |
| | <i>Scartella cristata</i> (Linnaeus, 1758) | 0.01 (0.06) | — | — | — |
| Centrolophidae | <i>Centrolophus niger</i> (Gmelin, 1788) | 0.13 (0.77) | — | 0.03 (0.18) | — |
| | <i>Schedophilus ovalis</i> (Valenciennes, in Cuv. Val., 1833) | 0.20 (0.72) | — | 0.34 (0.64) | — |
| Balistidae | <i>Balistes carolinensis</i> Gmelin, 1789 | 0.17 (0.52) | — | 0.25 (0.72) | — |
| Bothidae | <i>Bothus podas</i> (Delaroche, 1809) | — | 0.09 (0.30) | — | — |

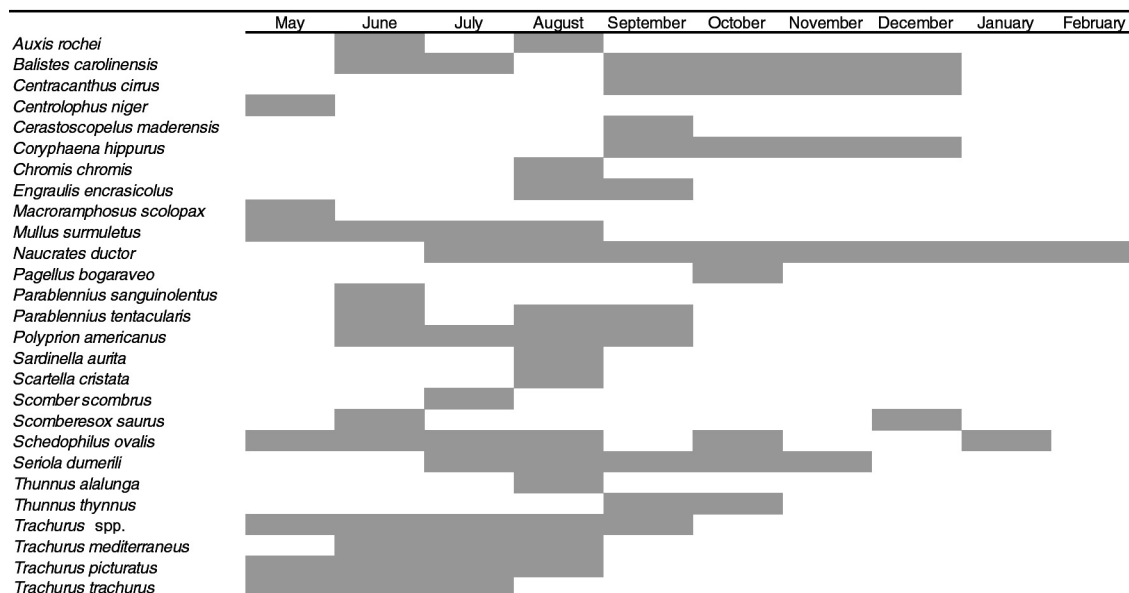


FIG. 2. – Seasonal occurrence of the species beneath FADs around Majorca for the stations (location A and location B).

icantly affected by the sampling date and exhibited a peak in the summer (Fig. 2). The number of individuals/FAD peaked in the spring, then declined through the autumn and was almost negligible in

winter (Table 2), whereas the mean number of fish in the control areas fluctuated widely (Table 1).

Diversity showed a slight seasonal variability as the different species started colonising the floating

TABLE 2. – Summary of statistical indexes for the fish species associated to FADs (standard deviation in brackets). H' (Shannon-Weaver diversity index), J' (evenness), S (species richness), and abundance (n. individuals/FAD).

| | Spring | | Summer | | Autumn | | Winter | |
|-------|----------------|-----------------|---------------|---------------|--------------|--------------|---------------|--------|
| | Loc. A | Loc. B | Loc. A | Loc. B | Loc. A | Loc. B | Loc. A | Loc. B |
| H' | 0.25 (0.17) | 0.20 (0.23) | 0.44 (0.36) | 0.58 (0.13) | 0.23 (0.19) | 0.47 (0.14) | --- | --- |
| J' | 0.19 (0.11) | 0.13 (0.16) | 0.23 (0.18) | 0.32 (0.04) | 0.16 (0.11) | 0.31 (0.03) | --- | --- |
| S | 2.50 (0.71) | 3.12 (0.88) | 3.00 (1.41) | 3.60 (1.33) | 1.64 (0.82) | 2.73 (0.42) | 1.00 | --- |
| Abund | 100.44 (40.51) | 262.62 (181.67) | 33.66 (12.99) | 74.38 (43.83) | 10.61 (6.52) | 25.14 (9.58) | 18.00 (26.89) | --- |

objects. Summer samples gave the highest diversity ($H' = 0.44$, $J' = 0.23$ for the location A FAD group, and $H' = 0.58$, $J' = 0.32$ for the location B FAD group) (Table 2). The fish community collected at the location A group revealed a lower specific richness than that found in the location B community. Furthermore, the abundance was significantly higher at the location B FAD group than at the location A group ($U_{0.05(2), 10, 11} = 18$).

Correspondence analysis pooled the 38 sampling dates along the first axis according to their faunistic similarities. The first axis explained 37.1% of the variability, whereas the second accounted for 18.4%. A clear seasonal pattern was observed following the sequential arrival and permanence of the species under the FADs (Fig. 3). The first organisms to recruit were the juveniles of middle-sized pelagic fish, especially *Trachurus* spp. The three species of this genus were cohabitants of the FADs during the spring-summer period, together with other solitary

species, such as *P. americanus* and *S. ovalis*. The target species of the artisanal dolphinfish fishery, predominantly *C. hippurus* and *N. ductor*, were notably grouped together and corresponded to the autumn samples, as did *S. dumerili*, although this species was present mainly in the summer. *B. carolinensis* was another species coexisting with the autumn species group, although it was encountered under the FADs from June till December.

The percentage appearance of the nine most representative species was plotted in conjunction with the monthly distribution of the size range (Fig. 4). The most common fish species attracted to the FADs were represented by juveniles, although some adult individuals of *S. ovalis* and *N. ductor* were observed. These two species were encountered for almost the whole year below the FADs, but while *S. ovalis* was present in groups of a few individuals ranging from 12 to 50 cm TL, *N. ductor* was found in larger shoals that contained smaller sized individuals (5-30 cm FL).

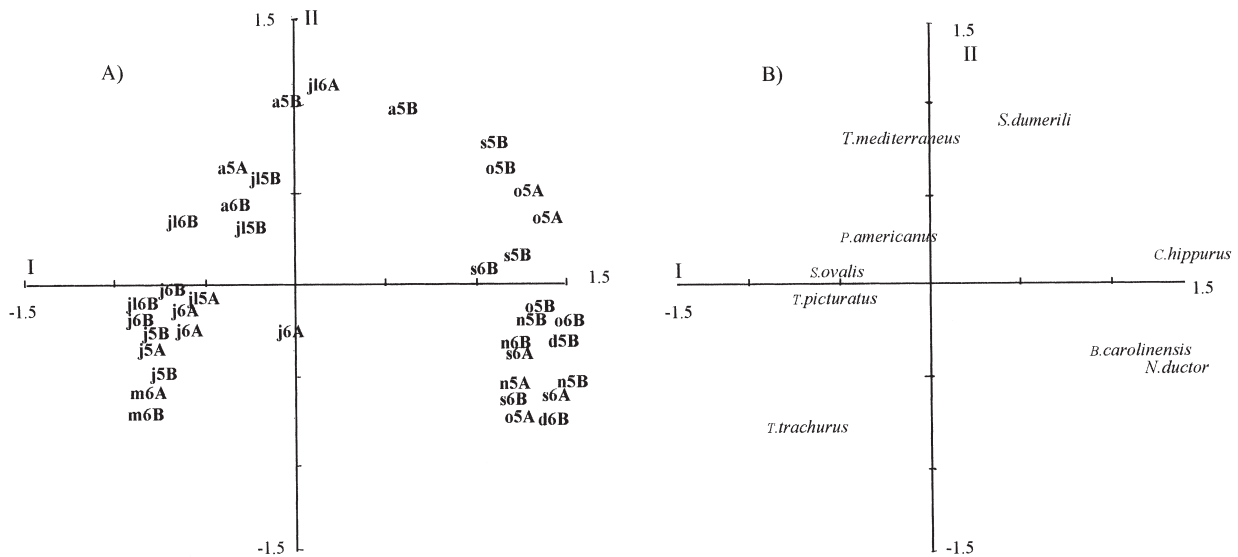


FIG. 3. – Correspondence analysis of the sampling dates (A) and of the nine more abundant species associated to FADs (B). For the sampling dates codes the first character represent the month (M= may, j= June, jl= July, a= august, s= September, o= October, n= November, d= December), the second the year (5= 1995; 6= 1996) and the third the location (A= location A; B= location B).

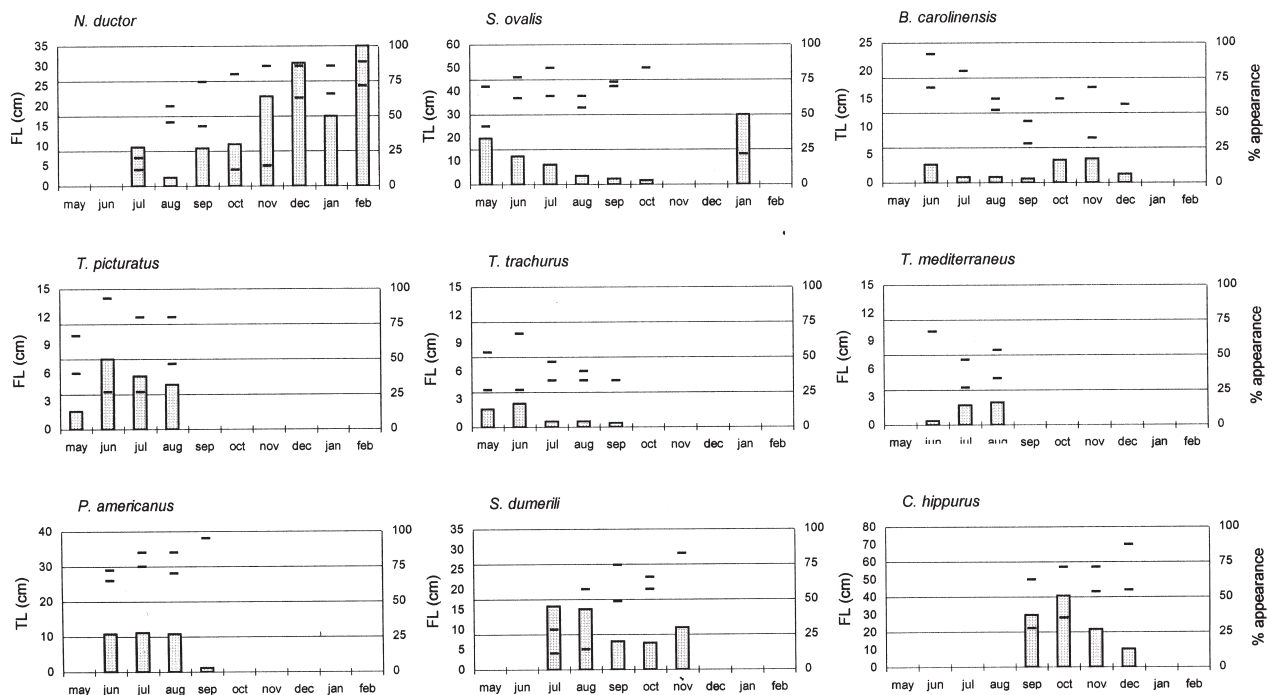


FIG. 4. – Monthly distribution of the percentage of appearance (bar diagram) with indication of the size range (maximum and minimum mensural length) of the nine selected species beneath FADs.

B. carolinensis lived below flotsam from June to December in groups fluctuating between 1 and 5 individuals. This species occurred sporadically as small specimens of about 6-10 cm TL in September and 17-23 cm TL in June. FAD colonisation took place between September and November, with specimens of about 5-7 cm TL, although another peak was present during June.

The three congeneric species of carangids, *T. picturatus*, *T. trachurus* and *T. mediterraneus*, were present only as small juveniles (size range from 3.6 to 12.4 cm FL). *T. picturatus* was the more abundant species, and it appeared during spring and summer in shoals of up to 500 or more individuals. *T. trachurus* occurred from spring to the beginning of autumn in smaller shoals. *T. mediterraneus* was the less frequent and less abundant of the three species and its presence was limited to the summer period.

P. americanus juveniles were found in association with the FADs from June to September. In most of the samples it was present as a solitary species.

Juveniles of *S. dumerili* were present from July to November in shoals of variable size, from a few individuals up to 30 specimens.

C. hippurus appeared at the beginning of autumn and lasted until the beginning of winter. During this period, it showed a rapid growth and reached the maximum length (up to 70 cm FL). This species,

along with *S. dumerili*, *N. ductor*, *P. americanus* and *S. ovalis*, showed a definite length increase throughout its stay under the FADs (Fig. 4).

DISCUSSION

The fish fauna associated with FADs off Majorca was similar to earlier findings reported from Mediterranean waters (Massutí and Reñones, 1994; Relini *et al.*, 1994). Many of the species found in this study had been previously included as species with a tendency to associate with floating objects or seaweed, especially in their juvenile phases (Hunter and Mitchell, 1968; Rountree, 1989, 1990; Relini *et al.*, 1994; Massutí and Reñones, 1994; Kingsford, 1992, 1995). The observed specimens were mainly juveniles, with the exception of a few adults of *S. ovalis* and *N. ductor*. The recruitment of juvenile middle-sized pelagic fishes to FADs was rapid, with shoals being present only a few days after FAD placement. A rapid recruitment of bait fish to artificial structures was previously described by Klima and Wickham (1971) and Wickham and Russell (1974). However, the duration of this study has allowed a more complete colonisation pattern to be described. In addition, the use of a smaller mesh size permitted the sampling of small juveniles associated

with FADs that the artisanal Majorcan dolphinfish net does not capture.

The differences and similarities between the fish fauna associated with floating devices and the fauna found in the control areas allowed species typical of FADs communities to be discriminated from others not apparently influenced by flotsam. In the first group 9 were considered as strictly representative of this community: *Balistes carolinensis*, *Coryphaena hippurus*, *Naucrates ductor*, *Polyprion americanus*, *Schedophilus ovalis*, *Seriola dumerili*, *Trachurus mediterraneus*, *Trachurus picturatus* and *Trachurus trachurus*. However, not every species caught near FADs should be considered as associated with these structures. The control stations indicated that some species may be fished with the same or higher density in pelagic waters away from any FAD. Thus, *Centracanthus cirrus*, *Mullus surmuletus*, *Sardinella aurita*, *Scomberesox saurus* (Walbaum, 1792), and the myctophids *Lampanyctus pussillus* (Johnson, 1890) and *Ceratoscopelus maderensis* (Lowe, 1839), do not seem to be especially attracted to FADs, and their juvenile stages are more or less ubiquitous in the surface layers. Therefore, their catches were fortuitous and more sporadic. This suggests that thigmotaxis in fishes in the western Mediterranean is not a general phenomenon for the pelagic juvenile stages, as reported by Kingsford (1992) in the drift algae of north-eastern New Zealand.

The appearance and permanence of species beneath FADs seems to be strictly related to season, since no important differences were found between years or locations. The sequence of species colonisation begins in May, with small juveniles of *Trachurus* spp., followed by juveniles of *P. americanus* in June, *S. dumerili* in July and *C. hippurus* in September. Three species, *N. ductor*, *S. ovalis* and *B. carolinensis*, may be found all year round, although with some interruptions. The dominance of *N. ductor*, *C. hippurus* and *S. dumerili* together with *T. mediterraneus*, *T. picturatus* and *T. trachurus* is mainly concentrated over a 4-5 month period, although *N. ductor* shows a longer residence time and can be considered as a characteristic inhabitant of flotsam since it spanned the longest period under the FADs. However, Reñones *et al.* (1998) suggest that this species appears to be associated with floating objects only during its first year of life. The other two resident species, *S. ovalis* and *B. carolinensis*, are demersal and mesopelagic, and live beneath FADs as juveniles before changing their living pattern (Johnson and Saloman, 1984; Orsi-Relini *et al.*, 1990).

The FAD-associated fish community found in the Majorca area exhibited a peak abundance in May-June, which then decreased throughout the autumn. The summer peak was the most consistent, especially for the *Trachurus* species, whereas an autumn peak was the rule for *N. ductor* and *C. hippurus*. This might be related to the spawning period and the school dynamics of each species, which in turn is affected by the current patterns, presence or absence of frontal zones, eddies and other features that may act on fish distribution, patchiness, etc.. The fact that there is considerable aggregation of recruits in an area means that either reproduction or survival are patchy (Hall and Lennert, 1992). In this sense, the FAD can function as a nursery structure where juveniles could find the conditions required for existence and survival. However, the survival benefits for big, fast swimming juveniles such as *C. hippurus* are not very clear. Probably, the aggregation phenomenon develops in conditions where flotsam accumulates as an indication of areas of hydrographic convergence (Uda, 1961), and where the food might be more abundant.

The size of a shoal is quite variable depending on the ecology of the species and on its propensity to be preyed upon. Thus, the species that exhibited a more solitary behaviour (*P. americanus*, *S. ovalis* and *B. carolinensis*) have a large body size, spines and appendages to prevent being swallowed by predators. These three species take advantage of their stay under the floating objects by preying on other species associated with FADs (e.g., *Trachurus* sp.). Moreover, *C. hippurus*, *N. ductor*, *S. dumerili* and *Trachurus* spp. also seem to make use of the schooling tendency, as either a defence against predators or as a mechanism for an enhanced predator's foraging activity. According to Radakov (1973), the schooling behaviour lessens the possibilities for predator's gaining access to the shoal, although it actually increases them for predators which hunt in shoals themselves. On the other hand, the visual component is also important in the predation factor (Rountree, 1990), since greater structural complexity reduces visual encounters between prey and predators. This could also be the case for *Trachurus* spp., where the availability of interstices presented by the artificial structure provides more possibilities for survival.

FADs provide a useful tool for studying species and life phases that are difficult to sample using more conventional methods. For instance, our results confirm the rare observations of stromateoids

Centrolophus niger (Gmelin, 1788) and *S. ovalis* made by Relini *et al.* (1994) in the Ligurian Sea. Moreover, in the Balearic Sea (north-western Mediterranean) only 3 catches of *S. ovalis* have been reported (Massutí and Stefanescu, 1994). The appearance of this species throughout the whole period is in accordance with the reports from Relini *et al.* (1994). Another little-known species in the Mediterranean is *B. carolinensis*, which was found from June to December, and seems to stay about one year before changing its mode of existence from pelagic to demersal.

The diversity values obtained, H' ranging from 0.2 to 0.58, are rather low in comparison with other studies. However, the lack of studies carried out on similar habitats (artificial flotsam) does not allow close comparisons. For example, Fine (1970) reported high diversity values ($H'=2.41$), resulting from a stable environment and an area low in productivity, such as the *Sargassum* community. On the other hand, Safran and Omori (1990) found higher diversities ($H'=2.69$, $J'=0.596$) for 1200 individuals and 23 species associated with drifting seaweed off the Tohoku coast (northern Japan). Helvey and Smith (1985) also recorded higher diversity values ranging from 2.42 to 3.09 in several locations off southern California for the fish assemblages associated with cooling-water intake structures. The communities studied exhibit lower values due primarily to differences in the epipelagic fauna between the oligotrophic Mediterranean waters and the *Sargassum* fauna.

The location of FADs may have an effect on fish distribution. The submerged and floating objects represent a substrate for many organisms. Moreover, the underwater appendages of FADs, made of perishable materials such as palm fronds and shrub leaves, form an important part of the structure. This combination gives rise to an increase in complexity in the epipelagic zone, which is a structureless habitat. This complexity enlargement in open waters and the patchiness of the associated faunal assemblages are aspects to be considered. Additionally, the scarcity of natural flotsam in the waters around Majorcan outweighs the impact of the FADs on the fish distributions. However, in highly vagrant species such as *C. hippurus*, their distribution might be more related to food availability. Closer spacing of FADs may support fish shoals in numbers large enough to attract transient predators such as *C. hippurus*, *S. dumerili*, *Auxis rochei* (Risso, 1810) or *Thunnus thynnus* (Linnaeus, 1758).

There are probably two main mechanisms which may explain the association of some fish species with FADs: the attraction of drifting materials as schooling companions (e.g. *Trachurus* spp., *N. ductor*, *S. dumerili* and *C. hippurus*), and the fact that they provide a substitute substrate for species undergoing a change to another mode of existence (e.g. *B. carolinensis*, *P. americanus*, *S. ovalis*), as suggested by Hunter and Mitchell (1967). Moreover, it may be hypothesised that they also function as shelter from predators for the small juveniles and the possibility of a food source for certain species. Some species are piscivorous like *C. hippurus* (Massutí *et al.*, 1998), or planktivorous like *N. ductor* (Reñones *et al.*, 1998). Although the adult *C. hippurus* is an active open water predator, the young specimens may expend less energy foraging for flotsam-associated preys (Manooch *et al.*, 1984). Competition for planktonic food resources may be another determining factor in the faunal composition aggregated to floating devices (Rountree, 1990). Reñones *et al.* (1997) reported pelagic planktonic organisms as the main prey species of *N. ductor*. This and other species feed in the epipelagic waters, taking advantage of the diel vertical migration of many planktonic organisms such as hyperiids, amphipods, euphausiids and gastropods (Deudero, unpublished). Another possible source of food for the fish assemblages are the fouling organisms attached to FADs. However, there is no evidence of fishes feeding on them. The only exception is *B. carolinensis*, which eats barnacles and amphipods attached to FADs (Deudero, pers. obs.). Gallaway and Lewbel (1982) determined that fishes not trophically dependent on the invertebrate biofouling community of FADs are often dominant in terms of biomass, which also seems to be the pattern in our study.

The seasonal character of the FAD-associated fauna and the patchiness of their spatial distribution appear to be determining factors in the community structure. The results reported in this paper represent the only long-term study of the fish community associated with FADs in the Western Mediterranean. The temporal partitioning of the habitat associated with FADs, the biomass abundance, species richness and the rapid growth of several species, showed that the FADs may affect the distribution, feeding and survival of young fish, providing adequate conditions for recruitment not only for pelagic species. However, the use of FADs in the fishery and the exploitation of mainly young fish also has to be considered for mortality estimations and fishery management.

ACKNOWLEDGEMENTS

We wish to express our gratitude to O. Reñones, L. Prats, T. Quetglas, K. García, A. Gutierrez and T. Barcenilla for their useful collaboration. A special thanks to Bernat and Joan Oliver, crew of the F/W “Virgen del Carmen II”, for their active participation and helpful advice during the sampling. This work has been financed by the Directorate General for Fisheries (Project UE 94/031 and 95/73) and was supported by grants from I.M.E.D.E.A. to the first author.

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