Behaviour of two major bycatch species of tuna purse-seiners at FADs: oceanic triggerfish (*Canthidermis maculatus*) and rainbow runner (*Elagatis bipinnulata*)

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Abstract

Elagatis bipinnulata (Bennet, 1840) and *Canthidermis maculatus* (Bloch, 1786) are widely distributed species and are two of the main bycatch species of tuna purse seiner fisheries. To date, very little information is available of the biology and behaviour of those two species. The increasing importance of Fish Aggregating Devices (FADs) within the fishery has raised concern over the impacts of these devices on the pelagic ecology and populations of those bycatch species. In this study, acoustic telemetry was used to investigate the behavioural ecology of these two species around FADs. Three tuna purse seine FADs in the northern Mozambique channel were equipped with satellite linked acoustic receivers. Two *E. bipinnulata* and 13 *C. maculatus* were equipped with coded acoustic tags some of which had pressure sensors. The average Total Time of Association (TTA) with the FAD for *E. bipinnulata* was of 67 days and 21.5 days for *C. maculatus.* No departures lasting more than 24 hours were observed for both species. The diel pattern in vertical distribution of *E. bipinnulata* and *C. maculatus* where similar averaging 9.9 m (SD ± 11.7m) and 5.1 m (SD ± 9.2 m) during the night, 19.7 m (SD ± 14.1 m) and 10.1 m (SD ± 12.5 m) during the day, respectively. The high fidelity and limited vertical distribution of the two bycatch species studied confirms the high catchability by the FAD based purse seiner fishery.

Introduction

Elagatis bipinnulata (Bennet, 1840) and *Canthidermis maculatus* (Bloch, 1786) are two widely distributed species with a circumglobal distribution in the tropical and subtropical belt with the exception on the Mediterranean Sea for the latter. These two species share a coastal habitat associated with reefs but are also very abundant in the pelagic environment where they are known to aggregate under floating objects (Romanov 2002, Taquet et al. 2007, Gaertner et al. 2008). Their aggregating behaviour, wide distribution and abundance in the pelagic environment make these two species a major bycatch of the tuna purse seine fisheries (Romanov 2002) using Drifting Fish Aggregating Devices (DFADs). According to Romanov (2002), *E. bipinnulata* represents the most important bycatch in biomass on FADs whereas *C. maculatus* ranks as the 4th most important bycatch for this fishery in the Western Indian Ocean (WIO).

While much concerns has been raised on other FAD bycatch species such as sharks, turtles and juvenile tuna species, to date little attention has been given to *E. bipinnulata* and *C. maculatus.* Furthermore, the biology and ecology of these two species in the pelagic is generally poorly understood. Knowledge about their biology and behaviour is important to better understand pelagic ecosystems. Tropical tuna purse seiners deploy large numbers of FADs, with this strategy increasing in importance in the fishery since the mid-1980s (Fonteneau et al. 2000, Moreno et al. 2007). The impact of this increase on the ecology, biology and population status of these two species has largely been ignored to date. One objective of the European MADE project is to improve the current understanding of the behavioural ecology of these species in order to assess the impacts of FADs on their ecology. In this paper, we report the first results obtained from acoustic telemetry on these two species under this project.

Materials and methods

A scientific cruise was conducted in March 2010 in the northern Mozambique Channel. Three drifting FADs belonging to the European tuna purse-seiners fleet were instrumented with satellite-linked VEMCO VR4 Global acoustic receivers. These receivers utilise the Iridium satellite system to transmit data on the tagged individuals. During the cruise several species of pelagic fishes were caught and equipped with acoustic transmitters (Filmalter et al. 2010, Govinden et al. 2010) that were surgically implanted in the peritoneal cavity, following the methods of Dagorn et al. (2007). Amongst these fishes were 13 *C. maculatus* and two *E. bipinnulata* which were captured using baited hand lines and tagged with acoustic coded transmitters VEMCO V9 and V9P (containing a pressure sensor) (Table 1). Both *E. bipinnulata* were tagged at the same FAD (FAD #34), while the 13 *C. maculatus* were tagged at all three FADs (Table 1).

The temporal behaviour and fidelity to FADs were investigated at several scales. The Total Time of Association (TTA), defined as the period between the first and last detections, was calculated for all the tagged fish. We also calculated the Continuous Residence Time (CRT) which has previously been used (Ohta and Kakuma, 2004, Dagorn et al. 2007) to characterise the associative behaviour of several species that aggregate around FADs. The CRT is defined as the period of time that a tagged fish is detected by

the receiver without an absence of at least 24 hours (Ohta and Kakuma, 2004). We also defined the Fine-scale Continuous Residence Time (FCRT) (see Govinden et al. 2010) which corresponds to the period of time that a tagged fish is detected by the receiver without an absence of at least 1 hour. These FCRTs allow us to calculate the excursions of fish away from FADs. Hence, by definition, these excursions have a minimum duration of 1 hour. The distribution of times at which departures and returns from these excursions occurred was investigated to determine potential diel patterns of the *E. bipinnulata* and *C. maculatus* around the FADs.

The vertical behaviour of the two *E. bipinnulata* and eleven *C. maculatus* equipped with pressure sensitive tags was also examined. The mean depth (with standard deviation) during each hour of a 24-hour cycle was calculated for both species at all the FADs.

Results

The observations at the three FADs where artificially stopped due to failure in communication with the receiver. FAD #32 was fished which is likely to have caused the technical failure of the receiver. For FAD #31, it is very likely that the failure also came from a fishing set, but we have not been able to validate this information yet. FAD #34 was not fished so the technical failure certainly came from the receiver itself. As a result the observation lasted 67 d for FAD #34, 11.5 d for FAD #31 and 9.9 d for FAD #32 (table 1). The TTA for both *E. bipinnulata* on FAD #34 was 67.0 days which represents the total time of the observation as it was artificially ended. The average TTA for *C. maculatus* at FAD #34 was 39.6 d (SD ± 24.9 d) and 10.2 d (SD ± 1.4 d) for FAD #31. The TTA was of 9.9 d for the only individual tagged at FAD #32 and the overall average TTA for the three FADs was 21.5 d (SD ± 20.8 d). The maximum TTA for *C. maculatus*, observed for two individuals, was of 66.2 days (at FAD #34). It must be noted that the TTA is an underestimation of the true time of association as there is no way of knowing when the association with the FAD began, prior to tagging. Five natural departures were observed while the observation was artificially ended for the ten remaining fish (table 1).

No absences greater than 24 hours were observed in either of the species and hence all CRTs equal all TTAs.

A total of 313 FCRTs were observed for *E. bipinnulata*, the mean duration of these FCRTs was 16h39 (SD ± 46h24). For *C. maculatus*, a total of 261 FCRTs were observed with a mean duration of 8h42 (SD ± 12h24).

Table 1: Summary of all the fish tagged, Total Time of Association (TTA) and proportion of time of excursions from FAD by *E. bipinnulata* and *C. maculatus* at all FADs in the Mozambique channel . * Denotes when observation was artificially stopped

Species	Tag ID	FL	FAD #	Tag type	Date tagged	TTA		Total time of excursion	% of total excursion of TTA
E. bipinnulata	64804	45	34	V9P	08/03/10	67.0	*	14.0	20.9
E. bipinnulata	64805	43	34	V9P	08/03/10	67.0	*	14.7	22.0
C. maculatus	64806	39	34	V9P	09/03/10	66.2	*	4.5	6.7
C. maculatus	64807	34	34	V9P	09/03/10	12.5		0.6	5.1
C. maculatus	54305	31	34	V9	09/03/10	66.2	*	11.9	18.0
C. maculatus	54304	28	34	V9	09/03/10	26.8		1.1	3.9
C. maculatus	64808	30	34	V9P	09/03/10	26.4		0.1	0.5
C. maculatus	64810	33	31	V9P	15/03/10	11.5	*	0.2	2.1
C. maculatus	64811	33	31	V9P	16/03/10	7.3		0.0	0.0
C. maculatus	64813	31	31	V9P	16/03/10	10.8	*	2.1	19.1
C. maculatus	64814	32	31	V9P	16/03/10	10.8	*	0.6	5.7
C. maculatus	64815	33	31	V9P	16/03/10	9.3		0.3	3.5
C. maculatus	64816	33	31	V9P	16/03/10	10.8	*	0.1	0.8
C. maculatus	64817	33	31	V9P	16/03/10	10.8	*	0.2	1.7
C. maculatus	64809	32	32	V9P	14/03/10	9.9	*	0.0	0.0

E. bipinnulata spent an average of 21.4% of their TTA away from the FAD, whereas *C. maculatus* only spent an average of 5.2% of their TTA undertaking excursions. It is interesting to note that one *C. maculatus* from FAD #34 and one from FAD #31 spent considerably more time undertaking excursions than the rest of the group (17.9% and 19.5% of their TTA respectively)(Table 2).

The hourly distribution of the departures and returns from the excursion of *E. bipinnulata* clearly shows that this behaviour mainly occurs during the day (90% of the excursions occur during day light hours). This species shows a peak of departures around dawn and a peak of returns to FADs around dusk. *C. maculatus* performed 73% of the excursions during the day, although regular excursions at night were observed. The peak observed for the returns to FADs around dusk is actually due to one individual showing a pattern of regular returns every day that is not exhibited by the other individuals.
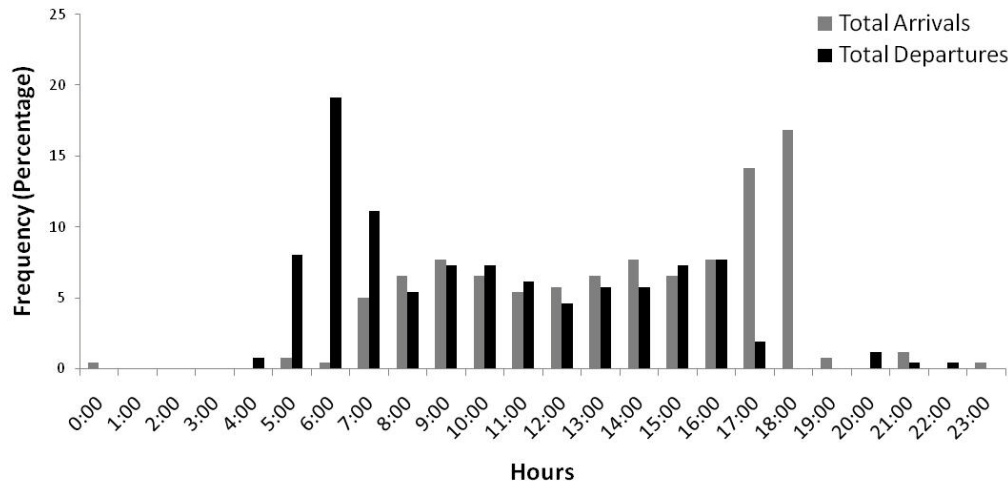
Figure 1: Frequency distribution (percentage) of departure and return events of acoustically tagged *E. bipinnulata* at three drifting FADs in the Mozambique Channel during each hour of a 24 hour cycle
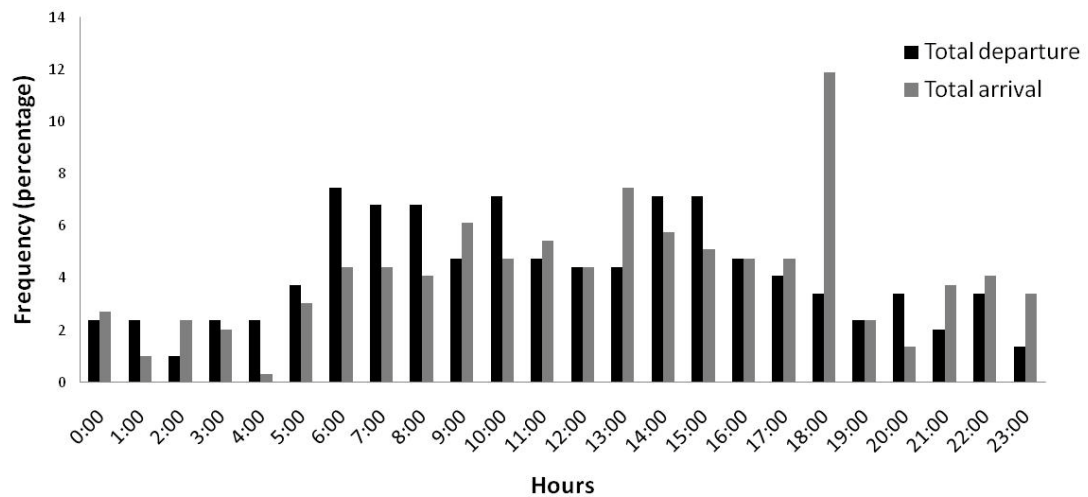

Figure 2: Frequency distribution (percentage)of departure and return events of acoustically tagged *C. maculatus* at three drifting FADs in the Mozambique Channel during each hour of a 24 hour cycle.

The mean duration of excursions for *E. bipinnulata* was 2h38 (SD ± 2h23) and 1h25 (SD ± 2h23) for *C. maculatus*. In both cases the majority of excursions lasted between 1 and 2 hours and represented 61 % and 85% of all excursions for *E. bipinnulata* for *C. maculatus* respectively. The longest excursion observed for *E. bipinnulata* was of 12h43 and 4h22 for *C. maculatus*.
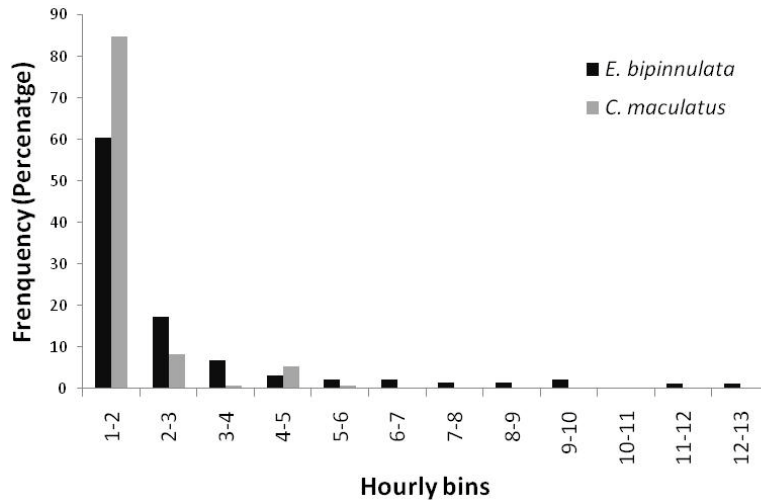
Figure 3: Frequency of the durations (percentage) of excursions of *E. bipinnulata* and *C. maculatus* at all FADs in the Mozambique Channel.

The overall patterns in vertical behaviour of *E. bipinnulata* and *C. maculatus* were very similar. The mean depth recorded over 24 h for the two *E. bipinnulata* was 9.9 m (SD ± 11.7 m) and 5.1 m (SD ± 9.2 m) for the eleven *C. maculatus* equipped with pressure sensitive tags. Both *E. bipinnulata* and *C. maculatus* were recorded deeper during the day than during the night. During the day, mean depths of *E. bipinnulata* and *C. maculatus* were 19.7 m (SD ± 14.1 m) and 10.1 m (SD ± 12.5 m) respectively. The high standard deviations are a result of large variation in vertical distribution, due to the numerous spike dives performed during the day by each species. Conversely, both species were generally distributed shallower at night with a mean of 6.7 m (SD ± 8.7 m) for *E. bipinnulata* and 1.8 m (SD ± 2.5 m) for *C. maculatus*. Less variation in depth was observed at night for both species (Figure 4 and Figure 5). After sunrise, a noticeable change in vertical distribution and variation was observed for both species (Figure 4 and Figure 5). The maximum depth observed for *E. bipinnulata* was of 81 m which was similar to that of *C. maculatus* 79 m.
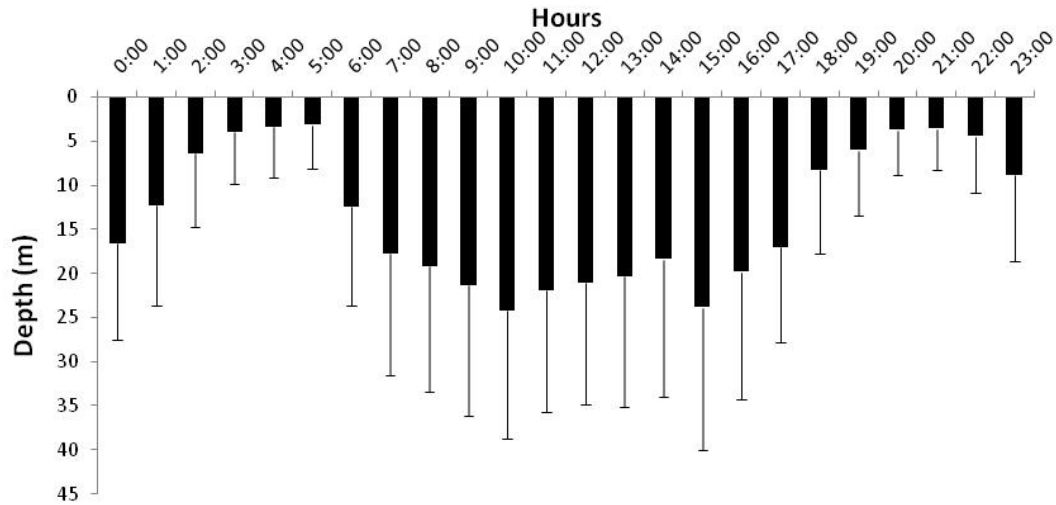
Figure 4: Mean hourly depths over a 24 hour cycle of *E. bipinnulata* at FAD #34 in the Mozambique Channel. Error bars represent standard deviation.
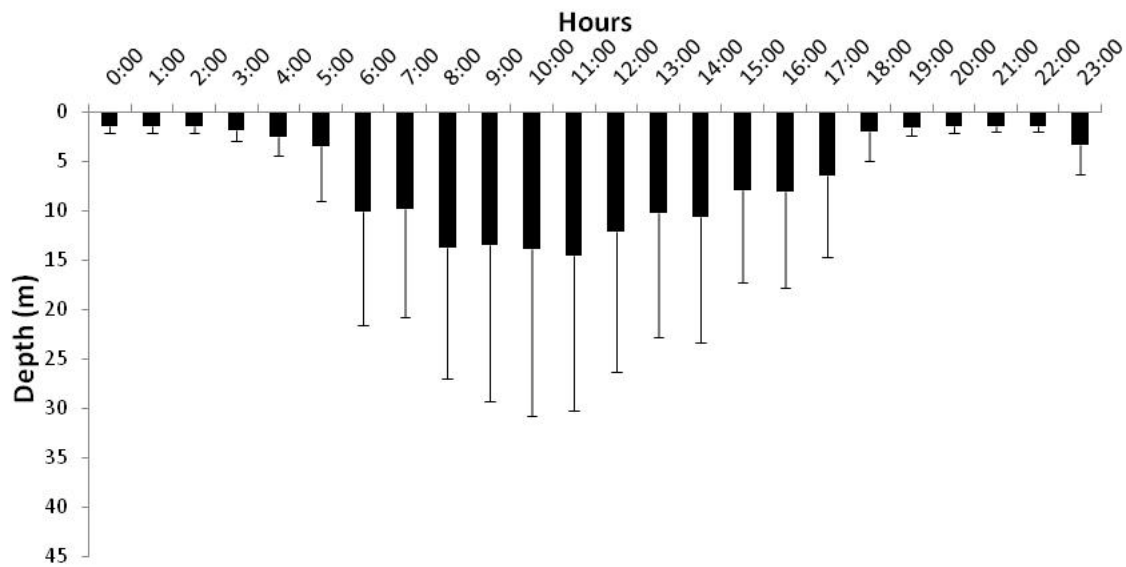

Figure 5: Mean hourly depths over a 24 hour cycle of *C. maculatus* at all three FADs in the Mozambique Channel. Error bars represent standard deviation.

Discussion

Dagorn et al. (2007) used acoustic telemetry to collect the very first data on time of association of *C. maculatus* with FADs (with 6 individuals tagged), but no detailed information on the behaviour of the individuals while at FADs was provided in this paper. To our knowledge, this is the first study providing data on the behaviour of *C. maculatus* and *E. bipinnulata* around drifting FADs.

The TTA recorded for the *E. bipinnulata* and *C. maculatus* were the longest times of association with DFADs recorded to date for any species. Dagorn et al. (2007) measured a maximum TTA of 15 days for *C. maculatus*, *Thunnus albacares* and *Coryphaena hippurus* at drifting FADs. Schaefer and Fuller (2010) recorded a maximum of 24 days at drifting FADs for *Thunnus obesus*. On anchored FADs, the maximum time of association was recorded for *T. albacares*: 55 days by Ohta and Kakuma (2004) and 64.7 days by Dagorn *et al.* (2007). The very long TTA and the lack of 24-hour departures of our tagged fish show that *E. bipinnulata* and *C. maculatus* associate very strongly to FADs. Considering the very long times of associations, it is clear that floating objects play a major role in the ecology of these species.

Most of the short excursions (> 1 hour) undertaken by the two studied species were found to be between one and two hours. It is interesting to note that despite having similar fidelity behaviour, *E. bipinnulata* was found to undertake more excursions with longer duration on average than *C. maculatus* did, suggesting a more dynamic horizontal distribution around FADs. According to the VEMCO tag characteristics, the V9 tags used for this study have a range of 300 – 400 m (depending on weather conditions). Our interpretation of 'FAD association' is limited by the range of our equipment; however absences of an hour or more from the FAD strongly suggest the existence of significant excursions away from the FAD. The observed excursions mainly took place during the day and might be a result of interaction with other species in both predator and prey scenarios. A diet study is currently underway to understand the feeding ecology and which, along with further tagging, will help us understand the ecology of the two studied species better.

The vertical behaviour patterns observed under the FADs by the two studied species were similar, with shallower distributions during the night and deeper distributions during daylight hours. Individuals of both species were observed to perform dives down to 80 m. The combination of high FAD fidelity and relatively shallow vertical distribution clearly shows that *E. bipinnulata* and *C. maculatus* have a very high catchability by the extensive and deep (150-200 m) nets used by the purse seiners, which explains why they are among the main bycatch species of this fishery.

Further studies (including more tagged individuals and diet studies) are clearly needed to better understand why these species associate with FADs. The comparison of the behaviour of different species at FADs (tunas, sharks, other bycatch species) will provide new insights and improve our understanding of these multispecies aggregations. Moreover, it is necessary to study whether FADs could act as ecological traps for these two species, although this hypothesis has only been advanced for tropical tunas thus far (Marsac et al. 2000, Hallier and Gaertner 2008).

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