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Fishing in the dark: the importance of integrating a nocturnal component into recreational fishing surveys

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ABSTRACT: To get a complete picture of how fish assemblages are affected by recreational fishing it may be necessary to combine daytime and nocturnal sampling. Most of the scientific literature on recreational fishing, however, neglects the nocturnal component. Discrepancies between daytime and night-time catches in a shore angling fishery in the mid-Atlantic were investigated in this study. Significant diel patterns in catch composition, fish sizes, and catch rates were detected. Catch diversity was lower at night, although the species profile overlapped by 35.9%. Different fish sizes were targeted by the fishery when night and day periods were compared. Larger specimens of some commercially important species, e.g. *Pseudocaranx dentex*, were also caught at night. Findings highlight the importance of evaluating differences between day and night catches before defining a sampling design of a recreational fishing survey. If significant differences in diel patterns exist, the incorporation of a nocturnal component is necessary to avoid misrepresentation of the diversity and quantification of catch composition.

KEY WORDS: Diel patterns · Index of fish vulnerability · Nocturnal fishing · Shore angling · Roving creel survey

INTRODUCTION

Marine recreational fishing is a globally popular leisure activity, involving a large number of participants, broadly dispersed in time and space with no central landing point. It is challenging for scientists and managers to gather reliable catch and effort data (Sullivan et al. 2006). Although recreational fisheries are far less monitored than commercial fisheries, awareness has been gradually increasing among fisheries scientists and managers of the importance of collecting recreational catch and effort data. Several studies underline the impact that recreational fishing has on marine fish stocks (Coleman et al. 2004, Cooke & Cowx 2004, Ferter et al. 2013, Diogo & Pereira 2013, 2014).

Accurate estimates of fishing effort and catch are crucial for the work of scientists and fisheries managers. Recreational fishing survey methods can be sub-divided into 2 main branches: the first focuses on fishing effort that can be estimated using strategies such as permit records (if permit systems exist), aerial flights over geographically limited areas, or mail and telephone surveys for large-scale studies; the second focuses on evaluating catch rates and species composition using on-site surveys based on interviews with recreational fishers, or off-site systems where fishers declare their daily catches through diaries or web-based declarations (Sullivan et al. 2006).

An important portion of scientific literature on recreational fishing is based on on-site surveys, generally using 'roving creel' or 'access point' survey

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methods (Pollock et al. 1997). These types of survey method, however, typically focus on daylight fishing, since night fishing surveys raise concerns for the safety of field agents and increase survey costs (Sullivan et al. 2006). Furthermore, survey operators may assume that a daylight fishing survey represents the fishery adequately. Overlooking night fishing can be a source of bias in survey programs due to potential differences in catch rate, species composition, species vulnerability and fish sizes. It is of high importance to assess whether nocturnal fishing has significant implications for vulnerable species or susceptible life stages of certain species. Despite their importance, diel patterns are often neglected by scientific studies. This study aims to assess the potential bias of omitting nocturnal fishing in recreational fishing surveys. For this purpose, a secondary temporal stratification was incorporated into a roving creel survey sampling frame to evaluate the difference between nocturnal and diurnal marine shore angling in terms of species composition, fish sizes, index of fish vulnerability and catch rate.

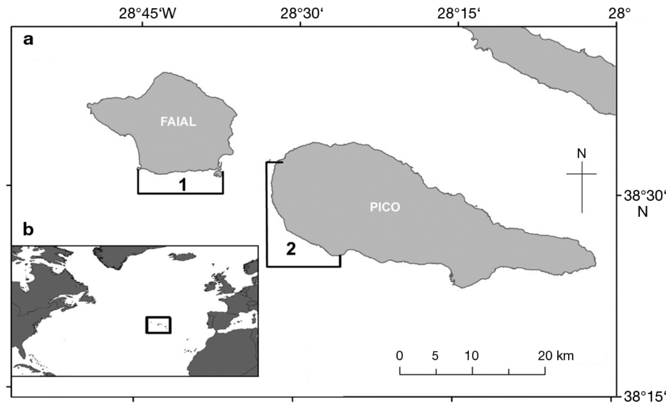

Fig. 1. Study area of (a) Faial and Pico islands and (b) the location of the Azores in the North Atlantic Ocean (black rectangle). The spatial units where the nocturnal and diurnal data were collected within a roving creel survey design are identified as 1 and 2

METHODS

This study was conducted in Faial and Pico islands, Azores archipelago, North Atlantic Ocean (Fig. 1). A secondary temporal component was designed in roving creel surveys used by Diogo & Pereira (2014), who estimated daylight fishing effort and catch for shore angling, to account for night-time catches. The field work was conducted from September 2004 to August 2005 over a total of 115 sampling days (see Table S1 in the Supplement at www.int-res.com/articles/suppl/m542p187_supp.pdf). A stratified monthly sampling design was used that considered the following strata: (1) day type (week day/weekend); (2) period of the day (morning, afternoon and night); and (3) spatial units. The original daylight temporal component sampled the entire coastline, with Pico Island divided into 5 spatial units and Faial into 4 (see Diogo & Pereira 2014). Owing to logistical and budget constraints, nocturnal surveys were only conducted in 2 spatial units (one in Faial and the one in Pico Island; Fig. 1). Only daylight data collected in the same spatial units (Fig. 1) were used for comparisons, the rest of the daylight sampling data were removed from the analysis. The monthly daylight sampling design was random: 2 replicates for each combination of week day/weekend and day/night strata were sampled in each spatial unit (with the duration of approximately 2.6 h in Faial and 3.0 h in Pico), in which the observer surveyed 2 different, randomly chosen spatial units during one day (one in the morning, one in the afternoon) (Diogo & Pereira 2014). Dates of night surveys were chosen randomly, requiring a third visit to a spatial unit. The survey direction was selected randomly, with random starting times in each combination. The interval for night roving creel surveys was set between 30 min after sunset and 03:00 h because preliminary surveys indicated that shore anglers were typically less active between 03:00 h and dawn. During the circuits, recreational fishers were documented and quantified, and their position subsequently plotted within a GIS. Shore anglers were typically distributed diffusely along the coastline, facilitating sampling of the majority of anglers. In areas where recreational fishers tended to concentrate (e.g. harbours), a minimum of 25% of the anglers were randomly selected to be interviewed. Interviews included the fishers' personal details (i.e. residence, age), the gear used and the objective of the catch. Analyses of the retained catches included species identification and size measurement (fork length) of all specimens. Discards were estimated but were relatively low (4.6% of total catch) and thus not included in the analysis. The total weight of the catch was extrapolated using species-specific weight–length relationships (Morato et al. 2001, Froese & Pauly 2013).

To account for incomplete trips, the catch per unit effort (CPUE) was calculated by the mean-of-ratio estimator, expressed as the mean of individual ratios of catch in number and biomass divided by the effort of each angler (Pollock et al. 1997). A total of 29 fishing operations of <30 min were excluded for reducing the variance, following Pollock et al. (1997). The CPUE in number ($CPUE_n$) and weight ($CPUE_w$) were calculated and compared for the nocturnal and diurnal periods. Fishing effort and catch estimation formulas were adapted from Reid & Montgomery (2005) (Table S2).

The index of intrinsic vulnerability of marine fishes is based on life history and ecological characteristics, and ranges from 1 to 100, distinguishing 4 levels of vulnerability: low [1, 40[, moderate [40, 60[, high [60, 80[, very high [80, 100] (Cheung et al. 2007). The values of intrinsic vulnerability for the sampled catch were obtained from Cheung et al. (2007) or, if species information was not available, from Froese & Pauly (2013). The arithmetic mean of the intrinsic vulnerability was computed for each trip.

Diel fish composition structure was analysed with multivariate statistical techniques using the PRIMER software package (Plymouth Marine Laboratory; Clarke & Warwick 2001). $CPUE_n$ (number of fish for each species caught per fisher hour) was used as a proxy of species abundance. A fourth root transformation was used to reduce the influence of prevalent species and increase the weight of rare species (Vroom & Braun 2010) and a Bray-Curtis resemblance matrix was created using PRIMER-E (Clarke & Gorley 2006) with the add-on package PERMANOVA+ (Anderson et al. 2008). A 4-way mixed model PERMANOVA (maximum permutations = 999) was used, with diel period (night and day), day type (week day and weekends/holidays), season (spring, summer, autumn, winter) and island (Faial and Pico) as factors. When significant main test effects were identified, pairwise tests were done to determine which factors were responsible for significance. A similarity percentage (SIMPER) analysis was performed to identify major fish taxa that contributed to dissimilarities between diurnal and nocturnal assemblages. Diel differences of $CPUE_{n/w}$ and intrinsic vulnerability to fishing were analysed with a Mann-Whitney *U*-test, and diel differences of mean sizes of 4 fish species were analysed with a *t*-test using STATISTICA version 6.0 (StatSoft 2001).

RESULTS

A total of 381 interviews were completed (82.9% day, 17.1% night) with a low refusal rate (5% day, 2% night). The overall $CPUE_w$ showed similar mean values for day and night (0.68 ± 1.05 and 0.63 ± 1.03, respectively), and no significant differences were found (Mann-Whitney *U*-test: U = 6465, $p > 0.05$; Fig. 2). The overall $CPUE_n$ was much higher for daylight fishing than night fishing (5.5 ± 7.8 and 2.2 ± 2.1, respectively), and significant differences were found (Mann-Whitney *U*-test: U = 5264, $p < 0.05$; Fig. 2). Four species were identified as common in nocturnal and diurnal fishing and were abundant in the catches. The size distribution of each of these species differed between temporal components. Mean larger specimens were caught at night of *Pagellus acarne* (day: 11.1 ± 3.5, night: 20.2 ± 2.9; 2-sample *t*-test: $t = -8.66$, $p < 0.05$), *Pseudocaranx dentex* (day: 26.2 ± 11.1, night: 52.5 ± 2.9; 2-sample *t*-test: $t = -4.61$, $p < 0.05$) and *Diplodus sargus* (day: 17.9 ± 6.2, night: 19.5 ± 5.7; paired *t*-test: $t = -2.48$, $p < 0.05$), while the mean typical size of *Trachurus picturatus* was similar in both periods (day: 12.0 ± 2.8, night: 12.0 ± 2.5; 2-sample *t*-test: $t = 0.02$, $p > 0.05$; Fig. 3).

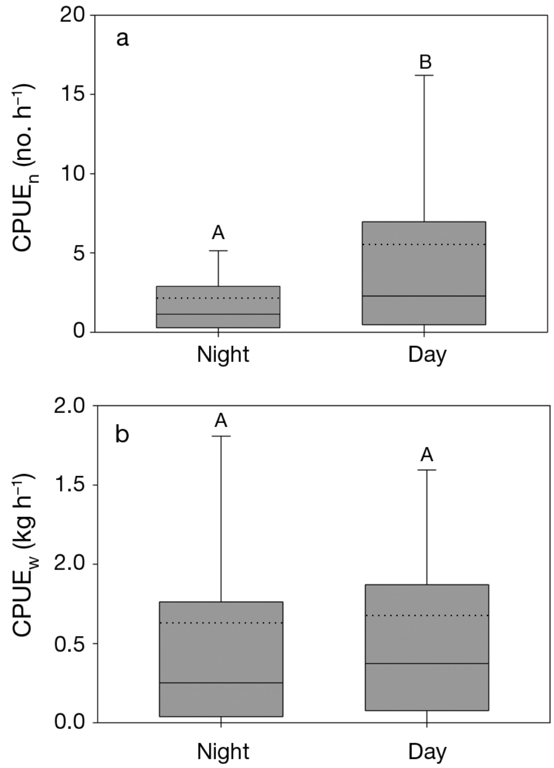

Fig. 2. Catch per unit effort (CPUE) in (a) number ($CPUE_n$) and (b) weight ($CPUE_w$) for shore angling during the diurnal and nocturnal periods. Mean and median lines are represented by dotted and solid lines, respectively. Upper and lower limits of boxes represent the 25th and 75th percentiles, whiskers above the box indicate the 5th and 95th percentiles, and solid line represents the average. Different upper-case letters correspond to significant differences between day/night periods (Mann-Whitney *U*-test)

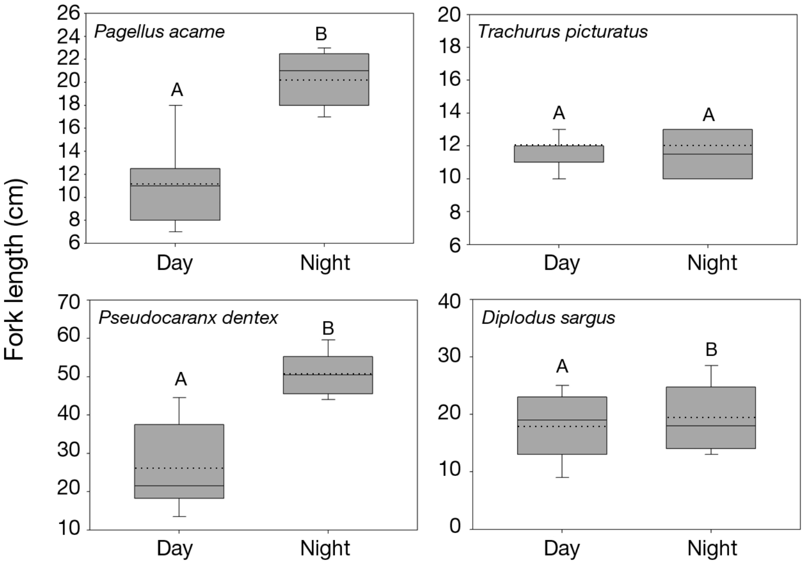

Fig. 3. Fork length of fish captured by shore angling during diurnal and nocturnal periods. Mean and median lines are represented by dotted and solid lines, respectively. Upper and lower limits of boxes represent the 25th and 75th percentiles, whiskers above the box indicate the 5th and 95th percentiles, and solid line represents the average. Different upper-case letters correspond to significant differences between day/night periods (paired *t*-test)

The mean intrinsic vulnerability (IV) of night and day fishing were comparable (Mann-Whitney *U*-test: $U = 3119$, $p > 0.05$; Fig. 4).

A total of 39 taxa belonging to 23 families were recorded, of which 30 formed the diurnal assemblage, 23 the nocturnal assemblage and 14 species were common in both (see Table S3 in the Supplement at www.int-res.com/articles/suppl/m542p187_supp.pdf). Overall, the most represented family were Sparidae (7 species), followed by Labridae (5 species). During the day, the most represented families were Sparidae, Scaridae and Carangidae (40.4, 12.3 and 7.0%, respectively), while Sparidae, Carangidae and Muraenidae (56.0, 20.6 and 7.4%, respectively) were the more frequently represented families during the night. Within the diurnal assemblage, *D. sargus* (28.7%) was the most prominent, followed by *Chelon labrosus* (23.5%) and *Sparisoma cretense* (12.3%). Within the nocturnal assemblage, the most-represented species was *D. sargus* (47.9%), followed by *P. dentex* (17.1%) and *P. acarne* (6.5%). PERMANOVA found significant differences in catch composition between day and night and between seasons ($p < 0.05$; Table 1). Interactions of diel pattern with season, diel pattern with day type and island with season were significant.

SIMPER analysis revealed that 14 species individually contributed >1.8% to the dissimilarity between nocturnal and diurnal captures. A total of 8 fish species (*S. cretense*, *Thalassoma pavo*, *C. labrosus*, *Sarpa salpa*, *Pagellus bogaraveo*, *Balistes capriscus*, *Serranus atricauda* and *Trachinotus ovatus*) were clearly more numerous during the day, while only 3 taxa (*P. acarne*, *Apogon imberbis* and *T. picturatus*) were more abundant during the night (Table 2).

DISCUSSION

This study highlights the importance of considering a nocturnal sampling component in the design of on-site recreational fishing surveys, when there is evidence of considerable differences between day and night catches. The findings of this study support this thesis, as catch composition differed significantly between day and night in the Azores. During night, catch diversity was lower, in congruence with studies in the Mediterranean that used visual census for analysing shallow-water fish assemblages (Azzurro et al. 2007). Diel variation in Azorean species composition and abundance was apparent. Several species were only registered at night (e.g. *Priancanthus arenatus*, *Phycis phycis*, *Gaidropsaurus guttatus*

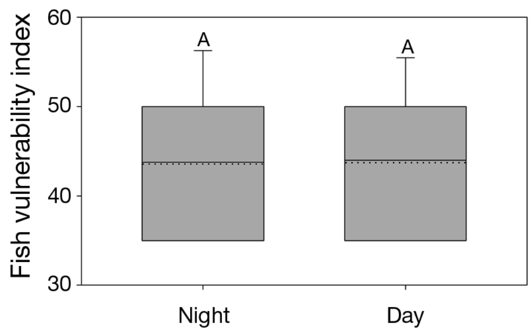

Fig. 4. Intrinsic vulnerability of fish captured by different commercial and recreational fishing methods. Mean and median lines are represented by dotted and solid lines, respectively. Upper and lower limits of boxes represent the 25th and 75th percentiles, whiskers above the box indicate the 5th and 95th percentiles, and solid line represents the average. Different upper-case letters correspond to significant differences between day/night periods (Mann-Whitney *U*-test)

Table 1. PERMANOVA main test. Di: diel; Is: island; Da: day type; Se: seasonality; Res: residual

Source	df	SS	MS	Pseudo-*F*	p (perm)	Unique perms
Di	1	8539.3	8539.3	2.5648	0.021	995
Is	1	2692.1	2692.1	0.80856	0.584	999
Se	3	29316	9771.9	2.935	0.001	998
Da	1	2361.7	2361.7	0.70933	0.681	998
Di × Is	1	3974.1	3974.1	1.1936	0.288	999
Di × Se	3	32786	10929	3.2824	0.001	998
Di × Da	1	3160.9	3160.9	0.94937	0.469	999
Is × Se	3	16325	5441.5	1.6343	0.032	998
Is × Da	1	3533.1	3533.1	1.0611	0.379	999
Se × Da	3	9859.8	3286.6	0.98713	0.49	997
Res	197	6.5591×10^5	3329.5			
Total	215	8.058×10^5				

Table 2. SIMPER analysis presenting fish species that contributed most (ranked in order of decreasing percentage) to the dissimilarity between nocturnal and diurnal assemblages and average abundance on the 2 sampling periods. Average dissimilarity between diurnal and nocturnal assemblages = 83.25

Species	Dissimilarity contribution (%)	Average abundance Day	Night
Diplodus sargus	18.63	0.64	0.64
Trachurus picturatus	7.40	0.15	0.22
Pagellus bogaraveo	7.13	0.33	0.06
Pagellus acarne	5.16	0.03	0.19
Trachinotus ovatus	4.58	0.19	0.04
Sarpa salpa	3.92	0.16	0.02
Sparisoma cretense	3.70	0.11	0.00
Chelon labrosus	3.25	0.16	0.00
Serranus atricauda	2.65	0.10	0.02
Boops boops	2.64	0.09	0.02
Thalassoma pavo	2.61	0.15	0.00
Balistes capriscus	2.14	0.07	0.00
Apogon imberbis	1.79	0.00	0.08
Pseudocaranx dentex	1.77	0.02	0.05

and *Apogon imberbis*) and others only during day (e.g. Labridae). During day, some nocturnally active taxa exhibit cryptic behaviour, sheltering in holes and crevices (Azzurro et al. 2007). In contrast, diurnally active species, such as pomacentrids and labrids, were not registered in night catches as these taxa appear to restrict feeding to daylight hours and seek cover at night (Rooker et al. 1997). In conclusion, in the Azores and probably in many areas of the world, it is necessary to combine daytime with nocturnal surveys to fully understand how fish assemblages are affected by recreational fishing, and to compute an accurate estimation of catch breakdown per species in weight and number. More robust nocturnal sampling, however, should fully validate this result in future studies.

In addition, the importance of night surveys is shown by diel differences in fish sizes. Larger *Pseudocaranx dentex*, *Diplodus sargus* and *Pagellus acarne* were registered during the night, while smaller specimens were registered during day, indicating nocturnal migration of larger specimens to shallow waters. Such patterns have been observed for *P. dentex* in the study area using active telemetry (J. Fontes unpubl. data) but also for other predator species (Nash et al. 1994). Wolter & Freyhof (2004) identified nocturnal inshore migrations of large-sized individuals as a general behavioural pattern in some temperate waters that have been linked to the need to avoid predators, and to trophic advantage (Rooker et al. 1997, Reebs 2002) or spawning (Ferraro 1980). The findings of this study suggest that on-site surveys that exclusively use daylight sampling can produce underestimations of mean fish sizes. Accurate harvesting size information is important for fisheries managers to understand the level of demographic pressure exerted by fisheries (Pinho et al. 2014).

Significant differences in $CPUE_n$ indicate distinct dissimilarities in species composition between day and night catches. In particular, Labridae and Pomacentridae species were absent during night, similar to patterns observed by visual censuses in the Mediterranean Sea (Azzurro et al. 2007). Results of diel catch rate in number and weight are concordant with studies from the same study area (Porto Pim Bay, Faial island; Nash et al. 1994). Daylight $CPUE_w$ may be used as a proxy for nocturnal harvest calculations since no diel differences were detected. However, this would not provide a true picture of the nature of the fishery (i.e. catch composition) during the night period. The shore angling fishery typically caught specimens that have low vulnerability to fishing, independently of day–night context, which means that this fishery is targeting short-lived, fast-growing species with higher reproductive potential. In comparison, shore angling is less of a causal factor in coastal ecological imbalances than other recreational fishing modalities (e.g. spearfishing; Lloret et al. 2008, Diogo & Pereira 2013).

The development and improvement of recreational fisheries survey methods is challenging for fisheries scientists and, despite many available methodological approaches, each is coupled with well-known biases (Sullivan et al. 2006). In particular, the on-site method applied in this study (roving creel survey) has known biases, namely the length-of-stay bias that affects the variance of the catch rate (and is usually reduced by using complementary surveys such as access point surveys; Pollock et al. 1994) or the effect of the angler skill and environmental conditions (Hoenig et al. 1997). Given these potential biases, the catch rates used as a proxy of species abundance index in the PERMANOVA analysis have to be considered with some caution. The results, however, indicate that in certain locations and recreational fishing modalities, the consequences of neglecting the nocturnal component in the design of a recreational fishing survey can increase the bias dramatically.

The methodological development and improvement of nocturnal recreational fishing surveys are still worth undertaking, since it is obvious that several on-site methods are difficult to apply at night. Such constraints were evident in this study by the limited amount of nocturnal surveys due to budget and operational constraints. Other potential limitations are terrain characteristics, survey method limitations (e.g. aerial surveys) or concerns for the safety of survey staff (Sullivan et al. 2006). Some authors suggest that the best way to design night surveys is based on off-site surveys (e.g. telephone and mail survey for licensed anglers), yet these methods raise a high number of complex problems usually coupled with data validation, recall bias (Lyle et al. 2002, Sullivan et al. 2006) and cooperation of the fishers.

The need to incorporate a nocturnal component in recreational fisheries surveys can be more evident in places where nocturnal species composition is influenced by factors such as moon phases and tidal cycle (Ramos et al. 2011, Lacerda et al. 2014). These circumstances may influence nocturnal catch rates and fishing effort, and need to be considered in the sampling design, and catch and effort estimations. Furthermore, nocturnal fishing can be relevant for some vulnerable and/or economically important marine species, because they are either nocturnally active species or are diurnal species that reside at night in predicable locations, making them easily harvested through methods such as night spearfishing (Hamilton et al. 2012). To date, the vast majority of scientific publications using on-site recreational shore angling surveys have only assessed the level of night fishing by extrapolation from daylight interviews, rather than direct sampling (e.g. Rangel & Erzini 2007, Veiga et al. 2010, Font & Lloret 2011). However, owing to the results presented here, it is recommend that recreational surveys use pilot studies to evaluate the level of differences between day and night catch rates, species composition and fish sizes before finalizing the study design. Otherwise, without fully considering the nocturnal components of fisheries, managers and fisheries scientists may be fishing in the dark.

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