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Research Article

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Human-Driven Effect on the Escape Responses of Two Commercially Important Coastal Fish Species

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Abstract

Objective: In this study we investigated the behavioral responses of two coastal Mediterranean sea breams (*Diplodus sargus* and *Diplodus vulgaris*) to the potential threat represented by an approaching diver.

Methods: Fish reaction to diver presence was assessed using flight initiation distance (FID) as behavioral metric. During each scuba diving trial, we also recorded i) fish size and group size, ii) fish behavior before and after the flight, iii) the abiotic context (depth and bottom slope) at the sighting location.

Results: Our results indicated that FID of *D. sargus*, which is more heavily targeted by spearfishers, was higher than that of *D. vulgaris*. In both species, no significant linear relationships between FID and body size, group size and depth were detected. The pre-flight behavioral patterns exhibited by these species were quite similar. “Tacking” was the most common behavior observed where fish halted activity and slowly swam away from the observer. The escape in open water was the most frequently adopted post-flight behavior by both species. The proportion of fish hiding into a shelter after fleeing was higher in *D. sargus* than *D. vulgaris*.

Conclusion: The knowledge of the human-driven modifications in the behavior of sea breams and other exploited species using FID measurements is a valuable tool to inform management about the impact of certain anthropic activities (e.g. spearfishing) on these resources and to assess the effectiveness of enforced protection measures.

Keywords

Fish behavior; Escape response; Flight initiation distance; Spearfishing; Sea breams; Mediterranean Sea

Introduction

Appropriate response to predation risk allows prey species to enhance their fitness and reproductive success [1,2]. Escape response is one of the most common strategies to avoid predation both in terrestrial and aquatic animals [1,3,4]. The behavioral pattern controlling the escape responses encompasses behavioral and kinematic components (e.g. reaction distance and locomotor performance, respectively). Each of these components potentially contributing to escape success is influenced by a variety of biotic and abiotic factors (e.g. presence of conspecific shoals, distance to shelter) contextualizing the environment around the prey [4].

Behavioral studies on escape responses have been mainly focused on reaction distance usually indicated as flight initiation distance (FID), in line with the terminology used by Ydenberg and Dill [1]. According to the economic hypothesis of Ydenberg and Dill [1], FID can be seen as a trade-off between the relative cost (lost foraging opportunities) and benefits (avoiding predation) of escaping. FID, defined as the distance between the prey and a potential predator at which the prey starts to flee, can vary depending on a variety of biological and environmental factors. Refuge availability has been demonstrated to have a significant effect on FID: animals near a potential refuge usually fled at shorter distances, likely due to a refuge-based perception of safety [3,5,6].

The influence of prey size on FID has been investigated in different fish species providing contrasting results. In a field work on parrotfishes, Gotanda et al. [6] observed a positive relationship between FID and fish size, indicating the size-related increase of reproductive value as a reasonable explanation. Similar results were observed in two labrid species targeted by spearfishing by Nunes et al. [7]. Conversely, Feary et al. [8] found no significant effect of fish body size on FID in six out of the seven investigated reef fish species. Difficult to predict is also the effect on FID of the presence of neighbors, usually related to a schooling behavior, because of the conflicting influences of variables (enhanced overall vigilance and risk dilution) associated with schooling [4]. Available data on fishes showed usually that larger groups resulted in smaller FIDs [3]. On the other hand, Januchowski-Hartley et al. [9] reported a significant effect of grouping in only one out of seven coral reef fish families, with larger groups being associated with higher FID. Experimental evidences revealed that the rate of previous experience with predators, which amplify the prey’s perception of risk, may exert a significant effect on FID: more experienced prey fishes frequently exhibited longer FIDs [3,10-12].

The behavioral changes determined in marine fishes by the prey-predator interaction with humans have received attention by scientists only recently. The effects of fishing (both professional and recreational activities) on fish behavior were mostly investigated in coral reef ecosystems [6-9,13-15], whereas few works have been performed in temperate seas [16]. The most evident changes in fish behavior due to fishing have been observed in those species actively targeted by spearfishing [6-9,13,14]. In these fishes, the perception of a diver's presence as a threat seems to be strengthened by the direct (lethal or non-lethal) interaction with spearfishers. A positive relationship between fishing pressure and wariness of fishes belonging to the most commonly spearfished families has been reported by Januchowski-Hartley et al. [9].

In the Mediterranean Sea, the white sea bream (*Diplodus sargus*) and the two-banded sea bream (*Diplodus vulgaris*) are commercially important species heavily exploited by artisanal and recreational fisheries [17,18]. An extensive analysis of catches during spearfishing competitions revealed that 30%-40% of total catches was represented by *D. sargus*, whilst the contribution of *D. vulgaris* was negligible

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[19,20]. The two sea bream species are conversely very valuable targets for recreational spear fishers [19,21]. Due to their frequent occurrence also at shallow depth, both *D. sargus* and *D. vulgaris* are thus suitable species to evaluate the antipredator responses of fishes to human.

In this study, the behavioral responses to a threat represented by humans (e.g. an approaching diver) were investigated in two sea bream species, *D. sargus* and *D. vulgaris,* with similar habitat requirements. Specifically, we aimed to address the following research questions: 1) are there differences in FID, pre-flight and post-flight behavior between the investigated species? and 2) what are the effects of some biological and environmental factors, such as fish size, group size and depth on FID estimates?

Materials and Methods

Study area

The study area is located along the northeastern coast of Sardinia (Italy, Central Mediterranean) in the Strait of Bonifacio (Figure 1). This area is frequently exposed to sea waves (the prevailing winds blow from the NW direction) and characterized by high hydrodynamism. The stretch of coast between Capo Testa and Punta Falcone is characterized by shallow-water inlets and bays bordered by granitic rocky cliffs. The infralittoral rocky bottoms, covered by photophilic algae or characterized by the presence of large granite blocks, extend from the coastline to 15-20 m depth; below this depth they are followed by soft seafloor (sand or gravel). The seagrass *Posidonia oceanica* forms large patches of meadows, from few meters to 35 m depth. Surveys were performed in June 2017 at two locations, namely Punta Contessa-Municca and Punta Falcone-Marmorata, which were comparable in terms of coastal geomorphology (both areas encompass a promontory and some small islets) and level of exploitation as fishing grounds. Moreover, these locations are placed within a coastal area of great interest due to its future establishment as marine protected area.

Different types of fishing activities, both professional (artisanal) and recreational (including line and spearfishing), are practiced along these coasts. The professional fishery sector operates all year round with fixed gears (nets, longlines, pots), whereas the number of recreational fishermen increases during summer months.

Data collection

The behavioral responses of sea breams to a potential threat were evaluated by the flight initiation distance or FID (i.e. the distance from a threat at which the fish begins to flee) using SCUBA diver's presence (a surrogate for a spearfisher) as stimulus for the escape reaction. The experimental trials were conducted using a minimum starting distance (i.e. the distance between the observer and the focal fish when the trial began) of 10 m, which we considered presumably greater than the FID of the target species. All trials were performed according to the following protocol. Once a suitable fish had been

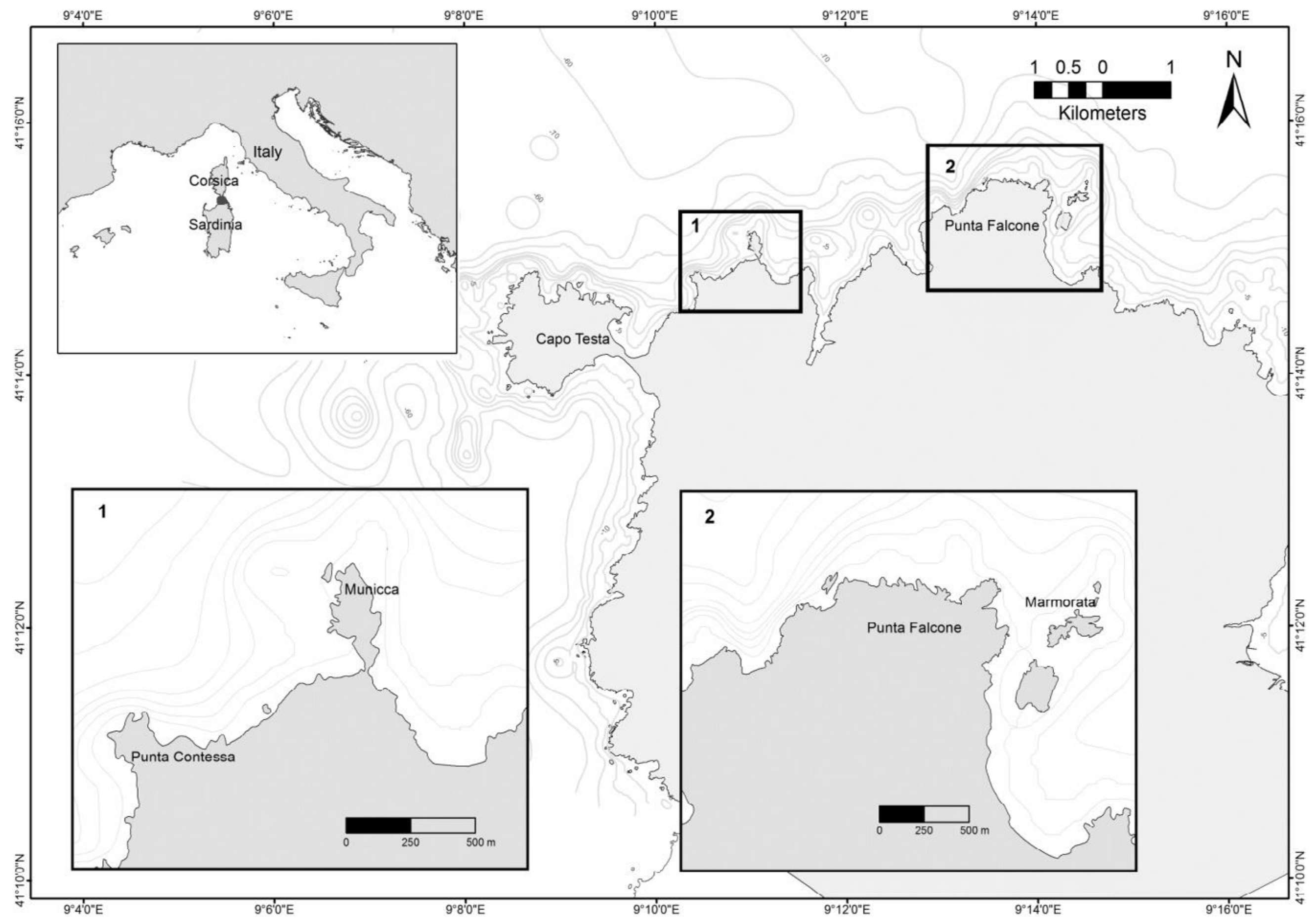

Figure 1: Map of the study area located along the northeastern coast of Sardinia (Italy, Central Mediterranean), with an enlarged view of the surveyed locations.

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sighted, the observer remained still for a short period (approximately 10 seconds), ensuring that the fish did not adopt specific behaviors related to predator-prey or competitive interaction, mating rituals or the defense of a territory. After this period, the observer swam at a steady speed (about 1 m/s) heading toward the target fish, maintaining the same depth as it. When the fish began the escape reaction, usually indicated by an increase in speed and a change in direction, the observer dropped a weighted marker on the bottom under his head [6]. A second marker was then dropped on the point where fish originally fled from. The distance (cm) between the two markers was then measured and recorded as FID.

During each individual trial, the following variables were also recorded: i) fish size (total length, TL) and group size (i.e. the number of conspecifics within a radius of 3 m from the focal fish), **i**i) fish behavior before the flight, using a set of predetermined behavioral categories (Table 1) [9,15], iii) fish behavior after the flight (i.e. whether they escaped into open water or hid into a shelter) [16] iv) the abiotic context at the location from which fish fled (depth and bottom slope). Only fishes greater than 10 centimeters (cm TL) were considered, because spearfishers usually do not target individuals under this size. All trials were carried out within 5-25 m depth range, between 10:00 am and 16:00 pm and with good sea-weather and underwater visibility conditions.

Data analysis

Univariate differences in FID between fish species and locations were tested by a two-way analysis of variance (ANOVA), according to an experimental design consisted of factor Species (2 levels, fixed) and Location (2 levels, fixed and crossed with Species). Prior to running ANOVAs, homogeneity of variances was tested by Levene's test and, whenever necessary, data were transformed and newly tested. If the assumption of homogeneity was not met, a setting of $\alpha=0.01$ was used to compensate for the increased likelihood of type 1 error [22]. The relationships between FID and three independent variables (fish size, group size and depth) were assessed using multiple regression analysis. Normal probability plots were examined to check whether the assumption of normality was violated and the residuals were plotted against the delete residuals to check for outliers. All statistical analyses were made using Statistica 7.1 (Statsoft).

Results

Fish behavior was recorded for 49 individuals of *D. sargus*, ranging in size between 10 and 35 cm TL (Mean=20.9, SE=0.8), and 70 individuals of *D. vulgaris*, with size between 11 and 30 cm TL (Mean=19.2, SE=0.6). The presence of conspecifics close to the focal individual was observed more frequently in *D. vulgaris* (80% of cases, with a variation in the number of fish between 1 and 10) than in *D. sargus* (43% of cases, with groups of 1-4 fish).

At both locations, the mean FID of *D. sargus* was greater than that observed in *D. vulgaris* (Figure 2). Comparison by ANOVA highlighted significant differences in FID between species, whereas no significant effects of locations and the interaction factor (species × location) were found (Table 2).

Results of multiple regression analysis indicated that in both species the relationships between FID and fish size, group size and bottom depth were very weak (Table 3). The regression models were not significant and the percentage of variation in FID totally accounted for by the investigated variables was negligible (14% and 3% for *D. sargus* and *D. vulgaris*, respectively).

The behavioral patterns before the escape reaction exhibited by the investigated species were quite similar ($\chi^2=5.76$, d.f.=6, $p>0.05$). The majority of fishes (>60%) stopped any activity, beginning slowly to turn and swim away from the observer, behavior that was defined as "tacking". In fewer cases, focal fish did not modify their behavior in the presence of the observer ("indifference") or changed position turning towards the observer or a shelter ("reorientation"). Even less frequently mixed behaviors were recorded, in which the "tacking" behavior was preceded by a phase of "indifference", "reorientation", "observation" or "approach" (Figure 3). Chi-squared test indicated significant differences in the post-flight behavior between *D. vulgaris* and *D. sargus* ($\chi^2=9.16$, d.f.=1, $p<0.01$). After the flight both species largely preferred to escape into open water (96% and 78% of *D. vulgaris* and *D. sargus*, respectively) rather than into a shelter (4% and 22% of *D. vulgaris* and *D. sargus*, respectively). However, the number of fish hiding into a refuge was in *D. sargus* higher and in *D. vulgaris* lower than expected.

Discussion

In the present work, differences in the behavioral responses of two sea bream species (both actively targeted by spearfishing) to a potential threat, represented by a diver presence, were tested for the first time using FID, taking also into account some characteristics of pre-flight and post-flight behavior. Several studies, mainly conducted in coral reef ecosystems, have clearly shown how anthropogenic disturbance related to fishing activities can drastically alter the behavior of heavily target species [6-9,13,14]. Such behavioral changes may concern the use of the habitat (e.g. the displacement of larger specimens at deeper,

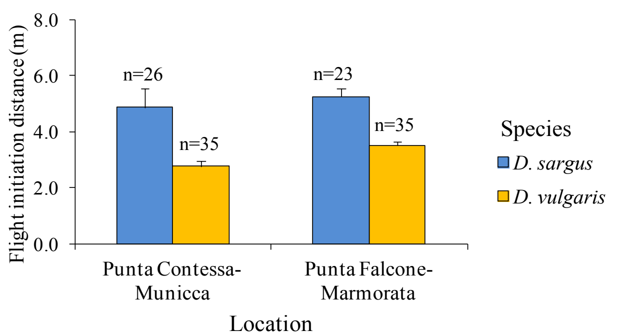

Figure 2: Mean (+S.E.) flight initiation distance (FID) and sample size of sea breams by species and location.

Table 1: Summary of pre-flight behavioral categories.

Category	Description
Approaching	Fish moves toward and inspects the observer
Indifference	Fish behavior does not change in the presence of the observer
Reorientation	Fish changes position reorientating towards the observer or a shelter
Tacking	Fish stops current activity and slowly starts swimming away from (but not faster than him) the observer in a tacking (side to side) pattern
Watching	Fish either stops any activity and turns toward the observer or remains still watching the observer

less accessible, sea bottoms) and/or lead to an increase of wariness of fishes towards humans [9,15,16,23].

Our results revealed a clear difference in FID between the investigated sea breams: *D. vulgaris* allowed the observer to approach themselves at a significantly shorter distance than *D. sargus*, hence displaying a less wary behavior. Moreover, this pattern was consistent across locations. In agreement with our outcomes, Guidetti et al. [16] observed that the percentage of individuals displaying a negative reaction in the presence of divers was higher in *D. sargus* (80%) than *D. vulgaris* (70%). The observed interspecific difference in wariness could be due to different spearfishing pressure. It has been experimentally demonstrated that the frequency of experiences with predators can significantly influence the anti-predator responses of preys through mechanisms of individual learning and social communication [3,24]. A number of investigations indicated that the escape reaction in more experienced prey fishes was usually characterized by longer FIDs [3,10-12]. On the other hand, if the less-wary fish are selectively harvested by fishing activities, the remaining populations will be mainly composed by individuals with a high degree of wariness. Unfortunately, the hypothesis of a different pressure from spearfishing on *D. sargus* and *D. vulgaris* in the investigated area could not be tested, because catch data on these species were not available. Nevertheless, some studies focused on this topic and carried out in other Mediterranean areas indicated that *D. sargus* was among the most frequent preys of spearfishers, especially during competitions, whereas the occurrence of *D. vulgaris* was almost negligible [19]. As suggested by the author, catch data from spearfishing competitions may be biased by the lack of interest of participants in those species, such as the two-banded sea bream, which seldom are large enough to meet the required weight limits.

Table 2: Results of analysis of variance used to test for differences in the flight initiation distance (FID) of sea breams between species and locations.

Effect	df	MS	F
Species (S)	1	106.63	28.95***
Location (L)	1	9.02	2.45 ns
S × L	1	0.87	0.24 ns
Error	115	3.68	

***P<0.001; ns: Non-significant (P>0.05)

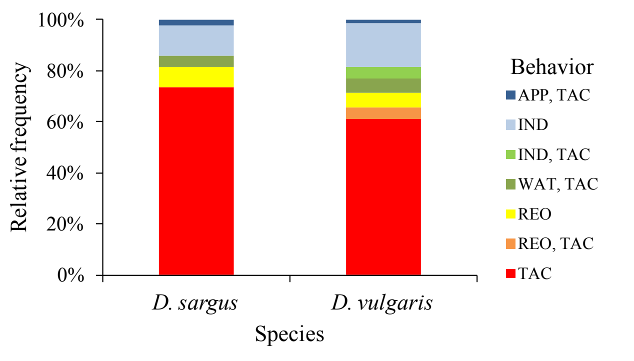

Figure 3: Relative frequency of pre-flight behaviors (APP: Approaching; TAC: Tacking; IND: Indifference; WAT: Watching; REO: Reorientation) observed in the two sea bream species.

An increase, often significant, in FID with increasing size of individuals has been observed in different fish species [6,7,9,15;25]. Conversely, no significant relationship between sea bream FID and body size was detected in the present work. This result may be due to the scarcity in the investigated samples of large-sized individuals (>25 cm), namely those preferentially targeted by spearfishers and, thus, more inclined to escape from an approaching diver. The lack of body size-related effect on FID in six out of seven reef fish species targeted by artisanal fishers of Papua New Guinea has been similarly addressed to an insufficient range of fish body sizes [8]. To explain the absence of a significant increase of FID with fish body size, we could alternatively hypothesize that in the study area also individuals of smaller size were subjected to intense spearfishing pressure.

The presence of conspecifics around the focal fish has proved to be ineffective on their FID as well. Previous results on the relationship between group size and fish FID are controversial and largely taxon- or species-specific [3]. For instance, Januchowski-Hartley et al. [9] observed a significant effect of grouping in only one out of seven investigated families of coral reef fish. The absence of changes in the FID of sea breams mediated by the presence of conspecifics may depend on the small size of the groups observed, generally composed by no more than 3-4 individuals. This number may have been insufficient to induce in focal fish an increase perception of safety when aggregated through, for example, an encounter-dilution effect, which has been observed in species with a more marked shoaling behavior [26].

Behavior of sea breams before the flight was sometimes better described using more than one of the six behavioral categories conceived by previous authors [15]. The low frequency of the more confident behaviors (“indifference” and “approaching”) observed in both species and the scarcity of large-sizes individuals as well are consistent with a situation of strong spearfishing pressure. Our results concerning the behavior of sea breams after the escape reaction largely confirm those previously reported by Guidetti et al. [16]. The escape in open water was the most frequently adopted behavior by both species. Less frequently, sea breams reacted to diver presence moving into a shelter, even though this behavior was more frequently recorded in *D. sargus* compared to *D. vulgaris*.

Conclusion

In conclusion, our results indicate that sympatric species with similar phylogenetic and ecological characteristics may react to human disturbance through different behavioral patterns. The improvement in the knowledge of the effects, still poorly investigated, that the interaction with humans exert on behavior of prey fishes

Table 3: Multiple regression results for the effects of fish body size, group size and bottom depth on flight initiation distance (FID) of the two sea bream species.

Species	Regression model				Contribution to total r^2 and regression coefficient (in parentheses)		
	df	F	p	r^2	Fish size	Group size	Depth
Diplodus sargus	3.45	2.49	<0.07	0.14	0.04	0.01	0.09
					(0.14)	(0.16)	(–0.20)
Diplodus vulgaris	3.66	0.67	<0.57	0.03	0.01	0.01	0.01
					(0.03)	(0.06)	(0.02)

may have useful implications for the management of these resources, allowing to indirectly assess the impact of certain anthropic activities (e.g. spearfishing) and the effectiveness of measures implemented to curtail or eliminate this impact [25,27]. Some interesting issues of the human-driven effect on sea breams behavior deserve further investigations. First, it would be interesting to conduct surveys in different seasons, to assess whether and how the level of anthropogenic pressure (mainly from spearfishing), which is presumably characterized by seasonal fluctuations, can modify fish behavior over short time scales. Second, the acquisition of new data on fish behavior after the establishment of the marine protected area and their comparison with those presented here represent a good opportunity to assess whether the undertaken protection measures are effective and, if not, to suggest new management solutions.

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References

1. Ydenberg RC, Dill LM (1986) The economics of fleeing from predators. Adv Stud Behav 16: 229-249.
2. Cooper WE, Frederick WG (2007) Optimal flight initiation distance. J Theor Biol 244: 59-67.
3. Stankowich T, Blumstein DT (2005) Fear in animals: A meta-analysis and review of risk assessment. P Roy Soc B: Biol Sci 272: 2627-2634.
4. Domenici P (2010) Context dependent variability in the components of fish escape response: Integrating locomotor performance and behavior. J Exp Zool Part A 313: 59-79.
5. Dill LM (1990) Distance-to-cover and the escape decisions of an African cichlid fish, Melanochromis chipokae. Environ Biol Fish 27: 147-152.
6. Gotanda KM, Turgeon K, Kramer DL (2009) Body size and reserve protection affect flight initiation distance in parrotfishes. Behav Ecol Sociobiol 63: 1563-1572.
7. Nunes JACC, Loiola M, Miranda RJ, Sampaio CLS, Barros F (2016) Are Abrolhos no-take area sites of naïve fish? An evaluation using flight initiation distance of labrids. Neotrop Ichthyol 14: 18.
8. Feary DA, Cinner JE, Graham NAJ, Januchowski-Hartley FA (2011) Effects of customary marine closures on fish behavior, spear-fishing success, and underwater visual surveys. Conserv Biol 25: 341-349.
9. Januchowski-Hartley FA, Graham NAJ, Feary DA, Morove T, Cinner JE (2011) Fear of fishers: Human predation explains behavioural changes in coral reef fishes. PLoS One 6: e22761.
10. Dill LM (1974) Escape response of zebra danio (Brachydanio rerio). II. The effect of experience. Anim Behav 22: 723-730.
11. Kelley J, Magurran AE (2003) Learned predator recognition and antipredator responses in fishes. Fish Fish 4: 216-226.
12. Januchowski-Hartley FA, Cinner JE, Graham NAJ (2014) Fishery benefits from behavioral modification of fishes in periodically harvested fisheries closures. Aquat Conserv 24: 777-790.
13. Januchowski-Hartley FA, Graham NAJ, Cinner JE, Russ GR (2015) Local fishing influences coral reef fish behavior inside protected areas of the Indo-Pacific. Biol Conserv 182: 8-12.
14. Januchowski-Hartley FA, Nash KL, Lawton RJ (2012) Influence of spear guns, dive gear and observers on estimating fish flight initiation distance on coral reefs. Mar Ecol Prog Ser 469: 113-119.
15. Bergseth BJ, Williamson DH, Frisch AJ, Russ GR (2016) Protected areas preserve natural behaviour of a targeted fish species on coral reefs. Biol Conserv 198: 202-209.
16. Guidetti P, Vierucci E, Bussotti S (2008) Differences in escape response of fish in protected and fished Mediterranean rocky reefs. J Mar Biol Assoc UK 88: 625-627.
17. Russell B (2014) Diplodus vulgaris. The IUCN Red List of Threatened Species 2014: e.T170261A42445899.
18. Russell B (2014) Diplodus sargus. The IUCN Red List of Threatened Species 2014: e.T170155A42779625.
19. Coll J, Linde M, García-Rubies A, Riera F, Grau AM (2004) Spear fishing in the Balearic Islands (west central Mediterranean): species affected and catch evolution during the period 1975-2001. Fish Res 70: 97-111.
20. Morales-Nin B, Moranta J, García C, Tugores MP, Grau AM, et al. (2005) The recreational fishery off Majorca Island (western Mediterranean): Some implications for coastal resource management. ICES J Mar Sci 62: 727-739.
21. Lloret J, Zaragoza N, Caballero D, Font T, Casadevall M, et al. (2008) Spearfishing pressure on fish communities in rocky coastal habitats in a Mediterranean marine protected area. Fish Res 94: 84-91.
22. Underwood AJ (1981) Techniques of analysis of variance in experimental marine biology and ecology. Oceanogr Mar Biol Annu Rev 19: 513-605.
23. Harmelin JG, Bachet F, Garcia F (1995) Mediterranean marine reserves: Fish indices as tests of protection efficiency. Mar Ecol 16: 233-250.
24. Brown C, Laland KN (2003) Social learning in fishes: A review. Fish Fish 4: 280-288.
25. Benevides LJ, Pinto TK, Nunes JACC, Sampaio CLS (2018) Fish escape behavior as a monitoring tool in the largest Brazilian multiple use Marine Protected Area. Ocean Coast Manage 152: 154-162.
26. Turner GF, Pitcher TJ (1986) Attack abatement: A model for group protection by combined avoidance and dilution. Am Nat 128: 228-240.
27. Goetze J, Januchowski-Hartley F, Claudet J, Langlois T, Wilson S, et al. (2017) Fish wariness is a more sensitive indicator to changes in fishing pressure than abundance, length or biomass. Ecol Appl 27: 1178-1189.

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