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BOTTLENOSE DOLPHIN DEPREDATION IMPACTS ON THE THERMAIKOS GULF GILLNET FISHERY BASED ON EXPERIMENTAL FISHING AND QUESTIONNAIRE DATA

Garagouni M.[1], Mouchlianitis F.[2], Avgerinou G.[1], Minos G[2]. and Ganias K.[1]

[1] *School of Biology, Aristotle University of Thessaloniki, Greece,* garagouni.m@gmail.com; georgiaavgerinou@gmail.com; kganias@bio.auth.gr

[2] *School of Health Sciences, Department of Nursing, International Hellenic University, Alexander Campus, Sindos, Greece,* amouchl@bio.auth.gr; gminos@ihu.gr

Abstract

Dolphin depredation is a long-standing source of human-wildlife conflict in the Mediterranean, but its impacts on small-scale fisheries can be varied and difficult to quantify. The aim of this study was to measure catch loss due to depredation in a bottom-set gillnet fishery in the inner Thermaikos Gulf (northern Aegean Sea). We conducted experimental trials over two seasons, in 2020 and 2021, and performed questionnaire interviews in 2021. Catch weight and number of damaged individuals were calculated per haul and modelled to assess the impact of depredation. Self-reported catch weight from the questionnaire data was also run through a similar model. Bottlenose dolphins depredated both experimental (RV) and questionnaire (GN) hauls with similar frequency (RV: 32.5% of 80 hauls; GN: 27.5% of 40 hauls). Depredation significantly reduced intact catch weight by 231% in RV hauls and 194% in GN hauls, while the number of damaged individuals in RV hauls increased significantly from 10.4% when dolphins were not present to 21.8% when they were. Besides quantifying the direct loss in catch, our findings highlight the similarity between self-reported and directly observed effects of depredation in coastal gillnet fishing.

Keywords: cetacean depredation, catch size, gear damage, coastal fisheries.

1. Introduction

Cetaceans taking fish from nets has long been a source of human-wildlife conflict in the Mediterranean (Bearzi, 2002). This behaviour is termed depredation and can have serious financial impacts on small scale fishers (e.g., Bonizzoni *et al*., 2016; Gonzalvo *et al*., 2015). Fishery observers or questionnaire surveys are the most frequently used approaches to quantify the scale and likelihood of such interactions (e.g., Garagouni, 2013; Milani *et al*., 2019; Pardalou & Tsikliras, 2020), but have not often been tried concurrently. Questionnaire surveys also generally include one interview per fisher and can include questions referring to periods of a year or more. For small scale fishers, even a small financial loss can be very serious, thus, when an interviewer asks about depredation rates or the magnitude of income loss, there may be a tendency on the part of the interviewee to overestimate (Garagouni, 2013). Repeated questionnaires, however, referring to shorter time periods, could potentially remove some of the personal bias from such interviews.

The present study fulfilled two objectives, namely: the quantification of catch size reduction because of cetacean depredation; and the comparison of this reduction measured in experimental hauls with the self-reported catch changes in concurrent questionnaire surveys.

2. Material and Methods

Two types of data were collected in this study, the first through a series of experimental hauls on a chartered fishing vessel (RV) and the second through a questionnaire survey of coastal fishers. Both the fishing and interview efforts took place in the inner Thermaikos Gulf in the northern Aegean Sea, one of the most important fishing grounds in Greece, both for medium- and small-scale fisheries. The experimental hauls were conducted outside the port of Nea Michaniona, while questionnaire surveys were conducted there and in the neighbouring port of Angelochori.

Fishing surveys took place over two seasons, from May to October in 2020 and 2021. We chartered a coastal fishing vessel (8 m, 2.3 GT, 43 hp) for the experimental part of the study and used bottom-set nylon gillnets, with a stretched mesh size of 36 mm. Each net panel measured 100 m in length and 1.8 m in height and was attached to a head rope with floaters and a lead-cored ground rope. Three net panels were attached to form a 300 m long fleet, and three fleets (that is, a total of 900 m) were deployed in each haul. Nets were set just before sunrise, in depths shallower than 20 m, and allowed to soak for approximately 1.5 hours. Throughout each fishing effort, two observers on board visually monitored the area for cetaceans and other predators. If cetaceans were sighted, the species was identified, their number estimated, and their behaviour around the fishing gear was recorded (Fig. 1a).

All fish and invertebrates caught in the nets were removed from the gear and subsequently taken to a wet lab for processing. Every individual was identified to as low a taxonomic level as possible and morphometric measurements, as well as weight, were taken. The catch was also visually assessed for damage due to depredation, such as bite marks or missing body parts, and individuals were labelled as intact or damaged (Fig. 1b, c).

Interviews were conducted in 2021, almost always on the same dates as experimental trials, with fishers who had just returned from their own hauls. The same fishers were approached as frequently as possible in order to get consistent information. Questions were asked regarding that day's fishing effort (including hr at sea, location, depth, type & length of fishing gear), catch size and composition (including kg and species caught), and whether or not dolphins interacted with their gear. To gain as complete a picture of depredation rates as possible, we also asked about fishing effort and cetacean interactions on the days preceding the questionnaire.

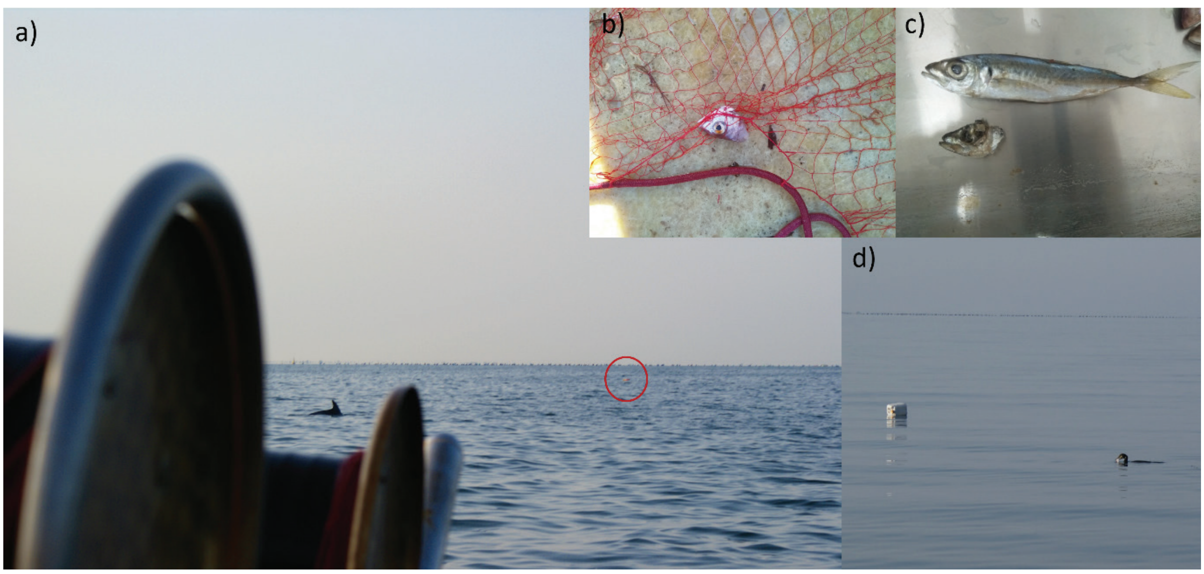

Fig. 1: a) Bottlenose dolphin surfacing in front of fishing vessel as gillnet is being hauled (surface buoy in red circle marks the end of that net). b) Head of a *Pagellus* sp. found on net following a depredation event. c) Intact (top) and damaged (bottom) *Trachurus* sp. identified in the lab. d) Cormorant surfacing near gillnet surface buoy with a fish in its mouth.

Depredation frequency was compared between the experimental hauls and the questionnaire fishing effort using a chi-squared test. The effect of depredation on catch size in the experimental hauls was assessed by modelling catch per effort (kg/haul) against dolphin presence, during the months when dolphins were most active (June to September). Only intact fish and cephalopods were used in this analysis, as the damaged individuals are essentially catch lost due to depredation. Because we observed a seasonal fluctuation in catch sizes, a mixed effects generalised linear model (GLMM) was used, with Month as a random effect and a Gamma error distribution family (log link).

A similar model was run on the self-reported catch size in the questionnaire data, which referred only to intact fish and marketable cephalopods. In order to be fully comparable with our experimental findings, we only included data from gillnet fishing effort that took place in depth < 20 m and when dolphins were reported most frequently (May to September).

The number of damaged individuals in our experimental catch was also compared between days when dolphins were the observed predators and days when they were not, using a chi-squared test. To test whether the pattern is consistent across all months despite the catch size fluctuations, we ran a GLMM on the number of damaged individuals per haul versus dolphin depredation occurrence, with Month as a random effect, total catch size (number of fish and cephalopods per haul) as an offset, and a Poisson (log link) error distribution.

3. Results

We conducted 36 experimental hauls (RV) in the first season and 44 in the second. Bottlenose dolphins (*Tursiops truncatus*) were observed depredating our gear during 11 hauls in 2020 and 15 in 2021, or 32.5% of all hauls. A total of 40 interviews pertained to shallow-set gillnets (GN, in 35 of which catch size was reported) with a 27.5% depredation rate. The chi-squared test confirmed that depredation frequency was similar between RV and GN fishing effort ($\chi^2 = 0.173$, $df = 1$, $p = 0.677$). Depredation events peaked in July and August and tapered off towards the end of both seasons. Catch for all cases is shown in Table 1.

Table 1. Catch sizes in kg and number (n) of individuals of intact and damaged fish (where applicable), for two seasons of experimental hauls (RV) and one season of questionnaire data (GN), in relation to dolphin depredation.

	Dolphins absent		Dolphins present	
	Intact fish (n; kg)	Damaged fish (n)	Intact fish (n; kg)	Damaged fish (n)
RV 2020	3134; 152.2	191	575; 25.8	80
RV 2021	3419; 158.7	246	405; 17	132
GN 2021	- ; 252.6	-	- ; 30	-

Both RV and GN catch was significantly lower in the presence of dolphins than in their absence, in months when cetaceans were most active (Fig. 2a, b). Indeed, both GLMMs resulted in similar estimated coefficients for the effect of depredation (RV: -2.31, $SE = 1.2$, $p < 0.001$, *conditional* $R^2 = 0.397$; GN: -1.94, $SE = 1.24$, $p = 0.003$, *conditional* $R^2 = 0.407$).

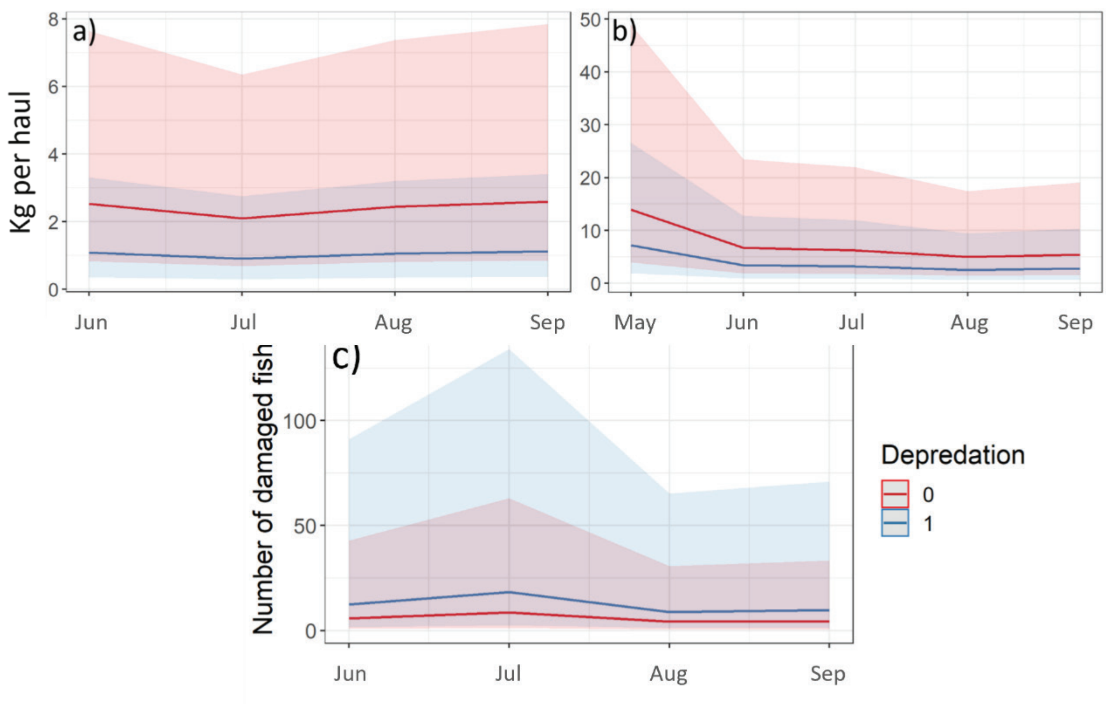

Fig. 2: Monthly GLMM predictions depending on whether dolphin depredation occurs (1) or not (0): (a) catch (kg) per haul based on experimental data; (b) catch (kg) per haul based on questionnaire data; (c) number of damaged individuals per haul.

Within the months when dolphins were most active (June to September in both years), the percentage of damaged fish per RV haul increased significantly from 10.4% when dolphins were absent to 21.8% when depredation occurred (χ^2 = 59.96, *df* = 1, *p* < 0.0001). The GLMM showed that this pattern remained consistent across all months (*estimated coefficient* = 2.12, *SE* = 1.11, *conditional* R^2 = 0.64; Figure 2c).

4. Discussion/Conclusion

Both experimental and questionnaire data showed clear changes in catch size due to dolphin depredation. Not only were the overall interactions with bottlenose dolphins in the area as frequent in our directly observed hauls as in the questionnaire surveys, but the magnitude of catch loss was also similar between the two. This is in contrast with other studies, which have shown that fishers overstate the negative effects of depredation in questionnaires (e.g., Bearzi *et al.*, 2011). This increased accuracy is a direct result of the repetitive nature of the interviews covering the most recent daily or biweekly records, as opposed to monthly or yearly estimates of depredation frequency and intensity.

Regarding the number of individuals damaged by depredation, we confirmed that such damage can happen even when dolphins are not the perpetrators. Indeed, during the experimental hauls we often observed cormorants diving near our gear and surfacing with fish in their beaks (Fig. 1d), on some occasions even damaging a very large proportion of the catch. So other marine megafauna do contribute to catch loss, and it is possible that because they are less noticeable than the dolphins, the latter are blamed by the fishers even when they (and associated gear damage) are not directly observed (Garagouni *et al.*, in press). Of course, the higher magnitude of the damage attributable to dolphins is clearly evident from our own data, and in fact highlights another reason that catch loss is difficult to quantify. That is, the difference in catch size is much larger than the number of damaged fish when dolphins are present—dolphins clearly remove large amounts of fish biomass either from the gear or the surrounding water column without leaving a measurable trace.

Our findings highlight the importance of conducting concurrent surveys of both directly observed and self-reported fishing effort, as a means of ground-truthing the accuracy of the latter and gaining a clearer bigger picture. Repetitive interviews are crucial to reducing personal bias in the estimation of depredation impacts. Finally, bottlenose dolphins do remove substantial and consistent amounts of biomass from the gillnets in the area, which should be a strong incentive to develop new mitigation techniques.

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