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Occurrence and impact of interactions between small-scale fisheries and predators, with focus on Mediterranean monk seals (Monachus monachus Hermann 1779), around Lipsi Island complex, Aegean Sea, Greece

Noelia Ríos[a,b,*], Matija Drakulic[a], Iosu Paradinas[b], Anastasia Milliou[a], Ruth Cox[c]

[a] Archipelagos Institute of Marine Conservation, Pythagorio Samos, 83102, Greece
[b] Universitat de Valencia Carrer del Dr. Moliner, 50, Burjassot, Valencia 46100, Spain
[c] Atlantic Veterinary College, University of Prince Edward Island, Charlottetown, PE, Canada

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ABSTRACT

Antagonistic interaction between Mediterranean marine mammals, including the endangered monk seal (*Monachus monachus*), and small-scale fisheries is a growing problem in the Aegean Sea. Effective management measures are needed to ensure both the survival of the monk seal population, and its coexistence with the small-scale fisheries. In this study, data from 371 fishing journeys by 8 different boats was collected between March and November 2014. Evidence of depredation by monk seals was recorded in 19.1% of fishing journeys, by cetaceans in 5%, and by other predators in 16.5%. Analysis of landings data showed that gear and depth were the variables most likely to influence the occurrence of depredation. There was a significant decrease in the catch per unit effort (CPUE) of four of the nine targeted fish species when depredation by monk seals occurred. The total cost of monk seal depredation was estimated to be 21.33% of the mean annual income of fishermen in the Aegean Sea. We discuss how the implementation of marine protected areas and the use of specific fishing gear could reduce the frequency of interactions, and thus mitigate the loss experienced by the fisheries as well as contribute to the conservation of an endangered species.

1. Introduction

The interaction between marine animals (e.g. marine mammals, sharks, turtles) and fisheries is a common occurrence in many parts of the world. It can often be antagonistic in nature (Read, 2008) and it has intensified as commercial fishing activities have increased (Northridge and Hofman, 1999; Read, 2008). Multiple studies have demonstrated the impact of interactions between fisheries and marine mammals, for example bottlenose dolphins (*Tursiops truncatus*) in Italy and Spain (e.g. Díaz López, 2006; Lauriano et al., 2004; Pennino et al., 2015; Rendell et al., 2008), grey seals in Ireland (Cosgrove et al., 2013) and monk seals in Turkey and Maderia (Güçlüsoy, 2008; Hale et al., 2011). Interactions are a problem for fisheries because they result in loss of catch and damage to fishing gear (Moore, 2003; Lauriano et al., 2004). The marine mammals can experience injury or mortality as a result of being tangled in fishing gear and also suffer from competition for resources with the fisheries. Indeed, one of the principal reasons that interactions occur is the decrease in food availability as a result of localized overfishing pressures (Moore, 2003). The interactions therefore represent a serious conservation issue for marine species and for the sustainability of artisanal fisheries.

Artisanal fisheries play a significant role in providing a source of food for hundreds of millions of people worldwide, thus contributing to poverty reduction and to the sustainable development of many areas of the world, including Europe, Asia and Central America (FAO, 2011; Chuenpagdee and Pauly, 2008). Given the importance of such fisheries, their sustainability is a high priority (Johnson et al., 2013) especially since the growth in fisheries in the developing world now outpaces growth in agriculture (Garcia and Rosenberg, 2010). In the European Union, Greek fisheries have the highest number of professional licenses (European Commission, 2001). Greek small-scale fisheries are of strong cultural and socio-economic importance to local communities (Fabio and Hazin, 2005). Preservation of artisanal fisheries is also impor-

* Corresponding author at: Archipelagos Institute of Marine Conservation, Pythagorio Samos, 83102, Greece.
E-mail address: noeriru@gmail.com (N. Ríos).

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tant because, compared to the industrial fisheries, they tend to be more selective in the species that are caught, use less destructive fishing gear, take less by-catch, and use less fuel (Fabio and Hazin, 2005). Losses in artisanal fisheries as a result of interactions with marine mammals could threaten the economic viability of the fisheries in the area.

As well as the detrimental impact on the fisheries, interactions are of conservation concern for marine mammal species in the region. The Aegean Sea is an important habitat for several dolphin species (Güçlüsoy et al., 2004b; Öztürk et al., 2008) and also supports the largest subpopulation (250–350 individuals that represents 35–50% of the total population) of Mediterranean monk seals (*Monachus monachus*), (Güçlüsoy et al., 2004a,b; Hellenic Society for the Study & Protection of the monk seal (Mom), 2007), the most endangered pinniped in the world (International Union for Conservation of Nature [IUCN], 2007). Monk seals are opportunistic predators (Jacobs and Panou, 1988; Boutiba and Abdelghani, 1997) and data from captive monk seals indicate that they consume 5 to 10% of their total body weight (240-400kg) per day (Jacobs and Panou, 1988; Scoullos et al., 1994; Caltagirone, 1995). They consume a wide variety of prey primarily from shallow water habitats (Sergeant et al. 1978), including fish such as red mullet (*Mullus sp*), sea bream (Sparidae), bogue (*Boops boops*), mullets (*Mugilidae*), and octopus (Octopodidae) (Sergeant et al., 1978) all of which are important commercial species in the Aegean.

Monk seals can become entangled in a variety of fishing gear including set-nets, purse seiners (Kiraç and Savas, 1996) and they are most vulnerable to static gear and abandoned nets (Panou et al., 1993; Kiraç and Savas, 1996; Tudela 2004). They also suffer from the depletion of fish stocks as a result of overfishing, habitat degradation and the seal deterrent practices that are used to protect aquaculture facilities (Westerberg, 2010). The economic loss suffered by the fishermen as a result of the marine mammal interactions causes hostility against the seals and has lead to deliberate killings by the fishermen (Johnson and Lavigne 1999; Güçlüsoy et al., 2004a; Johnson 2004).

In order to mitigate the existing problems, data is required about the factors that play an important role in the interaction between seals and fisheries and the impact on the fishery. This data can then be used to develop effective management plans such as the plan of action for marine mammals in UNEP/MAP (Anonymous, 1998). The objectives of this study were: i) to assess the influence of fishing practices on the occurrence of interactions with monk seals, ii) to evaluate how catch per unit effort (CPUE) of importance fish species is impacted by interactions, iii) to calculate the economic loss to the fishery as a result of interactions and, iv) to map the location of the monk seal-fishery interactions in order to determine the areas with the most interactions.

2. Methods

2.1. Study area

The study took place between 1st of March and 30th of November 2014 on the Dodecanese island of Lipsi (Fig. 1) and their islets (37°18′N 26°45′E). These are situated in the Southeast region of the Aegean Sea, 40 km off the coast of Turkey, between the islands of Leros, Patmos and Arki. The region around Lipsi island was divided into sections arbitrarily (N, S, E, W, SW, NW, SE, NE) (Fig. 1).

During the time of the study the Lipsi fishing fleet comprised of 29 boats bearing professional fishing licenses, out of which 15 operated full time, and the remaining 14 operated seasonally or were inactive. We categorized the level of dependence on small scale fisheries by the fishermen by following Tzanatos et al. (2006). Thus the full time fishermen were classed as "high dependence", spending an average of 229 days fishing. The seasonal/inactive fishermen spent in the range of 145–195 days fishing and were therefore categorized as "partially dependent" or "non-dependent". All fishermen involved in this study were in the 'high dependence' category. The fishermen fished in depths between 2–100 m, with a preferred depth of 10–20 m. Boat size varied between 5.80 m–12.80 m with engine power of 15–70 hp. The characteristics of the gear used by the fishermen are summarized in Table S1.

2.2. Data collection

Data was collected by Archipelagos Institute of Marine Conservation researchers on a daily basis throughout the fishing period between March and November 2014. A total of eight fishermen on eight separate boats took part in the study. Researchers recorded all data while speaking with the fishermen after the boats had landed in the harbour. Two different surveys were done depending on the collaboration level of the fishermen. In survey one; data was collected about gear characteristics, fishing location, depth, habitat, duration of activity, gear-fauna interaction from four fishermen. These fishermen also allowed the researchers to measure the individual fish in the catch. In survey two; the remaining four fishermen provided the same information, except they only provided total weight per species instead of size of landed species.

Information that we collected about gear-fauna interaction included the presence/absence of interaction, the animal involved in the interaction (monk seal, cetacean or other), type of damage (net damage, catch damage or both), gear, location (indicated by the fishermen on a map), depth (between 2–100m), habitat (sea-grass, rock, heterogeneous and sand) and time of the interaction. Previous research has illustrated the characteristic monk seal three-hole net damage pattern, with one large hole (20–30 cm diameter) caused by the mouth and two smaller holes caused by the fins holding the net (Karavellas 1994; Berkes et al., 1979). In contrast cetacean net damage pattern comprises of large irregular shaped tears (Öztürk and Dede, 1995) of approximately 1–2 m in diameter. We thus identified the animal involved in the interaction by inspecting the holes in the nets to look for the distinctive damage patterns and by asking for confirmation from the fishermen. Any damage to nets that did not result from monk seal or cetacean depredation was classified as 'other'. Catch damage was recorded when there were obvious bite marks on fish in the net. The specific predator of the net damage was identified from the nature of the net damage. We only recorded presence or absence of catch damage, not the proportion of fish that were damaged or undamaged. This is because we did not have the permission of the fishermen to record more detail in the time available. Fishermen who took part in survey two in particular only allowed us to record the total weight of the catch per fish species. In addition, in many cases of monk seal depredation, catch was lost and only a small number of fish remained in the nets. In these cases a measure of proportion of damaged fish would not have been reliable. Any depredation that resulted in damage to catch, but not damage to nets was classified as depredation by 'other' predators, since the predator was small enough to enter the net without causing net damage. For clarity, we refer to any interaction with a predator as 'depredation' and we identify damage resulting from the depredation as 'net damage' or 'catch damage'.

2.3. Data analysis

The occurrence of depredation was modeled using a binomial generalized linear model (GLM) with presence or absence of depredation by any species as the outcome. The predictors that were included were: geographic area (N, S, E, W, SW, NW, SE, NE) (Fig. 1), habitat type (Posidonia, rock, sand, heterogeneous), gear type (gill