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Fisheries Ecosystem Impacts and Management in the Mediterranean: Seabirds Point of View

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Introduction

During the last century, commercial fisheries have notoriously developed and extended their range of action, causing a wide diversity of impacts at an ecosystem scale (e.g., Tegner and Dayton 1999; Moore and Jennings 2000). Consequently, it is important to manage fisheries from an ecosystem-based approach, considering their effects not only on the exploited fish stocks, but also on the whole marine environment (Gislason et al. 2000; Pauly et al. 2002).

Seabirds often operate at high levels of marine food webs, and can be particularly influenced by the alteration of their environment by fishing practices (reviewed in Tasker et al. 2000; Montevecchi 2002). Interactions between seabirds and fisheries are complex (Yodzis 1998; Montevecchi 2002) and often confused by environmental perturbations (Boyd 2001; Frederiksen et al. 2004). Since seabirds are long-lived organisms, characterized by low annual reproductive rates and delayed, progressive maturity, any change affecting adult survival is likely to influence the dynamics of seabird populations (Weimerskirch 2002). Thus, activities such as longlining, which cause direct seabird mortality, seem to exert a particularly detrimental effect, in some cases driving seabird populations to near-extinction (e.g., Brothers et al. 1999; Tuck et al. 2001, Lewison et al. 2004). On the other hand, changes in food supply derived from fishing practices seem to mainly affect seabirds' reproductive performance (e.g., Oro et al. 1996; Regehr and Montevecchi 1997; Oro 1999), therefore having a more diffuse effect on seabird populations (but see evidences of food availability influencing both immature and adult survival [Hüppop and Wurm 2000; Oro and Furness 2002; Davis et al. 2005]). These changes in food supply resulting from fishing activities could be either negative (e.g., reduced food availability through competition and ecosystem alterations) or positive (e.g., increased food availability through offer of fishery waste) (Montevecchi 2002).

These interactions have led to changes in the structure of seabird communities, overall favoring generalist species over the more spe-

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cialized taxa (Furness 2003). This has important conservation implications and has raised several issues of current controversy (e.g., Votier et al. 2004). Here, we review seabird–fisheries interactions in a relatively low productive and highly diversified sea, the Mediterranean, paying particular attention to the better-studied western basin. We also suggest possible ways of taking seabird populations (often of high conservation concern) into account when managing fisheries. These strategies differ to some extent from those proposed elsewhere, most often derived from studies in relatively productive, low diversity areas (e.g., high latitude and upwelling areas).

Study Area

The Mediterranean is an enclosed sea, characterized by high diversity of organisms and heterogeneous, overall low productivity (Estrada 1996). Fisheries are diverse and primarily of artisanal type, characterized by multispecific catches (Farrugio et al. 1993). Seabird populations are modest, though also of particular conservation concern due to their diversity and often restricted distribution range (Zotier et al. 1999). The degree of interaction between seabirds and fisheries seems high and diverse in nature, ranging (considering seabirds' point of view) from directly harmful (mortality caused by some fishing activities) to potentially beneficial (discards). This complexity of seabird–fishery interactions in the area is summarized in Figure 1.

Seabird–Fisheries Interactions in the Mediterranean

1. Interactions Causing Direct Mortality

Birds can get entangled to death in several types of fishing gear, most importantly in longline hooks (Montevecchi 2002). There is increasing concern about the high seabird mortality caused by longlining in several areas of the world (Brothers et al. 1999; Hall et al. 2000; Lewison et al. 2004). Given its obvious effect on a key demographic parameter, adult survival, longlining is believed to threaten some seabird populations with extinction, particularly albatrosses from the southern hemisphere (e.g., Tuck et al. 2001). In the Mediterranean, there is little information about the incidence of this fishing practice on seabirds, which could pose a serious threat for some species (see review in Cooper et al. 2003). Cory's Shearwater *Calonectris diomedea* seems to be the most affected seabird; over 50% of the birds reported dead in longline hooks belong to this species, and often correspond to adult birds (Belda and Sánchez 2001; Valeiras and Camiñas 2003). This mortality coincides with an apparently general population decline of this species (Carboneras 2004), although this point deserves further research. Gill nets have received even less attention, though they could pose a threat to some diving species, particularly the Mediterranean Shag *Phalacrocorax aristotelis desmarestii* (Muntaner 2004).

2. Competition

Seabirds and fisheries often target either the same or interconnected prey, thus leading to potential conflict. This seems to be negligible for fisheries in most occasions, particularly given the modest seabird populations in the Mediterranean, though the reverse is not necessarily true. Particular attention should be drawn to small pelagic fish, which constitute the main prey for most seabirds. These fish are subject to important fluctuations, which often result from a combination of environmental factors and fishing pressure. Little consensus exist about the relative importance of these two general causes of fluctuation, but there is increasing evidence that fisheries play

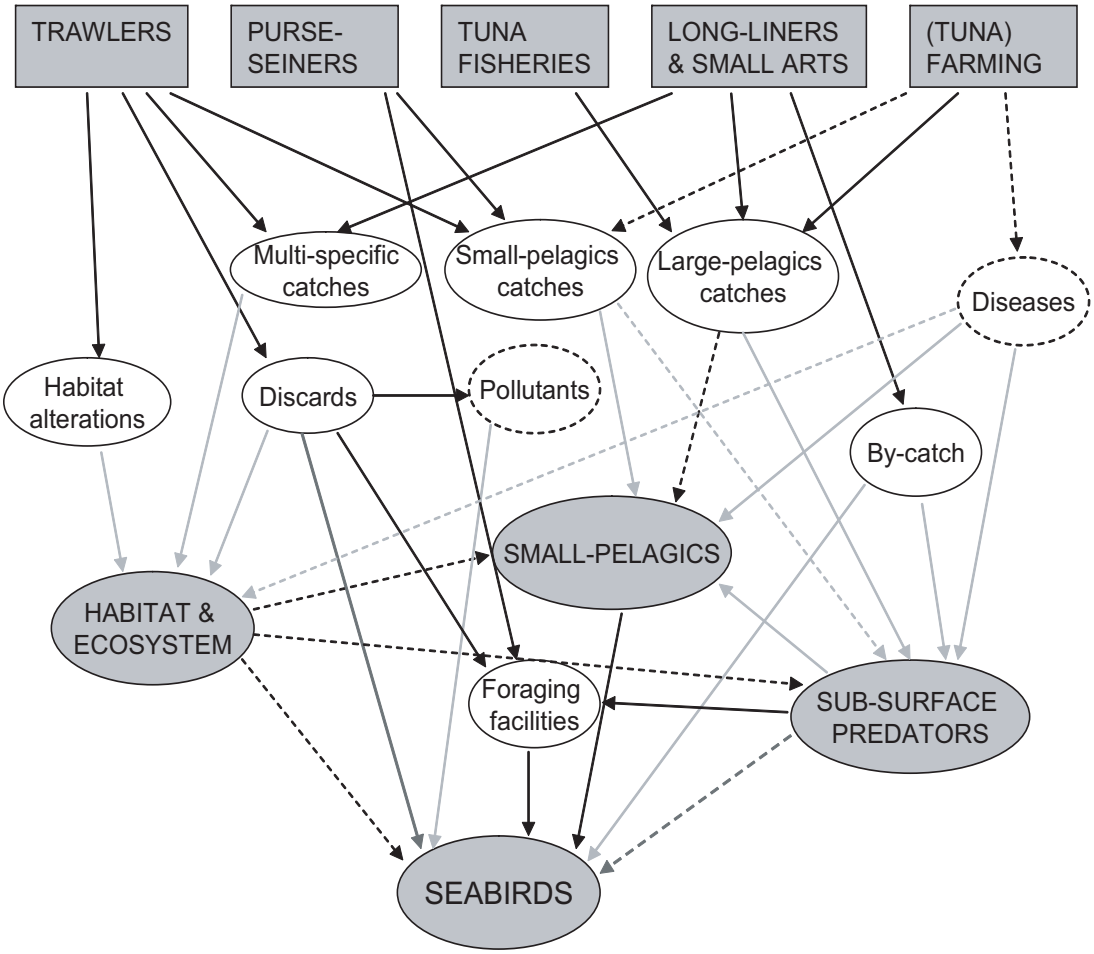

Figure 1. Simple summary representation of the main interactions between seabirds and fisheries in the Mediterranean Sea, based on the current knowledge available. Gray squares represent the main fishing practices, gray circles represent the main organisms/components of the ecosystem influenced by fishing activities, and open circles represent main consequences of fishing activities. Arrows represent causal interactions, either direct (solid arrows) or indirect (dashed arrows), and positive causal relationships are shown in black, negative in light gray and ambiguous in dark gray. Further research is needed to evaluate the magnitude of all these interactions and undertake management measures.

a significant role in the general decline of pelagic fish populations worldwide (Pauly et al. 2002; Frederiksen et al. 2004). In the Mediterranean, purse-seine fisheries are of particular concern, despite being relatively selective, as they target exclusively small pelagic fish. Purse-seiners have been reported to benefit some species, mostly the threatened Audouin's Gull *Larus audouinii*, through providing them with highly efficient feeding opportunities (Arcos and Oro 2002a). However, this benefit probably does not counterbalance the negative effect exerted by these vessels on the pelagic fish stocks. Indeed, the decline of some Mediterranean stocks (e.g., European anchovy *Engraulis encrasicolus*; Abad et al. 1996) could bring about a severe reduction in food resources for some seabirds, though other Clupeoids subject to lower fishing pressure (e.g., European pilchard *Sardina pilchardus* and guilt sar-

dine *Sardinella aurita*; Lloret et al. 2004) could mitigate this effect. This picture could get worse in the near future (Coll et al. 2006). Particularly, fish food required to sustain the current proliferation of tuna farming seems to increase fishing pressure on local stocks of small pelagic fish (irrespective of the species), and also poses a threat to local fish populations due to the spread of diseases by imported feed fish (WWF 2005).

3. Reduction of Competitors: A Real Advantage?

The reduction of predatory fish and cetaceans targeted by fisheries has often been believed to allow a surplus of their prey, thus favoring seabirds and other nontargeted predators (Tasker et al. 2000; Montevecchi 2002). However, ecosystem interactions are not as straightforward as sometimes believed (May et al. 1979; Yodzis 2001), and these increases in prey abundance are often only temporary (Myers and Worm 2003). Nevertheless, most studies reaching the above conclusion (i.e., seabirds benefiting of the removal of other predators) have been carried out in high-latitude regions, such as the Southern Ocean (Croxall et al. 1984) and the North Sea (Furness 2003). We believe that the situation is likely far different in medium to low-latitude regions, where the water column is either seasonally or full-time stratified. In this situation, fish prey tend to remain in the more nutrient-rich waters around the thermocline during the daylight hours (e.g., Plounevez and Champalbert 2000), and most seabirds have to rely on mechanisms driving prey up to the surface, basically subsurface pelagic predators such as tuna and dolphins (Au and Pitman 1986; Clua and Grosvalet 2001; Spear et al. 2001). In the Mediterranean, where tuna and other predatory fish could be overexploited (Fromentin 2003), the association of seabirds with subsurface predators seems to be a common phenomenon, especially for the shearwaters and the specialized Audouin's Gull (Oro 1995; Arcos et al. 2000; Arcos and Oro 2002b). Hence, any surplus due to the removal of competitors would probably not compensate for the parallel reduction in feeding opportunities, though this topic deserves further investigation.

4. Fishery Waste: A Seabird Panacea?

Demersal trawlers and other fisheries return large amounts of fishery waste to the sea, in the form of offal and discards. This makes demersal fish available to surface-feeding seabirds, thus providing an extra source of food, which is widely used by several species (see review in Tasker et al. 2000). This phenomenon has been regarded as a key factor in the recent growth of some seabird populations, although this is a controversial issue that has been questioned by some authors (see discussion in Camphuysen and Garthe 1999). In the Mediterranean, seabird consumption of discards seems of particular importance (Sarà 1993; Oro and Ruiz 1997; Martínez-Abraín et al. 2002). This food is favored by seabirds due to the predominantly small-size and the high average energy content of the fish discarded, as well as by the high predictability of the resource both in space and time (Arcos 2001). In the Ebro Delta (northwest Mediterranean), an area of relatively high productivity which sustains a large trawling fleet, some gull species have taken particular advantage of the large availability of discards, attaining population numbers that could be larger than those potentially sustained in the absence of human influences (Oro 1999). Certainly, discards supply a significant proportion of the energy required by these gulls during the breeding period (up to 76.9% in Audouin's Gull and 57.7% in the yellow-legged Gull *Larus michahellis*) (Arcos 2001), and the lack of this resource during trawling

moratoria has been proven to strongly influence a wide variety of ecological and breeding parameters (see review in Oro 1999), as well as demographic parameters (Oro et al. 2004b). But, in the long term, this surplus of food could not be as beneficial as it may appear. Indeed, potential impoverishment of the ecosystem and increasing pressure for reducing discarding rates (FAO 1995) will probably result in a reduction of discards. Since seabirds already exploit over 80% of the discards available (Arcos 2001), a reduction of this food resource could seriously affect the seabird community. An increase in competition is likely to occur, first affecting the smaller and more specialized species (Arcos et al. 2001). These species would be forced back to their natural feeding strategies, but they would probably face a general food shortage, given the severe exploitation of their natural prey. In addition, the more opportunistic and aggressive species, such as the Yellow-legged Gull, could turn to kleptoparasitize and prey over other seabird species to compensate for the reduction of discards (Oro and Martínez 1994; González-Solís et al. 1997). Another negative effect of discards on seabirds is the increased supply of mercury and possibly other pollutants, since benthic fish (basically available through discards) are on average more polluted than epipelagic fish (Arcos et al. 2002).

The Balearic Shearwater *Puffinus mauretanicus*: Integrating the Effects of Fisheries on a Critically Endangered Seabird

The Balearic Shearwater is the rarest Mediterranean seabird, with a breeding population estimated in only 2,000 pairs and restricted to the Balearic Archipelago (Ruiz and Martí 2004). It has recently been classified as critically endangered (Arcos and Oro 2004; Baillie et al. 2004), after Oro et al. (2004a) reported an abnormally low mean adult survival rate (0.78) and a steady annual population decline of 7.4%, which would lead to the extinction of the species in an estimated average of 40 years. This shearwater interacts in several ways with fisheries, and this subject should receive particular attention regarding its management. Firstly, significant mortality in longlines is strongly suspected, given the high mortality experienced by the species. There is little published information supporting this idea (Belda and Sánchez 2001), but the gregarious behavior of the species and its frequent attendance to fishing vessels could result in occasional (i.e., difficult to detect) but important events of mortality (there are reports of up to 50 individuals entangled in a single line; Arcos and Oro 2004). Balearic Shearwaters are specialized consumers of small pelagic fish, and often feed on these prey in association with subsurface predators (Arcos and Oro 2002b; Louzao et al. 2006). Thus, reductions in both small pelagic fish and subsurface predators are likely to negatively affect this shearwater. On the other hand, probably as a result of reduced feeding opportunities, Balearic Shearwaters make extensive use of discards, which make up over 40% of the energy requirements of the species during the breeding season (Arcos and Oro 2002b). However, if discard availability declined, this species could be among the first to be outcompeted by larger and more aggressive seabirds. Moreover, high mercury content of discards could pose an additional risk for this shearwater at present (Arcos, Oro, and Furness, unpublished data).

Management of Mediterranean Fisheries: Taking Seabirds into Account

Seabirds should be seriously considered when managing fisheries. Longlining needs particular attention and several measures directed to

mitigate seabird mortality have been investigated in recent years (Hall et al. 2000; Sánchez and Belda 2003). These measures include the use of scaring lines, the underwater setting of the line, changes in the timetable of the fishery, and the use of fish oil to repel seabirds. Other fisheries' management measures are less specific, but should regard seabirds when being implemented. For instance, regulations of mesh size are difficult in the Mediterranean given multispecific catches, but severe control of illegal fine-mesh is likely to strengthen in the future. This would be of special importance in productive areas such as the Ebro Delta (where an important seabird community breeds), as it would cause a drastic reduction of rich-energy fish (basically Clupeoids) among discards, reducing the energy available to seabirds down to 50% (authors' unpublished data). Predicting the effect of this measure on seabirds and taking preventive measures is necessary to avoid derived problems. Another example is that of trawling moratoria, which are implemented for a 2-month period each year around the Ebro Delta, coinciding with the seabird breeding season. Of course, these moratoria are desirable if beneficial for the whole ecosystem, but little effort has been actually directed to monitor their effect on the fish stocks (Martín 1995). In fact, their temporal overlap with the seabird breeding season, which results in low seabird breeding performance (Oro 1999), seems to primarily respond to socioeconomic reasons. Likely measures concerning the reduction of effort should also consider their effect on seabirds in order to predict potential changes. The establishment of marine reserves in particularly rich areas and regarding highly mobile organisms such as birds seems a desirable management strategy that is gaining support in recent years (e.g., Hyrenbach et al. 2000; Hooker and Gerber 2004). Current efforts in this direction, in the Mediterranean, include EU funded projects to extend the important bird areas (IBAs) concept to the open sea (marine IBAs; BirdLife International 2004; SPEA-SEO/BirdLife 2005), as a first step towards the designation of marine special protection areas (SPAs) based on their importance for birds.

Conclusions

In this paper we have shown the high interrelationship existing between fisheries and seabirds. Overall, seabirds and other top predators should be regarded not as competitors, but as components of the marine ecosystem, and this requires a huge education effort. Further research is necessary to evaluate the real extent of the interactions here reviewed. It is important to note that the oceans and even populations are heterogeneous and that phenomena described in given areas are not necessarily alike in others. Cooperation between different agencies and countries is also necessary for a proper management of the ecosystem. Although fish stocks lie at the heart of fisheries management, considering other organisms will help preserving the ecosystem.

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