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ACCOUNTING FOR FOOD REQUIREMENTS OF SEABIRDS IN FISHERIES MANAGEMENT – THE CASE OF THE SOUTH AFRICAN PURSE-SEINE FISHERY

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In South Africa, four of the seabirds that feed mainly on sardine *Sardinops sagax* and anchovy *Engraulis encrasicolus* have an unfavourable conservation status or a small population: African penguin *Spheniscus demersus*, Cape gannet *Morus capensis*, Cape cormorant *Phalacrocorax capensis* and swift tern *Sterna bergii*. Availability of prey is thought to influence their population size, but their food requirements have not been accounted for in management of the purse-seine fishery on sardine and anchovy. Means of identifying and attaining target populations of predators that are dependent on forage fish prey are discussed. Criteria used by The World Conservation Union to assess the conservation status of a species may prove useful in determining minimum viable populations, and the use of functional relationships in coupled models of predators and their prey may allow quantification of levels of escapement of prey that are necessary to maintain or rebuild populations of predators.

Key words: competition with fisheries, dependent species, food, minimum viable population, seabirds, South Africa

Humans are one of several users of forage fish resources. Others include predatory fish, marine mammals and seabirds. In the southern Benguela, four species of seabird feed mainly on sardine *Sardinops sagax* and anchovy *Engraulis encrasicolus* (Crawford and Dyer 1995), fish species that also contribute the bulk of the catch of South Africa's purse-seine fleet. Three of these species, African penguin *Spheniscus demersus*, Cape gannet *Morus capensis* and Cape cormorant *Phalacrocorax capensis*, are endemic as breeding birds to the Benguela and western Agulhas ecosystems off south-western Africa (Cooper *et al*. 1984). The nominate race of the fourth species, swift (or crested) tern *Sterna bergii*, also is endemic to this region (Cooper *et al*. 1990). African penguins and Cape gannets are classified as Vulnerable in terms of criteria of The World Conservation Union (IUCN) because of large decreases in their populations, whereas Cape cormorants are regarded as Lower risk/Near Threatened (Barnes 2000, BirdLife International 2000).

Many seabirds have life history characteristics, such as high annual survivorship, great longevity and delayed sexual maturity, that act to buffer their populations from fluctuations in their food supply (Hunt *et al*. 1996). Large fluctuations of sardine and anchovy *Engraulis* spp., including long-term changes in abundance, apparently occurred in several ecosystems where they were found before purse-seine fisheries started harvesting them (e.g. Kikuchi 1958, Soutar and Isaacs 1969, De Vries and Pearcy 1982, Shackleton 1987, Baumgartner *et al*. 1992). Collapses of pelagic fish stocks and subsequent replacement of dominant species appear to be primarily environmentally linked; fisheries usually hasten and intensify collapses rather than driving the regime shift (Jennings and Kaiser 1998).

Fishing has the potential to decrease the extent and duration of peaks and to depress and prolong troughs in the abundance of certain fish resources (Schwartzlose *et al.* 1999). Hence, fishing may alter their temporal variability in such a way that the life history characteristics of seabirds are no longer able successfully to cope with the fluctuations.

In the Benguela system, it is thought that competition with fisheries for food has led to large decreases in the numbers of African penguins and Cape gannets (Crawford 1998, 1999). There were especially severe decreases of these species in southern Namibia following the collapse of the Namibian sardine in the 1970s (Crawford 1999, Crawford *et al*. 2001). The overall population of African penguins in Namibia decreased by 72% between 1956 and 1999 to less than 27 500 adults (Kemper *et al.* 2001). The overall number of Cape gannets breeding in Namibia decreased from 190 000 pairs in 1956 to 20 000 pairs in 2000 (Crawford in press). Off Namibia, the production of epipelagic fish has been depressed for several decades, initially possibly as a result of a deliberate policy to fish anchovy as intensively as possible when sardine was decreasing in the 1970s, because anchovy

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was then viewed as a competitor of sardine (Butterworth 1983).

Off South Africa, where anchovy replaced sardine in the 1960s and 1970s (Schwartzlose *et al*. 1999), Cape gannets were able to switch from eating sardine to feeding on anchovy (Berruti *et al*. 1993). Breeding African penguins have a relatively small foraging range and, because anchovy do not have the same distribution as sardine, there were large decreases in South African penguin colonies located north of Cape Town (Crawford *et al*. 2001). Numbers of penguins at colonies farther south, where anchovy was abundant throughout the breeding season, increased. It is thought that there was large-scale emigration of first-time breeders from colonies where food became scarce, after the collapse of the sardine, to the southern colonies (Crawford 1998). From the mid 1980s sardine increased off South Africa and there was a reversal in these trends for both African penguins and Cape gannets (Crawford 1999).

In 1998, South Africa enacted its Marine Living Resources Act (No. 18 of 1998; Anon. 1998), which in Section 2 lists its objectives and principles. These include:

"(a) The need to achieve … ecologically sustainable development of marine living resources;
(b) the need to conserve marine living resources …;
(c) the need to apply precautionary approaches in respect of the management … of marine living resources;
(d) the need to … achieve … a sound ecological balance …;
(e) the need to protect the ecosystem as a whole, including species which are not targeted for exploitation;
(f) the need to preserve biodiversity …" .

The Act took cognizance of several international initiatives aimed at encouraging the application of an ecosystem approach in management of fish resources (summarized in FAO 2003).

In 2002 at Johannesburg, the World Summit on Sustainable Development adopted a Plan of Implementation that agreed (Article 29d) to "encourage the application by 2010 of the ecosystem approach, noting the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem" (FAO 2003). The 2001 Reykjavik Declaration had called for the incorporation into fisheries management of ecosystem considerations "such as predator-prey relationships" (http://www.fao.org/PDF/acro-e.htm).

Earlier, at its 28th Session on 31 October 1995, the FAO Conference adopted the FAO Code of Conduct for Responsible Fisheries. Article 6.2 of that Code states "Management measures should not only ensure the conservation of target species but also of species belonging to the same ecosystem or associated with or dependent upon the target species." Article 6.5 reads "States and subregional and regional fisheries management organizations should apply a precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment, taking account of the best scientific evidence available. The absence of adequate scientific information should not be used as a reason for postponing or failing to take measures to conserve target species, associated or dependent species and non-target species and their environment" (http://www.fao.org/DOCREP/005/v9878e/v9878e00.htm).

The 1982 United Nations Convention of the Law of the Sea requires that "coastal states shall take into consideration the effects on species associated with or dependent upon harvested resources with a view to maintaining or restoring populations of such associated or dependent species above levels at which their reproduction may become seriously threatened" (FAO 2003).

However, by 2004, management of the South African purse-seine fishery for sardine and anchovy had not taken account of the food requirements of seabirds. This paper considers how it may move towards considering these requirements.

IDENTIFYING TARGET POPULATIONS FOR DEPENDENT SPECIES

In cases where the conservation of a dependent species is of concern, it will be desirable to set some target population level for that species. What the level should be merits consideration.

With regard to fished resources, the FAO Code of Conduct for Responsible Fisheries recommends (Section 7.2.1) that measures be adopted that are designed "to maintain or restore stocks at levels capable of producing maximum sustainable yield". Article II of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) indicates that the objective of the Convention is the conservation of Antarctic marine living resources and that such conservation includes rational use. Section 3 of that Article stipulates that: "Any harvesting and associated activities in the area to which this Convention applies shall be conducted in accordance with … the following principles of conservation: (a) prevention of decrease in the size of any harvested population to levels below those which ensure its stable recruitment. For this purpose its size should not be allowed to fall below a level close to that which ensures the greatest net annual increment; (b) maintenance of the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources and the restoration of depleted populations to the levels defined in sub-paragraph (a) above; …" (http://www.ccamlr.org/pu/e/pubs/bd/pt7p7.htm).

For several fish stocks in the North-West Atlantic, including Atlantic herring *Clupea harengus*, mackerel *Scomber japonicus*, haddock *Melanogrammus aeglefinus* and silver hake *Merluccius bilinearis*, Brown *et al*. (1983) presented empirical evidence that recruitment remained poor when stocks were reduced to 10% of pristine levels, but that often good year-classes were experienced and stock rebuilding took place when biomass was about 20% of peak levels. Life-history characteristics of seabirds are different from those of fish, so the same level of reduction that would achieve satisfactory recruitment may not apply. For example, at the time that guano collection at Ichaboe Island, Namibia, ceased in 1989, the area used by breeding Cape gannets was 33% of its level in 1956 (Marine and Coastal Management [MCM], unpublished data), when gannets occupied most of the island (Crawford 1991). Yet the gannet population at this island, and at other Namibian islands, continued to decrease during the 1990s (Crawford in press, MCM, unpublished data). At Dassen Island, during a period of exploitation of the eggs of African penguins, the penguin population decreased by almost 90%, from 1.45 million birds in adult plumage in 1910 to 0.14 million birds in 1967 (Shannon and Crawford 1999). Although egg collection at Dassen Island was terminated in 1967 (Shelton *et al.* 1984), the island's penguin population continued to decrease until the mid 1990s (Crawford *et al*. 2001).

In the Benguela, the restoration of seabird populations to a level that would ensure the greatest net annual increment would mean that management would target a large increase in the populations of some species. For example, the African penguin decreased by about 90% during the 20th century (Crawford *et al*. 1995, Shannon and Crawford 1999), and maximum production of penguin eggs, a formerly harvested commodity (Shannon and Crawford 1999), would be expected for a population that is several times its present size. The historical harvests of eggs are listed in Shelton *et al*. (1984).

In terms of the conservation of a species, it may be assumed that classification as Vulnerable (or worse), applying criteria of the IUCN, is an undesirable status. One of the criteria adopted by the IUCN Council in February 2000 for a species to be classified as Vulnerable, is that a quantitative analysis shows that the probability of its extinction in the wild is at least 10% within 100 years (http://www.redlist.org/info/categories_criteria.html). Based on this criterion, it has been suggested that a minimum viable population (MVP) should have a probability of extinction of <10% within 100 years (Crawford *et al*. 2001). A desired level for the population would be some multiple of the MVP.

Stochastic modelling, drawing demographic parameters from their observed distributions (e.g. Shannon and Crawford 1999), may be used to assess the probability of extinction of seabird colonies of different sizes. For African penguins, such modelling suggested the MVP to be about 10 000 pairs. However, off southern Namibia, numbers of African penguins decreased from 40 000 pairs in 1956 to about 1 000 pairs in 2000, leading to the observation that a total population (Namibia and South Africa combined) of at least 50 000 pairs would probably be needed to safeguard against extinction within 100 years and, applying the precautionary principle, should be regarded as the MVP. The discrepancy between the model and empirical observations was attributed to the fact that parameters used in the model had been estimated for a colony that had been growing, whereas the decreases off Namibia had occurred during a period of extreme food scarcity (Crawford *et al*. 2001).

In 2000, the overall breeding population of African penguins was about 63 000 pairs (Crawford and Whittington in press), ca. 10% of the level estimated for the start of the 20th century (Crawford *et al*. 1995, Shannon and Crawford 1999) and similar to the MVP adopted using the precautionary approach. Further, at all except two colonies the populations were <10 000 pairs, indicating a >10% likelihood of their loss within 100 years in the absence of immigration. Should there be immigration, as there has been at some colonies (Crawford 1998), the likelihood of colony extinction would reduce, but it is thought still to be high at some localities (Crawford *et al*. 2001). It is desirable to maintain as many colonies as possible as foci for growth in the event of an altered distribution of prey resources, as has been observed, because of the limited foraging ranges of breeding African penguins (Crawford *et al*. 2001).

Clearly, the population of African penguin is in need of rebuilding. However, the means for selecting a target population is less certain. Density-dependent effects have yet to be ascertained and hence have not been incorporated in population models (Shannon and Crawford 1999). A target of double the MVP would provide for greater confidence in the long-term conservation of the species. A 10% risk of extinction in 100 years is considered "high" by IUCN. For the African penguin, double the MVP would mean a target of 100 000 pairs, of the order of 20% of the population in the early 1900s. This would reduce the probability of extinction to about 5% (Crawford *et al*. 2001) and conforms to the level of about 20% of pristine biomass, above which several fish stocks have produced good year-classes (Brown *et al*. 1983). However, because of the substantial parental investment by most seabirds in chick rearing, maximum recruitment in seabird populations may well take place at a population level greater than this proportion.

For less abundant species, alternative IUCN criteria may be used to define MVPs. For example, a species is considered Vulnerable if its population is estimated to number <1 000 mature individuals. It is also considered Vulnerable if it is estimated to number <10 000 mature individuals and either there is an estimated continuing decline of at least 10% within 10 years or three generations, whichever is longer (up to a maximum of 100 years in the future), or there is a continuing decline, observed, projected or inferred, in numbers of mature individuals and either no subpopulation is estimated to contain >1 000 mature individuals, all mature individuals are in one subpopulation, or there are extreme fluctuations in the number of mature individuals.

In the context of the Benguela, for example, these criteria may be used to propose a MVP for that race of swift terns endemic to southern Africa, which is nomadic between breeding localities (Crawford *et al*. 1994). It numbers some 4 800–6 300 breeding pairs (Cooper *et al*. 1990, Crawford 2003). Although there has been no long-term decline in the number of swift terns, there have been substantial fluctuations in the number of breeding birds (Crawford and Dyer 1995) and all individuals may belong to the same subpopulation (Crawford *et al*. 2002). Therefore, any continuing decline to a level below 10 000 mature individuals, say to 4 000 pairs or 8 000 mature individuals, would be sufficient for a classification of Vulnerable. Hence, the MPV would be about 4 000 pairs and the desired population greater than this, at least as large as at present.

ATTAINING TARGET POPULATIONS FOR DEPENDENT PREDATORS

Once a target population for a dependent predator has been identified, it will be necessary to implement management measures to attain that population. It may not be adequate to estimate the overall amount of food required by the target populations of all predators of a forage fish resource and to allow for the escapement of that quantity of food from the fishery. There are at least two reasons for this. In the first instance, abundant predators may exceed their desired populations and may be increasing. Such predators will eat more than the food allocations for their target populations. In the Benguela system, there were large increases during the 20th century in numbers of opportunistic predators, such as kelp gulls *Larus dominicanus* and Cape fur seals *Arctocephalus pusillus*, for which humans have provided alternative sources of food and breeding habitat (Crawford *et al*. 1982, Steele and Hockey 1990, Crawford 1991, Butterworth *et al*. 1995, Crawford and Hockey in press). Second, it is often the density of prey that influences factors such as the proportion of mature birds that breed and hence the year-class strength of seabirds (Crawford 2003), so it is necessary to ensure adequate densities of prey around breeding colonies.

An approach may be to disallow fishing within a certain distance of seabird breeding colonies. Some information on the foraging ranges, while breeding, of African penguins and Cape gannets is available (summarized in Crawford in press, Crawford and Whittington in press), but more information is required and the efficacy of closed fishing areas around colonies needs to be tested. Sardine and anchovy are both migratory off South Africa (Crawford 1980). Therefore, even if catches are made away from breeding localities, fishing may cause pelagic fish densities to be reduced around breeding localities.

An alternative approach is to allow sufficient escapement of prey from fisheries to ensure adequate densities of prey. This could be based on functional relationships between the predator and its prey that are empirically determined. Such functional relationships may be used to couple models of the predator and the prey, in order to explore the long-term impact on the predator of different harvesting strategies for the prey. Observed uncertainty in the functional relationship, and in parameters used in models of the prey and predator populations, can be accounted for stochastically (Shannon and Crawford 1999). An example of such use of a functional relationship to couple models of a predator and its prey is given in Crawford *et al*. (1992).

Relationships between demographic parameters of predators and the biomass of sardine or anchovy estimated from acoustic surveys have been developed for several seabirds in South Africa. For the African penguin at Robben Island, the proportion of mature birds that bred was related to the biomass of both sardine and anchovy and the number of chicks fledged per pair was related to the biomass of anchovy (Crawford *et al*. 1999). Estimates of first-year survival of penguins from Robben and Dassen islands were also related to the biomass of anchovy (Whittington 2002). Fledgling production of African penguins in Saldanha Bay increased during the 1980s as the biomass of sardine increased, as did that of Cape gannets in the latter part of the same decade (Adams *et al*. 1992). For Cape cormorants, the numbers of birds breeding (thought to represent the proportion of mature birds breeding) and fledgling success were related to biomass of anchovy (Crawford *et al*. 1992). For swift terns, numbers of birds breeding (again thought to represent the proportion of mature birds breeding) were related to the combined biomass of sardine and anchovy (Crawford 2003). The relationship between adult survival of seabirds and food abundance has not yet been investigated for seabirds in South Africa, but elsewhere food has been shown to influence adult survival (e.g. Dann *et al*. 2000, Oro and Furness 2002).

When the objective is to maintain the population of the dependent species at its present level, it will mean ensuring reproduction and survival such that recruitment to the breeding population will on average balance mortality from it. When the goal is growth of the predator population, it will be necessary for recruitment to exceed mortality. The required excess will depend on the time frame within which the target is to be met. Provisionally it has been estimated that levels of escapement from purse-seine fisheries of 0.8 million tons for sardine and 0.9 million tons for anchovy may be sufficient to sustain seabirds off South Africa (Crawford 2001).

It can be anticipated that there will be an upper limit to the sizes of predator populations, brought about *inter alia* by limitations of space and food that will decrease recruitment and/or survival. However, because the African penguin is at a greatly reduced level of abundance (some 10% of its pristine level), such density-dependent responses have not yet been detected for this species and it may be some decades yet before they become apparent. Ideally some form of density dependence should be incorporated in population models of predators (e.g. Butterworth and Thomson 1995), but the absence of this information should not preclude the implementation of approaches based on empirical observations to account for their food requirements. The Reykjavik Declaration notes the necessity to take immediate action to address urgent problems on the basis of the precautionary approach (http://www.fao.org/PDF/acro-e.htm).

In the VORTEX model of populations (Lacy 1993), which is an individual-based simulation, the carrying capacity of the habitat is modelled as a ceiling population size. When the carrying capacity is exceeded, VORTEX applies an additional risk of mortality to each individual, such that the population size will on average return to the carrying capacity (Whittington *et al*. 2000). It may be possible to account for density dependence in this way by assuming that the ceiling population of African penguins was that estimated for the 1930s, about 1.45 million birds in adult plumage (Shannon and Crawford 1999).

As predator populations increase, they will likely consume a greater quantity of fodder resources. However, off South Africa, seabirds account for only a small proportion of the overall mortality of pelagic fish (8%; Shannon *et al*. 2003), of which a substantial part is taken by migratory seabirds (Crawford *et al*. 1991). Therefore, at the present level of abundance of seabirds, a one-way interaction model, in which fluctuations in prey abundance impact on the predator population but not *vice versa* (Butterworth and Thomson 1995), is considered adequate.

Although inadequate densities of food are thought to have a major negative impact on populations of seabirds off South Africa (Crawford and Dyer 1995), other factors also play a role and should be managed. These include the displacement of seabirds from breeding sites by seals (Crawford *et al*. 1989), heavy mortality of seabirds inflicted by seals around breeding colonies (David *et al*. 2003) and mortality of seabirds attributable to oiling (Crawford *et al*. 2000). The effective conservation of seabirds in the region will require holistic management.

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