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Population trends, breeding success and diet composition of gentoo Pygoscelis papua, magellanic Spheniscus magellanicus and rockhopper Eudyptes chrysocome penguins in the Falkland Islands

Accepted: 5 May 2001 / Published online: 26 June 2001
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Abstract Data on population size, breeding success and diet composition of gentoo (Pygoscelis papua), magellanic (Spheniscus magellanicus) and rockhopper (Eudyptes chrysocome) penguins, collected as part of the Falkland Island Seabird Monitoring Programme from 1986/1987 to 1998/1999, were analysed with regard to spatial and temporal variation, as well as potential interaction with local commercial fisheries. No significant population trends were detectable, mainly because of the short time-series and large spatial and inter-annual variation in the number of breeding pairs in the colonies monitored. However, the breeding success of all three penguin species has improved slightly over the last few years, indicating a potential for increasing populations in the near future. During the breeding season, all three penguin species preyed opportunistically on a mixture of fish, squid and crustaceans. Diet composition too showed a high degree of spatial and temporal variation. However, in all three penguin species studied, squid gradually disappeared from the diet over successive years, to be replaced by fish. Coincidentally, the commercial catches of the squid species Loligo gahi in Falkland Islands waters decreased and the by-catch of nototheniid fish increased. All three penguin species compete directly with the commercial fishing fleet for L. gahi; however, there may also be competition for Patagonian toothfish (Dissostichus eleginoides), hake (Merluccius sp.) and southern blue whiting (Microstomus australis), because juveniles of these species were found regularly in penguin diets.

Introduction

It is well accepted that commercial fisheries can have a significant effect on marine top predators (e.g. Moore and Jennings 2000). Some aspects of fishing practice can have positive effects, as they provide new resources for seabirds in the form of offal and discards (e.g. Thompson 1992; Camphuysen et al. 1995; Thompson and Riddy 1995). Other fishing practices can have very negative effects as, for example, incidental catch of albatrosses and petrels by longlining vessels (Gales 1998; Brothers et al. 1999; CCAMLR 1999, 2000) and bycatch of penguins in shrimp trawl fisheries (Gandini et al. 1999). Decreases in predator populations or their performance sometimes coincide with decreases in their main prey (e.g. Boersma and Stokes 1995; Crawford and Dyer 1995; Croxall et al. 1999), and there is some evidence that commercial exploitation of prey might be contributing to a decline (e.g. Furness 1982; Duffy 1983). However, it is still very difficult to confirm significant cause-effect linkages and there is usually much reliance on correlation evidence. Studying fishery-predator-prey interactions needs a good knowledge of diet (including scope for prey switching) and foraging ecology of predators, and the ability to assess changes in their population, together with similarly accurate data on fishery catches (and bycatches) and distribution of fishing effort. So far, only a few studies have addressed competitive interactions between fisheries and penguins (reviews in Croxall 1987). In particular, Duffy et al. (1987) suggested that the population of African penguins (Spheniscus demersus) may be threatened by competition from purse-seine fisheries. Nearer to the Falkland Islands, magellanic penguins are believed to compete directly with fishing fleets targeting anchovies.
over the Patagonian Shelf (Scolaro 1986; Boersma et al. 1990).

Fishing activities in the vicinity of the Falkland Islands have increased dramatically since the mid-1970s, potentially threatening fish and squid stocks (Patterson 1987). Consequently, concern grew over the potential effects of such activities on the globally significant seabird populations breeding in the Falkland Islands. There was a mass mortality of rockhopper penguins during the 1985/1986 breeding season, which was linked to starvation following food shortage (Keymer 1988). Subsequently, conservation zones have been established around the islands and the number of vessels fishing within these zones has been regulated to protect fish and squid stocks from becoming depleted. A pilot study, focussing on potential competition for food between seabirds and fisheries, was conducted during the austral summer of 1986/1987 (Thompson 1989). The results of this study led to the start of the Falkland Island Seabird Monitoring Programme (FISMP). The aim of the program was to collect data on diet composition, breeding pair numbers and breeding success of various seabird species, in order to establish baseline data, thereby enabling the detection of potential threats to Falkland Islands seabirds. The results obtained during each breeding season were summarised in annual reports (Thompson 1990, 1991, 1993a; Bingham 1994, 1995; Ingham 1998a, 1999).

In the mid 1990s, specific areas to the north of the Falkland Islands were designated for hydrocarbon exploration and possible exploitation; exploratory drilling took place during 1998. In addition, there are plans for further areas to the southwest of the islands to be licensed for hydrocarbon exploration in the near future. After more than 10 years of regulated fishing activities and with the prospect of oil exploration and exploitation in Falkland Islands waters, a comprehensive review of the data obtained so far by the FISMP is timely. The aim of this report is to summarise data obtained so far on population size (breeding pair numbers) and breeding success at selected colonies, as well as on the diet composition of the three penguin species covered in the FISMP, namely the gentoo penguin (*Pygoscelis papua*), the magellanic penguin (*S. magellanicus*) and the southern rockhopper penguin (*Eudyptes chrysocome*). All three penguin species breed in globally significant numbers in the Falkland Islands (Croxall et al. 1984; Ellis et al. 1998) and any significant changes in the parameters monitored would undoubtedly affect the world population of these particular species. There is already evidence of a decline in numbers for these penguin species (Bingham 1998), the main reasons for which remain unknown.

**Materials and methods**

Data on breeding pair numbers, breeding success and diet composition were collected annually from various sites around the Falkland Islands from the breeding seasons 1986/1987 to 1998/1999 (Fig. 1). For spatial comparison, sample sites were grouped into northern (Cow Bay, Seal Bay, Volunteer Beach), western (Beaver Island, Keppel Island, New Island, West Point Island) and southern (Beaufhene Island, Bull Point) locations.

In general, data collection followed the methods described in detail by Thompson and Ridd (1993), updated by Ingham (1998a). Briefly, numbers of breeding pairs (during incubation in November) and chicks (shortly before fledging in January) at specific sites were counted at least twice using tally counters. In cases where both counts differed by more than 10%, a third count was conducted and all counts subsequently averaged. The results obtained were then used to calculate the breeding success for each site. Counts were lost from all sites for the 1996/1997 breeding season due to a corrupt database and could not be recovered from field notes.

Diet sampling was based on the water-offloading technique described by Wilson (1984). Diet samples were drained and preserved in 40% industrial methylated spirits until final analysis. After weighing to obtain total sample weight, drained samples were rinsed in water and sorted into the main components: fish, squid and crustaceans. Unidentifiable material and stones were classified as “other”. Identification of individual species was carried out using either whole animals or remains such as otoliths (fish), beaks (squid) and carapaces (crustaceans), by comparing them with reference collections held by the Falkland Islands Fisheries Department.

**Fig. 1** The location of the breeding sites studied in the Falkland Islands between 1986/1987 and 1998/1999.