FRESHWATER FISHING IN SEABIRDS FROM THE SUB-ANTARCTIC KERGUELEN ISLANDS

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SUMMARY

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Salmonid fish were introduced into the freshwater ecosystems of the sub-Antarctic Kerguelen Islands between 1955 and 1992. Before that period, those ecosystems were free of freshwater fish. Because of the absence of competition and other factors, the various populations of salmonid fish increased exponentially soon after their first successful introductions. Field workers have been monitoring the populations of salmonids over a period of 40 years. Here, we present a summary of observations by those field workers of seabirds foraging on freshwater fish. Observations show that several seabird species benefit from the fish. However, although the density of fish is extremely high, the numbers of seabirds actually exploiting them remains low. Simple calculations show that seabirds probably do not affect freshwater fish demography significantly. The discrepancy between the numbers of seabirds freshwater fishing and the numbers of fish present could result from difficulty of access for seabirds to this potential resource.

Key words: Kerguelen Shag, *Phalacrocorax verrucosus,* Salmonidae, Gentoo Penguin, *Pygoscelis papua,* Kerguelen Islands

INTRODUCTION

By French government decree (no. 2006-1211 of the French Ministry of Ecology and Sustainable Development—3 October 2006), a very large nature reserve (7000 km^2) was created within the French sub-Antarctic territories, including all the terrestrial and adjacent marine areas of the Crozet Archipelago, Kerguelen Islands, Saint Paul Island and Amsterdam Island. Enforcement of this decree is accompanied by actions for the protection and restoration of indigenous communities of fauna and flora. Indeed, over the past 250 years, mice, rats, rabbits, cats, sheep, bighorn sheep, cows and reindeer have been introduced, more or less deliberately (Duchêne 1989). These animals have often had a negative impact on local species, through habitat destruction or direct predation (Chapuis *et al.* 1994).

Eight species of fish from the Salmonidae family (trout, char and salmon) were introduced into the rivers and lakes of Kerguelen between 1955 and 1992 for recreational or commercial purposes. Today, only five species, which have become acclimatized and naturalized (Duhamel *et al.* 2005), survive. The most abundant species among these are the Brown Trout *Salmo trutta* and the Brook Char *Salvelinus fontinalis.* The distinctive feature of the salmonids of Kerguelen is the absence of native freshwater fish before the introduction of this group by humans. Thus, the salmonids colonized a vacant niche—a situation that is unique for long-term studies of fish demography, population genetics and acclimatization physiology (Davaine & Beall 1997).

The expansion of the fish population has been monitored since the first successful introductions (1959 for the Brown Trout, 1962 for the Brook Char), but the relationship between this potential new resource and the seabird community of the Kerguelen Islands has never been investigated. Here, we present a synthesis of the observations that were made of seabirds (mainly the Kerguelen Shag *Phalacrocorax verrucosus*) that forage on trout and char in the rivers and lakes of the Kerguelen Islands. These observations were collected opportunistically by field workers monitoring the fish populations since the early 1970s.

RESULTS

The presence of the Kerguelen Shag on the river systems of the Kerguelen Islands was first noted in 1970, the year studies in hydrobiology were undertaken on a regular basis. The first observation was of a single individual foraging on Lac des Truites, an up-river lake of the Studer River (Fig. 1), a system in which the Brown Trout population derives from individuals introduced in 1959. Although this observation occurred only 10 years after the introduction of the Brown Trout, it is possible that shags started freshwater fishing before then. Over the following years, field workers continued to monitor the trout population of the up-river lakes of the Studer system in the same fashion (three to 10 times per year). Between 1960 and 1990, the fish populations of the Kerguelens followed an exponential model, in certain areas reaching densities that were considerably higher than those found in Europe [because

of strong fecundity and survival, and an absence of interspecific competition (Davaine & Beall 1997)]. Yet, over this same period, the number of shags observed at the lakes of the Studer system did not appear to increase. Although shags were regularly observed fishing in the lakes of the Studer system, only one or two individuals were present each time. On some occasions, no birds were present.

Thus, not only did the number of fish increase in a given river system between 1960 and 1990, but the number of systems colonized by the fish increased as well. Between 2001 and 2003, all river systems containing salmonids were sampled from their source to their estuary—a group representing 46 river systems (sometimes associated with an upstream lake). Most of these rivers are located on Péninsule Courbet (Duhamel *et al.* 2005), a large, 800-km^2 peninsula occupying the northeast side of Kerguelen (Fig. 1). In almost all of these systems (except in very small streams), one shag was commonly observed fishing in the downstream part and another in the up-stream lake (when present), even though a shag colony was not present near the estuary. Shags caught fish of all sizes, from juveniles to 400-g adults. Once, on a shallow portion of a river, an immature shag was observed catching and swallowing four juvenile trout in less than five minutes, and each dive was successful. Diving in rivers is not without risks, and two shags were found drowned, stuck underwater between rocks. They were perhaps unable to cope with the violent and rapid current characteristic of the rivers of the Kerguelen Islands.

Kerguelen Shags are not the only seabirds to profit from the introduction of salmonids to the Kerguelens. The Gentoo Penguin *Pygoscelis papua* has been observed since 1970 apparently foraging in rivers and lakes—lakes that are sometimes more than 10 km inland from the estuary. After entering the estuary, penguins swim up the river and walk alongside it when the water level is inappropriate for swimming. During the 2001–2003 sampling period, penguins were present on several of the rivers containing salmonids. Like the shags, only one or two individuals were observed in a given river and lake system. Penguins were not as frequently recorded as shags were, probably because shags can fly from one point to another, whereas penguins cannot explore rivers that are inadequate for swimming (smaller rivers).

Terns (probably the Kerguelen Tern *Sterna virgata*) were also regularly observed feeding on juvenile fish (up to eight centimetres), which live in shallow parts of rivers. Terns were either alone or in very small groups. During spawning, which occurs in very shallow waters (10–30 cm deep), the adult trout are exposed. Only then were they observed being attacked by the Kelp Gull *Larus dominicanus* and the Subantarctic Skua *Catharacta antarctica.* The Subantarctic Skuas were more skilful, capturing and swallowing whole 500-g trout. A fish weighing more than 1 kg was once captured and pulled ashore by a single skua.

DISCUSSION

Our observations suggest that, although the populations of trout and char have grown exponentially, the number of seabirds (shags and penguins at least) that can be found foraging in a given lake or river at the Kerguelens has barely changed since the days of fish introduction and early expansion. Consequently, there is a complete imbalance between the densities of available fish and the numbers of birds exploiting them. Simple calculations confirm that the impact of the seabirds on the demography of the salmonids is negligible. For example, when considering, on the one hand, the productivity of rivers at the Kerguelen Islands (Davaine & Beall 1997), and on the other, the daily requirements of Great Cormorants *Phalacrocorax carbo* (Grémillet *et al.* 1995) and Gentoo Penguins (Bevan *et al.* 2002) relative to the number of shags and penguins present on any river system, it is clear that neither seabird significantly affects the fish population. Kelp Gulls and Subantarctic Skuas opportunistically feed off salmonids during very short periods of accessibility, which correspond to spawning. The Kerguelen Terns catch only juvenile fish, a class that is naturally affected by high mortality (the proportion removed by the terns consequently has little impact on the population structure in the following years). From the seabirds' perspective, the impact of the growth of the fish population on seabird demography is also probably limited, except perhaps for terns. A Kerguelen Tern colony next to one of the lakes of the Studer system seems to have grown in parallel with the fish population.

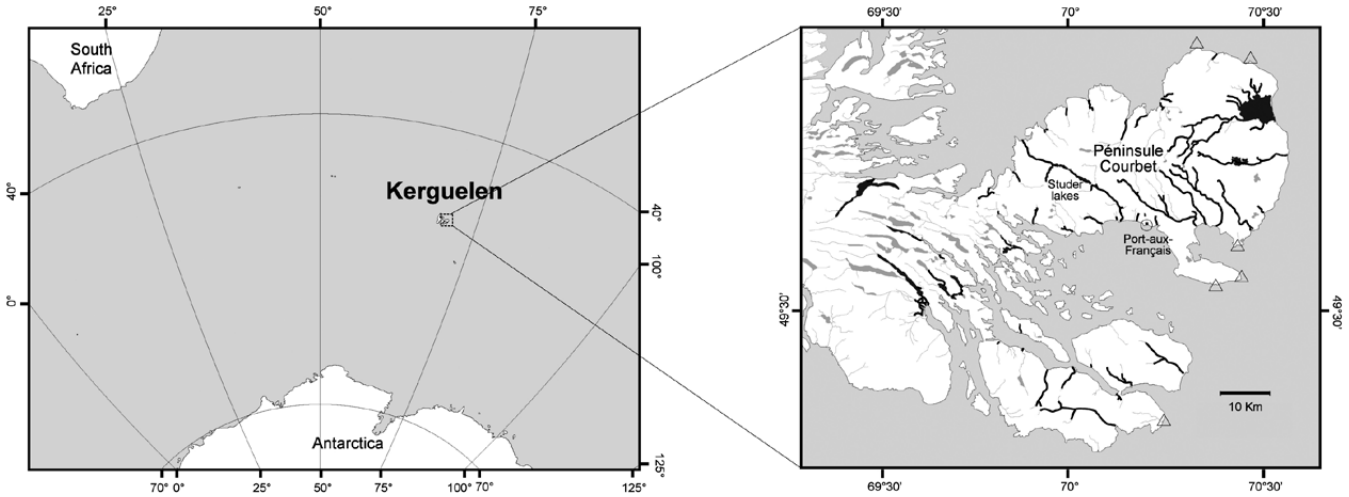

Fig. 1. (a) General location of the Kerguelen Islands in the Southern Ocean. (b) Map of eastern Kerguelen Islands, showing all river systems containing salmonid fish. Port-aux-Français is the French research station. Triangles represent the main known Kerguelen Shag *Phalacrocorax verrucosus* colonies of 200–2000 breeding pairs. Fish are present mostly on Péninsule Courbet. River systems in grey are free of fish. Systems or river portions in black are populated. The first successful introduction of fish took place in the lakes of the Studer river system, where the first observation was made of a Kerguelen Shag freshwater fishing.

The freshwater fish resource that is available for the terns, gulls and skuas is episodic. These species have mixed diets and do not depend exclusively on fish. Penguins are limited by their inability to move efficiently over land and to swim in very shallow waters—a limitation that may explain why more of them do not feed off salmonids. However, cormorants are typically piscivorous. Considering the high densities of salmonids at the Kerguelen Islands, why are the numbers of Kerguelen Shags that forage on trout not greater? Kerguelen Shags can fly from the sea to a lake that is 10 km inland in 10 minutes (Orta 1992). The proximity and densities of fish should be highly attractive to the shags.

The Kerguelen Shag belongs to the blue-eyed shag complex, a group of 13 closely related species of cormorants distributed across the Southern Ocean (Orta 1992). To our knowledge, our observations represent the first description of freshwater fishing in a blue-eyed shag species (and in Gentoo Penguins also). Blue-eyed shags normally feed off benthic fish from the saltwater Notothenioidei suborder (Cook 2008). The Kerguelen Shag population is around 10 000 breeding pairs (Weimerskirch *et al.* 1988), which, including non-breeders and immature birds (three years of age or younger), might amount to a total of approximately 40 000 individuals. Considering the presence of two individuals on every one of the 46 river systems containing salmonids, the number of shags that feed off trout may represent only 0.2% of the shag population. The shags observed freshwater fishing were mainly immature (as were many of the Gentoo Penguins—C.A. Bost pers. comm.), an interesting observation, because freshwater fishing may be practised mainly by inexperienced individuals or by a handful of adult specialists [individual-level diet specialisation (Bolnick *et al.* 2003)]. During reproduction, Kerguelen Shags form dense colonies by the sea (Fig. 1). Raising chicks efficiently requires the collection of food as close as possible to the nest, in this case at sea. Addition of the potential difficulty of catching the fish in freshwater systems and the higher risk of drowning when fishing in the torrential rivers of the Kerguelen Islands might help to explain why this behaviour is not more widespread in the Kerguelen Shag.

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