Episodic Predation on Post-Smolt Atlantic Salmon (*Salmo salar*) by Northern Gannets (*Morus bassanus)*

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Keywords: Atlantic salmon, gannets, post-smolt predation, regime shift

Salmon population declines in both the Atlantic and Pacific Oceans appear to be related to the demise of juvenile salmon at sea (Hansen and Quinn 1998). Predation may play a role and could contribute to cumulative effects with other sources of mortality, e.g. aquaculture practices (Gross 1998), climate change (Welch et al. 2000), and pesticide use (Fairchild et al. 1999). It has proven difficult to document natural mortality of marine-phase salmon (Friedland 1998), and most predation on Atlantic salmon has been recorded in rivers and estuaries (Cairns 1998). We present evidence of varying levels of mortality among marine-phase, post-smolt Atlantic salmon in an analysis of a 25-year data set of the prey landed by northern gannets at a large breeding colony on Funk Island off the northeast coast of Newfoundland in the Northwest Atlantic. We explore the implications of these findings and recommend research strategies at gannet colonies that will enhance understanding of avian predation on post-smolt Atlantic salmon throughout the North Atlantic. We also indicate ways in which light-weight data loggers attached to avian predators can be used to enhance knowledge of the behavioral ecology and habitat use of marine phase Atlantic salmon.

Gannets are the largest marine birds that breed in the North Atlantic. They are opportunistic foragers that prey on a variety of pelagic fish and squid, including mackerel (*Scombrus scomber*), herring (*Clupea harengus*), Atlantic saury (*Scomberesox saurus*), short- and long-finned squid (*Illex illecebrosus* and *I. loligo*), capelin (*Mallotus villosus*) and sand lance (*Ammodytes* spp.) (Montevecchi and Myers 1997). During the course of this research from 1977 - 2001, there have been major changes in oceanographic conditions (Drinkwater 1996) and fisheries activities in the Northwest Atlantic (Carscadden et al. in press). A significant cold-water event in 1991 produced numerous changes in biological oceanography (e.g. Regehr and Montevecchi 1997). Gannets showed a marked dietary change from warm-water prey (mackerel, squid, saury) diets during the late 1970s and 1980s to cold-water prey (capelin, herring) through the 1990s. These dietary changes are indicative of larger-scale shifts in pelagic food webs (Montevecchi and Myers 1996).

Post-smolts are a minor dietary component for gannets during their breeding season. Through the late1970s and 1980s, salmon comprised on average < 1% (range = 0 to 2%) of the mass of the gannets' diet (Fig. 1). During the 1990s, however, consumption levels of salmon increased by an order of magnitude to more than 2.5% (range = 0 to 6%) of dietary mass. In 2001, the gannets' estimated level of consumption of salmon increased to more than 25% of the mass of the prey consumed. We attribute the decadal shifts in diet between the late 1970s/80s and the 1990s to biological responses to a physical oceanographic regime shift (Steele 1998) in the early 1990s in the Northwest Atlantic (Montevecchi and Myers 1996). The high level of predation on salmon by gannets in 2001 was attributed to variation associated with episodic avian predation and limited sampling effort. Predation on salmon is related to their presence and detection within avian foraging ranges (up to 180 km) around colonies (Fig. 2). Predation on salmon might increase when other large prey (e.g. mackerel) are absent or in reduced abundance within the gannets' foraging range. More intra-annual sampling over longer periods is needed at Funk Island and

Fig. 1. Atlantic salmon as a percentage of mass of prey eaten by northern gannets at the colony on Funk Island off northeastern Newfoundland in the Northwest Atlantic. Estimated percentage of the post-smolt biomass in the Northwest Atlantic preyed on by gannets from a bioenergetics model presented in Montevecchi et al. 2002.

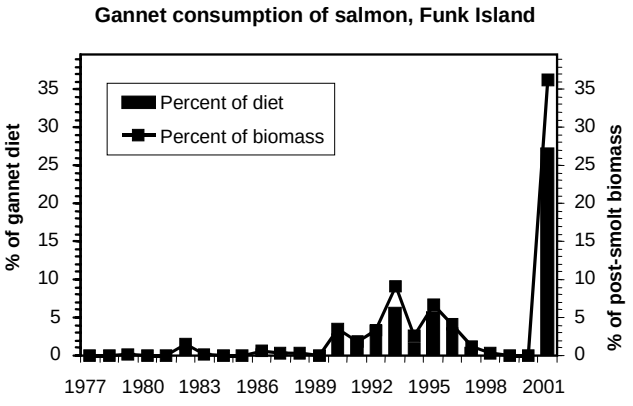

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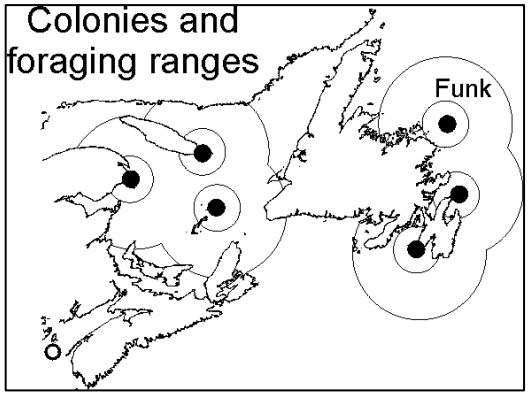
Fig. 2. Location of Funk Island and five other gannet colonies in North America. Circles around colonies represent average (60 km) and maximum (180 km) foraging ranges of gannets breeding in these colonies. Post-smolt Atlantic salmon from rivers in the Maritimes, New England and Newfoundland and Labrador pass through these foraging ranges.



especially at the other gannet colonies, referred to below, where dietary sampling is essentially nonexistent.

Predation by gannets may influence the population dynamics of North American Atlantic salmon. The migratory pathways of post-smolt Atlantic salmon pass through the foraging ranges of the six North American colonies of gannets, three of which are in the Gulf of St. Lawrence and three off eastern Newfoundland (Montevecchi et al. 1988; Reddin 1988; Fig. 2). Breeding populations of gannets at these colonies are increasing (Fig. 3).

Non-invasive, dietary sampling of gannets is an ecologically sound, cost-effective and efficient means of obtaining information about the natural mortality and behavioral ecology of marine-phase Atlantic salmon. There has, however, been very little sampling of gannet diets at colonies other than Funk Island, and even at Funk Island the intra-annual temporal extent of sampling is restricted. Systematic sampling of the diets of gannets at breeding colonies will greatly help quantify the predatory mortality that gannets impose on Atlantic salmon. It would be informative to expand dietary sampling regimes to gannet colonies in Europe, Norway (Montevecchi and Barrett 1987) and Iceland (Fig. 4). In view of recent findings that at least some Atlantic salmon of North American origin occur in the Northeast Atlantic (Tucker et al. 1999), such dietary sampling could be relevant for post-smolts from all origins.

Research with marine birds can also be used to collect data on the movements, behavior and ecology of Atlantic salmon at sea. Gannets equipped with stomach thermal sensors, externally attached compass recorders and miniaturized data loggers that record temperature and pressure (e.g. Benvenuti et al. 1998; Garthe et al. 2000) can also be used as sampling agents to collect information on the movements and behavioral ecology of post-smolt Atlantic salmon at sea. For example, the spatial and temporal movement patterns and thermal habitats of salmon can be derived from directional, water temperature and depth data obtained from gannets that catch salmon. Given the difficulty of tracking post-smolts at sea (Montevecchi et al. 1988; Ritter 1989), these research opportunities hold quite promising potential (e.g. Wilson et al. 2002).

Many people helped in field collections, especially Iain Stenhouse, Stefan Garthe, Gail Davoren, Nicholas Montevecchi, Janet Russell and Laura Dominguez who crewed our expeditions in the 1990s. Research was supported by grants from NSERC.

Fig. 3. Breeding populations of northern gannets in North America. Colonies (from top to bottom): Funk, Baccalieu, Cape St. Marys, Great Bird Rock, and Bonaventure Island. The population of gannets on Anticosti Island is too small to be plotted at this scale.

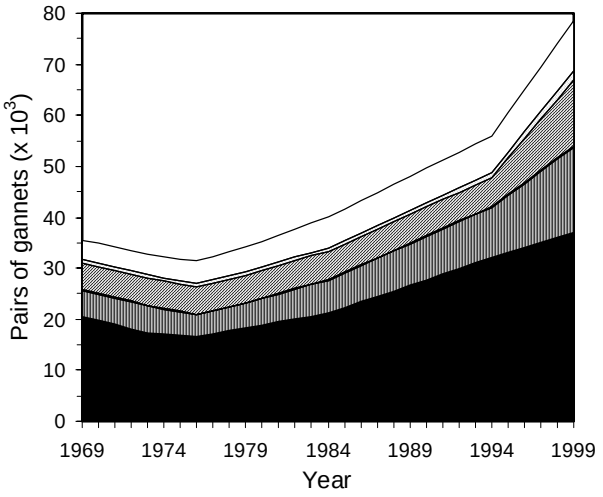
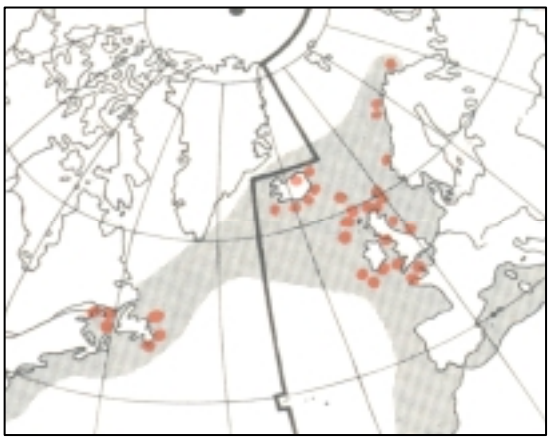


Fig. 4. Colonies of northern gannets throughout the North Atlantic Ocean.



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