

## **Interrogating Seabirds: Fishing for Answers in Marine Ecosystems**

William A. Montevecchi

Cognitive and Behavioural Ecology Programme, Memorial University of Newfoundland,  
St. John's, Newfoundland A1B 3X9

Email: [mont@mun.ca](mailto:mont@mun.ca)

Comprehensive approaches to multi-species interactions and ecosystem processes require the simplification of complexity to tractable scenarios that can be analytically engaged (e.g. Yodzis 2001, Harwood & Stokes 2003, Trites 2003;). In considerations of a simplified marine food web of the northwest Atlantic, for instance, the complexity of the direct and indirect interactions is so extensive as to preclude systemic measurement. In this respect, long-term studies of avian ecology as indicators or symptoms of broader system patterns can be helpful, especially if predators preying at different trophic levels are targeted (Fig. 1).

Seabirds sample oceanic (albatrosses, fulmars, petrels, kittiwakes), near-shore (gannets, gulls, auks) and benthic (cormorants, guillemots, ducks) environments. Their survival depends on their abilities to negotiate these challenging environments. Most seabirds, with the notable exception of penguins, store little body fat and hence must find and capture ephemeral prey on a daily basis. Much has been written about the usefulness and limitations of studying seabirds as indicators of prey and environmental conditions (e.g. Furness & Greenwood 1993, Boyd et al. 2006).

In a seminal paper on the derivation of information about food conditions from marine birds, Cairns (1987) proposed that different behavioural and population parameters respond nonlinearly to different levels of prey availability over different temporal scales (Fig. 2A). Following considerations of the potentials of different seabirds responses to changes in prey availability, he contended that “seabird data can yield information on marine food supply on ordinal scales, but assigning food availability to interval or ratio scales must await rigorous testing of the relationships proposed ...” (Cairns 1987, p. 267). During the 20-year interval since then, there has been considerable testing of relationships between seabird responses and varying levels of prey availability (e.g. Burger & Piatt 1990, Monaghan et al. 1994, Litzow et al. 2000). Despite these efforts, it still appears that the signals derived from seabird response parameters are ordinal in nature. Seabird responses to changes in prey

conditions tend to be most consistently recorded in binary (high – low, on – off) states, and it appears that with the exception of foraging behaviour, the nonlinear aspects of the seabird responses considered by Cairns (1987) are essentially threshold transitions between binary states (Fig. 2B).

The implications of such relationships are that signals from seabirds should provide indications of significant changes in prey availability and ecosystem state. Finer details of food web and ecosystem dynamics will likely not be so forthcoming from studies of avian ecology. Though, investigations of foraging behavior involving individuals carrying bird-borne telemetric and data logging devices that measure position and physical and physiological variables offer promise for assessing aspects of forager decisions that are the mechanistic underpinnings of higher level population responses to changing prey and environmental conditions (e.g. Benvenuti et al. 1998, Garthe et al. 2000, Wilson et al. 2002, Grémillet et al. 2004).

It is important to emphasize that understanding of ecosystem changes, even extraordinary perturbations that influence mega-scale oceanic patterns and processes, is challenging. For example, despite the considerable scientific effort that is directed at oceanic regime shifts, analyses tend to be retrospective and historical with little if any predictive power (e.g. Hare and Mantua 2000). In this respect, binary information derived from seabird response parameters, especially when interrogated over larger spatial and longer time scales, can generate telling ecological and biological information.

A striking demonstration of the informative power of binary comparisons of seabird breeding success and failure accumulated over a mega-scale scale region in the North Pacific is provided by Hatch et al. (1990). Figure 3 shows ocean-scale changes in the breeding success/failure of black-legged kittiwakes (*Rissa tridactyla*) in the Bering and Chucki Seas and in the Gulf of Alaska during a decade from 1978 to 1989. In 1978, colonies in Bering and Chucki Seas were productive while those in the Gulf of Alaska failed. Six years later in 1984, the circumstances were reversed. In 1988, colonies throughout the Bering and Chucki Seas and the Gulf of Alaska exhibited production, whereas in the following year (1989), colonies throughout the region failed (Fig. 3). The mega-scale responses of seabird predators shown during this decade provide powerful evidence of pervasive oceanographic influence

and change. The extent of these oceanic patterns is well beyond the scale of the fishery and well beyond the scale of oceanographic research.

In contrast to these large ocean scale binary comparisons, an example of informative seabird responses that accumulates binary information about prey types from a single seabird colony is provided by Montevecchi et al. (2006). During a three decadal period from 1977 – 2004, northern gannets (*Sula bassanus*) demonstrate a decadal shift in prey landings at Funk Island from warm-water migratory pelagic prey (mackerel *Scomer scombrus*, Atlantic saury *Scomberesox saurus*, short-fined squid *Illex illecebrosus*) during the 1970s and 1980s to diet of cold-water pelagic fishes (capelin *Mallotus villosus*, herring *Clupea harengus*, Atlantic salmon *Salmo salar*) from 1990 onward. These simple binary contrasts in diet are indeed reflective of larger scale shifts and changes in pelagic food webs in the Northwest Atlantic (e.g. Dempson et al. 2002, Frank et al. 2005). These changes are associated with a forcing physical oceanographic perturbation (cold sea surface temperature, SST) in the early 1990s (Drinkwater 1996) that may have precluded the movement of southerly distributed migratory warm-water pelagic prey into the region (Montevecchi and Myers 1996, 1996). These data in conjunction with other biophysical variables may also be indicating a system return to pre-perturbation conditions (Montevecchi submitted this volume).

In summation, robust information about oceanographic and food web shifts can be exploited from surface-feeding predators like kittiwakes that are expected to be highly sensitive to variation in SST and from generalist and opportunistic avian predators with broad diet breadth like gannets. This information is generated in the form of large spatial scale accumulations of binary breeding production/failure data and in the form of decadal scale accumulations of binary information on warm- and cold-water prey types. Methods for analyzing concordances and dis-concordances in breeding success and other reproductive parameters among different seabird species have been developed (Hatch 1996)

In addition to these sorts of comparisons, there are numerous examples of specialist predators, such as common murre (*Uria aalge*), providing potent information about changes in prey condition that reflect bottom up effects (e.g. Österblom 2001, Davoren & Montevecchi 2003, Parrish & Zador 2003, Miller & Sydeman 2004, Wanless et al. 2004, 2005). These documentations often precede, can complement and are often complemented by data from fisheries and oceanographic surveys (e.g. Dempson et al. 2002). These sorts of

indications from seabirds can be most informative when they concern forage species that play pivotal energy transfer roles in marine food webs and that tend to be overexploited and understudied (Springer and Speckman 1997, Stevenson 1997). Shifts in forage species abundance in turn alter food web dynamics in profound and unpredictable ways (e.g. Benson & Trites 2002; Chavez et al. 2003; Cury & Shannon 2004; Frederickson et al. 2004; Montevecchi et al. 2006).

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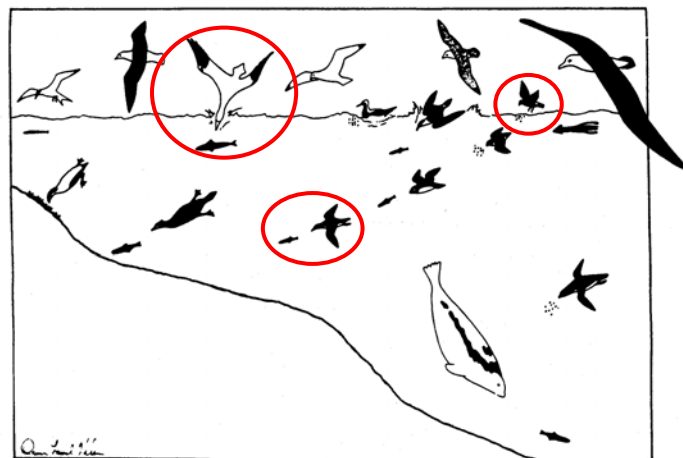
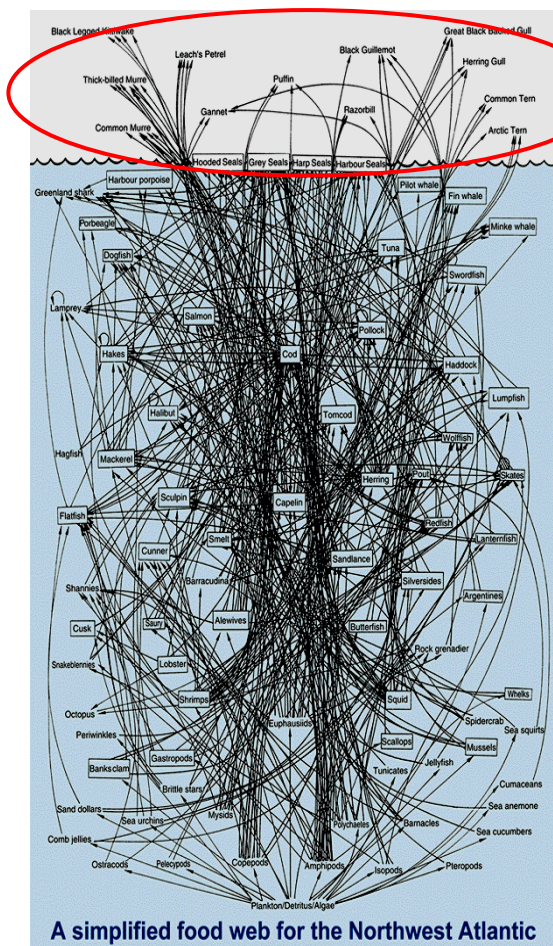


Figure 6.1 Different feeding methods and foraging sites used by marine birds. Note that almost all of the avian predators feed in groups and that all of the pelagic prey occur in schools. Drawn by D. Nelson.

Fig. 1. Simplified food web from the Northwest Atlantic with the selection of three focal avian species that forage in different oceanographic habitats and regions and feed at different trophic levels (modified from Lavigne 1996 and Montevecchi 1993)

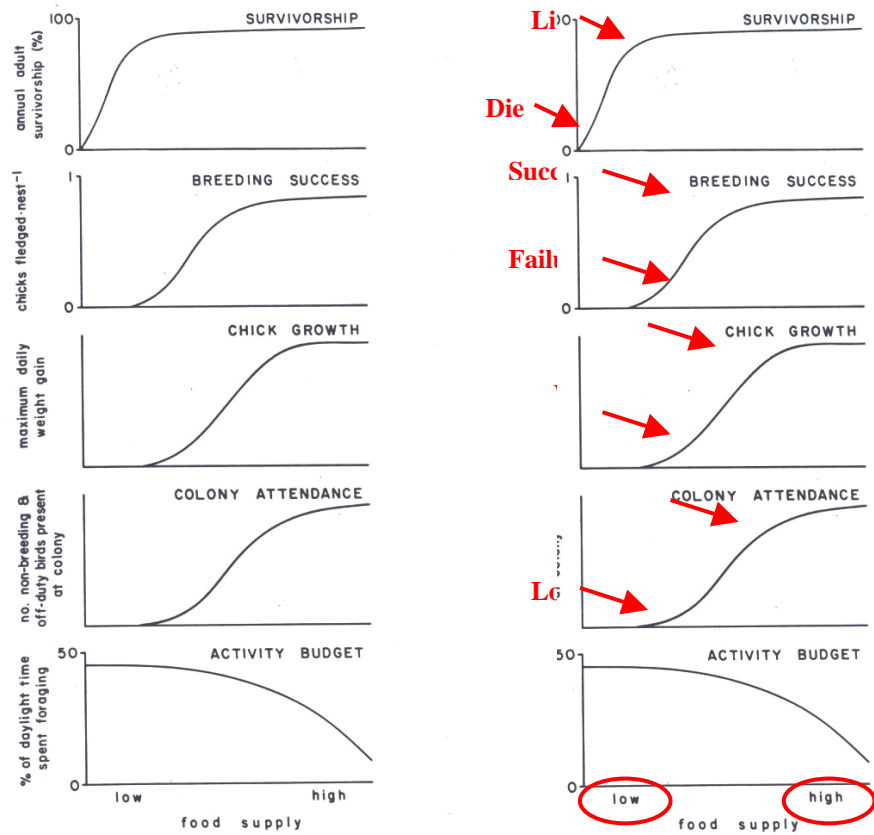


Fig. 2. A - Cairns' proposed relationships between different population and behavioural parameters and prey availability; B - binary aspects of seabird response parameters and prey availability (from Cairns' 1987).

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