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Seabirds and the shelf-break Front in the Amundsen and Southern Bellingshausen Seas

Shelf-break fronts are important to seabirds the world over. In most areas, however, their importance is masked by large numbers of migrating birds moving along continental margins and/or breeding birds that are commuting between colonies and pelagic habitats. In the high latitudes of the Southern Ocean, no migratory routes are present and, except during the summer, no seabirds commute between continental islands and pelagic waters. Thus, the shelf-break front surrounding Antarctica provides a simple system in which to learn more about the factors that increase its importance to seabirds. We investigated the Antarctic Shelf Front in the south-east Pacific area of the Southern Ocean in the Amundsen and Bellingshausen Seas. Data were collected from 15 February to 31 March 1994 along a series of cross-shelf sections extending from the continent outward to points well beyond the shelf break. Common species seen were snow petrel, Adelie penguin, emperor penguin, Antarctic petrel, Arctic tern, blue petrel and Antarctic fulmar. In relation to the Antarctic Shelf Front, snow petrel and Adelie penguin were more frequently seen on the shelf in old ice with large floes while the Antarctic petrel was more frequently seen on the shelf break and off the shelf in open water. The distribution of the avifauna of this area duplicated the Ross Sea pattern: few birds in waters overlying the continental shelf but elevated densities in conjunction with the shelf break and the Antarctic Shelf Front associated with it.

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Scale-dependence in the spatial distribution of seabirds

It has been suggested that ecological interactions occur at discrete scales and that they may be arranged in a scale-dependent hierarchy. As with ecological interactions, the spatial distribution of organisms may also be scale-dependent. Ecological functioning and the spatial distribution of organisms are clearly linked, although causation may operate in either direction. As a consequence of such relationships we might expect heterogeneity in organism abundance, usually in the form of an aggregative or "patchy" structure, to be coincident with interactions in a scale-dependent hierarchy. Empirical evidence exists to suggest that for certain ranges of scales in certain systems, both ecological interactions and the spatial distribution of organisms are scale-dependent. However, studies concerned with biotic and abiotic spatial structure in the marine environment have been unable to identify scales at which heterogeneity consistently occurs. This suggested that there was no pairing of ecological interaction with spatial distribution that was well defined with respect to scale, thereby implying that any ecological interactions occurred across a broad range of scales relative to the experimental resolution or that they were not tightly coupled with spatial distribution. In this study we address the issue of spatial distribution and scale. We utilise experimental variography to describe the spatial distribution of the fulmar (*Fulmarus glacialis*) and gannet (*Morus bassanus*) across a wide range of scales (0.3 km - 300 km) in an exploration of scale-dependence. We emphasise the identification of discrete scales of heterogeneity and the consistency of scale patterns with a view to suggesting whether ecological interactions involving these species may be identified at characteristic points within the range of scales studied.

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The spatial distribution of seabirds at a shallow sea tidal mixing front in the Irish Sea

The western Irish Sea front (ISF) is a shallow sea tidal mixing front that forms at the boundary between mixed and stratified water masses extending in an arc from the southern tip of the Isle of Man to Dublin Bay, Republic of Ireland. The front occurs seasonally in response to the stratification of an area of the northern Irish sea that develops from May to June and decomposes during September. The aggregation of marine organisms, including birds, at frontal systems is well documented. Enhanced primary production or physical entraining of planktonic and nektonic organisms provide alternative explanatory hypotheses for this effect, with the aggregation of organisms at higher trophic levels arising through predator-prey interactions. The biological characteristics of the ISF are largely in line with observations from other frontal systems, namely elevated nutrient levels and the aggregation of plankton and fish. The high density of several seabird species in the area during the summer months suggests that the ISF also provides an important source of food for these birds throughout their breeding seasons. In this study we examine the distribution of Manx shearwater (*Puffinus puffinus*), guillemot (*Uria aalge*), razorbill (*Alca torda*), fulmar (*Fulmarus glacialis*), and kittiwake (*Rissa tridactyla*) at the ISF in an attempt to understand the manner in which the front is utilised by seabirds. Bird distribution data were collected from nineteen crossings of the front along five transects from 16-18 July 1990 in conjunction with a hydrographic survey of the front. The spatial distributions of the seabirds were analysed with a combination of techniques including exploratory variography and the application of generalised additive models. Of the species studied, Manx shearwater, guillemot, and razorbill demonstrated a spatial distribution consistent with a response to the front. The spatial distribution of the remaining species were not obviously oriented with reference to the front but there was evidence of a positive relationship between the distributions of kittiwakes and Manx shearwaters. An explanation of the mechanism relating seabird distribution to the front was sought through a comparison with the distribution of surface temperature and salinity.

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The influence of petrochemicals and stress on the immune system of seabirds

The immune system is a known target of toxicants and increasing attention is being paid to the role of environmental pollutants in altering immune function. This is exemplified by the exposure of seabirds to oil spills and the subsequent potential for direct toxicity as well as immune suppression. Here, we review the components of the avian immune system and potential effects of petroleum ingestion on immune function. Indirect evidence for immunosuppression comes from experiments with petroleum ingestion and from seabird rehabilitation centres. Among oiled birds, leukocyte numbers (especially lymphocytes) are depressed in the major lymphoid organs (spleen and Bursa of Fabricius) and peripheral blood. The bone marrow is hypercellular, with an emphasis on erythropoiesis and decreased granulopoiesis. This suggests a shift from white cell to red cell development in response to haemolytic anaemia. Secondary fungal and bacterial infections that contribute to morbidity and mortality among seabirds in rehabilitation centres emphasise the immunosuppressive qualities of petrochemicals. Damage to the gastrointestinal tract following oil

ingestion has several effects on immune function. The mucosal immune system not only functions in immune defence, but is also important in suppressing responses to certain antigens, such as those in foods. Possible T lymphocyte development in intestinal sites and the Bursa's importance in avian B lymphocyte development emphasise the role of intestinal immune tissues in lymphocyte ontogeny. Damage to the gastrointestinal tract negatively affects the nutritional status of animals, leading to secondary immunosuppression. Direct challenge by known bacterial pathogens has been incorporated into very few relevant studies: compared with experimental controls, chickens and mallards fed petroleum distillates and/or oil-emulsifiers suffer greater mortality and have depressed ability to kill or phagocytize bacterial pathogens. Cell-mediated immune mechanisms appear to be more sensitive to the toxic effects of oil ingestion than those related to antibody production. Petroleum ingestion also produces abnormal concentrations or accelerated metabolism of adrenal corticosteroids. The same is true for birds subjected to handling stress. Corticosteroid hormones affect the immune system in many ways, including changes in numbers and functional capabilities of circulating lymphocytes. The liver is mainly responsible for corticosteroid metabolism and oil ingestion produces marked changes in the function of the liver, including alteration of steroid metabolism, induction of mixed-function oxidases (primary detoxifiers) and disruption and death of hepatocytes.

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Predicting seabird distributions in the North Sea: the consequences of being hungry

One approach to assessing the determinants of seabird spatial distributions is to model foraging behaviour in response to estimated prey distributions. We describe a model of a foraging seabird that couples the physiology of the individual with a simple behavioural rule to predict changes over the year in the spatial distribution of seabirds in response to changes in the distribution of their food. The present version of the model represents only immature individuals and avoids the behavioural complications arising from breeding and providing for young. The dynamic variables of the model are gut contents and 'reserves' (lipid and glycogen together), whereas the remainder of body-mass ('structure') is considered to be fixed. Feeding is controlled by a Type II functional response and the contents of the gut are removed exponentially, a proportion being assimilated into reserves. Metabolic costs impose a drain on reserves as a power function of total body-mass with parameters specific to the current activity, such as flying or surface-feeding. This is a simple yet plausible physiology that we can parameterise for various different seabird groups. The behavioural rule of the model is to continue feeding at a patch of food as long as the rate of change of reserves is positive. If this rate becomes negative the bird moves in a random direction to an adjacent patch. This rule can be shown formally to generate staying times that approximate to those predicted by the marginal value theorem. We review results from this model parameterised for the fulmar *Fulmarus glacialis* foraging over the entire North Sea to 62^{o}N 5'W. The potential-prey matrices for those simulations comprises 220 cells (ICES stat. rectangles) with offal discarding rates and small gadoid fish densities estimated from ICES fisheries and survey databases respectively. These data are quarterly for 1991. By interpolating linearly between quarters we have driving data for the simulation of flocks of fulmars. The simulated distributions are compared against monthly observed fulmar distributions from the European Seabirds at Sea database. We contrast the fulmar results with new results generated by reparameterising the model for the kittiwake *Rissa tridactyla* using offal and sandeels as potential prey.

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Fulmars *Fulmarus glacialis* as scavengers at fishing vessels in the North sea

Several studies have demonstrated a strong affinity between fulmars *Fulmarus glacialis* and fishing vessels (Rees 1963, Wahl & Heinemann 1979, Tasker *et al*. 1987). Today, fulmars are among the most abundant scavenging seabirds at fishing vessels in the North Sea and in the NE Atlantic (Camphuysen 1993a). From studies of scavenging seabirds at whitefish trawlers around Shetland, fulmars were ranked at the apex in the clear dominance hierarchy observed, being able to obtain the choicest pickings (i.e. fish livers or the entire offal; Furness *et al*. 1988, Hudson & Furness 1988, 1989). More recent investigations have shown that the position in the dominance hierarchy at fishing vessels was not quite so high in other parts of the North Sea (Camphuysen 1993b, Garthe 1993, Garthe & Hüppop 1993, 1994, Camphuysen 1994b, Camphuysen *et al*. 1995). It was also clear that the highest densities of fulmars were not found in areas where the largest quantities of discards and offal per km^2 were produced (Garthe, Camphuysen & Furness in press). Hence, despite the abundance and apparent feeding success of fulmars at some fishing vessels, the relative importance of discards and offal in their diets should perhaps not be overestimated in the absence of less easily gathered data on natural food resources. In this paper the importance of fishing activities for fulmars in the whole North Sea (51^o-62^{o}N, 4^{o}W-12^{o}E) is evaluated. The distribution of fulmars at sea is analysed in relation to the distribution of commercial fisheries and to hydrographical features. The behaviour of scavenging fulmars at the stern is described and attempts were made to trace concentrations of birds exploiting 'natural' sources of food. The position of the fulmar in the dominance hierarchy among scavenging seabirds at fishing vessels is re-examined and their feeding success and vulnerability to kleptoparasitism are described for different parts of the North Sea and different seasons, following methods developed by Hudson & Furness (1988, 1989). Quantities of discards from commercial fisheries in different parts of the North Sea are compared to fulmar numbers and the energetic requirements of these birds.

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Seabirds as monitors of the marine environment

Many studies have shown that seabirds are sensitive to changes in food supply, and therefore have potential as monitors of fish stocks. Seabirds have also been used, for a long time, as monitors of pollution, especially oil pollution. Beached bird surveys provide important evidence of geographical and temporal patterns, and, for example, show consistent declines in oil release into the southern North Sea over the last 15 years. Analysis of oil on birds now permits fingerprinting of sources, allowing prosecution of polluters. As predators high in marine food webs, seabirds also have potential as monitors of pollutants that accumulate with trophic level. Recent work on mercury in seabirds has permitted an analysis of spatial patterns and of the rates of increase in mercury contamination of ecosystems over the last 150 years, as mercury concentrations in feathers of museum specimens can be used to assess burdens in the birds when they were alive. Surprisingly, pelagic seabirds show higher increases than most coastal ones, and increases have been greatest in seabirds feeding on mesopelagic prey. This seems to relate to patterns of methylation of mercury in low-oxygen, deeper water. Accurate measurement of long-term trends in mercury contamination depend on the assumption that seabird diet composition has not changed. This can be assessed by analysis of stable isotopes of N and C from the same feathers used for mercury measurement, a technique that

also permits monitoring of the trophic status of seabirds over time or among regions. While high mercury contamination of seabirds in the southern North Sea is unsurprising, we cannot yet explain some unexpected patterns, such as high levels in seabirds from north Iceland compared with those from south Iceland or Scotland.

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Influence of hydrography, fishing activity and colony location on summer seabird distribution in the southeastern North Sea

Possible determinants of the distribution of eleven seabird/coastal bird species in the southeastern North Sea were investigated in July 1993 and 1994. During ship transects in both years, seabird distribution, trawling activity and hydrographic parameters (salinity, temperature, stratification/mixing, water depth, water clarity) were measured synoptically. Distances to colonies were calculated from positions at sea and from published reports on breeding birds. Bird densities at each counting interval of 2.5 to 5.2 km^2 around 199 hydrographic stations were compared to the abiotic parameters mentioned above. Cluster analyses on abundances per counting interval revealed a group of four offshore species (*Fulmarus glacialis, Uria aalge, Rissa tridactyla, Larus fuscus)* and six inshore species *(L. ridibundus, L. canus, L. marinus, L. argentatus, Sterna sandvicensis, S. hirundo/paradisaea*). Colony location was a major determinant of the at-sea distribution of all common breeding species except *L. fuscus*. Most of the inshore species were closely related to fishing vessels whereas the distribution of the offshore species and *S. hirundo/paradisaea* was not or only slightly affected by trawling activity. Salinity (*F. glacialis, R. tridactyla),* water depth *(U. aalge)* and water clarity *(F. glacialis)* were the most relevant parameters for some of these species. The relation between important abiotic parameters and seabird diet will be discussed.

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Catch per unit effort, foraging efficiency and parental investment in breeding great cormorants (*Phalacrocorax carbo carbo*)

The foraging behaviour of eight male and six female great cormorants (*Phalacrocorax carbo*) rearing young chicks at the Chausey Islands (France) was studied during 177 feeding trips. The activity of the birds, especially their position at sea and the mean time spent underwater, was monitored using a radio-tracking system. Furthermore, food intake was calculated from weights recorded by automatic nest-balances. Foraging birds caught a mean of 26.8g fish per minute spent underwater (sd = 46.8) and ingested a mean food amount of 430g per trip (sd = 188). In this paper I discuss possible reasons for the high catch per unit effort in great cormorants and show how sex, body mass, brood biomass, feeding location and feeding techniques influence the prey intake rate of these birds.

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Spatial variation in the feeding ecology, foraging ranges and breeding energetics of northern fulmars in the north-east Atlantic Ocean

Fulmars *Fulmarus glacialis* are one of the most abundant birds in the North Atlantic Ocean and the two largest fulmar colonies in the UK are at St. Kilda, Outer Hebrides and Foula, Shetland. These colonies are about 450 km apart and surrounded by waters that differ greatly in terms of potential food availability: fish offal and whole fish discarded from whitefish trawlers are a major source of potential food in Shetland but not at St. Kilda. Associated with this, previous studies have reported broad differences in diets and colony attendance patterns of adults at these two colonies, and have predicted higher breeding success in Shetland than at St. Kilda. However, more detailed information on differences between sites in foraging behaviour, foraging ranges and population dynamics of fulmars has not previously been available. This paper presents detailed dietary analysis and uses land-based data to determine the duration and range of foraging trips by adults at the two colonies feeding on different types of prey. We also describe unanticipated differences in growth and survival of nestlings at the two sites, which we explain using an energetic model incorporating differences in body maintenance requirements of chicks and caloric density of food.

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Sandeels, brood neglect and breeding success in the kittiwake *Rissa tridactyla* over an eleven year period

Data on the food of chicks, breeding success and brood neglect in the kittiwake *Rissa tridactyla* were collected in a standardised manner at the Isle of May, Firth of Forth over ten seasons. Sandeels *Ammodytes marinus*, predominantly O-group fish, were the main item of diet in all years; herring *Clupea harengus* and sprat *Sprattus sprattus*, waste from trawlers and planktonic crustacea were of lesser importance. Breeding success was significantly and positively correlated with the proportion of O-group sandeels in the diet of chicks and with the average energy value of O-group sandeels. Clupeids and trawler waste were probably taken only when sandeels were unavailable. The incidence of brood neglect was not correlated with breeding success or any measure of food. Reduction in breeding success occurred over the same period at colonies over a 250-300 km section of coast.

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Physics, zooplankton and the distribution of least auklets

In the eastern Bering Sea, the overall distribution of least auklets (*Aethia pusilla*) reflects the distribution of different water masses and their associated plankton communities. Within these water masses, the foraging distribution of least auklets is influenced by physical processes that result in predictable aggregations of prey, most often because of property or flow gradients with which the plankton interact. Examples include the accumulation of zooplankton at or above the pycnocline and near-surface patches of plankton concentrated in downwellings formed at convergences. These small-scale processes influence avian use of the larger-scale features. Breeding colonies of least auklets are located within commuting distance of physical features in the ocean at which appropriate prey are concentrated; where large copepods or physical features to concentrate them are absent, auklets do not breed. Thus, control of the distribution of foraging seabirds and their breeding colonies in the eastern Bering Sea is a multi-scale process.

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Estimating the energy requirements of gulls at sea by time-activity budgets

For many questions concerning the relationships between seabirds and their food organisms a thorough knowledge of their energy requirements is essential. There have been many detailed studies on the energetics of seabirds at their breeding sites (where the birds are more or less easily accessible) but our knowledge of seabird energetics in other seasons is poor. Possible pitfalls in estimating energy demands at sea include difficulties in determining the BMR, poor knowledge of thermoregulatory costs at sea and a lack of data on activity budgets at sea. A short, critical review of the methods available will be given. Using new and previously published data on 1) the energetic costs of thermoregulation and activity; 2) at-sea activity budgets; and 3) environmental factors (e.g. air and water temperatures, wind), I will attempt to estimate the energy consumption of gulls at sea outside the breeding season under various conditions.

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Summer at-sea distribution of seabirds and marine mammals in polar ecosystems: a comparison between the European Arctic and the Weddell Sea, Antarctica

The summer at-sea distribution of seabirds and marine mammals was established in both Antarctica (Weddell Sea) and in the European Arctic seas (Greenland, Norwegian and Barents). Data may be directly compared, since the same transect method was used by the same team in both regions. The main conclusion was that densities of flying seabirds and marine mammals are similar in open water and at the ice edge, but the presence of penguins and seals in very high densities in Antarctic pack-ice leads to a major difference in ecological structure. Ecological implications of these observations are discussed, especially concerning primary and secondary (krill) productions under the pack-ice.

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Estimate of summer food consumption of six species of seabirds in Iceland

Information on the feeding ecology of seabirds in Iceland is limited but they can be assumed to have a considerable impact on their marine environment. The six most common seabird species found in Iceland number an estimated 18 million individuals. Their food during the summers of 1994 and 1995 was studied. The stomach contents of 1,481 common murres (*Uria aalge*), thick-billed murres (*U. lomvia*), razorbills (*Alca torda*), puffins (*Fratercula arctica*), kittiwakes (*Rissa tridactyla*) and fulmars (*Fulmarus glacialis*) were analysed. All species except the fulmar rely heavily on capelin (*Mallotus villosus*), sandeel (*Ammodytes marinus*) and euphausiids as food. The food of fulmars is different from the others and offal from fishing vessels may comprise a substantial part of the summer diet. The results indicate differences between areas in the dominant fish species eaten, with sandeel being most important west, south and east of Iceland and capelin dominating in the north. That in turn may explain the difference in breeding distributions of the species. Puffins are most common where sandeels are available while the reverse is true for kittiwakes and thick-billed murres. The estimated food consumption of these birds is about 180,000 tonnes of capelin, 180,000 tonnes of sandeel, 30,000 tonnes of euphausiids and 50,000 tonnes of other food. These results indicate that the consumption of capelin by seabirds needs to be taken into account when modelling relationships

involving capelin, e.g. with commercially important fish species. They emphasise further the importance of sandeels and euphausiids as prey species for these seabirds.

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Scale-dependent correlations between the abundance of Brünnich's guillemots and their prey in Svalbard waters

We studied the foraging ecology of Brünnich's guillemots *Uria lomvia* during the breeding season in southeastern Svalbard. In the region of Storfjorden there are two large breeding colonies comprising a total of 540,000 individuals. These birds forage in the western part of Storfjorden and further to the south. Their main prey are polar cod *Boreogadus saida*, pelagic amphipods *Parathemisto* spp. and krill *Thysanoessa inermis*. A ship based transect survey was conducted with records of bird abundance and acoustic prey sampling. A total of 33 sections, each of 8-11 km in length, were made. The resolution of the survey was 150 m and analyses of correlations between predator and prey were performed at length scales from 150 m to 10 km. We differentiated acoustic signals from prey into aggregated and dispersed prey according to the estimated horizontal distribution of prey. Foraging guillemots were consistently more strongly correlated with the aggregated prey than with the dispersed prey over scales ranging from 150 m to 10 km. Correlations were weak at small scales (150 m to 1 km) and increased and stabilised at scales of 1-2 km. This scale was similar to the average distance between peaks in prey density (inter-patch density) of aggregated prey. Guillemots showed low correlations with prey at low prey densities. Similarly, correlations between guillemots and prey were low at low bird densities. The data support the hypothesis that the birds associate with prey patches at densities above a certain threshold.

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Trophic relationships of seabirds in the NW Atlantic

Temporal and spatial variation in the diets and prey harvests of seabirds in the NW Atlantic are monitored by sampling the foods that adults deliver to chicks. Focal seabird species cover the full range of foraging modes, body sizes and populations and include Leach's storm-petrels, Atlantic puffins, common murres and northern gannets. Avian prey harvests differentiated by species, genders, ages, reproductive conditions and sizes are compared with human harvests, fisheries research surveys and physical oceanographic data to help understand the roles of seabirds as consumers and bio-indicators in dynamic cold-water marine ecosystems. Findings are integrated into species-specific and community energetics and trophic models. Variation in seabird diets during the 1990s indicated shifts in pelagic food webs that had differential effects on surface-feeding and pursuit-diving seabirds. Studies of seabird diets also implicated the interactive effects of oceanographic perturbations (cold water events) and commercial fishing pressures on prey availability and the differential effects of natural and anthropogenic events on pelagic and demersal food webs.

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Breeding seabirds and trawlers in the northwestern Mediterranean: differences between the Ebro Delta and the Balearic Islands areas

Local trawler and purse-seine fisheries operate around the seabird colonies of the Ebro Delta and the southwestern area of Majorca in the Balearic archipelago. The use made of the discards produced by these fisheries by scavenging seabirds breeding there was examined from 1992 to 1995. The amount of discards and the number of seabirds following boats were lower than those recorded in other areas such as the North Sea, although breeding populations in this Mediterranean area are also lower. All breeding species were observed feeding on discards at both sites: Audouin's gull, yellow-legged gull, lesser black-backed gull, black-headed gull, slender-billed gull, common and Sandwich terns in the Ebro area and Audouin's gull, yellow-legged gull, Cory's and Balearic Manx shearwaters and common shags in the Majorca area. In Majorca, Audouin's gull was significantly more abundant than expected from its breeding population (Presence Index, PI >> 1), for both trawler and purse-seine fleets. In the Ebro area, by contrast, this trend was observed for the lesser black-backed, black-headed and slender-billed gulls and the common tern for trawlers and only Audouin's gull for purse-seine boats. However, the success rate feeding on trawler discards was not related to the PI recorded: in the Ebro area Audouin's gull, lesser black-backed gull and terns were the species that took greatest advantage of discards, whereas in Majorca only the yellow-legged gull consumed significantly higher amounts of discards than expected from its PI. In both areas the consumption rate of fish discards was high: 90% in the Ebro area and 80% in the Majorca area. Estimates of the weight of fish discarded throughout a breeding season suggest that seabird populations at both sites may obtain a substantial part of their energetic demands from fisheries, especially from trawlers.

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The relationships of seabird assemblages to physical habitat features in Pacific equatorial waters

We investigated the association of seabird species with physically defined water types in the eastern tropical Pacific Ocean, far from any breeding colonies. In so doing, we avoided birds that commute between colony and feeding habitat which could confuse associations with specific water types and current systems. Seabirds were censused on duplicate tracks in the eastern tropical Pacific each spring and autumn 1984-1991. On each track we measured seabird habitat on the basis of six factors. During spring, seabird habitats were defined mainly by an axis composed of sea-surface temperature and salinity, but also including thermocline depth. Regardless of season, placements of species along the habitat axes were consistent between years, as were associations with current systems for the majority of species. Associations with water mass were less consistent. We also investigated whether any species were consistently found with any other species. During spring, three species groups were apparent: 1) Leach's petrel and wedge-rumped storm-petrel; 2) black-winged petrel and white-winged petrel; and 3) Juan Fernandez petrel, wedge-tailed shearwater and sooty tern. During autumn, only one group was identified: Leach's petrel associated with either wedge-rumped storm-petrel or Juan Fernandez petrel and/or white-winged petrel. Species in the groups were not consistently placed in similar positions along the habitat axes, particularly in the autumn. This indicates that the co-occurrence of seabirds in the eastern tropical Pacific may reflect the overlap of individual species' distributions rather than a similar response to physical habitat.

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Occurrence and consumption of seabirds scavenging on shrimper discards in the Wadden Sea

The shrimp fishery in the coastal area of Lower Saxony produces a rich food source for ship-following seabirds. Large quantities of discarded small fish and invertebrates attract flocks of gulls and terns. Between March 1993 and August 1994 the number, species and age composition of birds following two shrimpers were determined. The main scavengers were herring gull (*Larus argentatus*) and black-headed gull (*L. ridibundus*). Common gull (*L. canus*), lesser black-backed gull (*L. fuscus*), great black-backed gull (*L. marinus*) and common/Arctic tern (*Sterna hirundo/paradisaea*) were less numerous. The distribution of scavenging seabirds behind the shrimp trawlers showed a marked species-specific seasonal and spatial pattern. Adult birds predominated at trawlers, but herring gulls showed a marked seasonal variation in age distribution. Scavenging behaviour of seabirds and feeding on discards were studied by means of experimental discarding. Of 10,370 items offered, 8,290 were picked up and in 8,085 cases the consuming bird was observed. Herring gull was the most successful species. Ship-following seabirds consumed 40.7% of all flatfish offered, 79% of round fish and 23% of four important invertebrates. Applying these consumption rates and bioenergetic data to the total quantity of discarded biota reveals that approximately 50,000 seabirds may be supported for the whole fishing season (April-November 1993) by shrimper discards of the Lower Saxony fleet. These results suggest that discards may have strong effects on seabird populations and on the ecosystem of the Wadden Sea.

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Modelling environmental and energetic effects on feeding performance and distribution of shags, *Phalacrocorax aristotelis*: integrating telemetry, geographical information systems and modelling techniques

The shag *Phalacrocorax aristotelis* is an important component of the inshore marine community. It is a foot-propelled pursuit diver, feeding predominantly on lesser sandeels *Ammodytes marinus* which it catches on or near the seabed. This paper describes how radio telemetry, dive depth recorders and an automatic balance system were used to collect data on two components of feeding performance - diving efficiency and feeding rate. These measures can be used to assess habitats that differ in both water depth and prey concentration. A Geographical Information System (GIS) was developed containing information on the size and location of seabird colonies along the North Sea coast of Britain and the bathymetry and seabed sediments for inshore waters along this coastline. Data on feeding performance were integrated with spatial information to calculate the gross rate of intake for a shag feeding at any given location. To test qualitatively whether gross rate of intake was a good predictor of the distribution of diving birds, two colonies (one island and one mainland) were selected and the spatial pattern in gross rates of intake, estimated for increasingly complex (but more realistic) models, compared with results from at-sea surveys in the two areas.

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A spatial comparison of guillemots and sandeels in the North Sea

The lesser sandeel *Ammodytes marinus* is an important prey of many seabirds and is the subject of the largest single species fishery in the North Sea. This common utilisation of a fish resource has led to concern over potential competition between fisheries and seabirds. A knowledge of the extent to which the spatial distributions of seabirds, sandeels and fisheries overlap is an important prerequisite to the evaluation of possible competition between sandeel fisheries and seabirds. Owing to their dependence on suitable sediment types, the distribution of post-settled sandeels (late O-group and older age-classes) is relatively restricted and constant through time. Consequently, it is possible to compare the presence/absence of post-settled sandeels with the distribution of predators without the requirement for simultaneous collection of data on predator and prey distributions. This is important since the most extensive data-set on seabird distribution at sea has not been collected in conjunction with surveys of prey fish densities. Post-settled sandeels are an important prey of guillemots *Uria aalge*, particularly during the breeding season. Recent estimates of sandeel consumption by guillemots suggests that these seabirds may be a major predator of sandeels in some areas. Given their locally high consumption rates of post-settled sandeels, guillemots are probably a good species to consider possible competition between seabirds and sandeel fisheries. This study makes use of recently collated databases on the distribution of post-settled sandeels and sandeel habitat together with data from the European Seabirds at Sea (ESAS) database to compare the seasonal distributions of guillemots and sandeels. Information on fishery landings per ICES rectangle is used to consider the degree of common utilisation of sandeel grounds by fisheries and guillemots in recent years.

POSTER ABSTRACTS

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Distribution of seabirds at sea in the Catalan-Balearic Sea, northwestern Mediterranean

During an oceanographic cruise through the Catalan-Balearic Sea (north-western Mediterranean) the distribution of seabirds at sea was examined. Between 4 and 16 June 1995, 81 censuses were carried out, coinciding with the hydrographic sampling stops of the vessel. The species observed were: Cory's shearwater *Calonectris diomedea*, Balearic Manx shearwater *Puffinus yelkouan*, storm petrel *Hydrobates pelagicus*, gannet *Morus bassanus*, common shag *Phalacrocorax aristotelis*, great skua *Catharacta skua*, Audouin's gull *Larus audouinii*, yellow-legged gull *L. cachinanns*, lesser black-backed gull *L. fuscus*, common tern *Sterna hirundo* and black tern *Chlydonias niger*. The commonest species in order of abundance were Audouin's gull, Cory's shearwater and Balearic Manx shearwater - those species with the highest breeding populations in the area. These species were found in both inshore and offshore waters and although it was not possible to assess whether the individuals observed were breeding they were censused up to 140 km from the nearest colonies. The area with the highest concentration of individuals coincided for Audouin's gull, Cory's and Balearic Manx shearwaters and was located c. 20 km south-east of the mouth of the Ebro river, also the site with the highest density of clupeiforms in the study area. Since the censuses carried out in this area were performed during a week-end this concentration of seabirds may not be related to commercial fishery activities. In contrast, yellow-legged gulls, a species with large breeding populations in the area, were not common, especially in offshore waters. This is probably because this species has a smaller foraging range and its diet depends more on human activities (e.g. inshore fisheries, refuse tips).

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Seabird mortality in fishing gear in Galicia (NW Spain)

Galicia holds one of the most important coastal fisheries in Europe with some 2,950 vessels operating from intertidal waters to the outer limits of a continental shelf that is on, average, fifteen miles wide. A total of eleven fishing techniques are employed. The interactions between fisheries and seabirds, including large breeding, wintering and migratory populations, are believed to be of great interest but have still to be evaluated. This work analyses the mortality of seabirds in fishing gear in Galicia, based on ringing recoveries and interviews with local fishermen. Mortality is described on a temporal basis and the relative impacts of different fishing gear on all seabird groups is assessed. Alcids, cormorants and shags account for most seabird mortality in gill nets while gannets and shearwaters are the main casualties in hook-lines.

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Significance of plumage polymorphism on the kleptoparasitic efficiency of Arctic skuas *Stercorarius parasiticus* during migration

The relationship between plumage polymorphism and kleptoparasitic efficiency of migrating Arctic skuas *Stercorarius parasiticus* was assessed in the springs (March to May) of 1990-1993 and 1995 in the north-western Mediterranean. The number of Arctic skuas and their kleptoparasitic behaviour were recorded from a coastal point in 214 hr of observation. Dark phase birds predominated up to mid-April (63%, n = 180 birds) while light phase birds were the commonest from mid-April onwards (66%, n = 161 birds). Kleptoparasitic chases performed by single adult birds (n = 75) were studied. The success rate of both phases was compared: a) for the whole observation period; and b) during periods of numerical dominance of each phase. There were no significant differences in either case. Therefore, these results do not support either the aggressive camouflage (i.e. dark birds being more successful) nor the apostatic selection hypothesis (i.e. the rarest morph being more successful). I suggest that this might be due to a different attack strategy from that reported from colonies (i.e. birds approaching the host from above or from a similar height). Since in most chases the skua approached the host from below (86% of chases, n = 19) the belly of the skua remained hidden.

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Auk distributions at sea between the Shetland and Faroe Islands

The Seabirds at Sea Team (SAST) of the JNCC has been undertaking surveys to assess the distribution and abundance of seabirds and cetaceans between the Shetland and Faroe Islands since 1994. Data from these surveys, along with data in the European Seabirds at Sea (ESAS) database,

have allowed mapping of the seasonal distributions of seabirds, including auks, between Shetland and the Faroes. Six species of auk occur in these waters. Guillemot *Uria aalge*, razorbill *Alca torda*, black guillemot *Cepphus grylle* and puffin *Fratercula arctica* all breed in internationally important numbers within the study area. The little auk *Alle alle* is a scarce winter visitor and Brünnich's guillemot *Uria lomvia* has been recorded only once between 1979 and 1996. Densities of auks that breed within the study area were highest between April and June particularly around their breeding colonies. Guillemots and puffins were the two most frequently recorded species and razorbills were recorded in comparatively low densities mainly around Shetland, Orkney and mainland Scotland. From July onwards densities of guillemots and puffins around the colonies tended to decrease with widespread dispersal of guillemots over the Faroese shelf during August. There was some evidence to suggest that puffins and guillemots remained near the Faroese colonies later than birds from Shetland or Orkney. From October to January densities of guillemots and razorbills were at their lowest with increases in densities from February onwards. Puffin densities remained low from October through to March. Black guillemots were recorded throughout the year in close proximity to their breeding colonies with slightly higher densities from April to September. Little auks were recorded in low densities along the north-west continental shelf and around the Faroes from October to March.

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Chick diet of common and Brünnich's guillemots at the Gannet Islands, Labrador, in 1996

We recorded diet composition and feeding rates simultaneously for common guillemot, *Uria aalge* and Brünnich's guillemot, *Uria lomvia* , chicks at the Gannet Islands, repeating and expanding protocols used by other researchers in 1981-83 and 1992. In 1996, a total of 929 common guillemot feeds and 124 Brünnich's guillemot feeds were observed. Although feeding rates and productivity in this year were comparable with those measured previously, chick diet composition changed significantly. Capelin, *Mallotus villosus*, which accounted for over 75% of common guillemot chick diet in past years, comprised less than 15% of items delivered to chicks in 1996. Both common and Brünnich's guillemot chicks subsisted predominantly on blennies, particularly on daubed shannies, *Lumpenus maculatus*. Other species fed to common guillemot chicks included sandlance, *Ammodytes* spp., sculpin, *Myoxocephalus* spp., Arctic cod, *Boreogadus saida*, and fish doctor, *Gymnelis viridis*. Brünnich's guillemots were fed fish doctors and capelin in addition to blennies. Our results indicate that major changes have occurred in the relative abundance of blennies and capelin in this ecosystem.

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Comparison of diet, breeding and foraging ecology of herring and lesser black-backed gulls in a mixed gull colony - causes of high predation pressure on herring gulls

This study was carried out in a mixed colony of herring (*Larus argentatus*) and lesser black-backed gulls (*L. fuscus*) on the island of Terschelling. In the 1970s the numbers of *L. fuscus* markedly increased but recently, breeding numbers and success of both species have declined. The aim of the study was to test whether and how food shortages might limit breeding success. Food, breeding and foraging behaviour were studied. We found that both hatching and fledging success of *L. argentatus* was significantly lower than *L. fuscus*. Starvation of chicks of both species accounted for only 10-12% of losses. Predation by *L. argentatus* was the main cause of low success of both species. Besides chicks, molluscs (food of low calorific value) were the main food source. Fish - the main

food of *L. fuscus* - comprised but a small proportion of *L. argentatus* diet. All behavioural parameters (frequency and duration of feeding shifts, territory attendance and contribution of both parents in chick care) were of significantly lower quality in *L. argentatus*. *L. fuscus* is dominant to *L. argentatus*. It forces *L. argentatus* to change feeding areas and exploit food of lower energetic quality. Many birds, however, begin preying on eggs and chicks in the colony. So when food is short, eggs and chicks of both species become the main food of these individuals.

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Communal roost formation of clupeid feeding auks and kittiwakes in the centre of the North sea in winter

Hydroacoustic surveys coupled with systematic seabird counts were performed in the Dogger Bank area in November 1994. Strong correlations were found between numbers of feeding guillemots, razorbills and kittiwakes and densities of sprat and immature herring. Kittiwakes were feeding only in close association with guillemots in areas where clupeids occurred relatively high in the water column. Guillemots and razorbills apparently shared feeding opportunities in areas with high clupeid abundance at any depth. Near dawn, it appeared that feeding ceased rather suddenly. In contrast to the rest of the day, flying auks and kittiwakes were seen very frequently and most were heading in a south-easterly direction. Fortuitously, the ship visited an area to where these birds had been flying. This was characterised by very high densities of all three species, the auks and gulls swimming in rather tight packs with many of the individuals preening. This apparent communal roost was situated c. 20 miles south-east of the feeding concentrations studied during the day and it coincided with an area that was rather poor in clupeids. Feeding birds were not seen at this site during the short visit. There is very little published information on roost formation in wintering, piscivorous seabirds at sea but it has been described before for some species (e.g. grebes). Future offshore studies should pay attention to the formation of communal roosts in order to find out if this is a common phenomenon in wintering seabirds. The roost formation could be important for seabirds that rely on highly patchy food resources such as shoals of clupeids and might serve as centres for information exchange similar to those mooted for communally roosting land birds.

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History of the herring gull on the north shore of the Gulf of St. Lawrence and its relationship with fisheries

The history of herring gull populations nesting along the north shore of the Gulf of St. Lawrence and the commercial fishing activities there are closely related. Coastal cod fishing is the main fishery in this part of the Gulf and has traditionally resulted in significant amounts of fish offal being discarded at sea and in fishing ports. We compared commercial fisheries catch data and data from herring gull surveys conducted in the migratory bird sanctuaries on the north shore from 1925 to 1993. Between 1925 and 1975 the fisheries harvested annually a mean of 5,234 tonnes of ground fish, with low and high catches of 1,700 and 11,000 tonnes respectively. During the same period, the herring gull population in the sanctuaries increased from 650 to 8,000 pairs. After 1975 and until 1993 the annual mean fisheries harvest was 5,771 tonnes, peaking in 1983 at 11,500 tonnes but then declining steadily until a complete fishery collapse in 1993. During the same period, the herring gull population increased from 8,000 pairs in 1975 to 14,400 pairs in 1988 but then dropped dramatically in most

sanctuaries and was estimated to be only 3,000 pairs in 1993. This general decline of gulls appears to be closely related to the decrease in commercial fishing activities in the region.

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Seabird studies off south-west Wales following the *Sea Empress* incident

On 15 February 1996 the *Sea Empress*, with a cargo of 130,000 tonnes of Forties light crude oil, ran aground while navigating the entrance to Milford Haven. By the time the vessel was salvaged, approximately 72,000 tones of crude oil were lost. Ten days after the start of the incident ship-based seabird surveys were undertaken in order to determine the densities of seabirds in the sea areas likely to have been impacted by the oil. Offshore surveys covered a distance of 760 km giving approximately 4% coverage of a total sea area of 5,500 km^2. Fifteen species and 3,408 birds were recorded, representing a mean density of 3.4 birds per km^2. Gannet was the most numerous species followed by guillemot, lesser black-backed gull, fulmar, herring gull, kittiwake and razorbill. Guillemot and razorbill comprised over 61% of the birds recorded on the water. Overall densities of gannet, guillemot, razorbill and lesser black-backed gull were slightly higher in nearshore waters than was indicated by existing data. Very low numbers of birds at sea were recorded as oiled. Standard seabird census methods did not appear to give a true estimate of the degree of oiling. Nevertheless, oiling rates were 3-17 times that recorded in the region in previous years. It was estimated that 2.6% of all birds showed some degree of oiling, the majority being flying birds that were lightly oiled. These data suggest that any survey of oiled birds at sea will be biased towards lightly oiled flying birds. Tagged seabird corpses (N=238) were released over four shore-parallel transects to the south of Milford Haven. Twelve corpses were recovered from south-east Ireland - the first fourteen days after release. Beached bird surveys covering 118 km of shoreline in counties Waterford and Wexford recorded 396 dead seabirds. Of this total, it is estimated that 338 birds (2.87 birds/km) might be attributed to the *Sea Empress*. This compares with over 7,000 beached birds recorded from Wales and south-west England. Computer modelling of corpse and oil dispersal suggests that both travelled south towards the Devon and Cornwall coasts before drifting across the Celtic Sea towards Ireland.

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Winter mortality of seabirds along the Belgian coast (1990-1995): an ecotoxicological approach

A programme to monitor the health status and causes of death of wintering seabirds was launched by the Belgian authorities. A multidisciplinary research group covering both field and laboratory work was set up. Stranded seabirds were regularly collected along the shore and all birds were fully necropsied for possible lesions, pathology and general status. Toxicological analyses were performed for heavy metals (Cu, Zn, Fe, Cd, Pb, Ni, Cr and Ti), organochlorines (PCBs, pesticides) and total and organic mercury in target tissues (liver, kidney and pectoral muscle). Attention focused on the

guillemot *Uria aalge*, by far the most numerous wintering species. Other species involved were *Alca torda*, *Larus argentatus*, *L. ridibundus*, *Rissa tridactyla* and *Fulmarus glacialis*. By far, oiling is the major cause of death for wintering birds entering the polluted southern North Sea. A large majority of these birds was in poor body condition (cachexia), an inevitable result of being oiled. On the other hand, the population of non-oiled birds showed the same signs of exhaustion. Whether or not this was caused by natural phenomena (food shortage, winter storms, diseases) or was induced by the presence of a large spectrum of contaminants is unclear. The fact that particularly high levels of Cu, Zn, Hg and PCBs were detected within the cachectic guillemot sub-sample, however, indicates the latter. In addition, only a small part of Zn and Cu were linked to the detoxifying metallothionein protein fraction, suggesting a possible harmful effect.

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Why do gulls forage on discards at night?

Although most fisheries operate around the clock, nocturnal scavenging by seabirds has attracted little attention. Daytime and nocturnal foraging on discards by large *Larus* gulls, which are considered to be primarily diurnal species, were compared quantitatively on board the research vessel "Heincke" fishing with commercial trawler fleets near Helgoland in the south-eastern North Sea. In October/November 1993 the total numbers of herring gull (*Larus argentatus*) and great black-backed gull (*L. marinus*) were on average 18% and 51% lower at night than during the day. Round fish were consumed by birds in highest proportions (84-88% of all items discarded), followed by starfish (59-71%) and flatfish (19-43%). Only flatfish were eaten in proportions that differed significantly between night and day. The ratios of interactions between birds per discard item were highest during the day. During both day and night, great black-backed gulls achieved a considerably higher foraging success than did herring gulls. In July 1994, lesser black-backed gulls (*L. fuscus*) and herring gulls were the most numerous ship-followers. While both round fish and flatfish were consumed at night (57-90% and 18-47% respectively), no fish were eaten during the day and starfish were not taken at all. Since the gulls were apparently able to exploit the food during day and night it seems most plausible that they utilise fishery waste without any diel preferences.

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The relationships between diet and commercial fisheries in two gull species breeding sympatrically in the Chafarinas Islands

The diets of breeding Audouin's *Larus audouinii* and yellow-legged gulls *L. cachinnans* were examined at Chafarinas Islands (Moroccan coast) during 1993, 1994 and 1995 in relation to the activity of commercial fisheries operating in the area. Both diurnal trawlers and nocturnal purse-seine boats fish in this area but fishing activity was quantified only with respect to purse-seine boats since diurnal trawlers run continuously except on stormy days. Thus, data were collected under two commercial fishing regimes: only diurnal trawling or trawling and purse-seine fishing. Fresh food, spontaneously regurgitated by chicks when they were handled, was collected from May to June for both species. We used two criteria to establish prey categories: taxonomy and ecological typology. To describe diet composition we used, at both taxonomic and typologic levels, the following parameters: prey number (N), numeric percentage (%N), percentage of occurrence (percentage of

sampling units containing the prey category, %P) and percentage of biomass (in dry weight, %B). Irrespective of fisheries activity, on average Audouin's gulls fed more on epipelagic fish (63% of occurrence) than yellow-legged gulls (46% of occurrence). Independently of purse-seine activity, the two species make similar use of trawler discards, with benthonic fish occurring in 34% and 28% of regurgitations respectively. In both species, the frequency of clupeiform fish in the diet was significantly higher when purse-seine boats were operating the previous night. When purse-seine boats did not operate, the two species increased their consumption of secondary resources but while yellow-legged gulls used both refuse tips and terrestrial prey, Audouin's gulls consumed only terrestrial prey.

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Fisheries and daily activity cycles of Audouin's *Larus audouinii* and yellow-legged gulls *L. cachinnans* breeding sympatrically in the Chafarinas Islands (Moroccan coast)

We analysed the daily activity cycles of Audouin's and yellow-legged gulls by counting the number of individuals that remained at the colonies. Two kinds of census were performed: a) counts using a telescope that covered large colony areas at hourly intervals; and b) counts by naked eye from a hide every 30 min. on a small portion of the colony. All counts were made during the breeding seasons of 1993, 1994 and 1995. The results of both counts were standardised to the largest number of birds observed and the number of counts per day. We also present data on some nocturnal censuses. In addition, we compared the average number of individuals remaining at the breeding grounds during periods of both purse-seine fishing and no purse-seine fishing. Assuming that gulls leave the colony to forage, our data suggest that Audouin's gull parents foraged and relieved each other continuously since no activity peak is apparent either during the day or at night. During the day they exploit trawling discards and at night they actively fish clupeiforms either alone or associated with purse-seine fisheries, taking advantage of fish attracted to the surface by boat lamps. Days with purse-seine fisheries activity show significantly lower numbers of Audouin's gulls remaining on their breeding grounds. The yellow-legged gull had a markedly diurnal activity cycle. However, some individuals left the colony before dawn and were able to exploit the last catches of purse-seine fisheries. The difficulty of predicting trawling fishery discards in Chafarinas probably underlies the absence of striking peaks of activity linked to these fisheries, as occurs in other areas.

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Species composition and distribution of seabird flocks in the NE Atlantic

Information held in the European Seabirds at Sea (ESAS) database was used to examine species composition and the seasonal and spatial distribution of large multi-species seabird flocks. The data were collected on a year-round basis in northern European waters between 1980 and 1995. Ordination methods were applied to identify primary "flock types" and an assessment was made of the association of these flocks with the fishing fleet. A total of 682 flocks, comprising fifty or more individuals of four or more species was extracted from the database (excluding flocks with unidentified gulls). Detrended Correspondence Analysis was carried out on transformed data using CANOCO (ter Braak 1988). Strong seasonal changes in the species composition of flocks were

evident as a result of the seasonal presence of migrant species, so separate analyses were carried out for each of the seasons: winter (December-February), spring (March-May), summer (June-August), and autumn (September-November). Overall 61% of the flocks were associated with trawlers; in winter this was higher (97%), and the species composition varied little. However, during the other seasons the species composition varied markedly and distinct flock types were identified:

- flocks dominated by Manx shearwaters or auks and not associated with fishing vessels
- flocks dominated by fulmar or petrels, usually with fishing vessels but sometimes with marine mammals
- flocks dominated by gulls and associated with fishing vessels.

The ordination suggested the primary source of variation in the data was the result of a dichotomy between flocks made up of sub-surface feeding seabirds on the shelf and flocks of offshore aerial species. The changing patterns in relative abundance of species inshore and offshore explained a secondary source of variation. The cumulative explained variance for the first and second axes was between 24% and 26%. The low explained variance suggests the need for caution in interpretation of these results. However, several questions arise from this study, particularly relating to the influence of discards on the seabird community structure. Studies of large multi-species flocks are rare, and the long term ESAS database permits further directed study of seabird flocks and the ecological relationships in the seabird community.

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Lesions observed on stranded seabirds along the Belgian coast from 1992 to 1995

From 1992 to 1995 dead seabirds found on Belgian beaches were collected, necropsied and various tissues sampled for toxicological investigations. Most frequent species were the guillemot *Uria aalge*, the oystercatcher *Haematopus ostralegus*, the kittiwake *Rissa tridactyla* and the razorbill *Alca torda*. Necropsies revealed three main observations: cachexia (severe emaciation), acute haemorrhagic gastro-enteritis and oil contamination. Associations between lesions and biological parameters (age, pelagic origin, etc.) were examined. Statistical analyses revealed that the pelagic origin of seabirds was correlated with all three observations; oil contamination was associated with acute gastro-enteritis and cachexia; and immaturity was associated with cachexia. It is possible that oiled, pelagic seabirds become cachectic and die of acute gastro-enteritis. In addition, toxicological investigations were performed on guillemots, for which further data will be presented.

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To what extent do German Bight common gulls (*Larus canus*) feed at sea?

More than 14,000 common gulls breed along the German North Sea coast. Feeding preferences were compared from birds in three colonies: one close to the open North Sea (Island of Amrum), one at the inner edge of the Wadden Sea (Island of Nordstrandischmoor) and one in the inner estuary of the River Elbe (Island of Lühesand). Diet was analysed by collecting pellets, faeces and other food

remains during both the early incubation period and the chick rearing period. Whereas about half of the pellets at each colony contained plant material, the percentages of other food types varied considerably. At the two colonies adjacent to the sea, crustaceans and insects were most numerous. In contrast, insects and earthworms were most often found on the island in the River Elbe. At all colonies, diet was remarkably diverse and varied within the breeding period (e.g. fruit became important in two colonies). Despite these inter-colony differences in diet, egg volume (considered to be a measure of condition) did not differ significantly between the three colonies. This suggests that the different utilisation of marine and terrestrial foods at these three colonies does not influence female condition during the egg-laying period.

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A new software system for analysing seabird distributions at sea using the PIROP database

PIROP (Programme Integré des Recherches sur les Oiseaux Pelagique) is a well known and unique database for seabird observations, having a maximum time span from 1966-1992 and covering spatially the whole eastern Canadian coast from the Gulf of Maine to the Canadian Arctic and some other regions. Although several major seabird publications have already used this huge data body (Brown *et al*. 1975, Brown 1986, Diamond *et al*. 1993, Lock *et al*. 1994), a large amount of data analysis still waits to be done. Since field collection of data for PIROP evolved and was modified over more than 20 years, the scheme proved to be successful and can be used in other locations and oceans as well. Following the PIROP scheme, new software for data entry was developed by Environment Canada, that allows for entering data efficiently and quickly from seabird observations at sea. Thus, advanced data analysis, such as spatial statistics using Geographical Information Systems (GIS), can be done. Data can be exported and previously compiled data-sets can be translated into the PIROP scheme as well. An application for this software and an analysis method for this PIROP data format is presented. CART (Classification and Regression Trees) is used as an EDA (Exploratory Data Analysis) method and a GIS shows related superimposed data-sets and research results for selected data-sets of the PIROP database.

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Impact of shorebirds and other predators on benthic macrofauna at Culbin Sands, Moray Firth, Scotland: an experimental approach

Coastal birds often occur at high densities and, since they are predators, their impact on the ecology of the intertidal zone and inshore waters is considerable. The most abundant species at Culbin Sands are the oystercatcher *Haematopus ostralegus* and the eider *Somateria molissima* feeding mainly on bivalve species (*Cerastoderma edule*, *Macoma balthica*) and the shelduck *Tadorna tadorna* feeding on other benthic macrofauna specimens (e.g. *Hydrobia*). Their diet does not include fish but because coastal areas are used as nursery grounds, birds can have important effects on fish production. Juvenile flatfish *Pleuronectes platessa*, adult Gobiid fish *Pomatochistus minutus* and the brown shrimp *Crangon crangon* also feed on benthic macrofauna and can be affected by birds. Impact of shorebird predation was measured in autumn 1995 and winter 1995/96 by using exclosures for all predators and enclosures for Gobiid fish and brown shrimp with meso-cosmic approaches. Benthic macrofauna composition from inside and outside cages was compared by using one-way ANOVA.

Results from enclosures with fish and shrimp were not significantly different from those outside cages. By comparing numbers and size distribution of bivalves from inside and outside cages, it is possible to conclude that effects of oystercatchers and shelduck on benthic macrofauna were more important than effects of Gobiid fish and brown shrimp.

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Henslow's swimming crab (*Polybius henslowii* Leach) as an important food for yellow-legged gulls (*Larus cachinnans* Pallas) in NW Spain

An analysis of the contents of 2,562 pellets sampled all year round from 1987 to 1993 showed that Henslow's swimming crabs *Polybius henslowii* are by far the most important marine prey for yellow-legged gulls *Larus cachinnans* on the coast of Galicia (NW Spain), occurring in 36.4% of pellets. The results also suggest that yellow-legged gulls in Galicia are to a great extent marine foragers. Galicia holds one of the largest yellow-legged gull populations in western Europe, largely dominating the seabird community. *Polybius henslowii* is the most important decapod of the continental shelf of Galicia, typically entering coastal waters in large swarms, often near the surface. The only studies in western Europe that show *Polybius henslowii* to be a component of the diet of either yellow-legged gulls or herring gulls *Larus argentatus* are of Atlantic Iberian populations. Furthermore, there are no examples of such a preponderance of a true swimming crab in their diets and there is some evidence that the regular irruption of large shoals of crabs is restricted to *Polybius henslowii* in Iberian Atlantic waters. It may be concluded that *Polybius henslowii* is a characteristic and even exclusive prey of these gull populations. Due to the abundance of the crabs and their susceptibility to predation by yellow-legged gulls, this peculiar situation could be of some importance in the dynamics of marine ecosystems in north-western Iberian Atlantic waters.

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Fluctuations in seabird numbers and breeding success on the Faroe Islands in relation to changes in the marine environment

In the late 1980s there was a drastic decline in the number of breeding guillemots in the Faroe Islands and the production of young guillemots and puffins almost completely failed. During the same period, plankton productivity and recruitment in the major food species for guillemots and puffins decreased dramatically. Recruitment in, and individual growth of, other fish stocks were reduced during these years but the situation is now improving. Guillemot numbers are increasing and breeding success and growth of young puffins also has improved. At the same time, plankton productivity and recruitment and growth of many fish stocks have increased substantially. The production of young gannets has been high throughout this period and this may be due to differences in food selection by this species. These results are linked to changes in the marine environment.

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The effects of trawler discard availability on the breeding ecology of sympatric *Larus audouinii, L. cachinnans* and *L. fuscus* at the Ebro Delta colony

Commercial fisheries affect the biology of seabirds and their populations. While fisheries may crop fish production and damage food availability for natural predators such as seabirds, scavenging seabirds feeding on offal and discards from fishing fleets may obtain food at relatively low energetic costs. In the Ebro Delta, north-western Mediterranean, the established fisheries seem to benefit the reproductive output of some scavenging seabirds. A trawling moratorium established around the colony since 1991 has allowed us to assess the effects of trawler discard availability on the breeding biology of some species. Several studies have recorded a decrease in the reproductive parameters of Audouin's gull, yellow-legged gull and lesser black-backed gull. Direct comparisons of these effects are difficult to draw up since the breeding phenology of these three species is different and the moratorium applies in two months each year, overlapping with different reproductive stages of the species. Respectively, fish from trawler discards formed 21%, 48% and 63% by occurrence of the diet of these species when trawlers operated normally. The mean number of chicks fledged per pair when the moratorium overlapped with the chick rearing stage was 0.42 for Audouin's gull, 0.57 for the yellow-legged gull and 0.15 for the lesser black-backed gull. Different factors may affect the influence of discard availability on the breeding ecology of these three species: number of breeding stages affected, availability of alternative foraging resources, foraging range and life-history strategies. During moratoria, all the species adopted secondary foraging strategies such as kleptoparasitism and predation on smaller seabirds. Audouin's and yellow-legged gulls were the species least affected by the moratorium: Audouin's gull is a specialised nocturnal predator on clupeiforms and has a larger foraging range than the other two species while the yellow-legged gull often feeds on refuse tips. Rice fields act as a buffer against the unavailability of discards for all three species but this is only a secondary foraging resource for the lesser black-backed gull. Furthermore, the moratorium has never affected the laying stage of the (early breeding) yellow-legged gull, whereas it normally affects the whole breeding cycle of Audouin's gull and, to a greater extent, that of the lesser black-backed gull. Results also suggest that fish (especially clupeiform) availability has been depleted in recent decades, probably because of overfishing.

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Differences in the feeding ecology of Audouin's gull between the Ebro Delta and the Chafarinas Islands colonies

We analysed and compared Audouin's gull *Larus audouinii* diet between the two most important breeding sites in the world - the Ebro Delta and the Chafarinas Islands. These two localities present striking differences in commercial fishing. While the Ebro Delta has a large fleet with a commercial strategy producing large amounts of discards, in the Chafarinas Islands there is a much smaller fleet that produces small amounts of discards. In order to compare diets we distinguished two types of fishing: diurnal (only trawling activity); and diurnal and nocturnal (trawling and purse-seine activity). We also distinguished regurgitations from young nestlings (up to 20 days of age) from those of older nestlings and adult birds since in previous analyses we detected differences between them. At the two localities fish are the main food of Audouin's gulls, epipelagic prey items being more important when both types of fishing were operating because purse-seine boats take only this type of fish. The main differences between localities are in secondary prey items, which in the Ebro Delta come from rice fields and salt marshes, whereas at the Chafarinas Islands they come from terrestrial habitats. These secondary resources attain maximum relative importance in the diet of young nestlings only when

diurnal fisheries were operating. This suggests that epipelagic prey linked to nocturnal fisheries are especially relevant in the feeding habits of Audouin's gulls. At the Ebro Delta, Audouin's gulls consumed greater proportions of both epipelagic and benthonic-mesopelagic prey, associated with purse-seine fishing and trawling respectively, than in the Chafarinas Islands. This indicates a greater dependence on fishing due, probably, to the availability of larger amounts of discards. This fact probably underlies the dramatic increase of the Ebro Delta population, which has become the largest in the world.

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Distribution of seabirds in the northern Gulf of Mexico in relation to physical features

Most of the work on seabirds in the Gulf of Mexico has been concentrated in coastal waters with relatively little work done in areas further out in the Gulf. We present information on the distribution of seabirds encountered in areas potentially affected by future oil and gas activities along the continental slope in the north-central and western Gulf of Mexico during autumn, winter, spring and summer 1992-1994. Terns *Sterna* spp. were the most common species seen in the northern Gulf of Mexico in late summer (54% of the thirteen most commonly seen species). A variety of oceanographic measurements were made on the cruises but only water depth had a significant relationship with bird density. We speculate that segregation by depth may relate to variation in productivity in the Gulf of Mexico. We are testing this idea on a cruise in August 1996, specifically looking at transects made from the highly productive waters of the Mississippi River delta out to the more oligotrophic Loop Current. Besides information on seabird distribution, we will collect information on prey such as nekton distribution and physical features such as sea surface temperature and salinity to define water masses, eddies and freshwater input. This information will be used to determine the scale at which physical and biological variables affect seabird distribution in the Gulf of Mexico.

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Habitat selection in Leach's storm-petrels *Oceanodroma leucorhoa*

Seabirds may experience their greatest exposure to natural selective factors during the reproductive season when they are tied to terrestrial habitats. Leach's storm-petrels are the most abundant breeding seabird in the north-west Atlantic, yet very little is known regarding their breeding habitat requirements. We examined breeding habitat preferences on Great Island, Witless Bay, Newfoundland, where the population is estimated at 340,000 pairs. We compared burrow density, activity, reproductive success and the extent of predation in grassland, woodland clearing and dense woodland habitats.

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Population dynamics of Dutch Sandwich terns *Sterna sandvicensis* in relation to food

During the 20th century, the number of nesting Sandwich terns in the Netherlands has shown large fluctuations. After the numerical decline in the 1960s, the population of Sandwich terns recovered only slowly and stabilised at about one third of the level prior to the collapse. The main question is: what caused the slow recovery and why has the population stabilised at such a low level? Food is supposed to be one of the major factors influencing the population size of this highly specialised fish-eater. In the Netherlands, the Sandwich tern feeds almost exclusively on herring and sandeels. The number of nesting pairs in the Netherlands correlates positively with the stock size of young herring in the North Sea. From 1992-1996, the number of nesting pairs at the main breeding area at Griend was positively correlated with the number of herring delivered to the chicks. However, breeding success and chick condition were not correlated with the number of fish supplied to the chicks. Studies on the relationships between food abundance, chick condition at fledging and recruitment in later years are now being undertaken.

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The UK Seabird Monitoring Programme and Seabird Colony Register

Britain's breeding seabird populations are of international conservation significance. This poster outlines the objectives and approach of the UK Seabird Monitoring Programme, which aims to co-ordinate seabird monitoring work in the UK and to ensure that appropriate and sufficient data are collected to identify the conservation needs of breeding seabirds in Britain. Information is given on the programme's geographical and species coverage, methods and outputs. The poster also describes the Seabird Colony Register database of seabird colony counts.