

PREDATOR – PREY INTERACTIONS IN A MARINE ECOSYSTEM IMPACTED BY INDUSTRIAL FISHERIES

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The industrial fishery for sandeels is currently, by quantity, the largest fishery in the North Sea. The top predator community in the North Sea consists of about 50 species of seabirds and mammals, most of which eat fish. Sandeels are important prey for many species, and reduced sandeel abundance has had detectable consequences for breeding success, most notably in surface-feeding seabirds. The IMPRESS project set out to investigate the complex predator-prey relationships as an aid in understanding the fisheries effects on prey availability.

Sandeels are major prey for top predators in the North Sea such as seabirds, whales, dolphins and seals. Severe effects of sandeel stock collapses on some species have been reported, but the relationship between prey density and availability to predators remains poorly understood. Some seabirds fail to reproduce in years when sandeel stocks are low, while other species adjust their foraging successfully or change prey. Recent investigations of the potential impact of the industrial sandeel fishery on seabirds were prompted by the knowledge that breeding success of seabirds depended on sandeel availability and the assumption that the industrial fishery may have reduced sandeel availability to levels at which avian reproductive output is affected. Effects of reduced prey availability

on breeding success were often more pronounced in surface-feeding seabirds such as black-legged kittiwakes *Rissa tridactyla* and arctic terns *Sterna paradisaea*. These findings have led to suggestions that these species are most sensitive to changes in prey availability, particularly sandeels.

Although severe ecosystem effects of sandeel stock collapses have occurred, the fishing industry contests the view that its activities negatively affect top-predators. In the IMPRESS project predator-prey relationships in marine ecosystems have been studied in unprecedented detail

IMPRESS (Interactions between the Marine environment, PRedators, and prey: implications for Sustainable Sandeel fisheries) was a partnership of Royal NIOZ, Natural Environmental Research Council (UK), DHI Water and Environment (Denmark), Fisheries Research Services (UK), Aberdeen University (UK), Leeds University (UK), Centre National de la Recherche Scientifique (France), University of Hamburg (FRG), and the Netherlands Institute for Fisheries Research (RIVO, NL), with the Federal Research Centre for Fisheries (FRG) and the Southampton Oceanography Centre (UK) as subcontractors.

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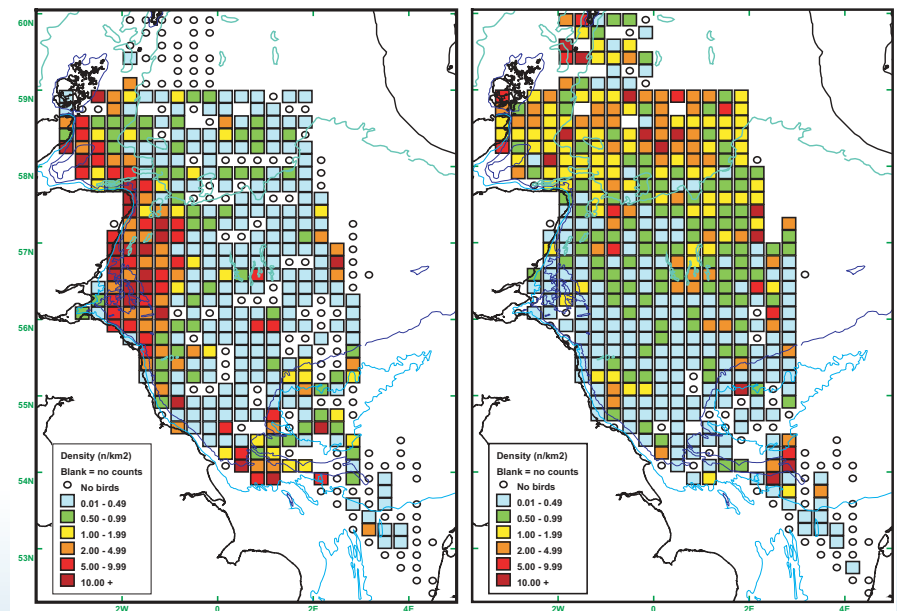
The Pelagia research team: June 2003, "mission completed" (left to right: Nicole Sonntag, Santiago Gonzalez, Philipp Schwemmer, Damien Nixon, Luc Meuwisse, Oliver Ross, Martin Laan, Jackie Smith, Dennis de Boo, Suzan van Lieshout, Beth Scott en Kees Camphuysen).

Previous studies on the impact of industrial sandeel fisheries on seabirds have focussed particularly on sandeel abundance. However, major factors governing the availability to seabirds were not considered. Availability is related to the interaction between the spatial patterns in the abundance of specific size classes of sandeels and the feeding behaviour of seabirds. The overall objective of the project was to determine the relationship between hydrography, relevant sandeel population characteristics, *i.e.* the temporal and spatial patterns in abundance and age- and size distributions, and the foraging performance of groups of seabirds and marine mammals.

The problem was 'attacked' by all available means and tools, using a combination of data loggers on individual birds (foraging performance), observations at the

colonies (breeding performance and diet), ship-based surveys (inter-specific interactions and at-sea distribution, hydrography, fish distribution), and modelling work. To examine the complicated interplay between predators, a large-scale study of the at-sea distribu-

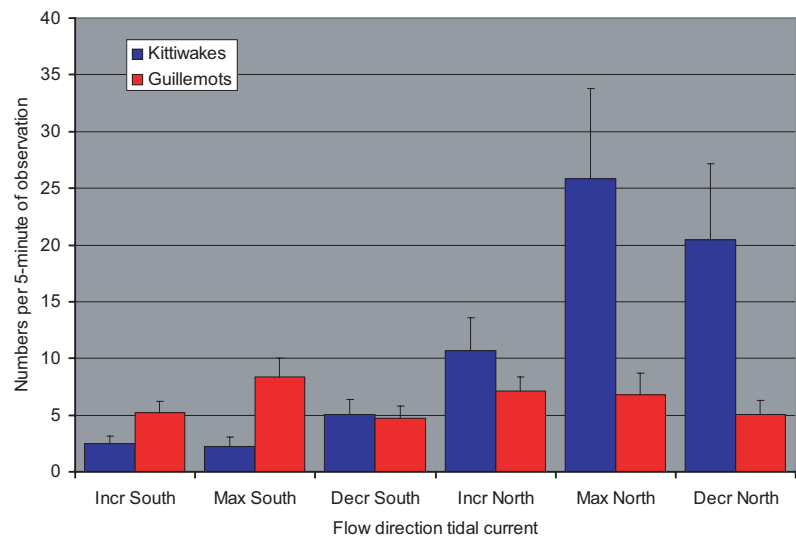
tion, foraging behaviour, feeding interactions and hydrographical characteristics of the feeding areas of all avian and mammalian top-predators was conducted, utilizing long-term data gathered in previous projects in similar ways. New GPS loggers, developed during this project and attached to northern gannets *Morus bassanus* (birds large enough to carry such devices seemingly undisturbed), provided unique insights in the whereabouts and specific activities of individual birds of known (breeding) status and performance. These birds had also dive depth recorders at their feet and a temperature sensor in their stomach, so that diving depth and prey



Contrasting distribution patterns: coastal orientation of black-legged kittiwakes (left), with high densities near the colonies along the Scottish east coast, and the offshore orientation and northerly distribution of northern fulmars (right), mainly inhabiting the deeper North Sea waters that are thermally stratified in summer.

ingestion were recorded real time with highly accurate location fixes. Radio telemetry techniques were used and compass loggers were deployed for smaller predators, such as black-legged kittiwakes, European shags *Phalacrocorax aristotelis* and common guillemots *Uria aalge*.

The survey work under IMPRESS has emphasized the importance of shallow sea fronts for foraging seabirds and indicated that these form an outer barrier for birds breeding down the east coast of Britain. In addition, combining information on at-sea distribution and activity with oceanographic data has highlighted the potentially complex interplay between seabird breeding success, feeding location and inter-specific competition. Water depth throughout most of the study area (the NW North Sea off the Firth of Forth) is less than 60 m and thus all diving seabirds and all the marine mammals potentially have access to the entire water column within their respective foraging ranges. Surface feeders, as their name implies, such as terns, gulls, northern fulmars *Fulmarus glacialis* and storm-petrels *Hydrobatidae* rely on the presence of prey near the water surface, while northern gannets are unlikely to dive deeper



Foraging black-legged kittiwakes and common guillemots (number \pm SE per 5-minutes of observation) with changing tide during continuous surveys in the Wee Bankie area (the full tidal cycle was surveyed twice, 12-13 June 2003; 56°15'N, 01°30'W). On the x-axis, indications of currents running south (ebb; increasing, maximum and decreasing) and north (flood) during six tidal stages.

than 20-25m. These differences in foraging capabilities have implications as to how prey stocks can be utilised by each predator. A dedicated cruise in 2003 with RV Pelagia, revealed that foraging activity varied during the day in relation to changes in tidal currents, suggesting that physical processes may help drive prey towards the surface. Inactive periods were recorded more frequently in surface feeding black-legged kittiwakes than (potentially) deep diving common guillemots, with the latter continuing to feed at certain phases of the tide when black-legged kittiwakes had stopped entirely. Clearly more surveys are needed to investigate these inter-specific differences further. Surface

feeders were found to commonly profit from small flocks of auks *Alca torda* driving sandeels and other fish in balls to the surface in Multi-species foraging associations (MSFAs). Seabirds used complementary tactics when feeding together (e.g. pursuit-diving, plunge-diving, dipping, scooping, surface-pecking and aerial-pursuit), but some of the large aerial species tended to exclude smaller species thereby preventing further access to the fish. For at least eight surface-feeding species, MSFAs must have contributed significantly to their daily prey intake.

Given the increasing pressure on the North Sea ecosystem from both fisheries and climate change, the use of top predators to monitor



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ecosystem health is an attractive concept. However, as the results from the IMPRESS project indicate, we are still a long way from having all the background knowledge required for such an approach. Only through multi-disciplinary projects, we can begin to understand the functional links between marine predators, their prey and the marine climate, allowing us to move towards ecosystem-based fisheries management.