Cross-polar collaboration

Professor Claus Bech, **Geir Wing Gabrielsen** and **Drs Olivier Chastel** and **Alexander Kitaysky** discuss their research into the effects of climate change in the Northern Hemisphere on polar colonies of kittiwakes which involves collaborators from Norway, France, Canada, the U.S. and Scotland




To begin, what are the main objectives of this research project?

CB: The main objective of our studies is to establish how and why the black-legged kittiwake (*Rissa tridactyla*) responds to climate change in different regions of the Northern Hemisphere. We are testing the hypothesis that the kittiwakes breeding in the North Pacific and Atlantic pursue different life history strategies. We believe that these contrasting life history strategies may play an important role in determining the resilience of different kittiwake populations to ongoing climate change.

What existing knowledge do researchers have of the influence of stressful environmental conditions on the timing of breeding in birds? How is your research exploring the mechanics behind this issue?

OC: We have established that a food shortage triggers the secretion of the stress hormone corticosterone (CORT) in kittiwakes. In Svalbard, we have explored the role of this hormone as a mediator of egg-laying date according to foraging conditions: females with experimentally decreased CORT levels laid their eggs earlier and had a higher breeding success. Furthermore, we have shown that CORT can disrupt other key hormones for the onset of breeding. However, it is not always clear whether the timing of breeding might affect overall reproductive performance. For example, our collaborators on the Pribilof Islands (SE Bering Sea) report an overall advance of kittiwakes breeding over the last three decades, yet they were not able to establish a direct link to climate or detect adverse effects of earlier breeding. In the North Atlantic, on the other hand, we found a trend for a delay in the timing of breeding and that late breeding was correlated with poor success.

Climate variability likely affects several parameters important to successful reproduction. In this project we are investigating how nutritional stress affects fecundity of chick-rearing individuals by influencing their allocation of limited resources between reproduction and self-maintenance.

To what extent are changes in food and environmental conditions a result of climate change? What data supports this understanding?

GWG: Nutritional stress has been related to climate variability in the North Pacific – warming is likely to be detrimental to the survival of kittiwakes in southern parts of the breeding range and might be beneficial to those breeding in northern regions. In the North Atlantic, where there has been a significant increase in sea temperatures, high Arctic energy-rich food items have been displaced by more southerly occurring and less energy-rich food items. This has resulted in later breeding and lower reproduction.

What key challenges have you faced during the research project, and how have you overcome these?

CB: Our project is complex in terms of the logistics of organising parallel studies in widely spread geographic regions and because of the number of fairly complex analytical techniques involved. These challenges are not unexpected, and we hope that for the next step of this collaboration we will be able to streamline the majority of approaches.

The project has a strong collaborative component. Who have been your key collaborators and what have been the benefits of these collaborations?

AK: In addition to the primary participants from Norway, the US and France, we collaborate with Jorg Welcker and Børge Moe from Norway, Scott Hatch, Rebecca Young and Chris Barger from the US, Kyle Elliott from Canada and John Speakman from Scotland. This widespread collaboration allows us to achieve the main objective of our project: to assess the effects of global climate change on one of the

Seabird survival

The **SPORE** project, based at the Norwegian University of Science and Technology, is investigating the different life histories adopted by seabirds and how this might be affected by changes in the environment

most common marine top predators. We rely on long-term data on population processes generously provided to us by collaborators. Collaborations also provide invaluable logistic support for our geographically widespread studies.

How do you expect your research findings to impact on knowledge in the field? Do you expect it to have any influence on environmental policy makers?

AK: The most important result of these ongoing studies will be the numerous collaborations established amongst young researchers in the field of marine ecology and seabird conservation. The results of our project will also be important to seabird monitoring programmes that are currently focusing on the documentation of numerical trajectories, and patterns of fecundity and survival.

However, because there are multiple sources of anthropogenic and climate-related stressors that might affect seabirds, these measures might not be sufficient to address the causal mechanisms underlying population changes. Our goal is to demonstrate to wildlife practitioners how physiological and molecular tools can be incorporated into their existing monitoring programmes to identify the nature of stressors and predict population responses to environmental perturbations.

CLIMATE CHANGES OVER coming years are likely to affect the number, distribution and phenology of invertebrate and fish species in our oceans. This will impact the availability of food to species in higher trophic levels: seabirds feed on these marine organisms, and in turn, their nutrient-rich droppings on land enable dense vegetation to grow, which is a source of food for animals.

Recent studies have suggested that population responses to environmental changes are not homogeneous, but may change across different regions where species are found. Two of the most fundamental elements of life history strategies, fecundity and survival, have been found to differ amongst black-legged kittiwake (*Rissa tridactyla*) populations in the North Atlantic and North Pacific.

Pacific kittiwakes generally have lower fecundity and higher survival than their Atlantic counterparts. The datasets currently available support the prediction of life history theory that long-lived individuals are likely to prioritise self-maintenance over reproductive effort: changes in food availability have been shown to have no effect on the survival of adults in Pacific populations.

In contrast, Atlantic kittiwakes respond differently, maintaining high levels of investment and higher reproductive success despite food shortages. Yet studies have demonstrated that food availability has an effect on adult survival. Recent research has also revealed that the adjustment of fecundity might be regulated differently between the two regions.

LIFE HISTORY STRATEGIES

A project led by the Norwegian University of Science and Technology (NTNU) is addressing these differences in kittiwake populations. The work is a collaborative effort with contributions from the Norwegian Polar Institute (NPI), the University of Alaska, Fairbanks (UAF) and CNRS in Chizé, France.

Professor Claus Bech from the NTNU is the joint Principal Investigator along with Alexander Kitaysky (UAF), Geir Wing Gabrielsen (NPI) and Olivier Chastel (CNRS). The project aims to identify whether differences in the life history strategies of kittiwakes can lead to differing responses to potential changes in food conditions.

These different strategies may have important consequences for the long-term adaptability of kittiwake populations, as Kitaysky explains: "High survival at the expense of low fecundity might be a beneficial trait in the face of high frequency environmental variability; however, it might hinder resilience of a kittiwake population under climate-driven continuous deterioration of environmental conditions".

The researchers have already discovered that the energy expenditure of kittiwakes in an Atlantic population was fixed at a high rate and did not fluctuate with food availability, indicating that investment into reproduction is maintained at a high level irrespective of potential negative consequences. Kittiwakes from Pacific colonies show more flexibility in their energy expenditure, suggesting that they adjust their reproductive effort.

The project seeks to address the question of whether these observations are indicative of fundamental differences between these populations. The team have hypothesised that their study colonies can be located on a continuum of life history strategies, with Atlantic and Pacific populations representing extremes: the Atlantic populations exhibit a 'fast living pace' strategy and the Pacific populations a 'slow living pace' strategy.

SPORE

SEABIRD POPULATION RESPONSES TO CHANGES IN FOOD CONDITION

OBJECTIVES

To study if differences in the life-history strategies between populations of a long-lived seabird (the Black-legged Kittiwake) in the North Atlantic and the Pacific can explain differences in trade-off decisions in response to changes in foraging conditions.

PARTNERS

Norwegian University of Science and Technology (NTNU), Trondheim, Norway • **University of Alaska**, Fairbanks, USA • **CNRS**, Chizé, France • **Norwegian Polar Institute**, Tromsø, Norway • **Norwegian Institute for Nature Research** (NINA), Tromsø, Norway • **University of Manitoba**, Winnipeg, Canada • **U.S. Geological Survey**, Anchorage, USA • **U.S. Fish and Wildlife Service**, USA • **University of Aberdeen**, Scotland

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CONTACT

Professor Claus Bech
Department of Biology

Norwegian University of Science and Technology
NO-7491 Trondheim, Norway

T +47 73 59 62 92
E claus.bech@bio.ntnu.no

www.ntnu.edu/biology

CLAUS BECH is a professor of zoophysiology at department of Biology, Norwegian University of Science and Technology in Trondheim, Norway.

ALEXANDER S KITAYSKY is assistant professor at Institute of Arctic Biology, University of Alaska, Fairbanks, USA.

OLIVIER CHASTEL is a researcher at the CNSR in Chizé, France.

GEIR WING GABRIELSEN is head of the Ecotoxicology Section at the Norwegian Polar Institute and adjunct Professor at the University Courses of Svalbard.

OXIDATIVE STRESS AND TELOMERES

To test this hypothesis, the underlying physiological mechanisms that control the response of individuals to environmental changes are being studied. Oxidative stress has been suggested as a primary mechanism which mediates the trade-off between self-maintenance and reproduction. It is evoked by the production of reactive oxygen species as a by-product of metabolic processes.

Excessive amounts of reactive oxygen can damage cellular structures, including DNA, and impair their functioning. It is expected that long-lived individuals would minimise the negative impact of oxidative stress on their own survival by investing in antioxidant defence and avoiding high levels of oxidative damage.

As a target of reactive oxygen species, telomeres – protective caps on the ends of eukaryotic chromosomes – may provide the physiological link through which oxidative stress affects mortality. The loss of telomeres eventually leads to cell death and is assumed to be a significant factor in the ageing and survival of organisms. It is known that reactive oxygen species have a damaging effect on telomeres.

> The energy expenditure of kittiwakes in an Atlantic population was fixed at a high rate and did not fluctuate with food availability

CORTICOSTERONE

The glucocorticosteroid hormone corticosterone (CORT) has been established as an indicator of food availability in free-ranging seabirds. Elevations of CORT levels reliably reflect food shortages, an effect that has been demonstrated in both observational and experimental studies.

Conveniently, CORT levels can also be manipulated experimentally with the use of hormone implants, which continuously release small amounts of the hormone into the blood stream. Thus, food shortages can be simulated and both behavioural and metabolic responses studied in a controlled fashion.

EXPERIMENT AND OBSERVATION

The group are combining both observational and experimental techniques to gather information from Kongsfjorden in Svalbard and the Middleton Island in the U.S. Observations are used to test the hypothesis that the loss of life expectancy is higher at the 'fast living' compared to the 'slow living' colony, while fecundity has an opposite trajectory. Experiments using CORT implantation are also being carried out, to discover whether the metabolic and reproductive responses to experimentally induced food shortages are different between the 'slow' and 'fast' colonies.

A cross-sectional sample of kittiwakes at both colonies is being tested at intervals to calculate telomere loss rates across the years of the study. This will give the researchers an approximation of the loss of life expectancy. Fecundity is being continuously monitored by observations of clutch size and fledgling and hatchling numbers.

The experimental part of the study is being performed with kittiwakes at both study colonies. Following the experimental elevation of CORT levels, the team are measuring oxidative stress and daily energy expenditure, as well as carrying out observations of parental efforts such as chick feeding and attending, in response to CORT administration.

The results of the project so far appear to confirm the team's hypotheses, as Bech explains: "Our preliminary data suggest that Pacific kittiwakes decrease investment in reproduction under conditions of experimentally elevated stress hormones. In contrast, Atlantic kittiwakes 'endure' an elevation of CORT and maintain their investment in offspring".

WIDENING THE STUDY

Ultimately, the project will result in a step towards the integration of Atlantic and Pacific based seabird research. The project also aims to stimulate and facilitate the exchange of graduate and postdoctoral students and researchers between the participating organisations.

The team also want to determine whether kittiwakes are able to change their life-history strategies in response to changes in the environment, or whether the differences they have observed are permanent.

It is hoped that the project findings can be used to predict how these different life history strategies affect the ways in which seabirds respond to changes in the environment in specific colonies and regions. The next step is to widen the study to other colonies in the North Atlantic and Pacific regions: "This would allow us to address questions of broader evolutionary and ecological importance," Bech states. "For example, whether the relative environmental stability of different geographic regions plays a role in the evolution of slow versus fast living life-history strategies."