Effects of climate change on biodiversity at the population and species level

A global interspecific analysis of an ecological guild

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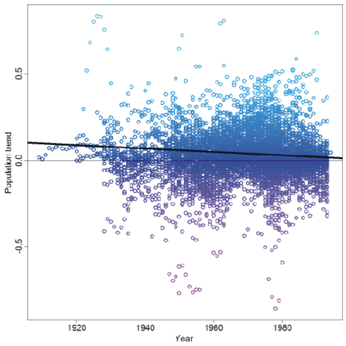

Figure 1. *Population trends in seabirds have declined over time (t = -4.4, p < 0.001).*

1) Introduction

The effect of climatic variability on population dynamics is well understood for a growing number of populations. Few studies have quantified the effect of climate across populations for an entire taxon or guild, however. The results presented here are based on data from seabirds from all oceans and climate zones. Analysing these global data interspecifically, renders it possible to quantify the importance of climate change as a threat to seabird biodiversity. It does not only identify the most vulnerable populations and species, but also whether their proportion is a larger fraction of this ecological guild than could be expected by chance alone.

2) Methods

Time series of seabird population sizes were collected from the scientific literature. Only time series covering twelve or more consecutive years were included. The resulting database consisted of 526 time series from 76 species at 253 seabird colonies, totalling 12,236 observation-years.

Each time series was divided into 11-year intervals, for which the temporal trend and population growth rate was estimated. All analyses were performed using mixed effects models with population (and, were appropriate, species, ocean and year) as random effects.

Effect of climate was estimated by using sea surface temperatures (SST) around each breeding colony as covariates. Variables considered were, for each 11-year period at each colony, the mean SST (corrected for the long-term average), the in- or decrease in SST, and the temporal variance of SST. All three measures were considered both unlagged (i.e., for the same years as the population time series) and lagged by age at maturity (i.e., shifted backwards by the number of years that recruitment takes in each species).

Life history of species was also included as an explanatory variable. It was derived by a principal components analysis of life history traits, which distinguishes between "slow" species and "fast" species (were the latter have high clutch sizes, low age at maturity and low annual survival).

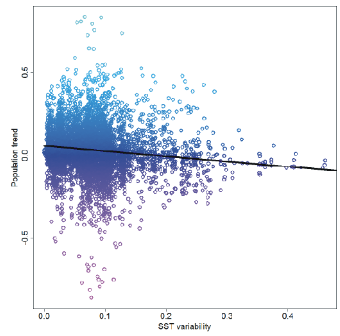

Figure 2. *Population trends of seabirds were more positive in periods of, and locations with, low variability in sea surface temperature* (t = *-4.4,* p *< 0.001).*

3) Results

Population trends of seabirds were, on average, positive, but declined throughout the 19th century (Fig. 1). This decrease was steeper in colonies at higher latitudes (t = -3.1).

Population trends increased with:

- decreasing unlagged SST variance (Fig. 2),
- decreasing lagged SST variance (t = -4.2),
- decreasing lagged SST trends (t = -3.1), and
- increasing lagged SST means (t = 3.9).

Life history was not important as a main effect. It exhibited interactions with two of the unlagged SST variables, however:

- The negative effect of SST variability on population trends was most pronounced in "slow" species (Fig. 3).
- While "fast" species seem to profit from decreasing SSTs, the opposite was true for "slow" species (t = -4.4).

Latitude was important both as a main effect (population trends being more negative in high latitudes; t = -3.6) and because it modified the effect of SST trends: at high latitudes (both north and south), population trends tended to decrease when SST increased, while the opposite was found at lower latitudes (t = -3.6).

Some seabird taxa were more vulnerable than others (χ^2 = 33): population trends were lowest in the storm-petrels (Hydrobatinae), auks (Alcinae) and penguins (Spheniscidae). Furthermore, while gannets (Sulidae) and terns (Sterninae) seemed to profit from high mean SSTs, albatross (Diomedeidae) populations increased most in periods of low SSTs (χ^2 = 53).

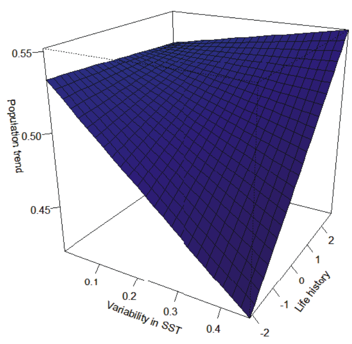

Figure 3. *High variability in sea surface temperatures lead to decreasing population trends in seabirds* (t *= -7,* p *< 0.001). This finding was most pronounced in species with "slow" life histories (interaction term:* t *= 4.9,* p *< 0.001).*

4) Discussion

The decline in seabird population trends with time (Fig. 1) does not allow any causal inferences. However, the analyses have shown the importance of a climatic factor (sea surface temperature, SST). SSTs affect seabird populations both unlagged and lagged by age at maturity. The former effects are due to the responsiveness of adult survival to climate, while the latter are caused by climatic effects on breeding success (because these effects cannot be detected before the fledglings recruit several years later; Sandvik et al. 2008, in prep.).

Overall, offspring production and thus recruitment in seabirds was higher in warmer periods. However, global warming does not only imply increasing temperature averages but also increasing meteorological and oceanographic variability. High SST variability had negative effects on seabird population trends, both by affecting survival and recruitment. It remains to be established which factor has most importance.

Life history traits have been suggested to influence the climatic responsiveness of species (Morris et al. 2008, Sandvik & Erikstad 2008). This is also found here, in that "slow" species show more negative trends under high SST variability than "fast" species. The interspecific analyses also allowed to identify taxa with particularly low population trends and/or with elevated vulnerability to high temperatures.

References:

Morris et al. (2008) *Ecology* **89**, 19-25.
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Sandvik H et al. (2008) *Glob Change Biol* **14**, 703-13.
Sandvik H et al. (in prep.) The climatic effect on population dynamics in seabirds is driven by offspring production (unpublished MS).