Reply to 'Sources of uncertainties in cod distribution models'

Wisz *et al.* reply — Ingvaldsen *et al.*[1] comment on our study assessing global fish interchanges between the North Atlantic and Pacific oceans for more than 500 species during the entire twenty-first century[2]. They propose that discrepancies between our model projections and observed data for cod in the Barents Sea are the result of the choice of atmosphere–ocean general circulation models (AOGCMs). We address this assertion here, re-running the cod model with additional observation data from the Barents Sea[1,3], and show that the lack of open-access archived data for the Barents Sea was the primary cause of local prediction mismatch. This finding highlights the importance of systematic deposit of biodiversity data in global databases.

There is currently no consensus on the best way to construct an ensemble of climate models and how to objectively evaluate their associated uncertainties. Using a large ensemble of AOGCMs could provide a weighted average of predictions with the closest fit to observations, and would directly reflect some of the model uncertainty in species forecasts[4,5]. In our study, we applied and separately analysed two different AOGCMs: IPSL-CM5A-LR (IPSL) and EC-Earth (EC). This choice was motivated by the results of a recent model comparison of 20 different AOGCMs[6]. In this comparison, IPSL was retained in the top six best models, and EC exhibited a very similar level of predictive performance when evaluated with recent observations of extent and trends in September Northern Hemisphere sea ice[6]. Importantly, differences in skill for the two AOGCMs were comparable with spread of the full ensemble of the 20 AOGCMs. We used these two AOGCMs in combination with an ensemble of four up-to-date niche-based modelling techniques. While most studies limit their analyses to a few future time slices (for example, only 2050, 2080 and 2100), our study addressed transient year-to-year distributional changes with both climate models for hundreds of fish species. Our results show that EC did not fully reproduce the contemporary distribution of Atlantic cod (Fig. 1a) in the Barents Sea, in contrast to the IPSL (Fig. 1c).

An additional source of potential error and uncertainty arising in niche-based

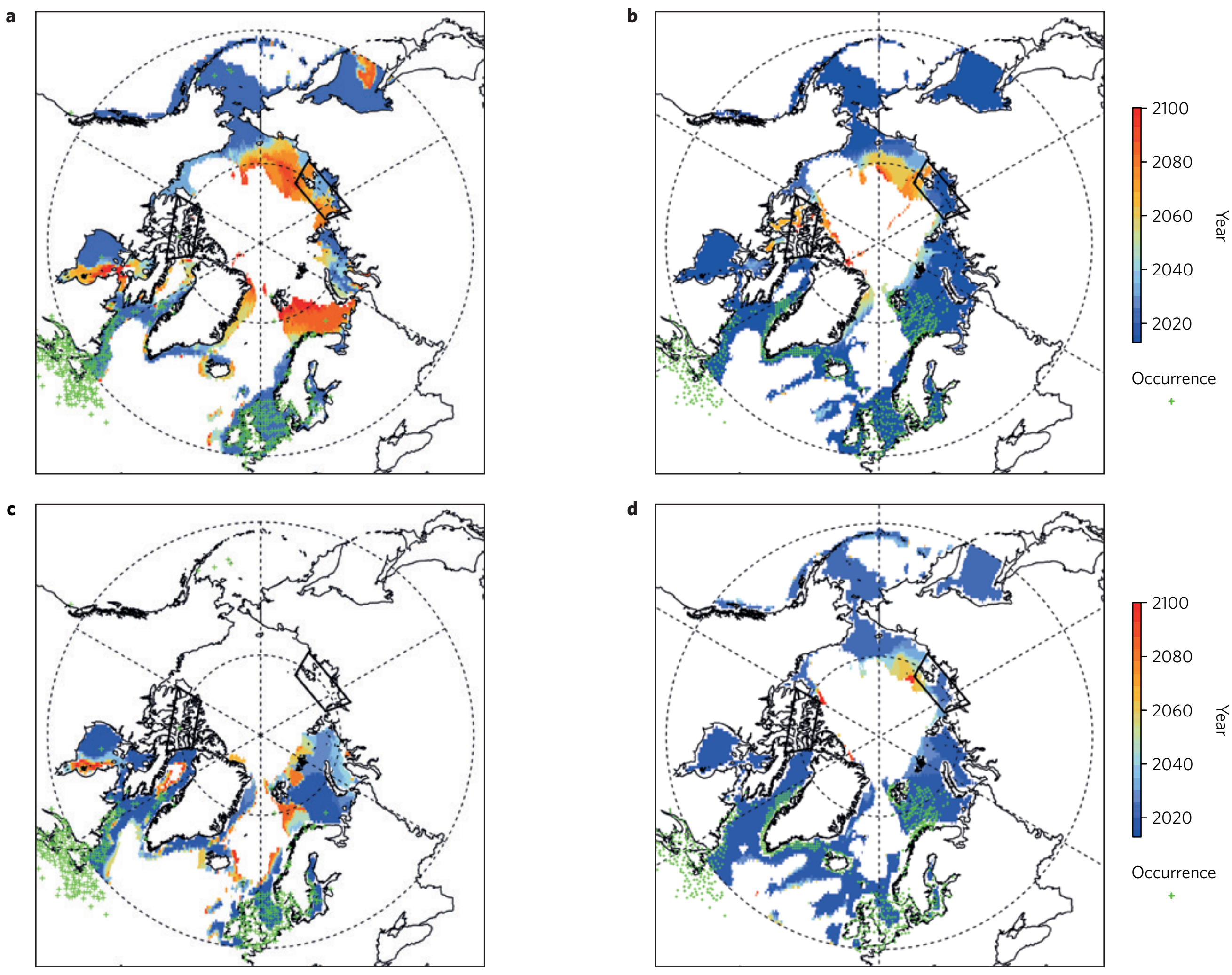

Figure 1 | Predictions of suitable environmental conditions for Atlantic cod (Gadus morhua). **a**–**d**, Colours indicate the forecasted year in which conditions become suitable based on the EC-Earth (**a**,**b**) and IPSL scenarios (**c**,**d**) with Global Biodiversity Information Facility (GBIF) data (**a**,**c**) and GBIF data supplemented from several other sources[1,3] (**b**,**d**). Continuous predictions of probability of occurrence were converted to binary presence–absence predictions using the threshold that maximized the true skills statistic and assuming a minimum of 10% predicted occupancy in an accessible intervening passage as in Wisz *et al.*[2]

models is the underlying species data used for calibration[7]. Under-representation of distinct environments within a species' range, or overlooked populations that possess adaptations to local conditions, may lead to reduced predictive power of niche models[8]. Vast numbers of locational records are thus needed to address broad-scale macro-ecological questions with statistical niche models, and a standard practice involves the use of global databases, such as the Global Biodiversity Information Facility (www.gbif.org). Ecosystem monitoring datasets that had not been deposited in this database, such as the ones presented by Ingvaldsen *et al.*[1], were thus not used to build models for Wisz and colleagues[2]. The resulting paucity of cod occurrence records for the Barents Sea affected the forecast of cod distribution in that area (Fig, 1a,c), especially for EC (Fig. 1a). After updating and refitting the model with Norwegian trawling data from the Barents Sea[1], Greenland[3] and elsewhere in the North Atlantic[3], our model predicted cod distribution more adequately in the Barents Sea, regardless of the AOGCM climate reconstruction used (Fig. 1b,d). Lack of predictions of cod near Novaya Zemlya and other Russian parts of the Barents Sea can be attributed to the lack of the Russian dataset used by Ingvaldsen and colleagues[1], as these data were not available to us to update our niche models.

The discrepancies with the data presented by Ingvaldsen *et al.*[1] illustrate how macro-ecological studies will benefit from additional, freely available sources of spatially explicit data. Distributions of fish species have already changed in recent years near or at the so-called high-latitude 'Arctic gateways'[9,10] (that is, connections between the Atlantic and Pacific oceans). High-quality distribution data[1] is still not systematically archived in open access biodiversity data portals, and the quality of the available data can be a challenge for many species (for example, ref. 11). Improving the availability of high-quality data in biodiversity data portals will lead to strengthened predictions of distributions, abundance and ecosystems that will serve science and society. Finally, including more occurrences in proximity to the Arctic gateways may unveil a faster rate of interchange than previously estimated[2], highlighting the need for more systematic transfer of data from ongoing long-term research and monitoring programmes to global databases. ❐

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COMMENTARY:

Playing hide and seek with El Niño

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A much-anticipated 'monster' El Niño failed to materialize in 2014, whereas an unforeseen strong El Niño is developing in 2015. El Niño continues to surprise us, despite decades of research into its causes. Natural variations most probably account for recent events, but climate change may also have played a role.

The scientific community has invested considerable effort over the past 50 years in studying El Niño, ever since Jacob Bjerknes first described unusual warm events in the tropical Pacific as the consequence of coupled interactions between the ocean and the overlying atmosphere[1]. El Niño and its cold counterpart La Niña represent the strongest year-to-year climate fluctuation on the planet[2]. What has motivated so much interest in these climatic siblings (which we collectively refer to as the El Niño/Southern Oscillation, or ENSO, cycle) is not only the quest to understand how they work, but also a societal imperative to accurately predict their evolution to help anticipate impacts on lives, property, economic activity and the environment.