
Climate change is likely to reduce the yield and alter the composition of many fisheries around the world.

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Climate change impacts on fisheries

Assessment of past fisheries productivity helps to predict and manage future changes

By **Éva Plagányi**

Food security, climate change, and their complex and uncertain interactions are a major challenge for societies and ecologies (*1*). Global assessments of predicted changes in crop yield under climate change, combined with international trade dynamics, suggest that disparities between nations in production and food availability will escalate (*2*). But climate change has already affected productivity. For example, weather-related factors caused declines in global maize and wheat production of 3.8% and 5.5%, respectively, between 1980 and 2008 (*3*). On page 979 of this issue, Free *et al.* (*4*) report a comprehensive analysis that indicates a 4.1% decline between 1930 and 2010 in the global productivity of marine fisheries, with some of the largest fish-producing ecoregions experiencing losses of up to 35%. Their spatial mapping can help to inform future planning and adaptation strategies.

The authors validated their assessments rigorously, using population models to hindcast the maximum yields that could have been sustainably caught and to evaluate statistically the influence of past rising temperatures (*4*). They found that temperature had a highly variable influence on different marine species, with evidence for both negative (19 species; 8% mean decrease) and positive (9 species; 4% mean increase) changes in productivity. They attribute these differences to not only ecoregion but also taxonomy, life history, and exploitation history.

Losses in seafood production are of concern because seafood has unique nutritional value and provides almost 20% of the average per-person intake of animal protein for 3.2 billion people (*5*). However, wild capture fisheries yield has likely already reached its natural limits (*5*). Coupled with projected human population increases, this means that per-person seafood availability is certain to decline. This shortfall will be exacerbated by future losses in fisheries production as a result of warming (see the figure). Aquaculture, which parallels the intensification of crop production on land, has been proposed as one potential solution. However, this sector's initial high growth rates have declined, and its future scope for growth is uncertain and susceptible to environmental extremes (*5*). Given the widening gap between current and projected per-person fisheries yield (see the figure), other protein sources and solutions will be needed to avoid food shortages.

Future fisheries production may be at even greater risk considering that, owing to anthropogenic climate change, the oceans are continuing to warm even faster than originally predicted (*6*). Moreover, extreme temperature events are on the increase, with profound negative consequences for fisheries and aquaculture (*7*). Regional declines in some species will thus increasingly not be counterbalanced by increases, as populations exceed their thermal optima or become subject to other environmental stressors such as reduced oxygen concentra-

Commonwealth Scientific and Industrial Research Organisation (CSIRO) Oceans and Atmosphere, Brisbane, Australia, Email: eva.plaganyi-lloyd@csiro.au

tion and ocean acidification (*8*). These additional effects could not be accounted for in the retrospective analyses of Free *et al.*

It is extremely challenging to quantify the additional influence of climate on fisheries, over and above the direct effects of fishing, and to also account for the linked components of social-ecological systems (including the fishers themselves) (*9*). Most analyses use models, which introduce uncertainties through the model structure and choice of parameter values. Given the substantial uncertainties and complications in climate impact forecasts (*6*, *9*), it is not surprising that projections of climate impacts on global food production differ widely. For example, Cheung *et al.* have predicted decreased productivity at the equator relative to the poles and forewarned that adaptation policies are especially needed in highly socioeconomically vulnerable tropical regions (*10*). By contrast, Free *et al.* suggest a different regional distribution of winners and losers [see fig. 4 in (*4*)] and draw particular attention to East Asian and North Sea ecoregions.

Improving the accuracy of current assessments and future projections is critical to informing planning and adaptation strategies. Free *et al.'s* study represents an important advance on earlier species-distribution–based assessments (*10*). Advances include the use of best practices for stock assessment meta-analysis, including careful accounting for model assumptions, uncertainty, and bias. For example, Free *et al.* used multiple lines of evidence to corroborate their results, including alternative modeling frameworks, parameterizations, and sea surface temperature datasets. Their study provides a solid foundation for ongoing validation of region-specific projections and enables more robust extrapolation to other similar systems for which data are not available.

The study of Free *et al.* provides additional guidance for resource managers grappling with implementing strategies that will enhance adaptation to ongoing climate change. They found evidence that historical overfishing compounds negative influences of warming. This corroborates previous findings that overfishing can amplify negative population fluctuations and hence that risk-based management policies should be considered (*11*).

Regional fishery managers and stakeholders can influence future sustainable fisheries production and food security through the development, adoption, and enforcement of sustainable management strategies and practices. These strategies should be pretested for robustness to temperature-driven changes in productivity (*9*). However, global efforts are needed to contain the rise in global mean temperature to no more than 2°C, beyond which the integrity of marine and terrestrial ecological systems, and hence our food supplies, become compromised (*12*). ■

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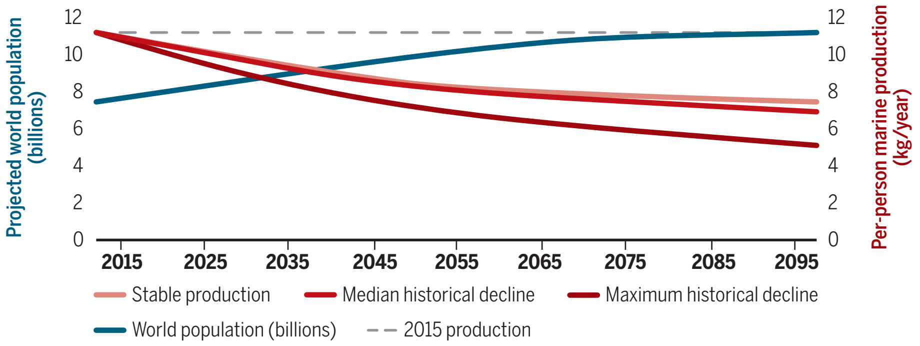
Projected change in per-person marine production

Even if marine production stays stable at the 2015 level, production per person will fall as the human population continues to grow. Climate warming is likely to further reduce marine production. The median and maximum historical decline curves below assume continuation of the average historical (1930–2010) rates of fisheries decline due to warming computed by Free *et al*.



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METABOLISM

Lipid-filled vesicles modulate macrophages

Fat cells use a special form of intercellular communication to shape their environment

By **Marc A. Antonyak**[1], **Michael J. Lukey**[1], *and* **Richard A. Cerione**[1,2]

Adipose (fat) tissue is a major site of energy storage that responds to fluctuations in nutrient availability to maintain systemic metabolic homeostasis (*1*). Adipocytes take up circulating free fatty acids (FFAs) from the blood and store them in lipid droplets in response to increased insulin concentrations (which occur after feeding); they then hydrolyze lipids to release FFAs under conditions of nutrient deprivation. A variety of other cell types are present within adipose tissue, including fibroblasts, endothelial cells, and adipose tissue macrophages (ATMs). In addition to their roles in immune surveillance and clearance of cellular debris, ATMs are important for lipid buffering and regulate adipose tissue function in both healthy and diseased states (*2*). Owing to the rising global incidence of chronic obesity and associated health issues, there is renewed interest in understanding how adipose tissue functions in physiological and pathological settings. On page 989 of this issue, Flaherty *et al.* (*3*) report that adipocytes communicate with ATMs by releasing a distinct class of extracellular vesicles (EVs) called adipocyte-derived exosomes (AdExos), which are loaded with fat and appear to be derived directly from adipocyte lipid droplets. The uptake of AdExos by resident ATMs allows for the direct transfer of lipids, revealing a form of intercellular communication and nutrient exchange with important implications for obesity-associated pathologies.

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[1]Department of Molecular Medicine, Cornell University, Ithaca, NY 14853, USA. [2]Department of Chemistry and Chemical Biology, Cornell University, Ithaca, NY 14853, USA. Email: rac1@cornell.edu

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Éva Plagányi

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