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Warmer oceans will harbor lower animal abundance

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ABSTRACT

Climate change is affecting the distribution and abundance of marine life. Yet the full extent of future changes is difficult to predict due to limitations in individual models used for forecasting. By combining different models, we project widespread declines in animal life in a warmer ocean.

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Climate change is not only altering the ocean's temperature, currents, and productivity, but also the most known forms of animal life. This includes a wide variety of species, from small invertebrates and fish to turtles, tuna, and whales — changes in the marine environment influence all these animals. Substantial environmental variations can affect their growth and survival and, on a larger scale, their abundance and distribution. Such changes will further affect the amount of seafood available for people, the survival of threatened species, and the distribution of marine habitats. The big question is: how much will marine animal abundance change under different degrees of future warming? Finding an appropriate way to answer this question is critical to inform policy, fisheries management, and marine conservation.

Predicting the future abundance of marine animals in a warming ocean requires a modeling approach. Generally, one needs a climate or Earth-system model that provides projections of temperature, currents, primary production, ice cover, and other physical and biogeochemical variables. These are then coupled to an ocean ecosystem model that provides estimates of animal abundance and distribution. The challenge is that there are many different climate and ecosystem models, each with its limitations and advantages, and all are necessary simplifications of the natural world. So far, several studies have aimed to project future marine animal abundance, but generally using only one ecosystem model combined with one or few climate models. This provides a minimal and potentially skewed picture of future changes. Our goal was to overcome the inherent limitations of individual models by using a multi-model ensemble approach, the new 'gold standard' in climate science. Such an ensemble approach combines standardized climate-change scenarios across ecosystem models to derive an average trend and associated uncertainties.

Our ensemble contained six different global marine ecosystem models that were combined with two contrasting climate models (one with low and one with high climate sensitivity) and four carbon emission scenarios. The emission scenarios provided different degrees of future warming, from a strong-mitigation to a business-as-usual situation. The six ecosystem models included those modeling the distribution of individual species, others modeling the energy transfer through different size classes, and again others the linkages among different taxa or functional groups in the marine food-web. Three of these models could also simulate the effects of fishing, so we could also compare future outcomes between a fishing and no-fishing scenario. All models provided a standardized measure of animal biomass for each year and grid cell in a future ocean over the 21st century.

Our results highlight that global marine animal biomass will decline under all future emission scenarios. Warming temperatures and declining primary production are the primary drivers of these declines. However, declines will be at least three times stronger under a business-as-usual scenario, which humanity is currently on track with, compared to a strong-mitigation scenario, which would limit global warming in accord with the Paris Agreement. This result highlights the benefits to be gained from climate-change mitigation. Our results also show that the climate-change effect was similar with and without fishing pressure, suggesting that fishing will not alter the climate-change impact. However, we found that climate-change impacts were more severe at higher food-web levels, meaning that fish and whales may suffer more severe declines compared to the microscopic plankton organisms at the bottom of food chains. Yet not all regions of the global ocean will respond similarly to climate change. Mapping revealed that animal biomass would decline in many temperate to tropical ocean regions, where people are highly dependent on seafood and where marine biodiversity is already strongly affected by human impacts. In contrast, many polar regions could see biomass increases, which may provide new opportunities for marine resource use but also challenges to marine governance and conservation.

Our ensemble projections provide the most comprehensive global-ocean assessment of climate change to date, using a combination of multiple climate scenarios and ecosystem models. It highlights that reductions in greenhouse gas emissions will help minimize the loss of marine life from climate change. Overall, our results can help anticipate changes in valuable marine resources and biodiversity under different climate-change scenarios in different regions of the global ocean. As such, they can inform ongoing international climate-change and biodiversity assessments and policy negotiations. This study represents a major undertaking that was only possible through the long-term collaboration of many climate and ecosystem modelers worldwide in the Fisheries and Marine Ecosystem Model Intercomparison Project (FishMIP; www.fishmip.org/).