Extreme and compound ocean events are key drivers of projected low pelagic fish biomass

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Ocean extreme events, such as marine heatwaves, can have harmful impacts on marine ecosystems. Understanding the risks posed by such extreme events is key to develop strategies to predict and mitigate their effects. However, the underlying ocean conditions driving severe impacts on marine ecosystems are complex and often unknown as risks to marine ecosystems arise not only from hazards but also from the interactions between hazards, exposure, and vulnerability. Marine ecosystems may not be impacted by extreme events in single drivers but rather by the compounding effects of moderate ocean anomalies. Here, we employ an ensemble climate-impact modeling approach that combines a global marine fish model with output from a large ensemble simulation of an Earth system model, to identify the key ocean ecosystem drivers associated with the most severe impacts on the total biomass of 326 pelagic fish species. We show that low net primary productivity is the most influential driver of extremely low fish biomass over 68% of the ocean area considered by the model, especially in the subtropics and the mid-latitudes, followed by high temperature and low oxygen in the eastern equatorial Pacific and the high latitudes. Severe biomass loss is generally driven by extreme anomalies in at least one ocean ecosystem driver, except in the tropics, where a combination of moderate ocean anomalies is sufficient to drive extreme impacts. Single moderate anomalies never drive extremely low fish biomass. Compound events with either moderate or extreme ocean conditions are a necessary condition for extremely low fish biomass over 78% of the global ocean, and compound events with at least one extreme variable are a necessary condition over 61% of the global ocean. Overall, our model results highlight the crucial role of extreme and compound events in driving severe impacts on pelagic marine ecosystems.