

REVIEW SUMMARY

OCEANOGRAPHY

Contrasting futures for ocean and society from different anthropogenic CO₂ emissions scenarios

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BACKGROUND: Although the ocean moderates anthropogenic climate change, this has great impacts on its fundamental physics and chemistry, with important consequences for ecosystems and people. Yet, despite the ocean's critical role in regulating climate—and providing food security and livelihoods for millions of people—international climate negotiations have only minimally considered impacts on the ocean. Here, we evaluate changes to the ocean and its ecosystems, as well as to the goods and services they provide, under two contrasting CO₂ scenarios: the current high-emissions trajectory (Representative Concentration Pathway 8.5, RCP8.5)

and a stringent emissions scenario (RCP2.6) consistent with the Copenhagen Accord of keeping mean global temperature increase below 2°C in the 21st century. To do this, we draw on the consensus science in the latest assessment report of the Intergovernmental Panel on Climate Change and papers published since the assessment.

ADVANCES: Warming and acidification of surface ocean waters will increase proportionately with cumulative CO₂ emissions (see figure). Warm-water corals have already been affected, as have mid-latitude seagrass, high-latitude pteropods and krill, mid-latitude bivalves, and

fin fishes. Even under the stringent emissions scenario (RCP2.6), warm-water corals and mid-latitude bivalves will be at high risk by 2100. Under our current rate of emissions, most marine organisms evaluated will have very high risk of impacts by 2100 and many by 2050. These results—derived from experiments, field observations, and modeling—are consistent with evidence from high-CO₂ periods in the paleorecord.

Impacts to the ocean's ecosystem services follow a parallel trajectory. Services such as coastal protection and capture fisheries are already affected by ocean warming and acidification. The risks of impacts to these services increase with continued emissions: They are

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predicted to remain moderate for the next 85 years for most services under stringent emission reductions, but the business-as-usual scenario (RCP8.5)

would put all ecosystem services we considered at high or very high risk over the same time frame. These impacts will be cumulative or synergistic with other human impacts, such as overexploitation of living resources, habitat destruction, and pollution. Fin fisheries at low latitudes, which are a key source of protein and income for millions of people, will be at high risk.

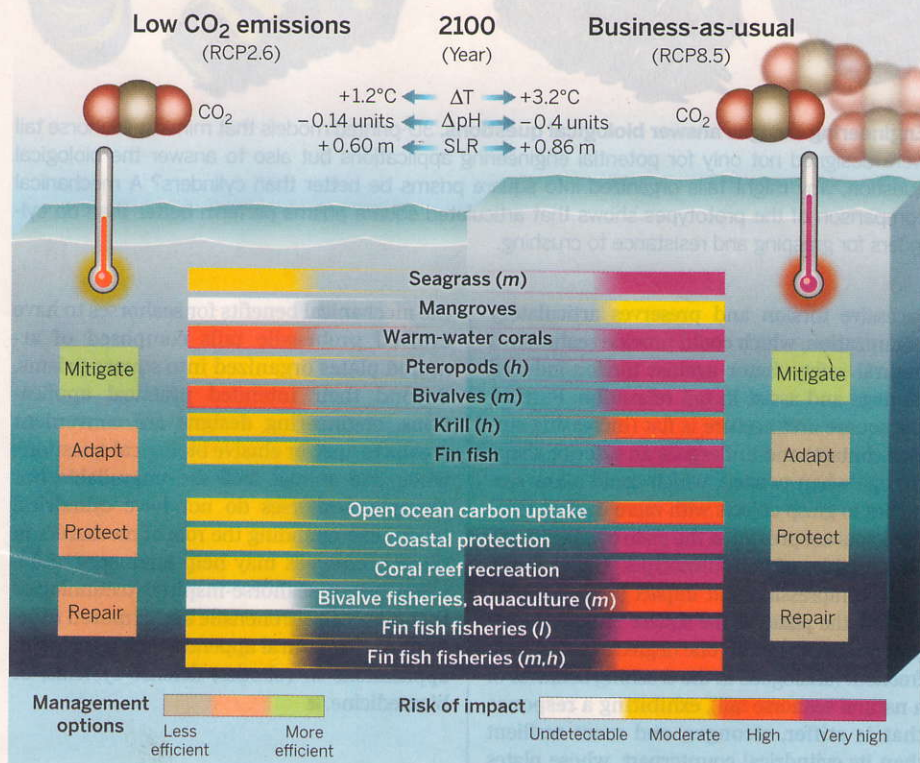
OUTLOOK: Four key messages emerge. First, the ocean strongly influences the climate system and provides important services to humans. Second, impacts on key marine and coastal organisms, ecosystems, and services are already detectable, and several will face high risk of impacts well before 2100, even under the low-emissions scenario (RCP2.6). These impacts will occur across all latitudes, making this a global concern beyond the north/south divide. Third, immediate and substantial reduction of CO₂ emissions is required to prevent the massive and mostly irreversible impacts on ocean ecosystems and their services that are projected with emissions greater than those in RCP2.6. Limiting emissions to this level is necessary to meet stated objectives of the United Nations Framework Convention on Climate Change; a substantially different ocean would result from any less-stringent emissions scenario. Fourth, as atmospheric CO₂ increases, protection, adaptation, and repair options for the ocean become fewer and less effective.

The ocean provides compelling arguments for rapid reductions in CO₂ emissions and eventually atmospheric CO₂ drawdown. Hence, any new global climate agreement that does not minimize the impacts on the ocean will be inadequate. ■

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Changes in ocean physics and chemistry and impacts on organisms and ecosystem services according to stringent (RCP2.6) and high business-as-usual (RCP8.5) CO₂ emissions scenarios. Changes in temperature (ΔT) and pH (ΔpH) in 2090 to 2099 are relative to preindustrial (1870 to 1899). Sea level rise (SLR) in 2100 is relative to 1901. RCP2.6 is much more favorable to the ocean, although important ecosystems, goods, and services remain vulnerable, and allows more-efficient management options. *l, m, h*: low, mid-, and high latitudes, respectively.