Climate Change Threatens the Biodiversity of the World’s Marine Protected Areas

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**Marine Protected Areas (MPAs)—coastal and open-ocean nature preserves—are a primary management tool for mitigating local threats to marine biodiversity**1**. MPAs and the species they protect, however, have been and increasingly will be impacted by anthropogenic climate change—raising questions about whether they can serve their intended purpose in a warming world. Here we show, despite local protections, that the warming associated with continued ‘business-as-usual’ (BAU) emissions (RCP8.5)**2 **will result in habitat and species loss throughout low latitude and tropical MPAs**4,3**. With unabated BAU emissions, mean sea-surface temperatures (SST) within MPAs will increase ~ 0.034 °C/year and warm an additional ~2.8 °C by 2100. We determined the “time of emergence”—the year that SST and oxygen concentration will exceed their range of natural variability for 309 no-take marine reserves—showing that with continued BAU emissions, both factors “emerge” by mid-century in most reserves. Moreover, we show the spatial distribution of emergence is stressor-specific. Hence, rearranging MPAs to minimize exposure to one factor may well increase exposure to another. Continued BAU emissions, therefore, will likely disrupt the species and ecosystems and offset the benefits purported for MPA protections.**

Species dependent on marine reserves could be especially sensitive to anthropogenic climate change because of their typically small populations, restricted geographic ranges, and low genetic diversities5. Case-studies indicate that global warming induced climate changes already are having substantial effects on populations and ecosystems otherwise protected within terrestrial and marine reserves6,7. Gradual warming over the last several decades and unusually high seawater temperatures in early 2016, for example, caused mass coral mortality across much of the northern Great Barrier Reef8 (GBR), a UNESCO World Heritage Site and model MPA. Despite its isolation and effective protection from harvesting, pollution, and other stressors, warming radically altered the northern GBR8. This and similar case studies as well as synthetic analysis9 call into question the long-term effectiveness of MPAs in protecting their resident biotas in the face of climate change.

Anthropogenic Carbon emissions lead to acute and chronic perturbations including increasing storm intensity, rising sea levels, altered upwelling regimes, ocean acidification, and deoxygenation5,12,13. As a result, organisms must simultaneously adjust their physiologies to cope with multiple threats that in some cases could be selecting for opposing traits. We focused on two critical effects influencing MPAs: rising temperatures and changing oxygenation. We asked how much MPAs can be expected to warm under the business-as-usual emissions trajectory RCP 8.5 and the RCP 4.5 mitigation scenario10, for which emissions peak around 2040 and CO2 concentration stabilizes at ~525 ppm in 2100(ref. 2). We used CMIP5 models to predict the mean 21st century rate of SST and O2 change at the geographic centers of 8236 MPAs around the world (Fig. 1A). We also assessed warming rates in 309 “no-take reserves,” in which fishing is banned. With BAU emissions, mean SSTs are predicted to increase within nearly all MPAs: the average warming rate is 0.034 °C/year (Table 1), with a maximum increase of 0.113°C/year (in northern Baffin Bay off northwest Greenland). This predicted future warming continues the trend of recent anthropogenic warming of 0.1 °C per decade11, on average, since 1960. Projected warming rates increase slightly with latitudinal zone, from the tropics to polar oceans (Tables 1 S1). Remarkably, under RCP 8.5, 99% of the world’s MPAs are forecasted to warm by ≥2°C by 2100. The RCP 4.5 mitigation scenario2 predicts substantially lower warming rates (Table 1), and thus presumably reduced impacts on marine organisms12,13.