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Neurobiological-induced breakdown of cleaning mutualisms under ocean warming and acidification

Cleaning mutualisms are drivers of fish abundance and diversity on coral reefs. Most reef fishes engage in cooperative interactions with cleaners, where they benefit from ectoparasite reduction and ultimately stress relief. Furthermore, such interactions elicit beneficial effects on clients' ecophysiology, with cascading effects on community diversity and abundance. However, the potential effects of ocean warming and acidification on these charismatic associations are unknown. We exposed cleaner wrasses *Labroides dimidiatus* and their clients *Naso elegans* to chronic conditions of ocean warming (+3C) and acidification (980 uatm pCO2). Here we show that after 45 days of acclimation there was a significant decrease in fish cleaning motivation and in the quality of the interactions between cleaner and client. At the neurobiological level, in cleaner wrasses, dopamine and serotonin concentration were only affected by ocean acidification but their activity increased under both ocean warming and acidification. In client fish, dopamine concentration decreased with temperature and serotonin with CO2 while dopamine activity increased with ocean acidification. Changes to cleaner behaviour under ocean warming and acidification were correlated to altered neurotransmitter concentrations and activity at the individual level. We propose that elevated CO2 interacts with: i) dopamine, impairing the cleaners' ability to negotiate and ii) serotonin, modulating motivation for interaction; while iii) temperature affected mostly enzymatic activity. Our results suggest that cleaning mutualisms that are important for maintaining local community structure on coral reefs will be degraded by future ocean conditions, through effects on brain monoamine systems.

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Impacts of climate change on sharks

Sharks play a key role in the structure of marine food webs, but are facing major threats due to overfishing and habitat degradation. Although sharks are also assumed to be at relatively high risk from climate change due to a low intrinsic rate of population growth and slow rates of evolution, ocean acidification (OA) has not, until recently, been considered a direct threat. New studies have been evaluating the potential effects of end-of-century elevated CO2 levels on sharks and their relatives' early development, physiology and behaviour. Using a meta-analysis approach, here it is showed that while embryo survival and development time are mostly unaffected by elevated CO2, there are clear effects on shark body condition, growth, aerobic potential and behaviour (e.g. lateralization, hunting and prey detection). Furthermore, the findings suggest that the effects of OA could be as substantial as those due to warming in some species. Besides OA, climate model predictions suggest on-going expansion of oxygen minimum zones (OMZs – "mesopelagic hypoxic dead-zones"). As OMZs shoal, acute oxygen gradients act to compress the habitat of high-oxygen-demand pelagic sharks (e.g. mako and blue sharks in the Eastern Tropical Atlantic - ETA) against the layer of hypoxic water. In general, at the ETA-OMZ, surface occupancy (0 – 250 m) was 27% higher, while space-use of deeper depths (> 600 m) by blue sharks was ~95% less when compared to areas outside the OMZ. Preliminary data also shows that in the fishing areas with OMZ, fishing effort is higher inside the OMZ when compared to waters outside. Clearly, information regarding the influence of mid-water oxygen on habitat-use patterns and distribution of commercially important shark species should be considered for effective management. Without such behavioural and physiological data, it will be difficult to further assess present impacts and future risks from pelagic fisheries.