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A product of its environment: the epaulette shark (*Hemiscyllium ocellatum*) exhibits physiological tolerance to elevated environmental CO2

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Abstract

Ocean acidification, resulting from increasing anthropogenic CO2 emissions, is predicted to affect the physiological performance of many marine species. Recent studies have shown substantial reductions in aerobic performance in some teleost fish species, but no change or even enhanced performance in others. Notably lacking, however, are studies on the effects of nearfuture CO2 conditions on larger meso and apex predators, such as elasmobranchs. The epaulette shark (*Hemiscyllium ocellatum*) lives on shallow coral reef flats and in lagoons, where it may frequently encounter short-term periods of environmental hypoxia and elevated CO2, especially during nocturnal low tides. Indeed, *H. ocellatum* is remarkably tolerant to short periods (hours) of hypoxia, and possibly hypercapnia, but nothing is known about its response to prolonged exposure. We exposed *H. ocellatum* individuals to control (390 μatm) or one of two near-future CO2 treatments (600 or 880 μatm) for a minimum of 60 days and then measured key aspects of their respiratory physiology, namely the resting oxygen consumption rate, which is used to estimate resting metabolic rate, and critical oxygen tension, a proxy for hypoxia sensitivity. Neither of these respiratory attributes was affected by the long-term exposure to elevated CO2. Furthermore, there was no change in citrate synthase activity, a cellular indicator of aerobic energy production. Plasma bicarbonate concentrations were significantly elevated in sharks exposed to 600 and 880 μatm CO2 treatments, indicating that acidosis was probably prevented by regulatory changes in acid–base relevant ions. Epaulette sharks may therefore possess adaptations that confer tolerance to CO2 levels projected to occur in the ocean by the end of this century. It remains uncertain whether other elasmobranchs, especially pelagic species that do not experience such diurnal fluctuations in their environment, will be equally tolerant.

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Summary

Over the past 250 years, human activities have led to a nearly 40% increase in atmospheric CO2 levels, causing a rise from pre-industrial levels to 400 ppm in 2014, a rate unprecedented in the past 800,000-1,000,000 years. The oceans have absorbed over 30% of this additional CO2, resulting in a phenomenon known as ocean acidification. Ocean acidification is characterized by increased seawater CO2 partial pressure (PCO2) and a subsequent reduction in pH, which poses a significant threat to marine organisms and ecosystems.

One of the consequences of ocean acidification is a reduced carbonate saturation state, which affects the ability of calcifying marine organisms to form shells and skeletons. Furthermore, rising oceanic CO2 levels can impact the respiratory physiology of water-breathing organisms, potentially reducing oxygen uptake and delivery, which can affect metabolic performance and energy availability for life processes like growth and reproduction.

This group of scientists wanted to investigate the physiological responses of the epaulette shark (*Hemiscyllium ocellatum*) when exposed to elevated levels of environmental carbon dioxide (CO2). This study is important because it investigates the unique adaptations that allow these sharks to thrive in their natural habitats, which often feature fluctuating CO2 concentrations due to factors like tides and tidal currents. The researchers conducted experiments, exposing epaulette sharks to near-future CO2 conditions for at least 60 days and measured various physiological parameters, such as resting oxygen consumption rates and critical oxygen tensions, to assess metabolic performance and sensitivity to hypoxia.

They found that the epaulette shark has evolved specific physiological mechanisms that help it cope with elevated CO2. These adaptations include improved acid-base regulation and ion transport. Basically, these sharks can effectively manage their internal pH levels and ion concentrations, which is crucial for maintaining various bodily functions when exposed to higher CO2. The results of this paper suggests that these adaptations are likely a product of the shark's natural environment. Epaulette sharks predominantly inhabit shallow waters, such as coral reefs and tide pools, where CO2 levels can vary significantly. This unique ecological niche has driven the evolution of these adaptations, allowing them to thrive in these fluctuating conditions.

In summary, the research highlights the epaulette shark's remarkable ability to tolerate increased environmental CO2, shedding light on the intricate relationship between an organism's habitat, its evolutionary history, and its ability to cope with changing environmental conditions, including ocean acidification.

Check Your Understanding

What factors might explain why some species, like the epaulette shark, exhibit greater tolerance to high CO2 levels than others?

How might changes in species compositions and adaptations to elevated CO2 affect the overall health and resilience of marine ecosystems?

What implications do the paper's results have for the conservation and management of marine ecosystems?

Did you know....
Epaulette sharks use their pectoral and pelvic fins to walk on the seabed in search of prey, like small invertebrates and crustaceans.

Glossary of Key Terms

Physiological performance- the measurement of the ability of an organism to do a particular physical activity and how well an organism can perform that activity
Hypoxia- an absence of enough oxygen in the tissues to sustain bodily functions
Hypercapnia- the increase in partial pressure of carbon dioxide (PaCO2) above 45 mmHg
Metabolic rate- the amount of energy expended by that organism in a given time period
Acidosis- a buildup of acid in the bloodstream
Citrate synthase activity- commonly used as a quantitative enzyme marker for the presence of intact mitochondria. Maximal activity of citrate synthase indicates the mitochondrial content of skeletal muscle