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Ph.D. Defence

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A multilevel assessment of the drivers of fish contribution to the inorganic carbon cycle on coral reefs

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A multilevel assessment of the drivers of fish contribution to the inorganic carbon cycle on coral reefs

Marine fish play important functional roles within the carbon cycle, including the production and excretion of intestinal carbonates. With fish accounting for at least 3-15% of total marine carbonate production, the global significance of this process is clear. A comprehensive assessment of the drivers of fish carbonate excretion rate and mineralogy is however lacking. Closing this gap is imperative to fully understand the role of fish in the inorganic carbon cycle and to predict how it may change in future. Focusing on tropical and subtropical reefs, this thesis assessed the drivers of fish contributions to the inorganic carbon cycle at different ecological levels and spatial scales. At the individual level, this project compiled intestinal traits for 142 species and carbonate excretion rates and mineralogy for 85 species. A comprehensive modelling approach then identified the species traits and environmental factors that influence individual excretion rates and mineralogy. At the community level and at the global scale, a novel analysis of >1,400 reefs mapped distribution patterns in fish carbonate excretion and mineralogy. A causal inference analysis identified the major ecological, environmental, and socio-economic factors driving these community-level patterns. At the regional scale (i.e., in the Australian coral reefs context), structural equation models disentangled the indirect effects of human gravity (i.e., a proxy for human pressure) and fisheries management on fish contributions to inorganic carbon cycling. Findings at the individual level confirmed the long-assumed direct link between fish carbonate excretion and metabolic rate and showed that diet strongly influences intestinal morphology. Relative intestinal length was uncovered as a strong driver of carbonate excretion rates and mineralogy, as were taxonomic identity and temperature. Current global patterns of fish contribution to the inorganic carbon cycle are primarily driven by fish community structure, sea surface temperature, and human gravity. Carbonate excretion rates peaked in highly productive areas supporting high fish biomass, especially within the upper trophic levels, and where human gravity is low. Globally, fish communities predominantly excrete the more soluble carbonates and their proportion increases with increasing temperature. On Australian reefs, fish carbonate excretion was strongly affected by human impact through reduced fish biomass despite the region's relatively low fishing pressure. In this particular geographic context, current fisheries management is not sufficient to maintain fish carbonate excretion, despite positive effects on fish biodiversity. This thesis advances our understanding of the role of fish in inorganic carbon cycling from the physiological, ecological, biogeographic, chemical, mineralogical, and conservation perspectives. It unravels the complex variability of this function across ecological levels and spatial scales. Coupled with predictive models, this information could yield solid predictions of the future levels of this function in light of anthropogenic impacts and climate-driven range shifts. While fish carbonate excretion may increase with climate change, excreted carbonates will dissolve faster and/or at shallower water depths, thereby changing their influence on seawater chemistry and reducing their sedimentation potential. Protecting large predators would promote inorganic carbonate production and other fish roles within the carbon cycle. However, fisheries management has in places limited capacity to sustain fish inorganic carbon cycling. The need for effective, context-tailored management approaches that address socio-economic factors beyond fishing pressure is strongly emphasised.