



Exploring the ecosystem services and potential futures of coral reefs

Tropical and temperate coral reefs connect natural and human systems in a way that supports long-term human development and well-being and marine biodiversity. The enormous abundance and diversity of life found on these shallow reefs provide ecosystem services upon which several billions of people depend. However, many of these services are at severe risk due to historic and ongoing overexploitation and the threats posed by climate change, which will further degrade habitats and deplete biodiversity.

Over the past four years, the Reef Futures Project has explored the delivery of five ecosystem services - biomass production, nutrient cycling, carbon cycling, cultural value and nutrition value - from coral reef systems, under different climate scenarios, to more effectively plan for the future and design and implement climate-smart management policies. This international collaboration of marine experts from 18 leading research institutions has developed coupled social-ecological models to identify potential win-win scenarios where biodiversity and shallow reefs ecosystem services are secured under future conditions. As the Reef Futures collaboration comes to a close, we present some of the key research findings from the Project:

BIOMASS

Considering dynamic ecological processes to boost provision of fish biomass on coral reefs. Traditionally, scientists have often made use of measures of standing biomass - the mass of all fish in a reef - to identify areas that warrant additional protection or more effective management for sustainable fisheries. However, this only provides information on how much fish are present at any point in time. Through Reef Futures, two more informative metrics have been developed: biomass production, which measures how much biomass a fish community can gain over a period of time, and biomass turnover, the ability of a coral reef to generate new fish biomass. Together, these metrics give a more informative measure of the reef's resilience, productivity and regenerative capacity, which can support setting future climate-smart quotas and developing conservation and restoration management plans which account for changing conditions.

Mr. Raphael Seguin, a student from the University of Montpellier (France), and Mr. Nicolas Loiseau, his supervisor from the French National Centre for Scientific Research (CNRS), with the support of Reef Futures colleagues, carried out data analyses which estimate fish biomass production and turnover on more than 1,900 coral reefs worldwide. In the light of their project findings, published in *Nature Sustainability*, the team

proposes three new classifications of coral reefs and then models these categories according to human and environmental factors. This information helps researchers, practitioners and stakeholders understand how standing biomass and biomass turnover shape the state of reefs worldwide, which reefs are at risk, and how to better protect them.

CARBON CYCLING

Fish provide an important component of the carbon cycle through the excretion of carbonates in their waste. To better understand the importance of this role and how carbonate excretion may change in the future, a team of Reef Futures scientists led by Mattia Ghilardi from the Leibniz Centre for Tropical Marine Research (Germany) determined which characteristics of fish and their environment determine carbonate excretion rates and their mineral composition. Their results show that the amount of carbonates excreted by a fish depends strongly on its body mass and the length of its intestine. Fish from the same family produce carbonates of similar mineral composition, but this also depends on the temperature of the reef and the length of their intestine. These findings allowed the researchers to more reliably calculate the amount of carbonates produced by fish communities on different reefs, in different regions, and globally. This information is useful to predict the impact of anthropogenic factors (mainly fishing and warming) on the contribution of fish to the marine carbon cycle. For instance, the results suggest that selective fishing pressure of larger fish and high trophic levels could cause disproportionately large reductions in carbonate excretion or shifts in the mineral composition of excreted carbonates.

NUTRIENT CYCLING

As with the carbon cycle, reef fish are also vital in the recycling of other nutrients through the excretion of metabolic waste and faeces, while also temporarily storing nutrients in their bodies as they grow. A team led by CNRS and the Practical School of Advanced Studies (France) assessed how



nutrient recycling and nutrient storage by fish varies across the world's tropical reefs and tried to identify the socio-environmental drivers of these differences. They used measures related to diet, metabolism and growth to run a bioenergetics model able to predict nutrient fluxes for 1,100 species from the most common families of reef fish. Their findings show that all components of nutrient cycling by fish are highly variable across reefs. Nutrient cycling is at least five times higher than nutrient storage on most reefs, emphasising the role of fish as a source, rather than a sink, of nutrients.

CULTURAL VALUE AND TOURISM

What's the relationship between people's perception of beauty and an animal's conservation needs? A wide consortium of researchers led by Nicolas Mouquet from CNRS led a study published in *Plos Biology* to find out. The team asked 13,000 people to rate the aesthetic attractiveness of photographs of various reef fishes in an online survey. They used this data, in combination with an artificial intelligence model they developed, to provide, for the first time, the aesthetic value of 2,417 of the most encountered reef fish species worldwide. They found that bright, colorful fish species with rounder bodies tended to be rated as most beautiful. Their findings also show that less beautiful fishes are the most ecologically and evolutionary distinct species and those recognised as threatened. Unattractive species were also of greater commercial interest. This study thus highlights the profound mismatch between aesthetic value and importance of conservation action for reef fish.

NUTRITIONAL VALUE

Despite fish being an essential source of micronutrients for over a billion people in mainly low-income countries, access to local fish resources for many of these dependent populations is reduced through exports, either after catch or through catch by foreign fishing vessels. In many cases lower-quality fish and fish products are then imported to meet local demand. A preliminary study conducted by Mrs. Christina Hicks of Lancaster University (UK) highlighted the need for fisheries and food policies focused on improving nutrition, rather than increasing volumes of food produced, or revenue generated from exports. They developed a finfish nutrient composition database, used to predict the availability of nutrients from the world's fisheries. The results provide nutrient composition information for more than 5,000 fresh and marine fish species and is freely and globally available. Scientists, policy makers, managers, and academics can use it to identify which of their local fish are the most nutritious and need protection. The initiative saw the nutritional data added to FishBase - an online encyclopaedia of fish with crucial information on more than 34,000 freshwater and marine species, available in 14 languages.

HOW CLIMATE CHANGE AND OVERFISHING JEOPARDISE MARINE FISHERIES

An international team of scientists sought to understand how overfishing and climate change, the two principal threats to marine fish stocks globally, influence the capacity for fisheries to support the food security of individual nations. The study was published in *Current Biology* and led by Dr. Eva Maire from the Lancaster Environment Centre of Lancaster University (UK). Their findings reveal that climate change is the most pervasive threat in many tropical coastal countries to the supply of essential micronutrients from marine fish catches. Fisheries micronutrient supplies in these countries were found to be less vulnerable to overfishing. The study also suggests that opportunities exist to move towards nutrient-sensitive fisheries management. Countries may be able to adapt their fisheries to switch from vulnerable species to alternative micronutrient-rich species that are resilient to climate change and overfishing, and which are currently under-represented within catches.

The Reef Futures Project was very ambitious with more than 18 partners combining their data and efforts. We particularly wish to thank the young researchers who maintained their motivation at high level and who cemented the consortium. Most of major project outputs were carried out under their remarkable leadership. We are also very proud to see that we reached our objective to provide new estimates for five services provided by fish on shallow coastal reefs, most of them being published or under revision in top scientific journals highlighting the novelty and importance of our results.

We also developed new modelling techniques to improve our ability to make future projections of scenarios mixing both environmental and socioeconomic factors. Last but not least, we clearly show the importance to better manage or even fully protect coastal reefs in future, to meet both social and ecological benefits - findings which clearly resonate with new global commitments to increase protection for marine ecosystems up to 30 percent coverage by 2030, as agreed at last year's COP15 biodiversity conference ■

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(Source: *Unep-wcmc.org*)