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Preview

Secure local aquatic food systems in the face of declining coral reefs

Christina C. Hicks,[1,*] Nicholas A.J. Graham,[1] Eva Maire,[1] and James P.W. Robinson[1]
[1]Lancaster Environment Centre, Lancaster University, Lancaster, UK
*Correspondence: christina.hicks@lancaster.ac.uk
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Coral reefs are harbingers of environmental change. In this issue of *One Earth*, Eddy et al. analyze long-term declines in reef condition and fish catches. Here, we highlight how policies that secure coral reefs as local food systems can safeguard diverse, nutrient rich diets and support vulnerable social-ecological systems.

Ecosystems globally are experiencing profound changes, driven by large-scale anthropogenic pressures. Although human caused, ecosystem change can undermine human wellbeing, reduce the availability of sufficient quantities of nutritious food and safe housing, and impact environmental health and psychological wellness. Coral reefs are among the ecosystems most vulnerable to, and impacted by, anthropogenic pressures. Ocean warming has increased the frequency and severity of extreme weather, producing tropical storms and heatwaves that can cause mass coral mortality. Rapid decline in coral cover and associated biodiversity loss is now evident across vast areas.[1] Yet, communities living adjacent to coral reefs are often heavily dependent on their natural resources for their food, cultural, livelihood, and economic needs. Coral reef social-ecological systems are thus acutely sensitive to the impacts of ecosystem decline, presenting a necessary and valuable lens through which to understand and address contemporary sustainability challenges.

Contributing to the evidence for the declining condition of coral reefs and wider changes within this social-ecological system, Eddy et al.[2] have assessed global patterns of change in live coral cover, species-area relationships for coral reef-associated organisms, and changes in attributes of reef fishery catches. Baselines in coral cover are uncertain, but long-term declines are evident,[2] and the increasing frequency and spatial footprint of climate-driven coral bleaching events suggest more decline is inevitable.[1] Eddy et al.[2] further highlight the relationship between coral reef area and marine biodiversity. With many reef-associated species reliant on the structures built by live coral, declines in biodiversity are a challenging consequence of coral degradation, and winner and loser dynamics in how species respond are leading to a substantial reorganization of species compositions.

A major contribution from Eddy et al.[2] is to ask what changes in coral reef condition may mean for people that rely on these ecosystems. While catches of reef-associated species increased from the 1950s, they peaked in 2002 and are now in decline. Catch per unit effort—a measure of catch as a function of fishing pressure—has been in decline for longer, with a 63% reduction evident since the 1990s,[2] and the contribution of higher trophic level species in catches has become unbalanced. The authors identify geographies, including Kenya, Madagascar, Palau, and Micronesia, where reef fish consumption by Indigenous communities is particularly high, highlighting the need to understand how coral reefs support local food systems now and how this may change into the future.

The incredible diversity of fish, invertebrates, and mollusks, supported by coral reefs, provide considerable nutritional benefits. Fish, like other animal source foods including beef, pork, and chicken, are rich in bioavailable micronutrients, such as calcium, iron, and vitamin A, which are often lacking in diets across the tropics.[3,4] But, compared to other animal source foods, reef-associated fishes are particularly rich in vitamin A and omega 3, and contain comparable concentrations of other nutrients commonly lacking in diets (Figure 1A). A 90 g portion of an average reef fish would provide a child with an average of 33% of their recommended daily requirements across six micronutrients, in comparison to 134 g of chicken or 74 g of beef (Figure 1B). However, unlike terrestrial animal-source foods, hundreds of species of coral reef fish are consumed, and micronutrient content varies considerably among these species.[5] Just 40 g of the most nutritious species is needed to meet an average of 33% of recommended daily requirements, or 140 g of the least nutritious species (Figure 1B). Furthermore, fish tend to be more affordable and accessible locally than other animal source foods.[4] Multi-species fisheries, such as from coral reefs, if sustainable, are thus capable of supporting diverse diets, and supplying the micronutrients needed to support human health in the tropics.[3]

Coral reefs have long been studied for their ecological, cultural, and economic contributions. However, the role of coral reefs within local food systems, although often implicit, is less well understood. This is in part because the discourse on food security takes a global or national focus, which can overlook the importance and role of diverse, local food systems and small-scale actors.[8] Coral reef fisheries often involve local and indigenous peoples harvesting a diversity of species, using a variety of methods, under customary systems of rules and norms. Practices are thus diverse, culturally distinct, and often differentiated by gender, identity, and age: which all

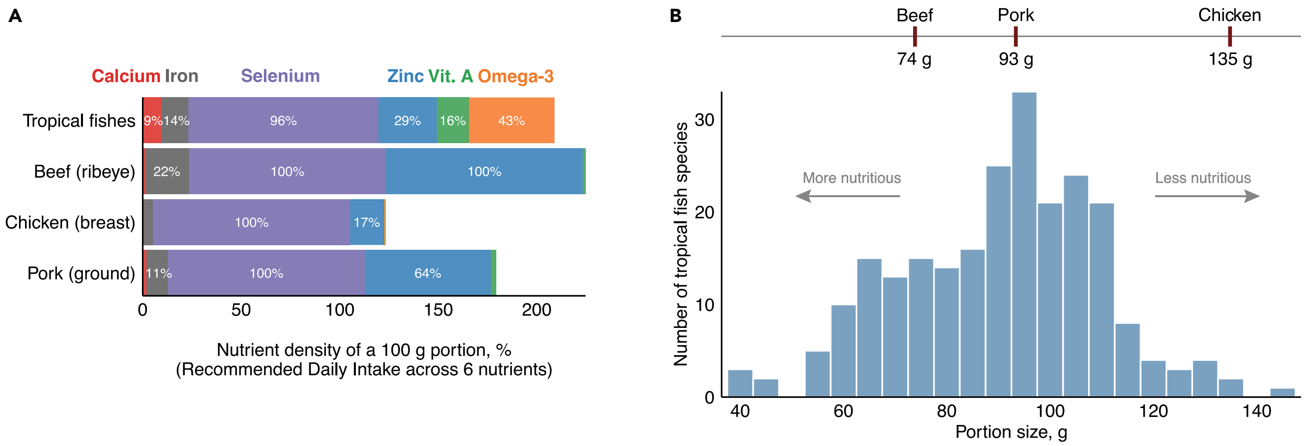

Figure 1. Nutrient content of coral reef-associated tropical fishes, with equivalent values shown for terrestrial animal-source foods

(A) Nutrient density represented by the combined % of recommended daily intake of six nutrients (calcium, iron, selenium, zinc, vitamin A, and omega-3 fatty acids) contained in 100 g portion of an average tropical fish (based on 239 fish species in subsistence catches from coral reefs[2]), beef, chicken, and pork (following Maire et al.[5]).

(B) The portion size required to reach an average of 33.3% of recommended daily intakes across six nutrients (calcium, iron, selenium, zinc, vitamin A, and omega-3 fatty acids) (following Ryckman et al.[4]), for all 239 reef-associated species in subsistence catches from coral reefs.[2] Equivalent values for terrestrial animal-source foods shown above from Tacon and Metian.[6] Recommended intakes are for children between 6 months and 5 years of age.[5] Fish nutrient data and code for estimation is freely available.[3,7]

influence how species are caught, shared, prepared, and consumed. When diets are composed of a greater diversity of species—whether aquatic or terrestrial—they tend to have a higher nutrient adequacy.[9] This is due in part to increasing the likelihood of consuming complementary nutrients and in part because cultures pair species with different foods, increasing the overall diversity of food on the plate. Local, traditional, and Indigenous diets thus often confer greater nutritional benefits. Indigenous communities also tend to consume more fish than non-Indigenous communities.[2] Yet, high rates of Indigenous reef fish consumption (>50kg $cap^{-1}year^{-1}$) tend not to be associated with higher catches.[2] Coral reef fisheries that support Indigenous food systems may thus be more sustainable, underscoring the importance of recognizing and supporting customary rules and norms.

Ongoing global declines in reef systems highlight the challenge of securing local aquatic food systems.[1,2] However, data from climate-impacted coral reefs and models of reef degradation suggest that reef fish communities can have diverse responses to coral mortality, offering hope for reef fisheries. Loss of coral cover is typically followed by increases in algal productivity, benefiting low trophic level fishes that feed on algal resources. These species, including parrotfishes and rabbitfishes that are targeted by fishers on many reefs globally, grow faster in response to algal growth, leading to higher fish biomass and productivity.[10,11] This emergence of novel reef ecosystems—rather than widespread population collapses—suggests that many reef fisheries may be able to adapt to short-to-medium term impacts of ocean warming. Although climate-impacted reefs will likely support less diverse fish communities and flatter food pyramids, many small-scale reef fisheries already target species that are resilient to coral loss. Local, culturally appropriate, and data-driven approaches to resource management have the potential to rebuild depleted fish stocks.[12] Such management systems could also be adapted to account for climate-driven shifts in stock productivity, for example by protecting long-term sustainable yields of macroalgal-feeding rabbitfish.[10]

What does this mean for local food policy? Like many aquatic food systems, ongoing declines in coral reef fisheries are heavily influenced by regional and global drivers, such as markets, trade, and economics.[13] Eddy et al.[2] underscore the importance, under such drivers, of sustaining coral reefs for people. Given the important role coral reef fisheries can play in the nutritional security of some of the most vulnerable and culturally diverse geographies globally, safeguarding local aquatic food systems is critical. This will require first maintaining and supporting diverse local food systems to flourish and resisting their replacement with less nutritious alternatives.[14] Such policies could promote "territorial" markets that prioritize local food over international trade[8] and bring Indigenous peoples and civil society to any negotiations on fisheries or trade agreements. Second, diverse approaches to ensuring sustainability of coral reef fisheries in the face of reef degradation and consumer demand will be necessary. Such policies could identify and co-design conservation strategies that recognize and work with customary rules and institutions,[12] prioritize nutritionally vulnerable populations, and promote traditional diets. Finally, adaptation of both the fishery to respond to the changes in composition and abundance of target species and food system practices in terms of consumer preferences and practices will be necessary to ensure local reef-associated food systems can continue to flourish. Such policies could support gear-based and dietary shifts to more resilient species and practices. All these adaptations will be context specific and may vary substantially from geography to geography, requiring place-based collaborations between scientists, resource managers, and stakeholders.

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DECLARATION OF INTERESTS

C.C.H. holds, or held, voluntary advisory or leadership roles in the Illuminating Hidden Harvest project, the Blue Food Assessment, and the UN Food Systems Summit.

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