

EXECUTIVE SUMMARY



The Role of Coral Reef Small-Scale Fisheries for Addressing Malnutrition and Avoiding Biodiversity Loss

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Integrated management of coral reef foods, as a highly diverse set of blue foods, can contribute to addressing the dual challenges of malnutrition and biodiversity loss. Advances in nutrition research have made it possible to understand nutritional benefits on a species by species basis, and to make comparisons with benefits derived from land-based foods. We provide a series of considerations about current understanding of nutrition from coral reef foods, including the predominance of finfish in nutritional assessments, the importance of contaminants for food safety, uncertainty stemming from climate and cumulative impacts, and the need for locally-specific assessments of food systems. Next we outline how nutrition, coral reef small-scale fisheries, and communities intersect. Aspects of equity and food sovereignty are reviewed as a basis for contextualizing current scientific understanding of nutrition while acknowledging who is actually benefiting nutritionally and materially from coral reef fisheries. Given this understanding of the state of knowledge of nutrition from coral reef foods, we encourage the development of nutrition-sensitive coral reef governance. We conclude with a set of recommendations for governance institutions, fishing organizations, philanthropic foundations, funding agencies, conservation organizations, and researchers, among others. To ensure coherence, we encourage these stakeholders to work with each other and with communities for implementation of the following recommendations:

- **Prioritize coral reef foods for local nutrition**
- **Advance gender equity and social inclusion**
- **Adopt a systems approach for coral reef foods**
- **Integrate food system policies with fisheries, public health, and development**
- **Strengthen small-scale fisheries rights, access, and governance**
- **Assess and monitor coral reef foods systems**



THE ROLE OF CORAL REEF SMALL-SCALE FISHERIES FOR ADDRESSING MALNUTRITION & AVOIDING BIODIVERSITY LOSS

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Introduction

The [Blue Food Assessment](#) emphasized marine foods as essential for healthy, equitable, and sustainable food systems. There is plenty of reason for optimism for the potential of blue food systems to help address challenges including marine biodiversity loss and malnutrition (Hicks et al. 2019; Gephart et al. 2021; Golden et al. 2021b), yet the realization of positive outcomes occurs at the local level. The focus of this whitepaper is on coral reef small-scale fisheries (SSF), where nutritional needs of reef-adjacent coastal communities meet the realities of livelihoods and conservation goals.

While addressing malnutrition will require multi-faceted and multi-level strategies, there is value in exploring the role that coral reefs can play in food systems of reef-adjacent communities. Reef foods, largely harvested by small-scale fishers, are and will continue to be important sources of accessible, affordable, nutritious foods in some places, but not necessarily to the same extent everywhere. To evaluate the role reefs can and should play in addressing malnutrition, it is necessary to recognise the suite of characteristics of local food systems, social factors, and economic conditions that determine how important, resilient, and irreplaceable reef foods are in a particular place.

On a global scale, addressing malnutrition is daunting. Major drivers of malnutrition and food insecurity include conflict, climate variability and extremes, disasters, economic slowdowns and downturns, the cost of healthy diets, and underlying poverty and inequality (FAO et al. 2021). Progress has been slow to confront these drivers, and the global COVID-19 pandemic has further set back efforts to end food insecurity and malnutrition (FAO et al. 2021; World Bank 2021). More pointedly, the pandemic has widened prominent inequalities in global food systems. According to the State of Food Security and Nutrition in the World 2021 report, in 2020 around three billion people globally were not able to afford healthy diets due to the high costs of food relative to their low income (FAO et al. 2021). This report also found that pandemic-induced economic downturns in low- and middle-income countries, especially in Africa and Asia, have caused a greater year-to-year increase in the number of undernourished people than seen in the last two decades. Although impacts and conditions vary regionally, many parts of the world have experienced vulnerability due to complex supply chains and inability to deal with food system shocks.

Coral reefs are changing and will continue to change (Eddy et al. 2021; Andrello et al. 2022). Discussion about societal benefits from coral reef foods needs to be balanced with recognition of ecological limits of coral reefs, as well as other competing economic and human development interests (Farmery et al. 2021). Because many reef resources are already considered fully or over exploited (MacNeil et al., 2015), what are reasonable expectations for further contributions to local community diets? Are nutrition and food security issues stemming from current catch being insufficient, or from globalization of local food systems (e.g., affordability and ease of access of alternative foods, export of reef foods to other places, and/or inefficiencies in certain places due to waste and loss)? Research suggests there may be [unexpected resilience](#) where bleached coral reefs continue to supply nutritious reef foods

1 ReConnect Consulting
2 Wildlife Conservation Society
3 Consultant
4 Rare
5 Arizona State University
6 Conservation International

7 The Nature Conservancy
8 Oceana
9 Lancaster University
10 Environmental Defense Fund
11 Talanoa Consulting
12 Coral Reef Alliance

13 WorldFish
14 Stanford Center for Ocean Solutions
15 University of British Columbia

(Robinson et al. 2022a), and how transient and broadly occurring is this effect (Rogers et al. 2014). Although we are not able to fully address these issues at this time, we suggest that enhanced SSF governance can contribute to the recovery or the improved health of coastal ecosystems to ensure long term food production. We do not make assumptions about the preferences and customs of particular places and communities, but this is an important time to ask how we can navigate this new landscape of SSF governance to support healthy ecosystems and the provision of accessible, affordable, sufficient nutritious foods.

In this whitepaper we *explore how and if coral reef foods can help secure and increase access to affordable foods* that are nutritious and safe for human consumption while also being harvested sustainably. Retaining and amplifying coral reef foods within local food systems could also help to strengthen culture, interpersonal relationships, shared identities, and the general well-being of many people who depend on reef foods (Kittinger et al. 2012; Valdés-Pizzini et al. 2012; Marshall et al. 2016; Dacks 2018). Understanding nutritional aspects of coral reef foods requires consideration of these human dimensions (including gender and intersectionality), the nutritional needs of different populations, the types and quality of nutrition available from reef foods, and environmental tradeoffs.

We summarize discussions and highlight important points of uncertainty and tension as well as provide recommendations for governance institutions, conservation organizations, and researchers. The year 2022 has been designated as the International Year of Artisanal Fisheries and Aquaculture (FAO). This coincides with the development of novel tools through global commons initiatives such as the publication of nutrient profiles of marine finfish species on [FishBase](#). Similar databases such as FAO's [INFOODS](#) that offer more complete coverage of aquatic foods, including invertebrates and aquatic plants, and interlinkages between databases, will further efforts to understand the contribution of marine foods to overall nutrition and food security.

Current Understanding of Coral Reef Foods and Nutrition

Advances in nutrition sciences have made it possible to gain a thorough understanding of exactly which nutrients can be gained from coral reef foods on a species by species basis. However, there are critical knowledge gaps and questions surrounding actual and potential contributions of coral reef foods to address malnutrition. Coral reef fish contain essential dietary nutrients in levels that are comparable to, or higher than, other animal-source foods, such as more calcium and omega-3 fatty acids than chicken, pork and beef, and comparable levels of iron, selenium and zinc (Robinson et al. 2022a). Nutrient content also varies among reef fish species according to multiple ecological traits, such as trophic level, body size, and habitat (Hicks et al. 2019), meaning that the nutrients supplied by reef fisheries will vary depending on catch composition. Herbivorous species, for example, have more iron and zinc than piscivorous species, but less omega-3 fatty acids and selenium (Robinson et al. 2022a). Publicly-available datasets on nutrient content of marine fishes (based on a combination of measurements and modeled

Box 1 | KEY DEFINITIONS

Community is used broadly in this paper to describe geographically distinct groups of people, who live in close proximity to reefs (not necessarily small in the area occupied). While some level of social identity and cohesion is implied, communities are assumed in this paper to be heterogeneous groups of people with multiple interests and variable influences on decision-making, and influenced by internal and external conditions (Agrawal and Gibson 1999; Kumar 2005).

Coral reef foods are broadly understood in this paper to include any fish, invertebrates, aquatic plants, algae, aquatic reptiles, or other organisms used for human consumption. We refer to coral reef foods as a form of blue food that are specifically derived from coral reef systems.

Malnutrition refers to imbalances, deficiencies, or excesses in the amount of energy and/or nutrients consumed (WHO 2021). Malnutrition can lead to a variety of health concerns, including wasting, stunting, micronutrient deficiencies, and noncommunicable diseases (e.g., heart disease, diabetes).

Small-scale fisheries (SSF), while generally characterized in contrast to industrial fisheries vary greatly worldwide and thus should be defined by countries and decision makers according to their contexts. SSF are increasingly recognized as encompassing not just production but also processing, transportation and consumption in addition to their sociocultural characteristics and the diversity of benefits that arise from them (Smith & Basurto 2019; March & Failler 2022).

calculations) and modeling efforts based on these data (see Hicks et al. 2019 for more details) are now available on FishBase, providing estimates of calcium, iron, selenium, zinc, omega-3 fatty acids and vitamin A in reef fish muscle tissue (see also Golden et al. 2021c). These can be used to measure the contribution of a portion of reef fish to recommended nutrient intakes, and thus evaluate the potential health benefits provided by the consumption of reef fish.

We outline here six considerations that temper current understanding of the contributions of coral reef foods for addressing malnutrition. First, current understanding of nutrition from reef foods is mostly based on fish. This is a significant contribution but it cannot be interpreted as the whole story. It is important to fill knowledge gaps in regards to invertebrate species and aquatic plants and algae that contribute significantly to nutrition in many lower income countries and are an especially large part of catches made by women, whose contributions to household nutrition is critical but mostly invisible (Harper et al. 2013; Tilley et al. 2021). It also remains important to collect field data from a variety of locations and across habitats and seasons.



Second, the discussion in this whitepaper does not fully address the importance of contaminants and other aspects of food safety. Deriving foods from any source is about balancing benefits and risks. For example, the longitudinal Seychelles Child Development Study offers informative lessons about the tradeoffs that come with nutritional benefits from reef foods and exposure to contaminants such as methyl mercury that can result in negative neurodevelopmental outcomes (van Wijngaarden et al. 2017; Strain et al. 2021).

Third, climate-induced changes will further complicate our understanding of the ecological status of coral reefs and coral reef foods. Climate-induced losses of fish resources will disproportionately impact the regions most dependent on fish for protein and micronutrients (Maire et al. 2021; Tigchelaar et al. 2021). However, the unique properties of coral reef ecosystems could create fishery “oases,” where plankton-eating fish communities concentrate marine nutrients around reefs even in degraded systems (Morais et al. 2019, 2021). There is evidence of increased fish productivity and biomass following coral loss, although the long-term stability of this increased productivity is unknown (Rogers et al. 2014; Robinson et al. 2019; Morais et al. 2020). In cases where this increased productivity is the result of a transition to macroalgal herbivore species (Robinson et al. 2019), fishery nutrient composition could change. For example, in Seychelles these herbivores have higher concentrations of iron and zinc, whereas piscivorous species have higher levels of selenium (Robinson et al. 2022a). Further study of the specific dynamics of coral reef fisheries under climate change is needed to better understand and anticipate future fish nutrient provisioning. Additionally, understanding how climate-related extreme storms and sea level rise may impact fishers’ harvesting ability and thus fish availability, as well as climate impacts on nutritious terrestrial foods (Farmery et al., 2020a, Medina Hidalgo et al., 2020), will provide a more holistic view of nutrition needs for coral reef SSF communities. Availability and access to coral reef foods will also be affected by supply chain disruptions (e.g., due to COVID-19 pandemic, Bennett et al. 2020; Lau et al. 2021).

Fourth, cumulative impacts on coral reefs are poorly understood with respect to their implications for nutrition from reef foods. The ecological productivity of coral reefs will continue to be impacted by cumulative impacts that include overfishing, expansion of aquaculture and mariculture, and ongoing marine impacts from human land uses (e.g., input of nutrients, pathogens, microplastics, and other pollutants to reefs; Tuholske et al. 2021; Malone and Newton 2020). These synergistic effects will influence the abundance and distribution of some species while also introducing contaminant concerns for human consumption of other species.

Fifth, it is important to distinguish the global fisheries picture from coral reef specific findings, gaps in knowledge, and questions. The evidence is clear at a global scale that fisheries will decline in the tropics, but evidence from Seychelles suggests that coral reef productivity may not decline because of a shift to herbivores and invertivores. Climate impacts on reef fisheries in Seychelles were linked to both macroalgal expansion and branching coral recovery after mass mortality, but reefs in other regions may respond differently to coral mortality. It is therefore important to consider specific places and contexts, using small-scale case studies to build a holistic understanding of climate impacts to reef fisheries and nutrient supply. Such research can then be used to identify areas of uncertainty that limit policy and require further study, such as fisheries dynamics on turf- and rubble-dominated reefs that have reduced ecological complexity following coral loss.

Box 2 | Shifting consumption from reef to pelagic fish: Impact on Palauans' health, nutrition, and reefs

The ocean is central to Palauans' culture and social organization (Johannes 1981) as well as providing them with food, income and livelihoods (Fitzpatrick et al. 2011). High levels of local-, tourism-, and export-driven demand for fresh fish have resulted in the overexploitation of Palauan reef fish populations (Prince et al. 2015; NEPC 2017). Pollution and coastal development represent further threats to the integrity of the coastal ecosystems and services that Palauans derive from them (NEPC 2017). Climate change poses a significant looming threat, with warmer, more acidic waters expected to exacerbate declines in reef fish biomass and coral habitat (Bell et al. 2013), thereby further impacting Palauans' food security, culture and livelihoods.

Palau is among many Pacific Island countries facing a double disease burden. Many households suffer from factors associated with hunger, including high levels of food insecurity and childhood micronutrient deficiencies, and also overconsumption, including high levels of obesity, diabetes and heart disease. This health crisis is in large part due to

a shift to nutrient-poor, imported processed and inexpensive foods (Sivert et al. 2019). Maintaining or re-introducing locally caught fish in the Palauan diet is an important tool in fighting the rise of micronutrient deficiencies and non-communicable diseases (Charlton et al. 2016; Ichigo et al. 2013). The challenge, though, lies in securing Palauans' consumption of local fish without further overexploiting Palau's reef fisheries.

Fishing pressure on reef fish could be reduced and local food security increased by sourcing more fish for food from tuna and other pelagic species within Palau's Exclusive Economic Zone (Bell et al. 2015; Bell et al. 2018). The '[Choose Pelagics' Directive](#), signed by former President Remengesau on World Tuna Day 2019, is indicative of the Palauan Government's commitment to a sustainable development strategy for its domestic fisheries. As fish vary in their nutritional (benefit) and contaminant (risk) profiles, it is important that increased consumption levels of tuna and other pelagics is encouraged within safe levels. The nutritional and mercury profiles of commonly consumed reef fish and pelagic species in Palau are currently being investigated* to inform dietary guidelines that limit human exposure to methylmercury while maximizing the nutritional benefits of fish consumption.

* This project is being undertaken in partnership with the Coral Reef Research Foundation in Palau with support from the Swiss embassy.



Related to the previous point, our sixth and final consideration is that it is essential to assess what people in reef-adjacent communities are actually consuming. Most national level estimates of fish consumption are based on "apparent consumption," that is, what is produced and imported minus what is exported. This tells us little about what and how much reef-adjacent communities are actually consuming. And without this information, we have no baseline to understand how changes in globalization, trade, and demand affect the diets of reef-adjacent communities.

There is the potential that exporting fish to take advantage of growing global demand can contribute to food security in reef-dependent communities by increasing local incomes. However, globalized trade and transitions to market economies drive the nutrition transition from consumption of high quality reef food toward consumption of processed, nutrient-poor food that contributes to the triple burden of malnutrition, micronutrient deficiency, and non-communicable diseases in small island developing states (Charlton et al. 2016; Farmery et al. 2020a; Savage et al. 2020; Golden et al. 2021). Growing demand and globalization could lead to further detrimental nutritional outcomes if: a) nutritious fish are rerouted to high-value domestic, export, or tourist markets (Wabnitz et al. 2018); b) marginalized groups such as women are excluded from trade benefits (Porter et al. 2008; Ferguson et al. 2021); and/or c) the demands of working in tourism or cash crops decrease the ability to grow, harvest, and consume local nutritious food and fish (Medina Hidalgo et al. 2020; Farmery 2021). While these patterns are global and generalized, they help to emphasize why region-specific policies and data will be needed to address nutrition challenges. As explored in Box 2, national policies aimed towards specific health or conservation goals can also shift consumption patterns for reef foods.

Nutrition for Whom?

This section outlines foundations for understanding that reef adjacent communities are diverse, internally heterogeneous and multi-faceted. Rather than prescribing a framing for reef-dependent communities, we raise a number of issues and considerations for how nutrition, coral reef SSF, and communities intersect. It is critical to appreciate different needs of people, who currently has the power, agency, and ability to shape food policy, and whether people have sovereignty over their food decisions. Recognition of the contributions of SSF has been overlooked internationally, and the importance of SSF as part of coral reef food systems - including national food security and nutrition strategies in the face of change - is no exception. Coral reefs support an estimated 5.2 to 6.8 million small-scale fishers globally (Teh et al. 2013), with women making up nearly half of the workforce. In many contexts reef foods are provisioned through a combination of subsistence catch, sharing or trading with kin and community, and retail markets (Bogard et al. 2021). The people who are the focus of this whitepaper typically live in coastal areas near coral reefs and tend to be in lower income regions.

One way to view the linkages within these issues is through consideration of pillars of food security. Availability, access, utilization, stability, agency, and sustainability have been cited as critical to food security as awareness has grown around the influence of inequality and power on hunger and malnutrition (Clapp et al. 2021). The latter two pillars help highlight, respectively, (1) the capacity of people to advocate and make decisions about their food, and (2) the long-term ecological, social, and economic bases of food systems. Thinking about coral reef SSFs through the lens of agency helps to highlight the importance of culture and food sovereignty (Patel 2009). Sustainability is an underlying emphasis in the [Vibrant Oceans](#) and [50 Reefs](#) initiatives that are discussed prominently throughout this whitepaper series. Taken as a whole the six pillar framework can be a useful tool for policy development at scale while recognizing important local nuances and complexities that affect nutrition and food security, and at the same time help understand which interventions might be likely to succeed.

Box 3 | Food Security and Small-scale Fisheries in Seychelles

In Seychelles, small-scale reef, pelagic and demersal fisheries provide almost half of national animal protein intake, with seafood consumed by over 95% of the population (Breuil et al. 2014). Coral reefs supply ~500 tonnes of rabbitfish, parrotfish and emperor fish species every year (SFA 2016), most of which is consumed domestically, with an average of 60g of reef fish consumed per person per day (Conway et al. 2018). These species are sources of zinc and selenium, and provide levels of calcium, iron, and omega-3 fatty acids similar to or greater than in beef, chicken and pork (Hicks et al. 2021, Robinson et al. 2022a). By providing these essential dietary nutrients, fish consumption in Seychelles has been linked to low nutrient deficiencies in pregnant women and, alongside meat, vegetables and fruit, contributes to meeting recommended daily intakes of iron, selenium and zinc (Bonham et al. 2009).

Coral reefs, alongside other SSF, therefore play a key role in supplying affordable and nutritious seafood in Seychelles. Yet while seafood consumption is very high in the country, it has decreased by 19% between 1989 and 2011, possibly in response to availability of other animal foods, such as chicken, or to changes in fish price and availability (Cardoso et al. 2013). Fisheries data collected by Seychelles Fishing Authority indicate that catches from offshore SSF have declined steadily over two decades (Robinson et al. 2020), whereas catch of reef species have been maintained or increased despite mass coral bleaching on many reefs (Robinson et al. 2018). It remains unclear how these reef fisheries will respond to further macroalgal expansion and coral loss, making it difficult to predict future fishery status. While acknowledging that this continuity in reef fisheries productivity may be temporary, the nutrient transitions in diets, alongside changes in ecosystem condition and fisheries production, underline the importance of understanding how reef fisheries contribute to healthy diets. As demonstrated by analyses of ecological and public health data in Seychelles, data on reef fish consumption, price, and availability, collected across socio-economic groups, can provide insights into linkages between coral reefs, SSF, and public health globally.



Evidence suggests that many coastal and island regions have become more reliant on imported, less nutritious foods (e.g., Albert et al. 2020; Vandenberg et al. 2021). Other research has considered the ways that economic pressures influence availability of reef foods. There is also evidence that tourists, as consumers of reef fish, can take away from local community nutrition (Grafeld et al. 2017; Cuetos-Bueno and Houk 2018; Wabnitz 2018, 2019), with economic and political forces at play in these situations beyond the direct purview and influence of local groups and communities. Any studies or programs focused on nutrition from reefs need to differentiate between foods for subsistence, local markets, national demand and exports. While it is beyond the scope of this whitepaper to delve into extensive details and situations for specific communities, Box 3 offers an example from Seychelles on the ways that nutrition from reefs is highly important.

"The lack of a nutrition-sensitive policy focus on capture fisheries and aquaculture represents an untapped opportunity that must be realised for ensuring sustainable healthy diets for all."

Thilsted et al. (2016)

Within communities, it is important to recognize and understand differences in needs and utilization of reef resources across different population segments (e.g., children, pregnant and lactating mothers, the infirm, and adolescent boys). For instance, mothers and children have specific nutritional needs in the first 1000 days of human development. A study based in Seychelles found that pregnant women who consumed higher quantities of fish were more likely to meet recommended levels of micronutrients (iron, zinc, selenium, and iodine) that are important for fetal development (Bonham et al. 2009). Other studies have found similar results, yet more work is needed to fully understand the relationship between reef foods and maternal health (e.g., Temsah et al. 2018; Byrd et al. 2021).

A key consideration for researchers and policy makers includes the need to better understand the potential for coral reefs to help address malnutrition and food security for certain groups (particularly related to access and

utilization of specific reef foods). More interdisciplinary or transdisciplinary linkages are needed with professionals such as epidemiologists, dieticians and health officials to understand local contexts for how fish consumption is changing, who eats reef foods (and how much of certain species; Simmance et al. 2021). As Thilsted et al. (2016) argued, there is a "lack of a nutrition-sensitive policy focus on capture fisheries and aquaculture [that] represents an untapped opportunity that must be realized for ensuring sustainable healthy diets for all."

Gendered and Intersectional Aspects of Nutrition

In coral reef fisheries, like SSF in general, the roles and contributions of women and men are often distinct, though often complementary, with geographic, economic, ecological and social components. Women's involvement in SSF spans the entire value chain, including pre-harvest (e.g., collecting and preparing bait, mending nets); harvest (from boats in some areas, gleaning nearshore invertebrates, small fish and aquatic plants), and post-harvest activities (e.g., selling and trading, processing, sorting at landing sites) (FAO 2017; Wabnitz et al. 2021). Furthermore, women are generally primary caregivers in fishing households, making them responsible for their families' nutrition (Williams 2010; Harper et al. 2013; Thomas et al. 2021). These gendered roles vary across locations, with quite strictly defined roles being the norm in some cultural settings and more loosely defined roles in others. Importantly, gendered norms are also connected to and vary across multiple intersectional social variables, including age, ethnicity, class, physical ability, and marriage status, creating additional complexity and variability across a community. In the Caribbean, and elsewhere, women's contributions are often considered household chores, rather than fishing, and are unpaid, unrecognized, or undervalued as a result (Rivera et al. 2021). Women can also be marginalized within the SSF sector. In Kenya - where women play a key role as fish traders - gender, geography, and religion vary according to the fisheries in which people participate. Overfished fisheries were associated with traders with low education, capital, and savings (often women), whereas sustainable stocks were associated with opposite characteristics (often men) (McClanahan and Abunge 2017).

Some examples can help highlight the importance of better understanding the roles of women in relation to coral reef foods. In the Pacific Islands, where women's roles in SSF are relatively well-documented, they are active in semi-subsistence nearshore fishing and gleaning from reef flats, seagrass beds and mangroves (De Guzman 2019; Rabbitt 2019; Thomas et al. 2021) and represent between 19 and 47% of small-scale fishers, with higher percentages seen in Melanesia compared to Micronesia and Polynesia (Harper et al. 2020). Across the region, women are estimated to account for 56% of annual small-scale catches, when gleaning activities are included (Harper et al. 2013). In southeast Asian countries, such as Indonesia and Myanmar, where much of the reef fish is still caught primarily by men, women are key players in processing fish (drying, smoking, salting, cooking) and selling fish and seafood products (Fitriana and Stacey 2012; Aregu 2017; Stacey et al. 2019; Matthews et al. 2020). The substantial contributions that women make to coral reef SSF and to household nutrition through these activities are still often overlooked or undervalued, and women are generally underrepresented in fisheries management decision-making processes (Kleiber and Vincent 2015; Thomas et al. 2021), which can lead to distrust and lack of compliance in management strategies (De La Torre-Castro et al. 2017).

While a number of efforts are underway to remedy this (e.g. [Illuminating Hidden Harvests](#)), the representation of men and women and their contributions within coral reef fisheries often remain unknown or hidden because key data including participation, resource use, nutrition and decision-making are not collected, and when they are collected are not disaggregated in national or international reporting. Many fisheries departments and management efforts continue to overlook the importance of the gendered aspects of SSF and do not adequately consider gender as part of how fisheries projects are designed or implemented (Barclay et al. 2021; Mangubhai and Lawless 2021). This is rooted in the much broader need to seek opportunities for synergies between national entities assigned to promote gender equality and those responsible for sectors of the ocean economy, to truly maximize efforts to mainstream gender in policies and across initiatives (Wabnitz et al. 2021). As a good deal of the overlooked contributions of women are directly connected to the health and nutrition of members of their households - that is, the semi-subsistence activities that bring nutritious seafood directly from the reef onto household plates - this under prioritization by fisheries departments and managers also impacts the sustainability of household nutrition (De Guzman 2019). In contrast, when women are empowered and their contributions to fisheries are valued, management effectiveness and community acceptance can improve (Pandolfelli et al. 2008; Siles et al. 2019).

By understanding the varied and interacting contributions both men and women make in coral reef fisheries, as well as recognizing the important connection between women and household food security and nutrition, coral reef management strategies will be better positioned to explicitly target nutritional needs for coastal communities, now and into the future. Effective management of complex, multi-species fisheries must integrate considerations around different fishing methods, species caught, areas fished, roles in pre- and post-harvest activities, and different uses of the catch (whether for income or household food and nutrition through subsistence). This is critical to ensuring that fisheries are managed sustainably and equitably in the present, while also creating designs and processes that are nimble to future changes while supportive of sustainability and justice.

Nutrition-Sensitive Coral Reef Governance and Policy

For coral reef foods to help alleviate malnutrition and avoid coral reef biodiversity loss, it will be crucial to support coral reefs' ecological integrity and to maximize the nutritional benefits to local communities. Increasing recognition of the role that coral reef foods can play in reducing malnutrition and food insecurity must be reconciled with the ecological limits of fisheries and ecosystems. Coral reef ecosystems are threatened by climate change, land-based pollution, and overfishing (Hughes et al. 2003; Eddy et al. 2021). Potential competing uses of ocean space and resources are likely to rise as countries continue to develop blue economies, which could further impinge on nutrition outcomes without explicit attention to smallholder rights and food provisioning (Cohen et al. 2019; Farmery et al. 2021). Already, over 75% of coral reef fisheries are currently being fished at unsustainable levels (MacNeil et al. 2015). Although catch data are lacking or incomplete for the majority of coral reef fisheries, a compilation of available data shows that catches on reefs peaked in the 1990s and 2000s, indicating overfishing on a global scale (Cramer and Kittinger, 2021).

Efforts to increase food and nutrition security from coral reef foods should ensure that catch levels are set within ecological limits to protect against overfishing and that fishing methods avoid damaging reef habitat. The nutritional benefits of coral reef fisheries can be maximized through a combination of improved fisheries management, protection and restoration of reef and associated coastal habitats such as mangroves, reduction of post-harvest waste, processing of reef foods to increase access to and distribution of key micronutrients, diversifying catch and diet to include higher nutrient species and size/age classes, and policies that prioritize maximizing the nutritional value of catches (Hall et al 2013; FAO 2021; Bennett et al 2021; Robinson et al 2022b).

With respect to this latter point, it is evident that securing nutrition from coral reef SSF is an issue that touches on conservation, livelihoods, and public health. Koehn et al. (2021) recently found that there is a trend towards national policies that mutually reinforce goals for marine foods and public health (i.e., especially nutrition), although more work



remains to be done towards further alignment in many countries. Moreover, fisheries have traditionally been valued in terms of their potential for national economic development (Arthur et al. 2021). As such, national agendas have often prioritized the development of industrial (often offshore) fisheries over SSF due to arguments around rent dissipation and efficiency (Cunningham et al. 2009; Hanich et al. 2018), which has served to promote industrialization and commodification of fisheries. This has driven policies that promote large-scale industrial and often subsidized forms of fishing, including foreign fleets that operate under fishing access agreements, and that tend to negatively impact SSF (Jacquet and Pauly 2008; Le Manach et al. 2012; Le Manach et al. 2013). In contrast, it will be crucial to frame coral reef SSF and foods as important sources for nutrition rather than only as natural resources for economic development (Bennett et al. 2018; 2021).

To further bring together themes around conservation, livelihoods, and public health, it is necessary to understand the relationship between biodiversity of resources, human health, livelihoods, and development outcomes. For coastal reef-based economies, the balance between biodiversity conservation and management that supports livelihoods and food provisioning is paramount (e.g., Hardy et al. 2013; Cruz-Trinidad et al. 2014). There are a number of international instruments to guide stakeholders to achieve this balance and desired outcomes. In particular, the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the context of Food Security and Poverty Alleviation (“SSF Guidelines”, adopted by the FAO’s Committee on Fisheries in 2014) outline principles to guide policies and legal frameworks, and their implementation by countries and institutions is a priority.

Particularly in low income countries in the tropics, small-scale reef fisheries provide critical sources of income and sustenance for coastal communities, and often represent the main source of essential nutrients in poor communities that cannot obtain nutrients from other sources (Golden et al. 2016; Vianna et al. 2020). As noted by Vianna et al. (2020), these linkages have highlighted the need for sustainable community-based management of local fisheries and better access to

nutritious seafood in international goals such as the United Nations Sustainable Development Goals and other policy vehicles (Thilsted et al. 2016; Lynch et al. 2017). Secure, equitable, and socio-culturally appropriate tenure rights, designed using inclusive processes and with special attention paid to women and Indigenous peoples are key to the realization of these goals and ensuring sustainable SSF and thriving ecosystems (see Wasu 2019 for an example where gender-based exclusion affects implementation of protection measures).



Many interventions that have been promoted to address overfishing, habitat destruction, and impacts from climate change (Bahri et al. 2021) carry short-term costs that can undermine the longer-term success of socio-economic and ecological management goals (Hardy et al. 2013; Cruz-Trinidad et al. 2014; McDonald et al, 2020). Critically, although Maire et al. (2021) found that, for most species, climate change is a greater threat to the nutrient availability of catches than fishing, the link between overfishing, climate change and other stressors on nutrient availability is not well-understood. Places where fisheries are viewed mainly as a commodity rather than as a public health, food-security, or development asset, tend to lag in policies that champion their role in curbing poverty and hunger (Thilsted et al., 2016; Vianna et al., 2020). This phenomenon highlights the potential for developing policies that prioritize the nutritional value of fish stocks when considering development

options between fisheries sectors or international access to marine resources. Some recent studies have called for shifts towards fisheries management goals that are “nutrient-sensitive” (Maire et al., 2021), such as Maximum Nutrient Yield (Robinson et al. 2022b), and recommend “policy reforms that shift management focus of fisheries as a commodity provider to a domestic public health asset to ensure food- and nutrient-security” (Vianna et al. 2020). Other studies have called for the maintenance of diverse local food systems with policies that promote territorial markets over international trade (Hicks et al. 2021). There is a need to find a balance between how to support local fisheries as a public health asset on the one hand, while sustaining sustainable income opportunities that are just and don't undermine local needs.

There are examples of such policies in practice (e.g., Baker-Médard and Faber 2020; Connell et al. 2020). The [A Comer Pescado](#) program in Peru, run by the Ministry of Production, partners with local producers to build local markets and promote the consumption of aquatic resources. In recognition of the key role that women play in coastal SSF and decision-making in households, the state government in Odisha, India, supported women’s groups’ use of local tanks in aquaculture projects (Panemangalore, 2021). There have been increased advocacy efforts to try to mainstream the role of coral reef foods systems into food, health and gender policies (e.g., at the United Nations Food System Summit), yet more needs to be done to incorporate fish into national food policies (Farmery 2020b) and involve health, development, and education ministries in reef fishery management.

Recommendations

The Blue Food Assessment developed a thorough and realistic [set of recommendations](#) that we further endorse. The following recommendations add context for coral reefs and are situated within a broad aim of enhancing local food sovereignty. The recommendations are also aimed to improve the nutrition and livelihoods of people living in reef-adjacent coastal communities while promoting sustainable and equitable management of coral reef SSF. The recommendations are targeted towards governance institutions, fishing organizations, philanthropic foundations and funding agencies, conservation organizations, and researchers. To ensure coherence, we encourage these stakeholders to work with each other and with communities for implementation.

1.

PRIORITIZE CORAL REEF FOODS FOR LOCAL NUTRITION

Elevate coral reef SSF as a foundation for local food provision within ecological limits.

Coral reefs are facing serious, cumulative threats, while reef fisheries are already at their limits, precluding expanded exploitation of reef resources. However, we recommend exploring the potential to reorganize and reorient value chains from coral reef and reef-adjacent fisheries (broadly including all species captured, gleaned, or otherwise harvested) so that they provide more benefits for reef-adjacent coastal communities. For instance, coral reef foods can be optimized to address malnutrition in nearby communities. In some places, this may mean placing more emphasis on customary practices and food systems. In other places, this may mean finding a new balance between fisheries exports, targeting less vulnerable pelagic species, and retaining reef catch for sale at local markets. In still others this could mean processing to reduce post harvest loss and increase shelf life. National fisheries and economic policies must consider (1) how fishing communities are incentivized (directly or indirectly) to consume foods from local versus imported sources, (2) implications for local food sovereignty, and (3) the needs and diets of nutritionally-vulnerable populations. Balance needs to be found between supporting nutrition and ensuring communities can also meet their economic needs (c.f. Fabinyi et al. 2017).

There is also a role for further education about the benefits of consuming sustainably harvested reef foods. Education could take the form of digital storytelling about reef SSF and customary food preparation, formal educational programs, knowledge exchange between communities or fishing organizations, and training materials for fishers and seafood traders. These educational materials can include the benefits of reef food consumption, and also promote the value (monetary or otherwise) of local reef food in ways that add value for small-scale fishers.



2.

ADVANCE GENDER EQUITY AND SOCIAL INCLUSION

Advocate for enhanced recognition of women's roles in coral reef SSF as essential for equitable benefits from coral reef foods, and effective local governance.

It is important that management and decision-making of coral reef SSF recognize women as key players in coral reef fisheries. Recognizing intersectionality requires an appreciation that people have many intersecting identities (i.e., related to age, ethnicity, wealth) that shape their needs and nutritional vulnerabilities in important ways. For instance, it is critical to determine the value of the unpaid work contributed by women to coral reef fisheries. Nearshore, low-tech, gleaning activities often do not appear in fisheries statistics based on economic metrics, whereas, consideration of whole value chains, and all aspects of a fishery, including pre-harvest, harvest and post-harvest activities (and roles) can help address these gaps. These activities can be supported through the use of a gendered approach from the earliest stages of project design and collection of gender disaggregated data to increase visibility of women's and men's roles in SSF. Governments and conservation organizations can create opportunities to empower women, allow them to participate equitably and safely in management decision-making processes, and to overcome barriers to their active participation in ways that are attuned to local gender dynamics, that recognize and minimize potential risks associated with changes in the status quo, and involve both women and men (such as when and where meetings are held, cultural norms about who speaks publicly, and ensuring the species and habitats women care about are part of management planning processes). It will be important to work with women and men to transform harmful gender norms and support equitable outcomes. Finally, ensuring gender equity as part of local food sovereignty should also involve continuing to develop practical, evidence-based gender inclusion guidelines for SSF and quantification of ecological, economic, and social outcomes.

3.

ADOPT A SYSTEMS APPROACH FOR CORAL REEF FOODS

Manage coral reef fisheries for nutritional, cultural, and social as well as economic outcomes.

Adopting a food-system approach could make coral reef fisheries production and consumption more sustainable, equitable and accessible for those who need it most. This approach requires consideration of fisheries' full value chains including processing, transportation, and consumption along with production and related factors. Reefs can be managed as linked social-ecological systems (e.g., ridge-to-reef or integrated coastal management), fisheries can be optimized for their nutritional as well as economic performance, governments can be supported to better ensure the nutritional security of local consumers, and governance and trade policy can be written to prioritize food security (McClanahan et al. 2015; Vianna et al. 2020; Farmery et al 2021; Koehn et al. 2021; Robinson et al. 2022b).

4.

INTEGRATE FOOD SYSTEM POLICIES WITH FISHERIES, PUBLIC HEALTH, AND DEVELOPMENT MINISTRIES

Advocate for holistic management of coral reef systems and de-silo ministries and policies related to public health, trade, development, tourism and biodiversity.

Food systems, fisheries, conservation, public health and development agendas and activities are often siloed. Taking a food systems approach requires integration of priorities and interventions across ministries and disciplines. A strong recommendation from this whitepaper is to integrate blue foods, coral reef, and SSF management across relevant agencies and departments. Fisheries and biodiversity agencies need to work together and across public health agencies and economic development agencies, rather than in a siloed manner. As demonstrated, coral reef SSF and foods are important sources for nutrition, rather than only resources for economic development. As such, national policies can be developed to promote equitable access to reef foods for nutritional needs (e.g., for specific groups such as school children, pregnant and nursing women, or IPLCs) and will require the participation and coordination of multiple governmental departments (Health, Education, Development, Fisheries, Natural Resources). Integrative governance structures that coordinate between these departments can address the unequal distribution of benefits from blue food systems and also ensure that environmental, economic, nutritional, and social goals are met.

5.

STRENGTHEN SSF RIGHTS, ACCESS, AND GOVERNANCE

Recognize and protect local SSF title, tenure, access, and resource rights, and promote participation and innovation by small-scale fishers and other local actors to prioritize local food and livelihoods.

Decentralizing and increasing local participation are essential for improving the equity and effectiveness of coral reef SSF governance. Actively including and empowering small-scale actors including Indigenous communities, women, and other marginalized groups in coral reef and fisheries management can improve both food system and environmental outcomes. Prioritizing local food and jobs provision while ensuring sustainability requires empowerment of and participation by local leaders. A food systems lens and approach can help towards these equity and sustainability goals by ensuring that policies recognize all aspects of livelihoods and wellbeing in reef-adjacent communities.

Participation-focused governance of SSF can be greatly improved with capacity-strengthening for local leaders in areas including traditional ecological knowledge, participation, fisheries management, and business development. An essential aspect of prioritizing local rights and access is empowering Indigenous communities by rebuilding and/or supporting local governance institutions and processes. These efforts could include support for Indigenous communities to secure and exercise their rights to manage and benefit from SSFs, support for Indigenous communities to build financial and management capacity, and promotion of gender inclusion in all aspects of reef management and resource use. Another avenue for enhancing local food sovereignty can be to support further implementation of the [SSF Guidelines](#), which includes securing tenure for small-holders, including Indigenous peoples and women and other vulnerable populations, as well as implementing co-management systems, community based natural resource management, and participatory processes.

6.

ASSESS AND MONITOR CORAL REEF FOODS SYSTEMS

Assess reef foods consumption and production, as well as nutrient profiles, availability, affordability, and desirability and how these may evolve in the face of change.

Research and data collection are integral for generating a better understanding of the ways that reef-adjacent communities are currently nutritionally benefiting from reef foods, and how this could be enhanced in the future. While increasing catch is not advised, it may be possible to optimize the ways that current reef foods are caught, handled, processed, distributed, and consumed. We recommend investing in country- and region-specific research and monitoring to address the following types of questions:

- How many livelihoods are supported by reef foods (and how)?
- What are consumption patterns for reef foods? Are there seasonal or other variable patterns to this consumption?
- Are reef foods accessible locally in terms of price and availability at markets?
- Is reef food consumption equitably distributed among reef-adjacent communities and within households?
- What kinds of coral reef foods do people have access to, what can they afford, and what do they want to eat?
- How many people directly rely on micronutrients obtained through reef foods?
- What are the specific nutritional deficiencies and needs in different communities or regions? Which nutrients and which species can help to meet those needs?
- Does nutrient adequacy link with reef food consumption?

To be most meaningful, it will be important for such research to be place-based and as localized as possible. Furthermore, the results of such research need to be shared with local decision-makers and communities so that it can effect change.

Improved quantification of the importance of reef foods beyond volume and economic value to include nutritional and cultural value could promote long-term stewardship and better management of resources. Coral reef management in this form will necessarily require improved fisheries management capacity (e.g., collection of data, setting appropriate catch limits, enforcement of regulations) to ensure fisheries sustainability. Innovative digital systems can be built and implemented to empower fishers, fishworkers, and traders to document and optimize their catch and sales (see Box 4).

Box 4 | Digital monitoring to facilitate co-management of coral reef SSF

New technologies are enabling detailed monitoring of SSF catch rates, locations, trends, and trade data, and these can be used by fishers, traders, managers, and other stakeholders for decision-making and co-management. These technologies hold promise for better understanding nutrition obtained through SSF, in particular by supporting transparency in supply chains. The following tools are examples that may hold promise as means of optimizing coral reef foods systems:

1. [Abalobi's](#) suite of apps offers e-logbook, data dashboard and community-based catch monitoring, traceability and trading functionalities that provides tangible economic incentives for fishers to actively monitor and professionalize their fishing and to contribute robust empirical data and analyses to co-management processes. ABALOBI's system [exemplifies how these technologies can be harnessed](#) to empower fishers with both the data and capacity to participate in co-management.
2. [OurFish](#) is an app that enables community-based fish buyers to digitally record their transactions with fishers. OurFish's simple recording system, now used in communities across eight countries, provides a verifiable income history to fishers while helping buyers with inventory, onward sales and cash flow management. Collated data (with personal information protected) provide production statistics for local fisheries management and near real time monitoring of landings and market value (Campbell et al 2021).
3. [PeskaAS](#) is an open source digital application that enables the automated collation, validation, analysis and visualization of SSF data. It is adaptable to different contexts and requires coding expertise. Co-designed with government managers, PeskaAS generates near-real-time analytics of fishing effort, catch rates, species composition, nutrient yields and revenue that can be used to guide management decisions and livelihood investments. The dashboard is [publicly available](#), and the system was adopted by the Timor-Leste government in 2019 (Tilley et al. 2020).
4. [Tails](#) is an app that allows coastal fisheries staff to easily collect pelagic and reef fish catch data from SSF in remote locations and send it instantly back to main offices for analysis, even when internet connectivity is limited. This technology eliminates the need for costly and time consuming delays in sending paper-based data from remote areas to central fisheries offices to help Pacific countries monitor and manage their artisanal tuna catch with today's, not last year's data. Developed by the Pacific Community, Tails was piloted in Nauru, and today many member countries are taking advantage of this tool to assist with artisanal data collection.



The data that the ABALOBI, OurFish, PeskaAS, Tails and similar systems are providing could inform a fundamental transformation of the management of SSF from being unmonitored and unmanaged to being locally monitored and co-managed. Accomplishing this requires investment in the development and testing of digital monitoring systems like those above. Codesign with end users, including fishers, fishworkers, traders and/or managers is crucial to adoption and utility of these systems.

Conclusion

Improving nutrition and conservation goals for coral reefs will benefit from a systems approach. Promotion of healthy ecosystems, sustainable fisheries, poverty alleviation, and improvements to food systems are inherently interconnected. To that end, several points of emphasis have been woven throughout this whitepaper: (1) the need to consider ecological limits of coral reefs in promotion of coral reef foods as part of efforts to address malnutrition ; (2) the importance of local data on coral reef conditions, perspectives of local communities, and local governance for developing contextually relevant understanding of challenges and opportunities; and (3) the need to balance shared goals for coral reef conservation, livelihoods, and food security. The International Year of Artisanal Fisheries and Aquaculture can be a learning moment and a pivot point for change. It is an opportunity to consider what we should be doing differently. ■

Photos by: Chiara Luxardo, Emily Darling, Alissa Everett, The Ocean Image Bank, James Robinson, Tom Vierus, Mike Markovina | Design by: Haley Williams



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