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From ocean to markets: fish exports threaten nutrition security in coastal communities

Check for updates

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Decreasing fish catch threatens the food security and livelihoods of coral reef-dependent communities. However, coastal food systems are too often managed through the narrow lens of fish production, while accessibility also matters. Here, using small-scale fishery, socioeconomic, and interview data from five coastal districts of Palawan, Philippines, we show that fish consumption—an important driver of nutrition security, since energy, protein, and micronutrient intakes depend on the amount and type of fish consumed by residents—is not correlated with production, as a large share of the catch is exported, particularly reef fish. Pelagic and soft-bottom-associated species, on the other hand, are less frequently exported, cheaper, and locally preferred, making them a vital food safety net. We suggest that coral reef fisheries and blue food management should take into account species differences and post-harvest processes to ensure more equitable food outcomes for coastal communities.

Fish greatly supports global food and nutrition security^{1–3}. Blue foods, which include all the animals and plants captured or cultured from coastal, marine, and freshwater ecosystems, represent both vital food and a source of revenue for coastal fishing communities⁴. The high concentration in micronutrients and protein of fish makes it essential to tackle malnutrition and its deleterious effects on public health^{5–7}. Globally, the demand for blue foods has tremendously increased in the past decades and is projected to further increase in the future^{8,9}.

Depleting fish populations threaten food and nutrition security across many coastal areas¹⁰. This is particularly true for coral reef social-ecological systems, where social dependence on rapidly degrading coastal ecosystems is high^{11–13}. Mainly driven by overfishing, the fish biomass of most reefs worldwide has drastically dropped, resulting in decreasing fish catch^{14–16}. The negative effects of climate change on coral reef habitats, massive and widespread¹⁷, are less clear when it comes to fisheries and food security^{18,19}: impacted reefs can still be productive, but catch instability resulting from climate impacts still threatens food and nutrient supply²⁰.

Better understanding the link between production, distribution, consumption, and food security is key to ensuring the sustainable contribution

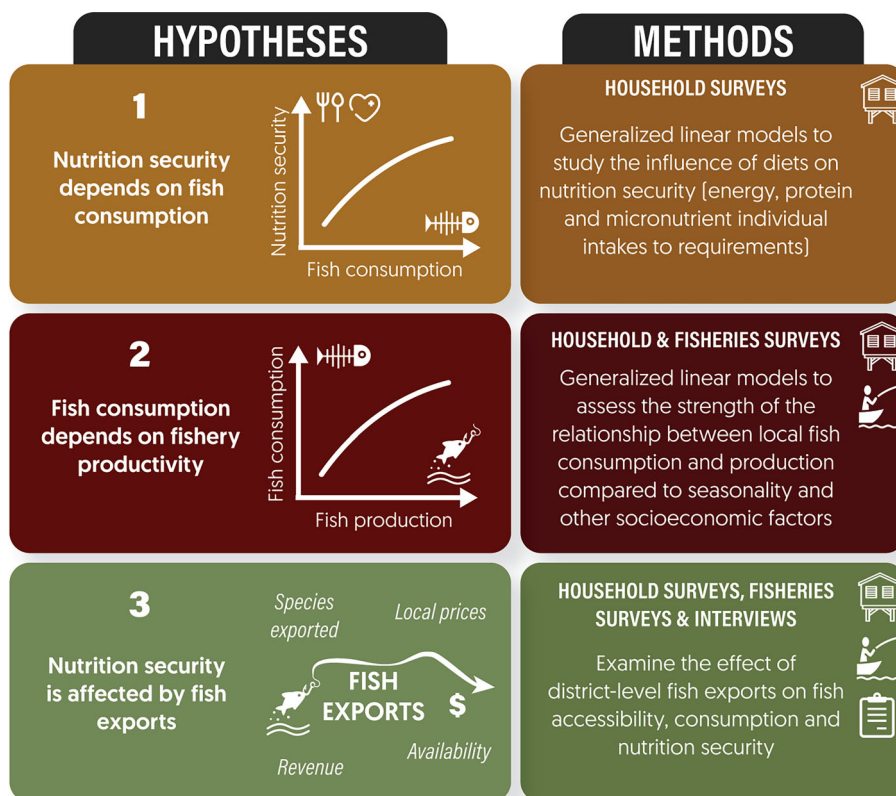
of blue foods to human health. Improving fisheries management is often proposed as a way to secure a higher and more stable supply of fish and thereby improve food and nutrition security^{3,21}. Nutrient yield optimization has been recently suggested as a complement to biomass and catch optimization²². Yet, in addition to production, food availability, access, and stability are also key food and nutrition security dimensions², and focusing management efforts on maximizing yields and economic rent can result in negative social and health consequences²³. Trade can globally improve fish accessibility and locally improve purchasing power, but the outcome is sometimes inequitable between and within countries^{24–26}. Therefore, optimizing both catch and nutrient availability without focusing on trade could have negative social and health consequences.

The nutrient supply from fish can have multiple drivers. Besides, fish production, distribution, and consumption are interlinked to other elements of the food system, including environmental, socio-economic, and cultural aspects⁵. In situations where most

coral reef species are exported, understanding how diets can adapt by incorporating other food sources, or other nutrient-rich marine species from other habitats (e.g., pelagic or softbottom species) is crucial to sustaining nutrition security^{27,28}. However, addressing these questions in coral

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Fig. 1 | Linking fishing and exports to nutrition security. Conceptual diagram representing the three hypotheses tested in this study and the methods used.



reef or other coastal social-ecological systems is limited by the paucity of fine-scale, reliable data on catch and diets^{2,11}.

Here, using a case study spanning five coastal districts in Shark Fin Bay, Palawan, Philippines, we study the links between fish production, consumption, and nutritional outcomes. Shark Fin Bay is home to fishing-dependent rural communities, and has experienced decreases in fish catch in the past^{29,30}. Using mixed methods including household surveys, fisheries assessments and interviews, we analyze the potential links between fish consumption and nutrition security (defined by household-level energy, protein, and micronutrient intakes—including calcium, iron, selenium, vitamin A and zinc—to requirements), identify the factors, including fishing yields, driving the local consumption of coral reef and associated habitats fishes (i.e., species from pelagic and soft-bottom habitats), and assess how exports can affect fish accessibility and consumption (Fig. 1).

Results

Contribution of fish to nutrition security

In Shark Fin Bay, we found the consumption of fish to be significantly correlated to higher energy, protein, and micronutrient intakes to individual requirements and therefore an improved nutrition security (Fig. 2 and Supplemental Table S3). Reef and small pelagic fish are equally important for energy and protein intake, but pelagic fish outperform reef fish for micronutrient intake. The consumption of vegetables and other seafoods (i.e., shells, cephalopods, and crustaceans) is also positively correlated with micronutrient intakes. Meat consumption is also positively correlated with energy, protein, and micronutrient intakes. The consumption of canned food, finally, is negatively correlated to energy, protein, and micronutrient intakes ($p < 0.05$, $p < 0.001$, and $p < 0.001$, respectively). Plateaus in adequate intakes are reached when fish consumption is approximately 100 kg/year (Fig. 2B–D), indicating that, considering fish consumption alone, households consuming higher quantities get closer to full nutrient adequate intakes. This value is lower than the average per capita consumption observed, and low fish consumption can therefore be pointed to as a driver of nutrient inadequacy.

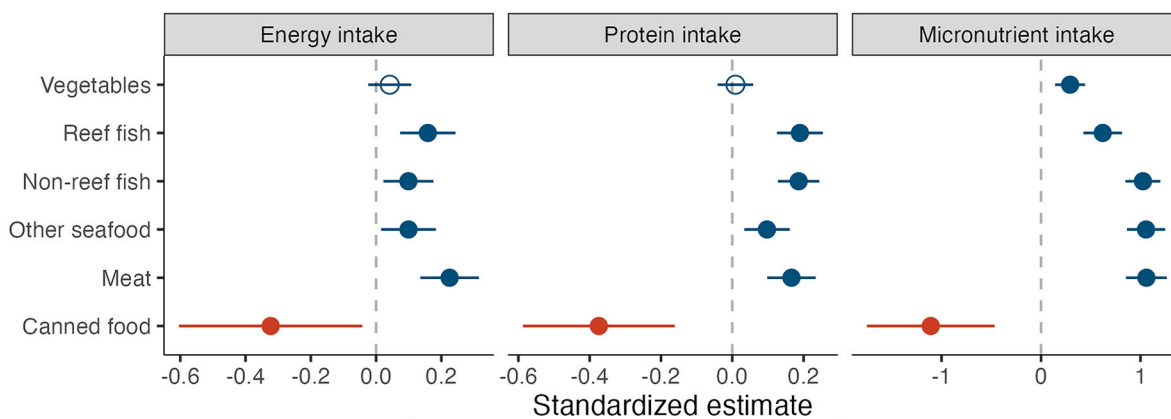
Inadequate intakes are widespread, as 47% of households do not meet 100% of their energy requirements, 31% do not meet 100% of their protein requirements, and 93% meet less than 400% of their micronutrient intakes (Supplementary Fig. S3) roughly indicating a potentially inadequate intake for at least one of the five micronutrients considered (calcium, iron, selenium, vitamin A, zinc).

We found fresh and dry fish to be, by far, the main food item consumed with rice, with an average per capita consumption of about 55 kg per year (Fig. 3A). It was also among the cheapest sources of protein, close to three times cheaper than meat and canned food, and more readily available than meat (Fig. 3A). Per capita consumption of reef fish and non-reef fish is roughly similar, respectively 22 kg/year and 21 kg/year. Non-reef fish consist of small pelagic and soft-bottom associated species (e.g., *Selar spp.*, *Rastrelliger kanagurta*, *Nemipterus spp.*, and Leiognathidae), and the consumption of large pelagic fish (e.g., *Auxis rochei*, and *Acanthocybium sp.*) was marginal, about 1 kg/year on average. The price difference between reef and non-reef fish is substantive, the latter being about 16% cheaper than the former (Supplementary Table S1).

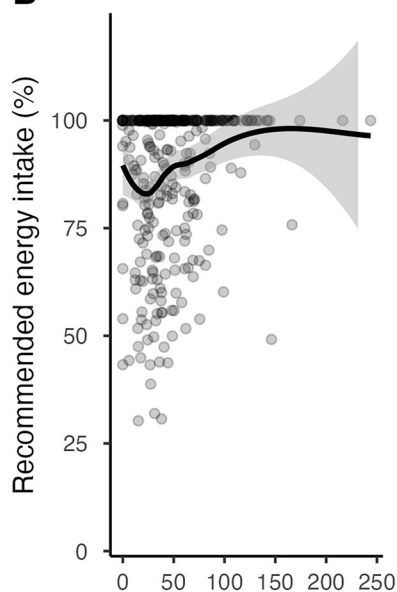
Linkages between fishing yields and consumption

The consumption of reef and pelagic fish is driven by contrasting factors (Fig. 3B and Supplementary Table S4). During the wet season, households consume significantly more pelagic fish than in the dry season ($p < 0.01$), and relatively (but not significantly) less reef fish (Fig. 3C). Food expenditure is positively correlated to reef fish consumption ($p < 0.05$), but no effect is detected on non-reef fish. On the other hand, fish consumption is not significantly correlated to district-level fishing yield, but a negative trend is observed for reef fish consumption ($p = 0.069$, Supplementary Table S4 and Fig. S6). Household size is negatively correlated to both reef and non-reef fish consumption ($p < 0.05$ and $p < 0.01$). Between 2019 and 2022, there were also some differences in reef fish and non-reef fish consumption between districts (s-Supplementary Fig. S2) as well as in catch and exports (Supplementary Table S2).

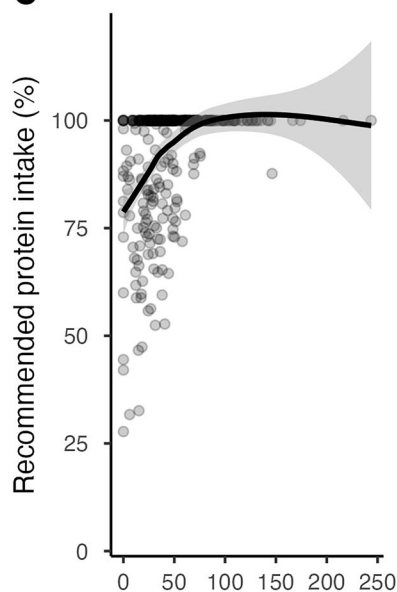
A



B



C



D

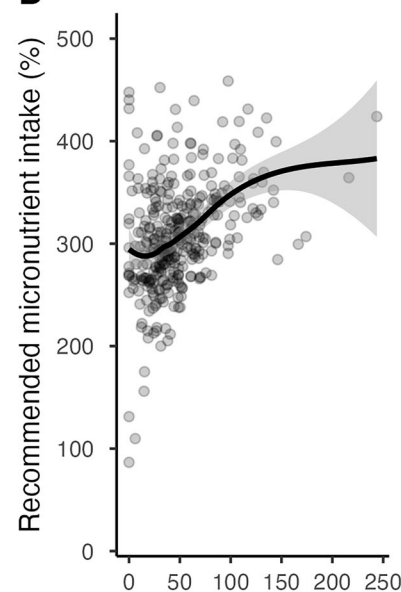


Fig. 2 | Contribution of fish and other food items to nutrition security. Standardized estimates from a generalized linear model (GLM) (A) showing how the consumption of different food products are driving energy, protein, and micronutrient intakes to requirements. Significance is indicated as follows: no asterisk for non-significant results, * $p \leq 0.05$, ** $p \leq 0.01$, and *** $p \leq 0.001$. Relationship between estimated per capita fish consumption and energy intake to requirements (B), protein intake to requirements (C), and micronutrient intake to requirements (D). Error bars represent 95% confidence intervals. Protein and energy intake are capped

at 100% representing a total intake per household that fulfills the total requirements of the household. Micronutrient intake is capped at 500% representing a total intake fulfilling total household requirements for each micronutrient. Five micronutrients are included: calcium, iron, selenium, vitamin A, and zinc. Since the trends followed for prices and consumption were similar for reef and non-reef fish, aggregated data are shown in (B–D); disaggregated data for reef and non-reef fish are available in Supplementary Information (Supplementary Fig. S4).

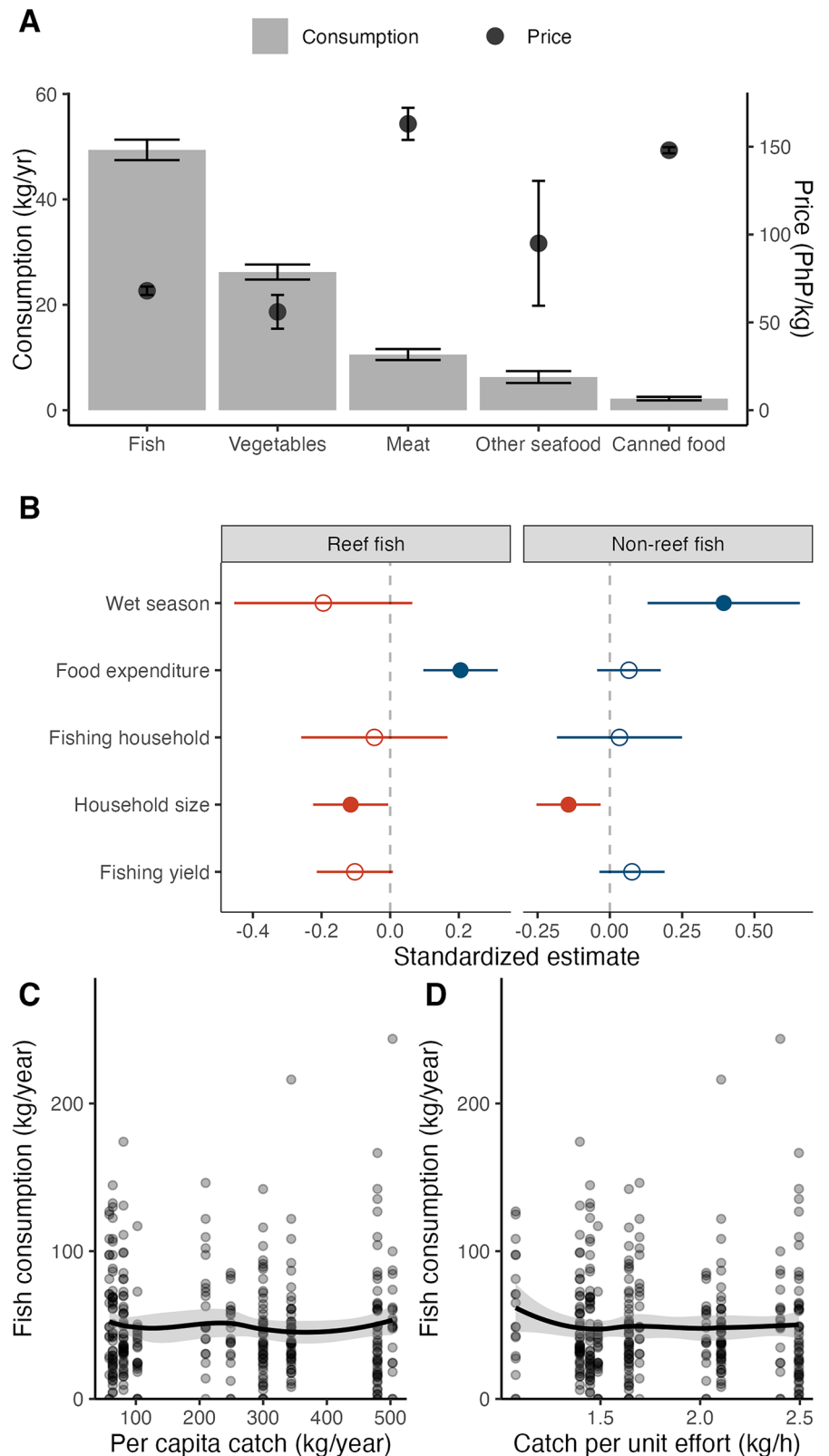
We observe large disparities in fishing yields among districts, ranging from 79 tons up to 614 tons per year, for Sandoval and Batas, respectively (Fig. 4C). These disparities are driven in part by differences in catch per unit effort (CPUE) between districts, and fishing effort measured by the number of active fishers and the regularity of their activity. Fish consumption among districts does not reflect these differences in production, with an average per capita consumption showing very little difference between districts and ranging from 51 kg/year up to 58 kg/year. Virtually all the fish consumed is caught locally (Fig. 4A), and the surplus is exported (Fig. 4B, C). Our estimates in total exports disaggregated at the year and district level range from 0 to 538 tons per year (Supplementary Table S2).

Influence of exports on fish consumption and nutrition

There is a widespread dependence on fishing activities and increasing concern about the depletion of fish stocks, as revealed by key informant

interviews. Close to 52% of households declare participating in fishing activities, with important disparities between districts (Supplementary Fig. S1). For 87% of fishing households, it would be difficult to stop fishing and shift to another livelihood, which they explain by a lack of alternative livelihood options (Fig. S1). According to 71% of respondents, the state of fish stocks has decreased in recent years. Importantly, 62% of respondents consider that they regularly lack fish to eat; the highest proportion is found in Batas, where the highest total fishing yields and exports are observed. When asking for explanations on these shortages in consumption, the most cited reason is the price of fish (or a lack of resources) by 31% of respondents. Other factors include insufficient catch (22% of respondents), bad weather conditions (22%), and insufficient availability on local markets (18%). When asked about what food is available to them when they do not have fish, most respondents declare eating vegetables (59%), but very few meats or other seafood products (7% and 8%, respectively), showing their limited

Fig. 3 | Drivers of fish consumption. Estimated annual per capita consumption and average prices observed (\pm SE) for different food categories considered in the study (A); standardized estimates from a GLM showing the effects of season, household food expenditure, livelihood, and size, and total fish exports on reef and non-reef fish consumption, significance is indicated as follows: no asterisk for non-significant results, * $p \leq 0.05$ and ** $p \leq 0.01$ (B); relationship between per capita fish consumption, per capita catch (kg/year) (C), and average catch per unit effort (CPUE, kg/h) (D). Error bars represent 95% confidence intervals. Since the trends followed for prices and consumption were similar for reef and non-reef fish, aggregated data are shown in (A, C, D); disaggregated price and consumption data for reef and non-reef fish are available in Supplementary Information (Supplementary Table S1 and Fig. S5).



potential as an alternative to fish. Canned food, including canned fish and processed meat, is also regularly consumed as an alternative to fish (13% of respondents). As families tend to share a single can, it only constitutes a limited per capita food and therefore nutrient intake (Fig. 3A), which is reflected in the negative correlation between nutrition security metrics and canned food consumption (Fig. 2B). Substituting fresh fish for canned food,

as many fishing households do after selling their catch, comes with the risk of negative nutritional outcomes.

There is a clear influence of fishing exports on local consumption (Fig. 5). Key informants describe a practice of selling fish to middlemen that already existed in the 1980s when larger ships were regularly coming from Manila to buy *daing* (dried fish) from them. But the practice was still rather

Fig. 4 | Fish consumption and exports. Origin of fish consumed for each meal surveyed in each district (A), main destination of catch declared by individual fishers (B), and an estimation of the total quantity of fish exported and locally consumed based on censuses of fishers and household surveys (C).

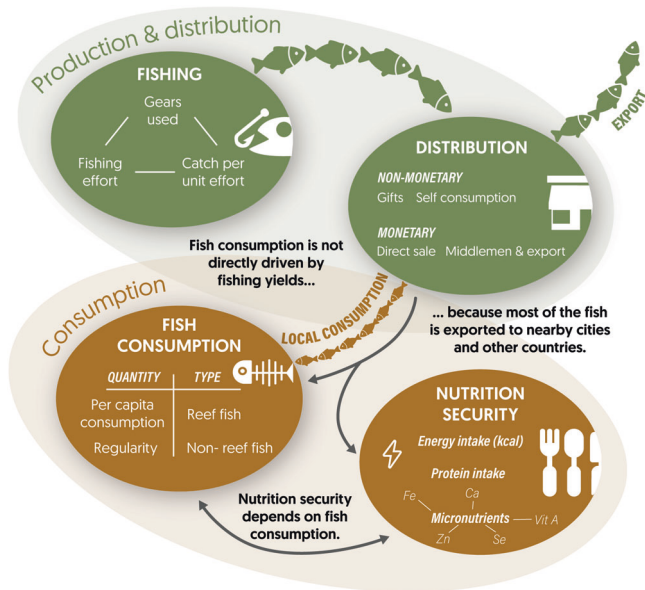
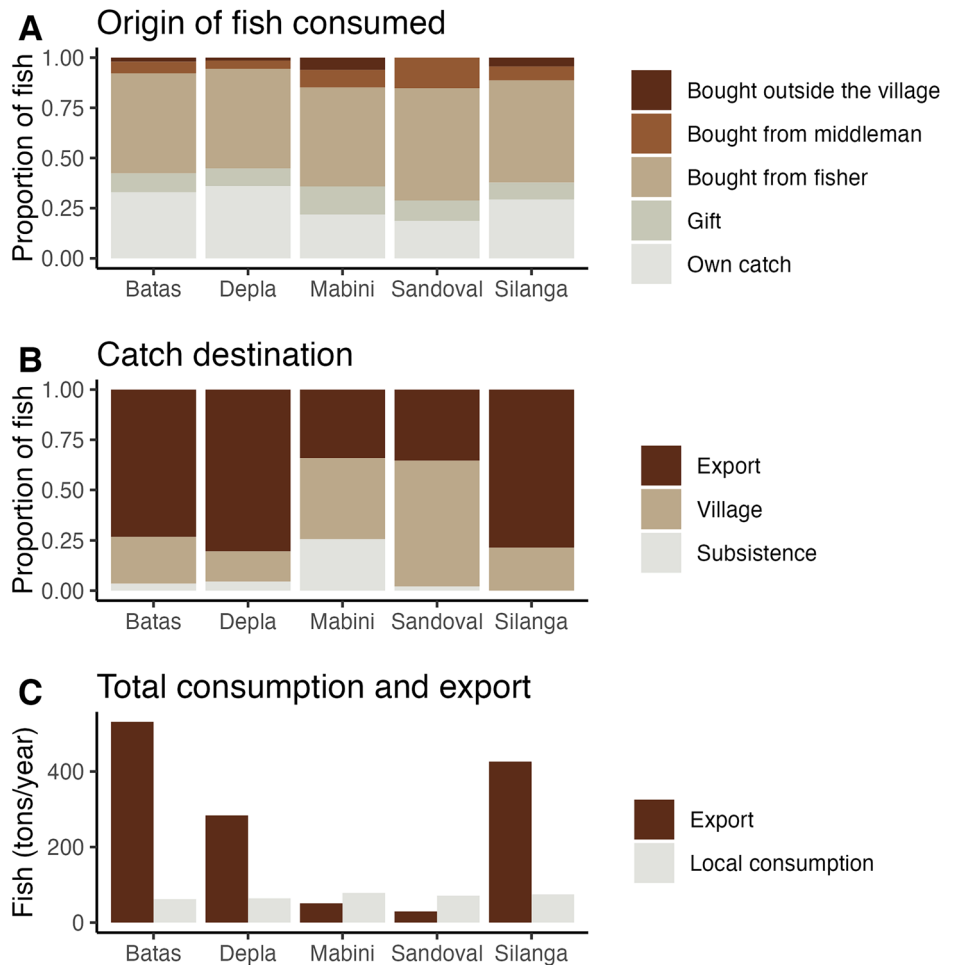


Fig. 5 | From ocean to markets. Conceptual diagram representing the links between fishing and nutrition security as evidenced in this study.

“When my grandfather would fish with a hook and line, on a small boat, he would just throw his hook and get big fish. Sometimes he would just tie his hook to the mangrove and leave it to catch some fish.” Our data now shows that hook-and-line fishers usually spend around 7 h at sea to catch, on average, 9 kg of fish. Fishing is now more intensive and less productive, because the motivation of fishers has changed: “Before, there was a lot of wasted fish. People would end up throwing some fish away because nobody would buy it”, added the same respondent. Respondents describe a system where most of the fish is bought by middlemen and exported to neighboring cities, mainly Taytay and El Nido. The price at which fish is bought by middlemen can be lower than local prices, respectively 80 and 100 pesos in Sandoval at the time of the interview. But fishers tend to favor selling to middlemen as they are assured of selling all their catch without having to peddle around the district. A fisher from Sandoval explains: “It would be really hard to peddle before, as you have to carry all your catch. Sometimes [my husband] would be too tired and I would have to sell all the fish on my own, which was very tiring.” Market orientations, and the individual motivations of fishers, have a direct influence on exports and on local fish availability. Finally, respondents discuss the relative importance of reef and non-reef fish. They tend to favor small and large pelagic fish over reef fish, but the motivations vary. Taste is one, as explained by a respondent: “For me, [both reef and pelagic fish are good for health], but sometimes when you keep eating reef fish, you would start to look for [the taste of] small pelagic fish”.

Discussion

Here, we showed that fish consumption is an important driver of nutrition security, but is not correlated to total production, with a large share of the catch, in particular, reef fish, being exported. Pelagic and soft-bottom associated species, on the other hand, are less frequently exported, cheaper,

and locally preferred, making them a vital food safety net. This disconnect is notable given that Palawan has high per capita fish consumption compared to global averages, and local communities rely on fish as their prime source of protein. The relevance of these results, supported by the unique combination of fisheries data, export estimates, and nutritional data, lies in the fact that it contradicts the assumption that positive Ecological Outcomes of Conservation automatically translate into improved local food security.

Aside from fish, other types of seafood, such as seaweeds, along with meat, fruits, and vegetables, can represent nutrient-rich alternatives to fish^{33,34}. In Shark Fin Bay, except for fruits and vegetables, these alternative products are not consumed in important quantities and can be more expensive in the case of meat (Fig. 3A). However, cheaper processed products, including canned food, are increasingly consumed, as observed in other communities facing diet transitions³⁵. To properly compete with less nutritious but potentially more affordable products, fish must be kept at low prices and sold in sufficient quantities³⁶. Local respondents noted the difficulty of managing prices that are externally driven, in particular by tourism in the neighboring town of El Nido. A respondent from Depla explained: “[Fish exportation] started with tourism in El Nido, because resort owners buy their fish from the market”; as most of the fish is sourced from the surrounding coastal districts, it also increases prices for fishing communities. But this is hard to restrict: “The price of fish for middlemen and local consumers should be [controlled]: even though a lot of fish is caught, middlemen still control the price.” Poorer households tend to have a very elastic demand for fish as compared to richer ones³⁷, which means that seafood affordability is key to tackling malnutrition³⁸. Households in Shark Fin Bay also stated they could not purchase fish when prices are too high, suggesting a high price elasticity. Despite the commodification of fish, subsistence fishing is still prevalent in the Philippines, and represents a livelihood safety net for marginalized communities³⁹.

Small pelagic fish are more nutritious than reef fish⁴⁰, and here cheaper, less affected by exports, and preferentially consumed by most consumers, making them a potential food safety net in the face of rising exports and prices⁴¹. Small pelagic fisheries can also have a lower environmental impact than demersal fisheries⁴². In tropical countries, safeguarding food will also mean managing properly other ecosystems aside from coral reefs, such as soft bottom ecosystems, mangroves, and seagrass meadows that can also provide many fish to coastal communities^{43–45}. These fish face a high fishing pressure to be used as fishmeal for aquaculture, and could instead be consumed for better nutritional outcomes⁴⁶.

To face these challenges and improve food and nutrition security in fishing coastal communities, systematic food policies are needed^{4,5,47}. Globally, countries are making increasing efforts to better include fisheries into food policies and vice versa, but many siloes still exist^{7,48}. Fisheries and aquaculture are still not managed as food systems, meaning that the diversity of factors influencing their production, distribution, and consumption, is often ignored^{4,49}.

In Shark Fin Bay, the overall decrease in fish catch is substantial and worrisome for local fishers. For this reason, MPAs have been implemented to secure the supply of fish with the explicit objective of improving food security^{29,30}. In the Philippines, where marine conservation is usually thought with and for coastal communities, food objectives are central^{50,51}. By showing a disconnection between productivity and fish consumption, our study demonstrates that socio-economic drivers and market orientation might matter more than productivity in the way it shapes local nutrition security. While it should not discourage the creation of MPAs that have the potential to improve the sustainability of coastal fisheries^{52,53}, they should not constitute a default option to improve the food security of surrounding communities.

Our study builds on assumptions that could be further tested with more data. Because of data limitations, we considered households as a homogeneous entity that hides potential intra-household variations in diets. For further research, studying these could be informative on other factors affecting individual fish consumption and nutrition security. We also used food expenditure as a proxy for wealth (Fig. 4B), but more robust estimates of incomes could be used to better understand the links between production,

income, and food accessibility³⁷. Another point that could benefit from more robust estimates would be exports; in this study, they were estimated based on yield and consumption estimates, but given proper monitoring of catch and sales, more precise and temporally explicit information could prove useful. The micronutrients we considered were those readily available for the fish species consumed in our case study, but other nutrients could be included: vitamin B12, for instance, is particularly relevant, as fish is an important source and inadequate intake is relatively high in the Philippines⁵. An important factor driving fish consumption is the season (Fig. 3B); given more data, the role of season on export patterns and the link with local consumption could be explored more in depth. Our estimates of CPUE and catch were based on the three main fishing gears used in Shark Fin Bay (gillnet, hook-and-line, and spearguns), but other fishing methods, such as fish corrals and traps, are used and represent about 18% of all gears used in the bay. Fish corrals can provide very high (but irregular) yields, although they have some negative environmental impacts⁵⁴. Finally, it is important to note that while we focused on the nutritional benefits associated with fish consumption, we did not consider trade-offs, in particular pollutants that can have negative health consequences^{11,55}, due to data limitations.

Methods

Case study

We study five coastal districts of Shark Fin Bay (Fig. 2) in the province of Palawan in the Philippines: Batas, Depla, Mabini, Sandoval, and Silanga. In 2020, they were home to a total population of 7134 inhabitants spread into 1106 households. The Philippines has experienced a substantive decrease in its coastal fish catch in recent decades⁵⁶. The country has a long history of traditional marine tenure and has pioneered many community-based marine conservation approaches, in particular MPAs^{50,57,58}. Due to the massive dependence of coastal communities such as Shark Fin Bay on coastal resources for food and income, the crossed goals of improving fisheries productivity and food security are at the foundation of coastal management efforts in the country^{27,58}.

Household surveys

We conducted surveys in a total of 340 households in 2019 ($n = 239$) and 2022 ($n = 101$). The questionnaire included demographic information, including age, gender, and main livelihoods of household members (consumption questionnaire included in Supplementary Table S5). We asked participants to recall all the food that was cooked and consumed in the household in the last 72 h. This method is an extension of the 24 h recall method (24HR), designed to measure individual food intakes, extended to 72 h in order to capture more of the day-to-day variability in food consumed⁵⁹. For each meal, participants were asked to estimate the quantity of food consumed, which was made easier by the fact that people are used to purchasing food by amounts of 0.25 kg, 0.5 kg, or 1 kg, and are therefore familiar with quantities. They were also asked about the origin (own product, gift, bought from a local producer, from a middleman, or coming from outside the district) and the price of products consumed when purchased. Prices were recorded in nominal terms and not adjusted for inflation. Given the relatively short time period (between 2019 and 2022), we considered this approach acceptable for our purposes. When fish was consumed, participants were asked its local name, which we used to retrieve the corresponding species, genus, or family based on a local guide⁵⁴ and a database we developed from field activities undertaken with local fishers. When respondents could not recall what they had for a particular meal, that meal was skipped. To estimate daily per capita consumption of different products (e.g. reef fish, vegetables, and meat), we added the total quantity of each product consumed by the household, divided by the total number of meals recorded for that household and the total number of household members sharing meals, and then multiplied by three as the vast majority of respondents were having three meals per day. In the 2022 survey, we added to the questionnaire a list of questions to assess the perceptions of respondents on the evolution of fish catch, the determinants of fish consumption, and their diets. We used a random sampling method that consisted of roaming around the five

districts and interviewing residents at different times of the day, on different days, and at different seasons. Making the selection of households as random as possible was crucial to obtain reliable food consumption estimates and interview households of various sizes, age composition, and with different livelihoods. Because of data limitations, we considered households as a homogenous entity that hides potential intra-household variations in diets^{60–62}. All interviews were conducted in Filipino (Tagalog).

Nutritional database and nutrition security metrics

To determine household nutrient intakes, we first built a database listing the nutrient content of all the food products we found to be consumed by respondents. Following De Guzman et al.⁶³, we used food composition tables (FCTs) from iFNRI (an online tool developed by the Philippine Department of Science and Technology's Food and Nutrition Institute, <https://i.fnri.dost.gov.ph/>) and complemented missing information with data from the US Department of Agriculture's FoodData Central database (<https://fdc.nal.usda.gov/>). To obtain the nutrient content of fish species, we used estimates from FishBase⁶⁴. When the vernacular name corresponded to a genus or family-level observation, we averaged the nutritional values of all the species observed in Shark Fin Bay and part of that genus or family. We collected, based on the data available, the energy (kcal), protein, and micronutrient content, including calcium, iron, selenium, vitamin A, and zinc. These five micronutrients were selected because they are particularly important for nutrient security, are present in important amounts in fish, and many populations face deficiencies of these⁶⁵. For each nutrient, we estimated the household's total intake of NI per meal, as the product between the nutrient content of each food item and its total quantity consumed. When a product was consumed over the course of several meals, the total quantity was divided by the number of meals. We also computed the household's total recommended intake (RI) per meal as the sum of all household members' daily RIs based on their age. As part of the data did not include a precise age but only the number of children below 10-years-old and the number of adults and children over 10-years-old, we therefore used the average daily RIs for males and females across these age groups. Philippine Dietary Reference Intakes were also obtained from iFNRI (<https://i.fnri.dost.gov.ph/>). We then computed the average RI to requirements for the household (IR) as follows $IR = \frac{(\sum_i^n NI_i / RI_i) \times 100}{n}$

where i represents an individual meal, n the total number of meals, NI the total nutrient intake from meal i , and RI the total recommended nutrient intake for meal i based on the number of household members that shared the meal—the vast majority of meals recorded had the same number of household members, but sometimes one was absent or another person joined. The main objective of computing IR, the ratio between total household intakes and requirements, was less to obtain a precise estimate of potential individual deficiencies but rather to scale total household intakes to requirements in order to obtain more robust comparisons between households. For each nutrient, IRs were capped at 100%. IRs for the five micronutrients were added, yielding a value between 0% and 500% when the requirements were completely covered for each nutrient. We obtained the following three nutrition security metrics expressed as IRs in percent: (i) energy intake, (ii) protein intake, and (iii) micronutrient intake.

Estimating fish catch and export

Small-scale coral reef fisheries usually include a high number of gears, and properly estimating catch is a difficult endeavor^{56,66}. We therefore used a mix of different data sources to assess the fisheries of Shark Fin Bay and provide reliable catch estimates (Supplementary Table S2). We collected data on all the gears used in the bay, but kept the three most common ones for further analyses: gillnet, hook and line, and speargun. This is because other gears were only marginally used (by less than 18% of fishers), and catch estimates were not robust. In 2019 and 2022, we conducted censuses of fisherfolk in the five study districts. These censuses included questions on the fishing gear and method used, the intensity of effort (estimated number of fishing days

per week), catch and distribution, and were meant to target as many of the active fishers as possible. This yielded an estimation of the proportion of different gears used in each district and at different times, and an estimation of the average fishing effort for each gear expressed in days/week. To estimate N , the total number of fishers using each gear, we used results from the household surveys where respondents declared their main livelihood and computed the percentage of fishing households. To estimate the total number of fishing households, we multiplied the total number of households in each district obtained from the 2020 census of population of the Philippine Statistics Authority (<https://psa.gov.ph/>) by the proportion of fishing households estimated from household surveys. We then multiplied the total number of fishing households by the percentage of fishers using each gear to estimate the total number of gears used per district. To estimate CPUE, we relied on more precise catch data coming from landings surveys where we identified, measured, and weighed the catch of fishers after their fishing trips, and data from logbooks distributed to several fishers in different districts where they logged their daily catch and the spot where they fished. Based on these data ($n = 1045$ recorded fishing trips), we grouped trips into two periods, matching the household surveys and censuses of fishers (2019–2020 and 2021–2022). We then computed the average daily catch per trip for each gear and in the waters surrounding each district. When CPUE data were missing for a gear, we used the value of the other time period, and when both were missing, we used the average CPUE in the district for that time period. As data were only missing for gears that were relatively less used in each district, the additional error created by inputting missing data was likely very limited. We then estimated the total catch of each district in 2019 and 2022 as follows:

$$Total\ catch = \sum_i^n CPUE_i \times E_i \times N_i$$

where i is an individual gear (i.e., gillnet, hook and line, and speargun), CPUE the average daily catch for gear i , E the average effort of fishers using gear i in that district, and N the estimated number of fishers using gear i . To estimate total fish consumption, we multiplied the average per capita consumption in each district by the total number of inhabitants obtained from the 2020 census of population of the Philippine Statistics Authority (<https://psa.gov.ph/>). As virtually all the fish locally consumed are caught locally, we then estimated total exports by subtracting total consumption from total catch in each district and at each time. Our estimates of CPUE and catch were based on the three main fishing gears used in Shark Fin Bay (gillnet, hook-and-line, and spearguns), but other fishing methods, such as fish corrals and traps, are used and represent about 18% of all gears used in the bay. Fish corrals can provide very high (but irregular) yields, although they have some negative environmental impacts⁶⁷.

Key informant interviews

We conducted six key informant interviews to better understand the links between exports and local fish consumption, and the perceptions of local communities on the importance of fish for health and management options. We selected: 2 leaders from fisherfolk associations, 2 fish wardens, and 2 fishers, who were well aware of local fishing activities, but also relied on a previous study of local perceptions of coastal communities of Shark Fin Bay³⁰. We developed an interview guide that included questions on fish distribution networks, important events in the local fishing history, as well as questions on preferences between eating reef and pelagic species. After transcription, we performed a thematic analysis of the interviews following Gibbs⁶⁸.

Statistical analyses

To analyze the influence of fish consumption and other products on nutrition security, we fitted one generalized linear model (GLM) for each nutrition security metric as a response variable: (i) energy intake, (ii) protein intake, and (iii) micronutrient intake. Explanatory variables were average per capita consumption of: (i) vegetables, (ii) reef fish, (iii) pelagic fish, (iv) other seafoods (shrimp, cephalopods, and shells), (v) meat, and (vi) canned

food. To analyze the drivers of fish consumption, we fitted two GLMs: one for reef fish consumption and the other for small pelagic fish consumption. Explanatory variables were the following: (i) season (dry or wet), (ii) food expenditure, (iii) presence of a fisher in the household, (iv) household size, (v) estimated fish exports in the district at the time of the survey. All analyses were conducted using R software (version 4.3.2).

Inclusion and ethics statement

This research was conducted with a strong commitment to ethical principles and inclusive practices, guided by respect for the rights, perspectives, and well-being of local communities in Palawan, Philippines. Prior informed consent was obtained from all participants, whose involvement was entirely voluntary, and confidentiality was maintained throughout, with anonymity strictly respected in all interviews. Before initiating any data collection, authorization was sought from municipal and barangay-level authorities. Fieldwork was carried out under a Wildlife Gratuitous Permit (2021-09) granted by the Palawan Council for Sustainable Development (PCSD) to Sulubaa Environmental Foundation. To build trust and foster genuine collaboration, the research team spent four years living on site with local communities. Local partners, including Sulubaa Environmental Foundation and Western Philippines University, were actively engaged in defining research priorities, collecting data, and interpreting findings. By highlighting the voices of coastal communities often underrepresented in academic and policy discourse, this study promotes equity and inclusivity while balancing conservation goals with social justice and food security, in full adherence to institutional ethical guidelines and national regulations in the Philippines and France.

Reporting summary. Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

All the data used in this analysis are publicly available online on the first author's GitHub (<https://github.com/victor-brun/food-sfb>).

Code availability

The R code used in this analysis is publicly available online on the first author's GitHub (<https://github.com/victor-brun/food-sfb>).

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Author contributions

Victor Brun conceptualized the idea for the study, collected data, conducted statistical analyses, wrote the original manuscript, and reviewed it. Anna Isabel J. Celis, Camille Dubrana, Ma. May Saludsod, Lea Janine A. Gajardo, Karen G. Madarcos, and Tracy Angela Ventilacion collected data, supported the writing and review of the manuscript. Lota A. Creencia, David Gill, and John Roderick V. Madarcos helped with data interpretation and manuscript writing, and review. Joachim Claudet conceptualized the idea for the study and supported data analysis, the writing, and reviewed the manuscript.

Competing interests

The authors declare no competing interest.

Additional information

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