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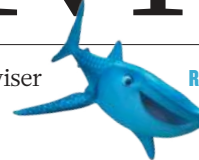
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MICHAEL D. KOCK



Women from a traditional sea-harvesting community fishing in Mozambique.

Fall in fish catch threatens human health

Christopher Golden and colleagues calculate that declining numbers of marine fish will spell more malnutrition in many developing nations.

How will the 10 billion people expected to be living on Earth by 2050 obtain sufficient and nutritious food? This is one of the greatest challenges humanity faces. Global food systems must supply enough calories and protein for a growing human population and provide important micronutrients such as iron, zinc, omega-3 fatty acids and vitamins.

Deficiencies of micronutrients — so called because the body needs them only in tiny amounts — can increase the risks of perinatal and maternal mortality, growth retardation, child mortality, cognitive deficits and reduced immune function¹. The associated burdens of disease are large. Forty-five per cent of mortality in children

under five is attributable to undernutrition; nutritional deficiencies are responsible for 50% of years lived with disability in children aged four and under¹.

Fish are crucial sources of micronutrients, often in highly bioavailable forms. And fish populations are declining. Most previous analyses have considered only how people will be affected by the loss of protein derived from fish. We calculate that this is the tip of the iceberg. Combining data on dietary nutrition, and fish catch, we predict that more than 10% of the global population could face micronutrient and fatty-acid deficiencies driven by fish declines over the coming decades, especially in the developing nations at the Equator (see ‘Troubled

Waters’ This new view underlines the need for nutrition-sensitive fisheries policies.

NUTRITIONAL RISK

Presently, 17% of the global population is zinc deficient, with some subpopulations being particularly at risk¹. Nearly one-fifth of pregnant women worldwide have iron-deficiency anaemia and one-third are vitamin-A deficient¹. We estimate that 845 million people (11% of the current global population) are poised to become deficient in one of these three micronutrients if current trajectories in fish-catch declines continue.

Considering nutrients found only in foods derived from animals, such as vitamin B₁₂, and DHA omega-3 fatty acids ▶

► (almost exclusively derived from meat consumption, see Supplementary Information; go.nature.com/25oll0p), we calculate that 1.39 billion people worldwide (19% of the global population) are vulnerable to deficiencies because fish make up more than 20% of their intake of these foods by weight.

IMPACT ASSESSMENT

To make this sobering new assessment, we coupled two databases from 2010, the most recent year for which both had data. The new Global Expanded Nutrient Supply (GENuS) database combines food balance sheets (total quantity of food production and imports minus livestock feed, post-harvest losses, and exports) and production or trade data from the Food and Agriculture Organization of the United Nations (FAO) with estimates of food group intake by age and sex². It estimates per capita edible supplies for 225 foods, paired with regional food composition tables to infer nutrient supplies by country. GENuS is supported by the Bill and Melinda Gates Foundation and the Winslow Foundation.

We categorized populations as nutritionally vulnerable if their nutrient supply was less than double the estimated average requirement (EAR), and if they derived from fish more than 10% of their vitamin A or zinc, or more than 5% of their iron. We chose to double the EAR for two reasons. First, even in countries where the national average intake is greater than the EAR, large variability of intake may still mean that a significant part of the population is eating less well. If we had used the EAR as our threshold, more than 50% of a nation's population would need to be deemed at risk of nutritional deficiency, which we feel is an irresponsibly high proportion required for raising an alarm. Second, our GENuS-derived estimates measure food supply rather than food intake, and are generally regarded as overestimates of true intake².

The Sea Around Us database, released in 2016, provides a portrait of marine fisheries catch between 1950 and 2010 for every coastal nation³. Over 15 years, a team of researchers in every coastal country collated information from government documents, academic research and maritime records to reconstruct the numbers of fish caught. This database measures the contribution of subsistence, artisanal and industrial marine fisheries to food supply at the country level more accurately than previous estimates³. This database was funded by the Pew Charitable Trust and the Paul G. Allen Family Foundation and is maintained by staff at the University of British Columbia in Vancouver, Canada.

These global marine catch data are alarming. Conservative estimates by the FAO characterize global fisheries as stable, but acknowledge that global catch has declined by 0.38 million tonnes per year since 1996 (ref. 4). The Sea Around Us estimates summarized

earlier this year³ paint a much bleaker picture, in which fish catch peaked in 1996 and has been falling by 1.22 million tonnes (roughly 1%) per year since — three times faster than the decline reported by FAO. The degradation of marine habitat by destructive fishing practices, industrial pollution, climate change and coastal development for urbanization and aquaculture is likely to further degrade ocean ecosystems and reduce fisheries yields. Such patterns call into question the ability of wild fisheries to support future demand for fish.

PERFECT STORM

The health impacts of fishery declines will hit some places harder than others. A perfect storm is brewing in the low-latitude developing nations. This is where human nutrition is most dependent on wild fish, and where fisheries are most at risk from illegal fishing, weak governance, poor knowledge of stock status, population pressures and climate change.

Sharp declines in the health of fisheries were first described in the twentieth century in high-latitude regions where industrial fishing began, such as the northwest Atlantic Ocean. Developed countries have compensated with intensive agricultural production, by importing goods (including fish), vitamins, supplements and fortified foods. Since the 1990s, the major declines in fish stocks have been in lower latitudes and developing nations. This rapid degradation probably results from the increasing industrialization of fisheries, poor governance and the accelerated expansion of foreign fishing in these regions.

These sensitivities in the tropics will be only exacerbated by climate change. Ocean warming and shifts in net primary production are likely to drive remaining fish and shellfish species from low to high latitudes, potentially reducing catch globally by more than 6% and by as much as 30% in some regions (such as the tropics) by 2050 relative to recent decades⁵. Fish will also probably get smaller in the tropics: ocean warming and associated declines in oxygen content are projected to reduce the average biomass of fish communities by around 20% during this period⁶. Coral reefs, essential ecosystems for many tropical coastal subsistence and artisanal fisheries, will be heavily degraded by warming and ocean acidification. Mangroves — nurseries for many fish that are crucial in developing nations — continue to decline. Also under threat are global inland freshwater fisheries, another crucial source of nutrition and livelihood for hundreds of millions of people around the world⁷.

In these same regions, fish play an important part in the avoidance of diseases associated with malnutrition. Nearly all countries that depend heavily on fish for nutrition are situated in the developing world (46 of 49); we

defined these as nations in which more than 20% of the population's animal-based food by weight is seafood. Furthermore, countries with the highest levels of undernourishment and the weakest governance are often net exporters of seafood to well-nourished countries with strong governance⁸.

Poor people have fewer alternatives to make up for these impending shortfalls in access to micronutrients. Meat, eggs, vitamin supplements and imported fish can be prohibitively expensive. Communities are often forced to rely on what they can harvest locally or on less-healthy processed foods.

FARMED FISH

Could global increases in fish farming meet the nutritional shortfalls we predict for poor equatorial populations? With today's production and distribution patterns, we think not. Aquaculture has expanded globally by more than an order of magnitude over the past three decades⁹. Farmed fish exceeded wild catch destined for human consumption for the first time in 2014 (ref. 10). However, aquaculture has not yet developed significantly in many low-income countries where food and technology is in short supply (particularly sub-Saharan Africa and the Pacific Islands¹¹). Such regions still largely depend on domestic, subsistence and artisanal fishing. These small-scale fisheries include the pirogue fleets of West Africa, the spearfishers of the world's coral reefs, and shore-based gathering of shellfish in mangrove creeks.

Where aquaculture is growing, much of it has been aimed at wealthier consumers in domestic cities or in international markets, rather than local rural areas¹². Globally, developing countries export higher value fish (caught and farmed) and import lower-value food from industrial fisheries in developed countries¹³. For example, shrimp, tilapia and Mekong catfish grown in developing and transitional countries such as Bangladesh, China, Indonesia, Ecuador, Thailand and Vietnam are mostly exported to the wealthy countries of Europe and North America, or consumed by the growing middle-classes in the megacities of these economies. The benefits of these export-oriented industries to livelihoods and nutrition of the coastal poor are unclear and cannot be inferred from national seafood balance data or national economic growth statistics¹³. Moreover, commercial aquaculture can displace coastal and inland fisheries, and small-scale aquaculture producers may not always profit from engagement in global value chains.

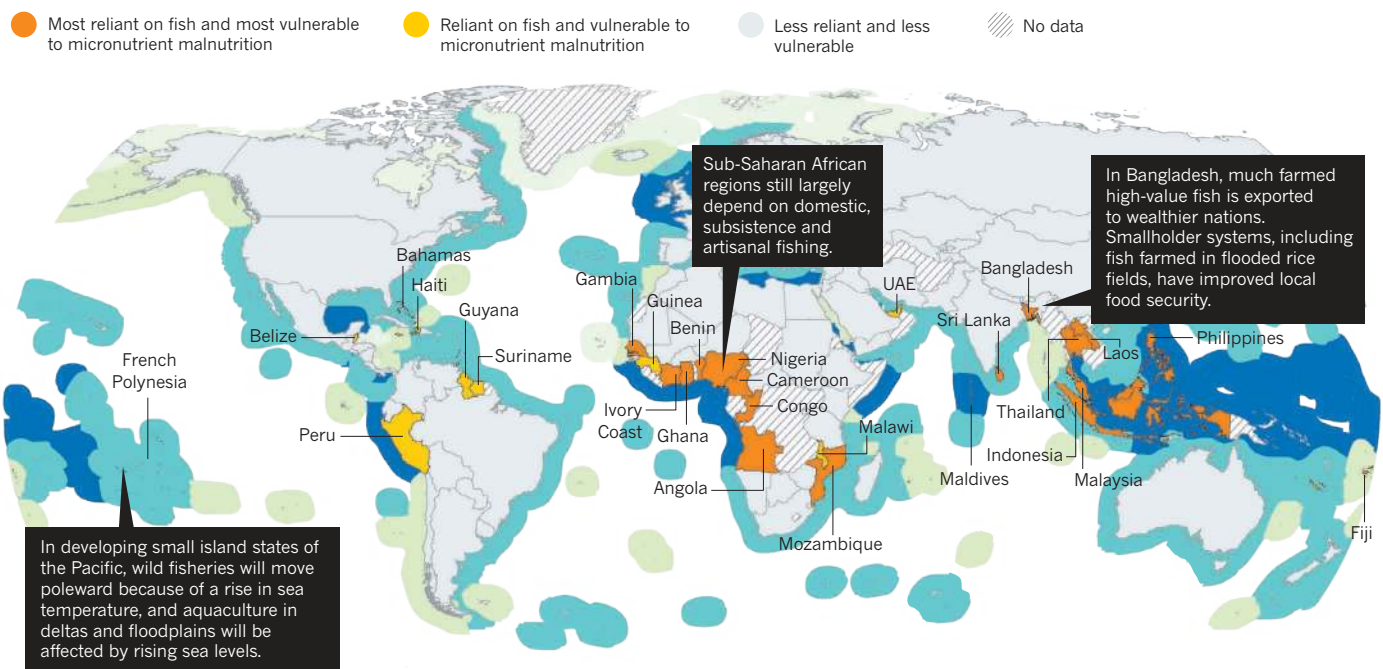
Farmed fish may also be of lower nutritional value¹². Aquaculture species that are most affordable, such as carp, are often not as rich in omega-3 fatty acids as are the wild species currently accessible to impoverished communities, such as sardines and mackerels. Oil-rich wild fish are also the basis for

“Poor people have fewer alternatives.”

SOURCE: V. LAM, G. REYMONDEAU, M. SMITH & W. CHEUNG

TROUBLED WATERS

In the low-latitude developing nations, human nutrition is most dependent on wild fish, and fisheries are most at risk from illegal fishing, weak governance, poor knowledge of stock status, population pressures and climate change. These countries urgently need effective strategies for marine conservation and fisheries management to rebuild stocks for nutritional security.



Projected percentage change in maximum marine catch potential by 2050 relative to 2000 levels



aquaculture feeds. Because supplies of these wild-fish have little potential for expansion under current management policies, plant-based feeds are increasingly used, further altering the nutritional composition of farmed fish. And aquaculture generally focuses on fewer species than those caught from the wild. A global fish supply dominated by aquaculture, as it is currently practiced, would lead to a drop in the diversity, and thus nutritional quality, of many diets¹².

Yet, when explicitly planned to improve local well-being, aquaculture can be a crucial contribution to local diets and economies. For example, in Bangladesh, smallholder integrated systems in which fish are raised in rice paddies have improved local food security¹⁴. Small indigenous fish, rich in nutrients, can be grown for household consumption in ponds together with carp, tilapia or catfish as cash crops. Less-intensive and more-diverse forms of aquaculture may have the most potential to meet the nutrition and food-security needs of the poor.

This promise may, however, be constrained by lack of suitable sites. Both inland and coastal production are under increasing pressure from urbanization and industrialization. In the same small island states likely to be hit hardest by shifts in the distribution of marine species⁵, prospects for increasing aquaculture are at best mixed. Much aquaculture production is concentrated in river deltas and

floodplains, brackish-water lagoons and other low-lying tropical coastal areas. These areas will be heavily affected by sea-level rise, ocean acidification and increased storm intensity. Non-intensive aquaculture technologies face many challenges and are currently minor contributors to global production.

NEXT STEPS

Next-generation models that integrate data on human health and fisheries, such as those explored here, with climate and population models need to play an important part in estimating the human health burdens of environmental change and the enormous public health dividends of natural-resource management. These models can also be used to identify hotspot countries that urgently need more effective strategies for marine conservation and fisheries management to rebuild stocks for nutritional security³.

Aquaculture also needs reform so that undernourished people can access nutritious products. The following can help: boosting investment in less intensive and domestically oriented aquaculture of cheap and nutritious species; farming species lower in the food chain to reduce dependence on wild-caught fish meal; and allocating coastal land and water resource rights to small-scale aquaculture (as has already been done for fisheries).

The analytical methods currently in use to inform fisheries and aquaculture policies

require refinement. Data on food-price fluctuations are needed for local economic models of fish supply and dietary substitution, and empirical research is required to understand and model how populations around the world will adapt to changes in fish supply and market prices. We need better data on freshwater fisheries and aquaculture, as well as on the nutrient composition of foods and nutritional status of more human populations around the world. Improvements should include separating data on farmed and wild fish to better characterize vulnerability to micronutrient deficiencies.

Addressing these emerging problems will require new interdisciplinary partnerships among fisheries scientists, aquaculture technologists, ecosystem managers, nutrition and public-health specialists, development economists, granting agencies and policymakers. As a first step, new funding streams are required to support the emerging discipline of planetary health, dedicated to characterizing and quantifying the human health impacts of accelerating global environmental change. For example, our work has been supported by the Wellcome Trust, the US National Socio-Environmental Synthesis Center and the Rockefeller Foundation. A second step would be more interaction between health agencies (such as the World Health Organization, the United Nations children's fund UNICEF, and health

ministries) and ocean-management agencies (such as the FAO, the UN Environmental Programme, regional fisheries management organizations, and ministries of fisheries and the environment).

Mitigating losses of biodiversity and income have been at the heart of fisheries-management policies. In our view, there should be a much stronger emphasis on human health. This would mirror recent shifts in agricultural policy that respond to rising burdens of diet-related diseases.

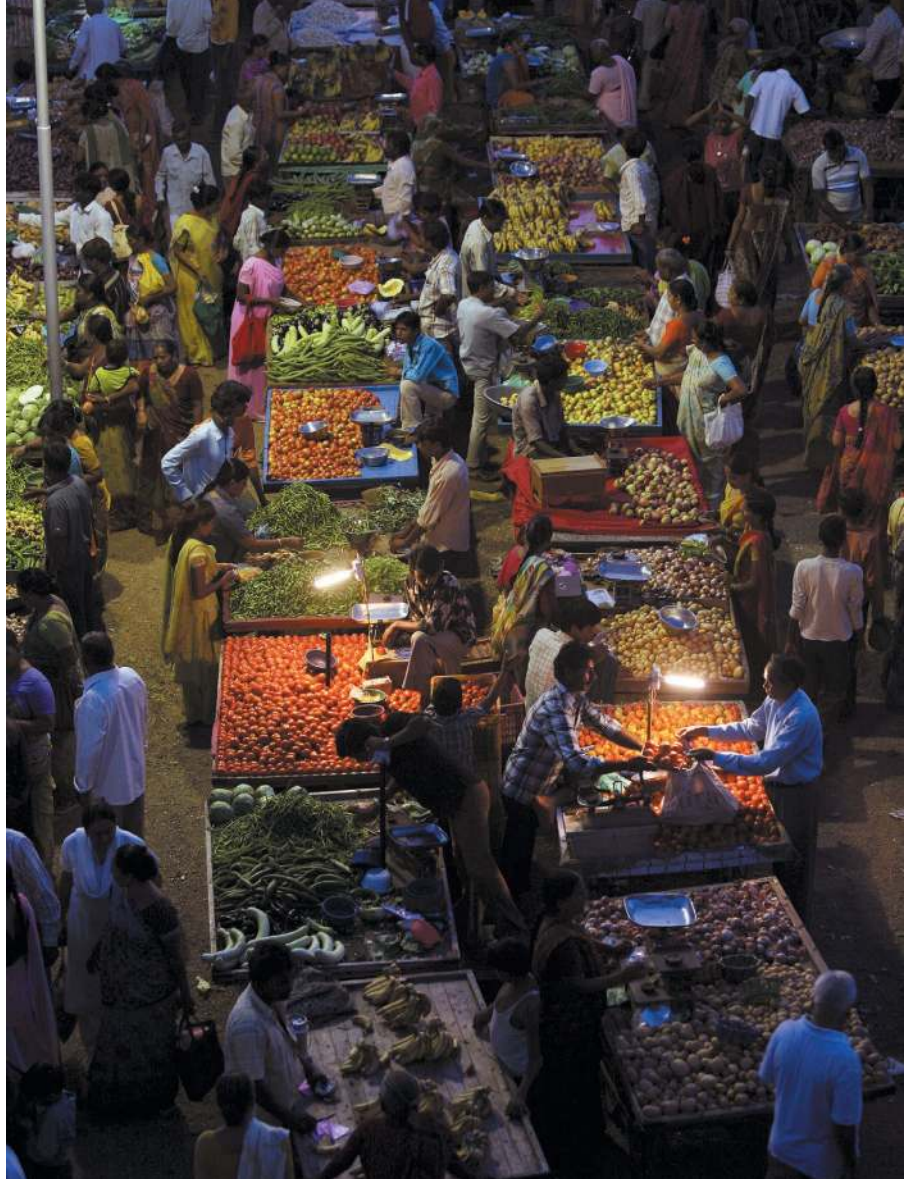
These policy changes are possible. We believe that improvements in fisheries management and marine conservation can serve as nutritional delivery mechanisms. A meta-analysis of nearly 5,000 fisheries worldwide found that applying sound management reforms to global fisheries could increase catch by more than 10%¹⁵. Without these changes, the health of the poor is at risk. ■

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Full author details and Supplementary Information accompany this article online at go.nature.com/25oll0p.



Solar lights are used by vendors in rural western India, where lack of electricity has stymied development.

Map the interactions between Sustainable Development Goals

Måns Nilsson, Dave Griggs and Martin Visbeck present a simple way of rating relationships between the targets to highlight priorities for integrated policy.

Next month in New York, the United Nations' 2030 Agenda on Sustainable Development will have its first global progress review. Adopted by the UN General Assembly in 2015, the agenda represents a new coherent way of thinking about how issues as diverse as poverty, education and climate change fit together; it entwines economic, social and environmental targets in 17 Sustainable Development Goals (SDGs) as an 'indivisible whole'.

Implicit in the SDG logic is that the goals depend on each other — but no one has specified exactly how. International negotiations gloss over tricky trade-offs. Still, balancing interests and priorities is what policymakers do — and the need will surface when the goals are being implemented. If countries ignore the overlaps and simply start trying to tick off targets one by one, they risk perverse outcomes. For example, using coal to improve energy access (goal 7) in Asian