FISHERIES

Micronutrient richness of global fish catches

Analysis of the nutrient composition of fish caught around the globe reveals locations where the retention of fish for consumption by local populations could help to tackle human disease caused by nutrient deficiencies. SEE LETTER P.95

DANIEL PAULY

Eating fish is good for us. Fish are a source of micronutrients that help to prevent nutrient-deficiency diseases, which are a leading cause of infant deaths worldwide. Determining whether the consumption of locally caught fish could reduce the incidence of nutrient-deficiency diseases in countries particularly affected by this problem requires having access to the relevant data. On page 95, Hicks *et al.*[1] report their assessment of the nutritional content of 367 species of fish. For 43 countries, the authors mapped the relationship between the fish-derived nutrients available from fisheries' catches and the prevalence of nutrient-deficiency diseases in communities living within 100 kilometres of the coast.

When assessing the nutritional composition of fish stocks, Hicks and colleagues focused on six crucial micronutrients: calcium, iron, zinc, selenium, omega-3 and vitamin A. They also considered protein content. Using some previously available data, the authors generated a model that could correctly predict the levels of these nutrients in different species of fish. By mining databases containing information about fisheries' catches taken between 2010 and 2014, the authors gathered information about the amount and type of fish caught in each country's exclusive economic zone (EEZ) — the area of its coastal waters over which it has sovereign fishing rights. Hicks and colleagues used their model to estimate the nutrients available from these fish catches and thus determine the spatial pattern of this nutrient availability in global fish catches. For example, they noted that tropical fish have higher concentrations of calcium, iron and zinc than have fish from other regions.

In developing countries around the tropics, fish are not usually just another healthy complement to an already rich assortment of foodstuffs. Rather, for millions of people living in these regions, fish add the missing micronutrients and proteins to what would otherwise be an unbalanced diet. In many developing countries, fish are the food source[2] that provides the majority of the inhabitants with most of the micronutrients studied by the authors. The protein from fish boosts the nutritional content of typical diets in such countries, where calories are obtained mainly from foods such as maize (corn) or rice.

Hicks and colleagues' data demonstrate that fisheries' catches in some developing countries should be enough to meet the key micronutrient needs of their populations. For example, more than 75% of the population in Namibia is at risk of calcium deficiency, even though enough fish is caught there to remedy this situation. In some cases, ensuring that even a fraction of a country's total fish catch is retained for local consumption could have a substantial impact on public health. This is particularly true for children under five years old, during a crucial stage of their development when micronutrient deficiencies have a severe effect. For 22 of the countries that Hicks and colleagues studied, 20% or less of the fish caught could provide enough key micronutrients to meet the needs of all children under five years old.

Not only do nutrient shortages harm public health, but this problem has a knock-on effect of lowering gross domestic product. It might be supposed, then, that the governments of developing countries in the tropics — along with international development organizations or institutions such as the United Nations — would be doing everything possible to encourage the domestic consumption of fish caught in the EEZs of these countries. However, most economic-development policies, including those of these countries themselves, are geared towards promoting fish exports to match the insatiable demand for fish in the markets of high-income Western countries and East Asia[3].

The waters surrounding developed countries became overfished before overfishing began to occur in other countries. For example[4], the combined fisheries' catch in the North Atlantic peaked in 1975, and the world's catch peaked in 1996. The catch limits placed on overfished regions has led such regions on a quest to obtain their fish from other sources. These days, much of the haul in many parts of the developing world is either caught by local fishermen and exported, or taken by foreign fleets — which, by paying a nominal fee to access the EEZs of developing countries, catch fish for their own markets. Such actions contribute to the scarcity of nutrients in many developing countries.

This problem is perhaps greatest for countries on the northwestern coast of Africa. There, fishing by fleets from the European Union, Russia and East Asia — and high fish exports to the EU — have led to local fish scarcity and price increases that have made fish increasingly inaccessible to local consumers[5]. In Senegal in western Africa, one of the countries studied by Hicks and colleagues, a small micronutrient-rich, herring-like fish called sardinella has been a staple for centuries. A 2016 documentary film called *An Ocean Mystery: The Missing Catch* (see

SYLVAIN CHERKAOUI/REUTERS

Figure 1 | Sardinella fish being processed in Mauritania to generate fishmeal. In many developing tropical countries, a substantial proportion of local fish catches are either exported for human consumption or processed locally to generate fishmeal that is then exported and used, for example, to feed farmed fish. Hicks and colleagues' analysis[1] suggests that the retention of fish for local consumption could help tackle human disease associated with nutrient deficiencies in countries where such conditions are prevalent.

go.nature.com/2kyjv51) shows sardinella being smoked, dried and hand-processed by Senegalese women and then trucked to the interior of the country, where these fish are the only affordable main source of micronutrients and animal protein. The leader of these workers emphasized in an interview in the documentary that it would be a catastrophe if the sardinella supply was interrupted, because they would have no fish to process.

Since then, this feared catastrophe has begun to happen. Despite much local consternation, more than 40 industrial fish-processing plants have been built, mainly by Chinese enterprises, along the coast of Senegal (see go.nature.com/2kva8bu) and neighbouring countries (see go.nature.com/2jtmcjq). These plants process sardinella (Fig. 1) and similar small fish into an animal-feed product called fishmeal. Many of the local fisheries, which had traditionally supplied the regional markets with sardinella for human consumption, now instead supply the fishmeal plants. These factories export their product mainly to China, which is the world's largest fishmeal importer, and it is commonly used there to feed farmed fish.

Thoughtful consumers often insist that they eat fish certified as sustainably caught. This nebulous term often implies a hope that such fish suffered as little as possible, and that their stocks are somehow being managed to ensure the continuation of an abundant supply. If such fish come from fish farms, as is the case for most salmon on offer, this, too, is considered a good thing, because it is widely thought that fish farming relieves pressure on capture fisheries. However, using sardinella to make fishmeal for farmed fish does not reduce the pressure on wild fish. Moreover, it deprives people in the developing world on low incomes of previously affordable, nutritious local fish — to aid the production of costly farmed fish that is mainly consumed in high-income countries[2].

When considering what fish we should eat, given that fish is good for us, it is time to take a broader perspective about how "us" is being defined. Hicks and colleagues' work points a way forward. The information they have provided could be used to put a spotlight on fish availability when thinking of ways to prevent human disease caused by micronutrient deficiencies. ■

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SYNTHESIS

Chemical libraries from a double click

Operationally simple chemical reactions, termed click reactions, are widely used in many scientific fields. A streamlined synthesis of compounds called azides looks set to expand the role of click chemistry still further. SEE LETTER P.86

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Generating molecules and materials that have desirable functional properties is arguably the central goal of synthetic chemistry. For example, drugs are developed to have a set of physical and pharmacological properties that can treat a specific disease safely. On page 86, Meng *et al.*[1] report a reagent that greatly simplifies the synthesis of compounds known as azides, and thereby opens up a remarkably straightforward route to making libraries of compounds that might have useful biological functions.

Altering the structures of molecules to tune their properties is much more complicated than modifying objects in the everyday world. In carpentry, for instance, the same starting materials (timber, nails and screws) and tools (saws, hammers and screwdrivers) can be used to construct objects that have diverse shapes and functions, such as chairs, doors and crates. By contrast, building structural analogues of molecules often requires very different starting materials (reagents) and tools (reactions). The need to develop a range of synthetic routes to such analogues can be a bottleneck when optimizing functional molecular properties[2], given that optimization can involve the laborious, resource-intensive synthesis of hundreds, or even thousands, of structural analogues.

A way of streamlining the optimization of desired functional properties was formalized in 2001, in a concept known as click chemistry[3]. A reaction is defined as click chemistry if it is operationally simple, is 'spring-loaded' (thermodynamically driven to produce a single product quickly), and generates new chemical bonds between two molecules. Ideally, the reactants should be used in a one-to-one ratio, rather than with an excess of one or more components (which is a common requirement for many reactions). Click reactions must be high-yielding, applicable to a broad range of compounds, and yet exceptionally selective, meaning that the chemical groups that undergo the reaction must react only with each other, and not with any other groups in the reactants. The product should also be easy to isolate or use without extensive purification. Although many synthetic reactions meet some of these criteria, surprisingly few meet all of them.

In 2002, two research groups independently reported[4,5] that copper(I) salts are effective catalysts for reactions known as alkyne–azide cycloadditions (the copper-catalysed reaction is abbreviated as CuAAC). These reactions link an azide group (N_3) with the carbon–carbon triple bond in an alkyne compound to form a triazole ring (Fig. 1). Because the CuAAC

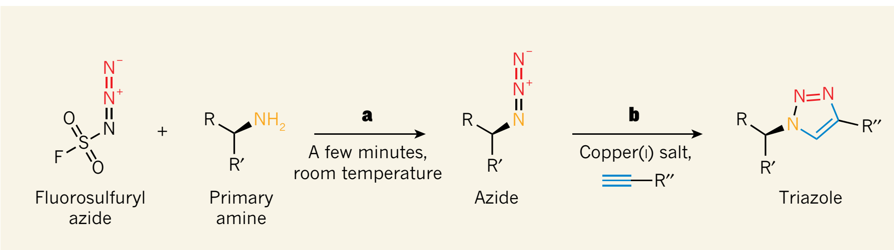

Figure 1 | A two-step click-chemistry sequence. a, Meng *et al.*[1] report that a reagent called fluorosulfuryl azide rapidly converts almost any primary amine into an azide at room temperature — a type of reaction known as diazotransfer. The reactions are fast and high yielding, and the reagent does not react with chemical groups other than amines; they therefore fulfil the criteria to be categorized as 'click' reactions. **b**, The authors show that the resulting azide solution can be used without purification in a copper(I)-catalysed click reaction with alkynes (compounds that contain carbon–carbon triple bonds) to produce products called triazoles, which are potentially useful in drug discovery. R, R′ and R″ represent any chemical group or molecular fragment.