

Simplistically, the proportion of seafood consumption from imports is obtained by dividing the consumption of imports by total consumption, which requires knowledge of a country's production, imports, and exports (Fig. 2A). However, conducting this seemingly simple calculation requires tallying up all domestic capture and aquaculture production and then converting the hundreds of traded seafood products, such as canned salmon, into effective live capture weights, such as whole pink salmon. This calculation excludes unreported domestic landings, mostly from small-scale fisheries and recreational catch, which were estimated to be 8.2% of total US capture production in 2014, the most recent year available (6).

Underestimating domestic production increases a country's apparent reliance on trade. Furthermore, the estimated percentage of consumption from imports is highly sensitive to conversion factors between processed and capture weights (Fig. 2C). These factors vary with harvest size and processing technology, are

Going forward, better production, processing, and trade statistics are essential to track the sustainability of our global food system and measure the effect of policy changes.

rarely reported with uncertainty levels, and are not often systematically updated. In fact, differences in conversion factors provide the best explanation for the difference between the estimate of 70% from the United Nations Food and Agriculture Organization (FAO) statistics, versus 90% from the National Oceanic and Atmospheric Administration (NOAA) statistics (Fig. 2B). Because available FAO conversion factors cover a greater number of products and countries, we expect them to better capture the current range of products and geographical variation in seafood production and, therefore, use these values in our estimates below. Going forward, ensuring well-documented conversion factors are publicly available is crucial for transparency and use in policy decisions.

Problems with the 90% statistic are not limited to production estimates and unreported domestic catches. This calculation implies all seafood imports are of foreign origin. Although this may seem logical, it is not always the case; large quantities of seafood landed in the United States are exported for processing and shipped back into the United States. As a result, some US seafood imports appear to be foreign but are actually caught in the United States. For example, China imports around one third of all US seafood exports with around 57% coming from species for which some portion is processed and shipped back to the United States (*SI Appendix*). In the extreme case that all such processed seafood is returned to the United States, as little as 61% of US consumption could actually be foreign imported seafood (*SI Appendix, Table S1*). Unfortunately, data on how much

imported seafood originated in the United States are scarce. Our best estimate based on the available data is that the percentage of consumption from foreign imports in the United States is in the range of 62–65%, not 90% (*SI Appendix, Table S1*). In other words, 35–38% of seafood consumed in the United States is of domestic origin, more than three times the amount previously suggested.

Going forward, better production, processing, and trade statistics are essential to track the sustainability of our global food system and measure the effect of policy changes.

Sustainable Seafood

Sustainability is hailed as a hallmark of domestic seafood in the United States, flowing from strong national laws designed to prevent overfishing and rebuild overfished stocks (7). Only 15% of assessed US stocks are currently overfished, and more stocks are being rebuilt every year (8), all while contributing 5 million metric tons in landings (2). Although the percentage of seafood consumed in the United States of foreign origin is highly uncertain, the United States does import large quantities of seafood, roughly double the amount it exports. As a result, seafood landed and seafood consumed in the United States can be very different things and often not as sustainable as US-caught seafood (9). To support sustainable US seafood, some have pointed to increasing domestic consumption of US-produced wild and farmed products.

Seafood source and sustainability have come into particular focus in the current political climate. In May 2018, the acting administrator of NOAA outlined the agency's strategies to reduce the US seafood deficit, including permitting commercial fishing in marine monuments, promoting domestic aquaculture, and reviewing seafood trade deals (10). However, capture fisheries are unlikely to reduce reliance on foreign imports because the opportunities to expand catch volume, including opening the marine monuments that only ever produced a tiny fraction of total production, are dwarfed by our current imports. Furthermore, the targeted wild species are generally not substitutes for less expensive, farmed imports. Instead, domestic fisheries would be better supported through policies that expand the access of US seafood to foreign markets.

There are more opportunities to boost US aquaculture production (5). Globally, more than half of all seafood is farmed, but the United States contributes less than 1% (2). NOAA is exploring opportunities to expand aquaculture production through new Blue Economy initiatives. Recently, NOAA unsuccessfully tried using existing fisheries regulations for the permitting of offshore finfish production in the Gulf of Mexico (4), resulting in the introduction of a new bill, Advancing the Quality and Understanding of American Aquaculture (AQUAA), which would officially designate NOAA as the coordinating body of marine aquaculture through the Office of Marine Aquaculture. This bill, similar to its predecessor passed in 1980 (National Aquaculture Development Plan), cites the US seafood deficit and 90% import statistic as a primary justification

for new policies to increase development and production of domestic farmed seafood (4, 5). Despite the uncertain future of the AQUAA bill, the Department of Commerce is working to grow US aquaculture production, announcing \$11 million of funding for 22 projects to expand sustainable US ocean, coastal, and Great Lakes aquaculture. However, increasing aquaculture production will not necessarily reduce apparent US reliance on imports. Under the current trade statistics, the portion of farmed seafood exported for processing will appear destined for foreign consumption, whereas the imported processed form will still appear to be a foreign product.

The global growth of aquaculture and globalization of supply chains complicate policies aimed at improving the sustainability of seafood consumed in the United States and are key drivers of US seafood imports. As aquaculture has grown rapidly worldwide, US imports from major aquaculture-producing countries have also increased (1). Today, three of the top four most consumed seafood products in the United States (shrimp, salmon, and tilapia) are among the most intensively farmed species (2) and are typically available at lower prices than wild-caught seafood (11). Imports of farmed seafood help meet US demand for inexpensive seafood, but the increasingly globalized seafood supply chains for both wild-capture and aquaculture products complicate efforts to track a single product and its sustainability.

Ultimately, consumer preferences for cheap seafood and traceability lie at the heart of questions concerning the overall sustainability of seafood consumed in the United States. Improving traceability to connect consumer demand to sustainable production requires improved monitoring along the supply chain and finer detail in international commodity code systems, which currently group many species and do not differentiate between farmed and wild products. Conversely, proposed policy changes that fail to acknowledge the underlying drivers of seafood imports or lack support for the development of foreign markets will do little to reduce the trade deficit, promote sustainable seafood, or expand domestic production.

Seafood Trade Policy

Trade policy is another tool for addressing US reliance on foreign seafood. However, to support US fisheries, tariffs and trade agreements should be structured to account for seafood's global supply chain and to promote the development of foreign markets for US products. The current trade war between the United States and China highlights these two issues. China is the United States' largest seafood trading partner because of its role as a prominent seafood processor and its growing market for US seafood. This makes the US seafood sector vulnerable to trade barriers. Since January 2018, back-and-forth escalation of tariffs has led to US tariffs on more than \$200 billion of Chinese goods, including 10–25% on Chinese seafood imports and China has imposed retaliatory tariffs in kind. With the current uncertainty over the US–China trade war, it is important to take stock of its impact on US industries.

Although it has received less attention and relief efforts than agriculture, US seafood is front and center in the trade war. US companies have slowly worked to build a market for US seafood in China, but now a combination of tariffs and exclusion from tariff cuts on 300 seafood products announced by China in January 2019 threaten US seafood investments in the Chinese market. For example, around \$130 million of Maine lobster was exported to China in 2017, a close second to Canadian lobster exports to China. But the combination of exclusion from a rollback of Chinese tariffs and the addition of new tariffs places US lobster at a 45% price disadvantage (12). In fact, in August 2018, Maine-based lobster companies announced layoffs because of the drying up of the Chinese market for US-produced lobster (13). Dealers are now reportedly exploring opportunities to shift operations to Canada to take advantage of more favorable tariffs (14).

Even more vexing are the large quantities of seafood the United States sends to China for processing (currently purported to be exempt from Chinese tariffs) that are exported back to the United States (and potentially subject to US tariffs). As Alaska Senator Lisa Murkowski has pointed out, the United States is effectively taxing its own seafood. NOAA has stated that imports from China of processed seafood with US origin will be exempt from the tariffs, but there is uncertainty around whether this will occur or indeed how processed seafood of US origin will be identified to allow this exemption. Although China is not currently imposing tariffs on seafood intended for processing, it is imposing tariffs on seafood destined for Chinese consumption, putting at risk the US seafood industry's efforts to become established in the Chinese market.

Although it has received less attention and relief efforts than agriculture, US seafood is front and center in the trade war.

The above policies focus on reducing the seafood deficit. But it is worth asking whether reducing reliance on foreign seafood is worthwhile to promote US industry, support sustainable fisheries, and supply affordable seafood to US consumers. Many seafood industry representatives are advocating for open-trade policies that allow US seafood to participate in global markets. Meanwhile, improved certification, traceability, and import standards are more promising solutions to support sustainable seafood production, ensure imports are of sustainable origin, and avoid foreign seafood "dumping." NOAA's recent Seafood Import Monitoring Program (81 FR 88975) is a good start, and sustainability commitments by major seafood industry representatives and new technologies on the horizon, such as blockchain, provide promising opportunities to verify sustainable and humane seafood supply chains.

US seafood consumption has grown modestly in recent decades, but still more than 80% of consumers fall below US Department of Agriculture (USDA)

seafood consumption recommendations (15). Sustained growth in seafood demand or an increase to meet the USDA guidelines provides opportunity for the US seafood sector. But policies supporting US seafood cannot ignore the central position the sector occupies in an increasingly global industry.

Data and Materials Availability

All data are publicly available through Google Trends, the NOAA statistical office, and the FAO FishStatJ database.

Acknowledgments

We thank Michael Liddel and Alan Lowther at NOAA for generously taking time to answer our questions about US fisheries statistics, as well as the network of industry and academic contacts who provided valuable insights throughout the development of this article. J.A.G. was funded by the National Socio-Environmental Synthesis Center under funding received from the National Science Foundation DBI-1052875. H.E.F. was funded by the Zegar Family Foundation through the Anticipating Climate Change Impacts on Ocean Aquaculture project. T.A.B. was funded in part by the Richard C. and Lois M. Worthington Endowed Professorship in Fisheries Management.

- 1 Gephart JA, Pace ML (2015) Structure and evolution of the global seafood trade network. *Environ Res Lett* 10:125014.
- 2 FAO (2018) *The State of World Fisheries and Aquaculture 2018: Meeting the Sustainable Development Goals* (United Nations, Rome).
- 3 Gonzalez S, Beaubien J (November 9, 2018) Planet Money Episode 875: Why did the cow cross the border? Available at <https://www.npr.org/sections/money/2018/11/09/666372072/episode-875-why-did-the-cow-cross-the-border>. Accessed April 3, 2019.
- 4 Montañez JL (2014) Offshore aquaculture regulations under the Magnuson-Stevens Fishery Conservation and Management Act. *Fisheries* 39:562–563.
- 5 Lester SE, Gentry RR, Kappel CV, White C, Gaines SD (2018) Opinion: Offshore aquaculture in the United States: Untapped potential in need of smart policy. *Proc Natl Acad Sci USA* 115:7162–7165.
- 6 Pauly D, Zeller D (2016) Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nat Commun* 7:10244.
- 7 Macpherson M (2017) In pursuit of optimum: Forty years of federal fisheries management under the Magnuson-Stevens Fishery Conservation and Management Act. *Tulane Environ Law J* 31:209.
- 8 NOAA (2017) Report to Congress on the status of U.S. fisheries. Available at <https://www.fisheries.noaa.gov/national/2017-report-congress-status-us-fisheries>. Accessed April 3, 2019.
- 9 Costello C, et al. (2016) Global fishery prospects under contrasting management regimes. *Proc Natl Acad Sci USA* 113:5125–5129.
- 10 D'Angelo C (July 5, 2018) Ocean agency suggests opening marine monuments to commercial fishing. *Huffington Post*. Available at https://www.huffingtonpost.com/entry/marine-monuments-commercial-fishing_us_5b3e945be4b05127ccf05a35. Accessed April 3, 2019.
- 11 Asche F, Dahl RE, Steen M (2015) Price volatility in seafood markets: Farmed vs. wild fish. *Aquac Econ Manage* 19:316.
- 12 Overton P (June 19, 2018) China's threatened tariff on lobster from U.S. has Maine's industry on edge. *Press Herald*. Available at <https://www.pressherald.com/2018/06/19/chinas-proposed-tariff-on-u-s-lobster-has-maine-industry-on-edge/>. Accessed April 3, 2019.
- 13 Whittle P (September 14, 2018) Layoffs hit, prices lag as lobster biz feels tariff pinch. *Business Insider*. Available at <https://www.businessinsider.com/ap-layoffs-hit-prices-lag-as-lobster-biz-feels-tariff-pinch-2018-9>. Accessed May 17, 2019.
- 14 Donnan S (November 7, 2018) Even lobsters can't escape Trump's trade war. *Bloomberg Businessweek*. Available at <https://www.bloomberg.com/news/features/2018-11-07/even-lobsters-can-t-escape-trump-s-trade-war>. Accessed April 3, 2019.
- 15 Jahns L, et al. (2014) Intake of seafood in the US varies by age, income, and education level but not by race-ethnicity. *Nutrients* 6:6060–6075.