This is the accepted manuscript of: Asche, F., Yang, B., Gephart, J. A., Smith, M. D., Anderson,J. L., Camp, E. V., Garlock, T. M., Love, D. C., Oglend, A., & Straume, H.-M. (2022). China's seafood imports—Not for domestic consumption? *Science*, *375*(6579), 386–388. https://doi.org/10.1126/science.abl4756

China's seafood imports – not for domestic consumption?

Authors: Frank Asche[1,2,*], Bixuan Yang[3], Jessica A. Gephart[4], Martin D. Smith[5], James L. Anderson,[3] Edward V. Camp,[1] Taryn M. Garlock,[1] David C. Love,[6] Atle Oglend,[2] Hans-Martin Straume[7]

[1] School of Forest, Fisheries and Geomatics Sciences and Food Systems Institute, University of Florida; Gainesville, FL 32611-057, USA
[2] Department of Safety, Economics and Planning, University of Stavanger; Ullandhaug, 4036 Stavanger, Norway
[3] Food and Resource Economics Department and Food Systems Institute, University of Florida; Gainesville, FL 32611-057, USA
[4] Department of Environmental Science, American University; Washington, DC 20016-8007, USA
[5] Nicholas School of the Environment and Department of Economics, Duke University; Durham, NC 27708, USA
[6] Johns Hopkins Center for a Livable Future and Department of Environmental Health and Engineering, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD-21202, USA
[7] Campus Bergen, Norwegian School of Management; 5006 Bergen, Norway

*Corresponding author. Email: Frank.Asche@ufl.edu

Abstract:

China produces and trades more seafood than any other nation. This dominance in seafood systems means that China represents both a lever and a challenge for global seafood sustainability. This study combines data on production, imports, and exports to show that China largely has two distinct seafood systems: 1) domestic production for domestic consumption and 2) imports and distant water fishing for re-export. We estimate 74.9% of Chinese seafood imports are re-exported, suggesting that domestic demand is not driving China's export orientation and associated sustainability concerns. Rather, China's seafood processing resembles its role in manufacturing and competes with coastal communities around the world. China's re-export model highlights the importance of traceability to address environmental sustainability and the need for oceans policy reform to sustain coastal communities in a globalized seafood economy.

One-Sentence Summary: An estimated 74.9% of China's seafood imports are re-exported, and seafood imports are generally not destined for Chinese seafood consumption.

Main Text: Because seafood is the most traded food commodity, the global seafood trade is tightly coupled with environmental, economic, and social sustainability (*1-3*). Yet, two common features of the global seafood trade hamper efforts to promote environmental and social sustainability. First, the practice of importing seafood, processing it, and then exporting it (hereafter referred to as "re-exporting") complicates tracing seafood sustainability from the water to the plate and enables mislabeling (*4*). Second, distant water fishing (DWF), which obscures the distinction between domestic and imported seafood, is implicated in Illegal, Unreported and Unregulated fishing and other unsustainable practices (*5*). Both features highlight the critical role of China (*5-6*), the world's largest DWF nation and largest seafood producer, consumer, exporter, and importer (by volume) (*Supplement*).

Here we relate Chinese seafood imports to exports to differentiate imports intended for the domestic market from imports intended to be processed and re-exported. We estimate that 74.9% of imports are processed and re-exported, virtually all these imports are from fisheries rather than aquaculture, and for some species exports are significantly higher than imports plus Chinese production (*Supplement*). Moreover, a significant share of China's DWF landings are exported. China is a leading exporter of species like cod for which it does not have domestic or DWF catches. Instead, China relies on imported raw materials from multiple species and origins, such as Russian Alaska pollock and Norwegian cod (*Supplement*). Thus, China is playing an increasingly important role as the world's fisher and fish processor, a role that is consistent with China's contributions in many manufacturing sectors.

Traditionally, most seafood was harvested from wild fish populations, processed near fishing grounds, and traded to large population centers. Globally, this structure created an important role for coastal communities where fish were processed and preserved before continuing their journey towards the final consumers, often far away. Improved preservation technologies combined with low transportation costs have challenged this traditional model: relatively unprocessed seafood can be shipped over long distances before secondary processing is undertaken, and finished products may travel long distances again before reaching final markets (*7*). As in most manufacturing, with low transportation costs, each segment of the seafood supply chain can be located where the cost is lowest.

Low wages and an undervalued currency explain the improved competitiveness of Chinese manufacturing in general (*8*), and because seafood processing is labor-intensive, these factors make China highly competitive in seafood processing. Low transportation costs for frozen seafood augment China's competitive edge in seafood processing over other coastal nations. The new structure of processing for re-export severs the link between fish stocks and coastal communities and inflates the share of seafood that is traded internationally. With 74.9% of China's imports being re-exported, 11.3% of the global seafood trade is due to seafood that is counted twice (*Supplement*). Re-exporting can also increase revenue from the same supply of raw product because labor-intensive manual processing gives higher yields than machine processing (*9*). Secondary processing reinforces competitiveness of the new structure by allowing processing plants to obtain inputs year-round and thus increase capacity-utilization relative to processors dependent on local fishery landings in compressed seasons (*10*).

Although high-quality data exist, it is difficult to reconcile seafood production and trade data due to mismatches in species- versus product-level reporting and weight losses during processing (*4*). As a consequence, species-level data on imports, country-of-origin, processing, and re-exports are scarce. To gain insights about China's role in the global seafood industry, we convert quantities of different product forms in imports and exports by species group using the same approach used to estimate apparent consumption (*4*). Conversion factors make the weights of different product forms at different stages in the supply chain comparable (*Supplement*).

The top 15 imported species groups account for 76.5.% of China's total seafood imports and 89.2% of the imports of identified species. Alaska pollock, primarily from Russia, accounts for over 21% of imports (Table 1). Cuttlefish and squid, salmon, the whitefish species (cod, blue whiting, haddock, and hake), and pelagic species (mackerel, herring, and tuna) are also important species groups. Of the top 15 species groups, five are almost exclusively for re-export (re-export share>75%), while six appear to be primarily imported for domestic consumption. Only three of the species groups, Atlantic salmon, catfish, and shrimp, are primarily produced by aquaculture (*11*), and these all have small re-export shares. Among all finfish imported into China, 91% are whole frozen fish (*Supplement*), a product category that typically is further processed before the final point of sale. For six species groups, the whitefish and salmon species, China has no domestic landings. This confirms that exports of these species rely entirely on imports. There are three species groups where the exports exceed imports plus production. This situation could reflect imprecise conversion factors, short-weighting and reporting error including so-called IUU (Illegal, Unregulated and Unreported) landings (*Supplement*). For the two high-valued whitefish species, cod and haddock, exports are about 35% higher than imports, suggesting that a cheaper whitefish such as blue whiting, where there are no recorded exports, are mislabeled. For tuna the re-export share is most likely greater than 100% because DWF landings are not recorded as tuna, but instead in the not specified category.

Table 1. Chinese seafood imports and re-exports 2012-2019. Import quantity is in product weight. Re-export share is exports/(domestic production + imports), where all quantities are converted to live weight equivalents.

Species	Imports (1,000 mt)	Import share by quantity (%)	Domestic production (1,000 mt)	Re-export share (%)
Alaska pollock	5,148.25	21.1%	0	84.8%
Cuttlefish and squid	2,464.69	10.1%	7,870	40.9%
Shrimp and prawns	1,512.98	6.2%	31,456	7.3%
Cod	1,490.87	6.1%	0	136.0%
Herring	1,288.65	5.3%	116	42.8%
Pacific salmon	1,281.56	5.3%	0	82.1%
Flatfish	1,106.99	4.5%	1,012	76.0%
Mackerel	874.26	3.6%	3,728	61.1%
Tuna	696.33	2.9%	813	155.3%
Crab	525.57	2.2%	14,252	8.4%
Hairtails	518.11	2.1%	8,294	1.2%
Catfish	490.26	2.0%	8,233	1.4%
Blue whiting	449.01	1.8%	0	0.2%
Atlantic salmon	413.83	1.7%	0	0.9%
Haddock	356.60	1.5%	0	135.0%

Two species groups dominate the long-distance Chinese DWF landings, cuttlefish and squid (71.6%) and tuna (15.3%) (*Supplement*), and both are important in imports and re-exports (Table

1). For both species groups the exports are significantly larger than the imports, but significantly lower than imports plus the landings of the DWF fleet. For groups like shrimp, crab, and hairtail, Chinese production is substantially larger than exports, highlighting the importance of the domestic market despite China being a large exporter of these species groups.

To shed further light on the Chinese seafood market, we constructed an indicator to account for origin (where the seafood is produced) and destination (where the seafood is consumed) using the 20 largest species groups by production and the 15 largest species groups by imports and exports. These indicators are sorted into four archetypes based on whether the production source is primarily (>50%) domestic or foreign and whether the consumer destination is primarily (>50%) domestic or foreign: 1) domestic production for domestic consumers, 2) domestic production for foreign consumers, 3) re-exports, and 4) imports for domestic market. Most species and those with the largest volumes are in the lower left-hand quadrant of Figure 1. Hence, domestic production primarily for domestic consumption is by far the most dominant archetype. Except for tilapia, all aquaculture species that makes up most of China's seafood production fall within this archetype and the importance of carp is apparent. However, there is some dispersion towards the right, indicating significant export quantities for some domestically produced species groups, e.g., shrimp. Only a few species groups are primarily export-oriented, including sardines, mackerel, octopus and tilapia, and a few species are primarily imported for domestic consumption, such as Atlantic salmon and catfish, or as in the case of blue whiting, most likely exported under a different name. The upper right quadrant contains seven major species groups that are primarily imported for re-export, with species in the upper right corner, such as cod, having essentially no domestic production or consumption.

We find that the majority of Chinese seafood imports for processing and re-export are wild-caught. This finding largely contradicts the narrative that Chinese domestic demand is driving massive Chinese imports (*6*, *12*), although some imported species like Atlantic salmon primarily go to the domestic market (Table 1). Instead, Chinese processing of wild-caught fish for re-export outcompetes processing in other parts of the world in a way that resembles China's success in manufacturing more broadly. Yet, China does not play a comparable role in the global aquaculture industry. Seafood processing thus can be competitive in high-income countries such as Canada and Norway despite favorable conditions of low wages and cost in China.

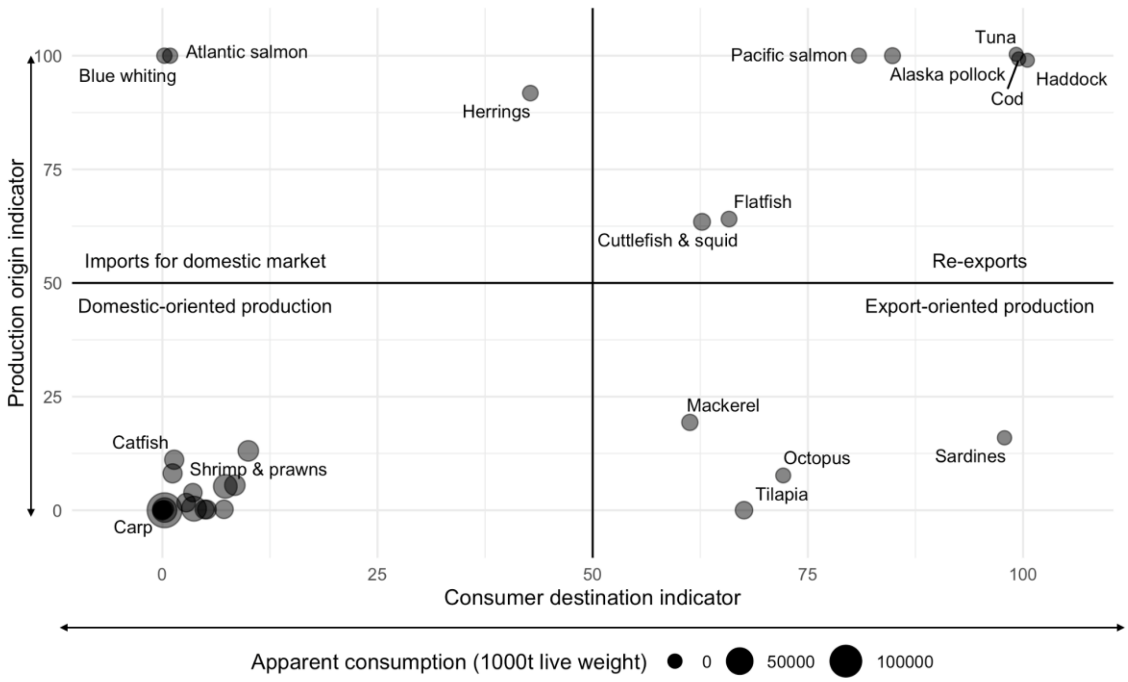

Fig. 1: Characterization of China's seafood market. Seafood products are sorted into archetypes based on whether the production source is primarily (>50%) domestic or foreign and whether the consumer destination is primarily (>50%) domestic or foreign. This results in four archetypes: 1) domestic production for domestic consumers (domestic-oriented production); 2) domestic production for foreign consumers (export-oriented production); 3) foreign production imported and processed, then destined for foreign consumers (re-exports), and 4) foreign production for domestic consumption (imports for domestic market). The production source indicator is calculated as imports divided by the sum of production and imports and the consumer destination indicator is calculated is calculated 100 minus apparent consumption (production + imports – exports) divided by the sum of production and imports. Both indicators are calculated in terms of live weight equivalents. Point size is scaled by apparent consumption.

Our analysis of China's position in global seafood trade has two important policy implications for seafood sustainability. First, work to increase traceability in the global seafood system. Narratives that emphasize Chinese demand as driving China's role in the seafood system (*6, 12*) pay too little attention to the re-export model, which highlights the complexity of tracing seafood sustainability. The same product can be harvested in multiple countries with different management and labor conditions and comingle in re-export data. For example, 57% and 39% of Pacific salmon imports originate in the US and Russia. This is crucial for seafood sustainability because the processing stage is an opportunity for seafood mislabeling with respect to country of origin and species. Consistent with this concern, we find that exports as a share of combined imports and production exceeds 100% for some higher valued species such as cod and haddock. Initiatives such as the EU's red and yellow card system, the U.S. Seafood Import Monitoring Program, and efforts to develop a global seafood traceability system (https://traceability-dialogue.org/) are a start, but their reach is still limited. For example, the U.S. program does not even include Alaska pollock and salmon. Systematic use of blockchain technology and international coordination could enable tracing seafood from different territorial waters that are comingled in processing and re-exported.

Second, fisheries management systems can inadvertently disadvantage local processing and increase the competitiveness of the re-export model. For example, policies like industry-wide quotas trigger a race to fish that increases the seasonality in landings and results in poor capacity utilization in the processing industry (*10, 13*). Low-capacity utilization effectively increases the costs of local processing, increasing China's competitiveness as a re-exporter. By creating less economic value and fewer jobs locally in the processing sector, fisheries management thus can undermine social sustainability (*14*). Alternatively, fisheries management that spreads out catches can enhance social sustainability by increasing capacity utilization. For example, catch shares empirically slow the race to fish (*10*).

China's import data and its limited role as a re-exporter of farmed seafood are consistent with this characterization of fisheries management and social sustainability. The vast majority of imports from China's top-15 species groups are not from fisheries managed with catch shares that spread out the catch (Table S2), e.g., Russian Alaskan Pollock, Russian cod, and Pacific salmon. So, it is not surprising that China can compete in processing these species groups. Aquaculture processing, by contrast, does not suffer from the same problems of seasonality. By controlling the production process, aquaculture can time the harvest to maintain high-capacity utilization, making local processing more competitive with the re-export model. This feature of aquaculture can explain why China has limited farmed seafood re-exports. Ultimately, maintaining seafood processing locally contributes to social sustainability of fisheries (*15*), and social sustainability, in turn, mutually reinforces economic and ecological sustainability (*14*).

References

1. F. Asche, M. Bellemare, C. Roheim, M. D. Smith, S. Tveterås, Fair enough? Food security and the international trade of seafood. *World Dev.* **67**, 151-160 (2015).

2. J. A. Gephart, M. L. Pace, Structure and evolution of the global seafood trade network. *Environ. Res. Lett.* **10**, 125014 (2015).

3. U. R. Sumaila, D. Zeller, L. Hood, M. L. D. Palomares, Y. Li, D. Pauly, Illicit trade in marine fish catch and its effects on ecosystems and people worldwide. *Sci. Adv.* **6**, eaaz3801 (2020).

4. K. Kroetz, G. M. Luque, J. A. Gephart, S. L. Jardine, P. Lee, K. C. Moore, C. Cole, A. Steinkruger, C. J. Donlan, Consequences of seafood mislabeling for marine populations and fisheries management. *P. Natl. Acad. Sci. U.S.A.* **117**, 30318-30323 (2020).

5. D. Pauly, D. Belhabib, R. Blomeyer, W. W. Cheung, A. M. Cisneros-Montemayor, D. Copeland, S. Harper, V. W. Lam, Y. Mai, F. Le Manach, H. Österblom, K. M. Mok, L. van der Meer, A. Sanz, S. Shon, U. R. Sumaila, W. Swartz, R. Watson, Y. Zhai, D. Zeller, China's distant-water fisheries in the 21st century. *Fish Fish.* **15**, 474–488 (2014).

6. B. Crona, E. Wassénius, M. Troell, K. Barclay, T. Mallory, M. Fabinyi, W. Zhang, V. W. Lam, L. Cao, P. J. Henriksson, H. Eriksson, China at a crossroads: an analysis of China's changing seafood production and consumption. *One Earth* **3**, 32-44 (2020).

7. J. L. Anderson, F. Asche, F., T. Garlock, Globalization and commoditization: The transformation of the seafood market. *J. Commod. Markets* **12**, 2-8 (2018).

8. F. G. Adams, B. Gangnes, Y. Shachmurove, Why is China so competitive? Measuring and explaining China's competitiveness. *World Economy* **29**, 95-122 (2006).

9. J. S. Ng, "Development of China as the world's largest reprocessing centre of frozen fish products and future challenges for the industry" in *Global Trade Conference on Aquaculture* (Food and Agriculture Organization of the United Nations, Rome, 2007), pp. 221–226.

10. A. M. Birkenbach, D. J. Kaczan, M. D. Smith, Catch shares slow the race to fish. *Nature* **544**, 223-226 (2017).

11. T. Garlock, F. Asche, J. L. Anderson, T. Bjørndal, G. Kumar, K. Lorenzen, A. Ropicki, M. D. Smith, R. Tveterås, A global blue revolution: aquaculture growth across regions, species, and countries. *Rev. Fish. Sci. Aquac.* **28**, 107-116 (2020).

12. J. K. Abbott, D. Willard, J. Xu, Feeding the dragon: The evolution of China's fishery imports. *Mar. Policy* **133**, 104733 (2021).

13. F. R. Homans, J. E. Wilen, Markets and rent dissipation in regulated open access fisheries. *J. Environ. Econ. Manag.* **49**, 381-404 (2005).

14. F. Asche, T. Garlock, J. Anderson, S. Bush, M. Smith, C. Anderson, J. Chu, K. Garrett, A. Lem, K. Lorenzen, A. Oglend, S. Tveterås, S. Vannuccini, Three pillars of sustainability in fisheries. *P. Natl. Acad. Sci. U.S.A.* **115**, 11221-11225 (2018).

15. J. N. Kittinger, L. C. L. Teh, E. H. Allison, N. J. Bennett, L. B. Crowder, E. M. Finkbeiner, C. Hicks, C. G. Scarton, K. Nakamura, Y. Ota, J. Young, A. Alifano, A. Apel, A. Arbib, L. Bishop, M. Boyle, A. M. Cisneros-Montemayor, P. Hunter, E. Le Cornu, M. Levine, R. S. Jones, J. Z. Koehn, M. Marschke, J. G. Mason, F. Micheli, L. McClenachan, C. Opal, J. Peacey, S. H. Peckham, E. Schemmel, V. Solis-Rivera, W. Swartz, T. A. Wilhelm, Committing to socially responsible seafood. *Science* **356**, 912-913 (2017).

16. L. Cao, R. Naylor, P. Henriksson, D. Leadbitter, M. Metian, M. Troell, W. Zang, China's aquaculture and the world's wild fisheries. *Science* **347**, 133-135 (2016).

17. Belton, S. R. Bush, D. Little, Not just for the wealthy: rethinking farmed fish consumption in the Global South. *Glob. Food Secur.* **16**, 85-92 (2018).

18. FAO, FishStat Plus Software. FAO, Rome. Accessed July 3, 2021.

19. T. G. Mallory, China's distant water fishing industry: Evolving policies and implications. *Mar. Policy* **38**, 99-108 (2013).

20. E. Sala, J. Mayorga, C. Costello, D. Kroodsma, M. L. D. Palomares, D. Pauly, U. R. Sumaila, D. Zeller, The economics of fishing the high seas. *Sci. Adv*. **4**, eaat2504 (2018).

21. China Fishery Yearbook, China Fishery Statistical Yearbook (China Agricultural Press, Beijing, various years).

22. Ministry of Agriculture, Bureau of Fisheries. (2018). China fisheries yearbook (China Agriculture Publishing Company, 2011)

23. R. J. R. Grainger, S. M. Garcia, "Chronicles of marine fishery landings (1950-1994): trend analysis and fisheries potential" (Fisheries Technical Paper No. 359, FAO, 1996).

24. FAO, "Fishery and Aquaculture Country Profiles - The People's Republic of China" (FAO, 2017).

25. FAO. "The State of World Fisheries and Aquaculture 2020. Sustainability in action" (FAO, 2020).

26. J. L. Anderson, F. Asche, S. Tveterås, "World fish markets" in *Handbook of Marine Fisheries Conservation and Management,* R.Q. Grafton, R. Hilborn, D. Squires, M. Tait, M. Williams, Eds. (Oxford University Press, 2010), pp. 113-122.

27. B. Yang, J. L. Anderson, F. Asche, Determinants of China's seafood trade patterns. *Mar. Res. Econ.* **35**, 97-112 (2020).

28. B. Yang, J. L. Anderson, Y. Fang, Trade duration of Chinese shrimp exports. *Aquacult. Econ. Manag.* **25**, 269-284 (2021).

29. M. Fabinyi, Historical, cultural and social perspectives on luxury seafood consumption in China, *Environ. Conserv.* **39**, 3–92 (2012).

30. EUFOMA, www.eufoma.eu. Accessed April 4, 2021.

31. M. Peterson, G. E. McBride, S. K. Jhita, R. S. Hellberg, An investigation into country of origin labeling, species authentication and short weighting of commercially sold frozen fish fillets. *Heliyon* **7**, e06713 (2021).

32. S. C. Clarke, M.K. McAllister, R.C. Kirkpatrick, Estimating legal and illegal catches of Russian sockeye salmon from trade and market data. *ICES J. Mar. Sci.* **66**, 532–545 (2009).

33. Leroy, F. Galletti, C. Chaboud, The EU restrictive trade measures against IUU fishing. *Mar. Policy* **64**, 82–90 (2016).

34. Y. Fang, F. Asche, Can U.S. import regulations reduce IUU fishing and improve production practices in aquaculture? *Ecol. Econ*. **187**, 107084 (2021).

Funding: Provide complete funding information, including grant numbers, complete funding agency names, and recipient's initials. Each funding source should be listed in a separate paragraph.

U.S. Department of Agriculture INFEWS grant #2018-67003-27408 (FA, BY, JLA, DCL)

Norwegian Research Council grant # 324685 and #295114 (FA, BY, AO, H-MS)

Florida Sea Grant

Author contributions:

Conceptualization: FA, BY

Methodology: FA, BY, JAG

Investigation: FA, BY, JAG, MDS, JLA, EVC, TMG, DCL, AO, H-MS

Funding acquisition: FA

Writing – original draft: FA, BY, JAG, MDS

Writing – review & editing: FA, BY, JAG, MDS, JLA, EVC, TMG, DCL, AO, H-MS

Competing interests: Authors declare that they have no competing interests.

Data and materials availability: The study uses data are from FAO's Fishstat Plus database and are publicly available at www.fao.org and the actual data used is available in the Supplement.