Updating the NOAA Fisheries Per Capita Consumption Model

Jeffrey R. Pulver, Alan Lowther, and Melissa A. Yencho

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-F/SPO-210
November 2020

Updating the NOAA Fisheries Per Capita Consumption Model

Jeffrey R. Pulver, Alan Lowther, and Melissa A. Yencho

NOAA Technical Memorandum NMFS-F/SPO-210
November 2020

U.S. Department of Commerce
Wilbur L. Ross, Jr., Secretary

National Oceanic and Atmospheric Administration
Neil A. Jacobs, Ph.D., Acting NOAA Administrator

National Marine Fisheries Service
Chris Oliver, Assistant Administrator for Fisheries

Recommended citation:

Pulver, Jeffrey R., Alan Lowther, and Melissa A. Yencho. 2020. Updating the NOAA Fisheries Per Capita Consumption Model. NOAA Tech. Memo. NMFS-F/SPO-210, 24 p.

Copies of this report may be obtained from:

Fisheries Statistics Division
Office of Science and Technology
National Oceanic and Atmospheric Administration
1315 East-West Highway
SSMC 3, Room 12441
Silver Spring, MD 20910

Or online at:
https://spo.nmfs.noaa.gov/tech-memos

Contents

Tables and Figures

Abstract

As part of the annual process of reporting fisheries data for Fisheries of the United States, the NOAA Fisheries Office of Science and Technology calculates Per Capita Consumption (PCC) of seafood products. The PCC model, and assumptions therein, have remained relatively unchanged for the last 30 years, thus historical values are comparable over time. However, a recent review of the PCC model determined that revisions were necessary to better estimate current seafood consumption. The PCC model was revised to account for improved processing efficiency of edible seafood produced domestically in the Alaska pollock (*Gadus chalcogrammus*) fishery, update conversions of edible seafood products into round weight (i.e. live weight) equivalents, and correct small errors discovered during the review process. The changes to the historic PCC model result in higher estimates of edible domestic seafood available for consumption and a resulting increase in the estimate of overall seafood consumption per person. The model changes also result in a reduction in the calculated percent of consumption attributable to imported seafood. The updates to the PCC model allow for a more accurate assessment of the seafood industry and the United States dependence on imports.

Background

Each year the NOAA Fisheries Office of Science and Technology calculates Per Capita Consumption (PCC) of seafood products as part of the process of reporting fisheries data for Fisheries of the United States (FUS) (NMFS, 2020; Table 1). The FUS report includes an estimate of the total apparent consumption of fish and shellfish. Here, apparent consumption, defined as production plus imports minus exports, serves as a proxy for actual consumption (FAO, 2020). In addition to the overall PCC value, FUS reports consumption rates of seafood broken down by product form (i.e., canned, cured, fresh, or frozen). Some product forms and species also allow for estimates that are more detailed. Estimates of canned seafood consumption are reported for certain species groups (tuna, salmon, sardines, shellfish) and consumption is also broken down by fillets and steaks, sticks, portions, and all preparations of shrimp.

The PCC calculation uses many types of fisheries-dependent data including information on commercial landings, aquaculture production, seafood processing, and international trade. The value generated by the PCC calculation serves as an indicator of seafood industry health and has many uses both internal and external to NOAA Fisheries. The PCC results are used by NOAA scientists, seafood industry professionals, academics, economists, non-governmental organizations (NGOs), the general public, and other government agencies. These groups use the PCC results for many purposes, including performing additional analysis or producing their own annual products. Due to the scope of PCC uses, the results of the PCC modeling effort generate a tremendous amount of interest from the seafood industry, the media, and seafood consumers, as well as within NOAA.

The calculation uses a "disappearance model" based on the concept of seafood supply, where seafood "losses" are subtracted from seafood "gains". In the case of the PCC model, imported seafood and fishery landings increase the available seafood supply (i.e. "gains") while exports and industrial uses (e.g. fish reduced to meal) decrease the supply (i.e. "losses"). All components of the total U.S. seafood supply, including trade products, are converted from round or product weight to a common standard of edible seafood meat weight for the purposes of the calculation. For example, the edible weight of salmon fillets is derived by converting the round, or live, weight of domestically harvested salmon to edible fillet weight based on the recovery rate of standard salmon filleting techniques. For another example, products in trade, such as breaded shrimp imported from Asia, are converted to an estimated edible weight that does not include the breading. The general methodology is described in FUS, but the detailed data used in the calculation are not released to the public due to issues of data confidentiality.

The basic PCC equation using the common weight standard of edible meat weight is:

Equation 1: $Per\ Capita\ Consumption = \frac{Domestic\ Production\ for\ Consumption + Imports - Exports}{U.S. Civilian\ Population}$

where the domestic production for consumption is the remaining total edible portion of domestic catch after industrial uses, such as reduction to meal and oil and pet food use, are subtracted.

Table 1. The annual per capita consumption of seafood products per person (lb) and percent of domestically consumed seafood from imports from 2000 through 2018 (NMFS, 2020).

Year	Per Capita Consumption	Percent Consumed from Imported Seafood
2000	15.0	68%
2001	14.6	76%
2002	15.1	79%
2003	16.3	80%
2004	16.0	81%
2005	15.9	83%
2006	16.6	84%
2007	16.5	83%
2008	16.0	83%
2009	16.0	82%
2010	15.8	86%
2011	15.0	91%
2012	14.3	94%
2013	14.4	94%
2014	14.5	94%
2015	15.5	90%
2016	14.9	95%
2017	16.0	91%
2018	16.1	94%

The PCC model, and the assumptions behind it, have remained relatively unchanged for the last 30 years, so historical values can be considered comparable over time. However, the PCC calculations are highly dependent on the underlying factors used to convert different species and product forms to the edible weight standard. Generally, the conversion factors used have not been updated, even as fisheries and seafood processors have updated their techniques, improved technology, and operated under new management regulations.

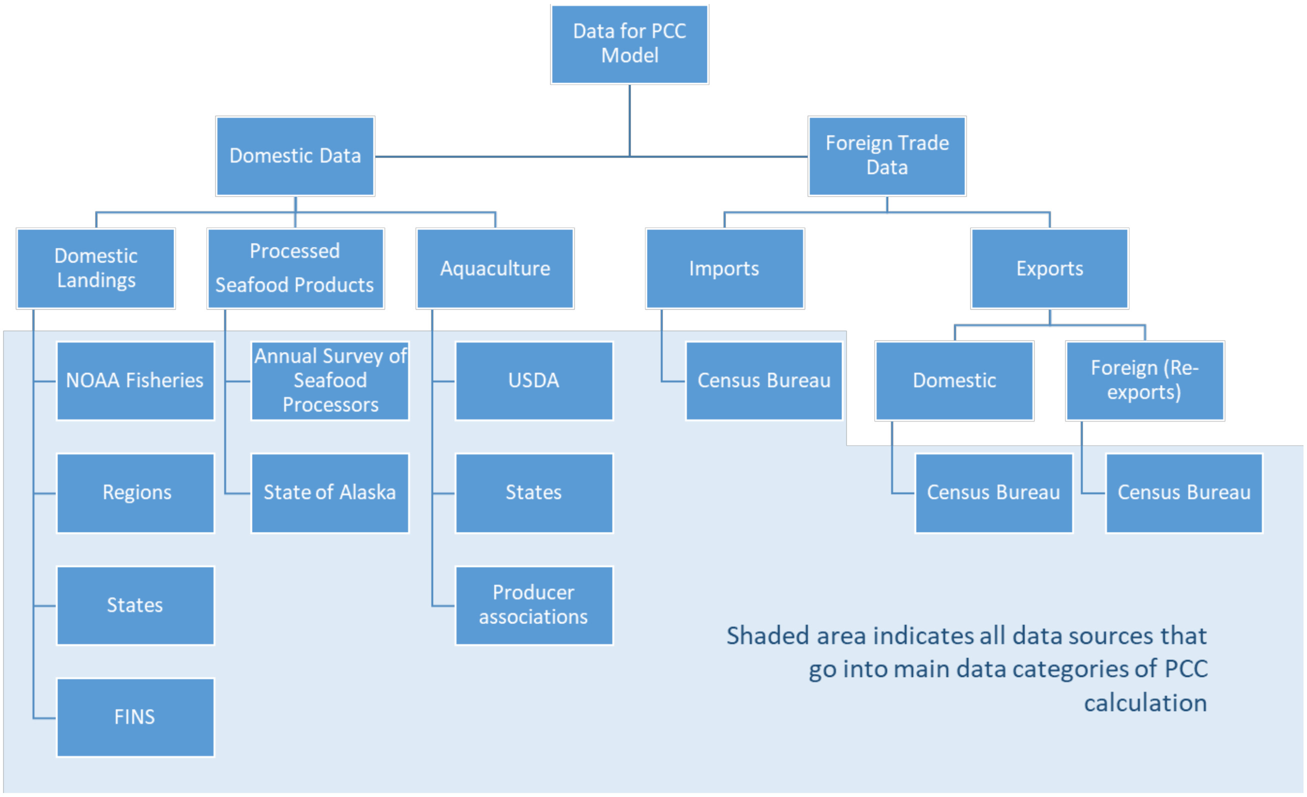

Figure 1. Data sources used in the PCC model.

Data for the PCC calculations come from several sources (Figure 1). Domestic landings data and disposition information come from regional NOAA Fisheries offices and state and regional Fisheries Information Network (FIN) partners. Foreign trade data (i.e., imports, exports, and re-exports) and population estimates come from the United States Census Bureau. Data regarding the quantity and type of processed seafood products originate mainly from the NOAA Fisheries Annual Survey of Seafood Processors. The survey covers domestic processing operations in the continental United States, Hawaiʻi, and U.S. territories and collects data on monthly employment, species utilized, product type (i.e. fresh, frozen, canned, cured, industrial), final product form, and volume and value of each reported product. One limitation of the PCC model is that the Survey of Seafood Processors is voluntary in most regions of the U.S. Therefore, the survey data used in the PCC model may not be a comprehensive reflection of the entire industry. Another potential issue with using processing data from the Survey of Seafood Processors is that data may include processing production using imported seafood, as some facilities process imported products, and that some products undergo multiple steps of processing at multiple plants (i.e. secondary processing). For example, one processing plant may fillet a fish and another processor could then smoke the fillet, which could lead to double counting of that product.

It is important to note that Alaska seafood processing data and salmon canning data are provided by the state of Alaska government and are compiled from the mandatory Commercial Operators Annual Reports (COAR), which is a census of primary processors and their production. The COAR data does not have many of the issues discussed in the previous paragraph. The availability of the more comprehensive COAR data is especially important due to the primacy of Alaska landings and, in particular, Alaska pollock landings in the PCC model, as will be discussed extensively further in this document.

Finally, some aquaculture data are provided by the United States Department of Agriculture (USDA) and other data sources, including states and associations of producers. Over time, there have been updates to the aquaculture data incorporated into the PCC calculation. Beginning in 1980, only farmed catfish, as reported by the USDA, were included in the PCC model. In 1991, farmed trout, again as reported by USDA, were added to the model. Farmed salmon, tilapia, and hybrid striped bass were included starting in 1996. Additional data were added in the 2000s, including domestically cultured shrimp and crawfish in 2007 and other cultured shellfish (mussels, oysters, and clams) in 2011. Another historical data change of note relates to the incorporation of starting seafood inventories. In 2003, beginning and end of year seafood inventories were no longer included in the model because NOAA Fisheries ended the collection of cold storage data. These minor changes to the model had only negligible impacts on the results of the PCC calculation.

Per capita consumption of fresh and frozen seafood products and of canned seafood products are calculated separately in the PCC model, due to differences in how the domestic production data are organized. Each calculation is based on the disappearance model described previously (i.e. the sum of domestic production and imports minus the exports, and divided by the population). The calculation for domestic fresh and frozen product consumption is the most complicated aspect of the PCC model. The estimation process starts with an estimate for the round weight equivalent of domestic landings of fish and shellfish. This estimate is produced as part of the annual Fisheries of the United States reporting. Then data from the Survey of Seafood Processors on the domestic product of fillets, blocks, steaks, and shellfish products is converted from product weight to an estimated round weight equivalent. This amount is then subtracted from the round weight equivalent of domestic landings. Next, fish and shellfish product that went into canned, cured, and surimi production are subtracted from the available total. Finally, a general conversion to edible seafood weight is applied to the remainder of the domestic landings.

$$
\begin{aligned}
\textit{Equation 2}: &\ \textit{Remainder of Domestic Landings (round weight)} \\
&= \textit{Domestic Landings (round weight)} - \textit{Fillets, Steaks \& Blocks (round weight)} \\
&- \textit{Surimi (round weight)} - \textit{Processed Shellfish (round weight)}
\end{aligned}
$$

The model was set up this way because the Survey of Seafood Processors is optional in most of the country and it was necessary to estimate the portion of domestic production not accounted for in the survey. But, because the Alaska processing data is based on a complete census, those data provide the actual volume of pollock processed products, so that pollock can be considered separately. This is the key fact that drives the improvements to be discussed later in this paper.

Canned item calculations are more straightforward due to the availability of data and known conversion factors. Canned product data are already converted to edible weight when received or known conversions exist that make conversion straightforward. Cured consumption is the most difficult to calculate, primarily due to a lack of data. The Survey of Seafood Processors provides some data on cured production but there are still gaps and limitations.

The purpose of this research was to review the PCC model, examine the parameters that have the greatest impact, and use the results to improve the PCC model and generate more accurate estimates of U.S. per capita consumption of seafood. The data and estimates that we aim to improve are important indicators of the state of the seafood industry and our dependence on imported seafood. Improvements in these estimates will allow NOAA Fisheries to better target their strategies and policies in areas related to seafood trade and availability.

Model Updates

The first step taken in reviewing the historical PCC model was to create a Sankey diagram (Kennedy and Sankey, 1898) mapping the flows and amounts of edible seafood from the different inputs in the model. The Sankey diagram can also show the relative impact of each flow, and therefore, can be used to identify areas of particular importance and influence over the model. The resultant Sankey diagram from the 2018 historical model revealed only a very small portion of domestic consumption originating from the domestic fresh and frozen seafood supply, with the vast majority of domestic production being exported (Figure 2).

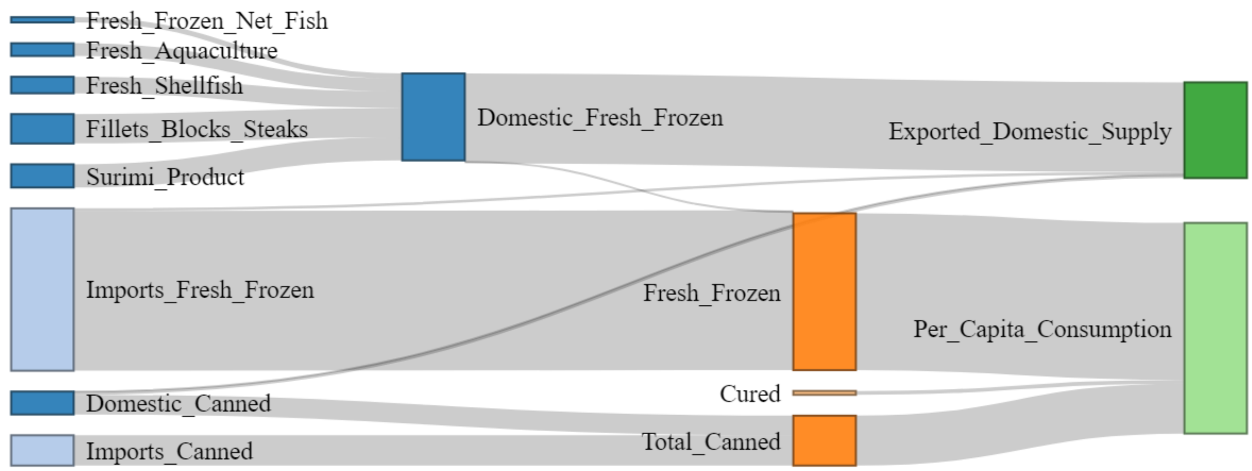

Figure 2. A Sankey diagram mapping the flows in the 2018 historic PCC model. Note: the height of the bar is proportional to the contribution to the model.

Although it is known that the U.S. imports and exports a large amount of seafood (NMFS, 2020), the very small percentage of the domestic fresh and frozen supply that is domestically consumed according to the model was thought to be an unrealistic underestimate. Thus, the initial focus was placed on exploring the domestic fresh and frozen section of the PCC model. In particular, the main area of interest in the domestic fresh and frozen section of the model was Alaska pollock (*Gadus chalcogrammus*) [note that this species is also often referred to as "walleye pollock." For the purposes of this paper, "pollock" will be used to refer to this species.], as this species constitutes the largest percentage of domestic landings. For example, in 2018, pollock landings were 3.4 billion pounds and represented 35.8% of total U.S. seafood landings (Table 2). After excluding menhaden, which are not typically consumed but are used for industrial products and bait, the percentage of domestic catch made up of pollock increases to 43.1%. This large percentage makes it clear that the correct treatment of pollock in the model is critical.

Table 2. Major U.S. domestic species groups landed in 2018 ranked by volume (NMFS, 2020).

Rank	Species	Thousand Pounds
1	Alaska pollock	3,363,901
2	Menhaden	1,581,578
3	Hakes (mostly **Pacific whiting)**	703,508
4	Salmon	575,972
5	Flatfish	546,999
6	Cods (mostly Pacific cod)	515,554
7	Shrimp	289,178
8	Crabs	289,021
9	Rockfishes	202,419
10	Squid	161,628
Total	**All Species**	**9,385,368**

The Pollock Fishery

A key assumption in the PCC model is that surimi from Alaska pollock is a primary product with no other edible portions associated with it. In reality, some of the surimi produced is a secondary, or ancillary, product, making use of scraps remaining after fillets and other products have been processed. For example, in 2018, 20% of the total surimi produced was from secondary production according to the Alaska COAR data. In this paper, the term surimi refers to raw frozen blocks and not to surimi seafood or surimi analog.

In the pollock fishery, the same fish can be processed into multiple edible products such as surimi, fillets, blocks, and roe (Strong and Criddle, 2013). The historic PCC model revealed that, when edible processed pollock products were converted to their whole or round weight equivalents, the sum of the round weights from those products was substantially greater than the volume actually landed in the fishery. For example, in 2018, the round weight equivalent when converting edible products from the processed products survey was calculated to be almost five billion pounds while the fishery only landed 3.3 billion pounds. The inflated round weight equivalent of pollock results in too much pollock being subtracted from domestic landings because the PCC model calculates consumption based on the disappearance of domestic landings from converted edible product. The overestimation causes the model to underestimate consumption of domestic edible seafood because an inaccurately high volume of pollock is being subtracted from the domestic landings. As was noted earlier, historically this indirect method was employed due to the voluntary nature of the national Survey of Seafood Processors. But the availability of a different data source, the Commercial Operators Annual Reports (COAR) from the state of Alaska allows for directly calculating edible products coming from the pollock processing industry.

Further investigation revealed policy and technological changes that affect some of the base assumptions of the PCC model. In 1979, foreign fishing fleets landed 99% of the pollock in the U.S., but a number of policies shifted nearly the entire catch to the domestic fleet by the end of the 1980s (Strong and Criddle, 2013). Domestic pollock landings have been fairly consistent since the early 1990s, with the exception of a reduction in quotas in 2009 and 2010 due to reduced biomasses (Figure 3). However, an increase in processing efficiency has occurred as evidenced by a substantial increase in fillet, steak, and block production in the early 2000s, while maintaining relatively consistent surimi and other edible seafood production (Figure 4). In the historic model, the effect of increases in processing efficiency are not accounted for, causing the model to assume more fish are required to produce a certain amount of edible meat weight. The result is a decrease in the consumption estimate as less product is available per person. The impact from pollock is most pronounced due to the huge volume of this catch and the industry changes detailed, but all conversion factors used also have the ability to affect the model.

Figure 3. Domestic landings of pollock beginning in 1986 compared to edible pollock produced annually.

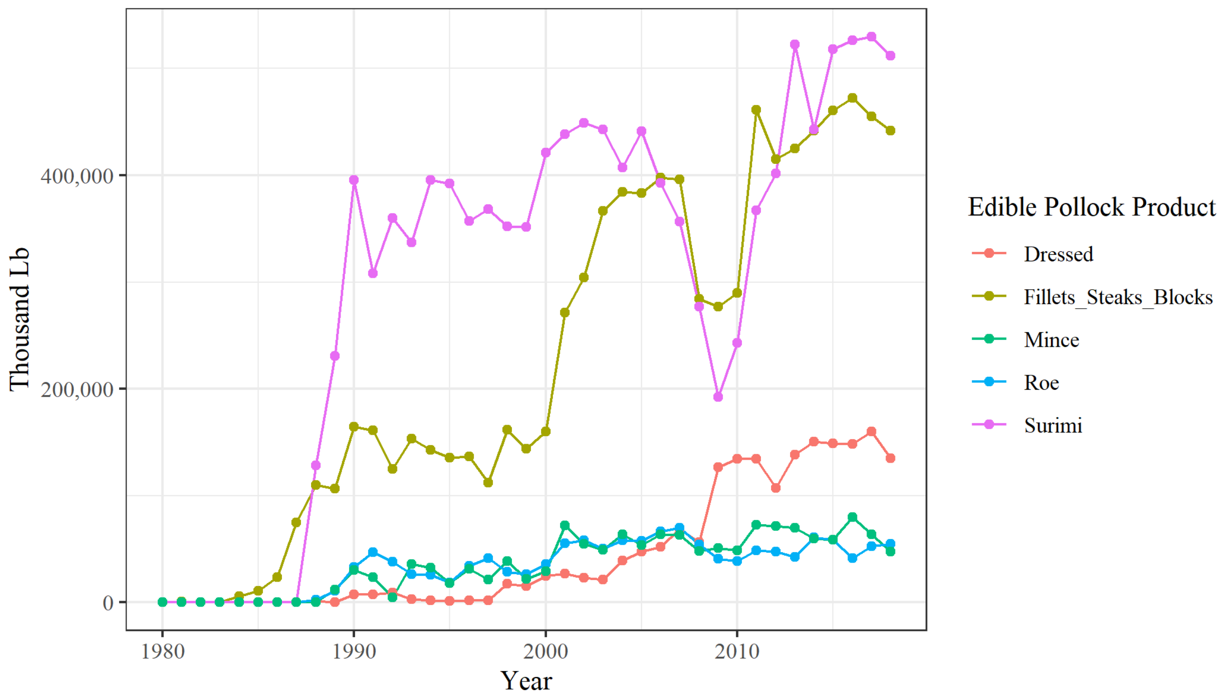

Figure 4. The amount of edible domestic pollock products included in the historical PCC model based on Annual Survey of Seafood Processors data.

Consultations with industry and NOAA Fisheries experts revealed three main factors that explain how the pollock fishery became more efficient at producing edible seafood. First, the American Fisheries Act (AFA, 1998) provided the Bering Sea and Aleutian Islands pollock fleet the opportunity to conduct their fishery in a more rational manner while protecting non-AFA participants in other fisheries. The AFA established sector allocations in the Bering Sea and Aleutian Islands pollock fishery, determined eligible vessels and processors, allowed the formation of cooperatives, set limits on the participation of AFA vessels in other fisheries, and imposed special catch weighing and monitoring requirements on AFA vessels. The AFA allowed for more efficient processing of pollock because the race to fish had been substantially diminished.

Second, technological improvements in the mechanical cutting of pollock have substantially increased yield (Park, 2014). Vessels and processors could now target larger pollock to produce fillets, which have a higher ex-vessel price compared to surimi. The third change was the development of decanter technology that allowed substantially more surimi to be produced from secondary products (Park, 2014). The historical PCC model treated surimi as a primary product, even though a significant portion of surimi can be a secondary product. The assumption of the historical PCC model was that pollock primarily processed for surimi or fillets had no other edible portion associated with it, leading to an overestimation of the round weight equivalent of pollock in the model. In reality, pollock byproducts were going into surimi production after primary processing. Preliminary calculations by NOAA Fisheries indicated that the value for surimi, and the associated conversion factor, have a significant effect on the PCC model due to the large scale of surimi production.

The combination of these factors led to a substantial increase in the efficiency of edible products being produced from the pollock fishery beginning in the late 1990s. Pollock processors have increased their overall recovery rates and also increased the portion of the fish devoted to high value flesh products. For example, the seafood product recovery rates of the Bering Sea and Aleutian Islands pollock have increased from 25% of retained catch in 1998 to over 40% of retained catch in 2010 (Strong and Criddle, 2013). The majority of processors have the ability to process everything except eyes. Previously, any part of the fish not used for fillets or surimi was turned into fishmeal and oil, or ground up and discharged as effluent. Strong and Criddle (2013) also report that pollock processors increased flesh (fillet and surimi) recovery rates from 17% of retained catch in 1998 to over 26% of retained catch by 2010, an increase of 56%. In 2018, based on COAR data, the flesh (fillet and surimi) recovery rate had increased to over 28% of the landings volume.

Prior to the utilization of flow scales in the pollock fishery in the 1990s, catch from pollock was estimated using product recovery rates and the production of surimi from the at-sea processing vessels. A consistent conversion factor was applied to expand the surimi production into an estimate of the actual catch. Advances in processing efficiency meant that this constant conversion factor was becoming less and less accurate. The use of flow scales allowed for the catch to be measured directly, reducing this inefficiency and inaccuracy in the measurement of the pollock catch. However, the historical PCC model continued to overestimate the amount of raw pollock catch contributing to the surimi production and thus, resulting in less pollock available for domestic consumption. Here, the historical PCC model was updated to account for the improvements in pollock processing efficiency by separating pollock from the rest of the domestic fresh and frozen edible supply. The updated model directly takes edible pollock products as edible seafood from the data provided by the Alaska COAR census. Because all edible pollock products are assumed to be accounted for, pollock landings are removed from the disappearance portion of the domestic supply calculation and no conversions to round weight are needed for edible pollock products. The update in how domestic pollock is input allows the model to automatically account for any future changes in processing efficiency that could occur in the fishery. Note that because pollock is primarily landed in Alaska and we have good data on product forms from the state, we can treat pollock separately. For most species the available data are not robust enough for similar treatment.

Conversion Factors

In addition to the treatment of pollock, other aspects of the calculation of edible domestic fresh and frozen seafood consumption were examined. As detailed previously, edible seafood products obtained from the Survey of Seafood Processors is a component of the model. However, most of the edible products need to be converted into a round weight equivalent using conversion factors (Table S.3). The round weight equivalents are then subtracted from domestic landings. Because the Survey of Seafood Processors is not a census, a general value is applied to convert the remainder of domestic landings into edible weight. The large number (76) of conversion factors for fillets, steaks, and blocks to round weight were first examined. Analyses determined that when the three largest edible product categories of Pacific cod, Pacific hake, and salmon fillets were removed, one value could be applied to the remaining edible fillets, steaks, and blocks. This reduces model complexity and results in a more parsimonious model less prone to annual shifts in potential biases resulting from non-reporting by companies. The annual weighted mean (product weight) of the conversions was retrospectively examined and based on the best fit, a value of 0.345 was estimated for use in the updated model, resulting in a more parsimonious model (Figure 5). The updated value of 0.345 is not capturing changes in production efficiency over time as much as it is capturing shifts towards or away from products with higher or lower product recovery rate.

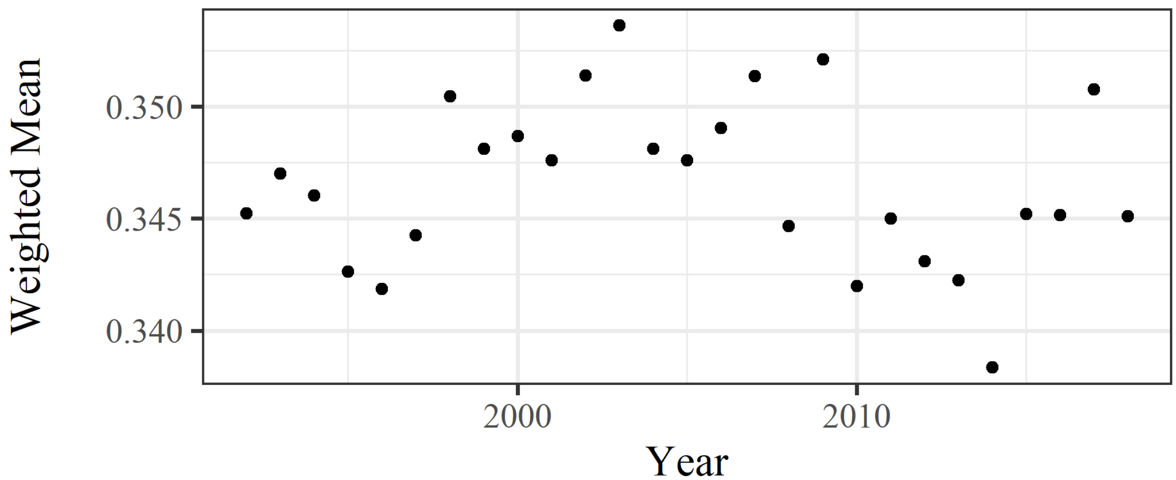

Figure 5. The annual weighted mean of fillet, steak, and block conversions removed from the updated PCC model.

In addition, the conversion to edible weight applied to the remainder of domestic landings was also examined. The remainder of domestic landings is calculated as

$$Domestic\ Landings(Round\ Wt.) - Fillets, Steaks, \&\ Blocks\ (Converted\ to\ Round\ Wt.) - \\ Surimi\ (Converted\ to\ Round\ Wt.) - Processed\ Shellfish\ (Converted\ to\ Round\ Wt.)$$

A value of 0.45 is used in the historical model for converting the remainder of domestic landings into edible meat weight. The previously described methodology was used, retrospectively examining the annual weighted mean (product weight) of all conversions for domestic fresh and frozen products in the model. The same conversion currently used (0.45) was determined to be accurate, assuming products in the Survey of Seafood Processors are representative of domestic landings not included in the survey (Figure 6).

Other small changes and updates

Some small changes were made in the canning section for a more parsimonious model. Some canned items entered twice in the model as both an addition and removal were simplified into one entry by altering certain conversion factors. A small error was also corrected by changing an input from round weight to edible weight when calculating the edible value of products labeled as "canned other." Because beginning- and end-of-year inventories were removed from the PCC model in 2004, the updated PCC model excluded those inputs due to the continued lack of data. Small differences when comparing the models prior to 2004 may be due to the removal of the beginning and end of year inventories in the calculations. Also, some small differences were present from the PCC values currently published in FUS 2018 (NMFS, 2020) and those in the updated model that could not be explained, due to the lack of historic model documentation.

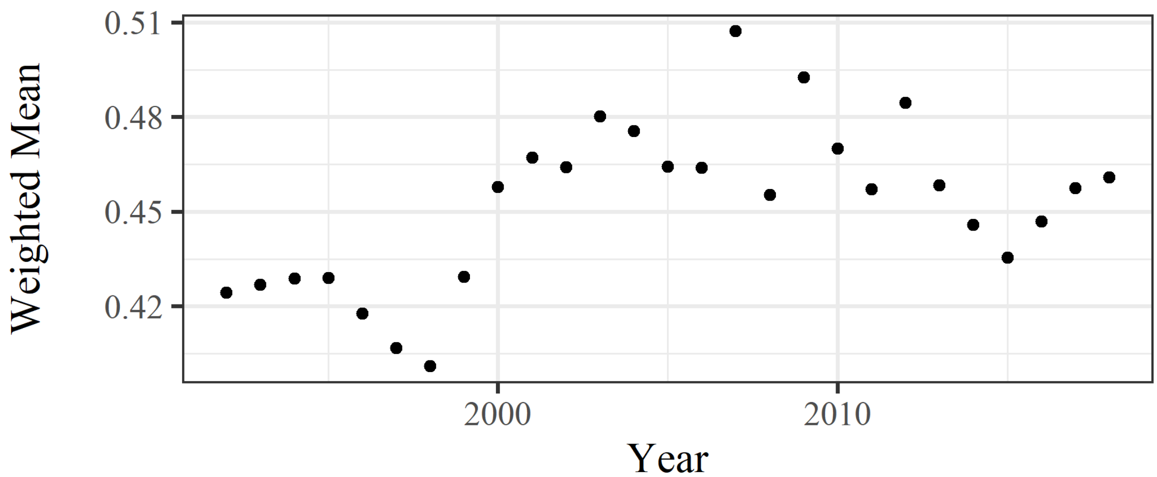

Figure 6. The annual weighted mean of all domestic fresh and frozen product conversions.

Historical Comparison

The updated PCC model results in an increase in edible domestic supply beginning in the mid-1990s, primarily as a result of improved processing efficiency of pollock (Figure 7) and the separate treatment of pollock in the model. The difference in edible domestic supply between the models steadily increased until 2011 and has been fairly consistent since then, likely due to a stabilization in the processing efficiency of pollock.

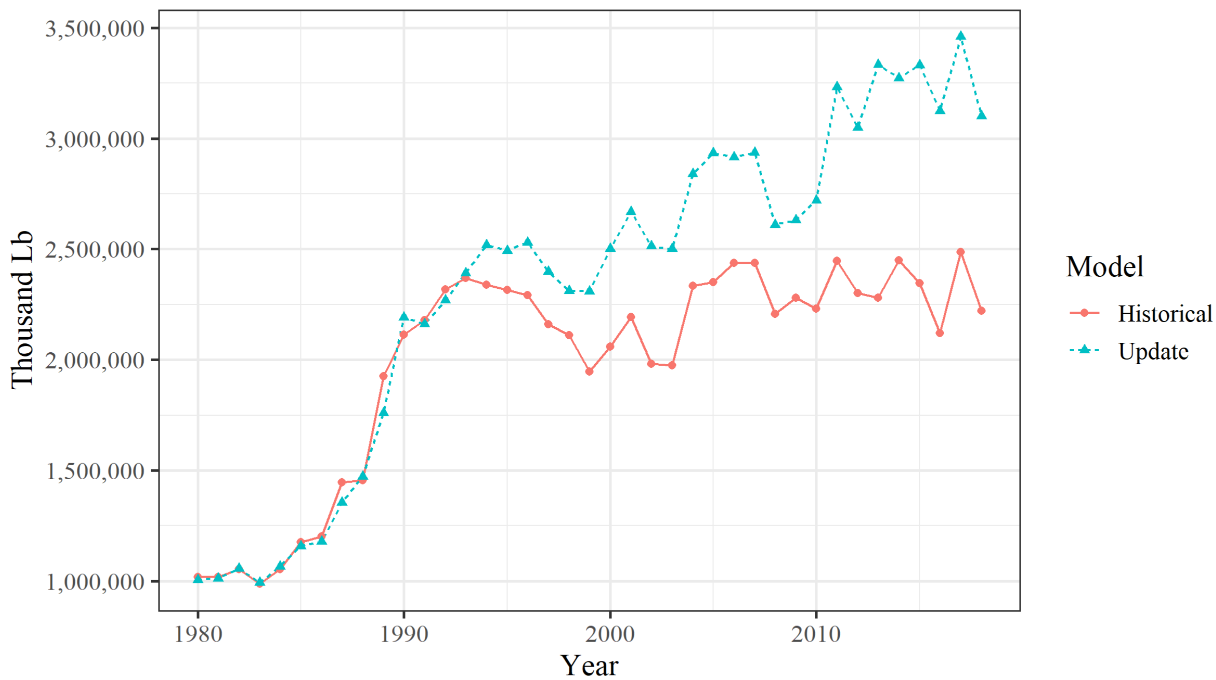

Figure 7. A comparison of edible domestic supply between the historical and updated model.

The updated PCC model results in a small increase in the per capita consumption of edible seafood compared to the historical model beginning in 1994, but the difference increases in 1999 coinciding with the introduction of the AFA (Figure 8; Table S.1). The updated model demonstrates a steady increase in the per capita consumption of edible seafood beginning in the late 1990s compared to the historic model, which has had a fairly flat trend on the same time series. In 2018, the updated PCC model predicts 18.9 lbs per person of edible seafood consumed in the United States. The 2018 updated PCC model consumption is 2.8 lbs per person increase compared to the historical model. The updated PCC model also estimates a lower percentage of seafood consumption that comes from imports, compared to the historical model (Figure 9; Table S.2). In 2018, the percent of seafood consumed that comes from imports declined from 94% in the historic model to 80% in the updated PCC model.

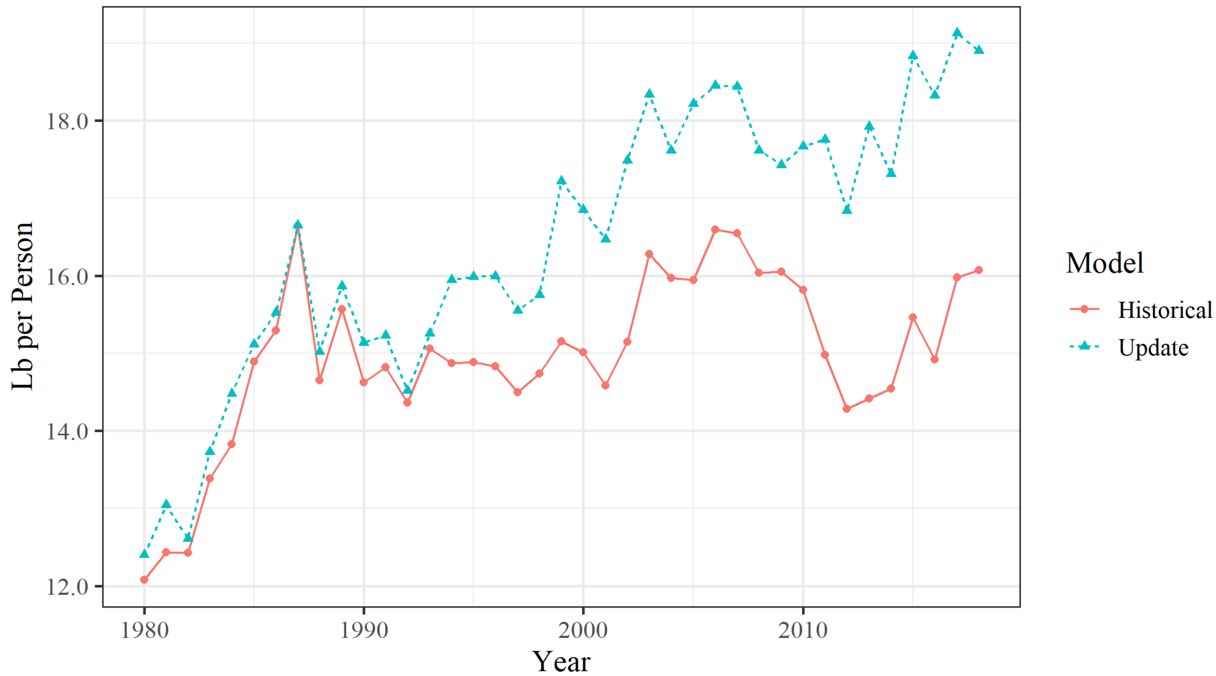

Figure 8. A comparison of per capita consumption of edible seafood between the historical and updated model.

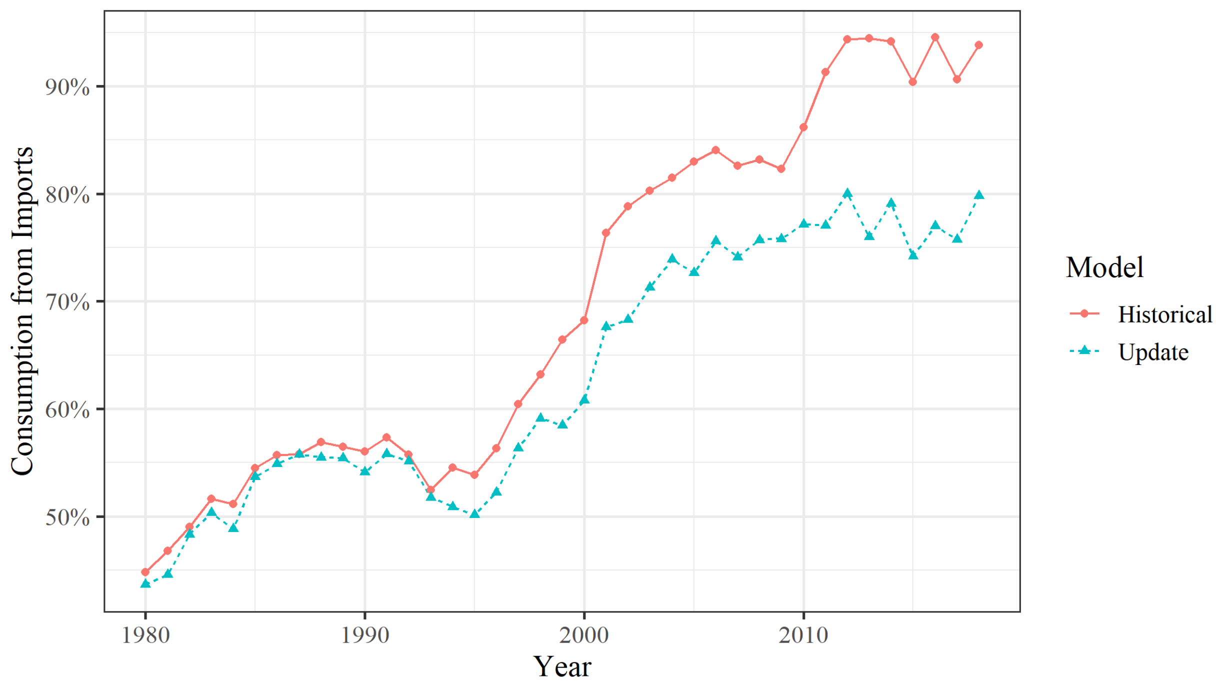

Figure 9. A comparison of percent of consumption of imported edible seafood between the historical and updated model.

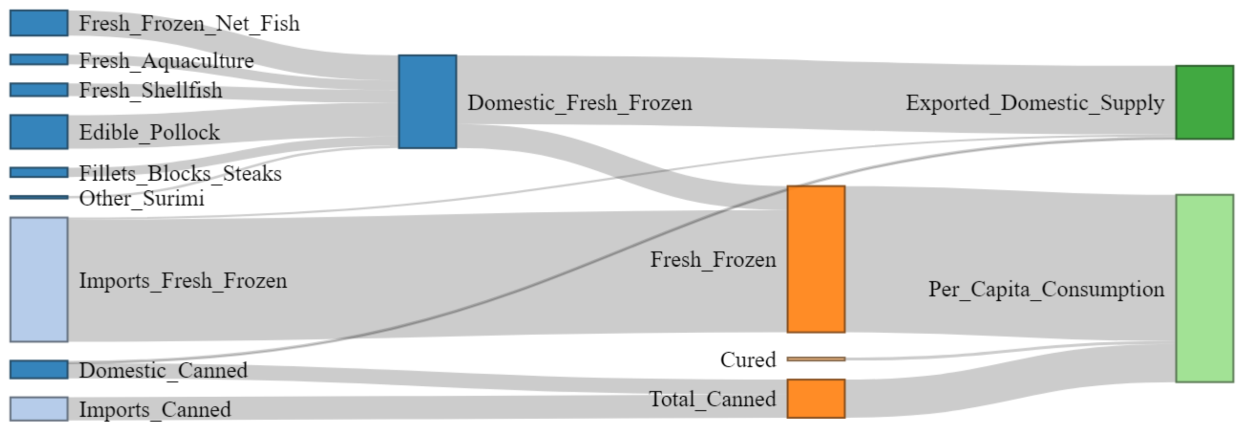

Figure 10. A Sankey diagram mapping the flows in the 2018 updated PCC model. Note: the height of the bar is proportional to the contribution to the model.

The Sankey diagram for the updated model in 2018 revealed a larger portion of the domestic fresh and frozen seafood supply being consumed domestically (Figure 10; Table S.4). The updated model's Sankey diagram for 2018 is thought to be a more accurate representation of the seafood supply compared to the historical model. A number of sensitivity analyses isolating the differences from the changes revealed that updating pollock in the model is responsible for over 80% of the increased consumption annually since 2000 and over 90% in recent years (Figures S.1-S.3).

Additional concerns were identified during the PCC model review process, including unreported and small-scale fisheries landings, recreational landings, imports of foreign products derived from domestic harvest, seafood waste, and potentially unreliable conversion factors for imported and exported products. These concerns could not be incorporated into this update of the model due to the lack of reliable or accurate data, but they could provide the starting point for developing further refinements and improvements. The updated model does not include estimates of unreported domestic landings and some small-scale fisheries, which would further increase the domestic supply and reduce the percent of imported seafood consumed. In addition, the model could incorporate those domestic recreational landings that would also contribute to the edible domestic supply. For example, approximately 0.3 lb per person of domestic consumption could be added to the consumption estimate by assuming a generic conversion value of 0.25 to edible weight for the 2018 recreational harvest, and assuming that all harvest was consumed (NMFS, 2020). Future work could explore treating other species similarly to the improvements made for pollock, such as Pacific cod, which is also reported through the COAR. A mandatory national seafood processing survey would greatly simplify the PCC model because all edible products could be directly accounted for.

The updated PCC model does not address consumption of imports that are of domestic origin. Seafood is one of the most highly traded commodities on the global market. From 1994 to 2012, the quantity of seafood traded globally increased by 58% and the value of those products increased by 85% (Gephart and Pace, 2015). Because of the lack of the necessary trade data, the updated PCC model cannot determine how much domestically harvested seafood is exported to be processed overseas and then is imported back into the United States for consumption as part of the global seafood chain. In addition, inaccurate conversion factors can cause the model to result in exporting more seafood and importing more foreign fish than actually occurred. Recent analyses by Gephart et al. (2019) using a range of possible values for imported seafood of domestic origin and different weight conversion factors indicated a substantially lower reliance on imported seafood than the historic PCC model predicted. Gephart et al. (2019) estimated as much as 38% of imported seafood consumed in the United States is of domestic origin. It is important to note that a calculation of the *foreign-caught* seafood contribution to consumption is not the same as a calculation of the *imported* seafood contribution to consumption. That is, imports of domestically caught, but foreign-processed seafood are still considered imports. Unfortunately, the current foreign trade data do not allow for precise estimates of the domestic seafood processed overseas that returns to the United States as an imported product.

The issue may be further compounded by imported illegal and unreported fish and seafood products. Some authors (Pramod, 2014) estimate as much as 20% and 32% of wild-caught imports are illegal or unreported seafood, primarily due to the murky supply chains and lack of reliable traceability controls. NOAA Fisheries Seafood Import Monitoring Program (SIMP) has established reporting and recordkeeping requirements for imports of certain seafood products to combat illegal, unreported and unregulated (IUU) catch and mis-identified seafood from entering U.S. commerce. SIMP is a risk-based traceability program requiring the importer of record to provide and report key data, from the point of harvest to the point of entry into U.S. commerce, on imported fish and fish products identified as vulnerable to IUU fishing and/or seafood fraud. If the ability to accurately track domestic products in the global seafood market develops, future research can develop better models to quantify the amount of imported seafood that is of domestic origin.

Overall, improved data collection systems should allow for more precise values to track the sustainability of our domestic food supply and guide effective policy changes. The United States continues to be a global leader in fishery management resulting in sustainable harvest (Melnychuk et al., 2017). The updates to the PCC model allow for a more accurate assessment of the state of the seafood industry and our dependence on imported seafood.

Acknowledgements

We would like to thank Ben Fissel, Jessica Gephart, Steve Koplin, Mike Larkin, Britni LaVine, John McGovern, Jae Park, Ron Rogness, Jessica Stephen, and Mike Travis for reviewing the manuscript. The National Marine Fisheries Service does not approve, recommend, or endorse any proprietary product or material mentioned in this publication. The scientific results and conclusions, as well as any views or opinions expressed therein, are those of the author(s) and do not necessarily reflect the views of NOAA or the Department of Commerce.

References

American Fisheries Act of 1998. U.S. Code, volume 46, sections 201–213.

Crapo, C., B. Paust, and J. Babbitt. 2004. Recoveries and yields from Pacific Fish and Shellfish. Alaska Sea Grant College Program Marine Advisory Bulletin No. 37, 32 p. https://doi.org/10.4027/rypfs.2004

Food and Agriculture Organization (FAO). 2020. Food balance sheets on apparent consumption. Food and Agriculture Organization of the United Nations, Rome, Italy. Available at: http://www.fao.org/cwp-on-fishery-statistics/handbook/socio-economic-data/food-balance-sheets/en/.

Gephart, J. A., and M. L. Pace. 2015. Structure and evolution of the global seafood trade network. Environmental Research Letters Vol. 10, No. 12. https://doi.org/10.1088/1748-9326/10/12/125014

Gephart, J. A, Froehlich, H. E., and T. A. Branch. 2019. Opinion: To create sustainable seafood industries, the United States needs a better accounting of imports and exports. Proc. Natl. Acad. Sci. U.S.A 116(19):9142–9146. https://doi.org/10.1073/pnas.1905650116

Kennedy, A. B. W., and H. R. Sankey. 1898. The thermal efficiency of steam engines. Minutes of the Proceedings of the Institution of Civil Engineers. 134:278–312. https://doi.org/10.1680/imotp.1898.19100

Melnychuk, C. M., E. Peterson, M. Elliott, and R. Hilborn. 2017. Fisheries management impacts on target species status. Proc. Natl. Acad. Sci. U.S.A. 114(1):178 –183. https://doi.org/10.1073/pnas.1609915114

National Marine Fisheries Service (NMFS). 2020. Fisheries of the United States, 2018. U.S. Dep. Commerce, NOAA Current Fishery Statistics No. 2018. Available at: https://www.fisheries.noaa.gov/feature-story/fisheries-united-states-2018

Park, J. W. 2014. Surimi and Surimi Seafood, third edition. 666 p. CRC Press, Boca Raton, FL.

Pramod, G., K. Nakamura, T. J. Pitcher, and L. Delagran. 2014. Estimates of illegal and unreported fish in seafood imports to the USA. Marine Policy 48:102–113. https://doi.org/10.1016/j.marpol.2014.03.019

Strong, J., and K. R. Criddle. 2013. Fishing for Pollock in a Sea of Change: A Historical Analysis of the Bering Sea Fishery. 188 p. Alaska Sea Grant, Univ. Alaska Fairbanks. https://doi.org/10.4027/fpschabspf.2013

Supplemental Information

Table S.1. A comparison of per capita consumption (lb per person) of edible seafood between the historical and updated model.

Year	Historic Per Capita Consumption	Updated Per Capita Consumption	Change
1980	12.1	12.4	+0.3
1981	12.4	13.0	+0.6
1982	12.4	12.6	+0.2
1983	13.4	13.7	+0.3
1984	13.8	14.5	+0.7
1985	14.9	15.1	+0.2
1986	15.3	15.5	+0.2
1987	16.6	16.6	—
1988	14.7	15.0	+0.3
1989	15.6	15.9	+0.3
1990	14.6	15.1	+0.5
1991	14.8	15.2	+0.4
1992	14.4	14.5	+0.1
1993	15.1	15.3	+0.2
1994	14.9	15.9	+1.0
1995	14.9	16.0	+1.1
1996	14.8	16.0	+1.2
1997	14.5	15.6	+1.1
1998	14.7	15.8	+1.1
1999	15.2	17.2	+2.0
2000	15.0	16.8	+1.8
2001	14.6	16.5	+1.9
2002	15.1	17.5	+2.4
2003	16.3	18.3	+2.0
2004	16.0	17.6	+1.6
2005	15.9	18.2	+2.3
2006	16.6	18.4	+1.8
2007	16.5	18.4	+1.9
2008	16.0	17.6	+1.6
2009	16.0	17.4	+1.4
2010	15.8	17.7	+1.9
2011	15.0	17.8	+2.8
2012	14.3	16.8	+2.5
2013	14.4	17.9	+3.5
2014	14.5	17.3	+2.8
2015	15.5	18.8	+3.3
2016	14.9	18.3	+3.4
2017	16.0	19.1	+3.1
2018	16.1	18.9	+2.8

Table S.2. A comparison of percent of consumption of imported edible seafood between the historical and updated model.

Year	Historic Percent Consumed from Imported Seafood	Updated Percent Consumed from Imported Seafood	Change
1980	45%	44%	-1%
1981	47%	45%	-2%
1982	49%	48%	-1%
1983	52%	50%	-2%
1984	51%	49%	-2%
1985	54%	54%	—
1986	56%	55%	-1%
1987	56%	56%	—
1988	57%	55%	-2%
1989	56%	55%	-1%
1990	56%	54%	-2%
1991	57%	56%	-1%
1992	56%	55%	-1%
1993	52%	52%	—
1994	55%	51%	-4%
1995	54%	50%	-4%
1996	56%	52%	-4%
1997	60%	56%	-4%
1998	63%	59%	-4%
1999	66%	58%	-8%
2000	68%	61%	-7%
2001	76%	68%	-8%
2002	79%	68%	-11%
2003	80%	71%	-9%
2004	81%	74%	-7%
2005	83%	73%	-10%
2006	84%	76%	-8%
2007	83%	74%	-9%
2008	83%	76%	-7%
2009	82%	76%	-6%
2010	86%	77%	-9%
2011	91%	77%	-14%
2012	94%	80%	-14%
2013	94%	76%	-18%
2014	94%	79%	-15%
2015	90%	74%	-16%
2016	95%	77%	-18%
2017	91%	76%	-15%
2018	94%	80%	-14%

Table S.3. The domestic fresh and frozen conversion factors from whole or round weight to edible weight used in the updated PCC model with source information if available.

Product Type	Species Group	Conversion Factor	Source
Fillets, Steaks, & Blocks	Pacific Cod	0.32	Crapo et al. (2004)
	Pacific Hake	0.33	From Original Model
	Salmon (Fillet)	0.60	From Original Model
	Unclassified	0.345	30-year weighted mean for all unclassified species
Surimi	Other Surimi (not Alaska pollock)	0.17	Park[1]
Aquaculture	Catfish	0.50	From Original Model
	Trout	0.72	From Original Model
	Salmon	0.60	From Original Model
	Tilapia	0.38	From Original Model
	Striped Bass	0.65	From Original Model
	Shrimp	0.49	From Original Model
	Crawfish	0.49	From Original Model
Shellfish	Blue Crab, Hard	0.14	From Original Model
	Dungeness Crab	0.24	From Original Model
	King Crab	0.19	From Original Model
	Snow Crab (Opilio & Bairdi)	0.24	From Original Model
	Crab, Other (All other including blue soft and peeler, Jonah)	0.18	From Original Model
	Crawfish (Wild catch not aquaculture)	0.49	From Original Model
	American Lobster	0.22	From Original Model
	Spiny Lobster	0.23	From Original Model
	Shrimp: Northeast, Pacific, & Other	0.28	From Original Model
	Shrimp: South Atlantic & Gulf	0.49	From Original Model
	Squid	0.60	From Original Model

[1] Park, Jae. Personal commun. Oregon State University, jae.park@oregonstate.edu.

Table S.4. The values used to create the Sankey diagram mapping the flows in the 2018 updated PCC model.

Data Source	Data Target	Lb/Person
Domestic_Canned	Canned_Total	1.28
Domestic_Canned	Exported_Domestic_Supply	0.25
Imports_Canned	Canned_Total	2.37
Fresh_Frozen_Net_Fish	Domestic_Fresh_Frozen	2.57
Fresh_Aquaculture	Domestic_Fresh_Frozen	0.99
Fresh_Shellfish	Domestic_Fresh_Frozen	1.29
Edible_Pollock	Domestic_Fresh_Frozen	3.43
Fillets_Blocks_Steaks	Domestic_Fresh_Frozen	0.94
Other_Surimi	Domestic_Fresh_Frozen	0.25
Domestic_Fresh_Frozen	Exported_Domestic_Supply	7.02
Domestic_Fresh_Frozen	Fresh_Frozen	2.46
Imports_Fresh_Frozen	Fresh_Frozen	12.49
Imports_Fresh_Frozen	Exported_Domestic_Supply	0.21
Fresh_Frozen	Per_Capita_Consumption	14.95
Canned_Total	Per_Capita_Consumption	3.65
Cured	Per_Capita_Consumption	0.30

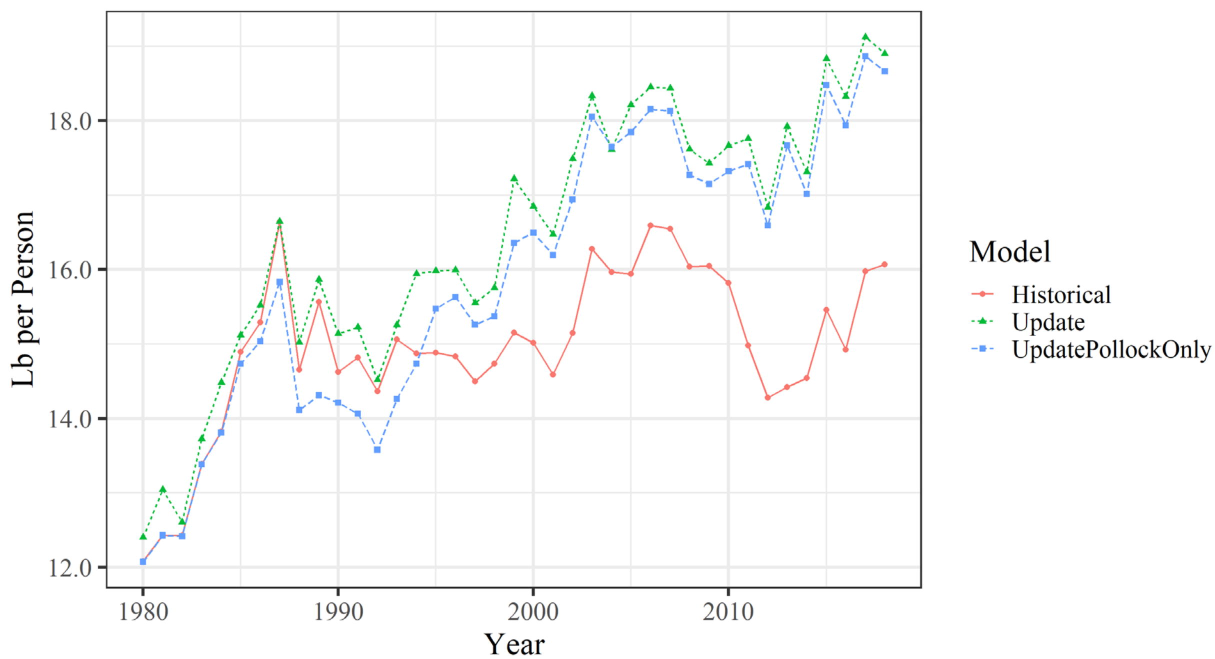

Figure S.1. A sensitivity analysis comparing the per capita consumption of edible seafood between the historical model, updated model, and the model updating only pollock.

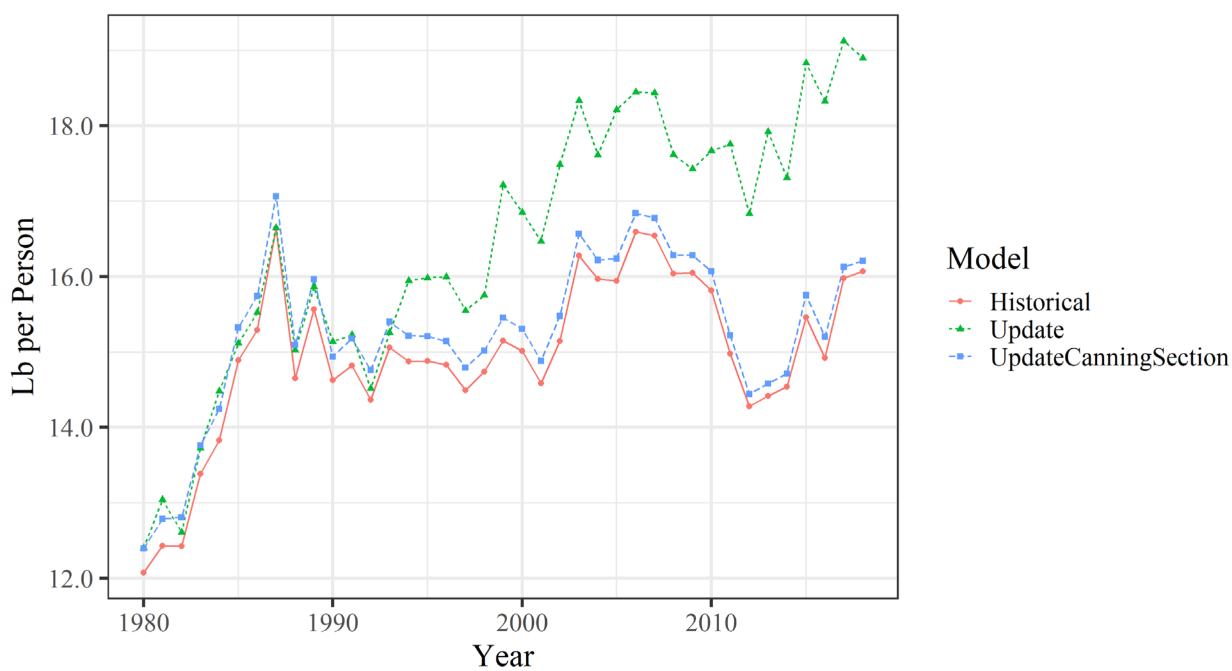

Figure S.2. A sensitivity analysis comparing the per capita consumption of edible seafood between historical model, updated model, and the model updating only the canning section.

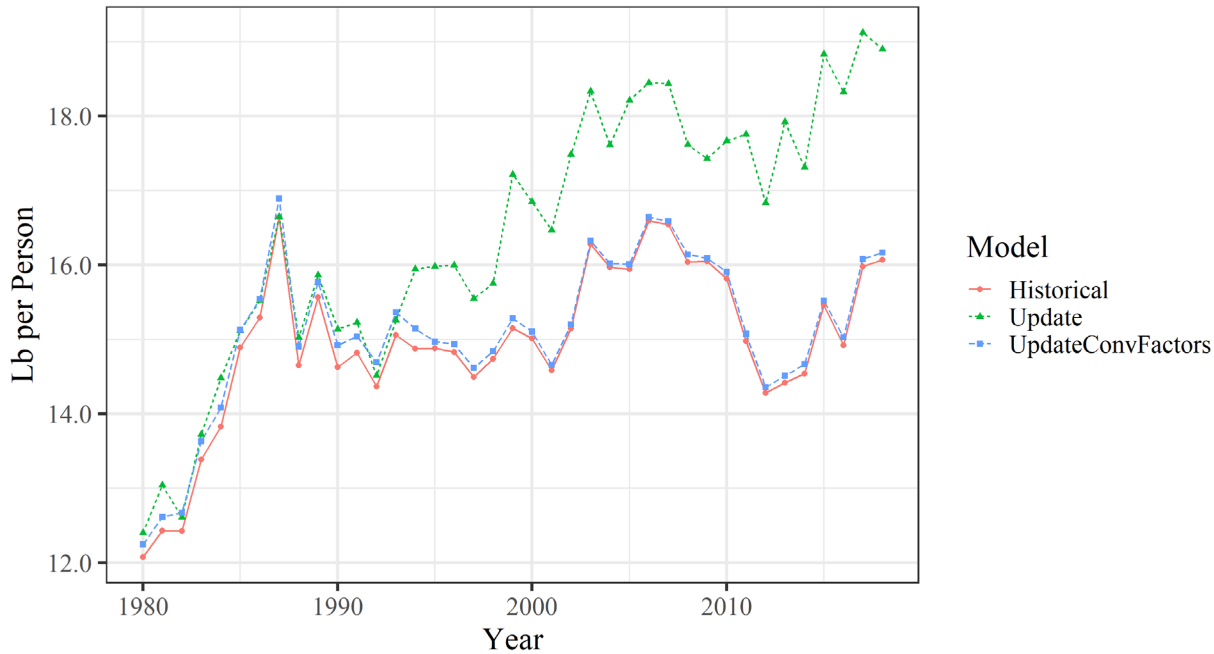

Figure S.3. A sensitivity analysis comparing the per capita consumption of edible seafood between the historical model, updated model, and the model updating only the conversion factors.