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https://www.st.nmfs.noaa.gov/economics/fisheries/commercial/catch-share-program/index

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Productivity Change in U.S. Catch Share Fisheries

Executive Summary

NOAA Fisheries Office of Science and Technology has initiated a national program including development and reporting of indicators of performance for catch share fisheries. The first national report of catch share program performance was published in 2013.[1] That report included an initial set of performance indicators that were readily available with existing data while noting that additional indicators of performance were being developed, one of which was productivity change.

Box 1. Selected U.S. Catch Share Programs and Sub-Components

Northeast

Northeast General Category Atlantic Sea Scallop IFQ, 2010
Northeast Multispecies Sectors, 2010
Mid-Atlantic Surfclam, 1990
Mid-Atlantic Ocean Quahog ITQ, 1990
Mid-Atlantic Golden Tilefish IFQ, 2009

Gulf of Mexico

Gulf of Mexico Red Snapper IFQ, 2007
Gulf of Mexico Grouper-Tilefish IFQ, 2010

Pacific

Pacific Coast Sablefish Permit Stacking, 2001
Pacific Groundfish Trawl Rationalization, 2011
  Shoreside Non-Whiting IFQ
  Shoreside Whiting IFQ

North Pacific

Alaska Halibut IFQ, 1995
Sablefish IFQ, 1995
  Catcher Vessels
  Catcher/Processors
American Fisheries Act (AFA) Pollock Cooperatives
  Catcher Vessels, 2000
  Catcher/Processors, 1999
Bering Sea and Aleutian Islands Crab Rationalization Program, 2005
Non-Pollock Trawl Catcher/Processor Groundfish Cooperatives (Amendment 80), 2008
Central Gulf of Alaska Rockfish Cooperatives, 2012
  Catcher Vessels
  Catcher/Processors
Bering Sea Freezer Longline Conservation Cooperative, 2012

In fisheries, productivity is the relationship between the quantity of fish produced and the amount of inputs used to harvest fish. In this context, productivity is referred to as "multi-factor" productivity since the concern is with the production of fish using multiple inputs such as capital (e.g. fishing vessels), crew, fuel, ice, bait, etc. A change in multi-factor productivity (MFP) measures changes in outputs and inputs between two time periods. MFP may improve either by harvesting more fish with the same amount of inputs or by harvesting the same amount of fish using fewer inputs. By ending the "race to fish" catch share programs may be expected to

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[1] https://www.st.nmfs.noaa.gov/Assets/economics/catch-shares/documents/Catch_Shares_Report_FINAL.pdf

lead to improved productivity through the ability to better plan harvesting activities to change the mix of outputs and/or make better use of capital and other inputs. Productivity gains may also be obtained through the transfer of quota from less to more efficient vessels.

Productivity change in most U.S. catch share fisheries including sub-components for some programs (see Box 1) was estimated using a Lowe index. The Lowe index is an aggregate index that avoids computational problems associated with changes in fleet size over time. The Lowe index is computationally easy to construct, less data demanding than most alternative productivity measures, and could be applied in a consistent manner for all selected U.S. catch share programs. Where biomass data were available the Lowe Index was adjusted for biomass change.

Annual MFP was estimated for a total of 20 catch share programs or sub-components of catch share programs using the Lowe index. Of the 20 programs, 13 included pre-catch share baseline conditions. In 10 of 13 cases, MFP improved or was improving during the first three years after program implementation. These productivity gains were maintained in all six catch share programs that have been in existence since at least 2007, and MFP continued to substantially improve in five of six longer-term programs after the first three years of program implementation.

Ideally MFP would be estimated using full information on inputs including capital, labor, energy, materials, and services. In 11 of the 20 fisheries evaluated in this report available data were limited to capital and labor. Analysis of the 9 programs that included energy and the 5 programs that also included materials found that energy made a larger contribution to estimated MFP as compared to capital and labor alone or to specifications including only capital, labor, and materials. This suggests that new data collection or new methods to estimate fuel use may be a priority in improving estimation of MFP in future studies.

The biomass index plays an important role in characterizing changes in MFP in catch share programs, as biomass changes may affect the catchability of fish and thus harvesting productivity. However, obtaining biomass data was a time consuming process, and in some cases, required a stock-by-stock evaluation of the reliability of the biomass information that was available. In most instances, biomass adjusted and biomass unadjusted measures of MFP were consistent in terms of productivity change relative to baseline conditions although, unadjusted MFP underestimates productivity change when biomass is declining and overestimates productivity change when biomass is increasing. The magnitude of the difference between unadjusted and adjusted MFP increases with the magnitude of the biomass trend. If the biomass trend is sufficiently large, then biomass unadjusted MFP may provide a false impression of change in MFP. This means that obtaining reliable biomass data will be important in any future updates to MFP in catch share fisheries conducted by NOAA Fisheries.

Introduction

NOAA Fisheries' Office of Science and Technology initiated development of a national set of catch shares performance indicators by convening a workshop of NOAA Fisheries' regional economists, anthropologists and sociologists. The workshop was hosted by the Southwest Fisheries Science Center in La Jolla, CA during November 2009. The regional experts identified a substantial number of potential indicators that were subsequently classified as being Tier 1, Tier 2, or Tier 3 metrics based on data availability and relative ease in quantifying each indicator. Tier 1 indicators were defined as metrics for which data were readily available, could be routinely produced and updated, and could be provided for all catch share programs. Tier 2 indicators were defined as metrics that could be produced using available data, but required additional research before they could be routinely produced. Tier 3 indicators were determined to be measures that would require large investments in research or new data collection programs. As research and data collection progresses, performance indicators in Tier 2 and Tier 3 will be moved up to Tier 1. The Tier 1 metrics were further refined in subsequent workshops and the first National report of catch share program performance was published in 2013.[2]

Among the Tier 2 metrics, vessel productivity and productivity change were identified as being important indicators of economic performance. Simply put, productivity is a measure of the relationship between aggregate output and aggregate input and productivity change measures changes in the ratio of outputs to inputs between two time periods. Although revenue per boat, which is included in the report cited above, is a crude proxy for single period productivity, it cannot serve as a measure of productivity change. As a measure of productivity change revenue per boat confounds price changes with changes in catch; does not take into account the quantity or mix of inputs used; and does not control for biomass.

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[2] https://www.st.nmfs.noaa.gov/Assets/economics/catch-shares/documents/Catch_Shares_Report_FINAL.pdf

To overcome these deficiencies a more comprehensive measure of productivity is needed.

Productivity measurement of fishing fleets has received intermittent attention over time. One of the earliest works was by Comitini and Huang (1967) who used a Cobb-Douglas technology to characterize the production of 32 halibut fishing vessels in the North Pacific over a seven-year period. Norton, Miller, and Kenney (1985) used aggregated data from vessels fishing in five U.S. fisheries to estimate an Economic Health Index, which contained a productivity component that could be examined separately. Squires (1988, 1992) published a study measuring productivity in the Pacific Coast Trawl Fishery using an index number approach. Weninger (2001) examined changes in productivity for surfclam vessels using a directional distance function model. More recently Walden et al. (2012) updated Weninger's analysis to examine productivity change in the surfclam and ocean quahog ITQ fishery using a Malmquist index. Jin et al. (2002) measured total factor productivity in the New England Groundfish Fishery during the period 1964-2003. Felthoven and Paul (2004) reviewed past productivity studies and suggested a method for productivity measurement to answer questions concerning economic performance. Fox et al. (2006) examined changes in capacity, quota trading and productivity after a license buyback in Australian fisheries. Hannesson (2007) used a growth accounting framework to measure productivity change in Norwegian fisheries. Squires, Reid, and Jeon (2008) examined productivity growth in the Korean tuna purse seine fishery operating in the Pacific Ocean. Felthoven, Paul, and Torres (2009) measured productivity in the Alaskan pollock fishery from 1994-2003 while incorporating environmental conditions, bycatch and stock effects. Eggert and Tveterås (2011) examined productivity change in Icelandic, Norwegian and Swedish fisheries between 1973 and 2003. Torres and Felthoven (2014) revisited their earlier productivity study in the Alaskan pollock fishery using a longer panel (1994-2009) and improved econometric techniques to account for the mixed distribution of the production data.

Productivity measurement in fisheries presents challenges that are different from traditional industries. Vessels are harvesting a natural resource stock where the government typically sets the total harvest level allowed in any given time period. Whether the harvest is controlled directly through a total allowable catch or input controls, total output is constrained. In many instances, regulations result in makeing vessels less productive. For example, biologically more productive areas may be closed, forcing vessels to fish less productive fishing grounds. This results in vessels using more inputs to catch the same amount of fish as they would in the more productive areas. Stock conditions and environmental factors can also influence productivity. External drivers such as changing ocean temperatures, can impact overall stock conditions. Failing to recognize external conditions when setting catch limits may lead to over-harvest in one year, and subsequent harvest reductions in the following years. Finally, different technologies (typically gear types) can be used to harvest the same resource, and this needs to be factored into productivity assessments. We are not attempting to monitor productivity of individuals over time among different technologies, but rather to assess productivity of a given gear technology applied to a particular fishery[3]. Given these considerations, NOAA Fisheries Office of Science and Technology sponsored a workshop held at the Southwest Fisheries Science Center in Santa Cruz to review the state of the art in productivity measurement and their potential application to fisheries in general and catch share fisheries in particular[4].

Based on this workshop and subsequent review of alternative productivity measures the Lowe index of multi-factor productivity was selected for implementation. The Lowe index was identified by O’Donnell (2012) as one that satisfies all economically relevant axioms for index number theory, including identity and transitivity. We construct the Lowe index as an aggregate index at the fishery level, that avoids computational problems associated with changes in fleet size over time. This index is computationally easy to construct, less data demanding than most alternative productivity measures, and can be applied in a consistent manner for all U.S. catch share programs. This report provides the estimated productivity change for the catch share programs noted in Table 1 using the Lowe index of multi-factor

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[3] The Pacific Groundfish Trawl Rationalization Program, for example, allows for gear switching, so it now operates with the use of multiple gear types.

[4] http://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-503.pdf

productivity. Note that Table 1 includes sub-components for several fisheries due to operational differences that may lead to differences in productivity change as well as differences in available data. The report is organized as follows. A technical exposition of the Lowe index is provided in the next section followed by the estimates of productivity for each catch share fishery organized by NOAA Fisheries region (Northeast, Southeast, Northwest, and Alaska). For each catch share fishery a brief synopsis of the fishery is provided followed by the estimates of productivity and a discussion of underlying constraints or external factors that may affect productivity. The final section of the report provides a synthesis of productivity change across catch share fisheries as well as considerations for further research.

Table 1. Catch Share Programs and Sub-Components Included in the Report

Program	Implementation Year
Mid-Atlantic Ocean Quahog ITQ	1990
Mid-Atlantic Surfclam IFQ	1990
Northeast General Category Scallop IFQ	2010
Northeast Multispecies Sectors	2010
Mid-Atlantic Golden Tilefish IFQ	2009
Gulf of Mexico Red Snapper IFQ	2007
Gulf of Mexico Grouper/Tilefish IFQ	2010
Pacific Coast Sablefish Permit Stacking	2001
Pacific Groundfish Trawl Rationalization	2011
Shoreside Non-Whiting IFQ	
Shoreside Whiting IFQ	
Alaska Halibut IFQ	1995
Alaska Sablefish IFQ	1995
Catcher Vessels	
Catcher/Processors	
American Fisheries Act Pollock Cooperatives	
Catcher Vessels	2000
Catcher/Processors	1999
Bering Sea and Aleutian Island Crab Rationalization	2005
Non-Pollock Trawl Catcher/Processor Groundfish Cooperatives (Amendment 80)	2008
Central Gulf of Alaska Rockfish Cooperatives[a]	2012
Catcher Vessels	
Catcher/Processors	
Bering Sea Freezer Longline Conservation Cooperative[b]	2010

a Estimated productivity in the Rockfish Cooperatives Program includes the Pilot Program years from 2007-2011.

b The Freezer Longline Conservation Cooperative operates in a manner similar to that of the Northeast Multispecies Sector program which is not considered an LAPP under the MSFCMA

Lowe Total Factor Productivity Change Index

In the economics literature multi-factor productivity is usually referred to as "total factor productivity", or TFP. This distinguishes it from productivity of a single input such as, labor. Simply put, TFP is defined as a ratio of aggregate outputs to aggregate inputs, and TFP change (ΔTFP) is the ratio of aggregate output change to aggregate input change during a time period, which for our purposes is one year. Output and input changes can be measured by constructing output and input quantity indices. A complicating factor in constructing indices for fishing fleets compared to traditional land-based industries is that TFP can be affected by changes in target species biomass. Biomass is an important input for the fishery production process, but its level and change between time periods is beyond the control of individual vessels in the fishery. Because biomass change may influence both outputs produced and the use of inputs by fishing vessels, failure to separate biomass from the remainder of the index makes it difficult to disentangle change in output and input use from biomass change (Squires, 1992).

The approach used by NOAA Fisheries to measure productivity change in catch share fisheries follows the KLEMS-Y format where the initials in KLEMS stand for capital (K), labor (L), energy (E), materials (M) and services (S), and Y stands for output. We define TFP in year *y* as the value of all landings in a fishery during year *y* using fixed base output prices (Q_y^O), while the denominator is the value of all inputs from a fishery during year *y*, also using fixed base input prices (Q_y^I), such that

$$TFP_y = \frac{Q_y^O}{Q_y^I}. \qquad [1]$$

As we are interested in changes in TFP, we create Lowe output quantity $(\Delta Q_{y,b}^O)$ and Lowe input quantity $(\Delta Q_{y,b}^I)$ indices which represent changes in output quantities and input quantities between a baseline period *b* and year *y*. Lowe indices are "basket" indices, meaning that output and input quantities are aggregated into output and input indices using fixed reference period prices. We then define the Lowe TFP index, which represents the change in TFP between a baseline period *b* and year *y*, as the ratio of the Lowe output quantity index to the Lowe input quantity index, such that

$$\Delta TFP_{y,b} = \frac{\Delta Q^{O}_{y,b}}{\Delta Q^{I}_{y,b}} . \qquad [2]$$

In this manner the index results in a measure of productivity change at the aggregate fishery level that weights the production of outputs and use of inputs in a consistent manner over the entire time period. Below the formulation of the Lowe output and input indices, and the Lowe biomass index will be discussed.

Lowe Output Quantity Index

The Lowe output quantity index represents the change in output quantities between a baseline period *b* and year *y*, and is defined as

$$\Delta Q^{O}_{y,b} = \frac{p_r \cdot q_y}{p_r \cdot q_b} , \qquad [3]$$

where *q* is a vector of output quantities in year y and baseline period b, and *p* is a vector of output prices during the reference period *r*[5]. It should be noted that the reference period chosen for the price vector does not have to be the same as the baseline period used for the quantity vector. Because the index is calculated at the fishery level and we are attempting to measure TFP changes in catch share fisheries, the vector of outputs should include all species landed on trips on which catch share species are landed during a given year. The price vector is the deflated price (GDP implicit price deflator, base year = 2010) for each species in the quantity vector during the reference period. The reference period was determined separately for each catch share fishery. Note that this reference period for prices could be a single year, or an average of several years, but the selection is constant over all years being compared for each catch share fishery.

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[5] In the case of a single species fishery, the quantity index would simply be defined as the ratio of quantities between two time periods, q_y/q_b.

Lowe Input Quantity Index

The Lowe input quantity index represents the change in input quantities between the baseline period b and year *y*, and is defined as

$$\Delta Q^{I}_{y,b} = \frac{w_r \cdot x_y}{w_r \cdot x_b} \qquad [4]$$

where *x* is a vector of input quantities in year *y* and baseline period *b*, and *w* is a vector of input prices in reference period r. A complete set of input categories would include capital (K), labor (L), energy (E), materials (M) and services (S). For each input category, price and quantity is required. If only cost data are available, an implicit estimate of quantity can be obtained by dividing cost by an appropriate price index, such as the GDP deflator. When only quantity data are available, an appropriate price index can be used in place of an explicit price. All input prices, whether explicit or an index, were deflated using the GDP implicit price deflator with base year = 2010 and only reference period prices are used in the calculation of the Lowe output and input indices.

Due to differences in data collection among catch share program implementation of the full KLEMS-Y approach may not feasible. In these cases the Lowe input quantity index can still be estimated by dropping the input for which data are not available from the quantity index. At a minimum, the input quantity index includes capital (K) and labor (L) and the extent to which changes in the use of these two inputs reflect changes in overall input use determines the robustness of our measures of TFP change in these fisheries. In fisheries where changes in the use of capital and labor do not reflect changes in overall input use, a KL-Y approach may result in substantially different estimates of TFP change than a KLEMS-Y approach. However, this study uses the best data available to provide our estimate of TFP change in each of the catch share fisheries presented.

Biomass Index

Changes in biomass can affect the catchability of fish and impact the estimated value of TFP change. If not accounted for, the productivity metric will reflect change in both biomass and TFP. The relationship between TFP that is biomass influenced (TFP_B) and biomass-adjusted TFP (TFP_{BA}) in any year y is

$$TFP_y^B = TFP_y^{BA} * B_y \,, \tag{5}$$

where B_y is a biomass adjustment factor. Solving for TFP_{BA} yields:

$$TFP_y^{BA} = TFP_y^B \Big/ B_y \,. \tag{6}$$

Because we are interested in productivity change, biomass-adjusted productivity change between any two periods, such as base period b and year y, $TFP_y^{BA} \Big/ TFP_b^{BA}$ can now be constructed as the ratio of productivity measures in two time periods

$$\frac{TFP_y^{BA}}{TFP_b^{BA}} = \frac{TFP_y^B \Big/ B_y}{TFP_b^B \Big/ B_b} \,. \tag{7}$$

Substituting in equation [1] for TFP_y^B and TFP_b^B and simplifying yields

$$\frac{TFP_y^{BA}}{TFP_b^{BA}} = \frac{Q_y^O \Big/ Q_y^I}{Q_b^O \Big/ Q_b^I} \frac{B_b}{B_y} \,, \tag{8}$$

which can be rearranged as

$$\frac{TFP_y^{BA}}{TFP_b^{BA}} = \frac{Q_y^O \Big/ Q_b^O}{Q_y^I \Big/ Q_b^I} \frac{B_b}{B_y} \,, \tag{9}$$

and simplified to

$$\frac{TFP_y^{BA}}{TFP_b^{BA}} = \frac{\Delta Q_{y,b}^O}{\Delta Q_{y,b}^I} \frac{B_b}{B_y} \,. \tag{10}$$

Substituting in equation [2] and simplifying yields

$$\Delta TFP^{BA}_{y,b} = \Delta TFP^{B}_{y,b} * \Delta B_{b,y}, \qquad [11]$$

meaning that the biomass-adjusted index of TFP change is the product of an index of unadjusted TFP change multiplied by an index of biomass change. The biomass index number is simply a quantity index. In order to maintain consistency with the Lowe TFP index, a Lowe quantity index is constructed for biomass change which utilizes hybrid expenditure shares as prices such that:

$$\Delta B_{b,y} = \frac{\sum_{i=1}^{n} s_r^i * sb_i^b}{\sum_{i=1}^{n} s_r^i * sb_i^y}, \qquad [12]$$

where:

$$s_r^i = \frac{p_r^i \, q_r^i}{\sum_{i=1}^{n}(p_r^i q_r^i)}. \qquad [13]$$

Here, sb_y^i is a measure of biomass for species *i* in year *y* (equivalent to *q* in the output quantity index), s_r^i is the share value of landings for species *i* using reference period *r* prices and reference period quantities *q*, and *n* is the total number of species included. The value of shares sums to one. As discussed above, reference period *r* prices and landings quantities can be from a single time period or an average over several years. As constructed above, the biomass index is the inverse of the usual Lowe quantity index, because base period biomass is in the numerator rather than the denominator. Therefore an increase in biomass between the baseline period and year *y* is represented by a biomass index value below 1.00, while a biomass index value above 1.00 signifies a decrease in biomass between the baseline period and year *y*.

General Procedures and Caveats

Productivity change in each catch share fishery was estimated by economists in collaboration with biologists with experience and expertise with catch share programs within their region. Although the KLEMS-Y approach was selected to measure productivity change, sufficient data on all inputs were not available in any of the catch share programs to make full implementation of the approach possible. For this reason, the term multi-factor productivity (MFP) is used throughout this report in place of the conventional reference to TFP. In all cases, capital (K) and labor (L) data were available to estimate productivity change. Where reliable data on energy (E) and materials (M) were available, these inputs were used in the estimates of productivity change. In general, data were available for some (e.g. ice, bait, supplies etc.) but not all materials that may be used by vessels harvesting fish. This means that the input and output data reported herein cannot be used as a measure of net return for two reasons. First, the input data are incomplete relative to the more comprehensive data that would be required to assess net return or profitability in catch share fisheries. Second, the Lowe input index and output index are both constructed with fixed prices meaning that the data cannot be used to estimate annual costs, revenues and net returns.

Both output quantities and prices for each catch share program were available at the regional level. Similarly, data on input quantities for the factors of production used to estimate productivity were available at the regional level, but input price data were not routinely collected in all regions. For this reason, a data set of input prices (see Appendix A) for labor, fuel, and capital services was constructed from secondary sources. Specifically, average hourly earnings of production and nonsupervisory employees from the U.S. Bureau of Labor Statistics current employment statistics survey was used for the price of labor[6]. The average price of retail sales of No. 2 diesel fuel by refineries from the Energy Information Administration was used as the fuel price[7]. The interest rate for BAA rated bonds was used as the capital services price[8]. Each of these price series were based on national averages and unless otherwise noted were used in the absence of

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[6] Source: http://data.bls.gov/pdq/SurveyOutputServlet

[7] Source: http://www.eia.gov/dnav/pet/pet_pri_refoth_dcu_nus_a.htm

[8] Source: http://research.stlouisfed.org/fred2/graph/?s[1][id]=BAA

alternative region-specific data. All input and output prices were converted to constant 2010 dollars using the GDP implicit price deflator (see Appendix A).

Estimates of biomass for each catch share program were obtained from several sources. These biomass estimates included the managed species/stocks under each catch share program as well as species that are not managed under the catch share program of interest yet were jointly harvested on catch share program trips. These jointly-caught species were further scrutinized to determine which may be jointly targeted and which may be incidental. The former may be expected to influence trip decision making affecting outputs and the mix of inputs used to harvest fish. Once both the catch share species and influential non-catch share species were identified biomass estimates were obtained from a combination of the NOAA Fisheries Species Information System and recent stock assessment reports. The biomass data and sources by species for each catch share program are reported in Appendix B.

The biomass estimates included in this study are meant to proxy for changes in the catchability of the target species and embody the assumption that, all else equal, a larger biomass will produce a higher level of output for a given level of inputs than a smaller biomass. However, changes in biomass may not always lead to changes in catchability. As the population of a species declines, the spatial distribution of that species may decline as well and the resulting density of fish may remain constant (particularly with species that exhibit schooling behavior) and catchability can remain relatively constant if these aggregations are easy for fishing vessels to locate (Squires, 1992). Since catchability may not be directly related to the size of the species biomass, it is possible to follow the approach used in Squires (1992) to adjust the biomass estimates based on individual species catchability if species and gear specific catchability coefficients are available. This would dampen the impact that changes in biomass currently have on biomass-adjusted TFP change for those species which exhibit a relatively high degree of schooling behavior. This approach is left for future analysis as these catchability coefficients are not currently available for all catch share program species.

Northeast Region

Mid-Atlantic Ocean Quahog ITQ Program

Fishery Synopsis

The ocean quahog is a bivalve mollusk distributed on both sides of the North Atlantic. In U.S. waters ocean quahogs occur from Maine to North Carolina although the majority of the resource is found exclusively within the Exclusive Economic Zone (EEZ) at depths from 20 to 80 meters[9]. Ocean quahogs are slow growing, long-lived organisms that do not start to reproduce until age 6 and do not reach a commercially harvestable size until around age 20. Ocean quahogs can live for at least 200 years[10]. Ocean quahogs are harvested using a hydraulic clam dredge that uses jets of water to remove sand and sediment from clam beds dislodging the clams that are retained in the dredge. The spacing of the bars in the dredge allows smaller clams to pass through while retaining larger clams.

The surfclam and ocean quahog fisheries, managed by the Mid-Atlantic Fishery Management Council, were the Nation's first fisheries to adopt an Individual Transferable Quota (ITQ) management system beginning in 1990. In the several years prior to ITQ program implementation, surfclams had been the more intensively exploited species and were subject to limited access, whereas ocean quahogs remained an open access fishery. Compared to surfclams, ocean quahogs are distributed farther offshore and the fishery was prosecuted by only the larger vessels. Like the surfclam fishery, ocean quahogs were subject to quarterly quotas, but the effort limits imposed on surfclam fishing time were not needed in the ocean quahog fishery. Thus, the economic problem in the surfclam fishery manifested in inefficient use of fishing vessels that were idled much of the year were not evident in the ocean quahog fishery. Nevertheless, when the Mid-Atlantic Surfclam ITQ Program was being considered the ocean quahog fishery was approaching the limit

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[9] For more information see Jacobson and Weinberg http://www.nefsc.noaa.gov/sos/spsyn/iv/quahog/

[10] For more information see http://www.fishwatch.gov/seafood_profiles/species/clams/species_pages/ocean_quahog_clam.htm

of its specified optimum yield and there was concern over the transfer of effort from surfclams to ocean quahogs if the former became an ITQ system and the latter did not.

In establishing the ITQ program, the Mid-Atlantic Fishery Management Council sought to i) conserve the ocean quahog resource and stabilize harvest rates, ii) minimize public and private costs of managing the resource, iii) bring harvest capacity in line with processing and biological capacity to allow industry participants to achieve economic efficiency and iv) create a management approach that is flexible and adaptive to short-term events or circumstances.

Initial shares for the Mid-Atlantic Ocean Quahog ITQ Program were primarily based on historical participation in the fishery in terms of landings. This meant that initial quota shares were allocated to owners of ocean quahog fishing vessels. However, the ITQ Program permits the transfer of quota shares to any individual or entity provided they are eligible to own a U.S. Coast Guard documented vessel. Quota shares may be transferred on a permanent basis or transferred (leased) on an annual basis to industry participants (processors or vessel owners) or other entities. Processors may purchase ocean quahogs from a vessel owner that owns quota share or they may operate their own fleet of vessels which may lease additional quota from others. Processors may also contract for harvesting services to a fishing vessel owner. The variety of possible business arrangements complicates interpretation of harvest-level productivity change since business decisions in vertically integrated firms may be made to affect the productivity of the entire enterprise and not just of the harvesting activity.

Productivity Estimates and Discussion

The Mid-Atlantic Ocean Quahog fishery (along with the surfclam fishery) is the longest running ITQ program in the United States. Productivity estimates are for a 23 year time period (1990-2012), and are only a partial measure compared to the other catch share fisheries, because estimates for the key inputs of fuel and materials are not available. Inputs included in these productivity estimates are only capital and labor, meaning this is a Y-KL index (outputs, capital and labor). Outputs are bushels of ocean quahogs multiplied by a common price. There is only a single vessel type using hydraulic dredge gear to harvest ocean quahogs. Included vessels are only those fishing for ocean quahogs in the ITQ fishery, and not those that fish for Maine mahogany quahogs in the state of Maine.

One key feature of the ITQ program is that the total output that can be produced from the fishery is strictly regulated through the quota setting process. Thus, output gains are limited. Reductions in input usage are possible as harvest is shifted to fewer vessels, but these reductions may be thwarted if large vessels replace smaller vessels.

Output from the fishery in the first year of the ITQ program decreased slightly from the baseline average, and then increased somewhat during the next three years (Table 2). For the remainder of the time period, output declined relative to the base period. This was likely due to lower demand for ocean quahogs in the final product market, and not due to changes in the technology used to harvest clams. Total inputs used in the fishery were higher than the baseline time period until 2005, and then were relatively stable. This may have been partly driven by a shifting of production to newer, larger vessels and increased steaming time spent on trips to access ocean quahog beds in deeper water farther from shore. Labor input was higher than the baseline time period until 2005, and was lower than the baseline time period from 2005-2012. Capital input was lower than the baseline for the entire time period which was primarily driven exiting vessels.

During the first year of the ITQ program (1990), unadjusted productivity declined to 0.92, an 8% decline from the base time period (Table 3). Between 1990 and 1994, productivity was generally less than 1.00, indicating a productivity decline compared to the base time period. Between 1995 and 1999, unadjusted productivity was greater than 1.00, indicating positive productivity gains, before falling below one between 2000 and 2004. Beginning in 2005, unadjusted productivity was again above 1.00, which was likely due to substantially lower input usage as the input index fell from 0.87 to 0.57 in 2005 (a 34% decline), and then fluctuated between 0.53 and 0.63 in subsequent years. Between 2005 and 2012, the output index was less than 1.00, but was also increasing, representing gains in output. This resulted in positive productivity change for the years 2005-2012.

The biomass index between 1990 and 2012 was generally above 1.00, which indicates declining biomass (Table 3). After adjusting the productivity index by the biomass index, there were only four years during the entire time period where productivity was less than one (1990, 1991, 1993 and 1994). The value of 1.82 in year 2012 showed that the fishery was 82% more productive in 2012 than in the base time period. Within the increasing biomass adjusted productivity trend, there was yearly variation as seen in the yearly productivity change column. Most of the years showed slight increases or decreases in yearly productivity. The biggest increase was 21% in 2005 (1.21), while the largest decline was 13% in 2000 (0.87). For the entire time period, the average year-to-year change was three percent (1.03).

Table 2. Output and Inputs in the Mid-Atlantic Ocean Quahog ITQ Fishery

Year	Output[a]	Capital[a]	Labor[a]	Total Input[a]
1987	28,458,150	774,245	6,011,760	6,786,006
1988	26,816,238	757,505	6,110,259	6,867,764
1989	29,575,920	882,594	6,896,824	7,779,418
Baseline Average	28,283,436	804,782	6,339,615	7,144,396
1990	27,727,566	719,928	6,875,059	7,594,987
1991	29,038,944	621,514	7,131,868	7,753,382
1992	29,555,118	614,719	6,596,288	7,211,007
1993	28,878,558	572,454	7,229,220	7,801,674
1994	27,671,898	524,440	6,751,138	7,275,579
1995	27,769,938	572,663	6,045,644	6,618,307
1996	26,348,568	549,223	5,398,229	5,947,452
1997	25,674,354	459,311	5,541,316	6,000,628
1998	23,384,922	436,595	5,189,974	5,626,569
1999	22,621,728	392,177	5,194,646	5,586,823
2000	18,987,762	454,571	5,025,802	5,480,372
2001	22,146,042	482,158	5,595,497	6,077,655
2002	23,228,316	478,339	5,604,876	6,083,214
2003	24,412,488	460,574	5,956,354	6,416,929
2004	22,947,456	474,701	5,765,082	6,239,784
2005	17,637,696	390,740	3,661,628	4,052,368
2006	18,398,016	300,341	3,507,627	3,807,968
2007	20,182,464	286,968	3,954,269	4,241,237
2008	20,537,088	297,919	3,950,099	4,248,018
2009	20,556,918	281,903	3,783,009	4,064,912
2010	21,322,500	296,276	4,240,140	4,536,416
2011	18,697,746	281,777	3,752,139	4,033,916
2012	20,717,532	289,162	4,024,880	4,314,042

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Table 3. Output, Input, and Multi-Factor Productivity for the Mid-Atlantic Ocean Quahog ITQ Fishery

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
Base	1.00	1.00	1.00	1.00	1.00	
1990	0.98	1.06	0.92	1.00	0.92	0.92
1991	1.03	1.09	0.95	1.00	0.94	1.02
1992	1.04	1.01	1.04	1.00	1.03	1.09
1993	1.02	1.09	0.94	1.01	0.95	0.92
1994	0.98	1.02	0.96	1.03	0.99	1.05
1995	0.98	0.93	1.06	1.05	1.12	1.12
1996	0.93	0.83	1.12	1.07	1.20	1.08
1997	0.91	0.84	1.08	1.10	1.18	0.98
1998	0.83	0.79	1.05	1.12	1.17	0.99
1999	0.80	0.78	1.02	1.14	1.17	0.99
2000	0.67	0.77	0.88	1.16	1.02	0.87
2001	0.78	0.85	0.92	1.18	1.09	1.07
2002	0.82	0.85	0.96	1.21	1.16	1.07
2003	0.86	0.90	0.96	1.23	1.19	1.02
2004	0.81	0.87	0.93	1.26	1.17	0.99
2005	0.62	0.57	1.10	1.29	1.42	1.21
2006	0.65	0.53	1.22	1.31	1.60	1.13
2007	0.71	0.59	1.20	1.34	1.61	1.01
2008	0.73	0.59	1.22	1.37	1.67	1.04
2009	0.73	0.57	1.28	1.40	1.79	1.07
2010	0.75	0.63	1.19	1.43	1.70	0.95
2011	0.66	0.56	1.17	1.47	1.72	1.01
2012	0.73	0.60	1.21	1.50	1.82	1.06

Mid-Atlantic Surfclam ITQ Program

Fishery Synopsis

The surfclam is a bivalve mollusk that is found in Northwest Atlantic waters from the Gulf of St. Lawrence to Cape Hatteras, North Carolina[11]. The surfclam is distributed in both state waters and the EEZ at depths ranging from intertidal beach zones to 160 feet. The majority of the resource is found in the EEZ off New Jersey, the Delmarva Peninsula, and on Georges Bank. Like ocean quahogs, surfclams are harvested in coarse-grained sandy bottom using a hydraulic dredge. However, compared to ocean quahogs, surfclams are harvested at larger sizes and not consumed live, but are processed as clam strips, minced clams sold fresh or frozen, and used in soups and chowders.

Managed by the Mid-Atlantic Fishery Management Council since 1977, the surfclam and ocean quahog fisheries were the Nation's first fisheries to adopt an Individual Transferable Quota (ITQ) management system beginning in 1990. In the thirteen years prior to adoption of the ITQ management system, the surfclam fishery was managed through limited entry, quarterly quotas, and restrictions on fishing time designed to maintain a steady flow of clams available to the market. Although these measures were successful in rebuilding the surfclam resource, quota levels were maintained by limiting vessels to only 36 hours each quarter. These limitations resulted in inefficient use of fishing vessels characterized by significant idle harvesting capacity for much of the year since the hydraulic dredge gear used in the fishery could not be used in other fisheries.

In establishing the ITQ program, the Mid-Atlantic Fishery Management Council sought to i) conserve the surfclam resource and stabilize harvest rates, ii) minimize public and private costs of managing the resource, iii) bring harvest capacity in line with processing and biological capacity to allow industry participants to achieve

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[11] For more information see http://www.fishwatch.gov/seafood_profiles/species/clams/species_pages/atlantic_surfclam.htm

economic efficiency, and iv) create a management approach that is flexible and adaptive to short term events or circumstances.

Initial quota shares for the Mid-Atlantic Surfclam ITQ Program were primarily based on historical participation in the fishery in terms of landings. This meant that initial quota shares were allocated to owners of surfclam fishing vessels. However, the ITQ Program permits the transfer of quota shares to any individual or entity provided that they are eligible to own a U.S. Coast Guard documented vessel without requiring actual ownership of a vessel. Quota shares may be transferred on a permanent basis or quota may be transferred (leased) on an annual basis to another entity. Quota shares or quota may be owned by industry participants (processors or vessel owners) or other entities. Processors may purchase clams from a vessel owner that owns quota share or they may operate their own fleet of vessels or may contract for harvesting services to a fishing vessel owner. The variety of possible business arrangements complicates interpretation of harvest-level productivity change since business decisions in vertically integrated firms may be made to affect the productivity of the entire enterprise and not just of the harvesting activity.

Productivity Estimates and Discussion

The Mid-Atlantic surfclam fishery (along with the ocean quahog fishery) is the longest running ITQ program in the United States. Productivity estimates are for a 23 year time period (1990-2012), and are only a partial measure compared to the other catch share fisheries in the Northeast region. This is because estimates for the key inputs of fuel and materials are not available. Therefore, inputs included in these estimates are only capital and labor, meaning this is a Y-KL index (outputs, capital and labor). Outputs are bushels of surfclams multiplied by a common price.

One key feature of the ITQ program is that the total output that can be produced from the fishery is regulated through the quota setting process. Thus, output gains are limited whereas reductions in input usage are possible as harvest is shifted to fewer vessels. However, these reductions may be offset if larger vessels replace smaller vessels.

Output from the fishery in the first year of the ITQ program increased relative to the baseline time period, and then declined the following year (1991). The years 1992-1994 saw a slight upturn in outputs, but then outputs declined through 1998 before increasing again (Table 4). Inputs generally declined through 2000, and then increased during the time period 2001-2012, although there were years within the period where inputs declined. Much of the decline was due to exiting vessels. During the entire time period, outputs fluctuated on a yearly basis, which was a function of the available quota and the demand for products produced from surfclams in the final output market. The increasing input use between 2000 and 2012 may have been partly driven by an influx of new, larger vessels, and longer steaming time on trips. The labor input rose to its highest level in 2011. Capital input also rose between 2000 and 2012, although there were years where it declined during the same time period. Vessels in this fishery can also be used to harvest ocean quahogs, and there are some vessels that do both in a year. Increased fishing by dual use vessels in the ocean quahog (surfclam) fishery would lower (raise) the capital input used in the surfclam fishery.

During the first year of the ITQ program, the unadjusted productivity index increased to 1.28, a 28% improvement from the base time period (Table 5). This was due to an eight percent gain in outputs (output index 1.08), and a 15% decrease in inputs (input index 0.85). The unadjusted productivity index was greater than one until 2008, indicating improved productivity compared to the baseline time period. After 2008, the unadjusted productivity index was less than 1.00, indicating declining productivity. After 2008, the output index was less than 1.00, while the input index was 1.00 or greater in three of the four years. Part of the reason for the decline in the output index may be that the fishery was harvesting less than the available quota because of declines in demand for surfclams in the consumer product market. Thus, the productivity metric is also reflecting a market issue that hasn’t been fully accounted for in the estimate.

The biomass index between 1990 and 2012 was increasing, which indicates declining biomass (Table 5). In 2012, the biomass index was 2.81 meaning the biomass was almost a third of the level available during the baseline time period. After adjusting the productivity index by the biomass index, the biomass adjusted productivity was 2.14 in 2012. On a yearly basis, the biomass adjusted productivity increased until 2003, then declined during the last eight years of the time period (Table 5). Beginning in the year 2000, the input index began to increase, indicating that more inputs were being used to harvest the quota. This is consistent with a declining biomass. As the stock declines and becomes more dispersed spatially, vessels will need to use more inputs to harvest the same amount of output. This also underscores the importance of adjusting the productivity estimate by a stock adjustment factor which indicates increasing or decreasing stock abundance.

Table 4. Output and Inputs in the Mid-Atlantic Surf Clam ITQ Program

Year	Output[a]	Capital[a]	Labor[a]	Total Input[a]
1987	30,820,622	1,686,102	4,338,593	6,024,695
1988	33,136,273	1,642,991	4,777,973	6,420,964
1989	30,410,495	1,558,558	3,530,942	5,089,500
Baseline average	31,455,797	1,629,217	4,215,836	5,845,053
1990	34,044,239	1,568,468	3,374,662	4,943,130
1991	29,220,404	736,721	3,245,652	3,982,373
1992	30,738,111	574,773	3,306,013	3,880,786
1993	30,970,865	502,174	3,015,346	3,517,520
1994	31,102,911	457,428	3,369,527	3,826,956
1995	27,820,184	435,454	3,095,924	3,531,378
1996	28,082,657	399,884	3,022,441	3,422,325
1997	26,380,375	392,694	2,845,290	3,237,984
1998	25,845,144	370,610	2,943,074	3,313,684
1999	27,748,417	387,792	2,972,712	3,360,503
2000	28,033,931	352,239	2,798,785	3,151,024
2001	31,206,964	391,952	3,336,176	3,728,128
2002	34,001,437	460,604	3,699,002	4,159,606
2003	35,426,753	438,502	4,183,604	4,622,106
2004	34,296,766	459,209	4,513,361	4,972,569
2005	29,996,205	503,402	3,991,547	4,494,949
2006	33,412,179	420,143	4,520,669	4,940,812
2007	35,314,568	464,048	5,482,549	5,946,597
2008	31,906,790	460,912	5,484,502	5,945,414
2009	28,440,232	510,105	5,400,251	5,910,355
2010	25,491,143	484,877	5,246,696	5,731,573
2011	26,702,504	486,923	5,764,694	6,251,617
2012	25,589,830	534,443	5,697,248	6,231,692

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Table 5. Output, Input, and Multi-Factor Productivity for the Mid-Atlantic Surf Clam ITQ Program

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
Base	1.00	1.00	1.00	1.00	1.00	
1990	1.08	0.85	1.28	1.05	1.34	1.34
1991	0.93	0.68	1.36	1.10	1.50	1.12
1992	0.98	0.66	1.47	1.12	1.65	1.10
1993	0.98	0.60	1.64	1.16	1.90	1.15
1994	0.99	0.65	1.51	1.20	1.82	0.96
1995	0.88	0.60	1.46	1.22	1.79	0.98
1996	0.89	0.59	1.52	1.28	1.95	1.09
1997	0.84	0.55	1.51	1.32	2.00	1.03
1998	0.82	0.57	1.45	1.30	1.89	0.94
1999	0.88	0.57	1.53	1.32	2.03	1.08
2000	0.89	0.54	1.65	1.41	2.32	1.15
2001	0.99	0.64	1.56	1.52	2.36	1.02
2002	1.08	0.71	1.52	1.63	2.47	1.05
2003	1.13	0.79	1.42	1.74	2.48	1.00
2004	1.09	0.85	1.28	1.78	2.28	0.92
2005	0.95	0.77	1.24	1.82	2.26	0.99
2006	1.06	0.85	1.26	1.94	2.44	1.08
2007	1.12	1.02	1.10	2.16	2.38	0.98
2008	1.01	1.02	1.00	2.38	2.37	1.00
2009	0.90	1.01	0.89	2.62	2.35	0.99
2010	0.81	0.98	0.83	2.78	2.30	0.98
2011	0.85	1.07	0.79	2.80	2.22	0.96
2012	0.81	1.07	0.76	2.81	2.14	0.97

Northeast General Category Atlantic Sea Scallop IFQ Program

Fishery Synopsis

Atlantic sea scallops are a bivalve mollusk distributed in the Northwest Atlantic from Newfoundland to North Carolina. The majority of the Atlantic sea scallop resource is concentrated on Georges Bank and the Mid-Atlantic Bight. Sea scallops are patchily distributed in so-called beds that may contain large concentrations of scallops. Scallops grow rapidly and an area-based management scheme may set side areas with particularly large concentrations of juvenile scallops to be harvested later when they are larger and more valuable. Scallops are harvested using a scallop dredge. The majority of scallops are shucked at sea keeping only the abductor muscle although a comparatively small quantity is sold as roe-on.

Most scallops landed in New England and Mid-Atlantic ports are harvested by fishermen operating under a limited access program managed by caps on days at sea and harvest limits for trips into scallop access areas defined through a rotational management area program. However, when the New England Fishery Management Council developed the limited access program in Amendment 4, it also created an open access permit to accommodate a small boat fishery that came to be known as the General Category Scallop fishery. This fishery was comprised of smaller vessels that had been harvesting comparatively small quantities of scallops (a trip limit of 400 pounds of scallop meats was imposed in 1994) on relatively short trips. As regulatory measures became more restrictive in a number of other fisheries, the general category scallop fishery increasingly became an alternative source of fishing income. Concerned with the growth in landings by the general category scallop fleet, in 2007, the Council proposed that a limited access program be implemented for the fishery; that small quota allocations be made for incidental harvest of scallops and for small-scale fishing in the Northern Gulf of Maine; that the fishery be subject to a landings limit of 5% of the total scallop catch limit; and that the majority of the fishery be regulated with an Individual Fishing Quota. This management program was implemented in 2008 and a start date of 2010 was set for the IFQ Program. Had the Council not taken action, growth in the fishery would likely have continued that may have led to reductions in the limited access days at sea fishery.

While recognizing that the fishery had changed over time, the Council's vision for the general category scallop fishery is one of "…a fleet made up of relatively small vessels, with possession limits to maintain the historical character of this fleet and provide opportunities to various participants including vessels from smaller coastal communities." The goals for the IFQ Program are to: 1) control capacity and mortality in the general category scallop fishery and 2) allow for better and timely integration of sea scallop assessment results in management.

Full implementation of the IFQ Program was anticipated to take one to two years. To provide for a transition to the IFQ Program, a quarterly quota was set for the fishery set at 10% of the total scallop catch limit. In 2010, the IFQ Program's quota was set at its planned level of 5% of the scallop catch limit where it has remained ever since.

Productivity Estimates and Discussion

Productivity estimates are for vessels which used scallop dredge gear to land scallops, held a general category permit, and took a general category scallop trip between 2007 and 2012. The baseline output quantities include scallops, and other species which were landed during a general category trip. Inputs included vessel capital, labor used (crew times days spent at sea), energy (fuel used on each trip), and materials (ice). Days spent fishing on each trip and crew size data were obtained from vessel logbook records. Vessel physical characteristics, such as length and horsepower, were taken from vessel permit files. Quantities of fuel and ice used on each trip were estimated using regression models.[12] Trip outputs and inputs from each vessel were then aggregated for each year, and then summed

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[12] Details on the regression models used are available upon request.

across vessels in a year to arrive at total output produced from the fishery, and total inputs used.

Because the year 2007 had a large amount of both outputs and inputs, the three year baseline average was high compared to the first three years of the catch share program. In 2008, there was a large exit of vessels from the fishery, which reduced both outputs produced, and inputs used in the fishery. During the first year of the Catch Share program (2010), both outputs and inputs fell relative to the baseline time period (Table 6). Outputs produced rose in subsequent years (2011 and 2012), as did input use.

Although total inputs rose in 2011 and 2012, the years 2010-2012 were a period of lower input usage than the base time period. Since outputs rose more than inputs during this time period, the unadjusted Lowe index increased (Table 7), indicating a productivity gain compared to the baseline time period. The biomass index is relatively stable during the same time period, but was lower than 1.00, indicating increasing biomass during the time period. This resulted in a slight downward revision to the Lowe index. The overall biomass adjusted productivity index in all three years was still substantially greater than 1.00.

The yearly change in the index showed that 2011 had a 27% productivity gain over 2010 levels, and that in 2012 the productivity gain over 2011 decreased to 2%. Because there was a substantial output gain in 2011 compared to 2010, and a much lower gain in 2012 compared to 2011, the 2012 overall gain was markedly lower. Additionally, input use rose in 2012, compared to 2011. The input use for both energy and labor were higher in 2012 than in 2011 (Table 6) which may indicate a shift in production to larger vessels. The capital component declined somewhat in 2012, which may simply reflect more time spent in other fisheries compared to 2011.

Table 6. Output and Inputs in the Northeast General Category Scallop IFQ Fishery

Year	Output[a]	Capital[a]	Labor[a]	Energy[a]	Materials[a]	Total Inputs[a]
2007	28,639,698	1,804,387	4,248,779	7,389,719	189,454	13,632,339
2008	12,481,429	637,796	1,459,307	2,047,107	58,885	4,203,095
2009	16,731,913	725,011	1,843,553	2,987,370	70,693	5,626,627
Baseline Average	19,284,346	1,055,731	2,517,213	4,141,399	106,344	7,820,687
2010	12,980,136	578,380	1,364,578	2,159,494	51,910	4,154,361
2011	16,878,613	583,754	1,551,501	2,151,564	51,993	4,338,812
2012	18,665,677	581,485	1,599,262	2,423,305	50,729	4,654,781

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Table 7. Output, Input, and Multi-Factor Productivity Indices for the Northeast General Category Scallop IFQ Program

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
Base	1.00	1.00	1.00	1.00	1.00	
2010	0.67	0.53	1.27	0.95	1.21	1.21
2011	0.88	0.55	1.58	0.97	1.54	1.27
2012	0.97	0.60	1.63	0.96	1.57	1.02

Mid-Atlantic Golden Tilefish IFQ Program

Fishery Synopsis

Golden tilefish are distributed throughout the Northwest Atlantic from Nova Scotia to South America.[13] In U.S. waters golden tilefish are harvested from along the Atlantic seaboard from Southern New England to Florida and in the Gulf of Mexico. Given this broad distribution golden tilefish are managed by three Fishery Management Councils the Mid-Atlantic (Golden Tilefish Fishery Management Plan), South Atlantic (part of the Snapper Grouper Fishery Management Plan), and Gulf of Mexico (part of the Reef Fish Fishery Management Plan). In the Mid-Atlantic region, tilefish are most abundant from Nantucket Island southward to Cape May, New Jersey.[14] Golden tilefish are a burrowing species that occur primarily in deep water canyons. The majority of tilefish are harvested using bottom longline gear although incidental amounts of tilefish are caught using otter trawl gear while targeting other species such as monkfish.

The Fishery Management Plan (FMP) for the Mid-Atlantic golden tilefish fishery was first implemented in 2001. The original FMP implemented a limited entry program establishing a tiered permitting system based on level of participation in the fishery. The fishery was managed with an overall landings limit that was sub-divided among each of the permit categories. The FMP included an open access permit category subject to a low trip limit to accommodate incidental quantities of golden tilefish that are occasionally landed while fishing for other species.

Prior to the Individual Fishing Quota (IFQ) program the fishery was quota managed. After setting aside 5% of the total quota to account for expected incidental landings in other fisheries. The remaining 95% of the annual quota was subdivided among the limited access permit categories including Full-Time Tier 1, Full-Time Tier 2 and Part-Time with two-thirds assigned to the Full-Time Tier 1 permit category, 15% to

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[13] See Nitschke http://www.nefsc.noaa.gov/sos/spsyn/og/tile/

[14] See http://www.fishwatch.gov/seafood_profiles/species/tilefish/species_pages/golden_tilefish.htm

the Full-Time Tier 2 category and 19% assigned to the part-time category. Fishermen in the Full-Time Tier 1 permit category were able to come to an agreement between themselves to manage the quota allocated to the permit category as a whole in such a way that harvesting could be timed to market conditions. This cooperative agreement allowed individuals in the permit category to stay within their collective quota while avoiding market gluts and spreading landings throughout the year (Kitts et al., 2007). Fishermen in the other permit categories were unable to come to agreement on any similar cooperative arrangements resulting in an early closure of the Full-Time Tier 2 fishery in 2005 and 2006 and the part-time quota was closed early in 2002, 2004, 2005, and 2006. These early closures prompted the Mid-Atlantic Fishery Management Council to develop a catch share program for the golden tilefish fishery. Amendment 1 to the FMP was submitted in 2008 and the IFQ became effective in 2009.

The primary objectives of the IFQ Program are to reduce overcapacity and eliminate problems associated with the race to fish golden tilefish. Ending the "race to fish" is anticipated to eliminate short fishing seasons, increase market stability, increase flexibility and efficiency of fishing operations, improve safety at sea, improve management and compliance, and provide biological benefits to golden tilefish and other marine resources.

Estimated Productivity and Discussion

The productivity estimates are for vessels which are in the ITQ fishery only. These are hook vessels which predominantly land tilefish, although they also land other species as by-catch. Both tilefish and the other outputs are included in the output index. Inputs include capital, labor (number of crew times days spent at sea), energy (fuel used on each trip) and materials (ice). Days at sea and crew size per trip were obtained from vessel logbook data. Vessel length data for the capital calculation was taken from vessel permit files. Quantities of fuel and ice used on each trip were estimated using regression models. There were no estimates of bait used on each trip due to a lack of data to construct a regression model for tilefish vessels. Trip outputs and inputs from each vessel were then aggregated for each year, and then summed across vessels in a year to arrive at estimates for total output produced from the fishery, and total inputs used in producing the outputs.

Vessels in the golden tilefish ITQ program increased outputs in terms of the baseline average during the first full year of the ITQ program, but then decreased output the next two years (Table 8). During the same time period, total inputs steadily declined and were nearly half the baseline average in 2012. All input categories declined between 2010 and 2012 as the number of vessels declined, and the overall fishing effort decreased. Between 2010 and 2012, there was an overall 25% reduction in total days at sea, and a 43% reduction from the baseline average, and this led to much lower input costs.

Outputs during the time period 2010-2012 were higher than the baseline time period, meaning the output index was above 1.00 (Table 9). At the same time, the input index dropped substantially. This resulted in an increasing productivity index, with a peak of 2.12 in 2012. Between 2010 and 2012, biomass improved slightly, which yielded a declining biomass index (Table 9). This lowered the initial productivity gains, and the 2012 index value was 1.75, which is still an impressive gain. On a yearly basis, the biggest productivity gain occurred in 2010, the first full year of the ITQ program. Gains in 2011 were not as substantial, while in 2012, they were less than 1.00, meaning the biomass adjusted productivity declined slightly.

Table 8. Outputs and Inputs in the Mid-Atlantic Golden Tilefish ITQ Fishery

Year	Output	Capital	Labor	Energy	Materials	Total Inputs
2007	3,409,778	66,239	374,080	330,910	51,594	822,822
2008	3,868,301	107,629	750,945	343,074	98,937	1,300,584
2009	4,735,154	105,843	797,804	759,196	115,097	1,777,940
Baseline Average	4,004,411	93,237	640,943	477,727	88,543	1,300,449
2010	4,893,878	97,753	488,636	303,028	83,866	973,283
2011	4,582,646	73,719	378,122	222,174	41,360	715,376
2012	4,303,568	67,139	405,360	141,158	44,907	658,565

Table 9. Output, Input, and Multi-Factor Productivity Indices in the Mid-Atlantic Golden Tilefish ITQ Fishery

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
Base	1.00	1.00	1.00	1.00	1.00	
2010	1.22	0.75	1.63	0.96	1.56	1.56
2011	1.14	0.55	2.08	0.86	1.79	1.15
2012	1.07	0.51	2.12	0.83	1.75	0.98

Northeast Multispecies Sectors Program

Fishery Synopsis

The Northeast multispecies fishery, hereafter, referred to as the groundfish fishery, is managed by the New England Fishery Management Council (NEFMC) and NOAA Fisheries. The groundfish fishery is prosecuted using both fixed (gillnet and hook gears including bottom longline, tub trawls and rod and reel) and otter trawl gears. The groundfish resource is distributed throughout waters of the Gulf of Maine and Georges Bank and, to a lesser extent, Southern New England and the Mid-Atlantic bight. In all, a total of 19 stocks are managed under the Northeast Multispecies FMP (Groundfish Plan) including three Georges Bank stocks of cod, haddock, and yellowtail founder that are jointly managed between the U.S. and Canada under a transboundary resource sharing arrangement.

The Groundfish Plan was first implemented in 1986 with a combination of minimum fish sizes and area-based controls intended to reduce effort and provide spawning protection for haddock and yellowtail founder. These measures and a series of Plan amendments were not sufficient to meet biological objectives, which eventually led to implementation of Amendment 5 in 1994. Amendment 5 included a moratorium on issuing groundfish permits and introduced an effort control program based on scheduled reductions in days-at-sea (DAS) supplemented by a number of indirect effort controls. Neither Amendment 5 nor subsequent Amendments and multiple Framework Adjustments were successful in ending overfishing on many key groundfish stocks leading to a finding in the 1999 Report to Congress that these stocks needed to be rebuilt. This finding initiated what would eventually become Amendment 13.

Implemented in 2004, Amendment 13 fundamentally redefined initial allocations of DAS and how DAS may be used in the groundfish fishery. More importantly, Amendment 13 introduced a new program called "Sector Allocation." Sector allocation provided fishermen with the ability to voluntarily form a sector that would be bound by a quota instead of the DAS-based effort controls of Amendment 13. The sector quota allocation is based on the aggregated catch histories of the fishermen that join a sector. Additionally, sectors would be allowed to request exemptions from certain regulations, and in the subsequent year, the sector's quota would not be reduced (provided the sector did not exceed its own quota) if the target catch for the stock as a whole was exceeded by the rest of the groundfish fleet. At the time Amendment 13 was implemented only one sector (the Georges Bank Cod Hook Sector) had been submitted to the Council for approval. A second sector (the Georges Bank Cod Fixed Gear Sector) was approved in 2006.

Prior to 2010, the Groundfish Plan established an annual Target Total Allowable Catch (TTAC) for each groundfish stock. The TTAC's were set based on desired fishing mortality rates and were used as a means for determining the need for adjustments to the effort control program in the subsequent year. Exceeding a TTAC did not result in a cessation of fishing although, for some stocks, an in-season adjustment may be triggered to reduce the likelihood that the TTAC would be exceeded. It would not be until the 2007 Magnuson-Stevens Act reauthorization requiring the setting of Annual Catch Limits (ACLs) that the NEFMC would transition from effort controls as the primary management tool coupled with catch targets to output-based controls using sector allocation as the primary management tool. The transition from effort controls to sector allocation was finalized through Amendment 16, implemented in 2010. Although Amendment 16 retained the underlying principle that sectors remain voluntary, the Amendment changed the qualification period for potential sector contribution (PSC) and provided a means for trading assigned quota or annual catch entitlement (ACE) between sectors. Amendment 16 further specified which of the 19 stocks would be allocated to sectors and which stocks would not be allocated. The allocated stocks include Acadian redfish, pollock, white hake, witch flounder, American plaice, winter flounder (Georges Bank and Gulf of Maine), yellowtail flounder (Georges Bank, Cape Cod/Gulf of Maine, and Southern New England/Mid-Atlantic), cod (Gulf of Maine and Georges Bank) and haddock (Gulf of Maine and Georges Bank).

In keeping with the voluntary nature of the sector allocation program, vessel owners may choose to join a sector or remain in the so-called “common pool”. Vessel owners that elect to remain in the common pool are principally regulated by DAS supplemented by a suite of additional effort controls such as possession limits, gear restrictions, and area closures. The common pool is also subject to an ACL. Since all vessel permits are assigned a PSC based on catch history, whether or not the permit is enrolled in a sector, the common pool ACL for all stocks is determined by the combined PSC for all permitted vessels in the common pool. In-season accountability measures may be made to specified effort control measures to prevent the common pool ACL from being exceeded.

The management objectives for the groundfish fishery are broadly defined in biological, social, and economic terms. Biological objectives include promoting rebuilding, habitat protection, bycatch monitoring and reduction, and improving the timing and quality of stock assessments. Social objectives include minimizing adverse impacts on fishing communities, prevention of excessive consolidation to protect the day boat component of the groundfish fleet, and maintain a diverse groundfish fleet. Economic objectives include matching fleet capacity to resource status, achieve goals of economic efficiency, give industry greater control over their own fate, and to provide a mechanism for economics to shape the fleet rather than regulations.

Estimated Productivity and Discussion

Productivity estimates are for vessels that used trawl, hook or gillnet gear only to land species in the multispecies complex during the years 2007-2012. The baseline quantities of outputs and inputs are the yearly average from the 2007-2009 fishing years. Total trip landings were counted as output on all trips by vessels any of these three gears on trips where groundfish were landed. This means that non-groundfish species were included if they were landed on a groundfish trip. Inputs included vessel capital, labor used (number of crew times days spent at sea), energy (fuel used on each trip), and materials (bait for hook vessels, and ice for all vessels). Days spent fishing on each trip and crew size data were obtained from vessel logbook records. Vessel physical characteristics, such as length and horsepower, were taken from vessel permit files. Quantities of fuel and ice used on each trip, and bait usage for hook vessels, were estimated using regression models.[15] Trip outputs and inputs from each vessel were then aggregated for each year, and then summed across all active vessels to arrive at total output produced from the fishery, and total inputs used.

During the first year of the Catch Share program (2010), there was a reduction in both total outputs and total inputs employed in the fishery, relative to the baseline time period (Table 10). This was driven primarily by the exit of vessels from the fishery. Vessel exit had started prior to implementation of the catch share program, and continued after catch shares were implemented. Under the catch share program, vessel owners can lease or sell their shares, and obtain revenue without fishing.

Because the total inputs used in the fishery declined more than outputs in 2010 (Table 10), overall productivity increased compared to the baseline time period (1.12, a 12% increase). When multiplied by the biomass index, the resulting biomass adjusted productivity (1.24) was 24% higher than the baseline time period (Table 11). The biomass index of 1.11 indicated that biomass declined in 2010 relative to the baseline time period.

In 2011, both the outputs produced and the inputs used increased relative to 2010 levels (Table 10). This may have been due to landings being harvested by larger vessels than in 2010. Note that both the labor and energy component increased in 2011, while the capital component declined slightly. A shift to larger vessels may be influencing these results, but more research is needed to fully understand these numbers. Because the total input index increased more than the total output index, the unadjusted productivity declined in 2011 relative to 2010 (1.07,Table 11). At the same time, the biomass index increased in 2011, which indicates a biomass

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[15] Details on the regression models used are available upon request.

decline relative to 2010. This results in an increase in the biomass adjusted productivity index in 2011 (1.26) relative 2010 (1.24).

The outcome in 2011 was reversed in 2012, with both a decline in outputs produced and inputs used relative to 2011 (Table 10). The resulting output quantity index was 0.62, and the input quantity index was 0.71. Because the output index declined more than the input index, overall productivity declined in 2012 (0.88). At the same time, the biomass improved, and the biomass index declined. This resulted in a decline in the biomass adjusted productivity index in 2012 (1.26 to 0.97) relative to 2011 (Table 11).

Table 10. Outputs and Inputs in the Northeast Multispecies Sector Allocation Program

Year	Output[a]	Capital[a]	Labor[a]	Energy[a]	Materials[a]	Total Inputs[a]
2007	126,242,130	3,979,977	14,291,104	31,232,521	2,852,599	52,356,201
2008	132,379,908	3,528,836	13,742,283	28,343,586	10,229,139	55,843,844
2009	130,258,217	3,247,951	12,785,995	25,853,782	2,149,257	44,036,985
Baseline Average	129,626,752	3,585,588	13,606,461	28,476,630	5,076,998	50,745,677
2010	94,228,865	2,123,429	9,550,188	19,564,331	1,729,283	32,967,232
2011	103,882,523	2,113,633	11,114,871	23,089,385	1,734,718	38,052,608
2012	80,772,238	2,103,863	10,532,857	21,708,985	1,430,667	35,776,372

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Table 11. Output, Input, and Multi-Factor Productivity Indices in the Northeast Multispecies Fishery

	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
Base	1.00	1.00	1.00	1.00	1.00	
2010	0.73	0.65	1.12	1.11	1.24	1.24
2011	0.80	0.75	1.07	1.18	1.26	1.01
2012	0.62	0.71	0.88	1.10	0.97	0.77

Southeast Region

Gulf of Mexico Red Snapper IFQ Program

Fishery Synopsis

Gulf of Mexico (GOM) red snapper stocks are managed by the GOM Fishery Management Council under the Reef Fish Fishery Management Plan. Since 2007, the fishery has been managed under an Individual Fishing Quota (IFQ) program. The objectives of the program are to reduce overcapacity and mitigate race to fish conditions. GOM red snapper are harvested primarily using vertical lines and, to a lesser extent, bottom longlines.

Prior to the 2007 implementation of the Red Snapper IFQ program, commercial fishermen raced to harvest the quota before it was met resulting in early closures. Limited access fishing permits, trip limits, closed seasons, and quotas were the primary management tools used to constrain commercial harvest. Overcapacity and overfishing led to progressively shorter fishing seasons, which resulted in quota overages, market gluts, and unsafe fishing conditions (Waters, 2001; Hood, Strelcheck and Steele, 2007). The five-year review of the Red Snapper IFQ Program found that the program had mixed success reducing overcapacity, but was successful in mitigating derby fishing behavior and preventing quota overages (Agar et al., 2014; Solis et al., 2014a; Solis et al., 2014b).

Productivity Estimates and Discussion

The productivity estimates presented are for those vertical line and bottom longline vessels that landed at least one pound of red snapper. The data used to construct the indices came from three sources: Southeast Coastal Fisheries Logbook Program (Logbook database), the Accumulated Landings System (ALS database), and the Southeast Regional Office Permits Information Management Systems (PIMS database). The output quantity index included landings from both red snapper and other jointly caught species. These data were obtained from the Logbook and ALS databases. The Logbook database contains self-reported trip reports for all trips that caught reef fish, mackerels, other coastal migratory pelagics, and sharks in federal waters. The logbook program also includes an economic add-on, which has been administered to a 20% sample of the fleet in the Gulf of Mexico region since mid-2005. On the other hand, the ALS contains information on the quantity and revenue of landings sold to seafood dealers. The quantity and revenue data were used to impute dockside prices.

Input quantities for labor and capital services were estimated from all trips in the Logbook database while input quantities for energy and intermediate materials, namely bait and ice were based on data collected through the economic add-on.

The PIMS database, which contains information on vessel characteristics (e.g., vessel length, gross tonnage, etc.) was used in conjunction with the Logbook database to construct an estimate of capital services.

If input quantities were not available, then we imputed them by dividing expenditures by a price index (e.g., ice) or price proxy (e.g., price of a commonly used bait species). Trip level outputs and inputs for each vessel were aggregated annually and then summed across the fleets to estimate annual total output and total input usage.

During the initial years of the Red Snapper IFQ Program there were significant reductions in the amount of harvest and effort devoted to catching red snapper. Table 12 reports that aggregate output or landings, which also includes other species jointly caught with red snapper, and input usage (e.g., fuel, bait, ice) by those vessels that prosecuted red snapper declined until 2009 relative to the 2004-2006 baseline. This decline was driven by fleet attrition and significant reductions in the quota of red snapper. Agar et al. (2014), report that the number of active vessels decreased from 443 in 2006 to a low of 296 in 2009. Also, the red snapper quota average during the first three years of the IFQ program (2007-2009) was about 60% of the average quota for the three years preceding the program (2004-2006). Nonetheless, these sharp quota reductions did not translate into proportional reductions in aggregate landings and input consumption because fishermen changed their fishing practices. Fishermen began taking fewer but longer fishing trips. They also adjusted the composition of their landings by targeting other species, particularly vermilion snapper and red grouper (Agar et al., 2014). Between 2007 and 2009, red snapper landings by weight contributed between 33% and 44% of the overall landings indicating that species other than red snapper play an important role in trip decision-making, which influences both the outputs and input mix. However, recent biomass information was not available for the main species jointly caught with red snapper upon which a reliable biomass index could be constructed. Therefore, biomass adjusted productivity estimates could not be calculated for the red snapper IFQ program.

Starting in 2010, there was an influx of additional vessels as quota levels began to increase (SERO, 2013a). In addition, the GOM Grouper-Tilefish IFQ program, which began in 2010, also attracted new participants since many of the grouper fishermen incidentally caught small amounts (by-catch) of red snapper. The incidental catch of red snapper became more prevalent in recent years because as the red snapper stock rebuilt, it extended its range to traditional grouper fishing grounds in the eastern Gulf and West Florida shelf.

Lowe biomass-unadjusted productivity indices suggest that the productivity of the red snapper fleet, on average, increased after the implementation of the IFQ program (Table 13). Productivity rose from 1.04 in 2007 to 1.19 in 2012. Productivity indices above one indicate that vessels are able to harvest more with the same amount of inputs. The realized productivity gains likely stem from the combined effects of fleet consolidation, which lowered input usage; the relaxation of trips limits (either 2,000 or 200 lbs. of red snapper per trip depending on the type of license held- Class 1 vs. Class 2) and the elimination of the 10-day fishing seasons (Agar et al., 2014).[16] This greater flexibility afforded by the IFQ program allowed fishermen to harvest, process, and market their catch more productively.

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[16] The fishing season increased from an average season of 109 days to a year-round season (Agar et al., 2014).

Although productivity rose by 19% in 2012 relative to the baseline, these gains were uneven over time. For example, in 2010 productivity declined to 1.07 from 1.16 in 2009 but rose again to 1.15 in 2011.We conjecture that this decline originated from the introduction of the Grouper-Tilefish IFQ program and the area closures ensuing from the Deepwater Horizon oil spill event - both which resulted in higher input use. The introduction of the Grouper-Tilefish IFQ program resulted in an influx of 80 additional vessels from 296 vessels in 2009 to 376 vessels in 2010 (Agar et al., 2014). Many of these vessels caught small amounts of red snapper incidentally. Also, the Deepwater Horizon oil spill event area closures may have forced some fishermen to relocate to other fishing grounds increasing their consumption of inputs, especially fuel. Moreover, the oil spill disrupted fishermen's seasonal fishing pattern, forcing them to land a significant share of their red snapper allocation later in the year, particularly in December.

Table 12. Outputs and Inputs for the Gulf of Mexico Red Snapper IFQ Fishery

Year	Output[a]	Capital[a]	Labor[a]	Energy[a]	Materials[a]	Total Inputs[a]
2004	21,383,299	1,990,278	5,939,596	2,045,254	1,346,841	11,321,968
2005	19,403,705	1,935,030	5,420,274	1,818,579	719,399	9,893,282
2006	20,883,807	1,965,663	6,068,702	1,992,673	1,139,347	11,166,384
Baseline Average	20,556,937	1,963,657	5,809,524	1,952,169	1,068,529	10,793,878
2007	17,551,868	1,600,270	5,044,259	1,301,035	893,624	8,839,188
2008	16,502,048	1,367,772	4,293,677	1,101,674	746,969	7,510,092
2009	16,163,986	1,304,203	4,161,093	1,078,959	761,019	7,305,274
2010	19,043,055	1,937,345	5,087,584	1,344,135	1,010,617	9,379,681
2011	23,581,748	1,972,894	5,927,279	1,543,575	1,344,121	10,787,870
2012	24,926,696	1,854,327	6,189,259	1,580,673	1,386,374	11,010,633

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Table 13. Output, Input, and Multi-Factor Productivity Indices for the Gulf of Mexico Red Snapper IFQ Fishery

Year	Output Index	Input Index	Biomass Unadjusted MFP	Year to Year MFP Change
Base	1.00	1.00	1.00	
2007	0.85	0.82	1.04	1.04
2008	0.80	0.70	1.15	1.11
2009	0.79	0.68	1.16	1.01
2010	0.93	0.87	1.07	0.92
2011	1.15	1.00	1.15	1.08
2012	1.21	1.02	1.19	1.04

Gulf of Mexico Grouper-Tilefish IFQ Program

Fishery Synopsis

Gulf of Mexico (GOM) grouper and tilefish stocks are managed by the GOM Fishery Management Council under the Reef Fish Fishery Management Plan. Since 2010, the fishery has been managed under an Individual Fishing Quota (IFQ) program. The objectives of the program are to reduce overcapacity and mitigate race to fish conditions. These species are mainly targeted with bottom longlines and vertical lines.

The GOM Grouper-Tilefish IFQ Program has five management units: red grouper, gag grouper, shallow water groupers (including black grouper, yellowfin grouper, scamp, and yellowmouth grouper), deepwater groupers (including yellowedge grouper, warsaw grouper, snowy grouper, and speckled hind) and tilefishes (including goldface tilefish, blueline tilefish, and golden tilefish). In 2012, the following species were removed from the Gulf of Mexico Grouper-Tilefish IFQ Program: rock hind, red hind, misty grouper, anchor tilefish, and blackline tilefish.

Prior to the implementation of the Grouper-Tilefish IFQ Program, the fishery experienced race to fish conditions that led to early closures and quota overages of certain species. For instance, quotas for deep-water groupers and tilefishes were met in four to six months and the shallow-water grouper quota was met six to 10 weeks prior to the end of the 2004 and 2005 fishing years. Limited access fishing permits, trip limits, closed seasons and quotas were the primary management tools.   Although, the grouper-tilefish IFQ program has not undergone a formal review early indications suggest that the program helped reduce the size of the fleet and lengthen the fishing season (SERO 2013b).

Productivity Estimates and Discussion

The productivity estimates discussed refer to those bottom longline and vertical line vessels that landed at least one pound of those species included in the Grouper-

Tilefish IFQ program. These two gear account for the majority of the grouper-tilefish landings. In a manner similar to that of red snapper, the data used to construct the indices came from three sources: Southeast Coastal Fisheries Logbook Program (Logbook database), the Southeast Regional Office Permits Information Management Systems (PIMS database), and the Accumulated Landings System (ALS database). The output quantity index included landings from those species under the Grouper Tilefish IFQ program plus any other jointly caught species. Input quantities were built for capital (capital user cost), labor, energy, and intermediate materials, namely bait and ice. Because we only had partial records for some of these variables, we estimated input usage and total expenditures from the economic add-on to the logbook, which started collecting data in mid-2005 (1 ½ years after our baseline). If input quantities were not available, then we imputed them by dividing expenditures by a price index (e.g., ice) or price proxy (e.g., price of a commonly used bait species). Trip level outputs and inputs for each vessel were aggregated annually and then summed across the fleets to estimate annual total output production and total input usage.

During the first year of the Grouper-Tilefish IFQ program there were significant reductions in the amount of catch and effort devoted to harvesting these species. Table 14 reports that aggregate landings (output), which also includes other species jointly caught with grouper and/or tilefish, and input utilization declined sharply in 2010 relative to the 2007-2009 baseline. Red grouper landings began decreasing in 2009 when area and gear (hook limits) restrictions were first imposed on the longline fleet, which is responsible for about 60% of the grouper-tilefish landings. These restrictions on longline fleet were in response to a significant take of sea turtles, mainly loggerheads, which was well above 85 permitted takes of loggerhead sea turtles over a 3-year period.

In 2010, Amendment 31 established an endorsement to use longline gear in the GOM. Vessels qualifying for an endorsement had to have an annual landings history in excess of 40,000 lbs. All in all, the adoption of the grouper-tilefish IFQ program, the longline endorsement requirements, and the area and gear restrictions resulted in a 30% reduction in the fleet size (from 630 to 447 based on 3 year pre and post IFQ averages, SERO 2013b). Starting in 2011, grouper-tilefish landings began increasing because the red grouper and gag quotas were increased. In addition, fishermen began taking shorter fishing trips but landing more red grouper per trip (SERO 2013b). Red grouper landings account for between 66 and 74% of the total grouper-tilefish landings.

Lowe biomass-unadjusted productivity indices suggest that the productivity of the grouper-tilefish fleet increased after the adoption of the IFQ program (Table 15)[17]. Productivity gains show a steady increase from 1.11 in 2010 to 1.35 in 2012. The realized productivity gains were likely the result of a combination of factors including fleet consolidation, which lowered input usage, and the relaxation of the aggregate deep-water and shallow-water grouper commercial trip limit (6,000 lbs). Also, the fleet may have benefitted from an extended harvesting season for several species, particularly deepwater groupers and tilefish. In addition, the 2010 longline endorsements may have played a role in culling less productive vessels. Lastly, productivity gains after 2010 may have also partly benefitted from the re-opening of the previously closed areas due to the Deepwater Horizon oil spill event.

Table 14. Output and Inputs in the Gulf of Mexico Grouper-Tilefish IFQ Fishery

Year	Output[a]	Capital[a]	Labor[a]	Energy[a]	Materials[a]	Total Inputs[a]
2007	35,060,880	4,275,123	13,573,535	3,908,087	2,666,229	24,422,973
2008	37,420,193	4,023,762	13,486,802	3,833,396	2,620,141	23,964,102
2009	33,702,290	3,977,631	13,252,194	3,538,689	2,425,467	23,193,980
Baseline Average	35,394,454	4,092,172	13,437,510	3,760,057	2,570,612	23,860,352
2010	25,358,084	3,018,979	8,451,716	2,317,247	1,628,698	15,416,640
2011	34,475,570	2,969,404	9,940,596	2,677,102	2,253,382	17,840,483
2012	37,216,683	2,934,864	10,519,456	2,739,891	2,329,216	18,523,427

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

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[17] Recent biomass information was not available upon which a reliable biomass index could be constructed. Therefore, biomass adjusted productivity estimates could not be calculated for the grouper-tilefish IFQ program.

Table 15 Estimated Multi-Factor Productivity in the Gulf of Mexico Grouper-Tilefish Fishery (IFQ Data

Year	Output Index	Input Index	Biomass Unadjusted MFP	Year to Year MFP Change
Base	1.00	1.00	1.00	
2010	0.72	0.65	1.11	1.11
2011	0.97	0.75	1.30	1.17
2012	1.05	0.78	1.35	1.04

West Coast Region

Pacific Coast Sablefish Permit Stacking Program

Fishery Synopsis

Sablefish or "Black Cod" are distributed in the Northeast Pacific Ocean from Northern Mexico to the Gulf of Alaska and through the Aleutian Islands.[18] Based on morphological differences in growth rates, seasonal reproduction, and tagging studies, sablefish are divided into Northern and Southern populations. The Northern population extends from Northern British Columbia to Alaska. The U.S. portion of the Northern population is managed by the North Pacific Fishery Management Council whereas the U.S. portion of the Southern population which extends throughout the West Coast is managed by the Pacific Fishery Management Council.

Sablefish is a fast-growing roundfish species reaching sizes of up to three feet. Females mature in 6 to 7 years at approximately 2 feet in length while males mature in about 5 years at slightly smaller size. Sablefish is a high value species that is targeted by both fixed gear (pots, and hook and line) and trawl gear. The Pacific Coast sablefish fishery is one of many groundfish species managed by the Pacific Fishery Management Council. The Pacific Coast fishery consists of a limited entry groundfish trawl fishery, a limited entry groundfish fixed gear fishery, an open access fixed gear fishery, and a tribal fishery. Limited entry in the West Coast groundfish fishery was established in 1994. The limited entry groundfish trawl and limited entry groundfish fixed gear fisheries receive about 80% of the sablefish allocation on the West Coast.

The limited entry trawl, open access, and tribal fisheries are managed separately from that of the fixed gear fishery. At the request of non-trawl industry representatives, the PFMC pursued a mixed seasonal and regional approach to

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[18] See http://www.fishwatch.gov/seafood_profiles/species/cod/species_pages/sablefish.htm

management of the limited entry groundfish fixed gear fishery based on differences in the manner in which the fishery was prosecuted among northern (above 36° N) and southern (below 36° N) fishery participants. The former had traditionally landed the majority of sablefish on directed trips while the latter tended to land sablefish in a daily trip limit fishery. It is this Northern fishery that is now managed under the Pacific Coast Sablefish Permit Stacking Program (referred to as the primary sablefish fishery) while the daily Southern fishery continues to be managed under a trip limit.

The Pacific Coast Sablefish Permit Stacking Program manages 85% of the sablefish allocated to the limited entry groundfish fixed gear fishery, and the remaining 15% is allocated to the daily limited entry fixed gear fishery. As a result, the productivity estimates provided in this report reflect only sablefish harvested in the primary fishery managed through the permit stacking program. The Pacific Coast Sablefish Permit Stacking Program covers approximately 30% of all commercially harvested sablefish on the West Coast including tribal fisheries. While any vessel with a limited entry fixed gear permit may participate in the daily fishery, only vessels having one or more sablefish endorsed limited entry groundfish fixed gear permits can participate in the primary sablefish fishery (where up to three permits may be "stacked" on one vessel.

The Pacific Coast Sablefish Permit Stacking Program was preceded by implementation of Sablefish endorsement permits in 1997. This permit program responded to premature closures that occurred two to three weeks after the season opening from 1992-1994 and after only five days in 1996. The program assigned equal harvest limits, effectively an Individual Quota (IQ) to each permit. However, the Magnuson-Stevens Act moratorium on implementing any individual quota-based programs was still in effect at that time and the PFMC adopted a short season of 10 days. The result was that some vessels were unable to harvest their assigned quota. In 1998, the PFMC modified the program by creating a three-tiered quota assignment, but still set a 10-day season. Permits in each tier (Tier 1, Tier 2, and

Tier 3 in order of highest to lowest) were assigned the same quota where eligibility for each tier was based on landings history.

The tiered allocation system meant that some vessel operators had to reduce their fishing activity while others were able to expand. The system provided limited capability for fishing vessel owners to scale their business plans up or down resulting in reduced efficiency. The short season made it difficult to match harvest with market demand resulting in market gluts that lowered product value followed by periods when no product was available at all. The short season was also thought to result in higher accident rates as fishermen had a short window in which to take their allotted quota.

The Magnuson-Stevens Act moratorium on new individual quota programs expired in 2000, but was extended through 2002 via a Congressional appropriations bill, with an exception for a permit stacking program for the fixed gear sablefish fishery. The Permit Stacking Program enabled vessel owners to "stack" up to three sablefish endorsed permits onto a single vessel. In effect, this meant that vessel owners could use the equivalent of three IFQ Program's allocations with set amounts on one vessel. Perhaps more importantly, the program enabled the season to be extended to seven months (April 1 to October 31). Implementation of the Pacific Coast Sablefish Permit Stacking Program began during 2001 and 2002 was the first year of complete implementation of the program for the primary sablefish fishery within the limited entry groundfish fixed gear fishery.

The Pacific Coast Sablefish Permit Stacking Program includes a number of features that were designed to meet its objectives. To prevent concentration of harvest privileges, no more than three permits may be stacked onto a single vessel. Furthermore, permits may not be owned by partnerships or corporations. An owner-on-board requirement assures that the fishery retains its traditional owner-operator character.

The program objectives for the Pacific Coast Sablefish Permit Stacking Program included promotion of economic efficiency through rationalization of the fixed gear fleet, direct benefits toward fishing communities, prevent excessive concentration of harvest privileges and promote equity, promote safety, and to improve product quality and value.

Productivity Estimates and Discussion

The Northwest Fisheries Science Center conducts voluntary cost and earnings surveys of vessels operating with a limited entry fixed gear groundfish permit. The productivity analysis in this paper is based on survey responses received from vessel owners holding one or more sablefish endorsed permits for their vessel. Because the cost-earnings survey did not begin until 2003, no input data were collected from the three years prior to the implementation of the Pacific Coast Sablefish Permit Stacking Program. Instead of the three years prior to implementation, the first year of the data collection, 2003, was used as the baseline. The voluntary survey collects, amongst other information, vessel characteristics including vessel value, average fuel use per day while fishing in the fixed gear groundfish fishery, average crew size per day while fishing in the fixed gear groundfish fishery, total expenses on fuel, and total expenses on crew and captain. With no other information available for days at sea from 2003-2008, we used the number of delivery days from fish tickets as a proxy. Fish ticket data also provided total annual pounds and an average price for sablefish caught in the Primary Sablefish Fishery, used to calculate the output for the vessels that submitted complete input data. We have complete input data from 31 vessels in 2003-2004, 28 in 2007-2008, and 25 for 2009-2010, which represents from 22-33% of the fishery overall. Due to technical and resource constraints, the survey could not be fielded for the 2005-2006 time period. Consequently, input quantities could not be estimated for those years.

Wording on the voluntary cost-earnings survey changed between the 2003-2004 and 2007-2008 surveys and the 2009-2010 surveys where the latter was modified to reflect the wording of the concurrent Economic Data Collection Survey. This primarily affected the productivity estimate in regards to the average fuel used per day, which fed into the energy calculation. In 2003-2008, participants were asked for average fuel use per hour, which was changed to fuel use per day in 2009-2010. To address this change, we calculated an hour per day measure for vessels that reported both the daily and hourly statistic, and then multiplied the calculated hours per day times the hourly fuel use reported in 2003-2008.

The baseline year, 2003, and the following year had the highest labor and fuel inputs, and these categories dropped to their lowest levels in 2007-2008 (Table 16). The lowest output occurred in 2008, and the highest in 2010.

Relative to the 2003 baseline, biomass unadjusted MFP increased 24% in 2004 to 1.24 (Table 17). Unadjusted MFP also increased in 2007 relative to the baseline, but was 5% below the baseline in 2008. In both 2009 and 2010, the unadjusted productivity index increased to 1.46 and 1.69, respectively. The biomass index for sablefish has increased in every year relative to the baseline, indicating decreasing biomass throughout the six-year period (Table 17). This stock effect amplifies the unadjusted Lowe index after the implementation of the stacking program.

In 2007, the biomass adjusted Lowe index was 1.74 which represents a 74% improvement over the baseline and a 38% increase over MFP in 2004 (Table 17). In 2008 adjusted MFP was 18% above the baseline, but was 32% below MFP in 2007. In 2009 biomass adjusted MFP increased to 1.90, which represents a 90% improvement over the baseline and a 61% increase compared to the time series low MFP of 1.18 in 2008. Biomass adjusted MFP index improved again in 2010 to 2.32 which was an 22% increase relative to 2009.

The decline in the number of vessels reporting inputs from the baseline through 2010 could explain the minor decreases in labor and energy inputs, however, the output, which is calculated only for vessels that reported input data, does not seem to follow a corresponding downward effect, which could explain the general increase in the Lowe index.

Table 16. Output and Inputs in the West Coast Primary Sablefish Fishery

Year	Output[a]	Capital[a]	Labor[a]	Energy[a]	Total Inputs[a]
2003 (Baseline)	417,677	541,317	1,750,298	332,180	2,623,795
2004	539,930	500,111	1,894,413	337,054	2,731,578
2007	531,191	625,717	1,371,415	246,206	2,243,338
2008	345,458	613,922	1,417,904	252,479	2,284,305
2009	574,925	518,750	1,606,183	347,631	2,472,564
2010	651,321	589,527	1,469,042	355,750	2,414,319

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Table 17. Estimated Multi-Factor Productivity in the West Coast Primary Sablefish Fishery

Year	Output Index	Input Index	Biomass-Unadjusted MFP	Biomass Index	Biomass-Adjusted MFP	Year to Year MFP Change
Base	1.00	1.00	1.00	1.00	1.00	
2004	1.29	1.04	1.24	1.02	1.26	1.26
2007	1.27	0.85	1.49	1.17	1.74	1.38
2008	0.83	0.87	0.95	1.25	1.18	0.68
2009	1.38	0.94	1.46	1.30	1.90	1.61
2010	1.56	0.92	1.69	1.37	2.32	1.22

Pacific Groundfish Trawl Rationalization Program

Fishery Synopsis

The Pacific groundfish trawl fishery includes several separate components: a non-whiting trawl fishery that targets a variety of flatfish, roundfish, thornyheads, and some rockfish using a bottom trawl, and a whiting fishery that uses a mid-water trawl to almost exclusively harvest whiting. The fishery also encounters numerous other rockfish species as bycatch – several of these rockfish species have been declared overfished. For management purposes, the whiting trawl sector was further subdivided into three sectors: a shorebased sector of fishing vessels that delivers whiting to shorebased processors; a catcher processor sector that harvests whiting and processes it on-board; and motherships, at-sea processors that receive whiting catch from catcher vessels. Under the West Coast Trawl IFQ Program, the shorebased whiting sector was combined with the non-whiting trawl sector.

Recognizing the differences between the shoreside and at-sea non-whiting and whiting sectors, the Pacific Fishery Management Council (PFMC) developed an Individual Fishing Quota program (IFQ) program for the shore-based trawl sector (vessels that land whiting and other groundfish) and a cooperative management structure for the whiting trawl sectors. Prior to the IFQ Program, the non-whiting component of the shore-based trawl sector had been managed through an overall quota combined with trip limits, seasonal closures, gear restrictions, and area restrictions such as the Rockfish Conservation Areas. These measures were adopted to rebuild groundfish and avoid bycatch of overfished stocks of rockfish. However, as these measures became increasingly restrictive, there was growing concern over the economic viability of the non-whiting trawl fishery. Lack of flexibility and individual accountability were cited as pressing management concerns. The shore-based whiting industry also was managed in ways to protect overfished species. As a result, the PFMC adopted an IFQ Program for the shore-based trawl sector and a program of cooperatives for the whiting catcher processor and the whiting mothership sectors. Since the whiting catcher-processor sector already was operating under a voluntary cooperative, this sector was largely left unaltered. (If the cooperative disbands, there are regulatory measures in place to convert this sector to an IFQ fishery.) Development of the shorebased trawl IFQ Program and whiting cooperative programs were initiated in 2003 and implemented for the 2011 year. Although the IFQ Program and cooperative programs manage two separate components (shorebased and at-sea) of the groundfish fishery, the programs are referred to collectively as the Pacific Groundfish Trawl Rationalization Program.

The catch share program indicators including productivity were developed to measure the performance of the harvesting sector. Since both the mothership and catcher processor components of the Trawl Rationalization Program have a significant processing component, a different set of indicators would be better suited to evaluate program performance for these components of the Pacific groundfish trawl fishery. For this reason this section focuses on productivity change in the shorebased IFQ fishery, which comprises the non-whiting and whiting trawlers. However, even though there is substantial overlap in terms of participating vessels the two fisheries are, by and large, distinct fisheries within the shorebased trawl IFQ program and are treated as such below for purposes of reporting productivity change.

The goal of the Pacific Groundfish Trawl Rationalization Program was to create and implement a capacity rationalization plan that increases net economic benefits, creates individual economic stability, provides for full utilization of the trawl sector allocation, considers environmental impacts and achieves individual accountability of catch and bycatch.

Productivity Estimates and Discussion

Groundfish Data

Input data for the whiting and non-whiting groundfish productivity estimates comes from the Economic Data Collection survey, a mandatory survey for all vessels registered to a limited entry trawl permit at any point during a calendar year.[19] The data from this survey thus provides a complete picture of the input of the entire West Coast Groundfish Catch Shares Program. The survey also collects information about days at sea in the groundfish trawl and fixed gear fisheries. The implementation of the catch shares program included a provision for vessels to fish Limited Entry Trawl quota with fixed gear, so days at sea reported for fixed gear by vessels that participated in both the IFQ fishery with fixed gear as well as the primary or open access fisheries were disaggregated by revenue for the productivity calculation. The average crew and captain wage was similarly derived from a disaggregation of these expenses by revenue. In addition to daily labor wage and days at sea, the EDC survey provides average fuel use per day and average crew per day for the whiting trawl, non-whiting trawl, and fixed gear fisheries. An annual summation of all IFQ-landed pounds and revenue obtained from fish tickets provided the average price for whiting and non-whiting groundfish, as well as output quantities for each vessel.

With only two years of catch-share input data available thus far, it is difficult to make meaningful observations about trends in productivity rates after the implementation of the program.

Non-whiting Groundfish Productivity Estimate

Because of the allowance for fixed-gear harvesting with the implementation of the catch share program, the baseline input and output data for this period only includes vessels using trawl gear, whereas the years 2011 and beyond include vessels with fixed or trawl gears. This inclusion of different gear types in the later years may have impacts on productivity independent of the catch share program.

One general caveat regarding the biomass index for non-whiting groundfish: this measure includes biomass indices for 23 different species, and some of the assessments used have not been updated in five to seven years. Biomass data on all species included in the program were not available. However, the species for

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[19] See http://www.nwfsc.noaa.gov/research/divisions/fram/economic/economic_data.cfm.

which no biomass data is available comprise only about 5% of the landings weight over the period, and about 3% of revenue. Biomass data are available for Dover sole and sablefish, which combined make up about half of non-whiting groundfish biomass and about two-thirds of the revenue. The next highest revenue groundfish, Petrale sole, has about 10% of the non-whiting IFQ revenue share but only makes up 0.05% of the total biomass.

2009 and 2010 had much larger outputs and inputs than 2011 and 2012, and this leads to a baseline average higher than the 2011 and 2012 outputs or inputs (Table 18). In 2011, biomass unadjusted productivity as measured by the Lowe index, increased by 27% compared to the baseline (Table 19). Unadjusted MFP in 2012 was also higher than the baseline. The biomass index in both 2011 and 2012 were above 1.0 indicating decreasing biomass although by relatively small amounts of 4% and 7% respectively. For this reason, the differences between biomass adjusted and unadjusted MFP were not large. The biomass adjusted MFP Lowe index was 1.32 in 2011 and 1.29 in 2012. Thus, while productivity was still above the baseline in 2011 and 2012, MFP in 2012 was 3% lower as compared to 2011.

Table 18. Output and Inputs in the West Coast Non-Whiting Groundfish Catch Shares Fishery

Year	Output[a]	Capital[a]	Labor[a]	Energy[a]	Total Inputs[a]
2009	35,307,155	4,210,826	14,582,162	11,943,409	30,736,397
2010	31,310,424	4,021,808	12,027,820	9,979,183	26,028,811
Baseline Average	33,308,789	4,116,317	13,304,991	10,961,296	28,382,604
2011	30,649,071	3,753,070	9,267,098	7,466,979	20,487,147
2012	30,132,485	4,075,127	9,434,987	8,010,943	21,521,057

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Table 19 Estimated Multi- Factor Productivity in the West Coast Catch Shares Non-Whiting Groundfish Fishery

Year	Output Index	Input Index	Biomass-Unadjusted MFP	Biomass Index	Biomass-Adjusted MFP	Year to Year MFP Change
Base	1.00	1.00	1.00	1.00	1.00	
2011	0.92	0.71	1.27	1.04	1.32	1.32
2012	0.90	0.76	1.19	1.07	1.29	0.97

Shoreside Whiting Productivity Estimate

The capital input for the whiting and non-whiting fisheries are roughly similar, despite the former having about a third as many vessels as the latter. Many of the shoreside whiting vessels also participate in Alaska fisheries, and these vessels tend to be much larger and more capital-laden, which might explain the high capital input for the fishery (Table 20). The highest output of all the years, by about 2,300 MT occurred in 2011, which translates to a 75% improvement compared to the baseline average output of $9.8 million. Total inputs used in 2011 declined by 15% compared to the baseline resulting in the biomass unadjusted Lowe index to be substantially greater than one (Table 21). The unadjusted MFP Lowe index was also above 1.0 in 2012.

Due to high variability in recruitment and very fast growth rates, the whiting biomass index may fluctuate quite a bit from year to year. The biomass index in both 2011 and 2012 were 0.67 and 0.52, respectively indicating that biomass was substantially above baseline conditions in both years (Table 21). This means that the biomass adjusted Lowe index was substantially lower in 2011 and 2012 than unadjusted MFP.

Table 20. Output and Inputs in the West Coast Shoreside Whiting Catch Shares Fishery

Year	Output[a]	Capital[a]	Labor[a]	Energy[a]	Total Inputs[a]
2009	7,615,998	3,633,979	4,497,598	5,453,428	13,585,005
2010	11,902,435	4,775,548	6,594,554	9,171,122	20,541,224
Baseline Average	9,759,217	4,204,763	5,546,076	7,312,275	17,063,114
2011	17,061,361	4,095,399	6,475,611	8,991,474	19,562,484
2012	11,065,498	3,429,399	5,731,072	6,494,700	15,655,171

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Table 21. Estimated Multi- Factor Productivity in the West Coast Catch Shares Whiting Fishery

Year	Output Index	Input Index	Biomass-Unadjusted MFP	Biomass Index	Biomass-Adjusted MFP	Year to Year MFP Change
Base	1.00	1.00	1.00	1.00	1.00	
2011	1.75	1.15	1.52	0.67	1.02	1.02
2012	1.13	0.92	1.24	0.52	0.64	0.62

Alaska Region

Alaska Halibut IFQ Program

Fishery Synopsis

Pacific halibut in the U.S. are distributed in the Northeast Pacific from coastal waters in California to Alaska with concentrations in the Central Gulf of Alaska.[20] Pacific halibut are among the largest of flatfish weighing up to 500 pounds and reaching lengths of 8 feet. Halibut is a high value species that is harvested and sold exclusively using hook gear (primarily bottom longline). Bycatch in the fishery includes seabirds, juvenile halibut and other groundfish species. The use of streamers is designed to reduce seabird takes while larger hook size tends to select for larger fish and the use of circle hooks reduces release mortality of discarded undersized halibut. The fishery is also subject to depth and area restrictions to reduce incidental takes on non-target groundfish species.

The Alaska Halibut and Sablefish IFQ Program is managed under two different management authorities: The Northern Pacific Halibut Act (Halibut Act; 1937), which led to the eventual creation of the International Pacific Halibut Commission (established in 1953); and the Magnuson-Stevens Act (1976), which established the Regional Fishery Management Council system. The International Pacific Halibut Commission (IPHC) is responsible for the biological management of the halibut resource, including biological studies, stock assessments, basic regulatory structure and establishing the Total Constant Exploitation Yield, which is equivalent to the acceptable biological catch (ABC). The North Pacific Fishery Management Council (NPFMC) in turn is responsible for establishing Annual Catch Limits (ACLs) and allocating the U.S. catch limits among various user groups.

Halibut fisheries were not overfished prior to the implementation of the IFQ Program but the fishery had been overcapitalized since the 1970s. When overcapacity was recognized as a major problem in the halibut fishery, it was

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[20] See http://www.fishwatch.gov/seafood_profiles/species/halibut/species_pages/pacific_halibut.htm

unclear which agency or regulatory body had jurisdiction over limiting access. The fishing industry approached the newly formed North Pacific Council in the late 1970s to develop a limited entry program because such a measure was not available through the International Pacific Halibut Commission under the terms of the convention establishing the IPHC. The Council's first groundfish fishery management plan was enacted in 1978 and included provisions for establishing limited entry; however, jurisdictional issues delayed implementation of limited entry within the halibut fishery. This jurisdictional issue was not solved until passage of The Northern Pacific Halibut Act of 1982, which designated that limited entry and allocation decisions were under the jurisdiction of the North Pacific Council. The Council did not reconsider limited entry in the halibut fishery until 1990, when these discussions were combined with the discussions of limited entry in the sablefish fishery. The regulatory amendments outlining IFQs as the chosen management tool for halibut and sablefish were published in 1992 and later implemented in 1995.

The Alaska Halibut and Sablefish IFQ Program operates within the Bering Sea and Aleutian Islands region and the Gulf of Alaska region with multiple area and vessel categories. The IFQ Program has 8 area allocations each with 4 vessel classes of halibut quota based and 6 area allocations each with 3 vessel classes of sablefish quota. Although halibut and sablefish fisheries are managed under the same IFQ Program, there are some key differences between halibut and sablefish management; therefore, the productivity assessments are presented separately.

The North Pacific Fishery Management Council designed the Alaska Halibut IFQ Program to allow eligibility based upon U.S. citizenship (or being a U.S. entity for non-individuals) and historical participation. Those eligible for initial allocations had to be owners or leaseholders of vessels with landings during 1988-1990. Initial halibut quota shares were based upon the best five of seven years of catch history from 1984 – 1990. Those who wished to receive quota share by transfer after the initial allocation had to demonstrate a minimum amount of active time as harvesting crew in any U.S. commercial fishery or be a Community Quota Entity

(CEQ)[21]. Other U.S. entities are allowed to purchase the “catcher/processor” (Category “A”) type of quota share, but entities that are not solely owned and were not initial qualifiers for QS may not acquire catcher vessel quota share.

Both quota shares (as a percentage of the catch limit) and annual IFQ pounds are designated by vessel length category and operation type (catcher vessel quota shares and freezer boat shares) and by whether the quota share is blocked or unblocked and whether or not it may be transferred among vessel classes. A transfer from a vessel in a larger size class to another vessel in a smaller size class is referred to as being able to “fish down” and vice versa to “fish up”. Blocked quota share, which cannot be separated and sold in separate units, was given to initial qualifiers if the amount of annual IFQ was less than a specified amount. Holders of blocked quota share are limited in the number of blocks that may be held at any one time. Quota shares can be sold to other eligible permit holders. Transfers are limited by excessive share provisions. Leasing, or annual transfers of quota pounds without underlying quota share is unrestricted for freezer shares, but very restricted for catcher vessel IFQ. The program also limits the use of shares outside of designated vessel type and length categories, although over time the provisions on vessel length restrictions on ‘fish down’ and ‘fish up’ have been somewhat relaxed. The North Pacific Council also included owner on-board requirements for use of catcher vessel shares and limits on the use of hired skippers.

Data

While the Alaska Halibut IFQ program has been in place since 1995, we lack important information on the inputs used by harvesting vessels until the Halibut IFQ program landings were integrated into the “eLandings” system for the year 2008. Prior to 2008, we do not have crew size information (and also lack a precise reporting of trip duration to calculate days at sea) and, therefore, are unable to present any estimates of multi-factor productivity for this fishery prior to 2008.

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[21] The CEQ program was implemented in 2002. The program provides for QS to be purchased and held by community based organizations for the benefit of resident fishermen.

Given the short time frame of available data, 2008 was selected as both the baseline year and reference period for the Lowe input, Lowe output, and biomass indices calculated for the Halibut IFQ program.

Data on output quantities and prices include the total net weight (in pounds) and total ex-vessel revenues, respectively, from all species caught while on halibut IFQ trips. Input quantity data include the number of crew days in the fishery (number of crew on a trip multiplied by the days at sea for the trip summed over all vessels and trips) and an estimate for the amount of capital involved in the fishery. To create a daily labor price, we estimate an opportunity cost wage to value crew days using the mean construction laborer hourly wage in Anchorage multiplied by 8 hours to approximate an opportunity cost daily wage for crew members. We use the self-reported vessel values for all vessels that participated in the Halibut IFQ program from the Alaska Commercial Fisheries Entry Commission (CFEC) vessel license application to estimate the total quantity of capital involved in the fishery. We use this estimate to create an estimated annual value per foot for program participants. The total annual quantity of capital in the fishery is then calculated as the annual mean value per foot multiplied by each vessel's length in that year, summed over all vessels that participated in the fishery in a given year. We value the capital quantity (the capital price) at the rate for BAA grade bonds. Fishery level aggregates for output value (net weight in pounds multiplied by reference year output prices) and input values, including labor (crew days multiplied by reference year labor price) and capital (vessel value multiplied by the reference year capital price), are included in Table 22.

Table 22. Output and Inputs in the Alaska Halibut IFQ Fishery

Year	Output[a]	Capital[a]	Labor[a]	Total Inputs[a]
2008	274,620,670	13,236,475	16,133,059	29,369,533
2009	241,600,736	13,655,239	15,017,862	28,673,101
2010	229,301,656	13,433,407	15,553,874	28,987,281
2011	191,505,214	13,389,059	13,581,861	26,970,920
2012	163,008,300	13,026,808	12,161,544	25,188,352

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Halibut biomass data are taken from the 2012 IPHC stock assessment. The data used for this study are the exploitable halibut biomass (legal sized fish), which is apportioned across areas based on the distribution of halibut from that year's assessment survey. The biomass estimate used in this study is the sum of exploitable halibut biomass for areas managed under the Alaska Halibut IFQ Program (2C, 3A, 3B, 4A, 4B, 4C, 4D, and 4E).

Productivity Estimates and Discussion

Using the data reported in Table 22 Lowe input and output indices were created and are presented in columns 1 and 2 of Table 23. The biomass unadjusted MFP (hereafter unadjusted MFP) estimate in the third column is simply the Lowe output index divided by the Lowe input index which represents the change in aggregate outputs divided by the change in aggregate inputs on an annual basis. Therefore, if the index goes above 1.00, it means that MFP growth is positive and the fishery is getting more output from a given level of inputs, but if the index is below 1.00, it means the opposite. As can be seen in Table 23, there have been declines in MFP for each year after the baseline year of 2008, which is by definition set equal to 1.00. The mean unadjusted MFP index for non-baseline years is 0.80.

It is possible that this decline in observed unadjusted MFP arose because we have not accounted for the declines in the biomass of halibut as an input into the production process. The biomass index is included in column 4 of Table 23 and represents the change in halibut biomass relative to the baseline period. Recall that the baseline year's biomass is in the numerator of the biomass index and, therefore, an increase in the biomass is represented by a number below 1.00, while an index value above 1.00 signifies a decrease in the halibut biomass. This allows the biomass adjusted MFP (hereafter adjusted MFP) index, shown in the final column of Table 23, to be calculated as the product of the unadjusted MFP index and the biomass index. Higher levels of biomass decrease the adjusted MFP index because if there are more fish it is assumed that they are easier to catch and the adjusted MFP index is calculated to account for the impact of changes in biomass on fishery productivity. Halibut biomass has declined in each year of the study period relative to the baseline period except for 2012, implying that the adjusted MFP index will be greater than the unadjusted MFP index for all years. After accounting for the decline in the halibut biomass, the estimated adjusted MFP index varies around 1.00 for all years except 2012 when output substantially declined. Overall, adjusted MFP averaged 0.98 for non-baseline years which means that there have not been many changes in the productivity of the fishery over this period. Additional years of data are necessary to determine whether the decline in 2012 was a one year event or whether the decline in MFP has continued.

Table 23. Estimated Multi-Factor Productivity in the Halibut IFQ Fishery

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
2008	1.00	1.00	1.00	1.00	1.00	
2009	0.88	0.98	0.90	1.12	1.01	1.01
2010	0.83	0.99	0.85	1.20	1.02	1.01
2011	0.70	0.92	0.76	1.31	0.99	0.97
2012	0.59	0.86	0.69	1.28	0.88	0.89

The adjusted MFP index is approximately 1.01 for 2009 and 2010, but there is a decline in adjusted MFP in 2011 and 2012. In 2011, the decline in biomass no longer accounts for the entire decline in unadjusted MFP and the adjusted MFP estimate declines slightly below 1.00 in 2011. However, in 2012, the year of the small increase in exploitable biomass, there was a substantial decline in the unadjusted MFP index as well as the adjusted MFP index which means something beyond biomass changes could be driving the decrease in unadjusted MFP; the continued decline in halibut biomass can no longer be compensated for using inputs more productively. This could also be the result of the way capital is quantified in this index. If a vessel participates in the halibut IFQ fishery, the entire capital value is deemed to be in the fishery even if they only spend a small amount of time in the fishery. The mean number of days for vessels participating in the fishery has declined from nearly 21 days in 2008 to less than 17 days in 2012, so this alternative specification would alter our estimate of capital use from current values. This decline in days fishing is, however, accounted for in our computation of labor input. Input specification aside, the trends we observe here in MFP, which is essentially a multidimensional measure of catch per unit effort (CPUE), provides useful information on the productivity of the halibut fishery and could be used by the IPHC in conjunction with stock trends when determining the Total Constant Exploitable Yield for the commercial fishery.

Alaska Sablefish IFQ Program

Fishery Synopsis

Sablefish or "Black Cod" are distributed in the Northeast Pacific Ocean from Northern Mexico to the Gulf of Alaska and through the Aleutian Islands.[22] Based on morphological differences in growth rates, seasonal reproduction, and tagging studies, sablefish are divided into Northern and Southern population. The Northern population extends from Northern British Columbia to Alaska. The U.S. portion of the Northern population is managed by the North Pacific Fishery Management Council whereas the U.S. portion of the Southern population, which extends throughout the West Coast is managed by the Pacific Fishery Management Council.

Sablefish is a fast-growing roundfish species reaching sizes of up to three feet. Females mature in 6 to 7 years at approximately 2 feet in length while males mature in about 5 years at slightly smaller size. Sablefish is a high value species that is targeted in the Gulf of Alaska primarily using hook gear and trawl gear. There are two main vessel types harvesting sablefish in the Alaska Sablefish IFQ Program: catcher vessels that catch sablefish and deliver to a shoreside processor, and catcher/processor vessels that catch sablefish and process it onboard. We will create estimates of total factor productivity separately for each vessel type.

Sablefish was originally managed under its own fishery management plan (FMP) and was later combined with the groundfish FMP in the Gulf of Alaska (1978) and Bering Sea and Aleutian Islands (1982). Coincident with the exit of foreign harvesters in 1987, the domestic portion of the sablefish fishery grew rapidly during the 1980s. In 1985, the North Pacific Council allocated the vast majority of the sablefish quota to vessels using hook-and-line and pot gear in the Gulf of Alaska, with a small portion allocated to vessels using trawl gear. Pot gear was subsequently phased out in the Gulf of Alaska due to gear conflicts. The North Pacific Council allocated one-half of the sablefish quota in the Bering Sea to the

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[22] See http://www.fishwatch.gov/seafood_profiles/species/cod/species_pages/sablefish.htm

fixed gear fleet and the remainder to trawlers. It was not until 1987 that the Council began to consider proposals for limited entry in the sablefish fishery.

The regulatory amendments outlining IFQ Programs as a management tool for halibut and sablefish were published in 1992 and later implemented in 1995. The Alaska Halibut and Sablefish IFQ Program operates within the Bering Sea and Aleutian Islands region, and the Gulf of Alaska region with multiple area and vessel categories. The IFQ Program has 8 area allocations each with 4 vessel classes of halibut quota and 6 area allocations each with 3 vessel classes of sablefish quota. Sablefish are managed by NOAA Fisheries and the North Pacific Council under the authority of the Magnuson-Stevens Act. Halibut and sablefish are combined in the same IFQ Program to minimize bycatch and discard mortality.

The North Pacific Fishery Management Council designed the Alaska Sablefish IFQ Program to allow eligibility based upon U.S. citizenship (or being a U.S. entity for non-individuals) and historical participation. Those eligible for initial allocations had to be owners or leaseholders of vessels with landings during 1988-1990. Initial sablefish quota shares were based upon the best five of six years of catch history from 1985 – 1990. Those who wished to receive quota share by transfer after the initial allocation had to demonstrate a minimum amount of active time as harvesting crew in any U.S. commercial fishery or be a Community Quota Entity (CQE). Other U.S. entities are allowed to purchase the “catcher/processor” (Category “A”) type of quota share, but entities that are not solely owned that were not initial qualifiers for QS may not acquire catcher vessel quota share.

Both quota shares (as a percentage of the catch limit) and annual IFQ pounds are designated by vessel length category and operation type (catcher vessel quota shares and freezer boat shares). Quota share is also designated as being either blocked or unblocked and whether or not it may be transferred among vessel classes. A transfer between a vessel in a larger size class to a vessel in a smaller size classes is referred to as being able to “fish down”; the opposite is to “fish up”. Blocked quota share was issued to initial qualifiers based on whether the initial IFQ allocation was less than a specified amount. Blocked quota share cannot be separated or sold in separate units. Quota shares can be sold to other eligible permit holders. Transfers are limited by excessive share provisions. Leasing, or annual transfers of quota pounds without underlying quota share, is unrestricted for freezer shares, but very restricted for catcher vessel IFQ. The program also limits the use of shares outside of designated vessel type and length categories, although over time the provisions on vessel length restrictions on 'fish down' and 'fish up' have been somewhat relaxed. The North Pacific Council also included owner on-board requirements for use of catcher vessel shares and limits on the use of hired skippers.

Data

Similar to other Alaska Region programs, we lack important information on the inputs used by harvesting catcher vessels in the Alaska Sablefish IFQ Program prior to 2007. However, we are able to gather a consistent set of input and output data for the catcher/processor vessels back to 1995, our baseline year. Because the Alaska Sablefish IFQ Program was implemented in 1995, we will not be able to demonstrate any changes in MFP before and after the Sablefish IFQ Program. However, this longer time horizon does provide a better sense of the trends in MFP for the catcher/processor sector. Given the short time frame of available data for the catcher vessels, the baseline year and reference period were selected to be a single year (2007), which differs from the 1995 baseline year and reference period used for catcher/processors.

For catcher vessels, data on output quantities and prices were used to construct the Lowe output index. Data include the total round weight (in pounds) and total ex-vessel revenues, respectively, from all species caught while on sablefish IFQ trips. Input quantity data used to construct the Lowe input index include the number of crew days in the fishery (number of crew on a trip multiplied by the number of days at sea for the trip, summed over all vessels and trips) and an estimate for the amount of capital involved in the fishery. To create a daily labor price we estimated an opportunity cost wage to value crew days using the mean construction laborer hourly wage in Anchorage multiplied by 8 hours. We use the self-reported vessel values for all catcher vessels that participated in the Sablefish IFQ program from the CFEC vessel license application to estimate the total quantity of capital involved in the catcher vessel sector of the fishery. We use this estimate to create an annual value per foot for catcher vessel participants. The total annual quantity of capital for the catcher vessel sector is then calculated as the as the annual mean value per foot multiplied by each vessel's length in that year, summed over all catcher vessels that participated in the fishery each year.[23] We value the capital quantity (the capital price) at the rate for BAA grade bonds. Catcher vessel sector aggregates for output value (round weight in pounds multiplied by reference year output prices) and input values, including labor (crew days multiplied by reference year labor price) and capital (vessel value multiplied by the reference year capital price), are included in Table 24.

Table 24. Outputs and Inputs of Catcher Vessels in the Alaska Sablefish Fishery

Year	Output[a]	Capital[a]	Labor[a]	Total Input[a]
2007	140,238,353	8,109,917	7,049,414	15,159,331
2008	135,403,058	9,274,763	6,845,401	16,120,165
2009	131,330,526	10,014,183	6,977,360	16,991,543
2010	129,006,290	9,210,910	7,365,194	16,576,105
2011	127,188,626	9,843,396	7,408,347	17,251,742
2012	125,372,170	9,689,471	7,718,364	17,407,835

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

For catcher/processor vessels from 1995-2007, data on output quantities and prices include the total produced weight (in metric tons) and total product revenues, respectively, from all species produced in weeks where some amount of IFQ sablefish (sablefish that was part of the Sablefish IFQ Program) was produced. For 2008 onward, catcher/processors began submitting daily production reports (instead of the weekly production reports they submitted between 1995 and2007). Therefore, for 2008-2012, data on output quantities and prices represent all species produced on days where some amount of IFQ sablefish was also produced. Input

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[23] There are several outliers at the low and high end that excluded when calculating annual mean values which include vessel values less than $49,999 and over $10,000,000.

quantity data include the number of crew days (harvesting and processing crew) in the fishery and an estimate for the amount of capital involved in the fishery. For the period 1995-2007, catcher/processor vessels that submitted a weekly production report with some amount of IFQ sablefish produced were assumed to operate for 4.295 days that week, which is the average number of days per week that these vessels were active on weeks where they caught sablefish during the 2008-2012 period. For 2008 onward, the number of days in the fishery is equal to the number of days in which the catcher/processor reported producing some IFQ sablefish. The labor input is therefore calculated as the number of days the vessel was in the fishery multiplied by the crew size for those days, summed over all vessels. We use the same mean construction laborer wage as for the catcher vessels for catcher/processor crew members. Similar to the catcher vessels, we use the self-reported vessel values for all catcher/processors that participated in the Sablefish IFQ program from the CFEC vessel license application. However, as there are some years with no vessels reporting values, we create a single estimate of the value per foot for all catcher/processors participants. The total annual quantity of capital for the catcher/processor sector is then calculated as the as the mean value per foot multiplied by each vessel's length in each year summed over all catcher/processors. We value the capital quantity (the capital price) at the rate for BAA grade bonds. Catcher/processor sector aggregates for output value (produced weight in metric tons multiplied by reference year output prices) and input values, including labor (crew days multiplied by reference year labor price) and capital (vessel value multiplied by reference year capital price), in Table 25.

Sablefish biomass data are taken from NMFS Species Information System (SIS) for the 2012 assessment year. The biomass data used in this study included abundance of age 2+ sablefish for the Eastern Bering Sea Aleutian Islands, and Gulf of Alaska regions in metric tons.

Table 25. Outputs and Inputs of Catcher/Processor Vessels in the Alaska Sablefish IFQ Fishery

Year	Output[a]	Capital[a]	Labor[a]	Total Inputs
1995	23,128,840	8,047,373	1,617,261	9,664,634
1996	20,699,810	5,190,082	1,295,637	6,485,719
1997	16,965,585	4,595,599	1,053,344	5,648,943
1998	24,855,126	5,064,211	1,340,277	6,404,488
1999	23,533,433	7,343,977	1,582,302	8,926,279
2000	27,023,775	7,414,914	1,719,449	9,134,363
2001	21,194,527	6,439,475	1,290,259	7,729,734
2002	14,335,282	5,009,277	985,846	5,995,123
2003	17,975,291	5,330,761	1,138,052	6,468,813
2004	19,539,152	5,566,500	1,250,459	6,816,959
2005	22,781,080	5,909,958	1,263,367	7,173,325
2006	21,864,864	5,282,753	1,150,423	6,433,176
2007	21,006,646	5,668,247	1,136,170	6,804,418
2008	9,033,265	4,542,814	779,703	5,322,518
2009	14,543,928	4,997,573	1,081,217	6,078,790
2010	12,834,266	4,762,312	890,392	5,652,704
2011	15,138,760	4,629,992	1,099,498	5,729,491
2012	15,927,599	3,357,192	1,089,857	4,447,049

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Productivity Estimates and Discussion

Using the data reported in Table 24, Lowe input and output indices were created and are presented in columns 1 and 2 of Table 26 for the catcher vessel sector. The biomass unadjusted MFP (hereafter unadjusted MFP) estimate in the third column is simply the Lowe output index divided by the Lowe input index, or the change in aggregate outputs divided by the change in aggregate inputs, on an annual basis. Therefore, an index value above 1.00 means that MFP growth is positive and the fishery is getting more output from a given level of inputs, but if the index is below 1.00, the opposite is true. As can be seen in Table 26, the unadjusted MFP had declined every year after the baseline year of 2007, which is by definition set equal to 1.00. The input index has increased and output index decreased every year after the baseline year. The mean unadjusted MFP index for the sablefish IFQ catcher vessels for non-baseline years is 0.83.

There have been some small declines in the sablefish biomass that may account for some of the declines in the unadjusted MFP. The biomass index is included in column 4 of Table 26 and represents the change in sablefish biomass relative to the baseline year. Recall that the baseline year's biomass is in the numerator of the biomass index, and therefore an increase in the biomass is represented by a number below 1.00, while an index value above 1.00 signifies a decrease in the sablefish biomass. This allows the biomass adjusted MFP (hereafter adjusted MFP) index, shown in the final column of Table 26, to be calculated as the product of the unadjusted MFP index and the biomass index. Higher levels of biomass decrease the adjusted MFP index because if there are more fish, it is assumed that they are easier to catch. The adjusted MFP index is thus calculated to account for the impact of changes in biomass on fishery productivity. Sablefish biomass declined slightly in each year, which means that the adjusted MFP index will be greater than the unadjusted MFP index in all years. However, even after accounting for the decline in the sablefish biomass, the estimated adjusted MFP index is still below 1.00 for all years and averages 0.89 for the catcher vessel sector.

Table 26. Estimated Multi-Factor Productivity of Catcher Vessels in the Sablefish IFQ Fishery

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
2007	1.00	1.00	1.00	1.00	1.00	
2008	0.97	1.06	0.91	1.03	0.94	0.94
2009	0.94	1.12	0.84	1.07	0.89	0.95
2010	0.92	1.09	0.84	1.06	0.90	1.01
2011	0.91	1.14	0.80	1.10	0.88	0.98
2012	0.89	1.15	0.78	1.13	0.88	1.00

Using the same methods as for the catcher vessels, we use the data presented in Table 25 to create Lowe input and output indices that are presented in columns 1 and 2 of Table 27 for the catcher/processor sector. As can be seen in Table 27 (column 3), there has been a lot of variation in the unadjusted MFP since the baseline year of 1995. The unadjusted MFP index has ranged from 0.71 in 2008 to 1.62 in 1998. The large variation in MFP between 2007 and 2008 is largely the result of a large drop in output and labor input from 2007 to 2008. The changes in output and labor input could be an artifact of the change in data resolution after 2007, where we began collecting daily production reports rather than the prior weekly production reports (for which we assumed vessels were active on a 4.295-day week, based on the number of active days during the 2008-2012 period).This drop in the output and labor input can be seen in Table 25. However, other than this potentially data driven change, unadjusted MFP ranged from 0.95 in 2010 to 1.50 in 2012 and averaged 1.20 for the catcher/processor sector in non-baseline years. In contrast to the catcher vessel sector, which has averaged 408 active vessels from 1995-2012 (347 from 2007-2012), the catcher/processor sector only averaged 19 active vessels from 1995-2012. Therefore, each catcher/processor vessel has a much larger impact on the overall sector productivity estimates, which could possibly account for the larger variation in the unadjusted MFP for the catcher/processor sector relative to the catcher vessel sector.

There have been several years of small declines and small increases in the sablefish biomass over the study period. The biomass index is included in column 4 of Table 27 and represents the change in sablefish biomass relative to a baseline year, where a number above 1.00 indicates a biomass decrease and a value below 1.00 indicates a biomass increase. The biomass index has ranged from 0.91 in 2004 to 1.16 in 1998 but averaged 1.03 over the entire period. As there have only been relatively small changes in the biomass index, the adjusted MFP index will likely be fairly similar to the unadjusted MFP index. The mean adjusted MFP index for non-baseline years for the catcher/processor sector is 1.23. As shown in Table 25, the capital and labor inputs for the catcher/processor sector generally move in the same direction (with the exception of 2007-2008), but changes in both the adjusted MFP and unadjusted MFP are positively correlated with the percent change in the labor input (correlation coefficients of 0.51 and 0.49, respectively) than percent changes in the capital input (correlation coefficients of -0.17 and -0.19, respectively).

Table 27. Estimated Multi-Factor Productivity of Catcher/Processor Vessels in the Sablefish IFQ Fishery

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
1995	1.00	1.00	1.00	1.00	1.00	
1996	0.89	0.67	1.33	1.07	1.43	1.43
1997	0.73	0.58	1.25	1.09	1.37	0.96
1998	1.07	0.66	1.62	1.16	1.88	1.37
1999	1.02	0.92	1.10	1.10	1.22	0.65
2000	1.17	0.95	1.24	1.07	1.32	1.08
2001	0.92	0.80	1.15	1.06	1.21	0.92
2002	0.62	0.62	1.00	0.94	0.94	0.78
2003	0.78	0.67	1.16	0.92	1.07	1.14
2004	0.84	0.71	1.20	0.91	1.09	1.02
2005	0.98	0.74	1.33	0.93	1.24	1.14
2006	0.95	0.67	1.42	0.95	1.35	1.09
2007	0.91	0.70	1.29	0.98	1.27	0.94
2008	0.39	0.55	0.71	1.01	0.72	0.57
2009	0.63	0.63	1.00	1.04	1.04	1.46
2010	0.55	0.58	0.95	1.04	0.99	0.95
2011	0.65	0.59	1.10	1.08	1.19	1.20
2012	0.69	0.46	1.50	1.10	1.65	1.39

The trends in unadjusted MFP and adjusted MFP are not consistent across the catcher vessel and catcher/processor sectors. For the catcher vessel sector, the year-to-year change in adjusted MFP averaged 0.97 for non-baseline years, which implies declining productivity at the sector level over the period 2008-2012. In contrast, the catcher/processor sector averaged 1.06 for the year-to-year change in adjusted MFP for non-baseline years, which implies an increasing productivity for the catcher/processor sector over the period 2008-2012. One explanation is that the catcher/processor sector outputs are produced weight rather than landed round weight for the catcher vessels, which means that the catcher/processor sector is potentially able to compensate for lower catch levels by increasing product recovery rates or producing additional ancillary products. This would increase their output but may not result in very much additional quantifiable input use. Another explanation is that catcher/processor vessels are able to take longer and farther trips and fish in more dense aggregations of sablefish than the catcher vessels that have to return to port to deliver their products. This would suggest that the catcher/processors may be able to reduce total steaming time between the port and fishing grounds, or may be able to fish in more productive areas. It is also possible that the catcher/processor sector relies more heavily on an omitted input (such as fuel to power the processing lines) than the catcher vessel sector, which would not be accounted for in our MFP estimates. Additional investigation would be required to assess which explanation is most likely driving these diverging results.

American Fisheries Act (AFA) Pollock Cooperatives

Fishery Synopsis

The Alaska pollock fishery is the largest by volume and among the most valuable fisheries in the U.S. Pacific Walleye pollock are found throughout the Northern Pacific Ocean, but are concentrated in the Bering Sea.[24] Pollock grow rapidly and have relatively short life spans. However, females produce large quantities of eggs and reach maturity between 3 and 4 years of age resulting in a robust and productive resource. Pollock are harvested using pelagic trawl gear. The fishery consists of a number of sectors; some catcher vessels harvest Pollock for delivery to shoreside processors, other catcher vessels deliver to motherships that conduct processing at sea, and catcher/processors that harvest and process pollock at sea.

The American Fisheries Act (AFA) Pollock Cooperatives Program (or simply AFA Program) was established by the U.S. Congress under the American Fisheries Act in 1998. Prior to the implementation of the AFA Program in 1999 and 2000, the fishery was often closed after only two months in order to ensure that the fleet did not exceed harvest limits.[25] While the pollock fishery was not overfished or experiencing overfishing prior to implementation of the catch share program, the short season often led to many negative consequences of the "race for fish" and there were frequent allocation disputes between the inshore and offshore fleets. The AFA Program manages Bering Sea and Aleutian Islands pollock. The AFA established participation requirements and authorized the formation of cooperatives. Other major components of the AFA were minimum U.S. ownership requirements, a permit/vessel buyout, a list of vessels eligible to participate in the Program, processor eligibility requirements, the establishment of three harvest sectors (and their respective allocations) and, allocations to the Western Alaska Community Development Quota (CDQ) Program. When the AFA Program was implemented, the buyback of the nine decommissioned vessels cost the

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[24] See http://www.fishwatch.gov/seafood_profiles/species/pollock/species_pages/alaska_pollock.htm

[25] The AFA allowed catcher/processors to form cooperatives in 1999 but did not allow the formation of mothership or inshore cooperatives until 2000.

government $90 million. The inshore sector agreed to pay back $70 million by paying $0.06 per pound of harvested pollock. The remaining $20 million was borne by taxpayers.

The AFA Program was designed to grant eligibility to those meeting the statutory requirements within the American Fisheries Act: meeting minimum pollock landings criteria, U.S. vessel ownership requirements and minimum delivery thresholds for shoreside processors. Eligibility for initial allocations was based upon historic participation with different criteria for inshore, offshore and mothership sectors. The inshore sector (catcher vessels) had to meet landings thresholds for 1996, 1997 and 1998. The offshore sector (catcher/processors) was required to be directly listed in the American Fisheries Act or meet a minimum landings threshold. Motherships were required to be listed in the American Fisheries Act. Shoreside processors must have met minimum delivery thresholds in 1996 and 1997 to be eligible to receive inshore sector deliveries.

Inshore catcher vessel cooperatives receive exclusive harvest privilege permits from NOAA Fisheries. Inshore cooperatives can only form between catcher vessels and eligible shoreside processors where the vessel delivered a majority of their catch in the previous year. Vessels in shoreside cooperatives are required to deliver 90 percent of their pollock catch to a member processor. Vessels choosing not to join a cooperative could operate in a limited access fishery, but must do so under a restrictive regulatory framework. Vessel owners choosing to switch cooperatives are required to sit out a year in the limited access fishery and are not eligible to participate in the cooperative system during that time. The mothership and catcher/processor sectors have formed voluntary cooperatives to manage their allocations, which then receive an exclusive harvest privilege from NOAA Fisheries.[26]

After 10 percent of the Total Allowable Catch is allocated to CDQ groups and an amount (about three percent) is established for incidental catch of pollock outside

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[26] https://npfmc.legistar.com/View.ashx?M=F&ID=2742795&GUID=5DE3725D-2728-4B6D-9E48-619C6CF50EAF

the Program, the remaining quota is divided among the sectors. The inshore sector receives 50% of the remaining total allocation for catcher vessels who deliver their harvests to shore-based processors. The offshore sector receives 40% of the remaining total allocation and includes catcher/processor vessels and those catcher vessels that deliver to catcher/processors. The mothership sector receives 10% of the remaining allocation and includes floating processors and the catcher vessels that deliver to them. Quota shares and quota pounds (inshore, offshore and mothership sectors) can be sold or leased to other participants in the same sector. Quota shares transfer with the sale of a vessel. This study groups all catcher vessels together into a single sector and examines trends in MFP change separately for the catcher vessel sector and for the catcher/processor sector.

Data

Similar to other Alaska Region programs, we lack important information on the inputs used by catcher vessels in the AFA Program prior to 2007. However, we are able to gather a consistent set of input and output data for the catcher/processor vessels back to 1996 and we use a 3-year average prior to program implementation (1996-1998) as the baseline and reference period for the catcher/processor sector. Given the short time frame of available data for the catcher vessels, the baseline year and reference period was selected to be a single year (2007), which differs from the 3-year average used for catcher/processors.

For catcher vessels, the Lowe output index was constructed using data on the total round weight (in pounds) and total ex-vessel revenues, respectively, from all species caught while on AFA trips. Input quantity data used to construct the Lowe input index include the number of crew days in the fishery (number of crew on a trip multiplied by the number of days at sea for the trip, summed over all vessels and trips) and an estimate for the amount of capital involved in the fishery. To create a daily labor price we estimate an opportunity cost wage to value crew days using the mean construction laborer hourly wage in Anchorage multiplied by 8 hours. We use the self-reported vessel values for all catcher vessels that participated in the AFA Program from the CFEC vessel license application to estimate the total quantity of capital involved in the catcher vessel sector of the fishery. We use this estimate to create an annual value per foot for catcher vessel participants. The total annual quantity of capital for the catcher vessel sector is then calculated as the annual mean value per foot multiplied by each vessel's length in that year, summed over all catcher vessels that participated in the fishery each year.[27] We value the capital quantity (the capital price) at the rate for BAA grade bonds. Catcher vessel sector aggregates for output value (round weight in pounds multiplied by reference year output prices) and input values, including labor (crew days multiplied by reference year labor price) and capital (vessel value multiplied by reference year capital price), are included in Table 28.

Table 28. Outputs and Inputs of Catcher Vessels in the AFA Pollock Program

Year	Output[a]	Capital[a]	Labor[a]	Total Inputs
2007	200,328,960	19,572,874	8,275,949	27,848,823
2008	146,522,793	19,310,762	6,504,055	25,814,816
2009	122,823,730	18,932,512	5,422,805	24,355,317
2010	121,336,873	16,982,433	5,019,872	22,002,305
2011	181,616,507	16,363,767	7,189,994	23,553,761
2012	181,725,618	19,344,390	7,046,779	26,391,168

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

For catcher/processor vessels from 1996-2007, data on output quantities and prices include the total product weight (in metric tons) and total product revenues, respectively, from all species produced in weeks where some amount of AFA pollock (pollock that was part of the AFA Program) was produced. For 2008 onward, catcher/processors began submitting daily production reports (instead of the weekly production reports they submitted between 1996 and 2007). Therefore, for 2008-2012, data on output quantities and prices represent all species produced on days where some amount of AFA pollock was produced. Input quantity data include the number of crew days (harvesting and processing crew) in the fishery and an estimate for the amount of capital involved in the fishery. For the period 1996-2007, catcher/processor vessels that submitted a weekly production report with

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[27] Two values below $5,000 were dropped because they were considered outliers.

some amount of AFA pollock produced were assumed to operate for a full 7 days that week. For 2008 onward, the number of days in the fishery is specified as the number of days in which the catcher/processor reported producing some AFA pollock. The labor input is therefore the number of days the vessel was in the fishery multiplied by the crew size for those days, summed over all vessels. Unfortunately, the Anchorage construction laborer wage time series used for the catcher vessels began in 1997, and therefore we use the annual average hourly wage for all U.S. production workers as the opportunity cost wage for the catcher/processor sector (shown in Appendix A). To estimate the average value per foot for each vessel we use two different valuation survey estimates taken from one vessel at different times and create an average.[28] This average vessel value is then converted to an average value per foot. The total annual quantity of capital for the catcher/processor sector is then calculated as the as the mean value per foot multiplied by each vessel's length in each year, summed over all catcher/processors. We price the capital quantity at the rate for BAA grade bonds. Catcher/processor sector aggregates for output value (produced weight in metric tons multiplied by reference period output prices) and input values, including labor (crew days multiplied by reference period labor price) and capital (vessel value multiplied by reference period capital price), are included in Table 29.

Pollock biomass data are taken from NMFS stock assessments for Eastern Bering Sea pollock and Aleutian Islands pollock for the 2012 assessment year.[29] The biomass data used in this study are the sum of the estimated age 3+ biomass for Eastern Bering Sea pollock and the age 2+ biomass for Aleutian Islands pollock in metric tons. The vast majority, 98% of pollock biomass in the two regions is located in the Eastern Bering Sea.

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[28] This value is taken from the Amendment 80 Economic Data Report from a vessel that participates in both the Amendment 80 Program and the AFA program.

[29] Available at: http://www.afsc.noaa.gov/REFM/Docs/2012/EBSpollock.pdf and http://www.afsc.noaa.gov/REFM/Docs/2012/AIpollock.pdf.

Table 29. Outputs and Inputs of Catcher/Processor Vessels in the AFA Pollock Program

Year	Output[a]	Capital[a]	Labor[a]	Total Inputs[a]
Baseline	384,389,701	66,307,442	31,862,550	98,169,991
1999	342,405,158	47,444,553	26,323,995	73,768,547
2000	415,724,811	33,577,447	28,999,360	62,576,807
2001	566,611,206	35,635,792	38,315,349	73,951,141
2002	555,679,510	37,760,839	32,867,216	70,628,055
2003	613,310,577	36,054,816	36,709,583	72,764,399
2004	613,307,340	38,341,486	35,467,937	73,809,423
2005	657,152,447	36,054,816	35,605,392	71,660,208
2006	668,186,019	36,054,816	37,362,267	73,417,083
2007	673,393,102	36,054,816	39,311,215	75,366,030
2008	455,762,344	37,760,839	23,022,184	60,783,023
2009	410,713,856	33,615,929	19,723,685	53,339,614
2010	415,483,905	34,172,631	18,373,008	52,545,639
2011	624,455,059	33,968,251	33,137,757	67,106,008
2012	587,043,156	32,466,608	24,927,858	57,394,466

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Productivity Estimates and Discussion

Using the data reported in Table 28, Lowe input and output indices were created and are presented in columns 1 and 2 of Table 30 for the catcher vessel sector. The biomass unadjusted MFP (hereafter unadjusted MFP) estimate in the third column is simply the Lowe output index divided by the Lowe input index, or the change in aggregate outputs divided by the change in aggregate inputs, relative to the baseline. Therefore, an index value above 1.00 means that MFP growth is positive and the fishery is getting more output from a given level of inputs, but if the index is below 1.00, the opposite is true. As can be seen in Table 30, there have been three years of substantial decline in the unadjusted MFP after the baseline year of 2007, which is by definition set equal to 1.00, one year of increase in the unadjusted MFP, followed by one year of decline in unadjusted MFP. On average unadjusted MFP for non-baseline years was 0.86 for the AFA catcher vessels suggesting a decline in productivity in the sector.

There have been some substantial changes in the pollock biomass over this period that may account for some of the changes that we observe in the unadjusted MFP. Pollock biomass began falling in 2005 from a relatively stable population above 10 million tons, and reached a low in 2008 of slightly below 5 million tons, but has since rebounded to approximately 8 million tons from 2011-2013. These biomass numbers are used to calculate the biomass index included in column 4 of Table 30, which represents the change in annual pollock biomass. Recall that the baseline year's biomass is in the numerator of the biomass index, and therefore an increase in the biomass is represented by a number below 1.00, while an index value above 1.00 signifies a decrease in the pollock biomass. This allows the biomass adjusted MFP (hereafter adjusted MFP) index, shown in the final column of Table 30, to be calculated as the product of the unadjusted MFP index and the biomass index. Higher levels of biomass decrease the adjusted MFP index because if there are more fish, it is assumed that they are easier to catch. The adjusted MFP index is thus calculated to account for the impact of changes in biomass on fishery productivity. Due to the highly variable biomass over this time period, the biomass index varies from a low of 0.76 in 2012 to a high of 1.25 in 2008. These large swings in the biomass index result in diverging unadjusted MFP and adjusted MFP indices. The adjusted MFP index is below 1 for all years after the baseline, but the impacts are sometimes muted and other times magnified by the changes in biomass. For example, a low biomass year in 2008 (biomass index=1.25) resulted in an adjusted MFP index of 0.98 from an unadjusted MFP index of 0.79, which implies that productivity remained close to constant from 2007-2008 after accounting for the declining biomass. In contrast, there was a substantial increase in biomass in 2011 (Biomass Index=0.77) which resulted in an adjusted MFP index of 0.82. Given the unadjusted MFP index was 1.07, this implies that the productivity actually declined after accounting for the increase in biomass.

Table 30. Estimated Multi-Factor Productivity of Catcher Vessels in the AFA Program

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
2007	1.00	1.00	1.00	1.00	1.00	
2008	0.73	0.93	0.79	1.25	0.98	0.98
2009	0.61	0.87	0.70	0.98	0.69	0.70
2010	0.61	0.79	0.77	1.03	0.79	1.15
2011	0.91	0.85	1.07	0.77	0.82	1.05
2012	0.91	0.95	0.96	0.76	0.73	0.88

Using the same methods as for the catcher vessels, we use data presented in Table 29 to create Lowe input and output indices that are presented in columns 1 and 2 of Table 31 for the catcher/processor sector. As can be seen in Table 31 (column 3), there has been a lot of variation in the unadjusted MFP since the baseline period, but it has consistently remained above 1.00. The unadjusted MFP index has ranged from 1.19 in 1999 to 2.61 in 2012. The change in output and labor input between 2007 and 2008 could be an artifact of the change in data resolution after 2007, where we began collecting daily production reports rather than the prior weekly production reports (for which we assumed a 7-day week).This drop in the output and labor input can be seen in Table 29. However, even including this potentially data driven change, unadjusted MFP averaged 2.07 for the catcher/processor sector in non-baseline years. There were also substantial gains in unadjusted MFP growth in the three years following implementation of the AFA program, as the unadjusted MFP index values were 1.19, 1.70, and 1.96 from 1999-2001.

As noted above, there have been large changes in the pollock biomass over the period of the AFA program. While the biomass numbers are the same for both the catcher vessel and catcher/processor sectors, the catcher/processor biomass index uses a different baseline period (1996-1998) and is included in column 4 of Table 31. The biomass index reached a low of 0.85 in 2003; however, it reached a high of 2.14 in 2008, and averaged 1.30 over the entire period. As with the catcher vessel sector, the variability in the biomass index results in sometimes amplifying the adjusted MFP away from a value of 1.00 and at other times muting the adjusted MFP toward a value of 1.00. However, as the average biomass index is above 1.00, the adjusted MFP index average at 2.70 is greater than the average for the unadjusted MFP index. On an annual basis, the year-to-year change in adjusted MFP averaged 1.11 over all non-baseline years. This estimate is larger than some other studies of productivity gains in fisheries such as Kirkley et al. (2004) which suggests a 0.8% annual increase, while other studies suggest a range from 1% (Hannesson, 2007) to 4.4% (Jin et al., 2002), but the estimate of 11% is only modestly above estimates on this same fleet of 8.8% by Paul et al. (2009) using the years 1994-2004 and 8% by Torres and Felthoven (2014) using the years 1994-2009 (the latter of which accounts for the role of biomass changes). As this study only focuses on post-AFA productivity gains, while Paul et al. (2009) and Torres and Felthoven (2014) use data back to 1994, it is reasonable that productivity gains would be on average higher in this study as many of the gains result from incresing flexibility in harvesting and processing decisions after the implementation of the catch share program.

Table 31. Estimated Multi-Factor Productivity of Catcher/Processor Vessels in the AFA Program

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
Baseline	1.00	1.00	1.00	1.00	1.00	
1999	0.89	0.75	1.19	0.96	1.14	1.14
2000	1.08	0.64	1.70	1.03	1.75	1.54
2001	1.47	0.75	1.96	1.05	2.06	1.18
2002	1.45	0.72	2.01	1.01	2.03	0.99
2003	1.60	0.74	2.15	0.85	1.82	0.89
2004	1.60	0.75	2.12	0.90	1.91	1.05
2005	1.71	0.73	2.34	1.07	2.52	1.32
2006	1.74	0.75	2.32	1.40	3.24	1.29
2007	1.75	0.77	2.28	1.71	3.91	1.20
2008	1.19	0.62	1.91	2.14	4.09	1.05
2009	1.07	0.54	1.97	1.68	3.30	0.80
2010	1.08	0.54	2.02	1.76	3.55	1.08
2011	1.62	0.68	2.38	1.32	3.13	0.88
2012	1.53	0.58	2.61	1.30	3.40	1.09

The catcher vessel sector experienced lower rates of unadjusted and adjusted MFP growth than the catcher/processor sector over the entire time period. However, just comparing the years 2008-2012, the year-to-year change in adjusted MFP growth are much more similar at 0.95 for the catcher vessel sector and 0.98 for the catcher/processor sector. However, this does not necessarily imply that the catcher vessel sector experienced similar overall gains in productivity before and after AFA implementation.

It appears that the biggest driver of productivity gains in the catcher/processor sector after AFA implementation was from reducing the use of capital in the fishery by nearly half between the baseline and 2000 while labor only fell 9% and output actually increased by 8%. The value of the capital in the catcher/processor sector has been relatively constant since 2000 and changes in output are largely driven by changes in labor input (correlation coefficient=.73). As there were on average 112 catcher vessels active during the three years prior to AFA implementation for their sector (1997-1999) and 98 active vessels in 2000, falling to 89 vessels in 2012, it is likely that the catcher vessel sector has experienced similar gains in productivity as the catcher/processor sector as a result of the decline in capital used in the fishery. However, since the early years after rationalization are not included in our catcher vessel estimates, we cannot provide estimates of TFP change due to these effects.

Bering Sea and Aleutian Islands Crab Rationalization Program

Fishery Synopsis

The North Pacific Fishery Management Council developed the Bering Sea Aleutian Islands (BSAI) Crab Rationalization Program over a six-year period. In 2005 the BSAI Crab Rationalization Program was implemented to address the race to harvest, high bycatch and discard mortality, product quality issues and balance the interests of those who depend on crab fisheries. The BSAI Crab Rationalization Program includes share allocations to harvesters, processors and crew. Processor quota was incorporated to preserve the viability of processing facilities in dependent communities and particularly to maintain competitive conditions in ex-vessel markets. Community interests are protected by Community Development Quota (CDQ) and Adak Community allocations as well as regional landings and processing requirements.

The Bering Sea Aleutian Islands (BSAI) Crab Rationalization Program includes most species of king and Tanner crabs in the Bering Sea and Aleutian Islands. The BSAI Crab Rationalization Program applies to the following Bering Sea and Aleutian Islands crab fisheries: Bristol Bay red king crab, Western Aleutian Islands (Adak) golden king crab, Eastern Aleutian Islands golden king crab, Western Aleutian Islands red king crab, Pribilof Islands red and blue king crab, St. Matthew Island blue king crab, Bering Sea snow crab, Eastern Bering Sea Tanner crab and Western Bering Sea Tanner crab. The Bering Sea and Aleutian Islands crab fisheries comprise large industrial vessels using pot gear, a few catcher/processor vessels, and a large-scale onshore processing sector.

The fishery management plan (FMP) governing these fisheries, the Bering Sea and Aleutian Islands king and Tanner Crab FMP, was approved by the Secretary of Commerce on June 2, 1989. The FMP establishes a State/Federal cooperative management regime that defers crab management to the State of Alaska with Federal oversight. State regulations are subject to the provisions of the FMP, including its goals and objectives, the Magnuson-Stevens Act, the National Standards and other applicable federal laws. The FMP has been amended several times since its implementation to limit access to the fisheries, establish a vessel license limitation program, define essential fish habitat and associated protection measures, amongst other topics.

Managing capacity in these fisheries has been a challenge since the inception of the FMP. Overcapacity in the Bering Sea and Aleutian Islands (BSAI) crab fishery required season limitations to control catch levels, with seasons in some fisheries only lasting five days. The resulting "derby fishery" led to unsafe fishing conditions and numerous fatalities for crew, particularly in winter months when most crab fisheries are prosecuted. Harvesting and processing capacity expanded to accommodate highly abbreviated seasons, leading to further economic inefficiencies.

To address overcapacity the North Pacific Fishery Management Council took a series of actions to limit access to these resources, including a moratorium on new vessels entering the fishery (1996); a vessel license limitation program (2000); a capacity reduction (buyback) program (2004); and, in 2005, the BSAI Crab Rationalization Program.

Prior to implementation of the BSAI Crab Rationalization Program, the Bering Sea Tanner Crab fishery was closed to fishing due to low stock abundance. Two fisheries (Western Aleutian Islands red king crab and Pribilof Island red and blue king crab) have been closed to fishing throughout the duration of the Crab Rationalization Program. The St. Matthew blue king crab fishery was closed for four of the eight years of the IFQ Program. In the second year of the IFQ Program and following a stock assessment, the Bering Sea Tanner Crab fishery was split into the Western and Eastern Bering Sea Tanner Crab fisheries. The Western Bering Sea Tanner crab fishery was closed for two of the five years, while the Eastern Bering Sea Tanner Crab fishery was closed for one year during the IFQ Program.

King and Tanner crab are harvested in nine distinct fisheries that are defined by a combination of species and spatial areas. Uniquely, the Council was granted special Congressional authority to allocate Individual Processor Quota (IPQ) in addition to harvesting quota. IFQ privileges are delineated as quota shares (that provide the holder a percentage of the IFQ allocation), which represents the annual harvestable pounds (derived from the shares) to harvesters. Harvest quota shares are subdivided into "A" shares (90% of the quota share) and "B" shares (10%) of the quota share. The former (A shares) must be matched with individual processor quota when making a delivery to a processor while the latter may be delivered without restriction to any processor. The BSAI Crab Rationalization program also includes processor delivery restrictions on A shares among designated regions (North, South, and West regions).

The initial allocation issued harvest shares to license limitation program (LLP) crab license holders and crew who were state permit holders (typically vessel captains) based on creditable historical landings. Processor shares were issued to processors with specific history in the crab fisheries. Harvest quota share and processor quota share are transferable, subject to limitations. Shares issued to LLP crab permit holders comprise 97% of all harvesting quota share; the remaining 3% were issued as captain/crew quota share (referred to as C shares, which do not have to be matched to IPQ). Both harvest and processor quota share are split into catcher vessel shares and catcher/processor shares. Annual individual processing quota is issued in the amounts matched to the amounts of catcher vessel LLP harvest quota for the nine fisheries.

Data

As part of the BSAI Crab Rationalization Program, program participants are required to submit an annual economic data report (EDR) to provide additional information on input use and the costs incurred by participants. In the first year of the program, the EDR also requested cost information for the years 1998, 2001, and 2004 to create an economic baseline period against which economic performance of the rationalized fishery can be compared. These years were chosen because they represented a variety of fishing conditions, prices, stock abundances, and TACs. The average of these three years will constitute the baseline and reference period prior to program implementation.

Data on output quantities and prices include the total whole weight (in pounds) and total product revenues, respectively, from all species caught on trips where some amount of any BSAI Crab Rationalization Program species was caught. Input quantity data include the number of crew days in the fishery and an estimate for the amount of capital utilized in the fishery. The labor input is computed as the number of days the vessel was in the BSAI Crab fisheries multiplied by the crew size for those days, summed over all vessels. We use the sum of total annual labor cost and total annual food and provision cost data from the EDR divided by the number of days the vessel participated in the BSAI Crab fisheries to estimate a daily cost for crew members. The total annual capital quantity used is the replacement value of the vessel reported on their EDR summed over all vessels that participated in the fishery in a given year. We price capital using the rate for BAA grade bonds. Fishery level aggregates for output value (whole weight in pounds multiplied by reference period output prices) and input values, including labor (crew days multiplied by reference period labor price) and capital (vessel value multiplied by reference period capital price), are included in Table 32.

Only five species that are included in the BSAI Crab Rationalization Program have stock assessments: Bristol Bay red king crab, Pribilof Islands red and blue king crab, St. Matthew Island blue king crab, Bering Sea snow crab, and Bering Sea Tanner crab. Biomass data for these species are taken from NMFS stock assessments for each species using the most recent full assessment year, and represent mature male biomass.[30] These five biomass estimates are then weighted by their revenue shares among the BSAI Crab Rationalization Program vessels each year and used to create the BSAI Crab species biomass index.

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[30] Available at http://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CrabSAFE2012.pdf

Table 32. Outputs and Inputs in the BSAI Crab IFQ Fisheries

Year	Output[a]	Capital[a]	Labor[a]	Total Inputs[a]
Baseline	161,150,512	72,300,934	55,871,594	128,172,527
2005	73,812,134	50,533,800	25,339,144	75,872,944
2006	97,968,136	31,120,125	32,125,962	63,246,087
2007	100,457,995	26,940,933	29,229,390	56,170,323
2008	146,959,566	30,023,530	40,919,832	70,943,362
2009	132,715,178	29,827,204	37,388,960	67,216,164
2010	115,319,221	27,839,774	33,179,688	61,019,461
2011	112,902,988	30,322,135	28,822,162	59,144,297
2012	169,738,392	36,477,637	46,805,870	83,283,507

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Productivity Estimates and Discussion

Using the data presented in Table 32, Lowe input and output indices were created and are presented in columns 1 and 2 of Table 33. The biomass unadjusted MFP (hereafter unadjusted MFP) estimate in the third column is simply the Lowe output index divided by the Lowe Input Index, and represents the change in aggregate outputs divided by the change in aggregate inputs on an annual basis. Therefore, if the index goes above 1.00, MFP growth is positive and the fishery is getting more output from a given level of inputs, but if the index is below 1.00, the reverse is true. As can be seen in Table 33, there have been fairly large changes in unadjusted MFP over this time period. Interestingly, there was a dramatic decrease in the unadjusted MFP in the first year after program implementation. As can been seen in Table 33, there was a relatively larger drop in outputs than inputs, which accounted for this change. This result is largely a function of the years used for the baseline, which were meant to represent a broad set of conditions in the fishery prior to rationalization rather than the three prior to implementation. The implication of this is that one of the years chosen (1998) had over 215 million pounds of crab landed, while landings in the other baseline years were far lower at about 36 million pounds and 43 million pounds for 2001 and 2004, respectively. This results in a baseline average output of 98 million pounds of crab, which is substantially above the combined TACs of these species in the years that immediately preceded and followed program implementation. Even taking this data-driven decline in unadjusted MFP into account, the mean index for non-baseline years was 1.41, which corresponds to a year-to-year change in unadjusted MFP of 1.08 indicating a high degree of productivity gains in the fishery.

It is possible that this average increase in observed unadjusted MFP arose because increases in the biomass of BSAI Crab species may make the existing technology more productive. The biomass index is included in column 4 of Table 33 and represents the change in BSAI Crab species biomass relative to the baseline period. Recall that the baseline period's biomass is in the numerator of the biomass index. Therefore, an increase in the biomass is represented by a number below 1.00, while an index value above 1.00 signifies a decrease in the crab species biomass. This allows the biomass adjusted MFP (hereafter adjusted MFP) index, shown in the final column of Table 33, to be calculated as the product of the unadjusted MFP index and the biomass index. Higher levels of biomass decrease the adjusted MFP index, because if there are more crab available it is assumed that they are easier to catch and the adjusted MFP index is calculated to account for the impact of changes in biomass on fishery productivity. BSAI Crab species biomass has varied over the study period from a low of 0.92 in 2009 to a high of 1.07 in 2012, with an average of 0.97, which implies that, on average, the adjusted MFP index will be similar to, but slightly below the unadjusted MFP index. The estimated adjusted MFP index varies widely between 0.78 in 2005 to 1.73 in 2012, but the average adjusted MFP for the BSAI Crab fishery over the study period is 1.36, which corresponds to a year-to-year change in adjusted MFP of 1.09. This is similar to the unadjusted MFP index, which implies that there have been steady improvements in productivity for the BSAI Crab fisheries.

Table 33. Estimated Multi-Factor Productivity in the BSAI Crab Fisheries

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
Baseline	1.00	1.00	1.00	1.00	1.00	
2005	0.46	0.59	0.77	1.01	0.78	0.78
2006	0.61	0.49	1.23	0.94	1.16	1.48
2007	0.62	0.44	1.42	0.95	1.35	1.17
2008	0.91	0.55	1.65	0.97	1.60	1.18
2009	0.82	0.52	1.57	0.92	1.44	0.90
2010	0.72	0.48	1.50	0.95	1.43	1.00
2011	0.70	0.46	1.52	0.93	1.41	0.98
2012	1.05	0.65	1.62	1.07	1.73	1.23

As shown in Table 32, there was a large immediate reduction in the number of vessels participating in the BSAI Crab fisheries after program implementation. This reduction in capital from an estimated $72 million during the baseline period to an average of $30 million from 2006-2012 has lead to impressive increases in MFP post-rationalization. Comparing the year 2012 with the baseline period, the fishery used just over half the capital and 16% less labor input in 2012, but output was 5% higher than the baseline average. This rapid vessel consolidation has led many to suggest that there have been substantial negative impacts on crew employment and payments to crew in this fishery. However, Abbott, Garber-Yonts, and Wilen (2010), find that while there are fewer short term jobs (because the derby fishery for some crab species pre-rationalization lasted only several days), these were made up for with longer duration jobs such that the total number of crew hours remained roughly constant. It also appears that in years with large volumes of catch, such as 2012, output increased by 50% relative to 2011, but the labor input increased by 62% and the capital input only increased by 20%, which suggests that crew days are still an important component in overall productivity.

Non-Pollock Trawl Catcher/Processor Groundfish Cooperatives (Amendment 80)

Fishery Synopsis

Amendment 80 to the Bering Sea and Aleutian Islands (BSAI) Groundfish Fishery Management Plan was developed to allow the formation of cooperatives with attendant quota allocations to catcher/processor vessels using trawl gear that were not listed in the American Fisheries Act and was implemented in 2008. This so-called "Amendment 80" fleet receives allocations of Atka mackerel, Pacific cod, Aleutian Islands Pacific ocean perch and three species of flatfish (yellowfin sole, rock sole and flathead sole).

Amendment 80 allocates sideboards for pollock, Pacific cod, Pacific Ocean perch outside of the Aleutian Islands, northern rockfish, pelagic shelf rockfish and a prohibited species catch allocation for halibut and crab. Sideboards are intended to limit the ability of vessels in rationalized fisheries from exceeding historic levels of participation in other fisheries, which otherwise might exacerbate a "race for fish." Sideboards can be collective catch limits that apply to all vessels in a particular sector. Vessels subject to a sideboard limit are allowed to fish up to that limit but may not exceed it. Amendment 80 vessels that do not join a cooperative are eligible to participate in a limited access fishery.

The North Pacific Fishery Management Council designed the Amendment 80 Cooperatives Program to allow eligibility based upon those persons who: 1) did not meet the qualification criteria of an American Fisheries Act trawl catcher/processor sector as defined in section 219(a)(7) in the American Fisheries Act; and 2) held a portion of the catch history of Amendment 80 species during the period from 1998 to 2004. Initial allocations were issued to eligible vessel owners based on catch history.

Amendment 80 quota share holders may, on an annual basis, elect to form a cooperative with other Amendment 80 quota share holders to receive an exclusive harvest privilege for the portion of the catch limit resulting from their aggregated quota share holdings. This cooperative quota is the amount of annual Amendment 80 species catch limit dedicated for exclusive use by that cooperative. Quota shares can be transferred with vessel and catch history, while annual allocations of quota metric tons can be leased annually within and between eligible cooperatives. Those quota share holders electing not to join a cooperative participate in the Amendment 80 limited access sector, which receives an allocation equal to the product of the catch limit and the combined share holdings of the sector as a whole.

The Amendment 80 fleet comprises medium to large catcher/processor vessels (average length is 159 feet) using trawl gear with limited factory space and processing capability. From 2008 – 2010, the majority of vessels were in one cooperative, with the remainder being in the limited-access fishery. Since 2011, all of the catcher/processors are in one of two cooperatives. These voluntary harvest cooperatives manage the target allocations, incidental catch allowances and prohibited species allocations amongst themselves.

Data

Coincident with the implementation of the Amendment 80 Program, program participants were required to submit an annual economic data report (EDR) that provides additional information on input use and the costs incurred by participants. However, the EDR program was not in place prior to program implementation and no historic data were collected from participants. As such, there are no cost data prior to 2008 in order to assess potential changes in productivity before and after Amendment 80 implementation. It is possible to estimate MFP metrics using only capital and labor data (as in other Alaska Region programs), but we chose to estimate MFP with greater data resolution over fewer years to better understand the mechanisms that are driving changes in MFP. Therefore we selected a single baseline and reference year (2008) instead of a 3-year average prior to program implementation.

Data on output quantities and prices include the total product weight (in metric tons) and revenues, respectively from all species caught on days where some amount of any Amendment 80 species was also produced. Input quantity data include the number of crew days (harvesting and processing crew) in the fishery, an estimate for the amount of capital involved in the fishery, and total fuel use by the fleet. The labor input is defined as the number of days the vessel was in the Amendment 80 fishery multiplied by the crew size for those days, summed over all vessels. We use the total annual labor cost data from the EDR divided by the number of production days in the Amendment 80 fishery to estimate a daily wage for crew members. The annual capital quantity used is the marine survey value of the vessel reported on their EDR summed over all vessels that participated in the fishery in a given year. We price the capital quantity using the rate for BAA grade bonds. The total fuel used and total fuel expenditures (used to calculate average fuel prices paid) by the fleet comes from the EDR data. As the EDR data are annual data, we prorate all EDR data using the share of a vessel's total processing days where they processed any Amendment 80 species. Fishery level aggregates for output value (product weight in metric tons multiplied by reference year output prices) and input values, including labor (crew days multiplied by reference year labor price), capital (vessel value multiplied by reference year capital price), and energy (fuel use in gallons multiplied by reference year fuel price) are included in Table 34.

Table 34. Output and Inputs in the Alaska Amendment 80 Program

Year	Output[a]	Capital[a]	Labor[a]	Energy[a]	Total Inputs[a]
2008	278,662,817	16,646,092	72,633,808	42,567,081	131,846,981
2009	263,998,556	16,352,410	63,933,923	36,164,546	116,450,878
2010	294,940,149	18,605,248	69,261,169	37,762,205	125,628,623
2011	300,185,176	18,866,617	65,033,070	38,464,131	122,363,819
2012	306,254,599	20,239,682	65,466,603	36,041,927	121,748,212

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Biomass data for the 6 primary Amendment 80 species in the BSAI region (Atka mackerel, Pacific cod, Aleutian Islands Pacific ocean perch, yellowfin sole, rock sole, and flathead sole) are taken from NMFS stock assessments for each species using the most recent full assessment year.[31] The biomass data used for this study include the 2013 estimates of age 3+ biomass for BSAI Atka mackerel, the 2012 estimates of age 3+ biomass for BSAI Pacific ocean perch, the 2012 estimates of age 3+ biomass for BSAI flathead sole, the 2012 estimates of age 2+ biomass for rock sole, the 2013 estimates of age 3+ Eastern Bering Sea Pacific cod biomass, and the 2013 estimate of age 2+ BSAI yellowfin sole biomass. These six biomass estimates are then weighted by their revenue shares among the Amendment 80 vessels in each year and used to create the Amendment 80 species biomass index.

Productivity Estimates and Discussion

Using the data reported in Table 34 Lowe input and output indices were created and are presented in columns 1 and 2 of Table 35. The biomass unadjusted MFP (hereafter unadjusted MFP) estimate in the third column is simply the Lowe output index divided by the Lowe input index, which represents the change in aggregate outputs divided by the change in aggregate inputs on an annual basis. Therefore, if the index goes above 1.00, it means that MFP growth is positive and the fishery is getting more output from a given level of inputs, but if the index is below 1.00, it means the opposite. As can be seen in Table 35, there have been increases in MFP for each year after the baseline year of 2008, which is by definition set equal to 1.00. The mean unadjusted MFP index for non-baseline years is 1.13, which corresponds to an average year-to-year change in unadjusted MFP of 1.04.

It is possible that this increase in observed unadjusted MFP arose because we have not accounted for increases in the biomass of Amendment 80 species that may make the existing technology more productive. The biomass index is included in

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[31] A full stock assessment is completed every other year for some species. The 2013 assessment year stock assessments are available at: http://www.afsc.noaa.gov/refm/stocks/assessments.htm. The 2012 assessment year stock assessments are available at: http://www.afsc.noaa.gov/refm/stocks/2012_assessments.htm.

column 4 of Table 35 and represents the change in Amendment 80 species biomass relative to the baseline. Recall that the baseline year's biomass is in the numerator of the biomass index, and therefore an increase in the biomass is represented by a number below 1.00, while an index value above 1.00 signifies a decrease in the Amendment 80 species biomass. This allows the biomass adjusted MFP (hereafter adjusted MFP) index, shown in the final column of Table 35, to be calculated as the product of the unadjusted MFP index and the biomass index. Higher levels of biomass decrease the adjusted MFP index, because if there are more fish it is assumed that they are easier to catch and the adjusted MFP index is calculated to account for the impact of changes in biomass on fishery productivity. Amendment 80 species biomass has declined slightly over the study period, implying that the adjusted MFP index will be greater than the unadjusted MFP index. The estimated adjusted MFP index is above 1.00 for all years and averages 1.21 for non-baseline years which, corresponds to a yearly change of 1.07, and implies that there have been steady improvements in productivity for the Amendment 80 fishery.

Table 35. Estimated Multi-Factor Productivity in the Amendment 80 Fishery

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
2008	1.00	1.00	1.00	1.00	1.00	
2009	0.95	0.88	1.07	1.02	1.10	1.10
2010	1.06	0.95	1.11	1.07	1.19	1.08
2011	1.08	0.93	1.16	1.08	1.25	1.05
2012	1.10	0.92	1.19	1.11	1.32	1.05

There are several mechanisms in the Amendment 80 Program that may help explain this growth in productivity. First, allocating catch shares to vessels has eliminated the race for fish, and could have subsequently reduced fishing costs for inputs such as fuel use, which dropped 15% between the first year after implementation (2008) and 2012. Second, the cooperative structure of the Amendment 80 Program could be improving communication among cooperative members and reducing search costs. Third, Amendment 80 changed the way in which halibut prohibited species catch (PSC) allocations were made, which has likely had a dramatic impact on the vessel's ability to increase their catch (Abbott, Haynie, and Reimer, 2014). Prior to the Amendment 80 program, there was a sector-wide PSC limit on halibut that was allocated across target species based on the anticipated usage of halibut PSC in each target fishery. Once this sector wide halibut PSC limit was reached in any target fishery, the entire target fishery would close and often resulted in closures of rock sole and yellowfin sole fisheries prior to full exploitation of the TAC. The Amendment 80 Program provides for individual vessel PSC that is tradable across vessels and also removed the target species PSC allocations so the vessels are now able to use their halibut PSC in the most profitable fisheries. Because target fisheries are now not closing because of halibut PSC limits, this has allowed vessels to increase the number of active days in the fishery from an average of 258 days during the three years prior to Amendment 80 (2005-2007) to an average of 322 days over the period 2008-2012. This added flexibility, in addition to increases in quota allocated to the sector, has allowed the sector to increase their average catch from 200,346 tons from 2005-2007 to 241,087 tons from 2008-2012.

Central Gulf of Alaska Rockfish Cooperatives Program

Fishery Synopsis

In 2007 the Central Gulf of Alaska (GOA) Rockfish Pilot Program was established as a two-year program and later extended to five years. The North Pacific Fishery Management Council modified the pilot program and implemented the Central Gulf of Alaska Rockfish Program in 2012. Note that this study will use the term "Rockfish Program" referring to the program as a whole (starting with the Rockfish Pilot Program in 2007), but may refer to the Rockfish Pilot Program specifically where necessary. While the fishery was not overfished or experiencing overfishing in the years leading up to implementation of the Rockfish Pilot Program, the window of fishing opportunity was down to a mere three weeks.

The North Pacific Fishery Management Council designed the Rockfish Program so that only those who held valid License Limitation Program (LLP) licenses would be eligible to participate. The fleet comprises catcher vessels and catcher/processors, both of which are required to form sector-specific cooperatives that receive an exclusive harvest privilege based on cooperative member quota share holdings. Rockfish quota share can only be harvested through cooperative membership. The Rockfish Program also includes an entry-level longline fishery sector that (starting in 2012) receives a small allocation of Pacific ocean perch, Northern rockfish, and Pelagic shelf rockfish. Therefore, since these vessels are not given an exclusive harvesting privilege they are not included in this study.

The Rockfish Program allocates 97.5% of quota share for eight species (including primary species Pacific Ocean perch, northern rockfish, and dusky rockfish as well as valuable secondary species, which includes Pacific cod, rougheye rockfish, shortraker rockfish, sablefish, and thornyhead rockfish) and a prohibited species catch (PSC) allocation for Pacific halibut to LLP license holders based upon catch history for the initial allocation. The remaining 2.5% is allocated to LLP license holders that participated in the Rockfish Pilot Program entry level trawl fishery from 2007-2009 based upon catch history. Catcher vessel history for the initial allocation was based upon license holders' catch history in the Central Gulf of Alaska for 2000-2006. Catcher/processor history was based upon processing history in 2000-2006. Eligible LLP license holders receive quota share based on their catch history but do not receive an exclusive harvesting privilege. Cooperatives receive cooperative quota (CQ) annually based on its member LLP license holders quota share, and can be transferred between cooperatives. Catcher/processors are not permitted to receive transfers of CQ from catcher vessel cooperatives, but catcher vessel cooperatives are allowed to receive catcher/processor CQ. All transfers are subject to excessive share limits.

Data

Similar to other Alaska Region programs, we lack important information on the inputs used by catcher vessels in the Rockfish Program prior to 2007. However, we are able to gather a consistent set of input and output data for the catcher/processor vessels back to 2004 and we use a 3-year average prior to program implementation (2004-2006) as the baseline and reference period for the catcher/processor sector. Given the short time frame of available data for the catcher vessels, the baseline and reference year was selected to be a single year (2007), which differs from the 3-year average used for catcher/processors.

For catcher vessels, data on the total round weight (in pounds) and total ex-vessel revenues from all species caught while on Rockfish Program trips were used to construct the Lowe output index. Input quantity data used to construct the Lowe input index include the number of crew days in the fishery (number of crew on a trip multiplied by the number of days at sea for the trip, summed over all vessels and trips) and an estimate for the amount of capital involved in the fishery. To create a daily labor price we estimate an opportunity cost wage to value crew days using the mean construction laborer hourly wage in Anchorage multiplied by 8 hours. We use the self-reported vessel values for all catcher vessels that participated in the Rockfish Program from the CFEC vessel license application to estimate the total quantity of capital involved in the catcher vessel sector of the fishery. We use this estimate to create an annual value per foot for catcher vessel participants. The total annual quantity of capital for the catcher vessel sector is then calculated as the as the annual mean value per foot multiplied by each vessel's length in that year, summed over all catcher vessels that participated in that year's fishery. We price the capital quantity using the rate for BAA grade bonds. Catcher vessel sector aggregates for output value (round weight in pounds multiplied by reference year output prices) and input values, including labor (crew days multiplied by reference year labor price) and capital (vessel value multiplied by reference year capital price), are included in Table 36.

Table 36. Outputs and Inputs of Catcher Vessels in the Central Gulf of Alaska Rockfish Program

Year	Output[a]	Capital[a]	Labor[a]	Total Inputs[a]
2007	7,012,698	2,171,054	492,812	2,663,866
2008	8,042,661	2,332,080	502,907	2,834,987
2009	6,372,891	2,722,516	455,556	3,178,072
2010	9,624,667	3,386,287	525,868	3,912,155
2011	12,995,429	3,065,431	641,209	3,706,640
2012	11,413,739	2,822,416	643,085	3,465,502

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

For catcher/processor vessels from 2004-2007, data on output quantities and prices include the total product weight (in metric tons) and total product revenues, respectively, from all species produced in weeks where some amount of Rockfish Program species (species that was part of the Rockfish Program) was produced. For 2008 onward, catcher/processors began submitting daily production reports (instead of the weekly production reports they submitted from 2004-2007). Therefore, for 2008-2012, data on output quantities and prices represent all species produced on days where some amount of Rockfish Program species was produced. Input quantity data include the number of crew days (harvesting and processing crew) in the fishery and an estimate for the amount of capital involved in the fishery. For the period 2004-2007, catcher/processor vessels that submitted a weekly production report with some amount of Rockfish Program species produced were assumed to operate for a full 7 days that week. For 2008 onward, the number of days in the fishery is defined as the number of days in which the catcher/processor reported producing some Rockfish Program species. The labor input is therefore calculated as the number of days the vessel was in the fishery multiplied by the crew size for those days, summed over all vessels. To create a daily labor price we estimate an opportunity cost wage to value crew days using the mean construction laborer hourly wage in Anchorage multiplied by 8 hours. Similar to the catcher vessels, we use the self-reported vessel values for all catcher/processors that participated in the Rockfish Program from the CFEC vessel license application. However, as there are some years with no vessels reporting values, we create a single estimate of the value per foot for all catcher/processors participants. The total annual quantity of capital for the catcher/processor sector is then calculated as the as the mean value per foot multiplied by each vessel's length in each year summed over all catcher/processors. We price the capital quantity using the rate for BAA grade bonds. Catcher/processor sector aggregates for output value (produced weight in metric tons multiplied by reference period output prices) and input values, including labor (crew days multiplied by the reference period labor price) and capital (vessel value multiplied by the reference period capital price), are included in Table 37.

Table 37. Outputs and Inputs of Catcher/Processor Vessels in the Central Gulf of Alaska Rockfish Program

Year	Output[a]	Capital[a]	Labor[a]	Total Inputs[a]
Baseline	12,718,869	1,690,382	1,127,254	2,817,636
2007	11,736,268	865,371	1,008,574	1,873,945
2008	8,156,896	1,531,508	502,249	2,033,757
2009	6,567,966	1,663,952	423,031	2,086,983
2010	11,188,526	1,794,881	717,575	2,512,456
2011	15,347,061	1,125,084	895,152	2,020,235
2012	14,479,246	1,125,084	889,481	2,014,564

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

We have estimated a separate biomass index for the catcher vessel sector and the catcher/processor sector for three reasons. First, while there are 8 species with quota share under the Rockfish Program, catcher vessels do not receive quota for shortraker or rougheye rockfish, so those two species are not included in the biomass index for the catcher vessels. Similarly, the catcher/processor sector does not receive quota for Pacific cod, and therefore only 7 species are used in the biomass index for the catcher/processors. Second, the two sectors derive different shares of their revenue from each species, and therefore, the biomass index should weight the biomass estimate of the included species differently for each sector to account for their differing contributions. Third, the sectors use different baseline and reference years. The biomass estimates are taken from NMFS stock assessments. The biomass data used in this study are the 2013 estimate of the GOA Pacific cod spawning stock biomass, the 2013 estimate of the GOA Pacific ocean perch age 2+ biomass, the 2012 estimate of the combined BSAI and GOA sablefish age 2+ biomass, the 2013 estimate of the GOA northern rockfish age 6+ biomass, the 2013 estimate of GOA dusky rockfish age 4+ biomass, the 2011 estimate of GOA rougheye rockfish age 6+ biomass, the 2011 estimate of the GOA shortraker biomass, and the 2011 estimate of the GOA thornyhead rockfish biomass. These biomass estimates are then weighted by their revenue shares among the two different sectors in each year and used to create a catcher vessel biomass index and a catcher/processor biomass index.

Productivity Estimates and Discussion

Using the data reported in Table 36 Lowe input and output indices were created and are presented in columns 1 and 2 of Table 38 for the catcher vessel sector. The biomass unadjusted MFP (hereafter unadjusted MFP) estimate in the third column is simply the Lowe output index divided by the Lowe input index, or the change in aggregate outputs divided by the change in aggregate inputs, on an annual basis. An index value above 1.00 means that MFP growth is increasing and the fishery is getting more output from a given level of inputs, but if the index is below 1.00 the opposite is true. As can be seen in Table 38, there have been large changes in the unadjusted MFP index in several years, with values ranging from a low of 0.77 in 2009 to a high of 1.32 in 2011 with a mean index value for the Rockfish Program catcher vessels for non-baseline years of 1.07.

It is possible changes in species biomass and catchability over this period may account for some of the changes that we observe in the unadjusted MFP. The biomass index included in column 4 of Table 38 represents the change in Rockfish Program species biomass relative to the baseline. Recall that the baseline year's biomass is in the numerator of the biomass index, and therefore an increase in the biomass is represented by a number below 1.00, while an index value above 1.00 signifies a decrease in the rockfish biomass. This allows the biomass adjusted MFP (hereafter adjusted MFP) index, shown in the final column of Table 38, to be calculated as the product of the unadjusted MFP index and the biomass Index. Higher levels of biomass decrease the adjusted MFP index because if there are more fish, it is assumed that they are easier to catch. The adjusted MFP index is thus calculated to account for the impact of changes in biomass on fishery productivity. However, it is unlikely that changes in biomass in this fishery have affected productivity as the biomass index for catcher vessels average is 1.00 and only ranges between 0.96 and 1.02 over the study period. Therefore the adjusted MFP index is very similar to the unadjusted MFP index.

Table 38. Estimated Multi-Factor Productivity of Catcher Vessels in the Rockfish Program

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
2007	1.00	1.00	1.00	1.00	1.00	
2008	1.15	1.07	1.09	1.00	1.09	1.09
2009	0.92	1.20	0.77	1.00	0.77	0.71
2010	1.37	1.48	0.93	0.99	0.92	1.19
2011	1.86	1.41	1.32	0.96	1.27	1.39
2012	1.64	1.33	1.24	1.02	1.26	0.99

Using the same methods as for the catcher vessels, we use data reported in Table 37 to create Lowe input and output indices that are presented in columns 1 and 2 of Table 39 for the catcher/processor sector. As can be seen in Table 39 (column 3), similar to the catcher vessel sector, there has been a lot of variation in the unadjusted MFP since the baseline period. The unadjusted MFP index has ranged from 0.70 in 2009 to 1.68 in 2011. However, the change in output and labor input between 2007 and 2008 could be an artifact of the change in data resolution after 2007, where we began collecting daily production reports rather than the prior weekly production reports (for which we assumed a 7-day week).This drop in the output and labor input can be seen in Table 37, which also shows a drop in capital in 2007 as only 4 catcher/processors participated in that year while 7 vessels did the year before and after. However, even including this potentially data driven change, unadjusted MFP averaged 1.21 for the catcher/processor sector in non-baseline years, which corresponds to a yearly change in unadjusted MFP of 1.15.

As noted above, we calculated a separate biomass index for the catcher/processor sector and it is included in column 4 of Table 39. However, the index values are not meaningfully different from the catcher vessel biomass index as the catcher/processor biomass index still has an overall average of 1.00. Therefore the adjusted MFP index is very similar to the unadjusted MFP index for the catcher/processor sector as well.

Table 39. Estimated Multi-Factor Productivity of Catcher/Processor Vessels in the Rockfish Program

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
Baseline	1.00	1.00	1.00	1.00	1.00	
2007	0.92	0.67	1.39	1.00	1.39	1.39
2008	0.64	0.72	0.89	1.00	0.89	0.64
2009	0.52	0.74	0.70	0.99	0.69	0.77
2010	0.88	0.89	0.99	0.97	0.96	1.39
2011	1.21	0.72	1.68	1.01	1.70	1.77
2012	1.14	0.71	1.59	1.04	1.66	0.98

Both the catcher vessels and catcher/processors experienced a substantial decline in MFP in the year 2009, with the catcher/processors also experiencing a sharp decline in 2008, but that change is partially due to changes in the underlying data between 2007 and 2008. Outputs declined in both sectors between 2008 and 2009 by 21% and 19% for the catcher vessel and catcher/processor sectors while their labor inputs only declined by 9% and 16% and their capital input actually increased in both cases by 17% and 9%, respectively. The average number of days in the Rockfish Program by catcher vessels was stable at 24 days between 2007-2010 before increasing to an average of 32 days for 2011 and 2012. The catcher/processor vessels spent considerably less time in the fishery at 23 days for 2004-2007 and only averaged 15 days for 2008-2012 (to some degree this could be explained by the change in data source). However, the catcher/processors only spent an average of 8 days in the Rockfish Program in 2009 but there were 8 catcher/processors prosecuting the fishery in that year. Therefore, the amount of labor in the fishery was very low and capital was relatively high. The increase in capital for the catcher/processors is likely a function of only 8 vessels participating in the baseline, which dropped to 4 in 2007, resulting in a near doubling of capital between 2007 and 2009. Abundances, TACs, ABCs, and aggregate GOA catch of the three primary species were relatively constant over this period so it is unclear why the Rockfish Program vessels experienced such a sharp decline in output. However, for the period outside of 2008-2009, both sectors experienced substantial increases in their MFP, and appear to have done so for different reasons. The catcher vessels appear to have increased their outputs by increasing both capital and labor inputs, while the catcher/processor sector appears to have reduced capital and labor inputs while also managing to increase their output.

Bering Sea and Aleutian Islands Pacific Cod Hook and Line Cooperative (Freezer Longliners)

Fishery Synopsis

The Bering Sea/Aleutian Islands (BSAI) Freezer Longline Catcher/Processors (hereafter the Freezer Longliners) are a group of catcher/processor vessels that are eligible to harvest the hook and line catcher/processor sector allocation for BSAI Pacific cod. Since 2003, Freezer Longliners are required to have hook and line Pacific cod catcher/processor endorsements on their federal groundfish License Limitation Program (LLP) license to target Pacific cod using hook and line gear and process the catch onboard. These Freezer Longliners are allocated a fixed percentage of the targeted BSAI Pacific cod allocation that is allocated to the hook and line catcher/processor sector. From 2000 to 2007, the hook and line catcher/processor sector was allocated 40.8% of the BSAI Pacific cod non-Community Development Quota (CDQ) total allowable catch (TAC). The passage of Amendment 85 increased their share of the BSAI targeted Pacific cod TAC to 48.7% from 2008 to the present. These vessels typically produce head and gutted Pacific cod with the collar on or collar off, but do not do much processing of ancillary products due to limited production and freezer space.

In 2007, the sector voted to obtain a $35 million NOAA Fisheries loan to purchase and retire 4 groundfish LLP licenses with hook and line catcher/processor endorsements. The Longline Catcher Processor Subsector Single Fishery Cooperative Act was passed by congress in 2010 and allows Freezer Longliners participating in the BSAI directed Pacific cod fishery to form a single harvest cooperative. The Act also requires NOAA Fisheries to implement regulations to allow the establishment of a harvest cooperative within two years of receiving a request from at least 80% of the eligible hook and line catcher/processor LLP license holders. However, while the vessels participating in this fishery have formed a voluntary cooperative (the Freezer Longline Conservation Cooperative or FLCC), they have not taken steps that would require NOAA Fisheries to write regulations. The voluntary cooperative has been fishing cooperatively since the B season of

2010 (starting August 15th). This sector is included in this report because the members of the FLCC have ended their own race for fish and the sector operates similarly to how a catch share program would operate.

Data

As the Freezer Longliners began fishing under their voluntary cooperative in the B season of 2010, we have chosen to use a 3-year baseline and reference period of 2007-2009. This does not allow for a strict comparison of immediate short run changes that occurred between the A and B seasons of 2010, but comparing the baseline with years 2011 and onward will provide useful estimates of the change in MFP growth before and after cooperative formation.

Similar to other catcher/processor sectors in the Alaska Region, there was a change in the reporting of these vessels' production between 2007 and 2008 from a weekly production report to a daily production report. Therefore, for one year in the baseline (2007), data on output quantities and prices include the total product weight (in metric tons) and total product revenues, respectively, from all species caught on weeks where some amount of any Pacific cod was produced. In addition, the 2007 estimate of total days the catcher/processors participated in the fishery was calculated differently from the 2008 – 2012 data. Specifically, we multiply the average number of days per week that these vessels processed Pacific cod from the period 2008-2009 (5.03) by the number of weeks they produced Pacific cod in 2007. This difference results in lowering both output and labor values for the first year of the data transition (2008). Input quantity data include the number of crew days (harvesting and processing crew) in the fishery and an estimate for the amount of capital involved in the fishery. To create a daily labor price, we estimate an opportunity cost wage to value crew days using the mean construction laborer hourly wage in Anchorage multiplied by 8 hours. We use the self-reported vessel values for all vessels that participated in the Halibut IFQ program from the CFEC vessel license application to estimate the total quantity of capital involved in the fishery. We use this estimate to create an estimated annual value per foot for program participants. The total annual quantity of capital in the fishery is then calculated as the annual mean value per foot multiplied by each vessel's length in that year, summed over all vessels that participated in the fishery in that year. We value the capital quantity (the capital price) at the rate for BAA grade bonds. Fishery level aggregates for output value (net weight in pounds multiplied by reference period output prices) and input values, including labor (crew days multiplied by reference period labor price) and capital (vessel value multiplied by reference period capital price), are included in Table 40.

Table 40. Outputs and Inputs in the Alaska Freezer Longline Fishery

Year	Output[a]	Capital[a]	Labor[a]	Total Inputs[a]
Baseline	149,714,045	10,394,834	12,873,280	23,268,114
2010	141,582,863	9,613,803	12,347,963	21,961,766
2011	193,440,559	9,026,895	16,888,822	25,915,717
2012	224,280,697	9,014,469	19,613,356	28,627,825

a Data reported in 2010 constant dollars using the GDP implicit price deflator.

Pacific cod biomass data are taken from NMFS stock assessment for the 2013 assessment year. The biomass estimate used in this study is the estimate of age 3+ Eastern Bering Sea Pacific cod biomass.

Productivity Estimates and Discussion

Using the data presented in Table 40, Lowe input and output indices were created and are presented in columns 1 and 2 of Table 41**Error! Reference source not found.** The biomass unadjusted MFP (hereafter unadjusted MFP) estimate in the third column is simply the Lowe output index divided by the Lowe input index, which represents the change in aggregate outputs divided by the change in aggregate inputs on an annual basis. Therefore, if the index goes above 1.00, it means that MFP growth is positive and the fishery is getting more output from a given level of inputs, but if the index is below 1.00, the opposite is true. As can be seen in Table 41, there have been increases in MFP for each year after the baseline year of 2007-2009, which is by definition set equal to 1.00. The mean unadjusted MFP index for non-baseline years is 1.13.

It is possible that this increase in observed unadjusted MFP arose because we have not accounted for increases in the biomass of Pacific cod that may make the existing technology more productive. The biomass index is included in column 4 of Table 41 and represents the change in Pacific cod biomass relative to the baseline. Recall that the baseline period's biomass is in the numerator of the biomass index, and therefore an increase in the biomass is represented by a number below 1.00, while an index value above 1.00 signifies a decrease in the Pacific cod biomass. This allows the biomass adjusted MFP (hereafter adjusted MFP) index, shown in the final column of Table 41, to be calculated as the product of the unadjusted MFP index and the biomass index. Higher levels of biomass decrease the adjusted MFP index because if there are more fish it is assumed that they are easier to catch and the adjusted MFP index is calculated to account for the impact of changes in biomass on fishery productivity. Pacific cod biomass has increased substantially over the study period (the biomass index average is 0.71), implying that the adjusted MFP index will be lower than the unadjusted MFP index. The biomass has increased so much relative to the baseline period that the estimated adjusted MFP index is below 1.00 for all years after the baseline. While the unadjusted MFP averages 1.13 for the non-baseline period, the adjusted MFP averages 0.79 for non-baseline years. This implies that, after accounting for the increases in biomass, the Freezer Longliner vessels have seen a significant decline in productivity since cooperative formation.

Table 41. Estimated Multi-Factor Productivity in the Alaska Freezer Longline Fishery

Year	Output Index	Input Index	Biomass Unadjusted MFP	Biomass Index	Biomass Adjusted MFP	Year to Year MFP Change
Baseline	1.00	1.00	1.00	1.00	1.00	
2010	0.95	0.94	1.00	0.88	0.88	0.88
2011	1.29	1.11	1.16	0.65	0.76	0.86
2012	1.50	1.23	1.22	0.61	0.74	0.98

The unadjusted MFP estimates for the fishery suggest a different trend in economic performance for the fishery than the adjusted MFP estimates. The relatively sizable increases in biomass relative to the baseline, according to the current model specification, require commensurate increases in catch for a given level of input use to keep MFP constant. The Pacific cod biomass hit a low in 2008 of 674,191 metric tons but has averaged 1.33 million metric tons for the period 1980-2012 and has only been below 1 million metric tons for the years 2006-2010 over that time. Therefore, observed increases at such a low threshold may not be uniformly distributed across the fishing grounds and one may not expect the same type of increase in productivity from an increase in biomass than would occur at higher biomass levels. Whether a given percent increase in biomass should generate the same increase in catch for given effort level is uncertain. However, this underlying construct is consistent with the treatment of the biomass adjustment, and it is consistent with assumptions used in a number of studies in the fisheries economics literature. The reader is cautioned to interpret the results carefully and recognize that the factor that drives inferences about the direction of change economic performance is the extent to which biomass increases should result in greater catchabilty. For now this can be identified as an area warranting further investigation.

Discussion

With the exception of the Wreckfish IFQ and the Alaska CDQ programs, MFP was estimated for all U.S. catch share programs using a Lowe index with a fixed time period as the base. For some catch share fisheries, MFP was estimated for sub-components of the fishery based on unique operational characteristics resulting in a total of 20 distinct estimates of productivity change. There is an expectation that catch share programs will, among other things, lead to improved productivity through the ability to make better use of capital and other inputs, and through quota transfers from less efficient to more efficient vessels. Evaluating this expectation requires the time period selected for the base to include years before and after catch share program implementation, which is the case for 13 of the 20 catch share fisheries included in this report. Several of the 13 programs have been operating for 10 or more years, while others have been more recently implemented. Therefore, productivity change was evaluated for the first three years (two years for both Shore-side Whiting and Non-Whiting IFQ programs) for all 13 fisheries and was evaluated over the longer term for the six programs that were implemented in 2007 or earlier. With the exception of the Gulf of Mexico Red Snapper and Grouper/Tilefish IFQ programs, this evaluation was based on biomass adjusted MFP. MFP was above pre-catch share levels in each of the first three years in six fisheries and was above pre-catch share levels in each of the first two years for the Non-Whiting Shoreside IFQ program (Table 42). In the Whiting Shoreside IFQ, biomass was substantially above baseline levels in 2011 and 2012 resulting in a two-year average MFP of 0.83, which is 17% lower than the baseline. In only the Bering Sea Freezer Longline fishery was MFP below baseline levels in all three years, although MFP was below the pre-catch share baseline in years two and three in the catcher/processor (CP) subcomponent of the Central GOA Rockfish program.

Over the longer term, MFP has remained above pre-catch share time period baseline in the Surfclam ITQ, the Catcher/Processor Sub-component of the AFA Pollock Cooperatives, and the Red Snapper IFQ program (Table 43). Furthermore, MFP was above pre-catch share time period baseline levels in the Ocean Quahog IFQ for 19 of 23 years and in 7 of 8 years for the BSAI Crab IFQ program. In the Catcher/Processor sub-component of the Central Gulf of Alaska Rockfish program MFP was above the baseline for 3 years and below the baseline for 3 years. In all cases, average MFP after the first 3 years of program implementation was higher than average MFP during the first 3 years.

Table 42. Multi-Factor Productivity for First Three Years of Catch Share Program Implementation

Program	Year 1	Year 2	Year 3	Three Year Average
Ocean Quahog ITQ	0.92	0.94	1.03	0.96
Surfclam ITQ	1.34	1.50	1.65	1.50
Atlantic Sea Scallops General Category IFQ	1.21	1.54	1.57	1.44
Mid-Atlantic Golden Tilefish IFQ	1.56	1.79	1.75	1.70
Northeast Multispecies Sectors	1.24	1.26	0.97	1.16
GOM Red Snapper IFQ[a]	1.04	1.15	1.16	1.12
GOM Grouper/Tilefish IFQ[a]	1.11	1.30	1.35	1.25
Non-Whiting Shore Side IFQ	1.32	1.29		1.31
Whiting Shoreside IFQ	1.02	0.64		0.83
AFA Pollock CP	1.14	1.76	2.06	1.65
BSAI Crab IFQ	0.78	1.16	1.35	1.10
Central GOA Rockfish CP	1.39	0.89	0.69	0.99
Bering Sea Freezer Longliners	0.88	0.76	0.74	0.79

a Unadjusted MFP, MFP for all other programs are biomass adjusted.

Table 43. Multi-Factor Productivity for Catch Share Programs Implemented Prior to 2008.

Program	Start Year	Years MFP Above Baseline	Years MFP Below Baseline	Mean MFP for First 3 Years	Mean MFP After 3 Years
Ocean Quahog ITQ	1990	19	4	0.96	1.34
Surfclam ITQ	1990	23	0	1.50	2.19
GOM Red Snapper IFQ[a]	2007	6	0	1.12	1.14
AFA Pollock CP	1999	14	0	1.66	2.99
BSAI Crab IFQ	2005	7	1	1.10	1.52
Central GOA Rockfish CP	2007	3	3	0.99	1.44

a Unadjusted MFP, MFP for all other programs are biomass adjusted.

The shorter and longer term inferences about productivity change in catch share fisheries need to be considered in context. Estimated productivity change under pre- and post-catch share conditions may be affected by differences in input data among programs, and in the case of the GOM Red Snapper and GOM Grouper Tilefish IFQ programs, the lack of available biomass data. The former may affect estimated productivity change particularly for inputs that are not used in fixed proportions, while omitting biomass data creates uncertainty over the "true" change in MFP. These considerations do not affect the current estimates of MFP as they are based on accepted methods and available data. Rather, addressing these considerations may affect future studies of productivity change in catch share fisheries. Potential avenues for further research are noted below.

Further Research

Effect on Multi-Factor Productivity of Additional Input Data

Although the KLEMS-Y approach was selected for this study, full implementation of the approach was not feasible in any catch share fishery because of a lack of data on services. This means that all estimates of MFP were based on partial implementation of the KLEMS-Y approach subject to available data where capital and labor were deemed to be minimally required. In 11 of the 20 assessments of MFP, available data were limited to capital and labor (KL-Y) while in four fisheries data on energy input was also available (KLE-Y) and there were five fisheries for which data on both energy and materials (KLEM-Y) were available (Table 44). This provides an opportunity to evaluate the marginal contribution of additional data to estimates of MFP so as to identify possible data collection needs to improve NOAA Fisheries capability to estimate MFP in the future.

Table 44. Summary of Included Input Data by Program

Program	KL-Y	KLE-Y	KLEM-Y
Ocean Quahog ITQ	√		
Surfclam ITQ	√		
Atlantic Sea Scallops IFQ			√
Mid-Atlantic Golden Tilefish IFQ			√
Northeast Multispecies Sectors			√
GOM Red Snapper IFQ			√
GOM Grouper/Tilefish IFQ			√
Sablefish Permit Stacking		√	
Non-Whiting Shore Side IFQ		√	
Whiting Shoreside IFQ		√	
Alaska Halibut IFQ	√		
Alaska Sablefish IFQ CV	√		
Alaska Sablefish IFQ CP	√		
AFA Pollock CV	√		
AFA Pollock CP	√		
BSAI Crab IFQ	√		
Amendment 80 Cooperatives		√	
Central GOA Rockfish Cooperative CV	√		
Central Gulf of Alaska Rockfish CP	√		
Bering Sea Freezer Longliners	√		

Marginal changes in data availability were estimated by first calculating MFP for just KL-Y, then sequentially recalculating MFP by adding energy (E), then materials (M) and energy and materials, if available. Mean values for KL-Y, KLE-Y, KLM-Y and KLEM-Y MFP are reported in Table 45 and average values of the percent change in MFP relative to KL-Y are reported in Table 46. Adding energy to capital and labor resulted in large changes in MFP in only the Mid-Atlantic Tilefish IFQ (15.5%). By contrast, adding energy had little or no effect on estimated MFP in either the GOM Grouper/Tilefish or the Sablefish Permit Stacking catch programs. In all other programs the absolute value of MFP changed between two and five percent. For the five catch share fisheries where data on materials (M) were available, the effect of adding materials to capital and labor on the estimated MFP was less than 1.5% in absolute value in all but the Multispecies Sectors program. In the Multispecies Sector program adding only materials resulted in nearly a 15% increase in MFP as compared to estimated MFP with only capital and labor. This effect was moderated in the Multispecies sector program by adding both energy and materials such that KLEM-Y MFP differed from that of KL-Y MFP by only 3.7%.

Table 45. Marginal Effect of Additional Input Data on Estimated Multi-Factor Productivity

	Mean KL-Y	Mean KLE-Y	Mean KLM-Y	Mean KLEM-Y
GC Scallops IFQ	1.37	1.43	1.38	1.44
Multispecies Sectors	1.12	1.09	1.28	1.16
Mid-Atlantic Tilefish IFQ	1.48	1.70	1.50	1.70
GOM Red Snapper IFQ[a]	1.09	1.14	1.08	1.13
GOM Grouper/Tilefish IFQ[a]	1.26	1.27	1.24	1.25
Sablefish Permit Stacking	1.69	1.68		
Non-Whiting Shoreside IFQ	1.27	1.31		
Whiting Shoreside IFQ	0.85	0.83		
Amendment 80	1.19	1.22		

a Analyis based on unadjusted MFP, MFP for all other programs are biomass adjusted.

Table 46. Marginal Change in Multi-Factor Productivity of Adding Input Data Relative to KL-Y

Program	Mean Marginal Change in MFP of Adding Energy	Mean Marginal Change in MFP of Adding Materials	Mean Marginal Change in MFP of Adding Energy and Materials
GC Scallops IFQ	4.02%	0.49%	4.70%
Multispecies Sectors	-2.08%	14.56%	3.72%
Mid-Atlantic Tilefish IFQ	15.53%	1.01%	15.19%
GOM Red Snapper IFQ[a]	4.68%	-0.96%	3.32%
GOM Grouper/Tilefish IFQ[a]	0.84%	-1.41%	-0.58%
Sablefish Permit Stacking	-0.08%		
Non-Whiting Shoreside IFQ	2.91%		
Whiting Shoreside IFQ	-1.52%		
Amendment 80	2.46%		

a Analysis based on unadjusted MFP, MFP for all other programs are biomass adjusted.

Effect of the Biomass Index on Multi-Factor Productivity

Of the 20 fisheries included in this report updated biomass data were not available for many species caught under either the GOM Red Snapper or the GOM Grouper/Tilefish catch share programs. Even for programs where biomass data were available, the timing of assessment updates vary which means that the ability to replicate estimates of biomass adjusted MFP in the future will depend on the reliability of biomass data. This may be particularly important in multispecies catch share programs and in catch share fisheries where a substantial part of decision making is influenced by jointly-caught species that may not be included in the catch share program. For this reason, we evaluate the performance of biomass unadjusted as compared to biomass adjusted MFP.

Changes in MFP in catch share programs may be expected as fishery participants alter the timing and mix of outputs as well as changing input use. These effects may be confounded by changes in biomass which is accounted for by the biomass index. However, unlike the Lowe input and output indices which rely on routine annual data collection programs, the biomass index is based on either fishery independent survey data or estimates of absolute biomass from stock assessments. Fishery independent surveys may not be conducted annually and may more reliably sample some species than others. Similarly, some stock assessments may routinely be updated while others are not. Projected biomass estimates may be obtained from a recent stock assessment, but the “age” of the stock assessment and the reliability of projected biomass need to be taken into consideration. Furthermore, assembling the biomass data was laborious. Wherever possible, the NMFS Species Information System (SIS) was used to obtain biomass data, but some species were not included in the SIS. Also, the SIS only includes biomass data as of the most recent stock assessment and does not include projected biomass. This meant that assessment reports for a substantial number of stocks needed to be tracked down to obtain projected biomass data to match the time period over which MFP was estimated. The importance of the biomass index may be evaluated by comparing the biomass unadjusted MFP to the adjusted MFP in terms of consistency relative to the baseline and magnitude. The former was evaluated by whether or not both unadjusted and adjusted MFP were simultaneously either above or below the baseline. The latter was measured as the percent difference between the adjusted and unadjusted MFP.

With the exception of the Bering Sea Freezer Longline program the unadjusted and biomass adjusted MFP are consistent indicators of productivity change relative to the baseline (Table 47). In the majority of catch share programs both unadjusted and adjusted MFP were simultaneously either above or below the baseline in all comparison years. In the Ocean Quahog ITQ and Surfclam ITQ programs unadjusted and adjusted MFP was consistent in 18 of 23 years and in 19 of 23 years respectively. Similarly, unadjusted and adjusted MFP was consistent in 16 of 17 years in the Catcher/Processor sub-component of the Alaska Sablefish IFQ program.

Table 47. Effect of the Biomass Index on the Direction of Change and Magnitude of Estimated Multi-Factor Productivity

Program	Comparison Years	Consistent Relative to Baseline	Percent Consistent	Average Biomass Index
Ocean Quahog ITQ	23	18	78.3%	1.19
Surfclam ITQ	23	19	82.6%	1.72
Atlantic Sea Scallop GC IFQ	3	3	100.0%	0.96
Northeast Multispecies Sectors	3	3	100.0%	1.13
Mid-Atlantic Golden Tilefish	3	3	100.0%	0.88
Sablefish Permit Stacking	5	4	80.0%	1.22
Shore Side Non-Whiting IFQ	2	2	100.0%	1.06
Shore Side Whiting IFQ	2	1	50.0%	0.59
AK Halibut IFQ	4	2	50.0%	1.23
AK Sablefish IFQ CV	5	5	100.0%	1.08
AK Sablefish IFQ CPs	17	16	94.0%	1.03
AFA Pollock CV	5	4	80.0%	0.96
AFA Pollock CP	14	14	100.0%	1.30
BSAI Crab IFQ	8	8	100.0%	0.97
Amendment 80	4	4	100.0%	1.07
Central GOA Rockfish CV	5	5	100.0%	1.00
Central GOA Rockfish CP	6	6	100.0%	1.00
Bering Sea Freezer Longliner	3	0	0.0%	0.71

While adjusted and unadjusted MFP gave consistent indicators of the direction of productivity change relative to baseline conditions, the differences between the two were related to the biomass index. That is, the biomass index acts as a “shifter” of unadjusted MFP change. When the biomass index was greater than 1.00 (biomass was declining), the adjusted productivity change was higher than the unadjusted change and the opposite occurred when the biomass was increasing (i.e. the biomass index was less than 1.00). The difference between adjusted and unadjusted MFP increases with the magnitude of the direction of change in the biomass index. This reflects the underlying concept that biomass change acts as a "shifter" of productivity change. For the most part, the trend was similar between unadjusted and adjusted MFP; it is just the magnitude of change that is uncertain when biomass is omitted. However, as is illustrated for the Bering Sea Freezer Longliner program, a large change in biomass can result in a false impression of productivity change.

Conclusions

This report provides the first comprehensive estimate of productivity change in U.S. catch share fisheries. In all, annual MFP was estimated for a total of 20 catch share programs or sub-components of catch share programs using a base period Lowe index. Of the 20 programs, 13 included pre-catch share baseline conditions. In all but three of these 13 cases, MFP improved or was improving during the first three years after program implementation. In the three instances where MFP had declined relative to the baseline during the first three years, the common denominator was a substantial increase in biomass resulting in changes in catchability that offset any changes that may have been made in the ratio of outputs to inputs used to harvest fish. For programs that have been in existence at least since 2007, productivity gains during the first three years were positive, and more often than not, MFP continued to improve after the first three years of program implementation.

The KLEMS-Y approach was selected as the most complete measure of MFP while recognizing that data would not be available to support full implementation. In about half of the fisheries evaluated in this report MFP estimates were based only on capital and labor. Evaluation of the potential contribution of having additional data on energy and materials showed that in four of the five fisheries where these inputs were included the contribution of energy to MFP exceeded that of materials. This suggests that new data collection or new methods to estimate fuel use may be a priority in improving estimation of MFP in future studies. Additional research on materials used particularly for catch share fisheries where bait is an important input, and services purchased by fishing vessels would also aid in refining future MFP estimates.

The biomass index plays an important role in characterizing changes in MFP. However, obtaining biomass data was a time consuming process, and in some cases, required a stock-by-stock evaluation of the reliability of the biomass information that was available. In most instances, biomass adjusted and biomass unadjusted measures of MFP were consistent in terms of productivity trends, although, unadjusted MFP underestimates s productivity change when biomass is declining (biomass index above 1.0) and overestimates productivity change when biomass is increasing (biomass index below 1.0). The magnitude of the difference between unadjusted and adjusted MFP increases with the magnitude of the biomass trend. If the biomass trend is sufficiently large, then biomass unadjusted MFP may provide a false impression of change in MFP. This means that obtaining reliable biomass data will be important in any future updates to MFP in catch share fisheries conducted by NMFS.

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Appendix A: Default Data for Input Prices

Table A 1 Default data for fuel price, wages, capital services, and GDP deflator

Year	No 2 Diesel Retail Sales by Refiners ($ per gallon)[a]	Hourly Wages of Production Employees[b]	Moodys BAA Rate[c]	GDP Price Deflator 2009 = 100[d]	GDP Price Deflator 2010 = 100
1984	$0.82	$8.49	14.19	55.57	54.90
1985	$0.79	$8.74	12.72	57.35	56.66
1986	$0.48	$8.93	10.39	58.51	57.81
1987	$0.55	$9.14	10.58	59.94	59.22
1988	$0.50	$9.44	10.83	62.04	61.30
1989	$0.59	$9.80	10.18	64.46	63.68
1990	$0.73	$10.20	10.36	66.85	66.05
1991	$0.65	$10.51	9.80	69.06	68.23
1992	$0.62	$10.77	8.98	70.64	69.79
1993	$0.60	$11.05	7.93	72.32	71.45
1994	$0.55	$11.34	8.62	73.86	72.97
1995	$0.56	$11.66	8.20	75.40	74.50
1996	$0.68	$12.04	8.05	76.78	75.85
1997	$0.64	$12.51	7.86	78.10	77.16
1998	$0.49	$13.01	7.22	78.94	78.00
1999	$0.58	$13.49	7.87	80.07	79.11
2000	$0.94	$14.02	8.36	81.89	80.91
2001	$0.84	$14.55	7.95	83.77	82.76
2002	$0.76	$14.97	7.80	85.06	84.03
2003	$0.94	$15.38	6.77	86.75	85.71
2004	$1.24	$15.69	6.39	89.13	88.06
2005	$1.79	$16.13	6.06	91.99	90.88
2006	$2.10	$16.76	6.48	94.82	93.68
2007	$2.27	$17.43	6.48	97.34	96.17
2008	$3.15	$18.09	7.45	99.21	98.02
2009	$1.83	$18.63	7.30	100.00	98.80
2010	$2.31	$19.07	6.04	101.22	100.00
2011	$3.12	$19.46	5.66	103.20	101.96
2012	$3.20	$19.77	4.94	105.01	103.75

a Energy Information Administration http://www.eia.gov/dnav/pet/pet_pri_refoth_dcu_nus_a.htm

b Bureau of Labor Statistics http://data.bls.gov/pdq/SurveyOutputServlet

c Federal Reserve Bank of St Louis http://research.stlouisfed.org/fred2/graph/?s[1][id]=BAA

d Bureau of Economic Analysis http://www.bea.gov/iTable/iTable.cfm

Appendix B: Biomass Estimates and Sources

Table B 1 Exploitable Biomass in 1,000 MT Meat Weight for Surfclams and Ocean Quahogs

Year	Surfclam[a]	Ocean Quahog[b]
1987	1974	2101
1988	1967	2103
1989	1956	2106
1990	1880	2107
1991	1789	2110
1992	1756	2112
1993	1696	2073
1994	1634	2034
1995	1608	1996
1996	1539	1957
1997	1490	1919
1998	1511	1882
1999	1488	1846
2000	1399	1810
2001	1294	1777
2002	1207	1742
2003	1128	1705
2004	1104	1668
2005	1079	1632
2006	1013	1600
2007	912	1567
2008	827	1534
2009	750	1500
2010	706	1466
2011	703	1431
2012	700	1404

[a] Source Table A25 of http://nefsc.noaa.gov/publications/crd/crd1310/atext.pdf

[b] Source Table A13 of http://www.nefsc.noaa.gov/publications/crd/crd1317/crd1317.pdf

2012 data NEFSC personal communication

Table B 2 Biomass Estimates in Metric Tons for Stocks Included in the Northeast Multispecies Sector Biomass Index

	Year					
Species/Stock[a]	2007	2008	2009	2010	2011	2012
American Plaice	12,271	15,963	16,919	10,805	11,631	12,171
GOM Cod	8,725	10,282	11,457	11,141	9,903	8,995
GB Cod	10,970	11,520	14,725	17,168	13,216	18,184
GOM Haddock	6,796	4,481	3,864	2,868	2,127	1,711
GB Haddock	252,065	238,744	210,557	167,279	148,422	177,136
Acadian Redfish	241,090	264,670	289,090	314,780	318,300	344,665
White Hake	14,205	15,888	16,017	21,106	26,877	28,886
GB Winter Flounder	6,229	6,457	7,917	9,703	11,864	14,168
SNE/MA Winter Flounder	6,221	5,850	5,729	7,076	9,268	9,903
Witch Flounder	2,710	3,194	3,900	4,099	5,175	5,767
GOM/CC Yellowtail Flounder	824	1,067	1,523	1,680	2,844	2,922
GB Yellowtail Flounder	2,734	3,234	3,227	3,004	2,988	2,593
SNE/MA Yellowtail	1,920	2,336	2,648	3,319	3,873	3,908
Pollock	224,000	227,000	196,000	194,339	168,273	151,248
GOM/NGB Monkfish	51,410	58,230	66,060	74,102	81,907	81,204
SGB/MA Monkfish	129,200	131,090	131,220	131,344	132,243	126,295

[a] All stocks except monkfish reported as spawning stock biomass, monkfish reported as exploitable biomass.

Table B 3 Assessment Year and Source Documents for Stocks Included in Northeast Multispecies Sector Biomass Index

Species/Stock	Assessed Year	Source[a]	URL
American Plaice	2010	Table E.12	http://nefsc.noaa.gov/publications/crd/crd1206/americanplaice.pdf
GOM Cod	2012	Table A.85	http://nefsc.noaa.gov/publications/crd/crd1311/texta.pdf
GB Cod	2012	Table B.23	http://nefsc.noaa.gov/publications/crd/crd1311/textb.pdf
GOM Haddock	2012	Table C.31	http://nefsc.noaa.gov/publications/crd/crd1206/gomhaddock.pdf
GB Haddock	2012	Table B.16	http://nefsc.noaa.gov/publications/crd/crd1206/gbhaddock.pdf
Acadian Redfish	2012	Table G8	http://nefsc.noaa.gov/publications/crd/crd1206/Acadian.pdf
White Hake	2013	Table B72	http://nefsc.noaa.gov/publications/crd/crd1310/btext.pdf
GB Winter Flounder	2010	Table B27	http://www.nefsc.noaa.gov/saw/saw52/crd1117.pdf
SNE/MA Winter Flounder	2010	Table A.38	http://www.nefsc.noaa.gov/saw/saw52/crd1117.pdf
Witch Flounder	2012	Table F.15	http://nefsc.noaa.gov/publications/crd/crd1206/witchflounder.pdf
GOM/CCC Yellowtail Flounder	2012	Table D.30	http://nefsc.noaa.gov/publications/crd/crd1206/cc.gom.yellow.pdf
GB Yellowtail			NEFSC Personal Communication
SNE/MA Yellowtail	2012	Table B.53	http://www.nefsc.noaa.gov/publications/crd/crd1218/btext.pdf
Pollock	2010	Table C8	http://www.nefsc.noaa.gov/publications/crd/crd1017/pdfs/ctables.pdf
GOM/NGB Monkfish	2010	Table A.35	http://www.nefsc.noaa.gov/publications/crd/crd1017/pdfs/atables.pdf
SGB/MA Monkfish	2010	Table A.35	http://www.nefsc.noaa.gov/publications/crd/crd1017/pdfs/atables.pdf

[a] Biomass for years not included in each source table were updated via personal communication with NEFSC assessment scientists.

Table B 4 Spawning Stock Biomass for Mid-Atlantic Golden Tilefish and Atlantic Sea Scallops

Year	Golden Tilefish Spawning Stock Biomass (MT)[a]	Atlantic Sea Scallop Spawning Stock Biomass (MT Meat Weight)[b]
2006	4378	
2007	4240	114164
2008	4241	116390
2009	4489	121626
2010	4540	123024
2011	4989	120509
2012	5229	121689

[a] Source: Table B.6 http://nefsc.noaa.gov/publications/crd/crd1404/textb.pdf

[b] Source: NEFSC Personal Communication

Table B 5. Biomass Data in Metric Tons for Species Included in the Biomass Index for Shoreside Whiting and Non-Whiting IFQ

Species	2009	2010	2011	2012
Arrowtooth flounder	65625	59139	52993	47804
Aurora rockfish	4237	4240	4275	4326
Blackgill rockfish	6499	6556	6595	6519
Bocaccio rockfish	11334	12184	13920	16561
Canary rockfish	15258	15706	16124	16743
Chilipepper rockfish	32995	30011	27957	26715
Darkblotched rockfish	13212	13979	14736	15692
Dover sole	708295	695649	684685	670394
English sole	56494	42894	35259	31137
Greenspotted rockfish	3015	3110	3208	3308
Greenstriped rockfish	29248	29876	30421	30808
Lingcod	62638	62878	62454	62370
Longspine thornyhead	150302	147020	143964	141150
Pacific sanddab	12130	13069	13244	13479
Petrale sole	8921	9718	12245	15015
Rougheye rockfish	8365	8406	8441	8494
Sablefish	222936	211793	205662	194356
Shortspine thornyhead	140803	139267	137795	136374
Starry flounder	8945	9309	9536	9701
Widow rockfish	67404	67937	68238	67696
Yelloweye rockfish	2263	2308	2351	2388
Pacific Whiting	1221820	1772740	2236730	2903650

Table B 6. Sources of Biomass Data for Species Included in the Shoreside Whiting and Non-Whiting IFQ Biomass Index

Species	Assessed Date	Source	Assessment Document
Arrowtooth flounder	2007	Table 11	http://www.pcouncil.org/wp-content/uploads/ArrowtoothAssess_Aug22.pdf
Aurora rockfish	2013	Table 13	http://www.pcouncil.org/wp-content/uploads/G3a_ATT1_FULL_AURORA_ASSMNT_2013_postSTAR_SEPT2013BB.pdf
Blackgill rockfish	2011	Table 20	http://www.pcouncil.org/wp-content/uploads/Blackgill_2011_Assessment.pdf
Bocaccio rockfish	2013	Table 12	http://www.pcouncil.org/wp-content/uploads/F5a_ATT8_BOCACCIO_UPDATE_2013_ELECTRIC_JUN2013BB.pdf
Canary rockfish	2011	Table 13	http://www.pcouncil.org/wp-content/uploads/Canary_2011_Assessment_Update.pdf
Chilipepper rockfish		Jason Cope Personal Communication	
Darkblotched rockfish	2013	Table 13	http://www.pcouncil.org/wp-content/uploads/F5a_ATT4_DARKBLOTCHED_ASSMT_2013_ELECTRIC_JUN2013BB.pdf
Dover sole	2011	Table 23	http://www.pcouncil.org/wp-content/uploads/DoverSole_2011_DRAFT_Assessment.pdf
English sole	2007	Table 12	http://www.pcouncil.org/wp-content/uploads/2007_English_sole_update_council.pdf
Greenspotted rockfish	2011	Table 45 & Table 50	http://www.pcouncil.org/wp-content/uploads/Greenspotted_Rockfish_2011_Assessment.pdf
Greenstriped rockfish	2009	Table 40	http://www.pcouncil.org/wp-content/uploads/GreenstripedSAFE.pdf
Lingcod	2009	Jason Cope Personal Communication	
Longspine thornyhead	2005	Table 22	http://www.pcouncil.org/wp-content/uploads/LST_08_30_05.pdf
Pacific sanddab	2013	Table 21	http://www.pcouncil.org/wp-content/uploads/G3a_ATT11_FULL_DRAFT_SANDDAB_ASSMNT_2013_postSTAR_SEPT2013BB.pdf
Petrale sole	2012	Table 17	http://www.cio.noaa.gov/services_programs/prplans/pdfs/ID_228_STOCK_ASSESSMENT_PETRALE_SOLE_2013_JUN2013.pdf
Rougheye rockfish	2013	Table 21	http://www.pcouncil.org/wp-content/uploads/G3a_ATT3_FULL_ROUGHEYE_BLCKSPOT_ASSMNT_2013_postSTAR_SEPT2013BB.pdf
Sablefish	2011	Table 15	http://www.pcouncil.org/wp-content/uploads/Sablefish_2011_Assessment.pdf
Shortspine thornyhead	2013	Table 11	http://www.pcouncil.org/wp-content/uploads/Shortspine_2013_Assessment.pdf
Starry flounder	2005	Table 13	http://www.pcouncil.org/wp-content/uploads/Starry05-final.pdf
Widow rockfish	2011	Table 14	http://www.pcouncil.org/wp-content/uploads/Widow_2011_Assessment.pdf
Yelloweye rockfish	2011	NMFS SIS	http://www.pcouncil.org/wp-content/uploads/Yelloweye_2011_Assessment_Update.pdf
Pacific Whiting	2014	Allen Hicks Personal Communication	

Table B 7. Biomass Data for Pacific Coast Sablefish

Year	Biomass[a]
2003	290,492
2004	285,256
2005	276,343
2006	263,494
2007	248,481
2008	233,025
2009	222,936
2010	211,793

[a] Source: http://www.pcouncil.org/wp-content/uploads/Sablefish_2011_Assessment.pdf

Table B 8 Biomass Data in Pounds for Alaska Halibut	
Year	Exploitable Biomass[a,b]
2008	192,240,000
2009	172,190,000
2010	159,620,000
2011	146,970,000
2012	150,600,000

[a] Halibut biomass in pounds for areas managed under the Alaska Halibut IFQ Program (2C, 3A, 3B, 4A, 4B, 4C, 4D, and 4E)

[b] Source: Coastwide totals from http://www.iphc.int/publications/rara/2012/rara2012093_assessment.pdf, exploitable biomass by area are from personal communication with Ian Stewart at the IPHC for the 2012 assessment year

Table B 9 Biomass Data in Metric Tons for Eastern Bering Sea, Aleutian Islands Sablefish

Year	Biomass[a]
1995	269,572
1996	251,551
1997	246,865
1998	232,678
1999	244,127
2000	253,001
2001	255,316
2002	285,778
2003	292,171
2004	296,208
2005	288,797
2006	283,056
2007	274,853
2008	266,571
2009	258,034
2010	258,263
2011	249,897
2012	244,265

[a] Source: NMFS SIS database for the 2012 assessment year

Table B 10 Biomass Data in Metric Tons for Eastern Bering Sea and Aleutian Islands Pollock

Year	Biomass[a,b]
1994	11,708,110
1995	13,403,800
1996	11,461,600
1997	10,030,480
1998	10,111,160
1999	10,975,900
2000	10,200,310
2001	9,991,590
2002	10,409,380
2003	12,463,970
2004	11,691,830
2005	9,809,320
2006	7,546,290
2007	6,148,930
2008	4,926,620
2009	6,285,360
2010	5,992,530
2011	8,009,420
2012	8,102,240

[a] Source: Eastern Bering Sea: http://www.afsc.noaa.gov/REFM/Docs/2012/EBSpollock.pdf

[b] Source: Aleutian Islands: http://www.afsc.noaa.gov/REFM/Docs/2012/AIpollock.pdf

Table B 11 Biomass Data in Metric Tons of Mature Males for BSAI Crab Rationalization Program Species

Year	Bristol Bay Red King Crab[a]	Pribilof Islands Blue King Crab[a]	St. Matthew Island Blue King Crab[a]	Bering Sea Snow Crab[a]	Bering Sea Tanner Crab[a]
1998	27,114	2,453	6,828	390,400	10,560
2001	30,340	1,454	2,297	179,400	18,200
2004	28,182	97	1,227	183,000	25,560
2005	29,477	313	1,276	177,100	43,990
2006	32,377	137	2,946	186,200	66,890
2007	30,097	254	4,153	226,200	72,630
2008	28,809	42	3,336	265,000	59,700
2009	30,468	452	4,622	279,600	37,600
2010	29,346	322	8,141	266,200	36,140
2011	30,875	461	9,516	246,300	46,300
2012	26,319	644	5,652	233,000	43,150

[a] Source: http://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CrabSAFE2012.pdf

Table B 12 Biomass Data in Metric Tons for Amendment 80 Program Species

Year	BSAI Atka Mackerel[a]	BSAI Pacific Ocean Perch[b]	BSAI Flathead Sole[c]	BSAI Rock Sole[d]	EBS Pacific Cod[e]	BSAI Yellowfin Sole[f]
2008	518,674	722,295	796,712	1,738,660	674,191	688,110
2009	474,208	710,471	779,516	1,688,750	780,237	648,594
2010	406,848	702,831	759,754	1,634,890	847,845	623,607
2011	335,863	692,564	735,405	1,650,160	1,146,670	601,560
2012	297,682	676,409	726,859	1,626,770	1,169,120	581,630

[a] Source: http://www.afsc.noaa.gov/REFM/Docs/2013/BSAIatka.pdf
[b] Source: http://www.afsc.noaa.gov/REFM/docs/2012/BSAIpop.pdf
[c] Source: http://www.afsc.noaa.gov/REFM/Docs/2012/BSAIflathead.pdf
[d] Source: http://www.afsc.noaa.gov/REFM/docs/2012/BSAIrocksole.pdf
[e] Source: http://www.afsc.noaa.gov/REFM/Docs/2013/ebspcod.pdf
[f] Source: http://www.afsc.noaa.gov/REFM/Docs/2013/BSAIyfin.pdf

Table B 13 Biomass Data in Metric Tons for Rockfish Program Species

Year	GOA Pacific Cod[a]	GOA Pacific Ocean Perch[b]	All Alaska Sablefish[c]	GOA Northern Rockfish[d]	GOA Dusky Rockfish[e]	GOA Rougheye Rockfish[f]	GOA Shortraker Rockfish[g]	GOA Thornyhead Rockfish[h]
2004	87,923	339,591	296,208	160,287	93,041	40	42,296	98,158
2005	87,611	348,326	288,797	155,403	94,683	41	42,568	94,740
2006	83,399	355,002	283,056	150,111	95,290	42	38,847	89,758
2007	79,240	357,190	274,853	143,617	94,664	42	35,125	84,775
2008	73,601	367,486	266,571	137,022	92,368	42	39,655	81,785
2009	73,230	378,730	258,034	130,113	88,975	43	44,185	78,795
2010	81,752	389,669	258,263	123,314	85,484	43	54,510	70,988
2011	95,863	396,949	249,897	116,783	81,544	43	64,835	63,180
2012	116,606	403,230	244,265	111,153	77,897	43	48,048	73,990

[a] Source: http://www.afsc.noaa.gov/REFM/Docs/2013/GOApcod.pdf
[b] Source: http://www.afsc.noaa.gov/REFM/docs/2013/GOApop.pdf
[c] Source: NMFS SIS database for the 2012 assessment year
[d] Source: http://www.afsc.noaa.gov/REFM/docs/2013/GOAnorthern.pdf
[e] Source: http://www.afsc.noaa.gov/REFM/docs/2013/GOAdusky.pdf
[f] Source: http://www.afsc.noaa.gov/REFM/docs/2011/GOArougheye.pdf
[g] Source: http://www.afsc.noaa.gov/refm/docs/2011/GOAshortraker.pdf
[h] Source: http://www.afsc.noaa.gov/refm/docs/2011/GOAthorny.pdf

Table B 14 Biomass Data in Metric Tons for Bering Sea and Aleutian Islands Pacific Cod

Year	BSAI Pacific Cod[a]
2007	819,008
2008	752,091
2009	887,286
2010	980,157
2011	1,313,520
2012	1,408,210

[a] Source: http://www.afsc.noaa.gov/REFM/Docs/2012/BSAIpcod.pdf