Title: History of the West Coast Groundfish Trawl Fishery: Tracking Socioeconomic Characteristics across Different Management Policies in a Multispecies Fishery

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Highlights (85 characters)
• West Coast groundfish trawl fishery management evolves in response to many factors.
• The catch share program followed 19 amendments to the original management plan.
• The program has more comprehensive data than any other US catch share fishery.
• Extensive high-quality data result in increased research and analysis of the program.
• The complex history of the program is documented to ensure informed analysis.

Abstract

The Pacific groundfish fishery management plan was first approved in 1982, formalizing what would become one of the most economically important fisheries on the West Coast of the U.S. In 2015, the fishery as a whole generated approximately $170 million in income and supported almost 3,000 jobs. Since its inception, the fishery management plan has been amended 32 times, transforming a fishery characterized by high discards and overcapacity into one managed under a catch share program that was designed to reduce fishing capacity, rebuild overfished stocks, and provide for a viable, profitable, and efficient fishery. This paper reviews historical management changes as well as changes in both the fishery resource and the operational characteristics of fishery participants, such as rebuilding stocks, reduced bycatch, season length, diversification, and revenues. Observed changes vary across sector and target species, but mandatory cost-earnings data highlight, among other findings, that consolidation has occurred across shorebased sectors, the season has lengthened for whiting sectors, and fleet-wide days at sea have decreased for non-whiting groundfish. Though these changes cannot be directly attributed to any single management measure, the transition to catch shares has arguably facilitated increasing economic benefits to many harvesters and communities in a fishery that was declared an economic disaster less than two decades ago. This review can serve as a resource for managers, stakeholders, and researchers involved in developing, implementing, and analyzing regulations in complex multispecies fisheries.

Keywords: groundfish; fisheries management; catch shares; economic outcomes; fleet consolidation.

1. Introduction

Designing fisheries management regulations involves choosing between various alternatives in order to meet the diverse goals outlined in a Fisheries Management Plan (FMP) while weighing the trade-offs between the potential socioeconomic and biological impacts of each option, and the distribution of those impacts across participants. This paper examines historical management measures alongside socioeconomic and operational changes in the West Coast groundfish fishery ("Fishery") to highlight the complexities and challenges of managing and studying a multispecies catch share fishery.

The West Coast Groundfish Trawl Catch Share Program ("CS Program") implemented for the limited entry trawl component of the Fishery in 2011 was the culmination of nearly three decades of planning and gradual management changes (see Supplemental information) aimed at reducing overcapacity and building an efficient and profitable fishery. The implementation of the CS Program was anticipated to consolidate the fleet, reduce discarding, rebuild overfished stocks, and lead to higher revenues for remaining participants (PFMC and NMFS, 2010a, p. xviii). Since 2011, the Fishery has experienced fleet consolidation, rebuilding stocks, regional redistribution of fishing effort, increased target species quota allocations, and gained the flexibility to buy, sell, or lease quota. This descriptive history of management changes and related shifts in the biological and socioeconomic landscapes of the Fishery and fishery resource is a useful tool for informing future policy alternatives. This CS Program is one of the most complex and intricately managed programs in the world with some of the most comprehensive economic data available for analysis, making this review a significant contribution to the tome of information for fisheries scientists and managers.

1.1 Fishery Description

The Fishery takes place off the coasts of Washington, Oregon, and California, and includes over 87 species harvested across limited entry, open access, and tribal components using trawls and fixed gear such as longlines and pots. The CS Program encompasses four sectors that are all part of the limited entry component of the Fishery: shorebased catcher vessels, shorebased buyers, and at-sea catcher-processors and motherships. Primary target species for shorebased vessels include Pacific whiting and non-whiting groundfish such as sablefish, rockfish, Dover sole, petrale sole, and lingcod, all harvested under individual fishing quotas (IFQs) allocated to participants based on catch history. At-sea catcher-processors and catcher vessels that deliver to motherships operate as cooperatives (co-ops) and target Pacific whiting while participating in the CS Program, but spend the majority of their time fishing for Alaska pollock in the Bering Sea and Aleutian Islands.

Due to the co-occurring nature of species managed under the CS Program, bycatch of overfished and rebuilding stocks has been an ongoing concern and motivation for the implementation of various management measures over time. The impact of management measures varies substantially across participants depending on the size, location, diversity of their operations (ranging from small owner-operated vessels to large multi-entity companies), and how much time they spend participating in the CS Program.

2. Management History

2.1 Expanding Industry Capacity and Scientific Understanding

Groundfish landings had increased rapidly throughout the 1970s due to growing market demand, improved processing technologies, and policies designed to encourage expansion of domestic fisheries. After the 1976 signing of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act; MSA) that extended the boundaries of national waters, large-scale harvesting and at-sea processing of Pacific whiting became federally managed under a preliminary management plan for foreign trawl vessels operating off the West Coast (NOAA, 1977; 42 FR 8578). The Pacific groundfish Fishery Management Plan (FMP) was first approved in 1982 (NOAA, 1982; 47 FR 43964) in accordance with MSA mandates to promote sustainable fisheries management, formalizing regulations for the Fishery that have continued to evolve over time (Figure 1). By 1989, foreign fishing was completely supplanted by joint venture agreements (U.S. harvesters delivering to foreign processing vessels), and then joint venture agreements were further and wholly replaced by domestic operations by 1991 (Figure 1).[1] This "Americanization" of the Fishery encouraged increased domestic processing capacity, with shorebased whiting processing plants focusing on surimi beginning in 1992 (Oregon Sea Grant, 1992; PFMC, 1993, p. 10). The continued development of shorebased processing operations was reliant on international market demand and the transition away from primarily surimi to a greater diversity of product types, which fueled the construction of additional facilities along the coast.

Total shoreside landings reached a historical high in 1982 at just over 120,000 metric tons (mt), worth $53 million in ex-vessel revenue, the majority of which was non-whiting groundfish due to the relatively lower whiting catches at the time (PFMC and NMFS, 2010a, p. 119) (Figure 2). However, shortly after the FMP was established, the Fishery was facing declining biomass and catches of non-whiting stocks as they were being fished down to what were believed to be

[1] Though joint venture operations were no longer occurring, the Council did not officially amend the FMP to exclude them until 2000 when they declared groundfish as being fully utilized by domestic harvesters and processors in FMP Amendment 12 (65 FR 59815; NOAA, 2000b).

maximum sustainable yield biomass levels (B_{msy}). The management philosophy of fishing a stock to B_{msy} combined with overestimation of stock productivity led to what are retrospectively recognized as having been unsustainable harvest levels. As a result, several groundfish species[2] were declared overfished starting in 1999. By 2000, non-whiting groundfish landings had decreased by two-thirds and revenue had decreased by almost half (Figure 2).

As non-whiting groundfish stocks were showing evidence of decline, landings of Pacific whiting were ramping up, rising from 1,000 metric tons to 85,000 metric tons from 1983 to 2000 (PFMC and NMFS, 2010a, p. 119), facilitated by increasing domestic harvesting and processing capacity. However, similar to non-whiting groundfish, it is now understood that increased landings were coinciding with declining relative spawning stock biomass (total weight of mature female fish in the stock), which had dropped from 94% to 29% by 2000 due to a combination of low stock recruitment and heavy fishing pressure (Taylor et al., 2016). Since the mid-2000s, Pacific whiting landings have fluctuated, largely reflecting changes in total allowable catch (TAC), but have remained high relative to non-whiting groundfish (Figure 2).

During the first decades under the FMP, the management concern was controlling effort, as the trawl fleet was heavily overcapitalized, with more than 500 vessels in the early 1980s and more than 400 in the early 1990s (Figure 1). The number of participants was estimated to be 2-3 times the number needed to fully harvest trawl sector catch limits (Hastie, 2001; PFMC and NMFS, 2010a, p. 119). Under the FMP, the non-whiting groundfish component of the Fishery was managed by landings limits.[3] The landings limit system began as trip limits and continued evolving into a complex framework of cumulative landings limits that varied depending on species, species complex, gear type, and fishing location. Pacific ocean perch, sablefish, and widow rockfish were among the first to be managed according to these limits due to concerns over declining catches. Landings limits for additional species groups were eventually added to the FMP and the amounts that could be landed were significantly reduced in 1991 due to growing concerns about declining stocks. These complex regulations governing landings were critical to preventing short derby seasons for most species, but were laborious for managers and participants to track. Additionally, limits may not have reduced bycatch because although landings were limited per vessel, there was no limit on catch. The result was an incentive to discard lower value

[2] Included bocaccio rockfish, canary rockfish, cowcod, darkblotched rockfish, lingcod, Pacific ocean perch, Pacific whiting, widow rockfish, and yelloweye rockfish.

[3] Broadly defined as species or complex-specific limits on the amount or sizes allowed to be landed per trip or over a specified time period.

fish or species with lower catch limits until the limits of all species were reached (Pikitch et al., 1988; Gillis et al., 1995).

Similar to the challenges within the non-whiting groundfish fleet, management of Pacific whiting was also aimed at establishing limits and curbing the race-to-fish. The transition away from joint venture agreements to domestic at-sea processing prompted the Pacific Fishery Management Council (Council) to begin delineating separate harvest guidelines for shorebased vessels (30% of harvest) and at-sea processors (70% of harvest) beginning in 1991 (PFMC, 1993).[4] Existing FMP regulations allowed for coast-wide competitive harvest beginning on April 15, with landings limits implemented once the harvest guidelines were reached in order to terminate directed fishing while allowing for small incidental landings. In-season landings limits were rejected as a means of lengthening the season due to concerns that limits low enough to impact season length would result in delivery volumes insufficient for efficient large-scale operations for which the processing vessels were designed (PFMC, 1993, p. 16).

2.2 Limited Entry Program

To address overcapacity, improve efficiency, and meet other economic and biological goals of the FMP, the Council in 1994 approved a license limitation plan through FMP Amendment 6 that established the Limited Entry (LE) program for the trawl and fixed gear components of the Fishery (Figure 1). This framework is the mechanism that limits the number of participants to date. Under Amendment 6, participants were required to obtain a federal permit with endorsements for qualifying gear types and the capacity rating of their vessel.[5] Vessels qualified for an LE trawl permit if they reached minimum landings requirements[6] from 1984-1988 (PFMC and NMFS, 1992, p. 8-5). Based on these requirements, a total of 629 permits were initially issued, 384 of which were endorsed for trawl gear (PFMC, 2000, p. 6). With the transition to the LE program, trip-based limits were standardized to monthly or bi-monthly cumulative landings limits, which were intended to reduce discarding by providing greater flexibility in the timing and volume of harvests over longer time periods. Vessel owners not participating in the LE program

[4] The allocation share percentage was reevaluated in 1993, and then became the subject of litigation and debate throughout the late 1990s until separate allocations for tribal and at-sea sectors were implemented in 1997 (Iudicello and Lueders, 2016).

[5] The capacity rating system is based on vessel length and was designed to discourage participants from adding capital to existing permitted vessels (*e.g.*, a more powerful engine), which economic theory and observations from other limited entry fisheries suggest would occur.

[6] Minimum landings requirements were either nine deliveries of at least 500 pounds or an annual total of 450 metric tons of trawl-caught non-whiting groundfish; or 17 deliveries of at least 500 pounds or an annual total of 3,750 metric tons of trawl-caught Pacific whiting.

were permitted to target and or incidentally land small amounts of groundfish using fixed gears in what thenceforth would be referred to as the "open access" fishery, managed by trip limits.

The implementation of the LE program applied to at-sea catcher-processors, but not motherships because the program was designed to limit harvesting rather than processing. Catcher-processors were not initially issued LE permits because they had mainly targeted Alaska pollock in the Bering Sea and Aleutian Islands, and therefore did not have Pacific whiting catch within the qualifying window. Catcher-processors wishing to enter the Fishery were required to purchase and combine enough permits appropriate for the capacity rating of the vessel. In total, 109 LE permits were required for the ten existing catcher-processors to participate in the LE program and thereby continue operating in the whiting fishery, which accounted for the notable decline in the number of trawl-endorsed catcher vessel permits by 1995 (PFMC, 1997, p. 150).

2.3 Persistent Overcapitalization, Declining Stocks, and Economic Failure

The LE program was implemented with the understanding that it was a stopgap measure and that additional actions would still be required to reduce capacity. In the late 1990s, the fleet remained overcapitalized despite the buyout of many LE permits by the catcher-processor sector, with capital utilization rates[7] ranging from 27-41% for shorebased trawl vessels (PFMC, 2000, p. 37-38). This overcapacity coincided with declining stocks, where non-whiting groundfish landings had fallen by 65% and revenues by 54% from 1983-1999 (PFMC, 2000, p. 25-26). Though the volume of Pacific whiting landings had increased in this same period, overall fleet-wide revenues declined by almost 50% (Figure 2) due to reduced landings of higher value non-whiting groundfish species (PFMC, 2000, p. 25-26).

In 1997, the Council adopted management measures for the Pacific whiting fishery establishing season length limits, sector-specific harvest allocations (42% to the shorebased sector, 24% to motherships, and 34% to catcher-processors), and provisions for re-allocating unused end-of-season quota to other sectors. One of the most significant impacts of these measures was eliminating competition *between* the sectors for target species, but the race-to-fish *within* sectors remained for motherships and shorebased whiting vessels. The voluntary formation of the Pacific Whiting Conservation Cooperative in 1997 (Figure 1) enabled vessel operators to divide the sector allocation amongst themselves, thereby removing the race-to-fish incentive and allowing the sector to benefit from the improved economic efficiency, higher product recovery rates, and

[7] Defined as the percentage of active vessels or permits, depending on the sector, needed to harvest the total allowable catch.

operational flexibility that are often associated with IFQ programs (Sylvia et al., 2008). Although these sector-specific target species allocations were implemented in 1997, sector-specific allocations for bycatch species were not implemented in the at-sea sector until 2009, resulting in a race-to-bycatch across sectors throughout the 2000s.

In 2000, the Secretary of Commerce declared the Fishery a failure under section 312(a) of the MSA, citing "undetermined, but probably natural, causes" (*i.e.*, declining productivity and El Niño events throughout the California Current) in addition to poor scientific understanding of the stock population dynamics as the reasons for the downturn (NOAA, 2000a). This situation was estimated to have cost fishermen $11 million in lost revenue in a single year (NOAA, 2000a). This official disaster determination enabled the appropriation of $5 million in disaster relief funds to assess the socioeconomic effects of the commercial fishery failure and to conduct activities to restore the Fishery. States used these funds to create their own relief programs, including access to social services, payment to impacted individuals, and cooperative fisheries research (Shaw and Conway, 2007). California, Oregon, and Washington were apportioned funds proportional to the impacts of the disaster, with Washington receiving slightly less than the other two states.

In the meantime, the Council and NMFS continued to implement measures designed to help rebuild stocks and improve the outlook for the Fishery. Landings limits for rebuilding species were further reduced to meet the terms of rebuilding plans for seven species implemented through FMP Amendment 16. In 2002, the Council and NMFS established (originally through emergency rulemaking) Rockfish Conservation Areas (RCAs) spanning continental shelf areas of the U.S. West Coast. These areas were designed to minimize rockfish bycatch by closing specific areas and depths when and where those species are known to co-occur with target species in the Fishery. These measures were further developed and finalized in 2006 when the Council established Essential Fish Habitat in FMP Amendment 19 (PFMC, 2016). The RCA boundaries are different for each gear type and can be modified annually or seasonally if the need arises.

2.4 Buyback Program and the Development of Catch Shares

Discussions about the implementation of an IFQ program dated back to the 1980s, but it was not considered during the development of the LE program (Am 6) primarily due to the inability (at the time) to track landings and quota trading in a coast-wide multispecies fishery prosecuted using diverse fishing strategies. In the early 2000s, renewed discussions about the possibility of an IFQ program for the trawl component of the Fishery were forestalled by the nationwide

moratorium on new IFQ programs instituted in 1996.[8] However, the need to reduce capacity and fishing effort remained, and managers turned to measures for both whiting and non-whiting groundfish sectors that would reduce capacity in the interim. Overall, this was a period of considerable insecurity within the Fishery, with shrinking catch limits contributing to continued uncertainty about the degree to which the fleet should consolidate to maximize capital utilization rates, and therefore shifting estimates of the projected loan amount needed to finance the nascent buyback program.

To reduce capacity in the shorebased sector, a buyback program was instituted in 2003 using a reverse auction in which vessel bids were valued according to the average annual ex-vessel revenue of groundfish, crab, and pink shrimp landings (70 FR 40225). The auction process permanently retired 91 groundfish trawl vessels and associated federal and state permits (including 121 state permits for crab and shrimp used by those vessels), leaving 172 available LE trawl permits. The program was funded through a $10 million public funding appropriation and a $36 million loan to be repaid by remaining participants through a 5% fee collected on groundfish, crab, and shrimp landings over 30 years. Estimates based on 2002 data projected that revenue for both whiting and non-whiting groundfish would increase by more than 50% per permit (NMFS, 2004). The retired vessels accounted for 40% of ex-vessel revenue delivered by all LE trawlers in 2002 (PFMC and NMFS, 2010a, p. 84) and were prohibited from participating in this or any other fishery in the future.

In addition to the buyback program, the Nature Conservancy and the Environmental Defense Fund conducted a private buyout in central California in 2006 to purchase groundfish vessels and permits in exchange for closing certain habitat areas to bottom trawling. Their aim was to mitigate the community-level economic impacts of closing high-value groundfish habitat areas by purchasing the vessels that would later be redeployed to participate in cooperative research (PFMC and NMFS, 2005).

After the publicly-funded buyback program was complete, there was concern about new or recently bought-out entrants coming back into the Fishery by purchasing latent permits.[9] In 2004, NMFS published notice of a control date[10] for the future IFQ program to discourage new entrants

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[8] The moratorium was implemented through the 1996 reauthorization of the MSA and lasted until 2002.
[9] Defined as those permits associated with less than 50,000 pounds of landings in 2002 (NMFS, 2004).
[10] The control date for vessels was 2003, with catch histories based on landings from 1994-2003. The control date for shorebased buyers was shifted back to 2004, with quota allocation based on deliveries from 1998-2004 (NOAA, 2004; PFMC, 2007; PFMC and NMFS, 2010a, p. 229).

and "fishing for quota." Even though latent permits would not have landings history that would qualify for quota allocations under the future IFQ program, whiting prices were on the rise, making LE trawl permits particularly valuable ($138,000 - $230,000 per permit), and permit holders could still fish in the years leading up to the implementation of IFQs (NMFS, 2004). Within the year following the buyback program, almost one-third of latent permits were purchased by new entrants, previous participants, and shorebased buyers (NMFS, 2004).

In addition to concerns about re-entry into the non-whiting Fishery after the buyback, there were also rising concerns about non-whiting participants entering the Pacific whiting fishery (thereby exacerbating the existing race-to-fish) due to ongoing restrictions created by the RCAs, increasing ex-vessel Pacific whiting prices (having nearly doubled from 2004 to 2006), lower pollock quota in Alaska, and rationalization of the Alaska pollock fishery that was expected to facilitate increased participation in other fisheries (PFMC and NMFS, 2010a, p. 85). In 2008, the Council implemented provisions through FMP Amendment 15 to establish a LE program specifically for the Pacific whiting fishery as an interim measure to limit participation until the implementation of the future IFQ program. This modification required that catcher-processors, motherships, and catcher vessels wishing to continue operating in the Pacific whiting fishery had to have participated in at least one year during the more recent qualifying period (NMFS, 2009)[11] compared to the original LE program, which also did not apply to the mothership sector.

While overcapacity was being addressed in the Fishery, the distribution of groundfish buyers and processing capacity had been in flux throughout the early 1990s. In general, buyers can be particularly affected by regulatory changes (such as the implementation of closed areas) that could change the geographic distribution of fishing effort because stationary processing plants cannot shift their operation in space. Newer facilities were opening to meet the growing demand for surimi and managers were working to determine longer-term sector-specific allocations and season opening dates for Pacific whiting. In the early 2000s, Pacific whiting landings and purchases were concentrated in Newport and Astoria, Oregon, while smaller non-whiting groundfish buyers were operating throughout central and northern California. Based on state fish ticket data from 1998 to 2004, 400,000 mts of Pacific whiting were purchased by 12 buyers in Oregon, with smaller volumes in California (seven buyers purchased 24,000 mts) and Washington (four buyers purchased 100,000 mts). Over the same period, 70 buyers in California purchased 65,000 mts of non-whiting groundfish for $74 million, with fewer participants in

[11] The qualifying periods were 1997-2006 for at-sea sectors and 1994-2006 for shorebased vessels.

Oregon (35 buyers purchased 88,000 mts for $95 million) and Washington (18 buyers purchased 33,000 mts for $25 million).

2.5 Rationalization through Catch Shares

Many of the management changes implemented throughout the early 2000s were done with the future CS Program in mind, a program that was being discussed and developed for the better part of a decade. The goals of the CS Program included increasing net economic benefits, creating individual economic stability for participants, and providing full utilization of the trawl sector allocation while considering environmental impacts and rebuilding overfished species, among others. The Council deliberated at length about whether the future benefits of consolidation would outweigh the upfront costs of implementing an IFQ program, and whether this program could meet all of its intended goals, including but not limited to reducing bycatch, ending the race-to-fish in the whiting fishery, dispersing fishery benefits, and increasing community and processor stability. After years of discussion, the CS Program was implemented in 2011 through FMP Amendments 20 and 21 that established co-ops and IFQ allocations for 30 target and rebuilding species (Figure 1).

During the development of the CS Program, the Council considered 26 program elements and alternatives for implementing IFQs or co-ops based on target species (whiting versus non-whiting groundfish) or based on shorebased versus at-sea operations. The primary differences between the IFQs and co-ops are that NMFS distributes co-op allocations, which are then divided among individual vessels through private negotiations within the co-op. The distribution of allocations in the IFQ program are made directly to individual quota share holders, which can then be traded in the quota market. This structural distinction often makes co-ops more suitable when participants are homogenous in their operational characteristics and can benefit from coordinated harvest activities whereas IFQs are often most effective for diverse groups of fishery participants that operate independently across a multitude of fishing strategies (PFMC and NMFS, 2010a, p. 258). Separation of the at-sea and shorebased programs was desirable in order to avoid sectors with better access to capital from displacing smaller operations in the quota market (PFMC and NMFS, 2010a, p. 56). Several alternatives to IFQs were considered, including extending the duration of landings limit periods and requiring full catch retention, but these options were rejected on the basis that they would not provide the same benefits as rationalization (PFMC and NMFS, 2010a, p. 52).

2.5.1 Shorebased sector

The Council designed and selected program elements for the shorebased sector to balance

maximizing fishing opportunities, the distribution of net benefits across participants, and the rebuilding of stocks. The decision to implement IFQs (as opposed to co-ops) for non-whiting groundfish was due to the flexibility it would afford for the diversity of target species and fishing strategies. For shorebased Pacific whiting, IFQs were selected in part due to the anticipated complexities of ensuring effective linkages between vessels and shorebased buyers within a co-op, particularly since the Council did not have the authority to limit processor participation, a LE framework being a critical component of a co-op (Kitts and Edwards, 2003; PFMC and NMFS, 2010a, p. 54-55). The CS Program also included provisions for an Adaptive Management Program, where up to 10% of the quota would be set aside to support a range of possible objectives, including cooperative research. In addition to these changes, some management measures remained in place, such as landings limits for non-IFQ species, size limits, gear specifications, and area restrictions.

The CS Program represented a significant shift for the shorebased sector, establishing target and bycatch species quota allocations and a requirement to have 100% observer coverage and shoreside catch monitoring. Under Amendments 20 and 21, target species quotas are allocated based on participant catch history prior to the control date and bycatch species quotas are allocated based on a set bycatch rate. Quota allocations must be moved from a participant's quota share account and converted into quota pounds, at which point they can be used, traded, sold, or leased to cover catches throughout the season. If quota allocations are exceeded, participants cannot fish until they obtain sufficient quota pounds to cover their catch. However, to mitigate the risk of exceeding quota allocations and increase operational flexibility, a carry-over provision allows participants to carry over an amount[12] of remaining quota surplus or deficit to the following fishing season. Quota accumulation limits restrict the amount of quota share and pounds any given participant can control or harvest.[13]

For buyers, the impacts of the CS Program were expected to include a regional shift in processing activity corresponding to changes in geographic distribution of landings, increased fish purchasing costs, decreased whiting production costs over a longer season, and consolidation of facilities along the coast (PFMC and NMFS, 2010a, p. 410-413). Allocating Pacific whiting quota to buyers was discussed due to concerns about maintaining existing bargaining arrangements and compensating for potential "stranded" capital due to rationalization and any resulting

[12] Set at 10% of quota for each species, decreasing if Optimum Yield decreases.
[13] There was an initial grace period to divest initial allocations in excess of these accumulation limits.

consolidation or redistribution of fishing effort and deliveries (PFMC and NMFS, 2010a, p. 300, 419). Under Amendment 20, buyers were required to obtain a first receiver site license to purchase groundfish. Buyers were eligible to receive a portion of the 20% of Pacific whiting quota allocated to the processing sector if they received at least one metric ton of Pacific whiting in at least two years from 1998-2004 (PFMC and NMFS, 2010a, p. 229).

2.5.2 At-sea sectors

The CS Program included formal provisions for harvesting co-ops for the mothership and catcher-processor at-sea Pacific whiting sectors. Co-ops differ from IFQs in that they can be thought of as a common property framework where sector quota allocations do not belong to individuals but are pooled and only then accessible to co-op members based on joint decision-making, contracts, or trades (PFMC and NMFS, 2010a, p. 9). In theory, this structure allows companies to maximize target species harvest rates while minimizing the risk of exceeding bycatch quota allocations for the co-op as a whole. The decision to implement co-ops for motherships was based primarily on the fact that the co-op structure would create a limited entry framework, encourage bycatch information-sharing, and avoid concerns of quota market imbalances that could arise between shorebased vessels and those delivering to motherships if they were combined under the same program (PFMC and NMFS, 2010a, p. 56).

The mothership sector was rationalized through a LE system and catcher vessel co-op program, where Pacific whiting catch history assignments (CHA) were given to qualified catcher vessel permits. Each year, co-ops are allocated whiting and bycatch species in proportion to the CHAs of the LE permits that join the co-op. These allocations are obligated to a specific co-op during the permit application and renewal process, meaning motherships (and vessels delivering to those motherships) must identify which co-op they plan to participate in each year. Catcher vessels with LE permits for the mothership sector are not required to join co-ops but, thus far, all have chosen to and have organized themselves into a single co-op. As with IFQ allocations, there are limits on the allocation share an individual co-op entity can control.

Catcher-processors had been operating under a single voluntary co-op since 1997, where the sector quota allocation was already divided between members. The Amendment 20 provisions for catcher-processors allowed the existing co-op to continue operating under the status quo with the new requirement of obtaining a catcher-processor-endorsed permit, which were given to all LE permits registered to a catcher-processor vessel on a one-time basis for the transition. Therefore, catcher-processors were expected to experience fewer changes with the implementation of the CS Program.

3. Evaluating Catch Shares: Season Length, Participation, Diversification, and Revenues

The transition to catch shares was expected to result in a number of changes, including longer fishing seasons, fleet consolidation, and higher revenues for remaining participants. These metrics are broadly discussed for each sector below but are not intended to encompass the multitude of possible measures and participant groups over which socioeconomic outcomes in the Fishery can be examined.[14] Any observed changes are likely the result of numerous factors both internal and external to the Fishery rather than directly or solely attributable to the CS Program.

To monitor changes in the distribution of economic benefits as a result of the transition to catch shares, Amendment 20 established the Economic Data Collection (EDC) Program, designed to collect, analyze, and report annual data on operating costs, revenue, and other characteristics from all Fishery participants. As of 2017, the EDC Program has collected nearly half a million data points, produced sector-specific reports (Guldin et al., 2017; Steiner et al., 2017a, 2017b; Warlick et al., 2017), performance metrics, and created an interactive web-based application ("FISHEyE"[15]) where users can explore available data.

In addition to the mandated EDC Program, comprehensive data from onboard observers and quota transactions arose as two new sources of additional information. First, to meet the objective of 100% catch accounting, vessels were required to have an observer on all trips. The 100% observer requirement provides thorough and accurate information about fishing locations, trip duration, and at-sea discards. Second, the quota transactions database was designed to execute and monitor quota transactions and provides information about the value and volume of quota trading as well as the network in which the trades occur. These new data sources have been integrated with mandatory logbooks to generate new research and facilitate productive discussions about the strengths of and ongoing concerns within the CS Program.

Participants in the CS Program are numerous and diverse, operating in different regions with varying gears and vessel sizes to target a range of species. Therefore, it is important to summarize economic outcomes across this spectrum of strategies. Using information from the EDC Program and other sources, revenues and operational characteristics from before (2009 and 2010)[16] and since (2011-2015) the implementation of the CS Program can be summarized on a variety of

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[14] An extensive examination of additional metrics and participant groupings are described in the CS Program Five-Year Review mandated under the MSA.

[15] FISHEyE application: https://dataexplorer.northwestscience.fisheries.noaa.gov/fisheye/

[16] Despite having had historically low Pacific whiting TAC in 2009 and 2010, these years are used as the baseline due to the burden on participants of requesting additional years of data.

levels, including port location, vessel size, and sub-fishery.[17] Though these finer-scale distinctions are outside the scope of this review, summary statistics for season length, consolidation, participation, and revenues are summarized below, with Pacific whiting and non-whiting groundfish delineated where possible.

3.1 Season Length

The implementation of IFQs and co-ops allowed participants to decide when, where, and how to harvest their quota allocations, shifting the incentive toward fishing more selectively to avoid exceeding individual quota limits. With the shift to 100% observer coverage and quota for bycatch species, there was reduced incentive to discard catches of non-target species or sizes, as they were counted against the quota regardless of whether they were retained or discarded. This marked a significant change in behavior that resulted in a lengthened fishing season in some cases, measured as the dates from the first to last haul. This additional flexibility also afforded greater opportunities to participate in other fisheries (see Section 3.3).

3.1.1 Catcher vessels

Prior to the implementation of the CS Program, existing landings limits for non-whiting groundfish effectively distributed catches throughout the year. As a result, seasonal harvest patterns are mostly unchanged since the implementation of the CS Program (Figure 3). For shorebased Pacific whiting, however, catch has shifted from primarily occurring in July during pre-catch share years to the largest proportion of harvests occurring in August since the implementation of the CS Program (Figure 3).

3.1.2 Shorebased buyers

For shorebased buyers, seasonal operational capacity is greatest when supply delivered from catcher vessels is highest. The peak of seasonal employment has shifted from June and July in 2009 to August and September in 2015, providing evidence of an extended season (Guldin et al., 2017).

3.1.2 At-sea processors

With the implementation of co-ops, the mothership fleet experienced a lengthening of their season, evidenced by a large amount of processing occurring in October rather than the majority

[17] Sub-fishery designations are based on target species and/or gear type (Steiner et al., 2017a), *e.g.*, shorebased Pacific whiting versus non-whiting groundfish trawl sub-fisheries for DTS, petrale, widow and yellowtail rockfish that are the primary focus of this review.

of processing occurring by the end of May as was the case prior to 2011 (Figure 4) (Steiner et al., 2017b). Less processing has occurred in July and August since the implementation of the CS Program, likely when vessels are operating in Alaska. In contrast, the catcher-processor season remained largely unaffected by the CS Program, as the sector had been operating as a co-op since 1997 (Figure 4) (Warlick et al., 2017).

3.2. Fishery Participation: Consolidation

Vessel operators and processing companies make decisions about whether to participate in the CS Program based on anticipated revenue, costs, and profitability under varying ex-vessel prices, conditions within the quota market, and possible opportunity costs of other foregone earning opportunities. This section describes the number of participants in each sector over time.

3.2.1. Catcher vessels

The goal of the capacity reduction measures (*i.e.*, LE program, buyback program, and rationalization) implemented in the Fishery was to reduce the number of participants and thereby raise revenues for those that remained. This consolidation did occur, evident in the number of vessels participating in the program over time (Figure 1). The number of catcher vessels was reduced from 350-400 to fewer than 250 after the implementation of the LE program in 1994, with a small subset of those vessels participating in shorebased Pacific whiting fishery (Figure 1). In the early 2000s, there were more than 200 vessels, which dropped to less than 130 after the buyback program, and again dropped to around 100 since the implementation of the CS Program in 2011 (Figure 1). Specifically, the number of vessels participating in non-whiting groundfish catch share fisheries decreased from 117 to 82 to from 2009 to 2015. The number of vessels participating in the shorebased Pacific whiting fishery also decreased from 34 to 22 despite an increase in TAC. The number of at-sea Pacific whiting catcher vessels delivering to motherships ranged from 28-43 during the 1990s, dropped to 11-24 prior to the Pacific whiting LE program in 2008, and has ranged from 14-18 since the implementation of the CS Program (Figure 1). Thus, while catch shares were expected to further consolidate the number of at-sea catcher vessels (PFMC and NMFS, 2010a, p. 297), the greatest reduction occurred after the implementation of the LE program.

3.2.2 Shorebased buyers

The number of shorebased buyers purchasing whiting and non-whiting groundfish each year on the West Coast declined from 50-80 during the 1990s to approximately 50 in the early 2000s, with a smaller number specializing in Pacific whiting. There were approximately 30-50 non-

whiting groundfish buyers in the late 2000s, which dropped to less than 30 since the implementation of the CS Program in 2011 (Figure 1) (Guldin et al., 2017). Qualitative survey data indicate that this decrease in the overall number of buyers is due to ownership consolidation and the concentration of quota shares, processing capacity, and industry infrastructure (NMFS, 2017, 3.2.2(c), 3.2.2(g)).

Not only is the *number* of facilities important when discussing consolidation, but the regional *distribution* of processing capacity warrants consideration as well. Astoria, Oregon, has historically maintained the largest share of non-whiting groundfish purchases by weight, though the share increased over time from 19% in 1994-2002 (after the LE program and before the vessel buyback program), to 30% during the mid-2000s, and 39% since the implementation of the CS Program. The larger port towns of Eureka (CA), Coos Bay (OR), and Newport (OR) each maintained approximately a 10% share of purchases since 1994, indicating that Astoria's share grew through a reduction in purchases in locations comprising smaller proportions of coast-wide processing such as the northern Washington coast, Puget Sound, Bodega Bay, San Francisco, and Tillamook. Many of these smaller port areas did experience a decrease in industry-related income and employment in the first two years after the implementation of the CS Program largely due to shifts in the distribution of vessel home ports and quota payments (Leonard and Steiner, 2017).

Buyers purchasing and processing the majority of Pacific whiting have been located primarily in Astoria, Newport, and southern Washington, which has not changed significantly since 1994. Newport fell from accounting for approximately 46% of all purchases by weight from 1994-2002 to 38% of purchases since the implementation of the CS Program. Purchasing activities in southern Washington grew from 13% in the 1990s to 33% since the implementation of the CS Program.

3.2.3 At-sea processors

Participation in the at-sea sectors largely depends on market conditions, ex-vessel prices, and opportunities in Alaska, and has generally mirrored changes in TAC (Table 1). The number of motherships grew from three to eight by the mid-1990s, and remained relatively constant during the 2000s, though only six participated consistently (Figure 1) (PFMC and NMFS, 2010a, p. 271; Steiner et al., 2017b). Since the implementation of the CS Program, the number of participating motherships has remained relatively constant, with a total of five motherships from 2011-2014, dropping to three when catch attainment was low in 2015 (Steiner et al., 2017b).

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Thirteen catcher-processors participated in the Fishery during the 1980s, which dropped to 9-10 vessels after the implementation of the LE program (Figure 1). Between four and ten vessels participated in the Fishery throughout the 1990s and early 2000s, which dropped to six vessels in 2009 and 2010 when TAC was lower, and then again rose to nine vessels in 2011 (Figure 1, Table 1) (PFMC and NMFS, 2010a, p. 161; Warlick et al., 2017). To date, there are six LE permits with a mothership endorsement, 34 with a MS/CV endorsement, and ten with a catcher-processor endorsement, representing the maximum number of participants in the at-sea fishery.

3.3 Fishery Participation: Days at Sea and Diversification

In addition to deciding whether to participate in the CS Program in a given year, vessel operators and processing companies also decide to what extent they participate in the CS Program or diversify their operation through participation in other state or federal fisheries. The CS Program was anticipated to encourage greater specialization when year-round fishing opportunities exist due to the potential costs of switching between fisheries (PFMC and NMFS, 2010a, p. 293). The number of days spent operating in the CS Program is driven by participants' ability to obtain quota, fishery-specific costs, and opportunities in other fisheries. In addition to examining days at sea, this section describes diversification in terms of (a) the proportion of days at sea participating in catch share fisheries as a measure of investment in the CS Program and (b) the proportion of ex-vessel revenue (catcher vessels), production value (shorebased buyers), and landings weight (at-sea processors) derived from participating in the CS Program compared to total production across all operations.

3.3.1 Catcher vessels

Total fleet-wide days at sea spent targeting Pacific whiting in the at-sea and shorebased fisheries increased from an average of almost 1,670 days in 2009-2010 to 2,050 from 2011-2015, largely due to increasing time needed to harvest higher whiting TAC. The fleet-wide percentage of days spent targeting Pacific whiting compared to all reported activities, including fishing in Alaska, increased from an average of 11% in 2009-2010 to 16% during 2011-2015 (Figure 5, top). This increase in the proportion of days coincides with an increasing percentage of revenue from landings of Pacific whiting between 2009-2010 (15%) and 2011-2015 (24%) (Figure 5, middle) despite a decrease in 2015 when catch attainment was low. The average number of sub-fisheries that these vessels participate in each year has decreased slightly from 3.5 to 2.9 from 2009-2015, potentially indicating increased specialization coinciding with increased Pacific whiting TAC.

In contrast, total fleet-wide days at sea for non-whiting groundfish activities decreased from an average of 7,330 during 2009-2010 to 4,190 since the implementation of the CS Program. The

proportion of operating days spent targeting non-whiting groundfish in the CS Program relative to all reported fishing activities decreased from 47% during 2009-2010 to 33% from 2011-2015 (Figure 5, top). The proportion of revenue earned from non-whiting groundfish catch share species also decreased, from an average of 31% during 2009-2010 to 24% since 2011 (Figure 5, middle). The number of sub-fisheries these vessels have participated in has remained constant over time, suggesting that though participants may be relying less on participation and revenue from non-whiting CS species, they are not necessarily expanding or diversifying their existing operations.

3.3.2 Shorebased buyers

For buyers participating in the CS Program, the proportion of production value generated from processing CS species amounted to 41% during 2009-2010 and decreased to 34% since the implementation of the CS Program. Specifically, the proportion of the value generated from non-whiting groundfish was higher in the baseline years (26% of total production value) compared to 2011-2015 (18%) (Figure 5, bottom). The proportion of value generated from Pacific whiting remained relatively constant since 2009 (16%) until dropping to 10% in 2015 when catcher vessel harvest was lower (Figure 5, bottom). Changes in the composition of processing operations are closely linked to those of catcher vessels and could be impacted by regional redistribution of fishing effort, which is outside the scope of this review.

3.3.3 At-sea processors

For both motherships and catcher-processors, days at sea participating in the CS Program vary depending on TAC, Pacific whiting ex-vessel prices, and opportunities in Alaska. For motherships, total fleet-wide days participating in the CS Program increased from an average of 144 during 2009-2010 to 264 from 2011-2015. The proportion of days spent operating on the West Coast (as opposed to targeting pollock in Alaska) increased from an average of 16% during 2009-2010 to 26% since the implementation of the CS Program (Figure 6). The proportion of fish purchases from at-sea catcher vessels derived from participating in the CS Program increased from 15% during 2009-2010 when TAC was low to 25% since the implementation of the CS Program (Figure 6).

Similar to motherships, landings and days operating in the CS Program for catcher-processors depend largely on fluctuations in the TAC and opportunities fishing in Alaska. Catcher-processor fleet-wide days in the CS Program increased from an average of 294 in 2009-2010 to a peak of 581 in 2015. The proportion of days spent operating on the West Coast in the CS Program

decreased from an average of 30% during 2009-2010 to 21% since the implementation of the CS Program (Figure 6). This observed range is similar to the proportion observed for motherships. Unlike motherships, however, the proportion of landings derived from participation in the CS Program was highest in 2009-2010 (26%) and declined to 16% after the implementation of the CS Program (Figure 6).

3.4 Revenue and production value

Fishery revenue was expected to increase for remaining participants after the implementation of the CS Program mainly due to consolidation and increased efficiency. However, in general, any observed trends in revenue cannot be directly attributed to specific management changes (*e.g.*, the implementation of catch shares) because revenue in any given year depends on a variety of factors, including but not limited to changing ex-vessel prices, market demand, and oceanographic conditions that drive the catchability of fish. Examining net revenue or profitability is additionally complicated by participants' individual costs and factors external to the CS Program and are not discussed further here.

3.4.1 Catcher vessels

Annual fleet-wide revenue from fishing in the at-sea and shorebased Pacific whiting fisheries has increased from approximately $14 million per year during 2009-2010 to $34.5 million from 2011-2014, though it dropped to $15.3 million in 2015 when catch attainment was low. Fleet-wide revenue from non-whiting groundfish landings has changed very little since 2009, ranging from $26.3 million to $32.4 million.

3.4.2 Shorebased buyers

Although the number of buyers declined in all ports, fish purchase volume increased in Astoria, Newport, and south/central Washington. Industry-wide production value generated from catch share species has grown, though this is attributed to Pacific whiting rather than non-whiting species. Production value from non-whiting groundfish has changed little, ranging from $65 million to $77.3 million since 2009. In contrast, production value generated from Pacific whiting has increased from $39.9 million during 2009-2010 to $61.3 million since 2011, again largely reflecting increases in the TAC (Table 1).

3.4.3 At-sea processors

Fleet-wide annual production value from Pacific whiting harvest in the mothership sector has generally followed changes in TAC (Table 1), increasing from $23.2 million in 2009-2010 to $37.7 million in 2011-2014 before declining to $20.3 million in 2015 when only approximately

40% of the sector allocation was harvested (Steiner et al., 2017b). Fleet-wide production value for catcher-processors also increased from an average of $43.4 million during the 2009-2010 period to a peak of $99.2 million in 2014.

3.5 Synthesis

Taken together, examining the number of participants, total number and relative proportion of days at sea, and the proportion of production value or volume derived from the CS Program can highlight how key operational and socioeconomic conditions have changed in the Fishery since the implementation of catch shares.

3.5.1 Catcher vessels

For vessels targeting Pacific whiting from 2009-2015, participation has been consolidated, diversification (in the form of participation in additional sub-fisheries) has not increased, the fleet-wide and relative proportions of days at sea in the CS Program have increased, and the fleet-wide total and relative proportion of revenue derived from the harvest of CS species have increased. These observed changes are likely a product of increasing Pacific whiting TAC more than changing incentives brought on by the transition to catch shares.

Though the non-whiting groundfish fleet also consolidated, the proportional days operating in and revenue generated from CS species did not increase as it did for those targeting whiting. Remaining non-whiting CS Program participants generated similar fleet-wide revenues across all activities compared to the baseline period but spent proportionally fewer days and generated proportionally less revenue from CS species since 2011. While some of these outcomes may have been partly due to management changes, they are also likely driven by ex-vessel prices and opportunities in other fisheries.

3.5.2 Shorebased buyers

Consolidation and regional concentration of processing capacity for both whiting and non-whiting groundfish is evident, with remaining buyers generating higher industry-wide revenues since the implementation of the CS Program. However, despite growth in gross revenues, the proportion of production value generated from processing catch share species has decreased slightly since the implementation of the CS Program, indicating that buyers are generating increased revenue from processing non-catch share species such as shrimp and crab.

3.5.3 At-sea processors

The most significant change with the implementation of the CS Program for at-sea sectors was

the additional flexibility afforded by co-ops, likely causing a lengthened season for the mothership sector. Participation (number of vessels), investment in the CS Program (days at sea), and resulting revenues are largely driven by changes in TAC but are also impacted by the structural elements of the CS Program that have facilitated company-level decisions that maximize opportunities in Alaska and on the West Coast according to ex-vessel prices, in-season fleet-wide bycatch rates, and varying fish catchability.

4. Moving Forward: Continuing Evolution of the Fishery and its FMP

While the implementation of the CS Program represented a significant milestone in the evolution of the Fishery, meeting the diverse goals of the FMP has required continued evaluation and adaptation of existing regulations in response to various IFQ management issues including rebuilding stocks, quota harvest rates, industry costs, and the impacts of changing consumer demand.

4.1 Rebuilding Stocks

Since the early 2000s, the Fishery was subject to tight bycatch restrictions established by the rebuilding plans that were in place for overfished species. Following the rebuilding successes of Pacific whiting and lingcod in 2004 and 2005, evidence continued to grow that the reduced catch limits and spatial restrictions to minimize catch of rebuilding species were beginning to pay off. In 2011, a stock assessment revealed that widow rockfish was rebuilt (He et al., 2011), allowing for increased fishing opportunities and renewed targeting of the species. In 2015, petrale sole (Stawitz et al., 2016) and canary rockfish (Thorson and Wetzel, 2016) were also declared rebuilt, the latter being particularly significant due to the constraints this species placed on catching co-occurring target species. In 2017, bocaccio and darkblotched rockfish were declared rebuilt (He and Fields, 2017; Wallace and Gertseva, 2017). Rebuilding stocks is mandated under the MSA and was an express goal of the CS Program that has largely been realized. However, while having rebuilt stocks leads to improved fishing opportunities, it also necessitates that Fishery participants and managers anticipate and adapt to the changes brought on by increased annual catch limits or increased likelihood of encountering bycatch species.

4.2 Quota Harvest Rates

A major objective of the CS Program was to maximize earnings through high quota harvest rates while providing for rebuilding species. Fishery participants have expressed persistent concerns that this goal of the CS Program has not yet been realized, as quota harvest rates have remained low to date. From 2011 to 2014, harvest rates of non-whiting species remained low (below 50%

of the overall quota allocation), suggesting, among other things, that inefficiencies potentially exist in the quota market (Holland, 2016). Under the CS Program, participants could at first lease quota shares and pounds of target and rebuilding stocks. However, starting in 2014, participants could begin selling their quota shares in addition to leasing them. This may provide greater flexibility for participants to more fully utilize quota of previously constraining species and therefore increase the overall value generated by the Fishery in future years. Trading mechanisms such as these in a multispecies IFQ program must be implemented in such a way as to achieve the right balance between flexibility, profitability, overexploitation risk, and administrative ease (Sanchirico et al., 2005).

To minimize the risks associated with constraining species and availability of bycatch species quota, a number of participants have formed "risk pools." Members of these pools combine their quota to be managed and distributed to cover catches when needed. Although the long-term viability of this strategy is unknown and depends greatly on external factors, initial data reported from these groups suggest lower bycatch ratios, lower harvest rates of rebuilding species, and in some cases higher target species harvest rates compared with the overall fishery (Kauer and Oberhoff, 2015).

4.3 Cost Recovery and Observer Fees

Projected cumulative costs of participating in the CS Program factored into not only the design of the CS Program, but still influence participants' decisions about when and where to fish, what species to target, or even whether to continue participating. As required under the MSA, "cost recovery fees" must be collected from all participants of limited access privilege programs to recover additional government costs attributable to the private sector use of a public resource. In 2014, NMFS implemented the collection of cost recovery fees from all shorebased and at-sea participants in the Fishery, not to exceed 3% of ex-vessel revenue in a given year. Cost recovery fees have been a source of contention among members of the catcher-processor sector, resulting in a lawsuit against NMFS on the grounds that the fee structure is inaccurate (Glacier Fish Company LLC vs. Pritzker, Case No. 2:14-cv-00040).

With the transition to 100% catch accounting, higher observer fees were anticipated for each trip targeting species harvested under IFQs. To minimize the burden of this transition, NMFS supplied a subsidy for observer coverage fees that decreased from almost $330 per day in 2011 to $108 per day in 2015. Thus, the average cost of observer coverage for catcher vessels has risen from approximately 0.9% of total variable costs in 2011 to just over 6% in 2015 (Steiner et al., 2017a). Though this represents a relatively small proportion of total costs across the fleet, for

some participants, it can amount to a substantial sum, impacting their ability to continue participating in the CS Program or further investing in their operation, a point of contentious discussions among industry and the Council to date. To overcome this impediment, the Council has worked with participants to institute incentives to evaluate and use electronic monitoring, which has substantially reduced monitoring costs for many vessels.

4.4 Market and Consumer Demand

Market demand for Pacific whiting and non-whiting groundfish is driven by local and global factors. On the local level, the ability of Fishery participants to market their product and generate higher or stable ex-vessel prices relies largely on providing consistent supply for buyers, balancing other fishing opportunities (*e.g.*, crab and shrimp), and consumer demand. In theory, the CS Program should provide participants with sufficient flexibility to generate a consistent supply of fish for buyers overall, though this might not be achieved in every case. In 2014, the Marine Stewardship Council certified 13 non-whiting groundfish species,[18] with the transition to catch shares being cited as key to achieving the sustainability benchmark (Medley et al., 2014). This certification opened new markets for these seafood products that were deemed to meet higher sustainability criteria.

On a global level, demand for Pacific whiting products exported from the U.S. is impacted by factors that are outside the control of Fishery participants, including, for example, trade sanctions against seafood products. Other unpredictable drivers include natural events such as the Tōhoku earthquake and tsunami that hit Japan in 2011 and the anomalous ocean conditions ("The Blob") that coincided with a strong El Niño event along the West Coast in 2015. These occurrences can have a significant impact on Fishery participants, but the flexibility afforded by the CS Program should enable harvesters and buyers to maximize earnings when demand for a given species is high and buffer against losses by turning to other species when demand or prices are lower.

5. Conclusion

Managing and studying multispecies fisheries is a challenging and long-term process. The West Coast groundfish trawl fishery has been continually evolving since the original FMP through the transition to a catch share program and will continue to evolve as new environmental, economic, political, or technological issues arise. The CS Program was designed to function across four sectors containing diverse operations and sub-fisheries, each with unique management histories

[18] Pacific whiting was certified by the Marine Stewardship Council in 2010.

and sometimes divergent priorities. Establishing and considering future refinements to a catch share framework within such a complex landscape required collaboration across disciplines and stakeholders long before the program was first implemented, with fishery managers aiming to analyze and weigh anticipated impacts of every FMP amendment.

By consolidating more than 30 years of information, this review offers a resource for those researchers and fishery managers looking for an overview of the historical management changes within this complex fishery to date. It also provides insights for those involved in other multispecies fisheries in the U.S. or around the world by highlighting the successes and challenges involved in implementing management in the West Coast groundfish fishery. Consolidation across shorebased sectors and season lengthening in the Pacific whiting fishery have helped to decrease overcapitalization and overfishing. However, participants have also experienced difficulties balancing portfolios of more than thirty quota species in order to maximize profits. With the implementation of catch shares and mandatory economic and observer data collections, this fishery became one of the most data-rich fisheries in the U.S. and continues to be the focus of academic research to inform fishery managers. Yet drawing causal relationships and quantifying the economic impacts of fisheries management policies in multispecies fisheries continues to be challenging due to the diversity of fishing operations and shifting natural and socioeconomic conditions, both endogenous and exogenous to the fishery.

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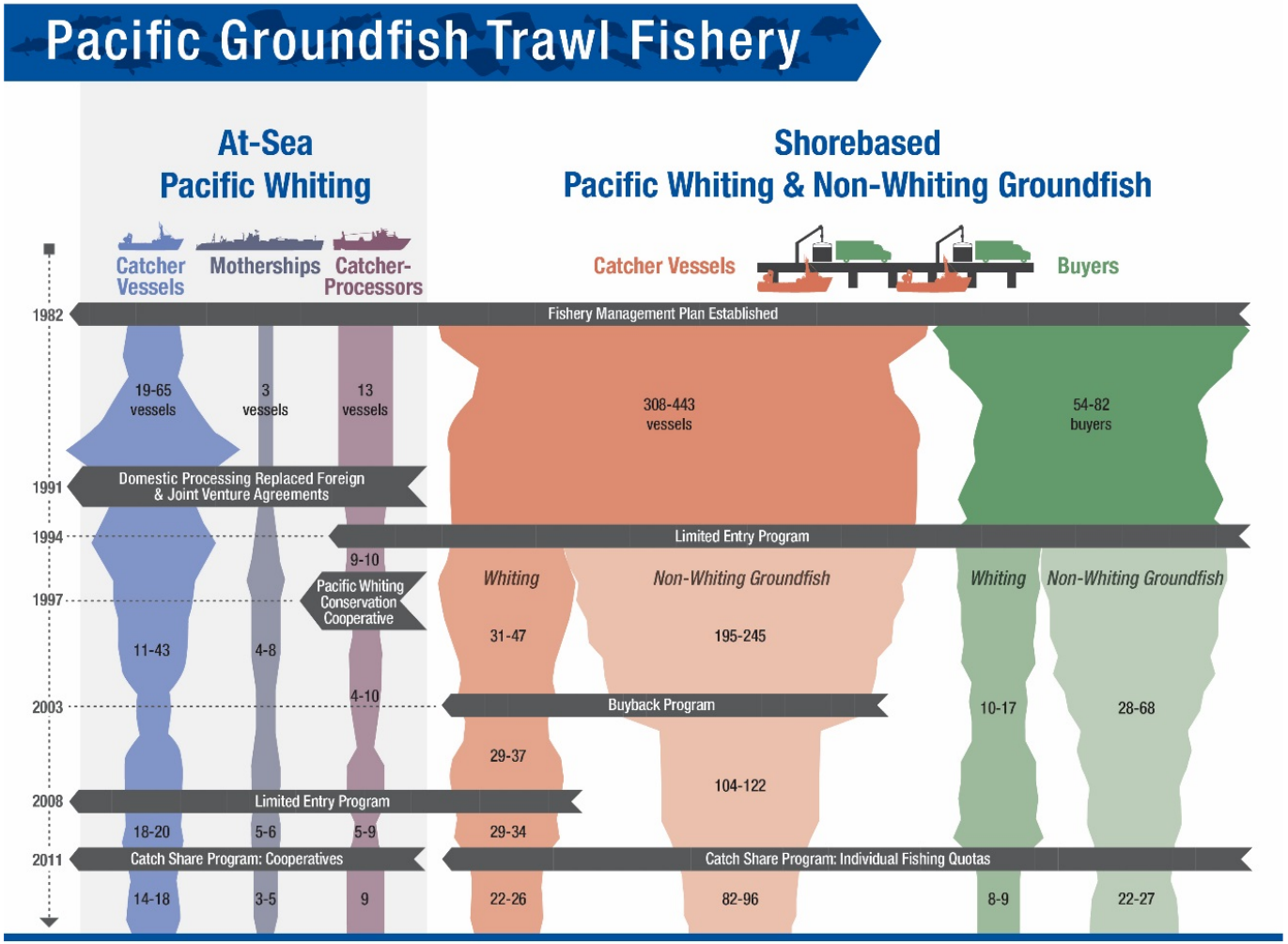

Figure 1. Ranges of the number of participating entities in the at-sea Pacific whiting (left) and shorebased whiting and non-whiting groundfish (right) sectors with respect to important management actions and capacity-reducing measures throughout the history of the Fishery.

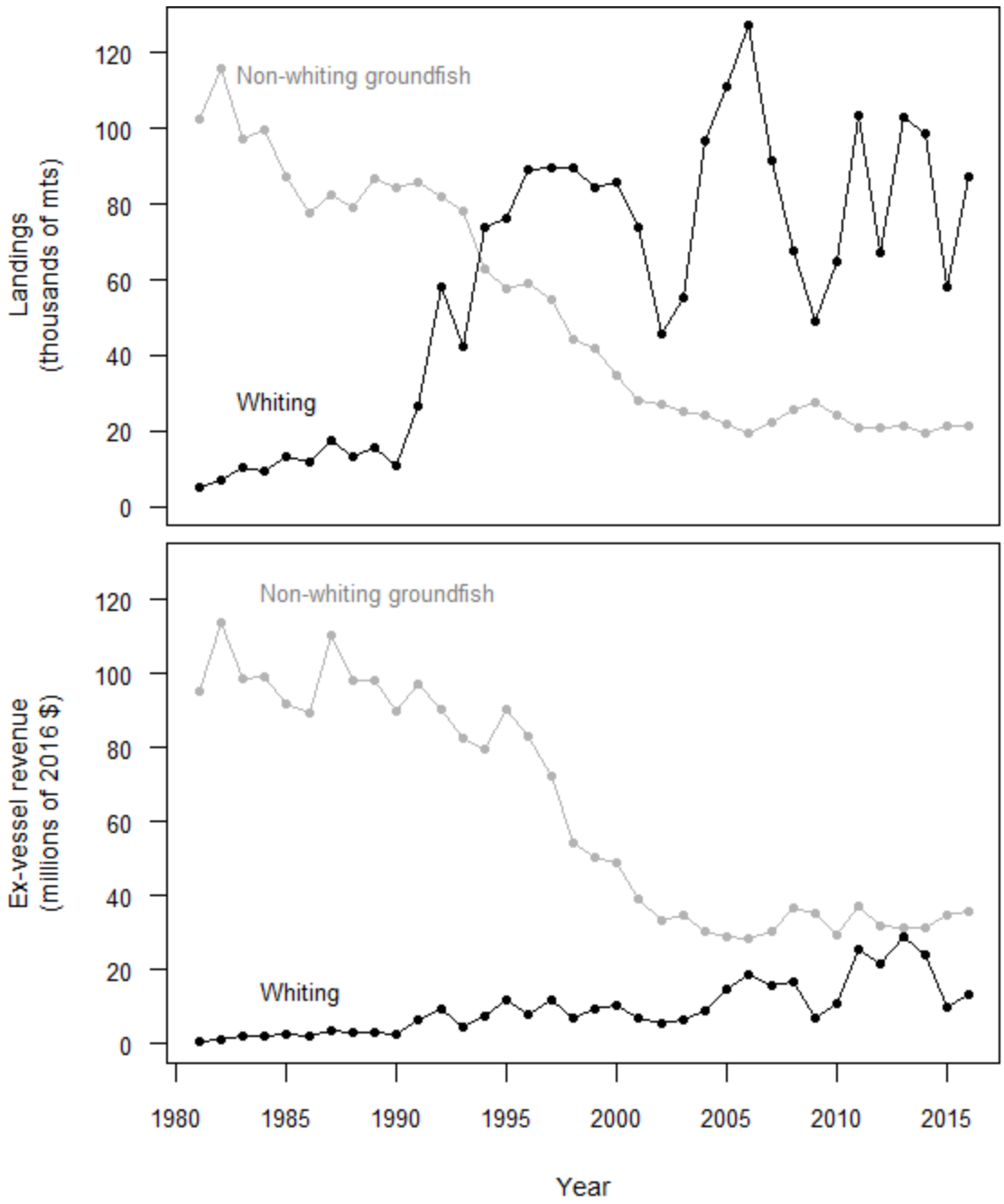

Figure 2. Total fishery-wide landings (top) and ex-vessel revenue (bottom) from shorebased trawl vessels harvesting Pacific whiting (black) and non-whiting groundfish (grey) from 1981-2016.

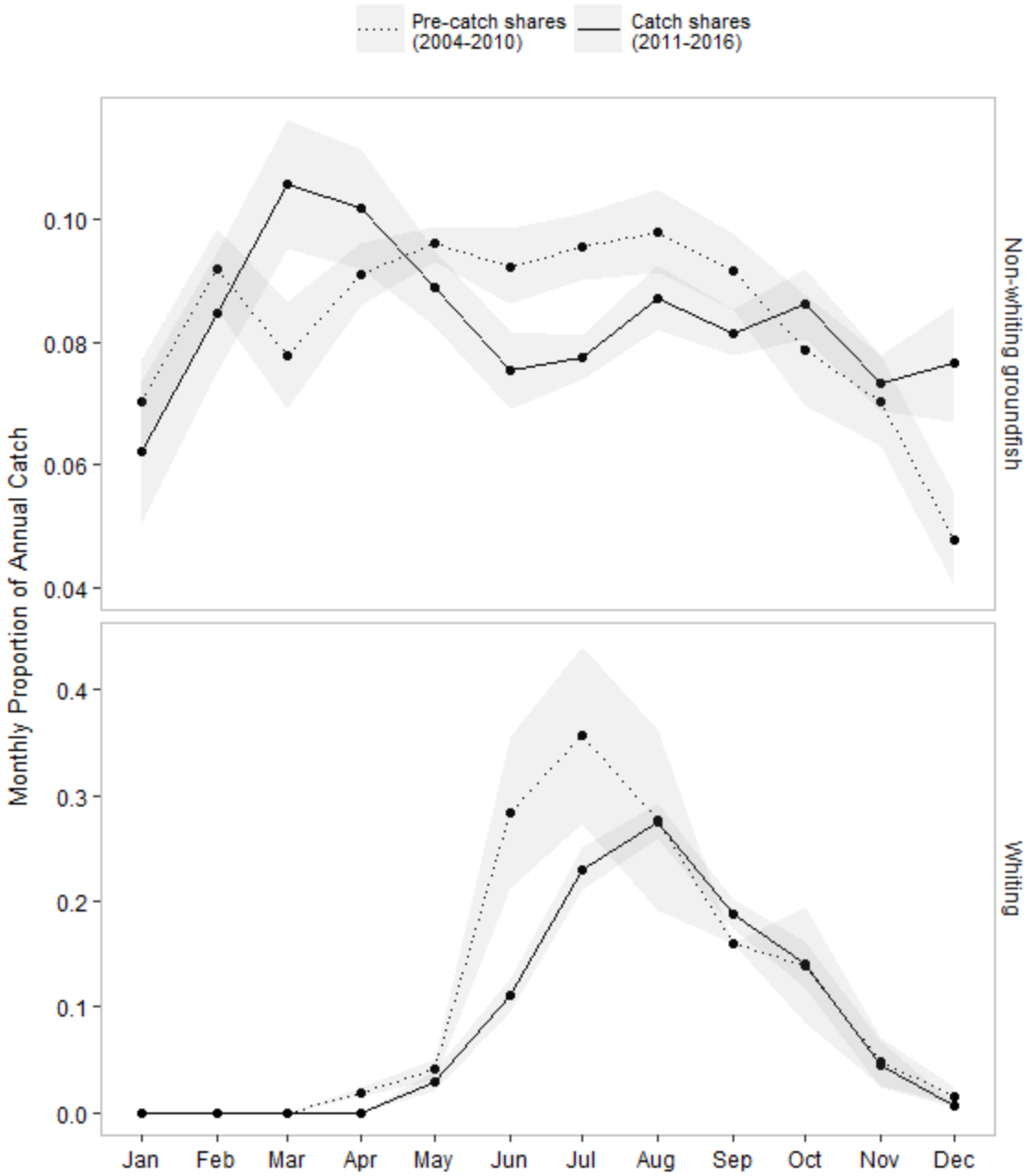

Figure 3. Mean proportion of annual landings in each month for shorebased non-whiting groundfish (top) and shorebased Pacific whiting (bottom) from 2004-2010 prior to the CS Program (dashed line) and from 2011-2016 since the implementation of the CS Program (solid line). Error bands represent ± 1 standard error of the mean.

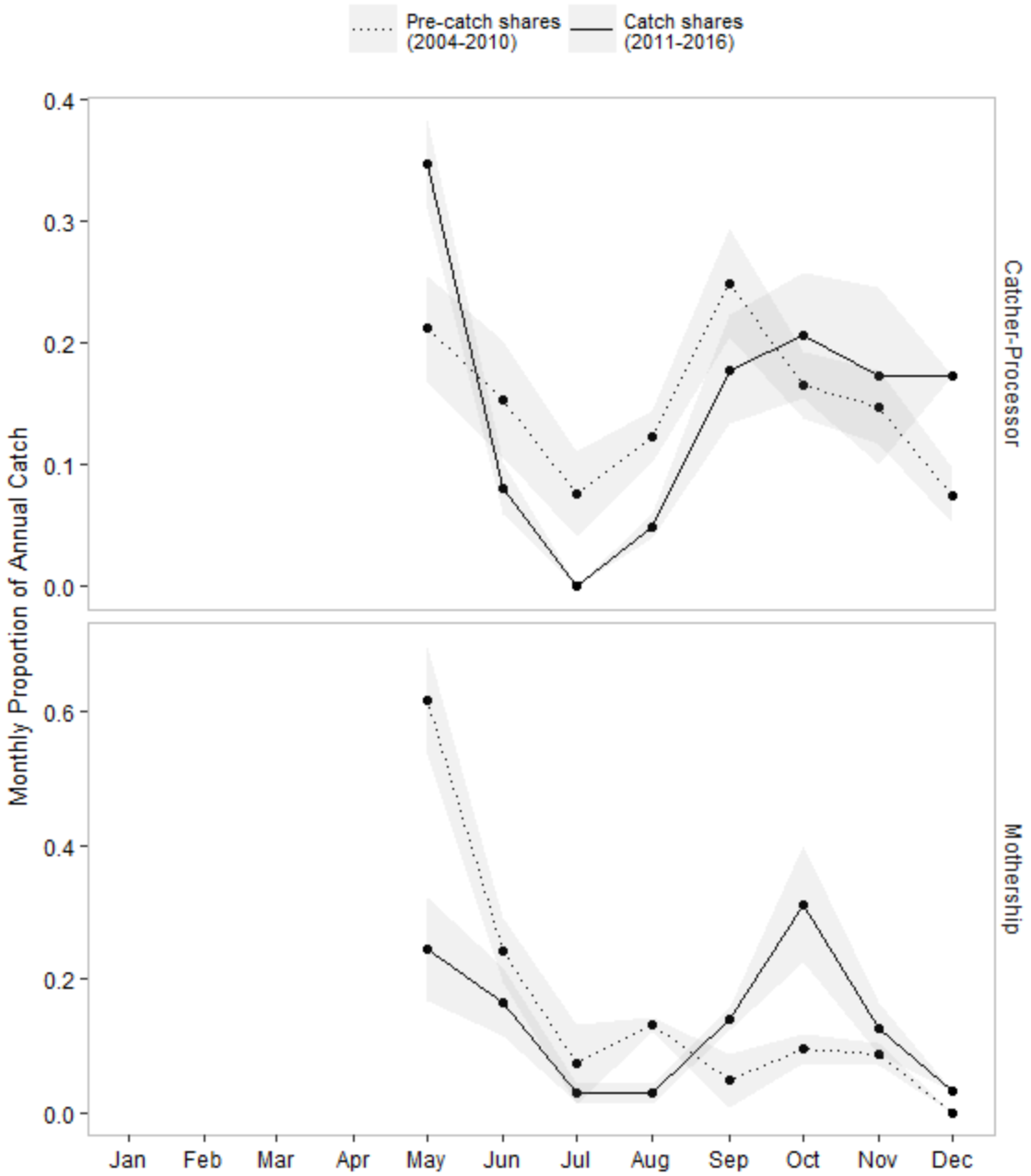

Figure 4. Mean proportion of annual harvest and processing in each month for the at-sea Pacific whiting catcher-processor (top) and mothership (bottom) fleets from 2004-2010 prior to the CS Program (dashed line) and from 2011-2016 after the implementation of the CS Program (solid line). Error bands represent ± 1 standard error of the mean.

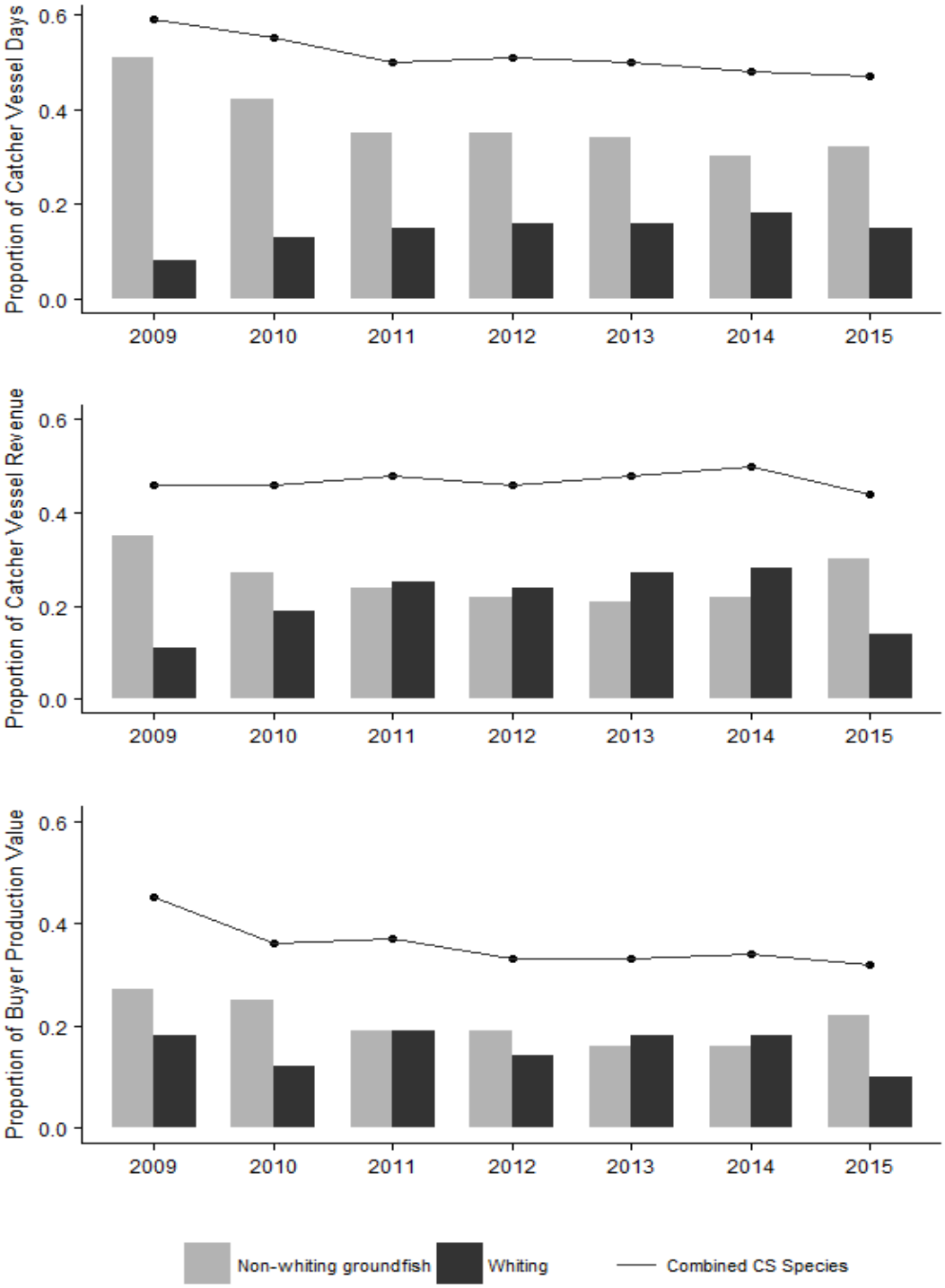

Figure 5. (Top) Catcher vessel days at sea spent harvesting all CS species (line), non-whiting groundfish (light grey), and Pacific whiting (dark grey) as a proportion of total fishing activities; (middle) catcher vessel revenue derived from harvesting all CS species (line), non-whiting groundfish (light grey), and Pacific whiting (dark grey) as a proportion of total revenue; and (bottom) shorebased buyer production value derived from all CS species (line), non-whiting groundfish (light grey), and Pacific whiting (dark grey) as a proportion of total production revenue.

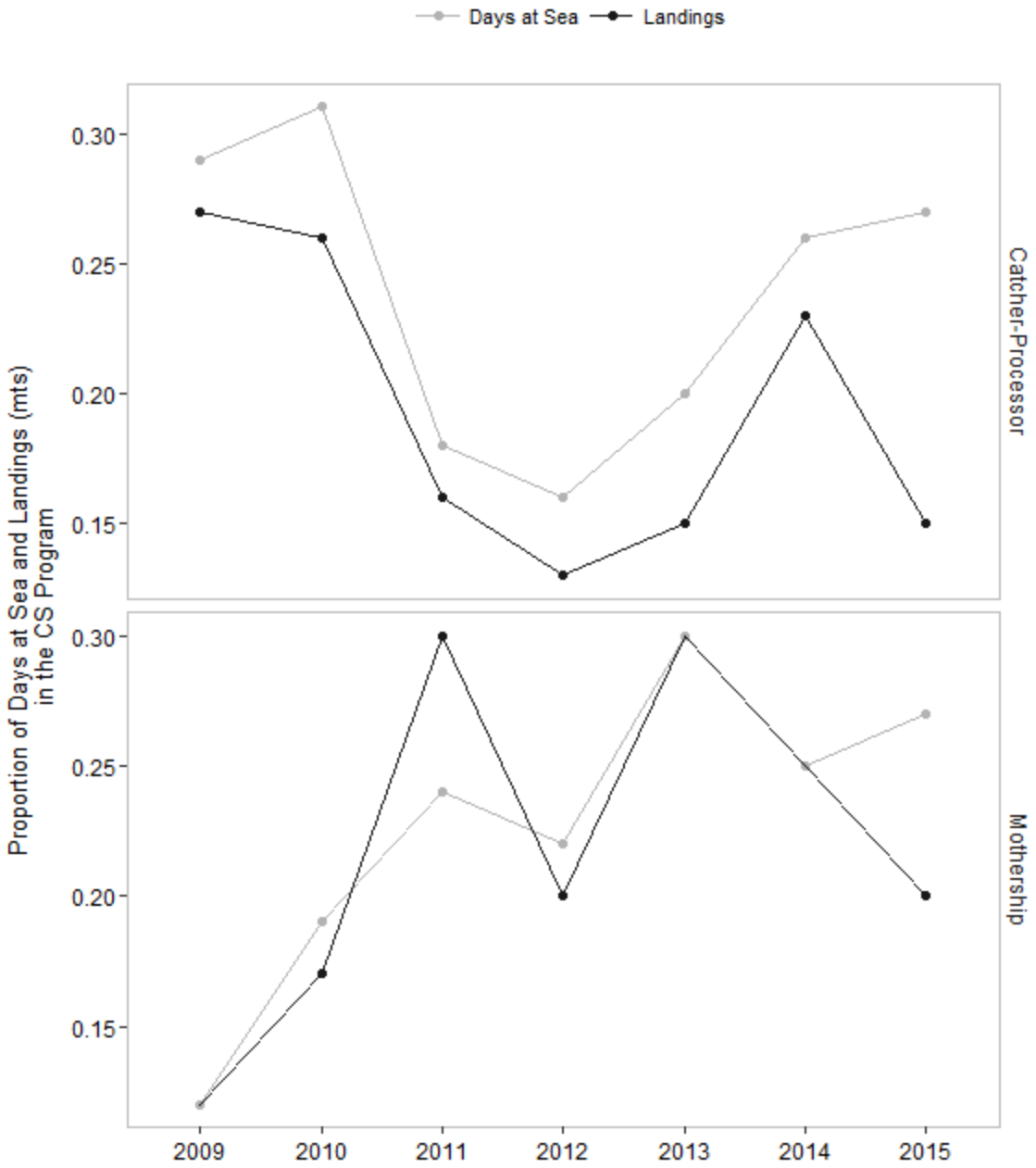

Figure 6. At-sea fleet-wide proportion of days at sea (grey) spent operating in and proportion of harvest (black) derived from Pacific whiting in the CS Program for catcher-processors (top) and motherships (bottom). Revenue not depicted because the data are not collected by the EDC Program for all activities.

Year	Catcher-Processors		Motherships		Shorebased	
	(mts)	(% attainment)	(mts)	(% attainment)	(mts)	(% attainment)
2005	78,903	99	55,696	87	97,469	100
2006	78,903	98	55,696	99	97,469	99
2007	70,751	100	49,942	95	87,398	84
2008	115,789	93	58,087	99	58,669	86
2009	35,376	98	24,034	100	40,738	99
2010	53,379	100	37,679	95	65,938	95
2011	75,138	95	53,039	94	92,818	98
2012	55,584	99	39,235	98	68,662	96
2013	79,573	98	56,170	93	98,297	97
2014	103,486	99	73,049	85	127,835	77
2015	100,873	68	71,204	39	124,608	47
2016	114,149	95	80,575	80	141,007	61

Table 1. Pacific whiting Total Allowable Catch (TAC) in metric tons (mts) and the percent of TAC harvested each year in the catcher-processor and mothership sectors.

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References

1. Gillis, D.M., R.M. Peterman, and E. K. Pikitch. 1995. Implications of trip limit regulations for high-grading; a model of the behavior of fishermen. Canadian Journal of Fisheries and Aquatic Sciences 52(2):402–415. DOI: 10.1139/f95-042

2. Guldin, M., Steiner, E., and Warlick, A. 2017. Economic Data Collection Program First Receiver and Shorebased Processor Report (2009-2015). NMFS Northwest Fisheries Science Center, Seattle, WA 98112. https://www.nwfsc.noaa.gov/research/divisions/fram/documents/EDC_First_Receiver_Sharebased_Processor_Report_June_2017.pdf

3. Hastie, J. 2001. Permit stacking as an approach to implementing harvest rights that can be transferred and accumulated. IIFET Proceedings 2000 Proceedings. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. E, Seattle, WA 98112. https://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/30766/243.pdf?sequence=1

4. He, X., D.E. Pearson, E.J. Dick, J.C. Field, S. Ralston, and A.D. MacCall. 2011. Status of widow rockfish resource in 2011. Pacific Fishery Management Council, Portland, OR 317 p. http://www.pcouncil.org/wp-content/uploads/Widow_2011_Assessment.pdf

5. He, X., and J.C. Field, 2017. Draft Stock assessment update: Status of Bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas for 2017. Southwest Fisheries Science Center, Santa Cruz, CA. June 2017. http://www.pcouncil.org/wp-content/uploads/2017/05/F4_Att3__2017_Bocaccio_Assessment_DraftFull_Version_Electronic_Only_Jun2017BB.pdf

6. Holland, D.S., Steiner, E., and A. Warlick. 2017. Can vessel buybacks pay off: An evaluation of an industry funded fishing vessel buyback, Marine Policy. 82: 8–15. doi:10.1016/j.marpol.2017.05.002.

7. Holland, D.S. 2016. Development of the Pacific Groundfish Trawl IFQ Market. Marine Resource Economics 31(4): 453-464. doi: 10.1086/687829

8. Iudicello S., and Lueders S.B. 2016. A Survey of Litigation Over Catch Shares and Groundfish Management in the Pacific Coast and Northeast Multispecies Fisheries. Environmental Law 46(1): 157-208. http://elawreview.org/articles/volume-46/a-survey-of-litigation-over-catch-shares-and-groundfish-management-in-the-pacific-coast-and-northeast-multispecies-fisheries/

9. Kauer, K. and D. Oberhoff. 2015. California Groundfish Collective Annual Report 2014. Report to the Pacific Fisheries Management Council. August 14, 2015. http://www.pcouncil.org/wp-content/uploads/2015/09/SUP_IR10_CA_GROUNDFISH_COLLECTIVE_RPT_SEPT2015BB.pdf

10. Kitts, A.W. and Edwards, S.F. 2003. Cooperatives in US fisheries: realizing the potential of the fishermen's collective marketing act. Marine Policy 27: 357-366. doi:10.1016/S0308-597X(03)00050-2.

11. Leonard, J. and Steiner, E. 2017. Initial Economic Impacts of the U.S. Pacific Coast Groundfish Fishery Individual Fishing Quota Program. North American Journal of

DRAFT

Fisheries Management 37(4). http://www.tandfonline.com/doi/full/10.1080/02755947.2017.1330784

12. Medley, P.A.H., O'Boyle, R., Pedersen, M., Tingley, G., Hanna, S., and Devitt, S. 2014. MSC Assessment Report for United States West Coast Limited Entry Groundfish Trawl Fishery. Oregon Trawl Commission, Brookings, OR and Intertek Fisheries Certification, Derby, UK.

13. National Marine Fisheries Service. 2003. Environmental Assessment and Regulatory Impact Review for a final notice of a fishing capacity reduction program in the Pacific Coast groundfish fishery. National Marine Fisheries Service, Financial Services Division, Silver Spring, MD 20910. http://www.westcoast.fisheries.noaa.gov/publications/nepa/groundfish/misc_ea/ea-buyback.pdf

14. National Marine Fisheries Service. 2004. The after effects of the Pacific groundfish Limited Entry trawl buyback program: A preliminary analysis. NMFS Northwest Region, Seattle, March 2004. http://www.pcouncil.org/bb/2004/0404/C17_Supp_NMFS_Apl04BB.pdf

15. National Marine Fisheries Service. Magnuson-Stevens Act Provisions; Fishing Capacity Reduction Program; Pacific Coast Groundfish Fishery; Industry Fee Collection System for Fishing Capacity Reduction Loan. 70 Federal Register 40225 (July 13, 2005). https://www.gpo.gov/fdsys/pkg/FR-2005-07-13/pdf/05-13692.pdf

16. National Marine Fisheries Service. 2009. A Limited Entry Program for the Non-Tribal Sectors of the Pacific Whiting Fishery: Final Environmental Assessment. National Marine Fisheries Service, 7600 Sand Point Way NE, Seattle, WA 98115. http://www.westcoast.fisheries.noaa.gov/publications/nepa/groundfish/misc_ea/amend15ea_finalfornoaanepa_final.pdf

17. National Marine Fisheries Service. 2010. Compliance guide Pacific coast groundfish trawl rationalization program: Application process for: quota share permit, mothership permit, mothership catcher vessel endorsement, and catcher processor endorsement. U.S. Department of Commerce. http://www.westcoast.fisheries.noaa.gov/publications/fishery_management/trawl_program/catch-shares-guide-appl.pdf

18. National Marine Fisheries Service. 2017. West Coast groundfish trawl catch share program five-year review – draft. Northwest Fisheries Science Center and NOAA West Coast Regional Office. Seattle, WA. https://www.pcouncil.org//wp-content/uploads/2017/08/5_Year_Review_August_Draft_for_public_review.pdf

19. National Oceanic and Atmospheric Administration. 1977. Trawl fisheries of Washington, Oregon, and California: Preliminary Fishery Management Plan. 42 Federal Register No. 28 p. 8578. https://alaskafisheries.noaa.gov/sites/default/files/42fr8578.pdf

20. National Oceanic and Atmospheric Administration. 1982. Foreign Fishing and Pacific Coast Groundfish Fishery: Final rule; notice of final management estimates. 47 Federal Register No. 193 p. 43964. https://alaskafisheries.noaa.gov/sites/default/files/47fr43964.pdf

21. National Oceanic and Atmospheric Administration. 2000a. Press release: Commerce Secretary Daley announces West Coast groundfish fishery failure.

DRAFT

http://www.nmfs.noaa.gov/sfa/management/disaster/determinations/13_west_groundfish/press.pdf

22. National Oceanic and Atmospheric Administration. 2000b. Pacific Coast Groundfish Fishery Amendment 12: Proposed Rule. 65 Federal Register No. 195 p. 59815. https://www.gpo.gov/fdsys/pkg/FR-2000-10-06/pdf/00-25777.pdf

23. National Oceanic and Atmospheric Administration. 2004. Pacific groundfish fishery Advance Notice of Proposed Rulemaking regarding a Trawl Individual Quota Program and to Establish a Control Date. 69 Federal Register No. 9 p. 1563. http://www.westcoast.fisheries.noaa.gov/publications/frn/2004/69fr1563.pdf

24. Oregon Sea Grant. 1992. Pacific whiting: Harvesting, processing, marketing, and quality assurance – a workshop, March 30-31, 1992. Eds G. Sylvia and M.T. Morrissey. Oregon Sea Grant, Corvallis, OR. http://nsgl.gso.uri.edu/oresu/oresuw92001/oresuw92001_full.pdf

25. Pacific Fishery Management Council. 1993. Pacific Whiting Allocation: Environmental assessment and regulatory impact review of the anticipated biological, social, and economic impacts of a proposal to allocate the resource in 1994, 1995, and 1996. Portland, OR 97201. http://www.pcouncil.org/wp-content/uploads/1993_Whiting_EA.pdf

26. Pacific Fishery Management Council. 1997. Pacific Whiting Allocation: Environmental assessment and regulatory impact review of the anticipated biological, social, and economic impacts of a proposal to allocate Pacific whiting among non-tribal sectors and to establish a framework for modifying season opening dates. Portland, OR 97201. https://www.pcouncil.org//wp-content/uploads/02_1997_EA_RIR_Whiting.pdf

27. Pacific Fishery Management Council. 2000. Overcapitalization in the West Coast Groundfish Fishery: Background, Issues and Solutions. Report by the Economic Subcommittee of the PFMC Scientific and Statistical Committee, Pacific Fishery Management Council, 16 March 2000. Pacific Fishery Management Council, 2130 SW Fifth Ave., Portland, OR 97201. http://www.pcouncil.org/wp-content/uploads/sscovercap0300.pdf

28. Pacific Fishery Management Council and National Marine Fisheries Service. 1992. Amendment 6 (Limited Entry) to the fishery management plan for Pacific coast groundfish including Supplemental Environmental Impact Statement and Regulatory Impact Review. Pacific Fishery Management Council, 2130 SW Fifth Ave., Portland, OR 97201. http://www.pcouncil.org/wp-content/uploads/GroundfishFMPAmend6.pdf

29. Pacific Fisheries Management Council and National Marine Fisheries Service. 2005. Pacific coast groundfish fishery management plan: Essential Fish Habitat designation and minimization of adverse impacts – Final Environmental Impact Statement Appendix G: Alternative 10 Draft EA. NMFS Northwest Region, Seattle, WA, 98115. http://www.westcoast.fisheries.noaa.gov/publications/nepa/groundfish/groundfish_efh_eis/appendix-g-draft-ea.pdf

30. Pacific Fishery Management Council and National Marine Fisheries Service. 2010a. Rationalization of the Pacific groundfish Limited Entry trawl fishery: Final Environmental Impact Statement, including regulatory impact review and initial regulatory flexibility analysis. Pacific Fishery Management Council, Portland, OR. June

DRAFT

2010. http://www.pcouncil.org/wp-content/uploads/1_Pacific-Coast-Grounddfish-Limited-Entry-Trawl-Fishery-FEIS.pdf

31. Pacific Fishery Management Council and National Marine Fisheries Service. 2010b. Analysis of components, elements, and options for the individual fishing quota alternative trawl individual quota components: Appendix A to the Rationalization of the Pacific Coast groundfish limited entry trawl fishery Final Environmental Impact Statement. Pacific Fishery Management Council, Portland, OR. June 2010. http://www.pcouncil.org/wp-content/uploads/2_1005_TRatFEIS_ApdxA__IFQ.pdf

32. Pacific Fishery Management Council. 2007. Components Discussion Paper: Qualifying eligibility and allocation time periods, agenda item D.7b, Pacific Fishery Management Council, Portland, OR. November 2007. http://www.pcouncil.org/bb/2007/1107/D7b_ATT1.pdf

33. Pacific Fishery Management Council. 2016. Pacific coast groundfish fishery management plan for the California, Oregon, and Washington groundfish fishery. Pacific Fishery Management Council, 7700 NE Ambassador Place, Portland, OR 97220. http://www.pcouncil.org/wp-content/uploads/2017/03/GF_FMP_FinalThruA27-Aug2016.pdf

34. Pikitch, E.K., D.L. Erickson, and J.R. Wallace. 1988. An evaluation of the effectiveness of trip limits as a management tool. NWAFSC Processed Report 88-27. National Marine Fisheries Service, Northwest Alaska Fisheries Center, Seattle, WA.

35. Sanchirico, J., D. Holland, K. Quigley, and M. Fina. 2005. Catch-quota balancing in multispecies individual fishing quotas. Resources for the Future 1-43. http://motu.nz/assets/Documents/our-work/environment-and-resources/fisheries-management/Catch-Quota-Balancing-in-Multispecies-Individual-Fishing-Quotas.pdf

36. Shaw, W. and F.D.L. Conway. 2007. Responses to the West Coast groundfish disaster: Lessons learned for communities and decision makers. Oregon State University, Corvallis OR. http://seagrant.oregonstate.edu/sites/seagrant.oregonstate.edu/files/sgpubs/onlinepubs/g07006.pdf

37. Stawitz, C., Hurtado-Ferro, F., Kuriyama, P., Trochta, J., Johnson, K., Haltuch, M., and O. Hamel. 2016. Stock assessment update: status of the U.S. petrale sole resource in 2014. Pacific Fishery Management Council, Portland, OR 376 p. http://www.pcouncil.org/wp-content/uploads/2016/04/Petrale2015Update_1Apr16.pdf

38. Steiner, E., Pfeiffer, L., Guldin, M., and A. Warlick. 2016a. Economic Data Collection Program Catcher Vessel Report (2009-2014). NMFS Northwest Fisheries Science Center, Seattle, WA 98112. https://www.nwfsc.noaa.gov/research/divisions/fram/documents/EDC_Catcher_Vessel_Report_October_2016.pdf

39. Steiner, E., A. Warlick, Guldin, M, and Pfeiffer, L. 2016b. Economic Data Collection Program Mothership Report (2009-2014). NMFS Northwest Fisheries Science Center, Seattle, WA 98112. https://www.nwfsc.noaa.gov/research/divisions/fram/documents/EDC_Mothership_Report_October_2016.pdf

DRAFT

40. Steiner, E., L. Pfeiffer, M. Guldin, and A. Warlick. 2017a. Economic Data Collection Program Catcher Vessel Report (2009-2015). NMFS Northwest Fisheries Science Center, Seattle, WA 98112. https://www.nwfsc.noaa.gov/research/divisions/fram/documents/EDC_Catcher_Vessel_Report_June_2017.pdf

41. Steiner, E., A. Warlick, Guldin, M, and Pfeiffer, L. 2017b. Economic Data Collection Program Mothership Report (2009-2015). NMFS Northwest Fisheries Science Center, Seattle, WA 98112. https://www.nwfsc.noaa.gov/research/divisions/fram/documents/EDC_Mothership_Report_June_2017.pdf

42. Sylvia, G., H. Mann, and C. Pugmire. 2008. Achievements of the Pacific whiting conservation cooperative: rational collaboration in a sea of irrational competition, In Case studies on fisheries self-governance. FAO, 2008. http://www.fao.org/3/a-a1497e/a1497e37.pdf

43. Taylor, I.G., C. Grandin, A.C. Hicks, N. Taylor, and S. Cox. 2015. Status of the Pacific Hake (whiting) stock in U.S. and Canadian waters in 2015. Prepared by the Joint Technical Committee of the U.S. and Canada Pacific Hake/Whiting Agreement; National Marine Fishery Service; Canada Department of Fisheries and Oceans. 159 p. http://www.cio.noaa.gov/services_programs/prplans/pdfs/ID334_Final_PacHake2016.pdf

44. Thorson, J.T. and C. Wetzel. 2016. The status of canary rockfish (Sebastes pinniger) in the California Current in 2015. Pacific Fishery Management Council, Portland, OR 682 p. http://www.pcouncil.org/wp-content/uploads/2016/05/Canary_2016_Final.pdf

45. Wallace, J. and V. Gertseva. 2017. Status of the darkblotched rockfish resource off the continental U.S. Pacific Coast in 2017 (Update of 2015 assessment model). Northwest Fisheries Science Center, Seattle, WA. May 2017. http://www.pcouncil.org/wp-content/uploads/2017/05/F4_Att4_DBRK_2017_Assessment_Update_Full-ElectronicOnly_Jun2017BB.pdf

46. Warlick, A., Steiner, E., Pfeiffer, L., and Guldin, M. 2017. Economic Data Collection Program Catcher-Processor Report (2009-2015). NMFS Northwest Fisheries Science Center, Seattle, WA 98112. https://www.nwfsc.noaa.gov/research/divisions/fram/documents/EDC_Catcher_Processor_Report_June_2017.pdf

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