Using Incentives to Reduce Bycatch and Discarding: Results Under the West Coast Catch Share Program

Kayleigh A. Somers, Lisa Pfeiffer, Stacey Miller & Wendy Morrison

To cite this article: Kayleigh A. Somers, Lisa Pfeiffer, Stacey Miller & Wendy Morrison (2019): Using Incentives to Reduce Bycatch and Discarding: Results Under the West Coast Catch Share Program, Coastal Management, DOI: [10.1080/08920753.2018.1522492](https://doi.org/10.1080/08920753.2018.1522492)

To link to this article: <https://doi.org/10.1080/08920753.2018.1522492>

Published online: 15 Jan 2019.

Submit your article to this journal [↗](#)

Article views: 17

View Crossmark data [↗](#)

Citing articles: 1 View citing articles [↗](#)

Using Incentives to Reduce Bycatch and Discarding: Results Under the West Coast Catch Share Program

Kayleigh A. Somers^a, Lisa Pfeiffer^a, Stacey Miller^b, and Wendy Morrison^c

^aFisheries Resource Analysis and Monitoring, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA, USA; ^bFisheries Resource Analysis and Monitoring, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Newport, OR, USA; ^cOffice of Sustainable Fisheries, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Silver Spring, MD, USA

ABSTRACT

Catch share management was implemented in the bottom trawl sector of the West Coast Groundfish fishery in 2011 to address a range of issues including high bycatch and discard rates. The catch share program was designed to remove the incentives to discard through full catch accounting, tradeable quotas, increased flexibility in fishing, and penalties for catch overages. We assess the effectiveness of the program in meeting its environmental objectives by comparing discard weights, proportions, and variability from 2004–2010 with 2011–2016. We analyzed these metrics for species managed using quota, including historically overfished stocks, as well as for non-quota species caught in the fishery. Discard amounts decreased over time for all species and declined to historic lows after the implementation of the program, remaining low through 2016 with much less inter-annual variability. Mean annual discards of two highly-targeted quota species, sablefish and Dover sole, showed the greatest decreases, falling by 97 and 86%, respectively. The discard proportion of overfished quota species fell by 50% on average. The unanticipated decline in discards of non-quota species as well as the decreased variability in discard amounts for all species indicate that the incentives produced by catch share management provided additional ecosystem benefits.

KEYWORDS

Bycatch; catch shares; discards; fisheries; quota; groundfish

Introduction

Bycatch, or harvested fish that are not retained or sold due to economic or regulatory reasons, remains a problem confronting fisheries around the world. Bycatch can exacerbate population declines, impede rebuilding efforts, and alter marine ecosystems (Kelleher 2005). In the United States, bycatch is legally defined to include both catch that is discarded to comply with regulations that do not allow retention and catch that is discarded for economic reasons, such as unmarketable size, sex, or quality, or to ease constraining vessel capacity or landings limits (PL 94-265, 50 CFR 600.350, Anderson 1994, NMFS 2016). Multispecies fisheries can provide an additional incentive to discard:

CONTACT Kayleigh A. Somers Kayleigh.Somers@noaa.gov Fishery Resource Analysis and Monitoring, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2725 Montlake Blvd. E, Seattle 98112, WA, USA.

Supplemental data for this article can be accessed <https://doi.org/10.1080/08920753.2018.1522492>.

fishermen may discard constraining or “choke” species to continue fishing on co-occurring stocks, even if discarded fish are high-value. In the West Coast Groundfish Trawl fishery, concerns about high bycatch by the shore-based bottom trawl fleet were one of the management issues that led to the development of the West Coast Groundfish Trawl Catch Share Program, which was implemented in 2011. One of the catch share program’s explicit objectives was to “reduce bycatch and discarded catch and minimize the ecological impacts of the fishery” (PFMC and NMFS 2017). Catch share management, when paired with full individual accountability of catch, is hypothesized to shift incentives away from at-sea *discarding* of lower value or constraining catch toward *avoiding* unwanted catch through changes in fishing practices (Arnason 1994). In this article, we assess the effectiveness of the West Coast Groundfish Trawl Catch Share Program in reducing discards by comparing discard weights, proportions, and variability prior to and after the program’s implementation.

Before the implementation of catch shares, high levels of discards in the bottom trawl fishery occurred for two primary reasons (Bellman and Heery 2013). First, there was no regulatory incentive to avoid catching of unmarketable and low-value species, which was typically discarded at high rates. From 2004 to 2010, fishermen discarded an annual average of 3,230 metric tons of generally untargeted fish species, which amounted to about 72% of the total catch of these species. Second, discards occurred to comply with complex vessel-level landing limits that regulated only retained, not total, catch. Trip-based limits were specific to species, gear, and area; were set for daily, weekly, monthly, and/or cumulative bi-monthly periods; and could be adjusted by managers during the fishing season. The complex nature of the trip limit system made it difficult for fishermen to synchronize the species composition of their catch with ever-changing landings limits (Squires and Kirkley 1991; Sanchirico et al. 2006). Thus, fishermen had the incentive to discard any portion of the catch that exceeded individual species limits in order to continue fishing for others. Unsurprisingly, this system resulted in discarding of both high- and low-value catch. From 2004 to 2010, an annual average of 5,000 metric tons of targeted stocks (one-fifth of total catch) was discarded.

This level of discarding was particularly concerning for eight stocks that were declared overfished between 1999 and 2002.¹ Fishery managers implemented rebuilding plans that drastically reduced landings limits for these overfished stocks, which restricted the fishery’s ability to catch healthy co-occurring target stocks. Again, because only landings were counted against trip limits, vessels had the incentive to discard the eight rockfish and one flatfish species that were under rebuilding plans. In 2005, for example, 31 metric tons of canary rockfish were discarded, while only 4 metric tons were landed. Scientists and managers recognized that such large discard amounts could affect progress toward rebuilding benchmarks.

In 2011, the catch share program replaced the trip-limit management system with a goal of reducing the incentives to discard through full monitoring and individual accountability of all catch. The program requires harvesters to possess quota to cover all catch of quota-managed species, whether landed or discarded. At-sea observers or electronic monitoring (EM) and shoreside sampling of all catch increases accountability and enforcement of regulations. Further, the catch share program provides more flexibility to fishermen than the trip limit system had. Harvesters can more effectively “match”

the species mixture in the catch to the species mixture in their quota portfolio, either by adjusting fishing practices, including altering the type and configuration of gear used or changing the location, depth, season, and time of fishing, or by trading quota.

We examined whether the change of incentives conferred by the catch share program, coupled with full individual accountability, have corresponded with the hypothesized reduction in discards in the bottom trawl fleet of the West Coast groundfish fishery. We examined discards and discard rates of four categories of species, described in “Methods”, below, that reflect different management rules within the fishery both before and after the implementation of the catch share program and analyzed changes at the species level for species now managed using quota, including historically overfished species.

Background

Secure harvesting rights provided by individual quotas are theorized to provide the incentives needed to develop and use cost-effective methods to avoid certain species. In multispecies fisheries, fishermen have demonstrated the ability to control their catch composition to a greater degree when they have the incentive and flexibility to do so (Abbott, Haynie, and Reimer 2015; Sanchirico et al. 2006; Miller and Deacon 2017; Branch and Hilborn 2008; Poos et al. 2010; Kuriyama et al. 2016). For example, fishermen may choose to use selective gear to more effectively target high-value species while avoiding bycatch, share information on hotspots, or increase self-enforcement (Branch, Rutherford, and Hilborn 2006; Holland 2016, 2010). In addition, when quota is tradeable, quota markets provide harvesters with the ability to further reduce the mismatch between the quota they hold and the composition of their catch (Holland 2016; Sanchirico et al. 2006). Market-determined quota prices and quota constraints theoretically provide price incentives to both avoid constraining species and target species with more liberal catch limits (Branch and Hilborn 2008). Further, catch share management based on total catch rather than landings may increase the incentive to avoid low-value species and retain marketable species when encountered, because quota will be deducted from a vessel’s account regardless of whether it is landed (Arnason 1994).

There is some contention about whether catch shares actually reduce discards in practice. Some researchers suggest individual landing quotas that do not account for total catch can increase the incentive to high-grade (Squires et al. 1998; Arnason 1994; Anderson 1994; Branch and Hilborn 2008; Copes 1986; Boyd and Dewees 1992). Others posit that discards may increase under catch share programs in multispecies fisheries when the mix of allocated quotas does not reflect the composition of the catch, particularly when some species have constraining quotas (Squires et al. 1998; Branch, Rutherford, and Hilborn 2006; Kuriyama et al. 2016). Asche et al. (2007) also noted that effort could be displaced on to species not managed with quota, increasing fishing pressure on less-regulated species. Numerous studies have shown these types of problems can be largely overcome with total catch accounting rather than landings limits, as well as effective monitoring and enforcement (Arnason 1994; Melnychuk et al. 2017; Bundy et al. 2017; Singh and Weninger 2015). However, in cases where bycatch is highly unpredictable or rare or where a vessel’s quota limit is very low, the inability of

harvesters to predict their future quota needs may lead to inefficient quota allocation even when quota applies to both landed and discarded catch (Holland 2010). In such cases, encounters may be so unpredictable that the incentive to avoid bycatch provided by individual quota limits may not affect actual bycatch encounters.

Despite these concerns, empirical evidence suggests that catch share programs often do lead to bycatch reduction. In a meta-analysis of 15 fisheries in North America, Essington (2010) found that discard rates declined significantly after catch share management was implemented. In another analysis of fisheries in the United States and British Columbia, Grimm et al. (2012) found that nearly all the catch share fisheries had lower discard rates than those using traditional management approaches and noted that rigorous monitoring and enforcement were features of those programs where discard rates decreased. Fina (2011) found that one of the most notable effects of the Central Gulf of Alaska Rockfish Pilot Program was reduction in bycatch. Abbott, Haynie, and Reimer (2015) found that after a quota program was implemented in another Alaskan groundfish fishery, there were sharp declines in the bycatch rates of halibut and cod, species that had frequently closed the fishery prior to the program. Harvesters were able to avoid halibut and cod through changes in fishing behavior that included distributing effort throughout the season, adjustments in the location of fishing, avoidance of and movement from hotspot areas, and reductions in night fishing. Branch et al. (2006) compared bycatch rates after the introduction of an individual transferable quota program in the British Columbia groundfish fishery with rates before the implementation of the program and with rates in the then-unrationalized West Coast groundfish trawl fishery. They found that US West Coast bycatch rates were much higher than those in British Columbia, primarily due to the presence of constraining trip limit quotas on the West Coast that incentivized discards. In the British Columbia fishery, full observer coverage and catch accounting for individual, non-tradeable vessel catch limits were implemented in the years prior to the tradeable quota program, so catch share implementation had a less dramatic impact than that observed in other fisheries. However, discard rates continued to decline to even lower levels, which Branch et al. (2006) attributed to participants' ability to trade quota and the incentive to avoid unwanted catch through behavioral changes and technical innovations.

The design of the West Coast Groundfish Trawl Catch Share Program took into consideration the theoretical research and empirical experience from other regions (PFMC and NMFS 2010b). The program aims to address fisheries management from a holistic perspective, including economic and social goals addressed in the other papers in this issue. The program's environmental objectives focus on the need to "Create and implement a capacity reduction program that...considers environmental impacts and achieves individual accountability of catch and bycatch" (PFMC and NMFS 2010b). Specifically, the program aims to "Promote practices that reduce bycatch and discard mortality and minimize ecological impacts," by establishing guiding principles that "Take into account the need to ensure that the total optimum yield (OY) and allowable biological catch (ABC) are not exceeded," "Account for total groundfish mortality," and "Provide efficient and effective monitoring and enforcement" (PFMC and NMFS 2010b). In 2011, after nearly 10 years of deliberation on how to realize these goals and objectives, the Pacific Fishery Management Council (PFMC) implemented an individual

tradeable quota for 30 stocks, comprised of both individual species and species complexes (e.g., “minor slope rockfish”). Quota shares for quota stock species were allocated to fishermen based on their historical landings and are converted to quota pounds each year, reflective of the estimated stock size. A number of species in the fishery management plan (FMP) with low annual landings continue to be managed with trip limits, and some species that are caught while participating in the fishery remain unmanaged. Catch is fully accounted for with complete monitoring of the fleet using on-board observers, at-sea EM systems, and shoreside catch monitoring (PFMC and NMFS 2010a).

While not the focus of this analysis, a provision in the catch share program allows participants with a trawl-endorsed limited entry permit to fish their quota with trawl or any other legal groundfish gear (50 CFR 660.130). The “gear-switching” provision was promoted for ecological and economic reasons, as fixed gear historically had lower bycatch rates than bottom trawl gear, is thought to have fewer habitat impacts, and provides increased flexibility for each vessel to choose its most profitable fishing strategy (Jenkins and Garrison 2013). In practice, the gear switching provision has been used almost exclusively to target sablefish. Additionally, a midwater trawl sector targeting yellowtail and widow rockfish has begun to emerge. These species were previously difficult to access due to the rebuilding status of widow rockfish and constraining quota of co-occurring species. While these portions of the fleet are important to understanding the overall impacts of catch share management on the fishery, we focus this analysis on how quota management has changed incentives and altered fishing behaviors for the majority of the shoreside fleet, which continues to use bottom trawl gear.

During the design of the West Coast Groundfish Trawl Catch Share Program, the PFMC was particularly concerned about catch of overfished species, as rebuilding was projected to take more than 70 years for some stocks due to slow growth rates, low productivity, and infrequent strong recruitment events (PFMC 2016). The PFMC limited the total amount of quota for overfished species that a vessel can own in an attempt to reduce “hoarding,” which could occur if fishermen held quota for species that could become constraining later in the season (PFMC and NMFS 2010b). Holding quota in this way could make it difficult for other harvesters to cover unexpected catches of low-quota species through the quota market. These limits were also intended to increase the economic consequences of very large “lightning strike” tows of rebuilding species, which, under annual quota holding limits, could restrict a vessel from participating in the fishery for several years. The risks of being unable to obtain enough quota to cover an unexpected tow of overfished species led to the organization of several quota risk pools (Holland and Jannot 2012), which was encouraged by the PFMC.

Seven rockfish stocks had overfished status at the outset of the program: Pacific ocean perch, bocaccio, canary rockfish, cowcod, darkblotched rockfish, widow rockfish, and yelloweye rockfish (PFMC 2016). In 2009, petrale sole was added to the list of overfished stocks with an estimated rebuilding target of 2016. To ensure successful rebuilding of these species, quota was set at low levels and, unlike other quota species, was not based on historical catch (PFMC and NMFS 2010a). However, they could be targeted, landed, and marketed as long as a vessel had quota. This design eased future re-incorporation of these species into the target fishery upon achieving rebuilt status. Shortly after the implementation of the catch share program, these species began to achieve

rebuilt status. The first to do so was widow rockfish in 2011, four years ahead of schedule (He et al. 2011). Other stocks continued to show progress toward rebuilding, and canary rockfish and petrale sole were declared rebuilt in 2015, followed in 2017 by bocaccio, darkblotched rockfish, and Pacific ocean perch (Thorson and Wetzel 2016; Stawitz et al. 2015; He and Field 2017; Wallace and Gertseva 2017; Wetzel, Cronin-Fine, and Johnson 2017). As of 2018, only two species remain overfished: cowcod and yelloweye rockfish. The successful rebuilding of seven species has been analyzed by managers and scientists, but little has been done to explore discard trends for other species. In this research, we analyzed bottom trawl discards of quota, non-quota, and non-managed species to better understand the effects of the catch share program on the ecosystem as a whole.

Methods

We used catch data from the “Groundfish Expanded Mortality Multiyear (GEMM)” product (Somers et al. 2017a)² to explore catch and discard trends in the West Coast bottom trawl fleet from 2004 to 2016, focusing on differences before and after the implementation of the catch share program. The Fisheries Observation Science (FOS) program, part of National Oceanic and Atmospheric Administration (NOAA) Fisheries, produces this dataset annually using four data sources: observer data from the FOS, and landing receipts, state logbook, and EM data from the Pacific States Marine Fishery Commission (PSMFC) (fully described in Somers et al. 2017b). The FOS program places trained biological observers aboard fishing vessels to record haul-level effort and catch information, document discards of all species, and collect biological data.

Prior to the implementation of the catch share program, approximately 20% of annual landings by the bottom trawl fleet were associated with observed trips. During this period, the FOS used stratified random sampling to select every active permit in the limited entry trawl fishery for observer coverage during a two-month period of the year.³ On-board observers sampled and accounted for all at-sea discards, focusing data collection on species of high conservation concern (NWFSC 2017). To estimate at-sea discards at the fleet level, the FOS used state logbook data to distribute shoreside landings into depth and area strata. The FOS then matched observed discard rates in these same strata to estimated landings and used ratio estimators to expand from observed hauls to fleet-wide estimates (methods are further described in Somers et al. 2017b).

Since the implementation of the catch share program, 100% monitoring of catch has been required. From 2011 to 2014, the FOS observed 100% of trips (Somers et al. 2017c).⁴ In 2015, some bottom trawl vessels began to use EM systems overseen by PSMFC to monitor discard compliance. In this portion of the fleet, 100% of quota species catch is monitored using EM and shoreside sampling. The FOS provides additional scientific coverage of an average of 31% of EM landings in 2015 and 2016 and continues 100% coverage of the non-EM portion of the fleet (Somers et al. 2017c). The FOS uses video reviewer estimates of discards of quota species and observed discard rates of non-quota species from those vessels selected for scientific coverage to estimate total discard at the fleet level. Although haul-level precision is higher in observer data,

managers consider estimates for the fishery as a whole comparable across the fully observed and electronically monitored portions of the fleet.

The difference in coverage rates prior to and after the implementation of the catch share program also impacts the accuracy and precision of discard estimates. Approximately 20% monitoring prior to catch shares resulted in greater variability in discard estimates. However, the FOS limited potential observer effects by aligning coverage selection and trip limit periods, making it costly for fishers to adjust their behavior when being observed.⁵ Additionally, the lack of individual accountability for discards likely minimized any observer effect. Managers consider discard estimates across the two time periods to be comparable.

To analyze the effectiveness of the catch share program in reducing discards, we explored trends in three metrics and compared how these trends differed across multiple species and species groupings. The first metric is total discard amount for each species or species grouping, which assesses the extent to which catch share management has met its goal of decreasing bycatch and discards. The second metric, the proportion of the total catch of a species or group that was discarded, removes the variability caused by changes in total effort. The discard proportion reflects bycatch avoidance behavior and technical innovations that have reduced encounters with and discards of a given species. For both of these metrics, we calculated and compared the simple means in both periods. Finally, we calculated the coefficients of variation (standard deviation for the given period divided by the simple mean across full analysis period) to explore differences in variability in discards across the two time periods.

We categorized each species as either: (1) quota species not overfished or rebuilding during the time period of this analysis; (2) quota species with overfished or rebuilding status during the time period of this analysis; (3) species not managed with quota but included in the FMP, such as cabezon and spiny dogfish shark; or (4) species that the trawl fleet encounters but which are not currently managed within the FMP, such as brown cat shark and deepsea sole. A full list of the species that fall into each category is available in Table A-1 of Somers et al. (2017b). Several species do not fall into these four categories, including those that are managed using individual bycatch quota (Pacific halibut) or protected by the Endangered Species Act (salmon species, eulachon, and green sturgeon). These species are not included here, as their management and the procedures used to estimate total bycatch differ greatly from the included species. The magnitude and trends of bycatch of these species are described in a number of reports produced by NOAA Fisheries (Jannot et al. 2017; Lee et al. 2017; Gustafson et al. 2017; Somers et al. 2014).

The quota species category contains all species that are primary targets that were not of rebuilding concern. From 2004 to 2016, non-rebuilding quota species comprised on average 77% of total catch weight. We hypothesized that discards of quota species would decrease with the shift from trip limit management to individual quotas. The second category consists of species with overfished or rebuilding status at the beginning of the catch share program. Species under rebuilding plans were also allocated tradeable quota, so discards were expected to decrease under the catch share program. The third category, non-quota FMP species, comprised the second greatest catch by weight and consists of species that are now, or could in the future be targeted, but are not currently of high conservation concern. There were no predictions

for these species groups discussed in the Final Environmental Impact Statement for FMP Amendments 20 and 21 implementing catch shares (PFMC and NMFS 2010b). While increased pressure on non-quota species might be expected (Asche et al. 2007; Hutniczak 2014), most of the species excluded from the quota groups are of low value and have no developed markets. Finally, the fourth category, non-FMP species, are also considered extremely low-value or unmarketable and even less likely to be targeted than non-quota FMP species, so we did not expect a change in discard amounts or rates for these unmanaged species.

Results

Discard amounts and proportions in the bottom trawl fishery

Discards and the discard proportion of quota species declined after the implementation of the catch share program in 2011, and remained much less variable and at historic lows through 2016 (Figure 1). While there is some evidence of a downward trend prior to the catch share program, discards of many species were highly variable during this time period (see Tables 1 and 2 and the online appendix). The downward trend in discards of quota species depicted in the left panel of Figure 1 is driven by discards of one species, Pacific hake, which were extremely high in 2004 (3,000 mt) and extremely low in 2010 (300 mt) (online appendix, Figure A-4). The declining trend in Pacific hake discards closely follows the declining trend of estimated biomass between 2003 and 2009 (Edwards et al. 2018). If Pacific hake is removed, the 2004–2009 time series remains variable, but no downward trend is evident (online appendix, Figure A-4). Similarly, the spike in quota species discards in 2009 and subsequent decline in 2010 is driven by high catch and discard of arrowtooth flounder (online appendix, Figure A-4).

Discards of the overfished and rebuilding quota species declined as well, although the magnitude of change was lower. A number of management actions impacted fishing effort and catch of the overfished and rebuilding species prior to catch share implementation, including gear restrictions, ongoing adjustments of “Rockfish Conservation Areas” (RCAs) that were created to protect overfished rockfish stocks,⁶ spatial closures of additional areas designated as “Essential Fish Habitat Conservation Areas” (PFMC 2005), and stricter trip limits implemented to address concerns about the status of these stocks (PFMC 2016). Discards and discard proportions of the overfished species both declined to historically low levels and again showed much less inter-annual variability after the program was implemented (Figure 1).

Discards of the two groups of non-quota species decreased as well. Both discards and discard rates of non-quota FMP species showed a downward trend prior to catch share implementation and remained at historic lows from 2011 to 2016. The trends for non-FMP species differed: despite similar decreases in discard amounts, the discard proportions remained constant at nearly 100% from 2004 to 2016.

Discards of target species in the bottom trawl fishery

Average annual metric tons retained and discarded, as well as discard proportions, of quota-managed target species that were not under rebuilding plans or declared

Figure 1. Total discard weight (mt, top panel) and proportion of catch discarded for species (bottom panel), grouped by management category, in the bottom trawl fleet of the West Coast federal groundfish trawl fishery. The dotted line represents the implementation of catch share management in 2011.

overfished are shown in Figure 2. These species comprise the greatest proportion of total catch by the fishery. The figure is ordered by average ex-vessel value per pound of each species, with the exception of Dover sole, which is shown on a different scale to reflect its high volume of landings. Discards decreased substantially after the implementation of the catch share program, reflecting the elimination of the incentive to discard constraining species in order to continue fishing under the trip-based limits and similarly, because all catch is debited from quota accounts, the increased incentive to retain rather than discard catch. Discard proportions also decreased for all species. The greatest decreases in the proportion of discarded catch occurred for high-value target species, while decreases were more moderate for low-value fish. Sablefish is by far the most valuable species, with ex-vessel prices averaging \$2.45/lb (inflation-adjusted 2015\$) in 2011–2016.⁷ For comparison, shortspine thornyheads averaged \$0.84/lb, lingcod \$0.83/lb, Dover sole \$0.44/lb, English sole \$0.31/lb, arrowtooth flounder \$0.11/lb, and Pacific hake \$0.10/lb. In the case of several low- and medium-value flatfish, like arrowtooth

Table 1. Year-to-year coefficient of variation (CV) (%) of discards, by species or species groups of quota species not overfished or rebuilding for the pre-catch share period (2004–2010) and catch share period (2011–2016).

Species or species group	CV (%) of discards: 2004–2010	CV (%) of discards: 2011–2016	Difference in CV
Sablefish	215	7	–208
Shortspine thornyhead	67	10	–57
Lingcod	268	23	–244
Chilipepper rockfish (S)	81	64	–17
Minor slope rockfish	359	103	–256
Pacific cod	159	10	–149
Yellowtail rockfish (N)	262	2	–260
Starry flounder	424	15	–409
Dover sole	61	16	–45
Longspine thornyhead	140	15	–125
Other flatfish	285	100	–185
Minor shelf rockfish	508	146	–361
English sole	119	30	–89
Arrowtooth flounder	101	32	–69
Pacific hake	133	17	–116

Table 2. Year-to-year coefficient of variation (CV) (%) of discards, by species or species groups of overfished or rebuilding quota species for the pre-catch share period (2004–2010) and catch share period (2011–2016).

Species or species group	CV (%) of discards: 2004–2010	CV (%) of discards: 2011–2016	Difference in CV
Bocaccio rockfish	118	5	–113
Canary rockfish	162	1	–161
Cowcod rockfish	103	1	–102
Darkblotched rockfish	96	7	–90
Mixed thornyheads	165	6	–158
Pacific ocean perch	142	3	–138
Petrale sole	107	17	–90
Widow rockfish	180	20	–160
Yelloweye rockfish	288	1	–287

flounder and English sole, discard proportions are lower than would be expected based on their value, because they can be processed, marketed, and shipped using similar technology and to similar markets as higher-value species like Dover sole and other flatfish. Pacific hake, on the other hand, has almost no marketable value in the low volumes caught by the bottom trawl fleet and continues to be mostly discarded.

In addition to lower discard amounts and proportions, the interannual variation in discards of all major quota species and species groups is lower after implementation of the catch share program (Table 1). The coefficient of variation of discards of sablefish, the most valuable retained species, declined from 215% in the pre-catch share period to 7% during catch shares. The decline in the coefficient of variation ranges from 17% (chilipepper rockfish (S)) to 409% (starry flounder). Taken together, discard amounts and proportions of quota species are more stable and lower in the catch shares period than before.

Discards of overfished species in the bottom trawl fishery

Discards of overfished and rebuilding species have been a primary concern in this fishery since the early 2000s. Many of the pre-catch share area closures and reductions in trip-based limits were implemented to meet the terms of rebuilding plans. All of the overfished species are now managed using quota, but we expected that their low quotas,

Figure 2. Mean annual retained weight (left panels), discarded weight (middle panels), and proportion discarded (right panels) for non-overfished quota species in the pre-catch shares period (2004–2010) and the catch shares period (2011–2016), in the bottom trawl fleet of the West Coast federal groundfish trawl fishery. Species managed north or south of the 40°10' N. latitude line are delineated with (N) or (S), respectively. Species are sorted from highest to lowest average price-per-pound in the catch shares period. Due to large difference in magnitude of retained catch of Dover sole, that species is shown on separate axes.

the potential difficulty of covering quota overages through the quota market, and the perceived likelihood of a disastrous “lightning strike” could result in different discarding patterns than for other quota species.

The mean annual amount discarded of all eight historically overfished species was considerably lower after catch shares (middle panel of Figure 3). For cowcod and yelloweye rockfish, which have not been declared rebuilt, discards fell to zero. The mean annual proportion discarded decreased dramatically as well, to less than 5% for each species. The change in discard proportion was smallest for petrale sole, which was discarded in very small proportions even before the catch share program and was declared rebuilt in 2015 (right panel of Figure 3).

The interannual variation in discards of all overfished and rebuilding species has declined to extremely low levels (Table 2). The decline in the coefficient of variation ranges from 90 percentage points (darkblotched rockfish and petrale sole) to 287 percentage points (yelloweye rockfish) and is 1% for canary, cowcod, and yelloweye rockfishes.

Discard of non-target species in the bottom trawl fishery

There was no documented discussion or prediction about the potential effect of the catch share program on discards of non-quota FMP species and non-FMP species in

Figure 3. Mean annual retained weight (left panel), discarded weight (middle panel), and proportion discarded (right panel) for species in rebuilding or overfished status at the start of the catch shares program in the pre-catch shares period (2004–2010) and the catch shares period (2011–2016), in the bottom trawl fleet of the West Coast groundfish trawl fishery. Due to the large difference in magnitude of retained catch of petrale sole, that species is shown on separate axes. The year that each species was declared rebuilt is noted in parenthesis.

the groundfish fishery (PFMC and NMFS 2010b). While the catch share program may provide increased flexibility for fishermen to more effectively avoid non-target, non-quota species, it does not include specific incentives to do so. Both groups of species are generally unmarketable or low-value, so harvesters have little reason to retain them. In addition, the non-quota FMP species continue to be managed with trip limits on landings rather than total catch, so no incentive exists to change fishing behavior to avoid impacting non-quota species. However, if a vessel or processor developed a market for these species, targeting and retention of non-quota and non-FMP species could increase while discards decrease. The lack of associated quota and thus lower marginal cost of landing these species compared to those managed using quota could make this catch economically viable (Asche et al. 2007; Hutniczak 2014).

Retention of both non-quota FMP and non-FMP species remained the same before and after catch share implementation (left panel of Figure 4). For both groups, average discards declined (middle panel of Figure 4). For non-quota FMP species, the decline in the amount discarded led to an approximately 40% decrease in the mean annual proportion discarded (right panel of Figure 4). Non-FMP species are retained at extremely low volumes, so while discard amounts decreased, the mean annual proportion discarded remained the same at nearly 100%. Further, the decline in total landings (Appendix Table A-1) does not explain decreased discards of non-quota FMP and non-FMP species groups, because the rate at which non-FMP species were discarded compared to landings of FMP species decreased by almost half, from 0.057 mt of non-FMP species discard for every 1 mt of FMP species retained to 0.032 mt. The year-to-year coefficient of variation decreased from 392 to 115% for non-quota FMP species, and from 857 to 277% for non-FMP species. Taken together, the changes in catch and

Figure 4. Mean annual retained weight (left panel), discarded weight (middle panel), and proportion discarded (right panel) for non-quota FMP and non-FMP species in the pre-catch shares period (2004–2010) and the catch shares period (2011–2016).

discard of non-quota FMP and non-FMP species suggest that fishermen are more effectively avoiding these species after catch share implementation, and there is no evidence that these decreases are due to non-quota species being increasingly targeted.

Conclusions

Prior to the catch share program in the West Coast groundfish trawl fishery, bottom trawl fishermen discarded an estimated 30% of total catch annually. This research documents a general decline in discard amounts and proportions from 2004 to 2010, with a particularly large decrease after the implementation of the West Coast Groundfish Trawl Catch Share Program in 2011. Further, the variation in discards declined for every major group of target species and for quota, non-quota, and non-FMP species overall. Prior to 2011, fishermen had an incentive to discard anything that was constraining under the trip limit system, leading to high levels of discard of both non-target and target species, including those under rebuilding plans. Overfished species had extremely small trip limits and in some cases were prohibited from being landed, resulting in high rates of discard when caught. Harvesters also had the incentive to discard low-value species in favor of higher value catch to maximize hold space. After the implementation of the catch share program, discards of overfished species and valuable target species have fallen to and remain at historic lows. Discards are now primarily low-value and unmarketable species.

The catch share program was designed to provide fishermen the flexibility to change their fishing patterns and remove the incentives to discard by aligning the costs of discarding with benefits of landing target species for individual vessels. This was achieved by full catch accounting, tradeable quotas, increased flexibility in fishing, and penalties for catch overages that cannot be covered with quota. Institutions have developed around avoiding bycatch; risk pools and cooperatives were initially formed to provide fishermen access to overfished species quota, but in return, members followed specific rules to avoid encountering overfished species (Holland and Jannot 2012). Fishermen have reduced fishing activity at night and stayed farther from the edges of RCAs to further decrease catch of these species (Miller and Deacon 2017). Harvesters are also developing and experimenting with a variety of gear modifications to more effectively reduce bycatch and target specific species, although the efficacy of these efforts is not yet clear. NOAA Fisheries, in collaboration with the fishing industry, is testing a variety of bycatch reduction devices, cod-end mesh sizes and configurations, and trawl designs to enhance trawl selectivity and catch utilization (Lomeli, Wakefield, and Herrmann 2017; Lomeli et al. 2017; Lomeli and Wakefield 2016). NOAA Fisheries researchers have noted a marked increase in communication with fishermen interested in net design innovations and bycatch reduction devices; harvesters have

stated that the catch share program has made it worth their time, money, and effort to invest in bycatch-reducing technology (Wakefield, pers. comm.).

This innovation in the fleet was expected to reduce discards of quota species, but can also help explain the unanticipated decrease observed in the discard amounts and proportions of non-quota FMP and non-FMP species. This result suggests that fishermen were able to control their catch composition, which unexpectedly resulted in the reduction of untargeted and unwanted non-quota FMP and non-FMP species in their tows. This may have implications for management of the larger ecosystem. The reduction in discards and potential for increased targeting efficiency likely varies by species within these broad groups, and the need for continued monitoring of all species remains.

These management and behavioral changes have resulted in decreased variability for discards of all species and species groups in the bottom trawl sector of the West Coast groundfish fishery, which will ultimately improve managers' ability to support a sustainable and profitable fishery. Increased precision of discard rates and amounts within stock assessment models leads to forecasts that are more accurate and decrease overall scientific uncertainty. The increased predictability of future fishing behavior, exploitation rates, discarding behavior, and catches into the future will improve stability in management models. The West Coast Groundfish Trawl Catch Share Program has achieved its goals of implementing a program that creates individual accountability for catch and bycatch and promoting practices that reduce bycatch and discard mortality and has created a system where scientists, managers, and harvesters can work together to support sustainability in this fishery.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. <https://www.fisheries.noaa.gov/national/funding-and-financial-services/fishery-disaster-determinations#numbers-53-16-2010-2000>
2. <https://www.nwfsc.noaa.gov/data/>
3. More information available at: https://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/bottom_trawl.cfm
4. Less than 1% of annual landings were not observed, usually due to observer illness.
5. More information available at: https://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/bottom_trawl.cfm
6. http://www.westcoast.fisheries.noaa.gov/fisheries/management/groundfish_closures/rockfish_areas.html, accessed 12/21/2017.
7. The gear switching provision has been used to target sablefish; about 37 percent of the sablefish catch in the West Coast Groundfish Trawl Catch Share Program was caught with fixed gear which contributed to the decline in mean annual sablefish retained (left panel of Figure 2, which shows only bottom trawl catch). The discard rate for fixed-gear caught sablefish in the catch share fishery is 0.02, which is essentially equivalent to the discard rate of trawl-caught sablefish (0.01).

References

- Abbott, J. K., A. C. Haynie, and M. N. Reimer. 2015. Hidden flexibility: Institutions, incentives, and the margins of selectivity in fishing. *Land Economics* 91 (1):169–95. doi:10.3368/le.91.1.169.

- Anderson, L. G. 1994. An economic analysis of highgrading in ITQ fisheries regulation programs. *Marine Resource Economics* 9 (3):209–26. doi:[10.1086/mre.9.3.42629081](https://doi.org/10.1086/mre.9.3.42629081).
- Arnason, R. 1994. On catch discarding in fisheries. *Marine Resource Economics* 9 (3):189–207. doi: [10.1086/mre.9.3.42629080](https://doi.org/10.1086/mre.9.3.42629080).
- Asche, F., D. V. Gordon, C. L. Jensen, S. Ussif Rashid, G. R. Munro, and J. G. Sutinen. 2007. Individual vessel quotas and increased fishing pressure on unregulated species. *Land Economics* 83 (1):41–9. doi:[10.3368/le.83.1.41](https://doi.org/10.3368/le.83.1.41).
- Bellman, M. A., and E. Heery. 2013. Discarding and fishing mortality trends in the U.S. West Coast groundfish demersal trawl fishery. *Fisheries Research* 147:115–26. doi:[10.1016/j.fishres.2013.04.007](https://doi.org/10.1016/j.fishres.2013.04.007).
- Boyd, R. O., and C. M. Dewees. 1992. Putting theory into practice: Individual transferable quotas in New Zealand's fisheries. *Society & Natural Resources* 5(2):179–98. doi:[10.1080/08941929209380785](https://doi.org/10.1080/08941929209380785).
- Branch, T. A., and R. Hilborn. 2008. Matching catches to quotas in a multispecies trawl fishery: Targeting and avoidance behavior under individual transferable quotas. *Canadian Journal of Fisheries and Aquatic Sciences* 65 (7):1435–46. doi:[10.1139/F08-065](https://doi.org/10.1139/F08-065).
- Branch, T. A., K. Rutherford, and R. Hilborn. 2006. Replacing trip limits with individual transferable quotas: Implications for discarding. *Marine Policy* 30 (3):281–92. doi:[10.1016/j.marpol.2004.12.003](https://doi.org/10.1016/j.marpol.2004.12.003).
- Bundy, A., R. Chuenpagdee, J. L. Boldt, M. de Fatima Borges, M. L. Camara, M. Coll, I. Diallo, and et al., 2017. Strong fisheries management and governance positively impact ecosystem status. *Fish and Fisheries* 18 (3):412–39. doi:[10.1111/faf.12184](https://doi.org/10.1111/faf.12184).
- Copes, P. 1986. A critical review of the individual quota as a device in fisheries management. *Land Economics* 62 (3):278–91. doi:[10.2307/3146392](https://doi.org/10.2307/3146392)
- Edwards, A. M., I. Taylor, C. J. Grandin, and A. M. Berger. 2018. Status of the Pacific Hake (Whiting) Stock in U.S. and Canadian Waters in 2018. Joint Technical Committee of the U.S. and Canada Pacific Hake/Whiting Agreement, National Marine Fisheries Service and Fisheries and Oceans Canada.
- Essington, T. E. 2010. Ecological indicators display reduced variation in North American catch share fisheries. *Proceedings of the National Academy of Sciences* 107 (2):754–59. doi:[10.1073/pnas.0907252107](https://doi.org/10.1073/pnas.0907252107).
- Fina, M. 2011. Evolution of catch share management: Lessons from Catch Share Management in the North Pacific. *Fisheries* 36 (4):164–77. doi:[10.1080/03632415.2011.564509](https://doi.org/10.1080/03632415.2011.564509)
- Grimm, D., I. Barkhorn, D. Festa, K. Bonzon, J. Boomhower, V. Hovland, and J. Blau. 2012. Assessing catch shares' effects evidence from federal United States and associated British Columbian fisheries. *Marine Policy* 36(3):644–57. doi:[10.1016/j.marpol.2011.10.014](https://doi.org/10.1016/j.marpol.2011.10.014).
- Gustafson, R., Y. W. Lee, E. Ward, K. A. Somers, V. Tuttle, J. E. Jannot, and J. McVeigh. 2017. Observed and estimated bycatch of eulachon in 2002–2015 US West Coast Groundfish Fisheries. Seattle, WA: Northwest Fisheries Science Center. http://www.pcouncil.org/wp-content/uploads/2017/03/F5a_NMFS_Rpt4_ElectricOnly_Eulachon_bycatch_rpt_2017_Apr2017BB.pdf.
- He, X., and J. C. Field. 2017. *Status of Bocaccio, Sebastes paucispinis, in the Conception, Monterey and Eureka INPFC areas for 2015*. Portland, OR: Pacific Fishery Management Council.
- He, X., D. E. Pearson, E. J. Dick, J. C. Field, R. Stephen, and A. D. MacCall. 2011. *Status of the Widow Rockfish Resource in 2011*. Portland, OR: Pacific Fishery Management Council.
- Holland, D. S. 2010. Markets, pooling and insurance for managing bycatch in fisheries. *Ecological Economics* 70 (1):121–33. doi:[10.1016/j.ecolecon.2010.08.015](https://doi.org/10.1016/j.ecolecon.2010.08.015).
- Holland, D. S. 2016. Development of the Pacific groundfish trawl IFQ market. *Marine Resources Economics* 31 (4):453. doi: [10.1086/687829](https://doi.org/10.1086/687829)
- Holland, D. S., and J. E. Jannot. 2012. Bycatch risk pools for the US West Coast groundfish fishery. *Ecological Economics* 78:132–47. doi:[10.1016/j.ecolecon.2012.04.010](https://doi.org/10.1016/j.ecolecon.2012.04.010).
- Hutniczak, B. 2014. Increasing pressure on unregulated species due to changes in individual vessel quotas: An empirical application to trawler fishing in the Baltic Sea. *Marine Resource Economics* 29 (3):201–17. doi:[10.1086/677760](https://doi.org/10.1086/677760).

- Jannot, J. E., K. A. Somers, N. Riley, V. Tuttle, and J. McVeigh. 2017. Pacific Halibut Bycatch in the U.S. West Coast Fisheries (2002–2016). Seattle, WA: NOAA Fisheries, NWFSC Observer Program. https://www.nwfsc.noaa.gov/research/divisions/fram/observation/pdf/PacificHalibutBycatch2002_16_Sept2017_accessible.pdf.
- Jenkins, L. D., and K. Garrison. 2013. Fishing gear substitution to reduce bycatch and habitat impacts: An example of social–ecological research to inform policy. *Marine Policy* 38:293–303. doi:10.1016/j.marpol.2012.06.005.
- Kelleher, K. 2005. “Discards in the World’s Marine Fisheries – An Update.” No. 470. FAO Fisheries Technical Paper. <http://www.fao.org/docrep/008/y5936e/y5936e00.htm>.
- Kuriyama, P. T., T. A. Branch, M. A. Bellman, and K. Rutherford. 2016. Catch shares have not led to Catch-Quota balancing in two North American multispecies trawl fisheries. *Marine Policy* 71:60–70. doi:10.1016/j.marpol.2016.05.010.
- Lee, Y. W., R. Gustafson, E. J. Jason, J. McVeigh, N. Riley, A. S. Kayleigh, V. Turtle, S. Wang, and E. Ward. 2017. *Observed and estimated bycatch of green sturgeon in 2002–2015 US West Coast Groundfish Fisheries*. Seattle, WA: NOAA Fisheries, NWFSC Observer Program. http://www.pcouncil.org/wp-content/uploads/2017/03/F5a_NMFS_Rpt5_ElectricOnly_Green_Sturgeon_Bycatch_rpt_2017_Apr2017BB.pdf.
- Lomeli, M. J. M., O. S. Hamel, W. W. Wakefield, and D. L. Erickson. 2017. Improving catch utilization in the U.S. West Coast groundfish bottom trawl fishery: An evaluation of T90-mesh and diamond-mesh cod ends. *Marine and Coastal Fisheries* 9(1):149–60. doi:10.1080/19425120.2016.1274697.
- Lomeli, M. J. M., and W. W. Wakefield. 2016. Evaluation of a sorting grid bycatch reduction device for the selective flatfish bottom trawl in the U.S. West Coast fishery. *Fisheries Research* 183:294–303. doi:10.1016/j.fishres.2016.06.011.
- Lomeli, M. J. M., W. W. Wakefield, and B. Herrmann. 2017. Testing of two selective flatfish Sorting-Grid bycatch reduction devices in the U.S. West Coast groundfish bottom trawl fishery. *Marine and Coastal Fisheries* 9(1):597–611. doi:10.1080/19425120.2017.1388888.
- Melnychuk, M. C., E. Peterson, M. Elliott, and R. Hilborn. 2017. Fisheries management impacts on target species status. *Proceedings of the National Academy of Sciences* 114 (1):178–83. doi:10.1073/pnas.1609915114.
- Miller, S. J., and R. T. Deacon. 2017. Protecting marine ecosystems: Regulation versus market incentives. *Marine Resource Economics* 32 (1):83–107. doi:10.1086/689214.
- NMFS. 2016. National bycatch reduction strategy. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. www.fisheries.noaa.gov/sfa/bycatch.
- NWFSC. 2017. 2018 Training manual. Northwest Fisheries Science Center West Coast Groundfish Observer Program. https://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_collection/manuals/2018%20WCGOP%20Training%20Manual%20Final3.pdf.
- PFMC. 2005. Amendment 18 (Bycatch Mitigation Program) Amendment 19 (Essential Fishing Habitat) to the Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington Groundfish Fishery. <https://www.pcouncil.org/wp-content/uploads/A18-19Final.pdf>.
- PFMC. 2016. Status of the Pacific Coast Groundfish Fishery Stock Assessment and Fishery Evaluation. Portland, OR: Pacific Fishery Management Council. http://www.pcouncil.org/wp-content/uploads/2017/02/SAFE_Dec2016_02_28_2017.pdf.
- PFMC and NMFS. 2010a. Groundfish fishery management plan amendment 20 (trawl rationalization). Pacific Fisheries Management Council and National Marine Fisheries Service.
- PFMC and NMFS. 2010b. Rationalization of the Pacific Coast Groundfish Limited Entry Trawl Fishery; Final Environmental Impact Statement Including Regulatory Impact Review and Initial Regulatory Flexibility Analysis. Portland, OR: PFMC. http://www.pcouncil.org/wp-content/uploads/1_Pacific-Coast-Groundfish-Limited-Entry-Trawl-Fishery-FEIS.pdf.
- PFMC. 2017. West coast groundfish trawl catch share program five-year review. Portland, OR: Pacific Fishery Management Council and National Marine Fisheries Service. <https://www.pcouncil.org/groundfish/fishery-management-plan/trailing-actions/public-review-draft-of-the-groundfish-trawl-catch-share-program-five-year-review/>.

- Poos, J. J., J. A. Bogaards, F. J. Quirijns, D. M. Gillis, and A. D. Rijnsdorp. 2010. Individual quotas, fishing effort allocation, and over-quota discarding in mixed fisheries. *ICES Journal of Marine Science* 67 (2):323–33. doi:[10.1093/icesjms/fsp241](https://doi.org/10.1093/icesjms/fsp241).
- Sanchirico, J. N., D. S. Holland, K. Quigley, and M. Fina. 2006. Catch-quota balancing in multi-species individual fishing quotas. *Marine Policy* 30 (6):767–85. doi:[10.1016/j.marpol.2006.02.002](https://doi.org/10.1016/j.marpol.2006.02.002).
- Singh, R., and Q. Weninger. 2015. Harvest efficiency and fishery discards under harvest uncertainty and trading restrictions. *Journal of Environmental Economics and Management* 70 :72–91. doi:[10.1016/j.jeem.2014.11.001](https://doi.org/10.1016/j.jeem.2014.11.001).
- Somers, K. A., A. B. Marlene, J. E. Jannot, Y. Woo Lee, M. Jon, and T. Vanessa. 2014. Observed and estimated total bycatch of salmon in the 2002–2013 U. S. West Coast Fisheries. Seattle, WA: West Coast Groundfish Observer Program, National Marine Fisheries Service, NWFSC https://www.nwfsc.noaa.gov/research/divisions/fram/observation/pdf/Salmon_Bycatch_Report_2002-2013.pdf.
- Somers, K. A., J. E. Jannot, N. Riley, V. Tuttle, and J. McVeigh. 2017a. Groundfish expanded mortality multiyear (GEMM). https://www.nwfsc.noaa.gov/data/metadata/observer.gemm_fact.
- Somers, K. A., J. E. Jannot, V. Tuttle, and J. McVeigh. 2017c. FOS coverage rates, 2002–2016. NOAA Fisheries, NWFSC Observer Program. http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/sector_products.cfm#ob.
- Somers, K. A., J. E. Jannot, V. Tuttle, N. Riley, and J. McVeigh. 2017b. *Estimated discard and catch of groundfish species in the 2016 US West Coast fisheries*. 2725 Montlake blvd E. Seattle, WA 98112: NWFSC Observer Program, NOAA Fisheries. https://www.nwfsc.noaa.gov/research/divisions/fram/observation/pdf/Groundfish_Mortality_2016.pdf.
- Squires, D., H. Campbell, S. Cunningham, C. Dewees, R. Q. Grafton, S. F. Herrick, and J. Kirkley, S. et al. 1998. Individual transferable quotas in multispecies fisheries. *Marine Policy* 22 (2):135–59. doi:[10.1016/S0308-597X\(97\)00039-0](https://doi.org/10.1016/S0308-597X(97)00039-0).
- Squires, D., and J. Kirkley. 1991. Production quota in multiproduct pacific fisheries. *Journal of Environmental Economics and Management* 21 (2):109–26. doi: [10.1016/0095-0696\(91\)90036-I](https://doi.org/10.1016/0095-0696(91)90036-I)
- Stawitz, C. C., F. Hurtado-Ferro, P. Kuriyama, J. Trochta, F. J. Kelli, A. H. Melissa, and S. H. Owen. 2015. *Stock assessment update: Status of the U. S. Petrale sole resource in 2014*. Portland, OR: Pacific Fishery Management Council.
- Thorson, J. T., and C. Wetzel. 2016. *The status of canary rockfish (Sebastes pinniger) in the California current in 2015*. Portland, OR: Pacific Fishery Management Council.
- Wallace, J. R., and V. Gertseva. 2017. *Status of the darkblotched rockfish resource off the continental U.S. Pacific Coast in 2017 (update of 2015 assessment model)*. Portland, OR: Pacific Fishery Management Council.
- Wetzel, C., L. Cronin-Fine, and F. J. Kelli. 2017. *Status of Pacific ocean perch (Sebastes alutus) along the US West Coast in 2017*. Portland, OR: Pacific Fishery Management Council.