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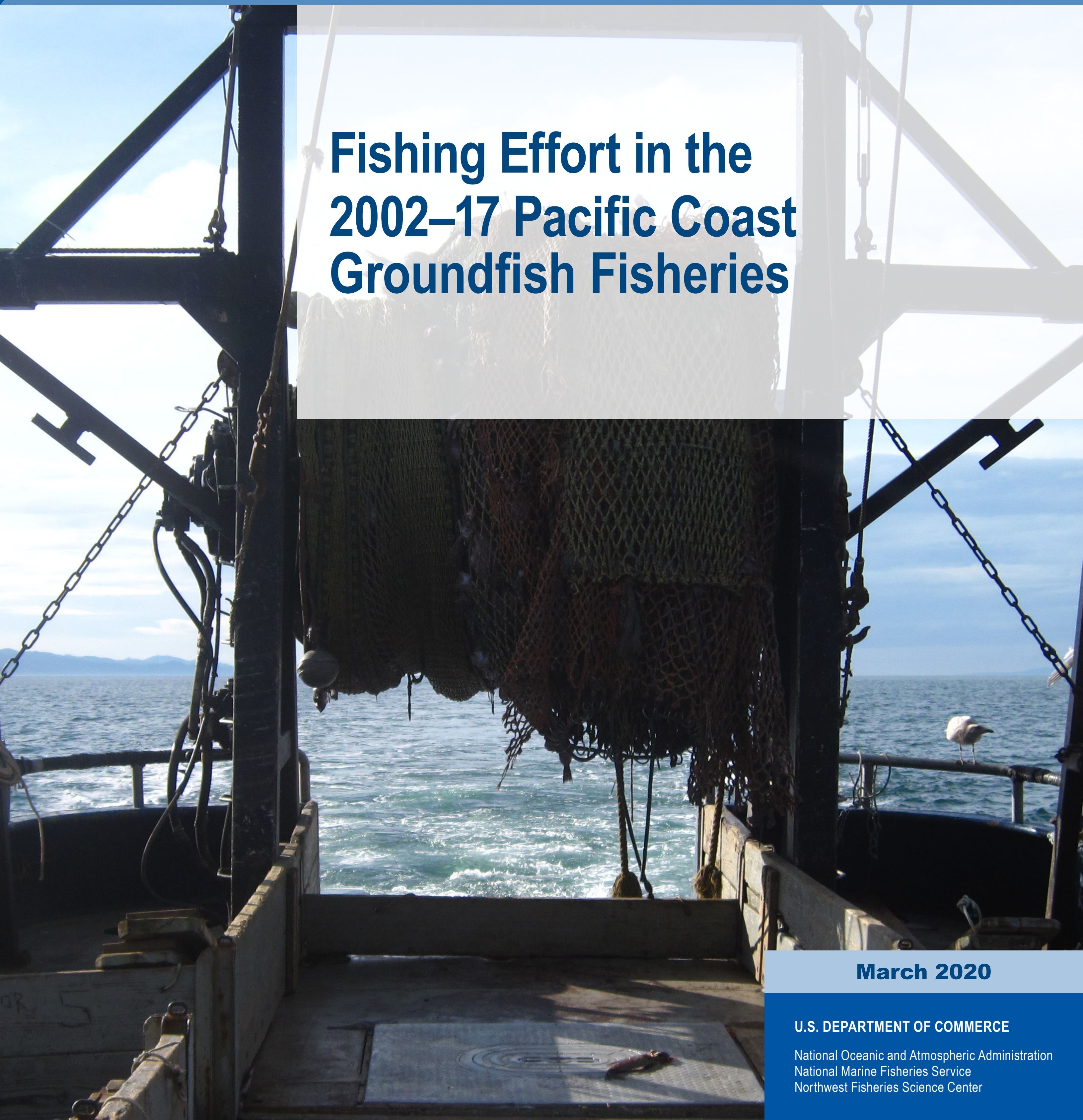

Fishing Effort in the 2002–17 Pacific Coast Groundfish Fisheries

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Cover image: Trawl gantry in the lower Columbia River, March 2011. Photograph by A. Phillips, WCGOP observer, NMFS/NWFSC.

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Fishing Effort in the 2002–17 Pacific Coast Groundfish Fisheries

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[1] https://repository.library.noaa.gov

Executive Summary

This report analyzes trends in fishing effort in the U.S. West Coast groundfish fisheries for the period 2002–17. We describe changes in the amount, timing, location, and depth of fishing effort by analyzing landed weight of targeted species, number of hauls, and tow duration or fixed gear units. We focus on changes that have occurred since the 2011 implementation of an individual fishing quota (IFQ) program. The 2012 NMFS Biological Opinion requires that we update these reports every two years, so we especially analyze developments from the two most recent years of data, 2016 and 2017, to provide context to the bycatch amounts and patterns reported in other Biological Opinion documents.

Bottom trawl effort, measured as tow hours, continued to decrease from 2015 through 2017, but landings increased and, when accounting for groundfish retained by other gears fishing bottom trawl quota, reached ~27,000 mt in 2017, the greatest since at least 2002. Median haul duration stabilized in 2016–17 at around 3.2 hours. The spatial distribution of landings and fishing effort in 2016–17 was similar to that of 2011–15, with landings at lat 46°N, near Astoria, Oregon, remaining high, and fishing activity continuing to concentrate off the northern coast and in deeper waters than in 2002–10. Temporal patterns of landings were consistent between 2011–15 and 2016–17; in both time periods they occurred evenly across bimonthly periods other than March/April, when a greater proportion was landed.

The catch share (CS) midwater rockfish trawl fleet has continued to grow as quota for yellowtail and widow rockfish increases. Landings and effort grew in 2016 and 2017, and median haul duration remained around 1–1.5 hours. The majority of landings and fishing activity continued to occur in Oregon. Landings were greater in the later months of the year throughout 2011 to 2017, but were more consistent across months in 2016–17 than in 2011–15. Effort continued to occur primarily in 50 to 150 fth depths, with deeper tows almost nonexistent after 2015.

The CS shoreside (SS) midwater hake trawl fishery in 2016–17 showed high variability in landings and effort metrics, similar to 2011–15. In 2017, both landings and effort by the shoreside fleet were the highest since at least 2002 and were greater than in either at-sea sector. Haul duration decreased in variability and magnitude from 2015 to 2017. In 2016–17, the majority of landings continued to occur in the 46°N latitudinal bin, but effort was more evenly distributed along the northern part of the coast. The seasonal nature of the fleet continued, with the majority of landings occurring in July/August. In 2016–17, effort was concentrated in depths between 50 and 250 fth.

Catch share at-sea catcher–processors (CPs) and mothership catcher vessels (MSCVs) had highly variable landings, reflecting annual changes in quota. The CP subsector showed a mostly increasing trend in both fleetwide landings and fishing effort from 2002 to 2017, while the MSCV sector showed more stability in both metrics. In 2016 and 2017, landings were greater than since at least 2002. Haul duration in both sectors has generally increased and was similar across CPs and MSCVs in most years. In 2016–17, CPs focused fishing effort in the southern part of their range, while fishing effort by MSCVs intensified in the northern part of the coast. During this time period, both sectors also moved farther seaward than observed since at least 2002. In both 2011–15 and 2016–17, the CP and MSCV portions of the fleet fished primarily in May/June and September/October, with almost no catch in July/August. Nearly all midwater at-sea hauls occurred in depths between 50 and 250 fth (Table 4, Figure 24).

CS and non-catch share (NCS) pot fleet sablefish landings have mostly increased through 2017, after declining from 2011 to 2013. CS pot vessels as a whole continued to land more sablefish than the NCS fleet, with that difference increasing from 2013 to 2017. Fleetwide pots used by both the CS and NCS fleets increased from 2013 to 2017, and the number of pots per set was highly variable, with the median number ranging from 16 to 49 across all years. Landings by the NCS pot fleet occurred primarily between lats 39–46°N in both 2011–15 and 2016–17, while CS pot landings shifted northward in 2016–17. CS pot effort became more concentrated in 2016–17 and was most intense between lats 44–47° N and around lat 36°N. Fishing effort in the NCS and CS pot fleets occurred primarily in depths between 0 and 750 fth, with bimodal peaks likely reflecting the depths of shelf and slope fishing.

Sablefish landings by the NCS hook-and-line (H&L) fleet increased from a nearly historic low in 2014, while CS H&L landings were extremely variable. Fleetwide, NCS hooks increased slightly from 2015 to 2017, while CS hooks decreased slightly from 2011 to 2017. The median number of hooks per set in the NCS fleet has increased to ~2,500 hooks per set, while CS has stabilized at ~3,200 hooks since 2015. Landings by the NCS H&L fleet were more uniform along the coast in 2016–17 than in 2002–10 or 2011–15, and spatial patterns in fishing intensity were similar across all three time periods. The CS H&L fleet landed nearly all catch in two locations: more than 70% of catch near Astoria, and ~20% around lat 44°N. Effort by the CS fleet largely overlapped the range of observed NCS fishing activity in the northern portion of the coast, while in the south, CS effort occurred where minimal or no NCS effort had been observed. Landings by the NCS H&L fleet were less variable throughout the year in 2016–17 than in previous time periods, but continued to peak in September/October. Landings by the CS fleet were also typically highest in September/October, but were much more variable than the NCS fleets. Both the NCS and CS H&L fleets fish in waters ranging from 0 to 700 fth depths. NCS H&L hauls were more common in deeper waters in the 2011–15 time period than in the earlier time periods; this trend partially reversed in 2016–17. In 2016–17, most effort by the CS fleet occurred in depths of 150–300 fth, with additional, evenly distributed effort at 300–600 fth.

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The authors are grateful to the many At-Sea Hake Observer Program and West Coast Groundfish Observer Program observers who work hard under sometimes extreme conditions to collect these valuable data. The authors would also like to thank members of the Groundfish Endangered Species Work Group for helpful feedback and suggestions. Additionally, the authors are very appreciative of extensive reviews provided by both Erin Steiner (Northwest Fisheries Science Center) and Lewis Barnett (Alaska Fisheries Science Center), whose comments greatly improved this report.

Introduction

The Pacific Fishery Management Council (PFMC) designs and adapts the groundfish Fishery Management Plan (FMP) with the goals of achieving maximum sustainable yield (MSY) and promoting year-round fishing opportunities to support domestic consumer markets and the economies of coastal communities. In 2011, PFMC implemented a major management shift by introducing a catch share program to the federal trawl fleets. This report assesses changes in the Pacific Coast groundfish fisheries, with an emphasis on differences before and after catch share implementation, and is mandated by the National Marine Fisheries Service (NMFS) Biological Opinion on the continuing operation of the Pacific Coast groundfish fishery (NMFS 2012). Because this and other associated reports are required to be completed every two years, we focus this analysis on the trends that have occurred in the most recent data set. We are cautious in definitively attributing differences to the implementation of individual fishing quotas (IFQs), because many other factors, including variations in weather, market price, stock size, quota leasing, and catch limits, are at play in the 16-year data set. Additionally, many management shifts and changes occurred prior to IFQ implementation, and provide important background and context in understanding and analyzing current fleet dynamics.

In the shoreside bottom trawl fleet, the number of commercial vessels participating was first limited in 1994, with the implementation of a federal licensing program. At that point, the fishery was already overcapitalized, and, rather than allow trawl seasons to shorten, the effort expended by individual vessels was constrained through a system of periodic (usually 1- or 2-month) cumulative landing limits. Beginning in the late 1990s, it became apparent that several species were depleted and in need of rebuilding. The severity and scope of management actions required to promote rebuilding led the Department of Commerce to declare the fishery a disaster in 2000, making it eligible for federal relief. Allocations for rebuilding species were reduced by more than 90% from levels of the 1990s, resulting in the need for development and implementation of new management approaches to ensure fishing opportunities for healthy stocks throughout the year.

One of the first new developments was the introduction of explicit modeling of fleet catch and bycatch in order to evaluate the effects of management alternatives. To collect the needed data, the West Coast Groundfish Observer Program (WCGOP) began to place trained scientists aboard fishing vessels operating in sectors that target and incidentally catch groundfish off the U.S. West Coast. From 2002–10, WCGOP observed 20–30% of bottom trawl landings using a random stratified sampling design, providing critical information that supported reliable fishery modeling and estimation of fishing mortality, especially for rebuilding species.

Using this new dataset and refined modeling tools, scientists and managers found that coastwide bycatch rates for rebuilding species were too high to support year-round fishing of target species. One response to this situation was the designation of closed areas. By preventing fishing from occurring in many of the areas where bycatch of rebuilding species was highest, average fleet bycatch rates could be lowered. Some closures, such as the cowcod and yelloweye rockfish conservation areas, had fixed boundaries, while the rockfish conservation area (RCA) combined fixed, minimum boundaries (for example, lines approximating the 100- and 150-fth contours) with the ability to extend the closed area shoreward or seaward. Cumulative limits for target species were frequently set differently for areas shoreward and seaward of the RCA, with limitations on fishing in both areas during the same cumulative period. To ensure that fishing did not occur in closed areas, all trawl vessels were required to install an approved vessel monitoring system (VMS). This requirement was later extended to cover other sectors of the groundfish fleet. On 12 June 2006, Amendment 19 to the FMP closed additional areas to bottom trawl fishing, and other areas to all bottom contact gears, in order to protect groundfish essential fish habitat (EFH).

In addition to area closures, gear restrictions were also implemented. Throughout the 1980s and 1990s, bottom trawl fishing on the continental shelf was characterized by two very different strategies. The targeting of flatfish was conducted over flat gravel or mud substrate, using nets with footropes whose bobbins were typically less than 12.7 cm in diameter, to minimize fish escaping under the footrope (PFMC 2000, Rogers and Pikitch 1992). The other strategy targeted rockfish, or a mix of rockfish and flatfish, using much larger footropes, including some that employed commercial truck tires to allow fishing in very rocky substrate. Concurrent with the implementation of the RCA, all bottom trawl fishing shoreward of the RCA was required to use footropes no larger than 20.32 cm in diameter and to restrict chafing gear, which protects the underside of the net but can damage habitat. Combined with the low landing limits provided for all shelf rockfish, these restrictions removed economic incentive for vessels to trawl in rocky shelf habitats that could cause expensive damage to trawl gear. Subsequently, based on fishery testing of innovative gear designs, a new, more selective flatfish trawl net was required in waters shoreward of the RCA and north of lat 40°10′N. This design featured a headrope that was longer than the footrope, which increased selectivity by exploiting the behavior of many rockfish to swim upwards and escape the net in response to encountering the footrope.

At the dawn of this fishery transformation in 2000, the economic subcommittee of PFMC's Scientific and Statistical Committee released a report on overcapitalization in the groundfish fleet; this report concluded that shore-based trawl capacity was 2–4 times the amount needed to harvest the available resource. With the help of NMFS analysis, the trawl industry developed its own proposal to reduce capacity and saw it enacted by the United States Congress. A buyback of trawl permits, along with the crab and shrimp permits of participating vessels, was initiated in late 2003 and permanently removed 91 vessels and 239 groundfish, crab, and shrimp permits from the fishery. The buyback was funded through both a grant from the federal government and a government-guaranteed loan, which is repaid by the fleet through landings fees.

Around the same time, PFMC adopted a control date of 6 November 2003 to serve as a cutoff for landings histories to qualify for initial allocation of fishing privileges under a new form of management: individual quotas. In 2011, the prior management regime of landing limits for trawl vessels was replaced by a catch share (CS) program. The goal of the program, as defined in Amendment 20 of the FMP, is to:

> Create and implement a capacity rationalization plan that increases net economic benefits, creates individual economic stability, provides for full utilization of the trawl sector allocation, considers environmental impacts, and achieves individual accountability of catch and bycatch.

The program's objectives include promoting a viable, profitable, and efficient groundfish fishery that provides participants with increased operational flexibility and safety, while promoting practices that reduce bycatch and discard mortality while minimizing ecological impacts. To accomplish these goals, shares of overall trawl sector allocations of numerous species were distributed to trawl permit owners based on catch history. Each year, share percentages are converted to poundage amounts that limit their catch of those species. Transfers of quota pounds (and, more recently, the quota shares themselves) are allowed, but subject to accumulation restrictions. To provide full accounting of catch against these quotas, each vessel is now required to be monitored on all trips, either via a federal observer or, starting in 2015, via electronic monitoring (EM).

IFQ management has altered three major aspects of the shoreside trawl fishery. First, accountability for discards has shifted from the fleet as a whole to individual operations, resulting in a rapid and substantial reduction in discards of most species. Second, the elimination of artificially low landing limits has provided new opportunities for individual operations to target healthy stocks, while the IFQ program creates incentives for individuals to avoid catching species that are overfished or rebuilding and ensures that the fleet remains under species catch limits. Over time, trading and selling shares should provide another means of addressing remaining excess capacity in this fishery. Third, the regulations that implemented the IFQ program allowed for gear switching, which occurs when permit holders with quota pounds and a trawl endorsement can use multiple gear types (although not within the same trip), including trawl (bottom and midwater) and fixed gear (pot and hook-and-line [H&L]). These management changes could impact fishing effort in bottom trawl and shoreside midwater sectors, as well as alter fixed gear fishing effort by providing a new opportunity for fixed gear fishing activity and potential competition between IFQ and other fixed gear sectors. Throughout this report, we aggregate the limited entry (LE) sablefish primary, open access (OA), and daily trip limit sectors into a single non-catch share (NCS) fixed gear fleet. These fisheries are similar to the catch share fixed gear fishery and, thus, likely to be impacted by catch share implementation. We include them here both as a reference against which to compare the IFQ fixed gear fleet, and for a broader understanding of catch share impacts to the groundfish fleet as a whole.

The at-sea midwater trawl fishery was observed by the North Pacific Groundfish Observer Program from 1975 until 2001, when the At-Sea Hake Observer Program (A-SHOP) began to manage observer coverage. Under both organizations, observer coverage onboard motherships (MS) and catcher–processors (CPs) was at or near 100% of fishing days prior to IFQ implementation. However, coverage was not required on catcher vessels delivering to MS until catch share management began. To achieve PFMC goals, the fishery changed primarily by developing cooperatives. The CPs had already done so before the implementation of catch share management, and the mothership catcher vessels (MSCVs) now did so in response to the new management. The shift to catch sharing had ramifications on quota management and bycatch accountability, but potentially very little effect on fishing effort due to the minor changes in monitoring and overall fishery management. The cooperative system somewhat relieved the race to fish, but the primary driver for change in amount of fishing effort for the at-sea hake fishery has been highly variable allocations over the last 16 years.

With this background in mind, we present trends in fishing effort in selected U.S. West Coast groundfish fishery sectors from 2002–17. The primary objective of this report is to evaluate changes in fishing effort over time by gear type since implementation of the IFQ management program in the U.S. West Coast groundfish fishery. This report updates the previous release (2002–15) and analyzes two additional years of data, 2016 and 2017, which sometimes results in comparing a time period of two years of data with sets of four or five years; we note potential issues of doing so where appropriate. We analyze fishing effort in the following sectors of the U.S. West Coast groundfish fisheries:

- Bottom trawl:
    - **LE bottom trawl:** Limited entry bottom trawl (2002–10).
    - **CS bottom trawl:** IFQ nonhake bottom trawl (2011–17).
- Shoreside midwater (MW) trawl:
    - **CS MW Rockfish Trawl:** IFQ shoreside midwater trawl targeting rockfish (2011–17).
    - **CS SS MW Hake Trawl:** IFQ shoreside midwater trawl targeting hake (2011–17).
- At-sea midwater trawl:
    - **CS AS CPs:** At-sea midwater trawl targeting hake, utilizing CPs (2002–17).
    - **CS AS MSCV:** At-sea midwater trawl targeting hake, utilizing motherships (2002–17).
- Fixed gear:
    - **CS Pot:** IFQ pot (2011–17).
    - **CS H&L:** IFQ H&L (2011–17).
    - **NCS Pot:** Pot gear fished in NCS, aggregating sablefish LE fixed gear primary (tier endorsed), OA fixed gear, and LE fixed gear daily trip or quota limits (2002–17).
    - **NCS H&L:** H&L gear fished in NCS, aggregating the same sectors as NCS pot above.

This report describes changes in the magnitude of fishing catch and effort coastwide, as well as subtler changes in timing, spatial location, and depth. We analyze total groundfish, sablefish, and hake landings and total and median tow duration or number of hooks or pots coastwide, as appropriate for the gear. We also present maps showing fishing effort across different sectors, gears, and time periods to compare and contrast fisheries and management regimes. To further explore changes in fishing effort, we present the proportion of shoreside landings (or catch, in the case of the at-sea midwater fleets) in bimonthly periods and latitudinal and depth bins. Together, this information helps to identify changes in the intensity and distribution of effort and catch over the past 16 years.

Data Sources

Data sources for this report include:

1. Observers aboard commercial fishing vessels landing catch shoreside (recorded and maintained by WCGOP).
2. Observers aboard commercial fishing vessels processing catch at sea (recorded and maintained by A-SHOP).
3. State logbooks from the Pacific Fisheries Information Network (PacFIN).
4. Fish tickets from PacFIN.
5. Electronic monitoring (EM) data from the Pacific States Marine Fisheries Commission (PSMFC).

Observer Data

Fishing effort estimates were derived from independent scientific observation of catch conducted on commercial groundfish vessels at sea by WCGOP and A-SHOP, which are managed under NWFSC's Fishery Resource Analysis and Monitoring Division's (FRAM) Fisheries Observation Science (FOS) program. WCGOP observes several federally managed sectors of the groundfish fishery, including the LE bottom trawl, LE and OA fixed gear, and shoreside midwater trawl. A-SHOP observes both the CP and MSCV portions of the at-sea hake midwater trawl fishery.

WCGOP's goal is to improve total catch estimates by collecting information on at-sea discards of west coast groundfish. A-SHOP accounts for total catch, and documents bycatch by sampling all catch on at-sea processors. For more details about observer program goals, vessel selection, and data collection, see the FOS website.[1] The website also provides estimates of observer coverage for each sector. WCGOP, A-SHOP, and fish ticket data quality assurance, quality control, and processing methods are described in detail in Somers et al. 2018.

Logbook Data

Vessel logbook recordkeeping is a state-mandated requirement for the LE and CS groundfish bottom trawl sectors in Washington, Oregon, and California. A common format logbook is used by all three states, and vessel-reported logbook information is entered into state agency databases. The electronic logbook data are then uploaded by state agencies to the PacFIN regional database, which is maintained by PSMFC.

Bottom trawl logbook data for 2002–17 were retrieved from the PacFIN database in December 2018. These data were divided into groundfish fishery sectors following the procedures described in Somers et al. 2018. Logbook and observer data sometimes have slight discrepancies, so summaries of fleetwide vessels, trips, and hauls may be inconsistent with other reports.

[1] https://www.nwfsc.noaa.gov/research/divisions/fram/observation/index.cfm

Landings Data

Fleetwide landing receipts are the cornerstone of landed catch information for shoreside sectors of the commercial groundfish fishery operating off the Pacific coast of the United States. These fish tickets are trip-aggregated sales receipts issued to vessels by fish buyers in each port for each delivery of fish. Fish tickets are designed and issued by each state agency (Washington, Oregon, and California) and must be returned to the agency for processing. Fish buyers are required to record catch by market category (single-species or a mix of species). Each state conducts species-composition sampling by market category and submits fish ticket and species-composition data to the PacFIN database. PacFIN applies the percentage of weight of each species within market categories obtained from species-composition sampling to the fish ticket data. In doing so, landed weights from sampled market categories are distributed to individual species whenever possible. PacFIN data for fish ticket landings with state species-composition sampling applied were queried in May 2018. As with logbook data, estimates of total vessels and trips in a fleet may differ between fish tickets and observer data, so discrepancies may exist between this and other reports.

Data Usage

We selected the data source for each analysis that ensures both high data quality and consistency for comparisons across sectors and time periods.

In the shoreside sectors, we report total landings of targeted species (or species group) for each sector—FMP managed groundfish (excluding Pacific hake), hake, or sablefish—as recorded on fish tickets. The LE bottom trawl fishery did not and the NCS fixed gear sectors do not have 100% observer coverage, so fish tickets are the primary data source available for fishing effort comparisons. We approximated spatial location of catch using the latitude of the port of landing, although effort occurs at varying distances from landing locations. We also used fish ticket data to describe the proportional landings in bimonthly periods and in latitudinal bins in the shoreside sectors.

To describe haul duration and proportion of hauls in depth bins for bottom trawl sectors, we use logbook data to account for all fishing effort. In fixed gear and shoreside midwater sectors, we use WCGOP data to explore trends in gear usage and depth on observed hauls. Although not all trips of the non-catch share portion of the fixed gear sector are observed, this is the only data source available. For 2015–17, logbook data for the EM portions of the CS pot and midwater fleets were incorporated. In NCS fixed gear sectors, we extrapolated the fleetwide number of hooks and pots based on observer data; see Methods for further details. The use of observer data in these less than 100% covered sectors produced a greater amount of uncertainty in reported trends of total gear usage, gear use per haul, and depth compared to sectors with logbook or observer data for all trips.

All data used to assess fishing effort in the at-sea hake fishery come from A-SHOP. Haul-level information on location and landings are captured directly in the observer data.

Methods

Many of the data summaries described below aggregate data to explore variation between different time periods. These groupings are consistent across analyses of different metrics. The LE bottom trawl sector was grouped into pre- and post-Amendment 19 periods, to account for changes caused by EFH closures that began on 12 June 2006. Bottom trawl data from 2006 were not included in summaries of annual proportion of bimonthly catch, as the year would be split into two periods; the data were included in all other summaries. The shoreside IFQ fishery was grouped, by gear, into two time periods: 2011–15, and the most recent data from 2016–17. A subset of EFH conservation areas, all south of Monterey, California, also prohibited use of all bottom-contact gears, which may have slightly impacted the distribution of NCS fixed gear effort in these areas. We could not explore these patterns due to the low coverage rates in NCS sectors. Instead, to address changes around the implementation of IFQ management, we grouped the non-IFQ fixed gear sector into the pre-IFQ period (2002–10), the initial IFQ period (2011–15), and the most recent data (2016–17). The at-sea hake fishery was not impacted by the EFH closures, so we grouped years to create approximately equivalent time periods: 2002–05, 2006–10, and 2011–15, as well as the most recent two years' data for 2016–17.

Landings

Total landings were estimated coastwide for each sector by year. We calculated total FMP groundfish landings (excluding hake) to provide a unit of effort for the multi-species-targeting bottom and midwater trawl sectors, total hake landings to estimate effort by hake-targeting midwater trawl fisheries, and total sablefish landings to assess fishing effort in the primarily sablefish-targeting fixed gear sectors.

Gear Usage

We calculated effort metrics of tow duration and number of hooks or pots, depending on gear type. This metric provides an estimation of effort that, unlike total catch, is not impacted by fishing efficiency, stock density, and other factors. Expansions were performed in non-catch share sectors to estimate total number of hooks or pots. Estimates were generated for each effort index by year, sector, and gear based on the following equation summed across each stratum:

$$\widehat{E} = \frac{\sum_h b}{\sum_h r} \times C$$

where:

- $\hat{E}$ = estimated effort,
- b = observed number of gear units,
- r = observed retained weight (mt) of sablefish,
- h = hauls in observer data, and
- C = weight (mt) of retained sablefish recorded on all fish tickets.

In 2002, no hauls were observed in the non-nearshore pot sector south of lat 40°10′N, so the observed ratios north of 40°10′N were used in combination with landings south of 40°10′N to estimate effort metrics.

We also calculated the number of sets or hauls where lost gear was observed and where gear was recovered in each sector, gear, and year. Recovered gear may consist of crab pots, other fixed gear, and even trawl nets, but does not include hauls where trawl gear was lost and immediately recovered in the same haul. We report only observed occurrences and do not expand observed events to create fleetwide estimates of gear lost or gear recovered. We report these summaries at finer sector-level scales than other analyses in this report to better describe these patterns. These data for the shoreside fleet recently underwent a number of quality control procedures, with some of the largest updates resulting from cases where an observer reported lost gear under one field but implied that gear was landed under another. We explored these past occurrences and corrected data as needed, and we also developed rules to better identify similar cases in the future during data entry and review. This process impacted the years and sectors for which we are able to report both lost and recovered gear, and allowed us to rectify some incorrect records of lost gear. Recovered gear is reported for all years, in all fisheries, except for 2002 in the fixed gear fisheries. In the catch share fixed gear fisheries, gear lost is reported for all years, while those data were only available from 2010 to 2017 in the non-catch share fixed gear fisheries. This report summarizes the most recent data and should be considered the best source of data for this information.

Seasonal Timing of Effort

To assess trends in the timing of fishing effort, we calculated the proportion of annual targeted landings in the shoreside fishery or catch in the at-sea fishery by each fleet and gear occurring in bimonthly periods over each year. We then calculated the median and first and third quartiles of that proportion across years in each time period. Due to fewer than three vessels fishing in each bimonthly period and in order to maintain confidentiality, we do not report these summaries for the catch share fixed gear fleets in the 2016–17 time period.

Location of Effort

To assess trends in the location of fishing effort, we explored patterns in landings in the shoreside fishery or catch in the at-sea fishery by one-degree latitudinal bins. Similar to the methods used for timing above, we calculated the proportion made in each latitudinal degree and then calculated the median and first and third quartiles across years in each time period.

Depth of Effort

Patterns in fishing effort by depth were explored by calculating the proportion of hauls in 50-fth depth bins. Similar to timing and location, we calculated the median and first and third quartiles across years in each time period.

Geospatial Analysis

In addition to describing broad trends in the location of landings and catch and the depth of fishing effort, we also attempted to assess spatial patterns by plotting individual fishing locations. We used a straight line connecting the start and end points of trawl hauls or fixed gear sets to represent each fishing event. We excluded hauls that intersected land, that occurred outside the U.S. exclusive economic zone (EEZ) or in waters deeper than 2,000 m, or that fished bottom trawl at greater than five knots (as calculated from straight line distance divided by recorded tow duration). From these line features, we created an effort density layer that depicts the relative intensity of fishing effort within relevant gear types and time periods. The following description of methods closely matches those used for development of fishing intensity layers created for PFMC's review of groundfish EFH (GEFHRC 2012).

Fishing intensity was calculated as the total length of all lines intersecting a standardized area. To calculate this metric, we used a line density algorithm in ArcGIS 10.5. The line density algorithm calculates density within a circular search area centered at a grid cell of specified size (see the web page, How Line Density works).[2] Effort values were standardized for each time period by dividing per-cell density values by the total number of years in each period. The value (units: $km/km^2/yr$) for each grid cell is the quotient of total line portions intersecting the circular area per grid cell area per year. Because density outputs are highly sensitive to the specified radius and cell size, relative values are more informative than absolute values. Relative density identifies areas where fishing effort is concentrated, while still ensuring confidentiality of individual fishing locations, and is thus superior to depicting confidential tow lines. The initial density output was more spatially extensive than that shown in the map figures, because it included confidential cells where density values were calculated from tows or sets made by less than three vessels. Confidential cells, representing less than three vessels, were removed from the maps presented in this report. Density parameters were chosen to minimize data exclusion but maintain confidentiality while still providing a high spatial resolution (500-m cell size). A larger search radius (5,000 m) was used to develop shoreside processing midwater trawl and fixed gear density outputs as compared to trawl densities (3,000 m), because effort in those sectors was generally patchier compared to the bottom and at-sea processing midwater trawl sectors. Because the density outputs cannot fully capture the entire footprint of fishing, we summarized length of all lines intersecting 10×10-minute rectangular cells. Cumulative lengths were divided by the total length of all lines for each gear sector and time period, and reported as relative coastwide effort (%).

[2] http://desktop.arcgis.com/en/arcmap/10.5/tools/spatial-analyst-toolbox/how-line-density-works.htm

Results

Trawl Sectors

Bottom Trawl

The bottom trawl sector retained ~16,700 mt of groundfish in 2016 and ~17,500 mt in 2017, continuing to rebound from low catch in 2014 and 2015 (Table 1, Figure 1). Further, when accounting for groundfish retained by other gears fishing trawl quota, 2017 landings reached a high of ~27,000 mt. Fleetwide bottom trawl effort continued to decrease from 2015 to 2017, but at a lower rate than observed from 2013 to 2015 (Table 1, Figure 2). Median haul duration decreased from 2011 to 2015, but stabilized around 3.2 hours in 2016 and 2017 (Table 1, Figure 3).

The spatial distribution of landings in 2016–17 was similar to that of 2011–15, although landings around lat 44°N increased. The proportion of coastwide landings made at lat 46°N, near Astoria, Oregon, remained high in 2016 and 2017 (Table 2, Figure 4). The proportions of landings north of lat 46°N and south of lat 39°N remained low, while the proportions of landings between lats 45° and 39°N (Newport, Oregon to Fort Bragg, California) were consistent with the previous time period.

Maps of average annual fishing intensity illustrated these patterns in more detail and revealed the similarity of spatial distribution and intensity patterns between 2011–15 and 2016–17 (Figure 5). The 2016–17 time period also illustrates the continued trend of effort concentrating in the more northern parts of the coast and in deeper waters. Effort in the southern parts of the coast is relatively low and patchy in the few places that bottom trawl fishing occurs.

The temporal pattern of landings in 2016–17 was similar to that of 2011–15 (Table 3, Figure 6). The percentage of annual landings made in a bimonthly period ranged from 13% in July/August to 23% in March/April.

The proportion of hauls in the 0–50 fth depth bin continued to decrease, while activity in the 50–100 fth waters increased slightly (Table 4, Figure 7). Across other depth bins, the distribution of effort was similar across all time periods.

Shoreside Midwater Trawl

As quotas for widow and yellowtail rockfish have increased, the CS midwater trawl rockfish fleet has continued to develop. Groundfish landings and effort increased every year from 2011 to 2017, except for a slight decrease in 2016 (Table 1, Figures 1 and 8). Hake landings and effort measured by tow duration in the shoreside midwater hake trawl fleet have been much more variable than the rockfish trawl fleet, but were very similar to trends in the at-sea hake fishery and likely reflect quota, price, and accessibility of hake (Table 1, Figure 9). In 2017, both landings and tow duration by the shoreside hake fleet reached historic highs and were greater than in either at-sea sector. Median tow duration per haul in the midwater rockfish trawl fleet in 2016–17 was similar to that of 2011–15 and was typically lower and less variable than the shoreside midwater hake trawl fleet, with a median around 1.5 hours. The duration of shoreside midwater trawls targeting hake decreased in variability and magnitude from 2015 to 2017, with a median of between 2 and 2.5 hours (Table 1, Figure 10).

In 2016–17, landings by the midwater rockfish trawl fishery occurred from central Washington to central Oregon. The majority of these landings occurred along the Oregon/Washington border, similar to 2011–15 (Table 2, Figure 11). The proportion of landings near Astoria (lat 46°N), decreased slightly from 72 to 67% and increased near Newport (in the 44°N latitudinal bin), from 23 to 33%. From 2011–15, about a quarter of midwater rockfish trawl catch was landed near Bellingham, Washington (lat 48°N), but no landings occurred in that area in 2016–17. Finally, a small number of hauls were made in California for the first time in 2017 as part of an exempted fishing permit (EFP). Due to the developing nature of the fishery, a small but increasing number of vessels have participated in this fishery, particularly in these three areas of concentration, that persisted from 2011–15 to 2016–17 (Figure 12). The spatial distribution of fishing effort in 2016–17 was similar to that in 2011–15, although annual effort was greater in the more recent time period. Fishing also became more concentrated in areas off the coast of Astoria and north of Newport.

In the shoreside midwater hake trawl fishery in 2016–17, the majority of landings continued to occur in the 46°N latitudinal bin, where the median proportion increased from 61% in 2011–15 to 73% in 2016–17 (Table 5, Figure 13). The remainder occurred near Newport in the 44°N latitudinal bin; unlike in 2011–15, no landings occurred south of lat 44°N in 2016–17. Due to a higher number of vessels and more concentrated fishing, only a small amount of total effort was excluded from the map of fishing intensity in the primary areas of fishing, north of lat 42°N (Figure 14). Although landings occurred primarily in Astoria, effort occurred throughout the northern part of the coast. In both time periods, fishing effort was particularly intense off of Newport, but in 2016–17 was most intense further north. Effort was more dispersed in 2011–15 than in 2016–17, which may reflect lower annual variability in two years compared to five years of data (Figure 14).

The shoreside midwater season starts in mid-May, so landings are restricted from May to December. However, in 2016–17, an EFP allowed the rockfish fleet to land 7.5% of landings in March/April (Table 3, Figure 15). Landings by the rockfish fleet were more consistent throughout the year in 2016–17 than in 2011–15, but continued to show a greater proportion of landings in September through December than earlier in the year. The bimonthly pattern of the midwater hake fleet from 2016–17 was similar to that of 2011–15 (Table 6, Figure 16).

Midwater rockfish trawl effort in 2016–17 was similar to that in 2011–15 and was most intense in shallow water in the 50–150 fth depth bins (Table 4, Figure 17). However, within those depths, the percentage of effort in the 50–100 fth depth bin decreased by about 10% and, in the 100–150 fth bin, increased by about 11%. Tows deeper than 150 fth all but disappeared in 2016 and 2017. The depth range of shoreside midwater hake hauls was greater than those by midwater rockfish trawl, from 0–600 fth in 2011–15 and from 0–450 fth in 2016–17 (Table 4, Figure 18). In 2016 and 2017, effort was even more concentrated between 50 and 250 fth, with the effort in 50–100 fth increasing by 10% in 2017 and in 100–150 fth by 10% in 2016 and 2017 compared to 2011–15.

At-Sea Midwater Trawl

The variability in hake landings by both the CP and MSCV portions of the at-sea fleet reflects annual quota changes (Table 1, Figure 9). Landings by CPs showed a mostly increasing trend, with two years of sharp decreases in 2008 and 2015. Annual catch increased in 2016 and 2017 to more than 137,000 mt, a level not seen since at least prior to 2002. The MSCV portion receives less hake quota than CPs, resulting in lower catch by MSCVs. Landings by MSCVs followed the same pattern as by CPs, but with lower interannual variability. However, while CPs showed a large increase in retained hake from 2016 to 2017, MSCVs landed an almost equivalent amount (~65,000 mt) in both years. Nonetheless, these years represent the greatest annual catch since at least 2002. Similar to trends in catch, fleetwide effort by CPs rose steadily from 2002 to 2008, with a large decrease in 2009, corresponding with historically low total allowable catch (Table 1, Figure 8). However, from 2009 to 2016, tow duration mostly increased, with 2016's ~7,300 fleetwide tow hours the greatest since at least 2002, before decreasing to ~5,700 hours in 2017. The MSCV portion of the fleet again followed a similar pattern as CPs, but with lower variability and range; in 2015, MSCVs diverged from CPs, with a large decrease in tow duration compared to previous years. The median and quartiles of duration per haul were similar for CPs and MSCVs in most years, although median tow duration by CPs was greater in nearly all years (Table 1, Figure 19). Tow duration in both sectors has generally increased, from a low of ~1 hour in 2003 and 2004 to a median between 2 and 3 hours since 2007.

Fishing effort in the at-sea midwater hake trawl fishery was focused on the northern part of the coast, off central Oregon, across all time periods (Table 5, Figure 20). In 2006–10, the proportion of catch by CPs was evenly distributed in that area, but in 2011–15, catch mostly occurred in the southern portion of the range, from lats 44–42°N. Variability in catch location also increased, especially in the 47°, 43°, and 42°N latitudinal bins. Both of these trends continued in 2016 and 2017, with much greater variability potentially reflecting extremes in the two years of data. MSCVs in 2002–05 focused the majority of effort in the 44° and 43°N latitudinal bins, but have been more variable in more recent time periods. In 2011–15, the largest median proportion of catch occurred in the 43°N latitudinal bin, while in 2016–17, around a quarter of catch occurred in each of the 47°, 43°, and 42°N latitudinal bins.

Maps of fishing intensity in the CP portion of the at-sea midwater hake fishery emphasized the movement of the fleet to the southern part of their range from 2002 to 2017 (Figure 21). Effort has increased around lat 42°N, and vessels in 2016–17 continued to fish farther seaward than observed in prior periods. A hotspot of effort around lat 43°N has steadily intensified over the three periods. In the north, a hotspot of effort around lat 48°N was present to varying degrees across all time periods. In 2016–17, the most intense concentration occurred where little effort had occurred in previous time periods, off of Newport, around lat 44°N.

Geospatial analysis illustrates a concentration of effort over time into two distinct areas, one off northern Washington and another off southern and central Oregon (Figure 22). The area of concentrated fishing around lats 44–43°N expanded from 2011–15 to 2016–17, and fishing effort became more intense in the northern part of the coast around lat 48°N. In 2016–17, the fleet also moved more seaward than ever before around lat 43°N.

The midwater at-sea fleet's season begins on 15 May; in 2015, the shoreside fleet's opening date shifted from 15 June to 15 May to coincide with the at-sea sector. In the CP sector, in 2002–05, the fleet processed nearly all catch evenly from May to October, and, in 2006–10, the fleet processed a majority of catch in May/June and the rest evenly between the three bimonthly periods from July to December. In the MSCV sector, however, nearly all catch was processed in May/June from 2002–10. Since the MSCV sector became a co-op, its fishing seasons have extended and the timing of processing now resembles that of the CP co-operative. Specifically, in both 2011–15 and 2016–17, the CP and MSCV portions of the fleet fished primarily in May/June and September/October, with almost no catch in July/August (Table 6, Figure 23).

Nearly all midwater at-sea hauls occurred in depths of 50 to 250 fth (Table 4, Figure 24). Over the three time periods summarized, the proportion of both CP and MSCV hauls in deeper waters increased. In 2011–15, more than half of CP hauls occurred in waters of 150–200 fth depth, and almost 80% of hauls by the MSCV sector occurred between 100 and 200 fth. In 2016, almost 60% of CP hauls occurred in the 150–200 fth depth bin, and in 2017 more than half of hauls occurred in the 100–150 fth depth bin. MSCVs also increased efforts in depths of 100 to 200 fth in 2016 and 2017, although not as dramatically.

Fixed Gear Sectors

Pot

After declining from 2011 to 2013, sablefish landings by both the CS and NCS pot fleet have mostly increased through 2017, although landings by the NCS pot sector were relatively consistent from 2015 to 2017 (Table 7, Figure 25). CS pot vessels continued to land more sablefish than the NCS fleet, with the difference increasing from 2013 to 2017. The fleetwide estimate of pots calculated using observer data varied annually, but the NCS fleet has increased from 2013 through 2017 (Tables 7 and 8, Figure 26). The number of pots in the CS fleet has shown a slight increasing trend from 2013 to 2017. A greater number of pots were fished by the CS than the NCS fleet in all years but 2014, when they were nearly equal, and 2016, when there were slightly more NCS pots. In most years, and in both the CS and NCS pot fleets, the median estimated number of pots per set has fluctuated annually between ~16 and ~50 (Tables 7 and 8, Figure 27). In the CS pot fleet between 2011 and 2015, all years showed a median ~30 pots per set, but in 2016 and 2017, that median dropped to ~20; across all years the quartiles showed a large range. In the NCS pot fleet, the median pots per set from 2011 to 2017 was between 30 and 35 in all years except 2013, when the historic low of ~16 pots per set was observed.

The proportional distribution of sablefish landings coastwide by the NCS pot fleet was consistent between 2002–10, 2011–15, and 2016–17 (Table 9, Figure 28). In all three time periods, ~80% of landings were made between lats 46–39°N, with the greatest proportions in the 46°, 44°, and 39°N latitudinal bins (near Astoria, Newport, Fort Bragg, respectively). Landings south of lat 39°N were more evenly distributed between lats 38–35°N in 2011–15 than in 2002–10 or 2016–17. Landings in the 48°N and 39°N latitudinal bins were greater in 2016 and 2017 than in either earlier period. The high dispersion of fishing effort by different vessels made it difficult to accurately display fishing intensity while maintaining confidentiality (Figure 29). However, comparing the primary fishing areas of nonconfidential data across time periods revealed similar spatial distributions and little change after CS implementation (Figure 29).

The spatial distributions of CS pot landings were less uniform across the coast than NCS. In 2011–15, almost 30% of landings occurred in the 35°N latitudinal bin, which decreased by half to almost 15% in 2016–17 (Figure 28). In the northern portion of the coast, most landings in 2011–15 occurred in the 46°, 44°, and 42°N latitudinal bins; in 2016–17, almost one-third of landings occurred in both the 46° and 44°N latitudinal bins. While landings around lat 43°N increased between 2011–15 and 2016–17, landings around lat 42°N decreased to almost zero. Due to lower observer coverage in the NCS fishery, direct comparisons of magnitude of effort between the NCS and CS maps are inappropriate. CS effort in both 2011–15 and 2016–17 was most intense between lats 47–44°N, overlapping with observed NCS pot effort (Figure 30). Fishing in the southern part of the coast was greatly reduced in 2016–17, but one intense area of fishing effort occurred around lat 36°N. This new area of fixed gear fishing may represent initiatives introduced with catch share implementation that supported a shift from trawl to fixed gear fishing near Morro Bay, California.

Landings by the NCS pot fleet peaked in May/June prior to IFQ implementation, with high proportions of catch from May to October (Table 10, Figure 31). In 2011–15 and 2016–17, this peak shifted to September/October and was more pronounced. The CS pot fleet also peaked in September/October in 2011–15, with half of landings occurring in that single bimonthly period. To maintain confidentiality, we cannot report bimonthly landings in 2016–17.

Fishing effort in the NCS and CS pot fleets occurred primarily in depths from 0–750 fth (Table 11, Figure 32). Both NCS and CS fleets showed bimodal peaks, likely reflecting the depths of shelf and slope fishing. In 2011–15, the proportion of hauls by the NCS pot fleet in depths 0–250 fth decreased, and the proportion in 500–600 fth increased; this trend reversed in 2016 and 2017. Effort in the CS pot fleet was more evenly distributed than in the NCS fleet, but the proportion of hauls showed small peaks around 150–300 and 450–650 fth in both time periods.

Hook-and-Line

Sablefish landings by the NCS H&L fleet in 2013 and 2014 were nearly the lowest since 2002, but have since increased through 2017 to the middle of the observed range (Table 7, Figure 25). Landings by the CS H&L fleet were similar across 2013 to 2017 and remained considerably lower than NCS landings. Increased harvest guidelines in 2009 are reflected in large increases in both the number of hooks and the total landings by the NCS H&L fleet. Subsequently, the estimated number of NCS fleetwide hooks declined from 2009 to 2015, but increased slightly in 2016 and 2017 (Table 8, Figure 33). The total number of hooks fished by the CS H&L fleet slowly decreased from 2011 to 2017 (Tables 7 and 8, Figure 33). The median number of hooks per set in the NCS fleet was stable from 2002 to 2010 at ~2,000 hooks; this number increased in 2012 and has been closer to ~2,500 hooks per set through 2017 (Tables 7 and 8, Figure 34). In the CS fleet, hooks per set decreased from 2011 to 2013 and have remained ~3,200 since 2015. The variability in hooks per set by the NCS fleet was similar across all years. In the CS fleet, this variability was much greater in 2013 and 2014 than in other years or in the NCS fleet, potentially reflecting poor fishing conditions that resulted in the two lowest annual catch amounts. From 2015 to 2017, annual variability decreased and was more similar to that in the NCS fleet.

H&L sablefish landings ranged from lats 48–32°N. Landings by the NCS H&L fleet were more uniform along the coast in 2011–15 and 2016–17 than in 2002–10 (Table 9, Figure 35). After IFQ implementation, landings by the NCS fleet decreased in the 48°N and 46°N latitudinal bins and increased south of lat 36°N. (around Monterey Bay). Patterns in 2016–17 were similar to those in 2011–15, but landings were even more evenly distributed along the coast. Spatial patterns in fishing intensity were similar across all three time periods, although effort has generally concentrated over time (Figure 36). Almost no effort was observed south of lat 34°N in 2016–17.

The CS H&L fleet showed a very different spatial distribution of landings in 2016–17 than in 2011–15. In 2011–15, ~70% of catch occurred near Astoria, in the 46°N latitudinal bin, while in 2016–17 this had decreased to ~30% (Figure 35). Conversely, the percent of coastwide landings in the 48°N latitudinal bin increased from ~8% to 40%. In both time periods, ~20% of landings occurred in the 44°N latitudinal bin, with smaller percentages of landings occurring south of this area. Due to a small number of vessels participating in the CS fleet, intensity could not be shown at a meaningful spatial scale, making it difficult to assess the full distribution of fishing. Nonconfidential data show that fishing by the CS H&L fleet largely overlapped the range of fishing by the NCS fleet in the northern portion of the coast (Figure 37).

Landings by the NCS H&L fleet peaked in September/October both before and after IFQ implementation, but this was more prominent in 2011–15 than in 2016–17, when the proportion of landings in May to August increased (Table 10, Figure 38). Landings by the CS H&L fleet showed extreme annual variability, but typically peaked in September/October, with some years showing very high catch in July/August and November/December as well. To maintain confidentiality, bimonthly landings in 2016 and 2017 cannot be reported.

Both the NCS and CS H&L fleets fish in depths ranging from 0–750 fth (Table 11, Figure 39). NCS H&L hauls were more common in deeper waters in 2011–15 than in 2002–10; this trend partially reversed in 2016 and 2017. The CS H&L effort focused on shallower waters than the NCS fleet in 2011–15, especially 50–100 fth and 200–250 fth. In 2016 and 2017, the CS fleet shifted most of its effort into depths from 150–300 fth, with additional, evenly distributed effort in 300–600 fth.

Lost Gear and Recovered Gear

Gear loss in the U.S. West Coast groundfish fleet is uncommon, so is reported at finer sectors than in other analyses. Gear loss was observed the least in trawl fisheries. In shoreside bottom trawl fleets, gear loss occurred on ~0.1% of observed hauls annually and was never observed in shoreside midwater trawl fleets (Table 12). On average, in at-sea midwater fleets, 0.02% of hauls lost gear annually, with a maximum of less than 0.2% (Table 13). Gear loss was observed more often in fixed gear fisheries than in the trawl fleet. Lost gear was observed in the CS and non-nearshore H&L fisheries on ~2% of hauls on average annually, representing 0.6% of observed hooks. In the CS and non-nearshore pot fisheries, gear loss incidents were observed more often (3.8% of hauls) than in the H&L fisheries, but the proportion of gear units lost was similar.

The percentage of hauls recovering gear was typically greater than those losing gear, likely reflecting gear loss in unobserved fisheries. Gear recovery was observed most frequently in fisheries using bottom trawl gear, when ~5.4% of hauls annually on average recovered gear. Gear recovery in the LE and CS bottom trawl fleet was less variable, ranging from ~2–8% of observed hauls annually and averaging 4%. Midwater gears rarely contact the ocean floor, so gear recovery is exceedingly rare. Less than 1% of observed shoreside midwater hauls recovered gear, and no recovered gear has been observed in the at-sea midwater fleet. Fixed gears are less likely than bottom trawl to recover gear due to differences in deployment and the gear itself. H&L fleets recovered gear on less than 0.2% of observed hauls on average annually, with no incidents in most years and a maximum of 1.9% observed in the OA sector in 2010. On average, 0.1% of observed pot hauls recovered gear per year, with a maximum of 0.8% of hauls in the CS EM fleet in 2016.

Figures

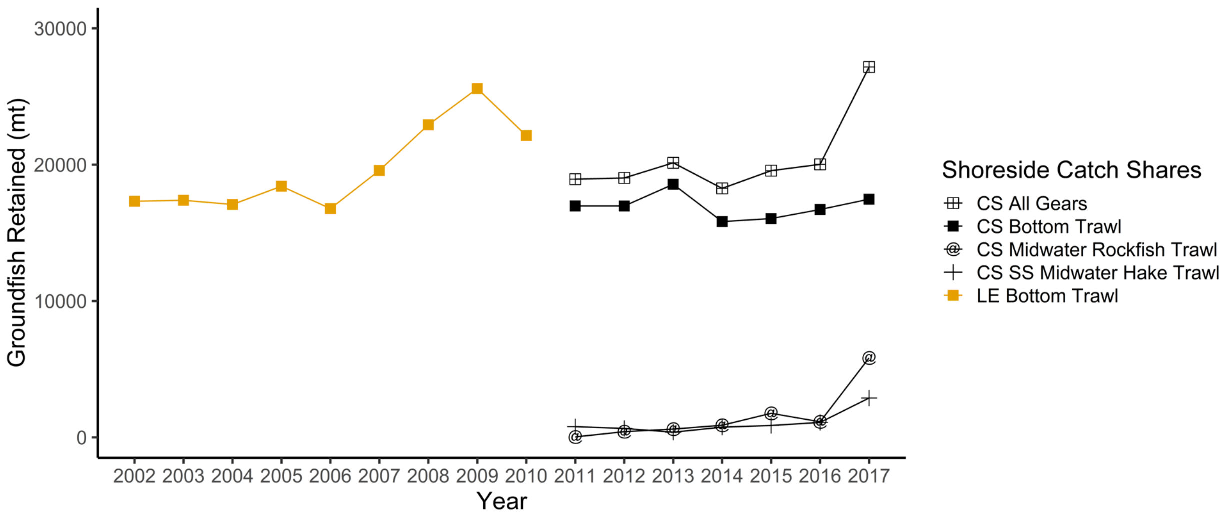


Figure 1. Annual total fleetwide FMP groundfish (not including hake) landings (mt) in shoreside trawl sectors. The LE bottom trawl fleet (2002–10) is shown here and in other figures in a different color to emphasize potential differences in the bottom trawl fleet before and after CS implementation.

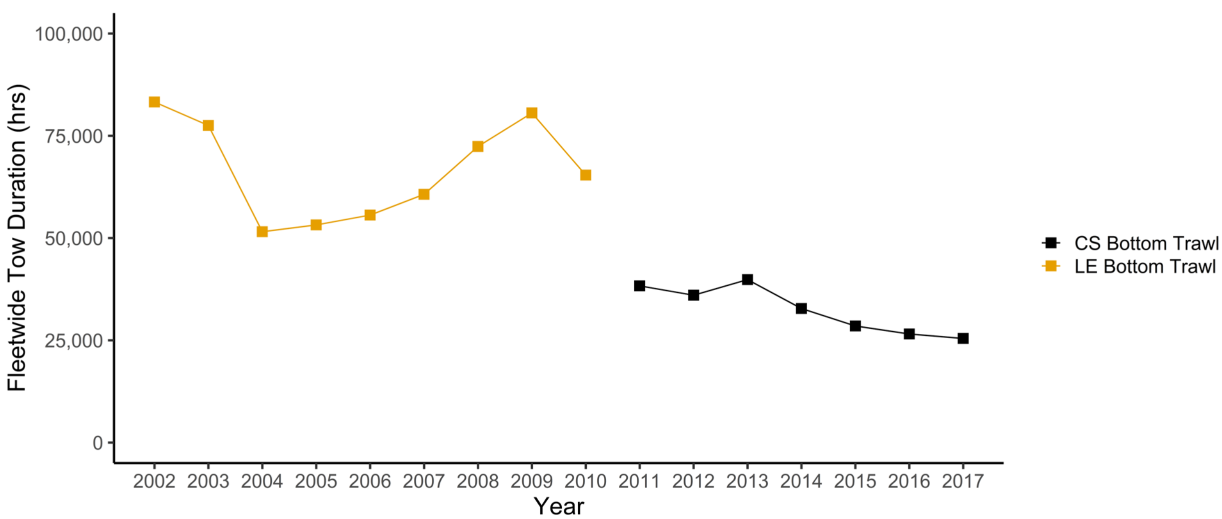


Figure 2. Annual total fleetwide tow duration (hours) in the bottom trawl sector.

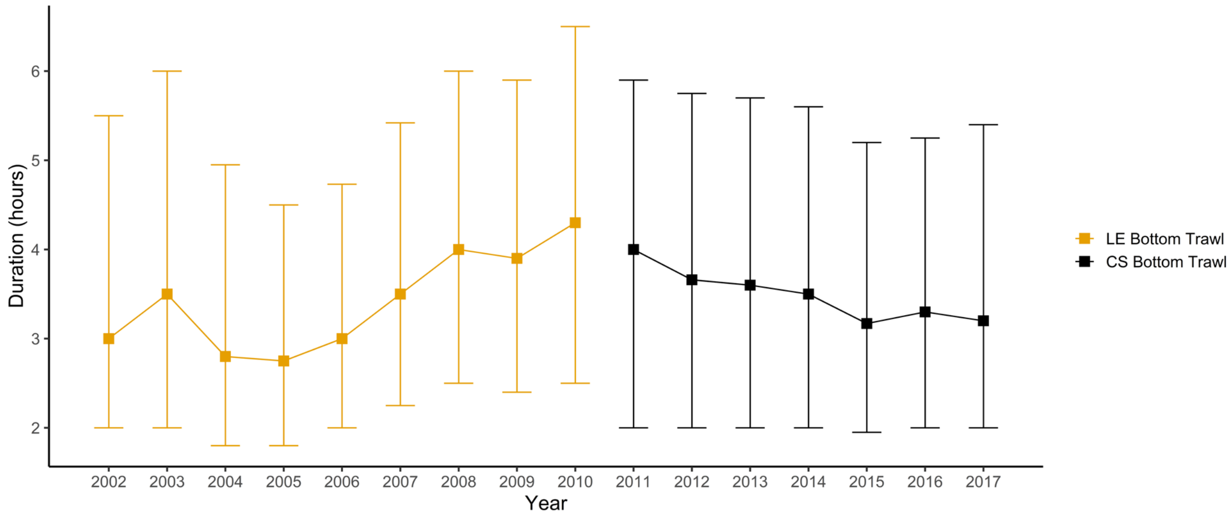


Figure 3. Tow duration (hours) per haul in the bottom trawl sector. Medians and first and third quartiles for each year are shown.

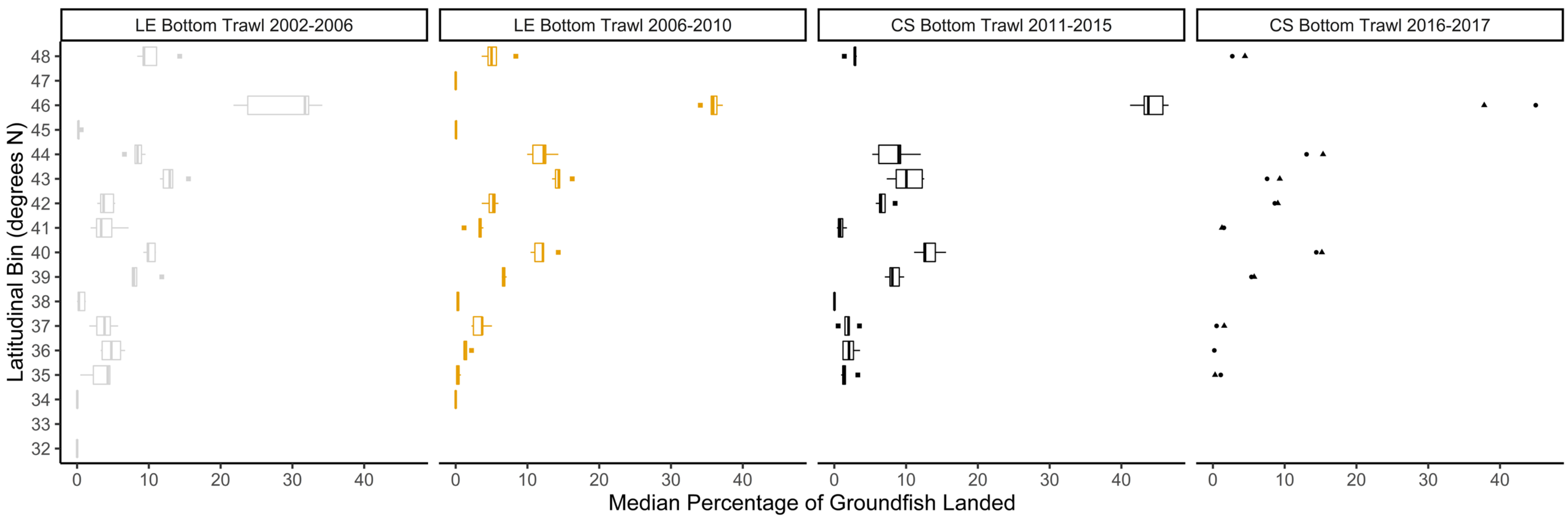


Figure 4. Percentage of retained FMP groundfish landed in latitudinal bins by bottom trawl; patterns in actual fishing activity are shown in Figure 5. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

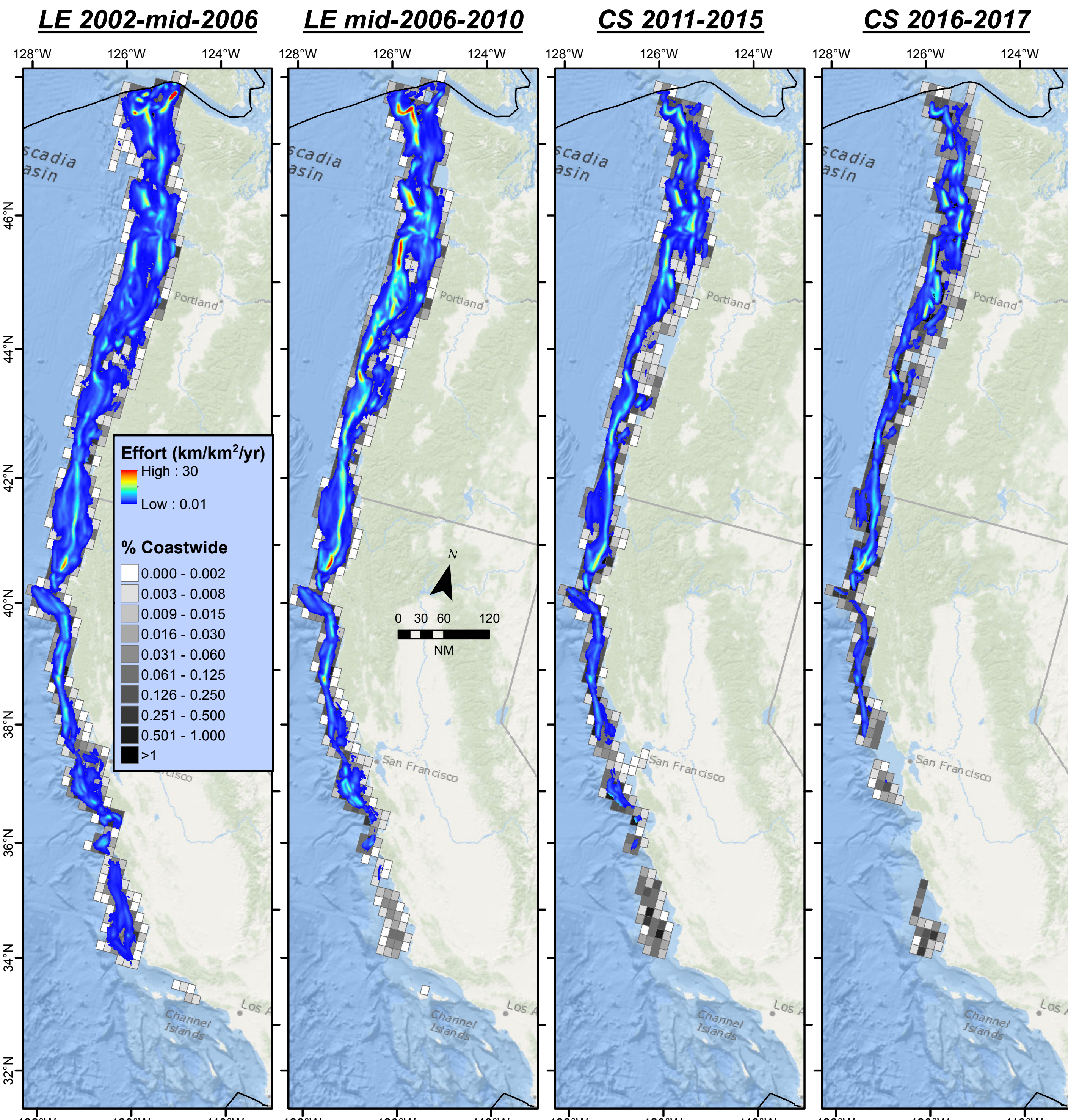
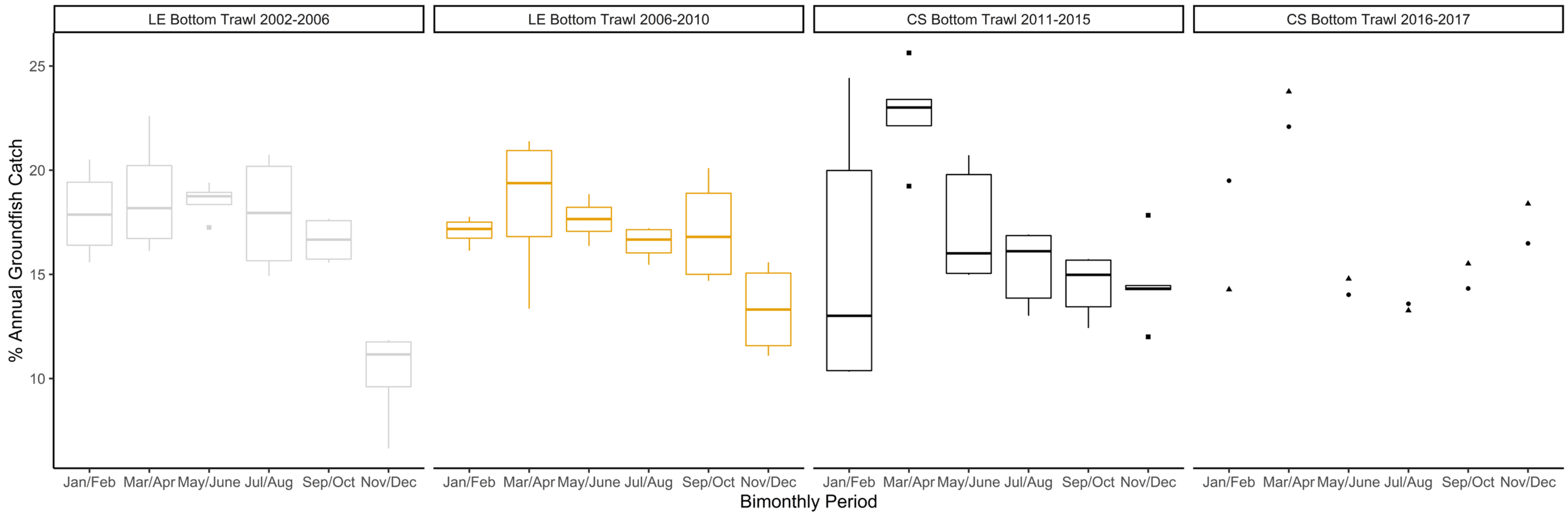


Figure 5. Spatial distribution and intensity of bottom trawl fishing effort. Intensity (units: km/km^2/yr) is depicted by a color ramp of cool (low) to warm (high) colors. The LE bottom trawl sector time periods account for EFH closures that began on 12 June 2006. To show the overall footprint of fishing for each time period, we display confidential cells in grayscale, with darker (black) tones depicting a higher relative contribution to coastwide effort within 10×10-minute cells.

Figure 6. Percentage of retained FMP groundfish landed in bimonthly bins by the bottom trawl sector. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.



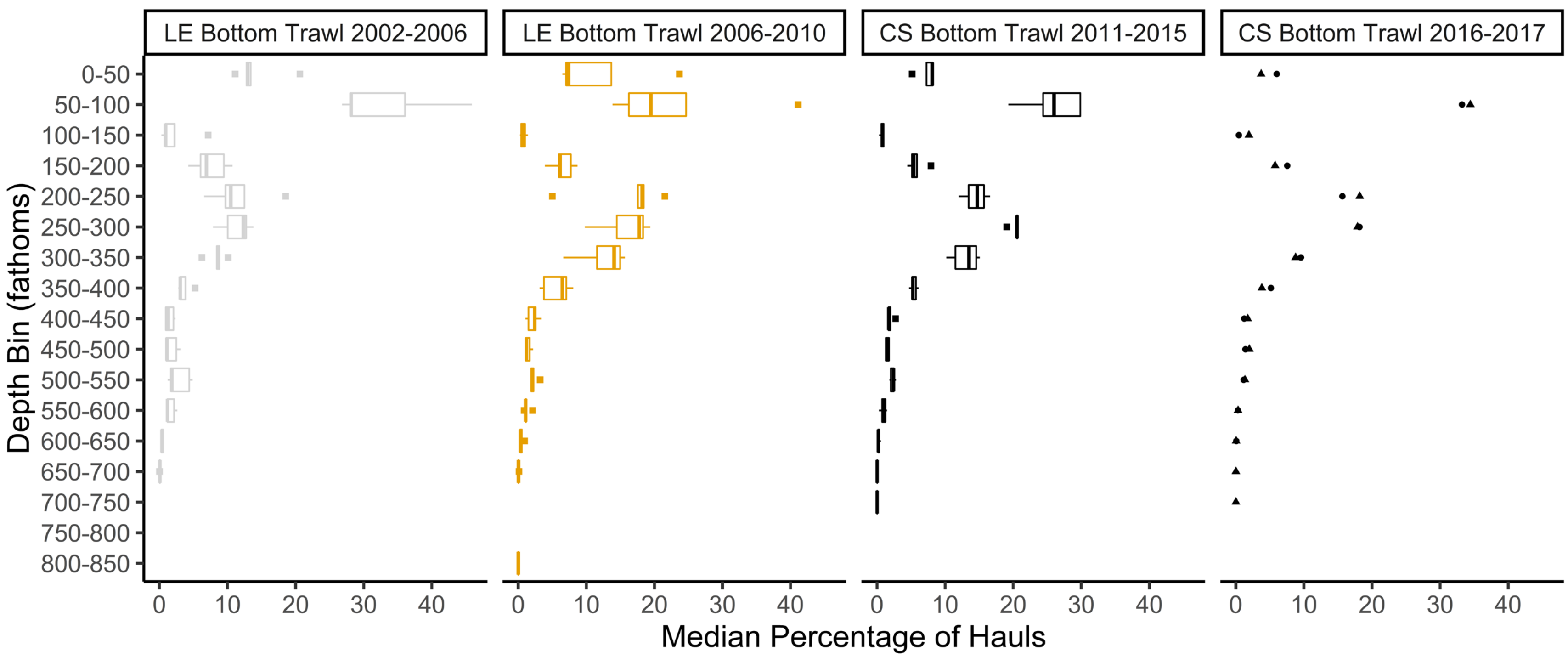


Figure 7. Percentage of bottom trawl hauls in 50-fathom depth bins. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

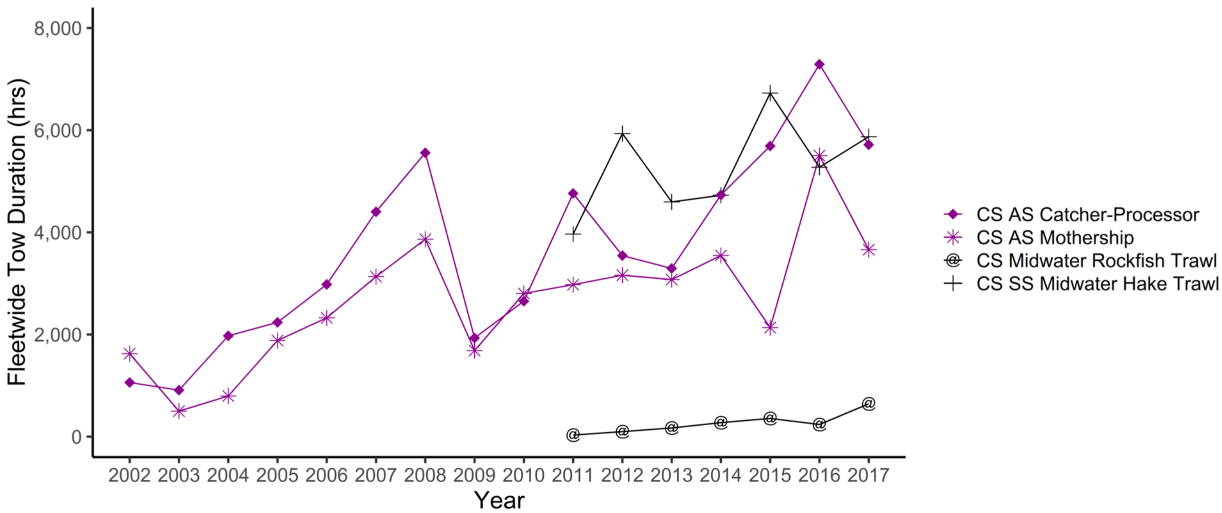


Figure 8. Annual total fleetwide tow duration (hours) in shoreside and at-sea midwater trawl sectors.

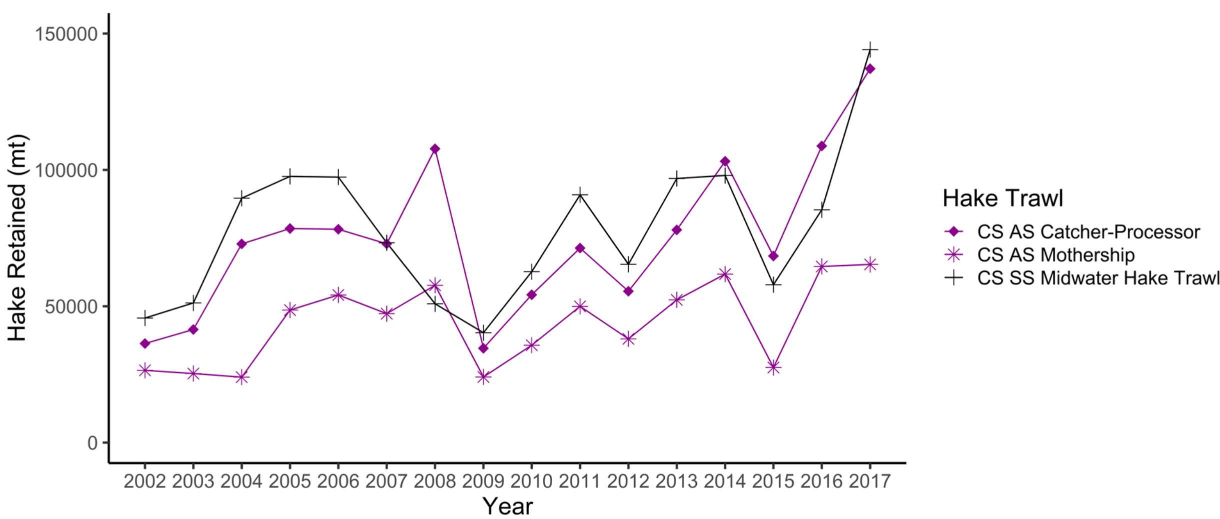


Figure 9. Annual total fleetwide hake landings (mt) in shoreside bottom and midwater and at-sea midwater trawl sectors.

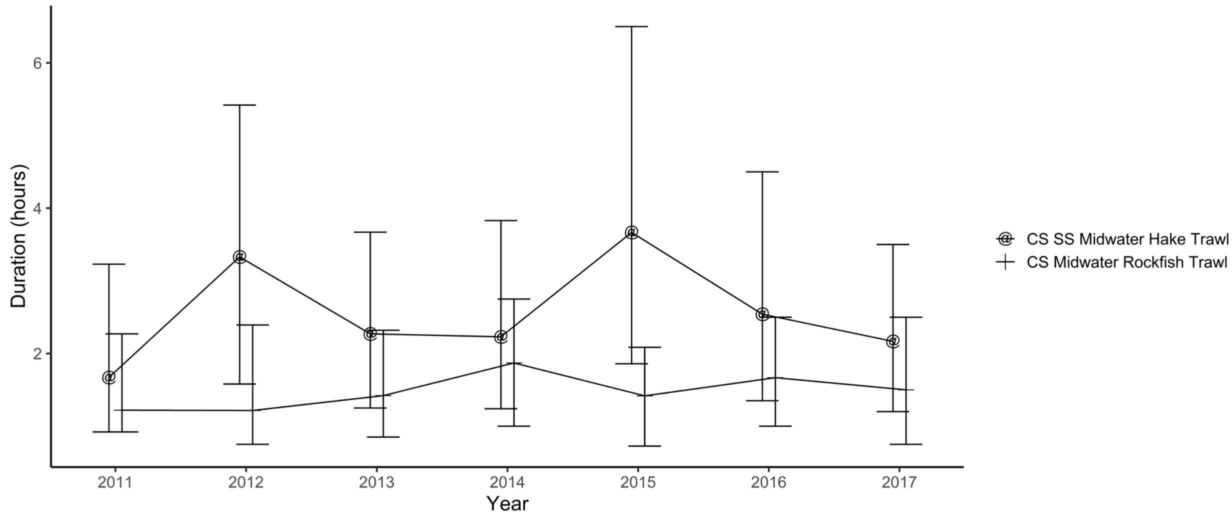


Figure 10. Tow duration (hours) per haul in shoreside midwater trawl sectors. Medians and first and third quartiles for each year are shown.

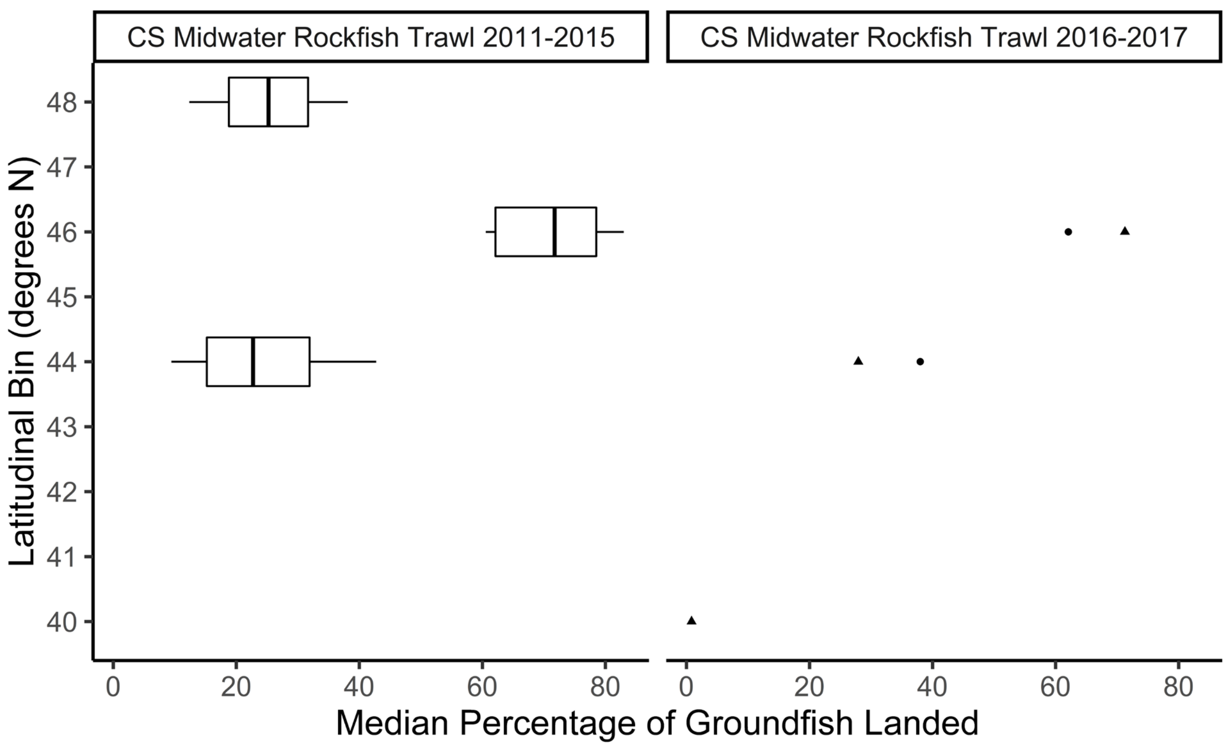


Figure 11. Percentage of retained FMP groundfish landed in latitudinal bins by shoreside midwater trawl targeting rockfish; patterns in actual fishing activity are shown in Figure 12. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

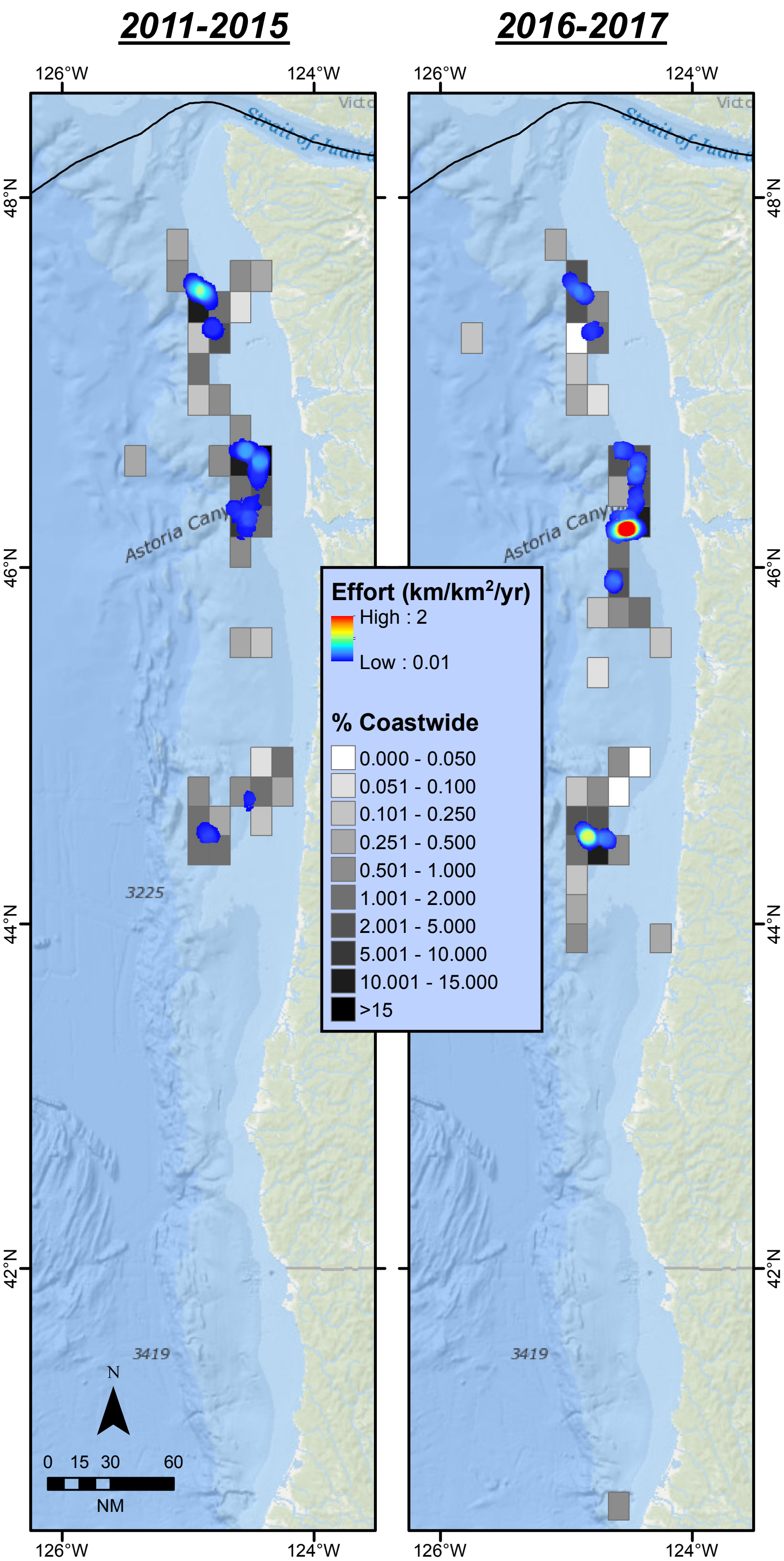


Figure 12. Spatial distribution and intensity of fishing effort by shoreside midwater trawl targeting rockfish. Intensity (units: km/km^2/yr) is depicted by a color ramp of cool (low) to warm (high) colors. To show the overall footprint of fishing for each time period, we display confidential cells in grayscale, with darker (black) tones depicting a higher relative contribution to coastwide effort within 10×10-minute cells.

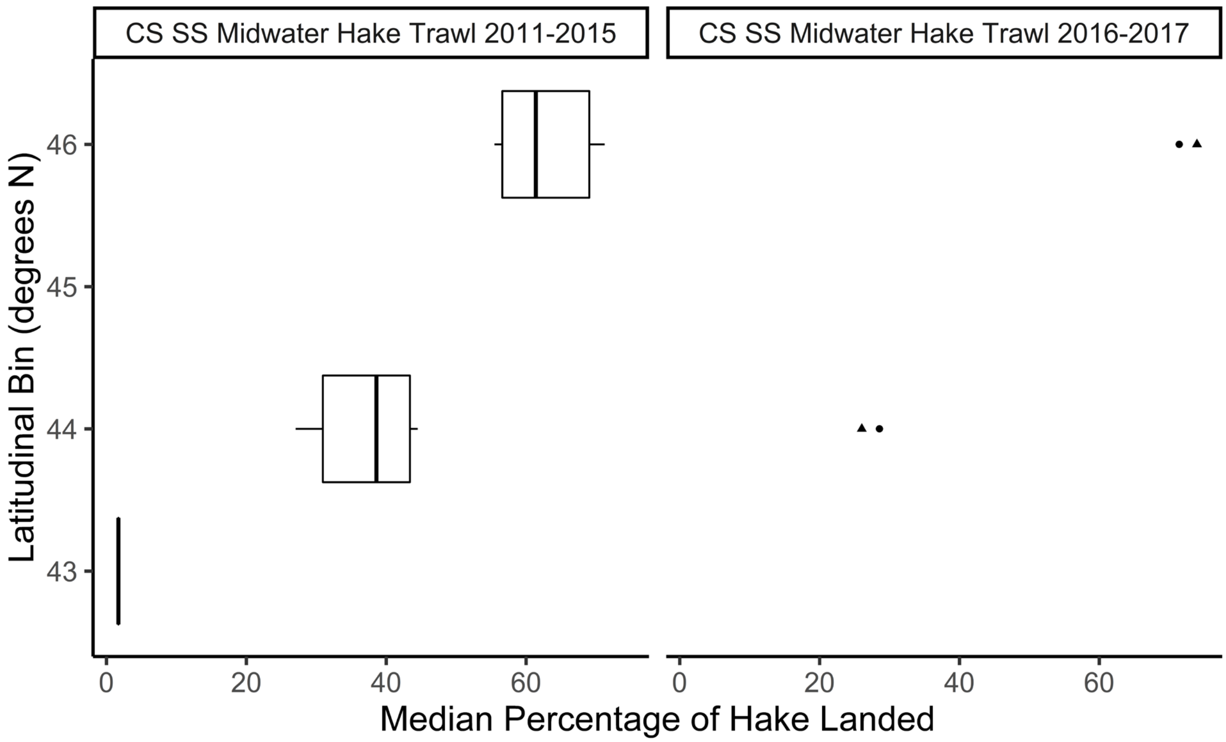


Figure 13. Percentage of retained hake landed in latitudinal bins by shoreside midwater trawl targeting hake; patterns in actual fishing activity are shown in Figure 14. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

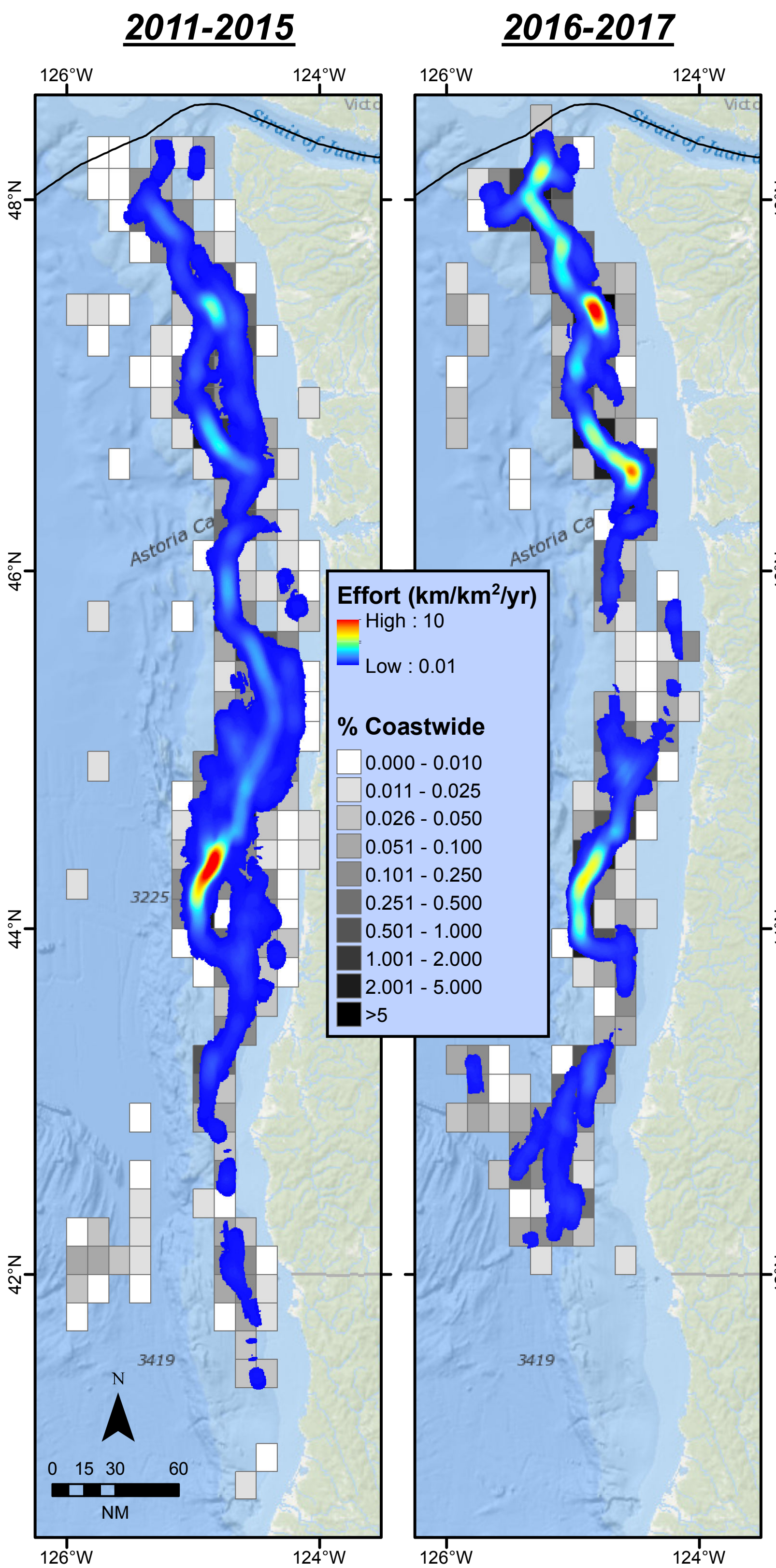


Figure 14. Spatial distribution and intensity of fishing effort by shoreside midwater trawl targeting hake. Intensity (units: $km/km^2/yr$) is depicted by a color ramp of cool (low) to warm (high) colors. To show the overall footprint of fishing for each time period, we display confidential cells in grayscale, with darker (black) tones depicting a higher relative contribution to coastwide effort within 10×10-minute cells.

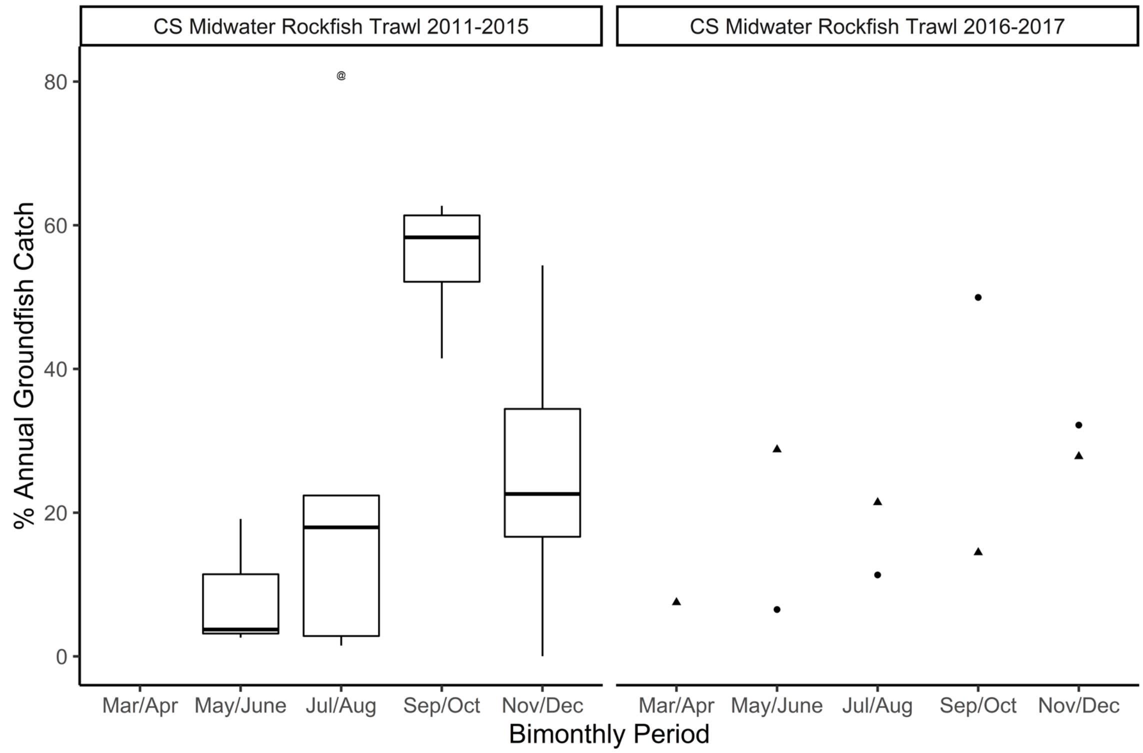


Figure 15. Percentage of retained FMP groundfish landed in bimonthly bins by shoreside midwater trawl targeting rockfish. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

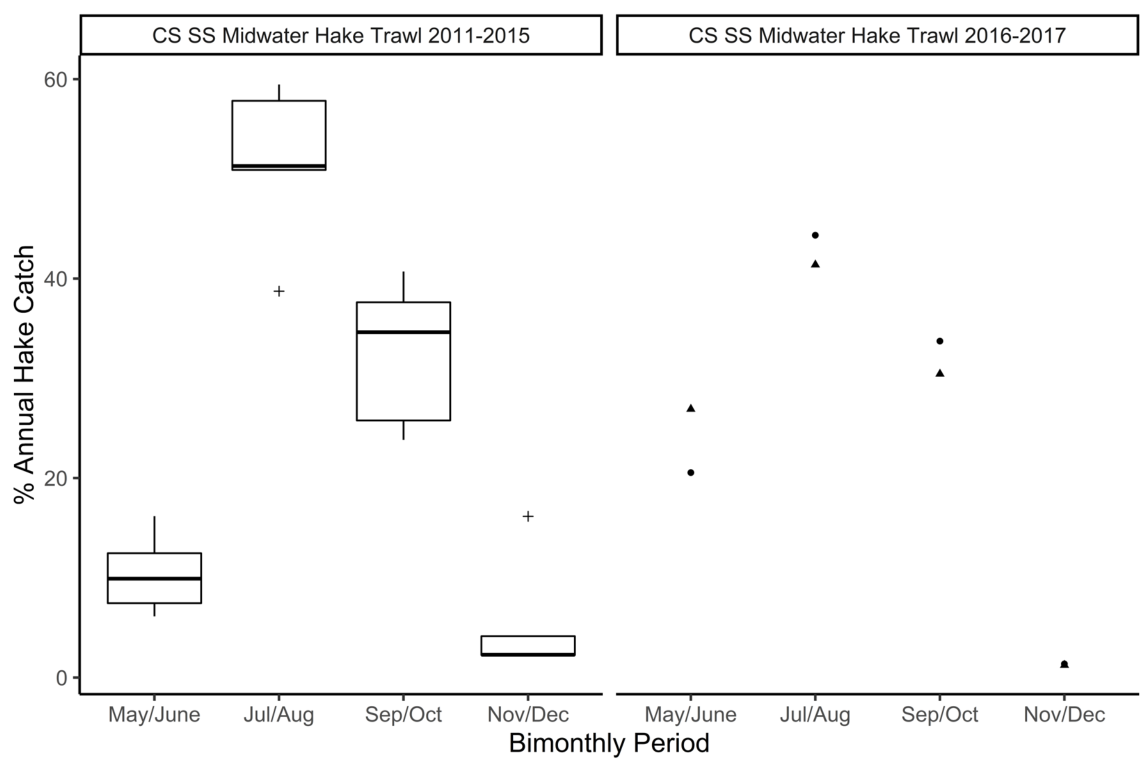


Figure 16. Percentage of retained hake landed in bimonthly bins by shoreside midwater trawl targeting hake. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

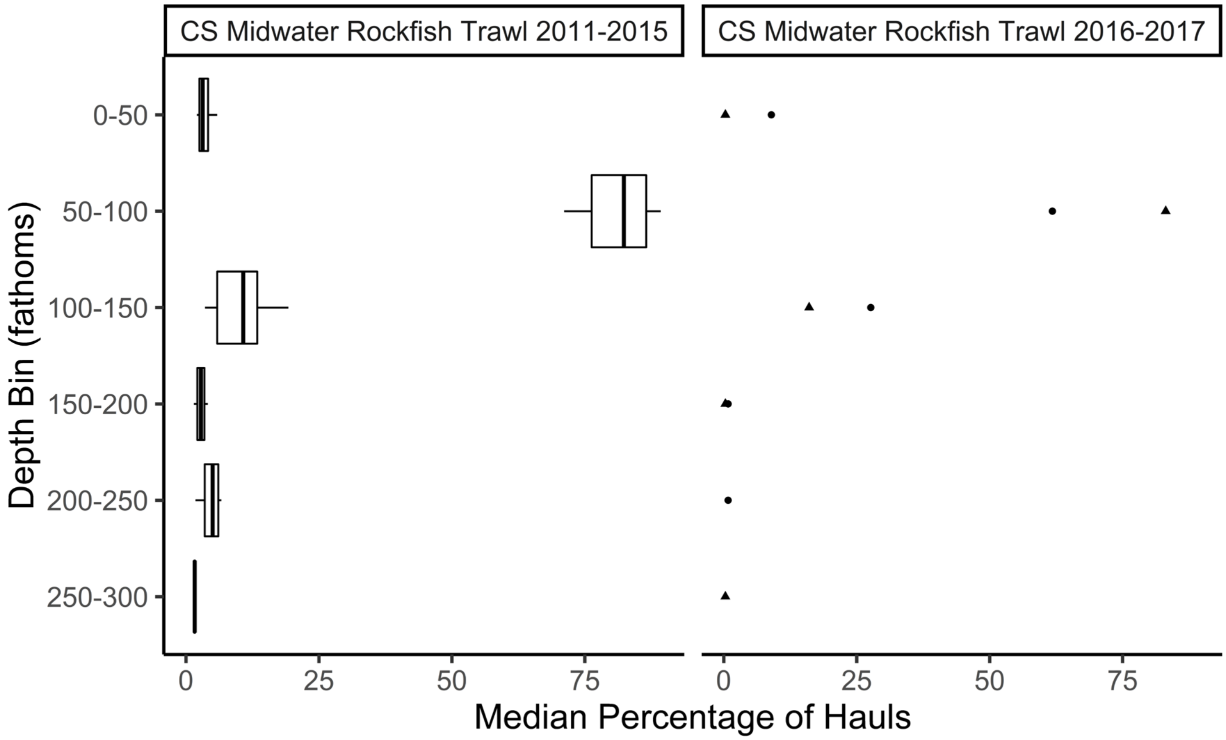


Figure 17. Percentage of shoreside midwater trawl targeting rockfish hauls in 50-fathom depth bins. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

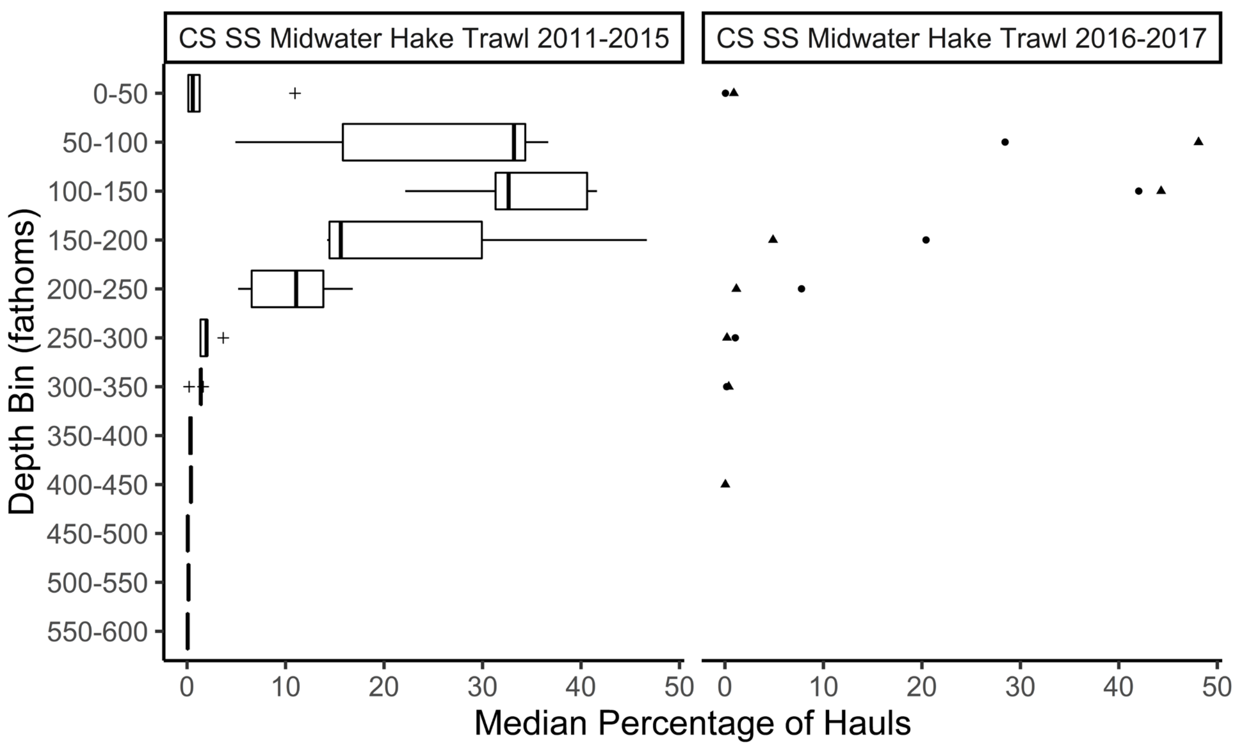


Figure 18. Percentage of shoreside midwater trawl targeting hake hauls in 50-fathom depth bins. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

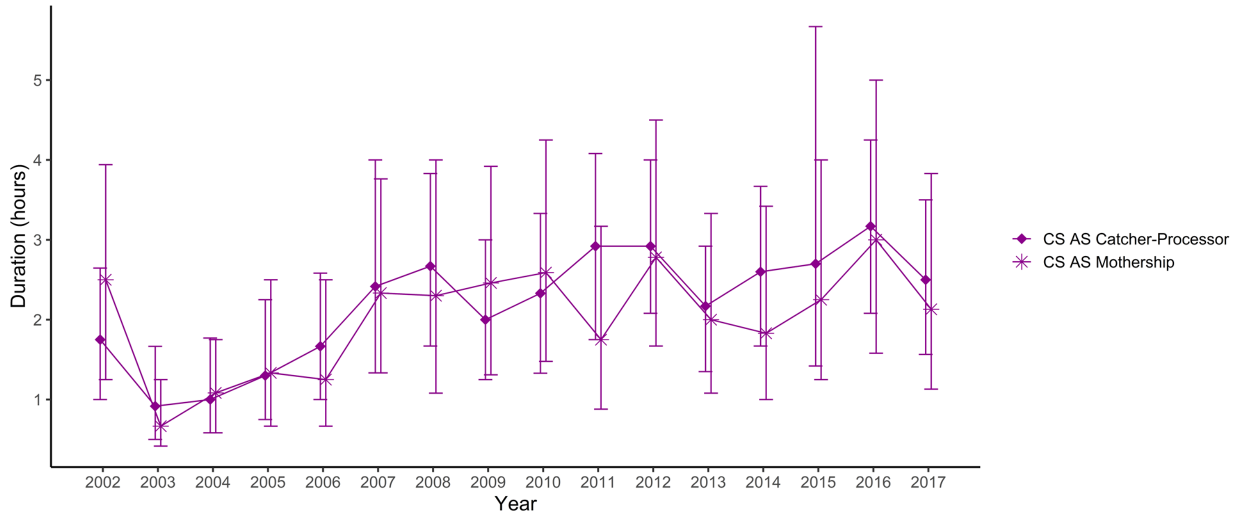


Figure 19. Tow duration (hours) per haul in at-sea midwater trawl sectors. Medians and first and third quartiles for each year are shown.

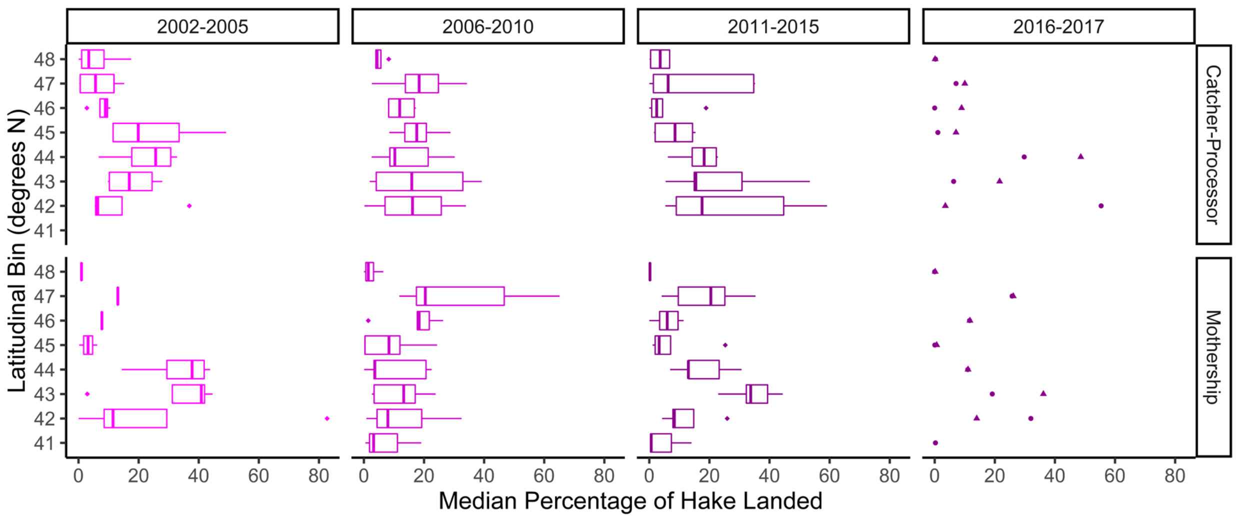


Figure 20. Percentage of retained hake caught in latitudinal bins by at-sea midwater trawl sectors. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

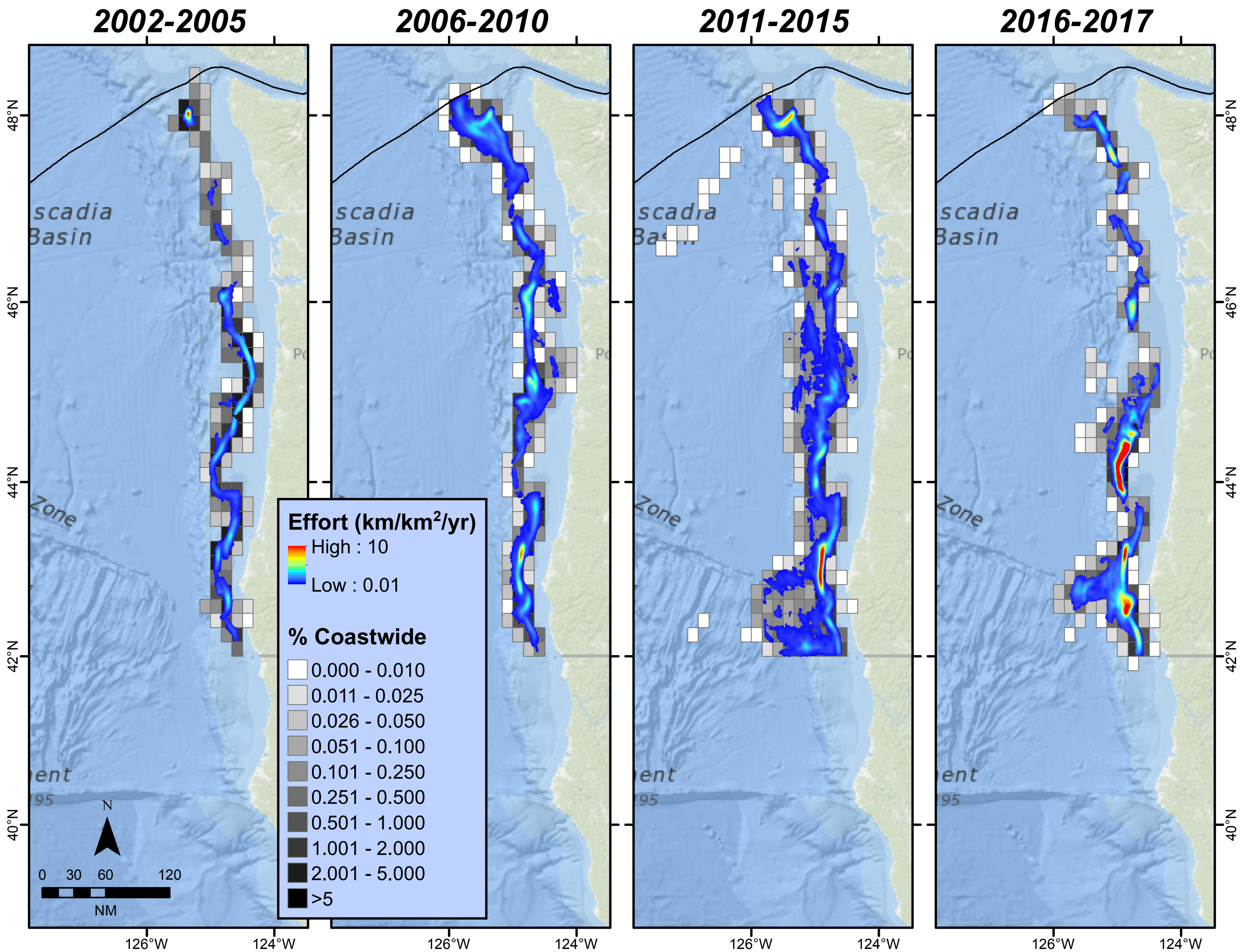


Figure 21. Spatial distribution and intensity of fishing effort by at-sea midwater trawl catcher–processors. Intensity (units: km/km^2/yr) is depicted by a color ramp of cool (low) to warm (high) colors. To show the overall footprint of fishing for each time period, we display confidential cells in grayscale, with darker (black) tones depicting a higher relative contribution to coastwide effort within 10×10-minute cells.

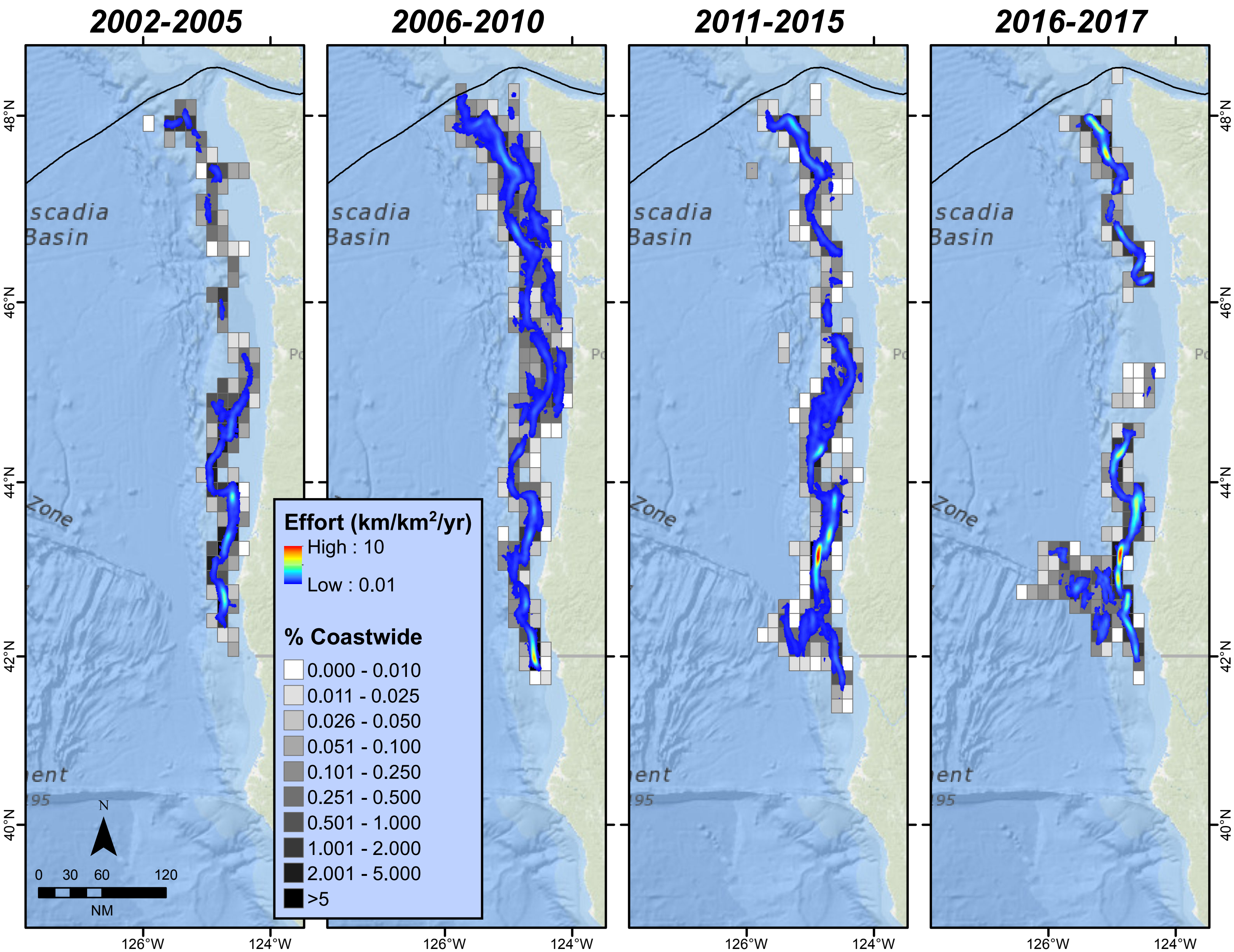


Figure 22. Spatial distribution and intensity of fishing effort by at-sea midwater trawl mothership catcher vessels. Intensity (units: km/km^2/yr) is depicted by a color ramp of cool (low) to warm (high) colors. To show the overall footprint of fishing for each time period, we display confidential cells in grayscale, with darker (black) tones depicting a higher relative contribution to coastwide effort within 10×10-minute cells.

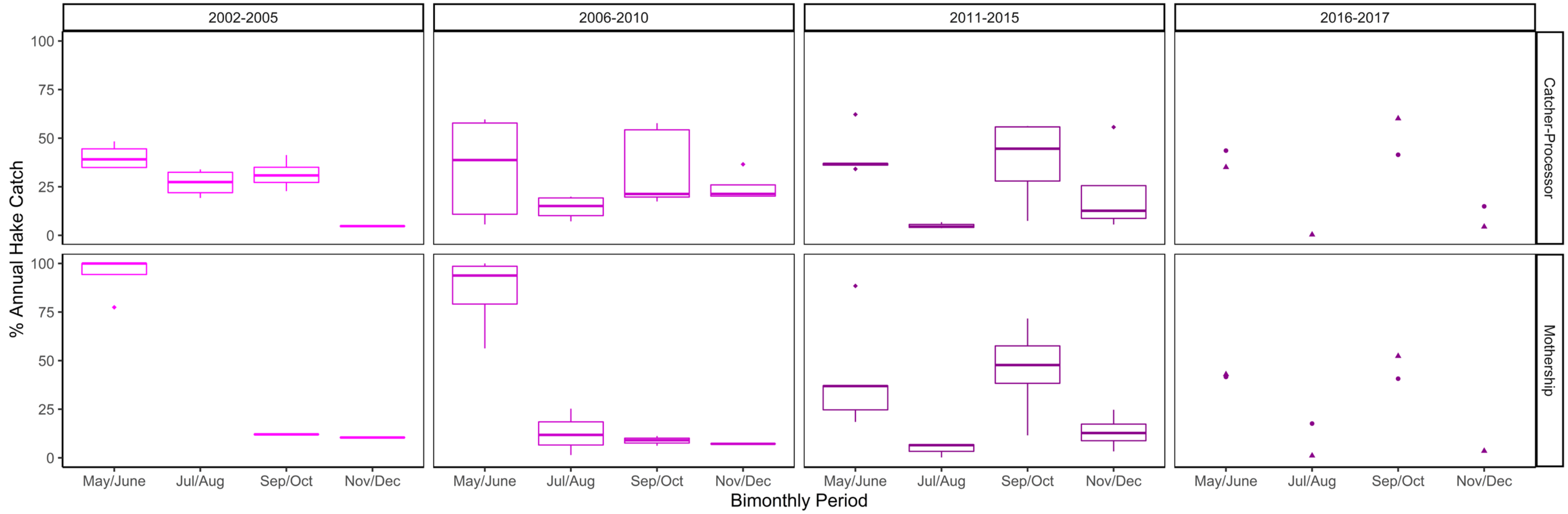


Figure 23. Percentage of retained hake caught in bimonthly bins by at-sea midwater trawl sectors. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

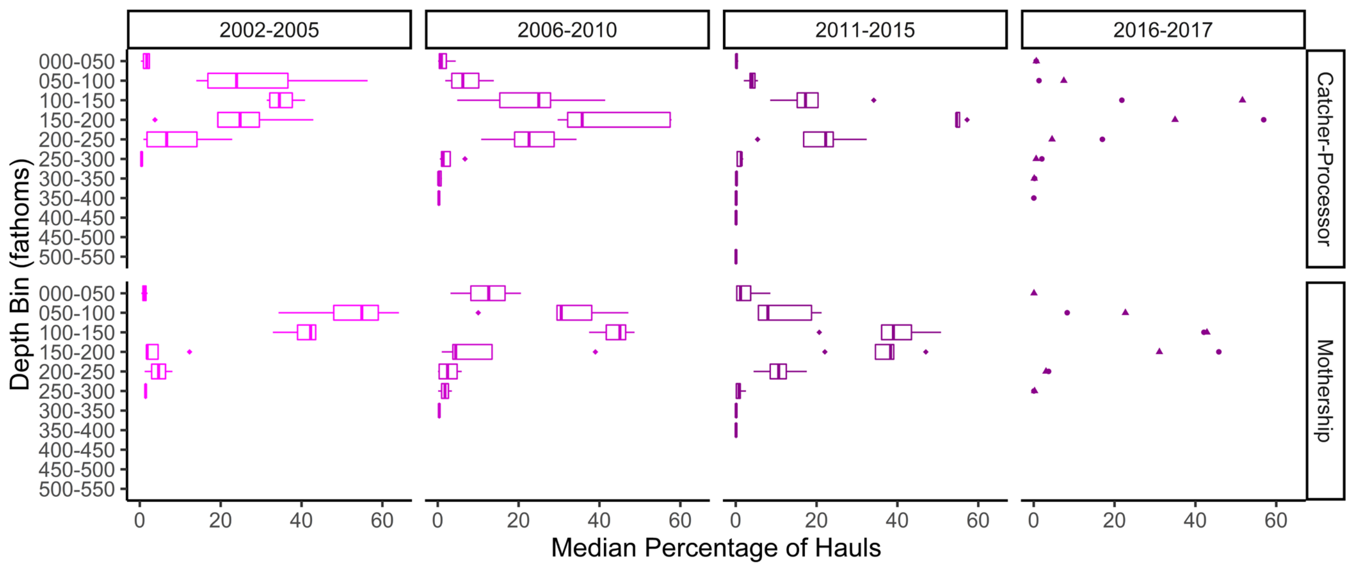


Figure 24. Percentage of at-sea midwater trawl hauls in 50-fathom depth bins. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

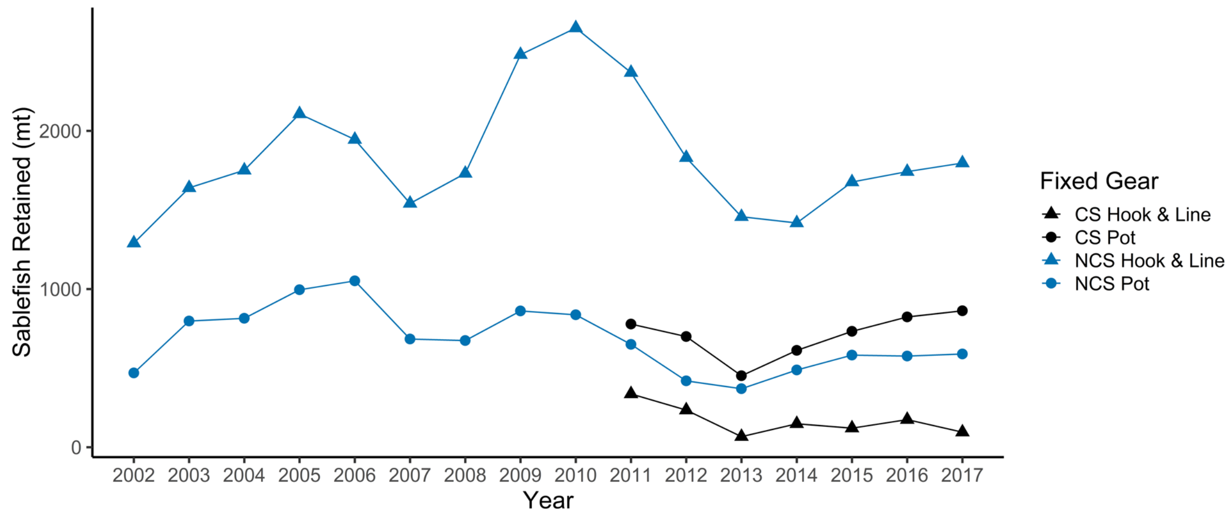


Figure 25. Annual total fleetwide sablefish landings (mt) in fixed gear sectors.

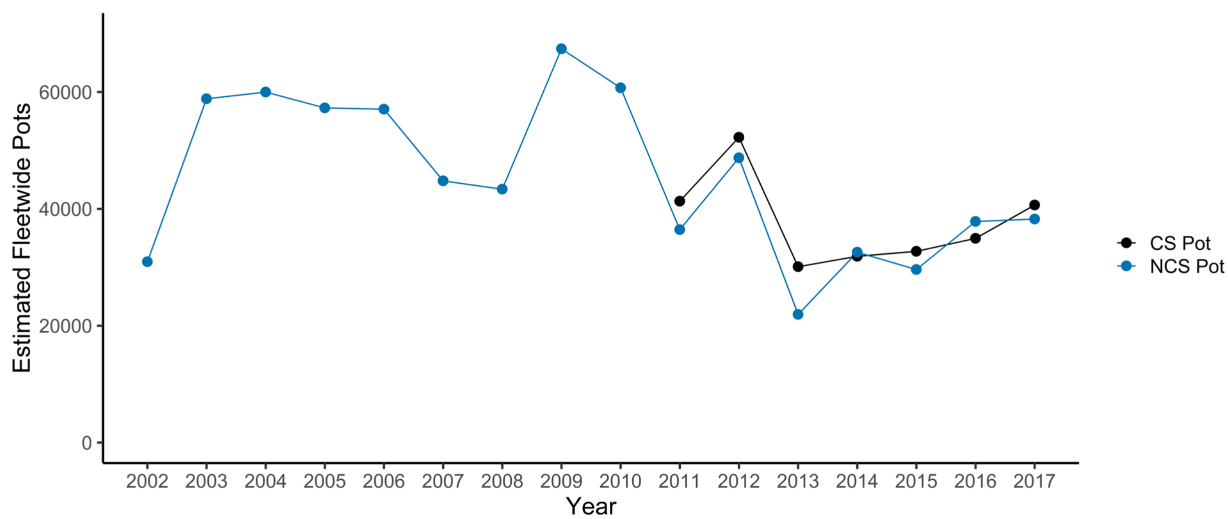


Figure 26. Annual total fleetwide gear units in pot sectors.

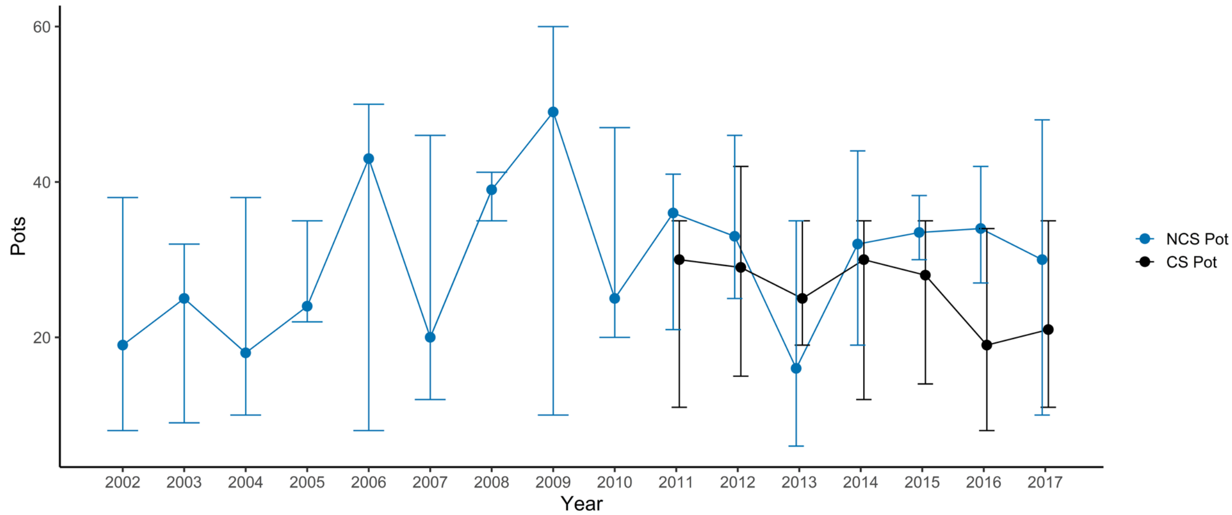


Figure 27. Gear units per haul in pot sectors. Medians and first and third quartiles for each year are shown.

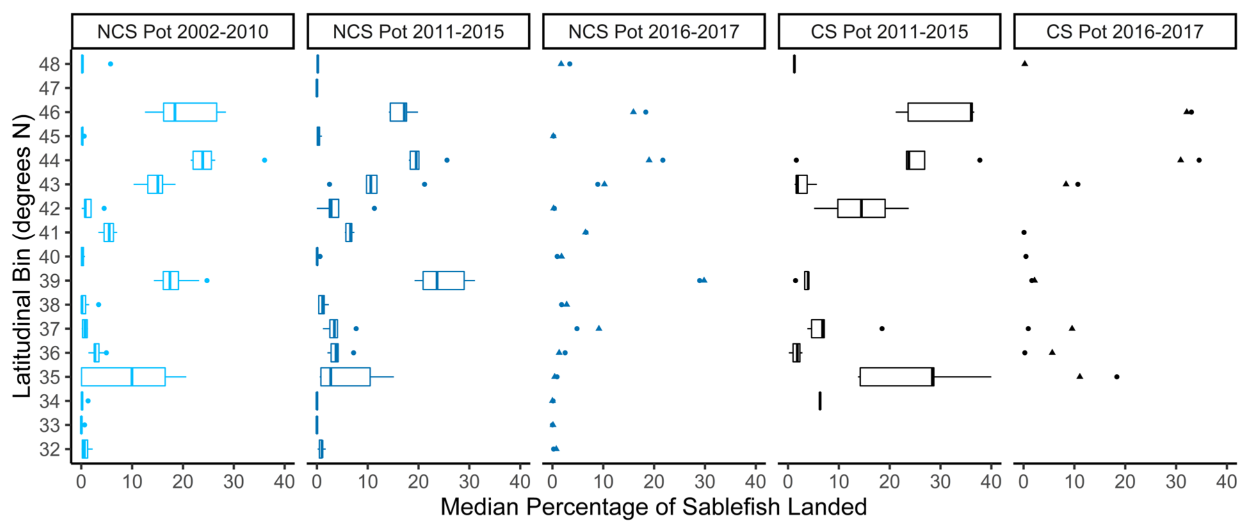


Figure 28. Percentage of retained sablefish landed in latitudinal bins by pot sectors; patterns in actual fishing activity are shown in Figures 29 and 30. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017. Catch share 2016–17 data are not shown to maintain confidentiality, because fewer than three vessels were active in some of the seasonal strata.

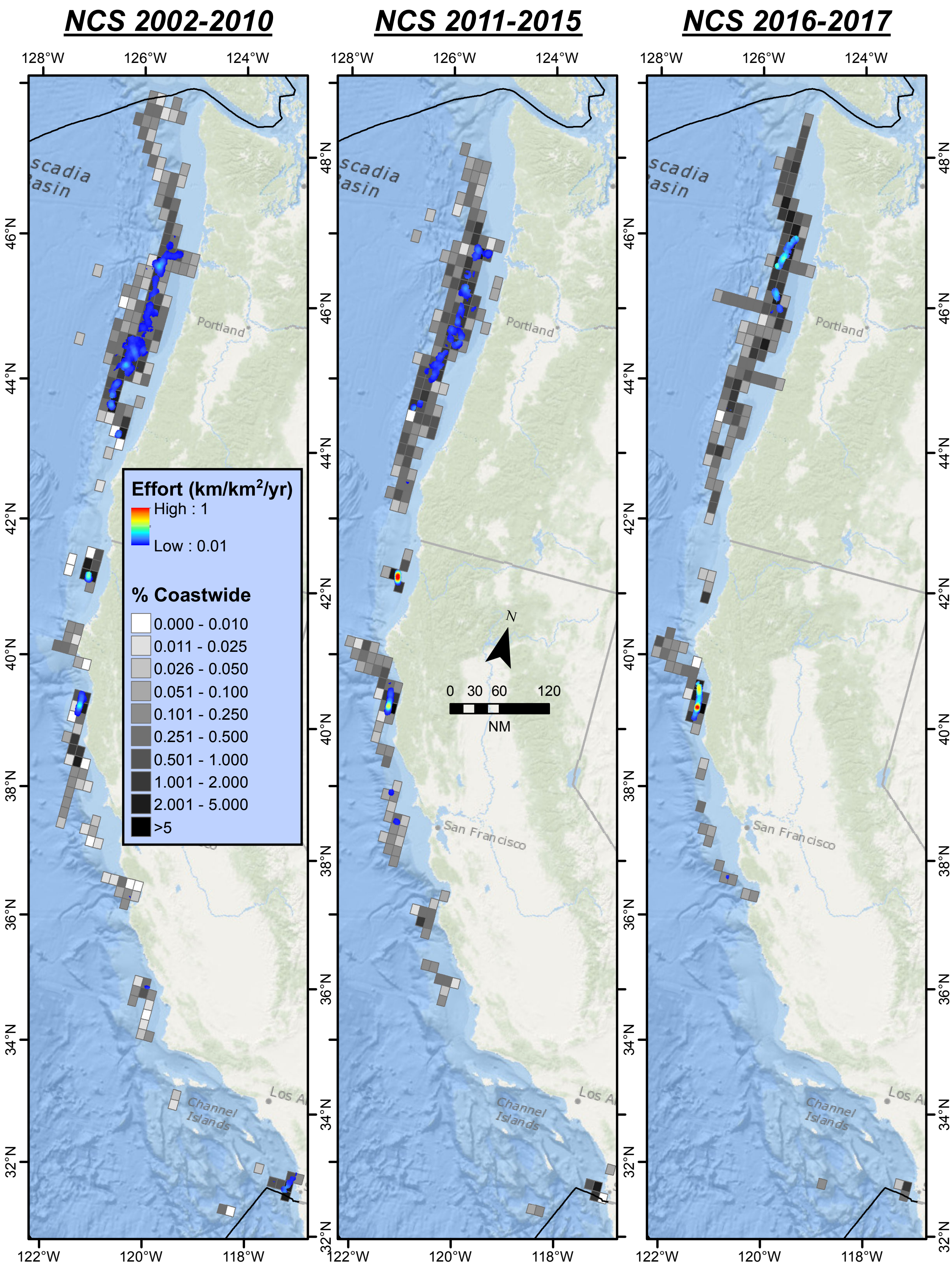


Figure 29. Spatial distribution and intensity of fishing effort by the non-catch share pot sector. Intensity (units: km/km^2/yr) is depicted by a color ramp of cool (low) to warm (high) colors. To show the overall footprint of fishing for each time period, we display confidential cells in grayscale, with darker (black) tones depicting a higher relative contribution to coastwide effort within 10×10-minute cells.

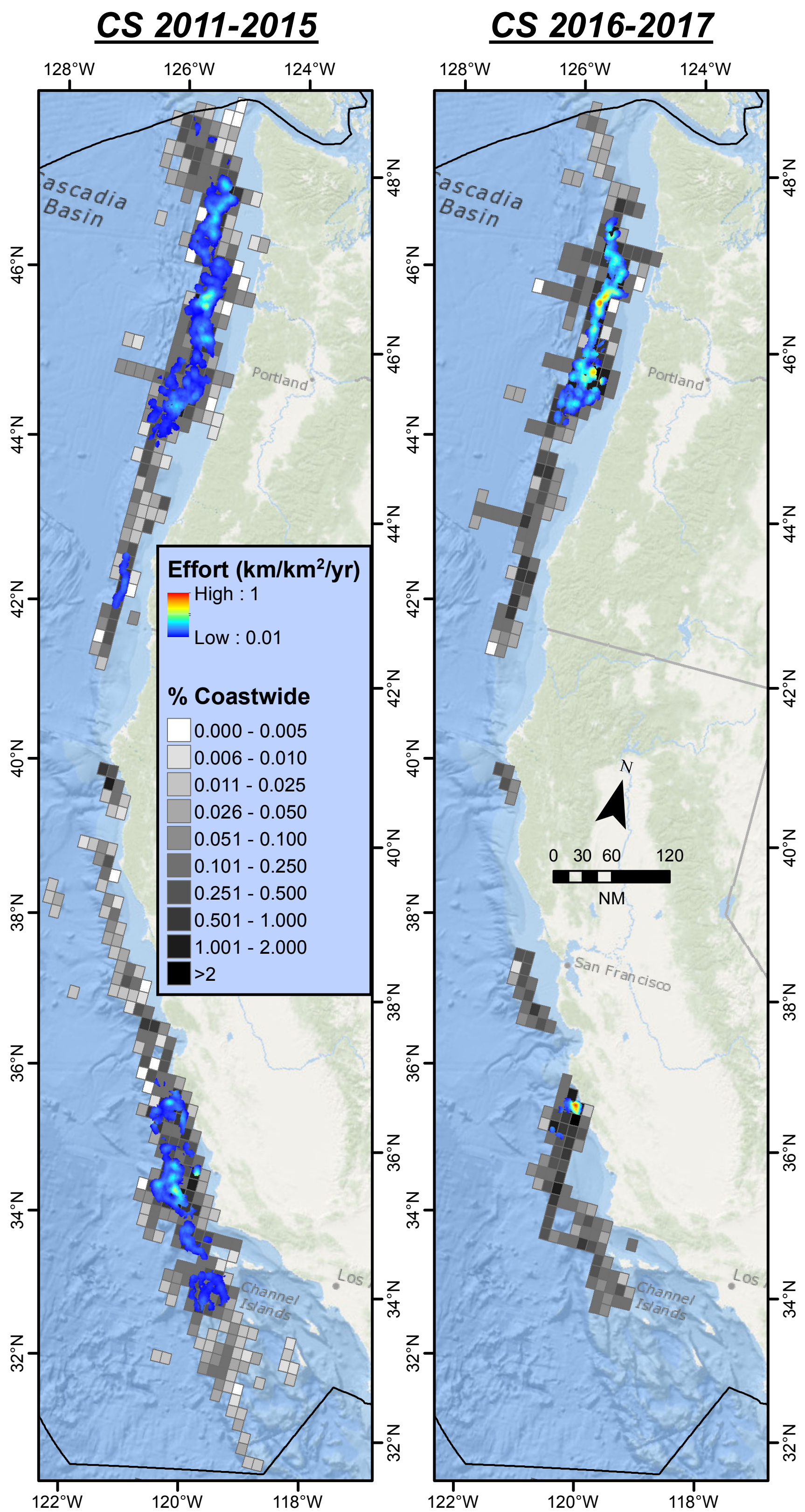


Figure 30. Spatial distribution and intensity of fishing effort by the catch share pot sector. Intensity (units: km/km^2/yr) is depicted by a color ramp of cool (low) to warm (high) colors. To show the overall footprint of fishing for each time period, we display confidential cells in grayscale, with darker (black) tones depicting a higher relative contribution to coastwide effort within 10×10-minute cells.

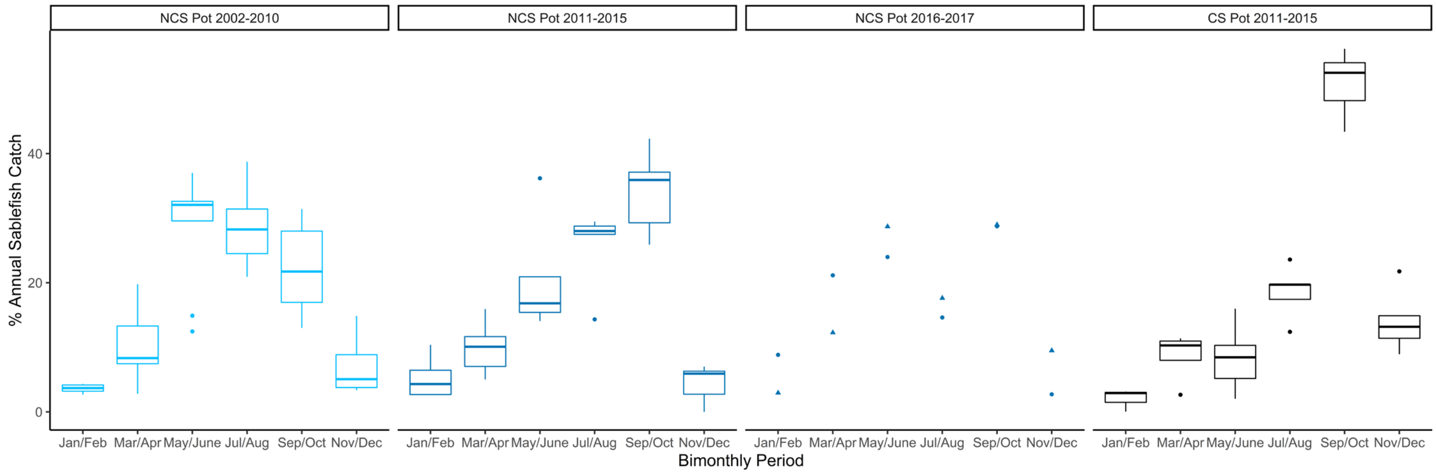


Figure 31. Percentage of retained sablefish landed in bimonthly bins by pot sectors. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017. The NCS pot fleet (2002-2010) is shown here and in other figures in a different color to emphasize potential differences before and after CS implementation and the introduction of gear switching.

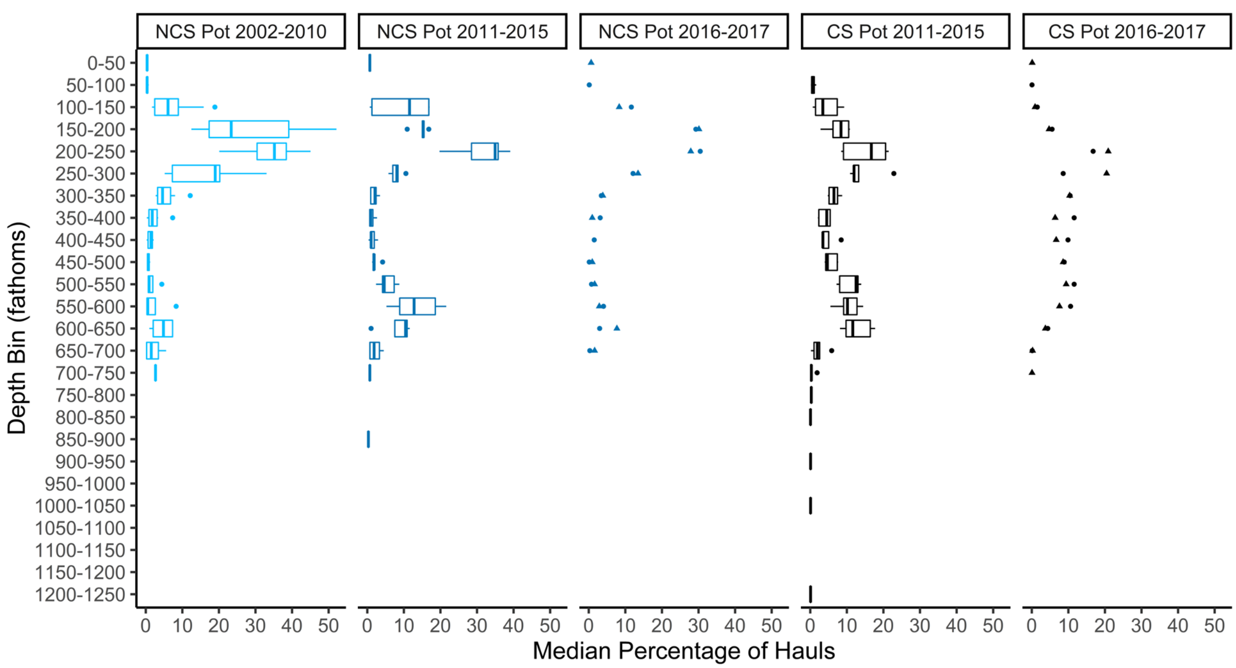


Figure 32. Percentage of observed pot hauls in 50-fathom depth bins. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

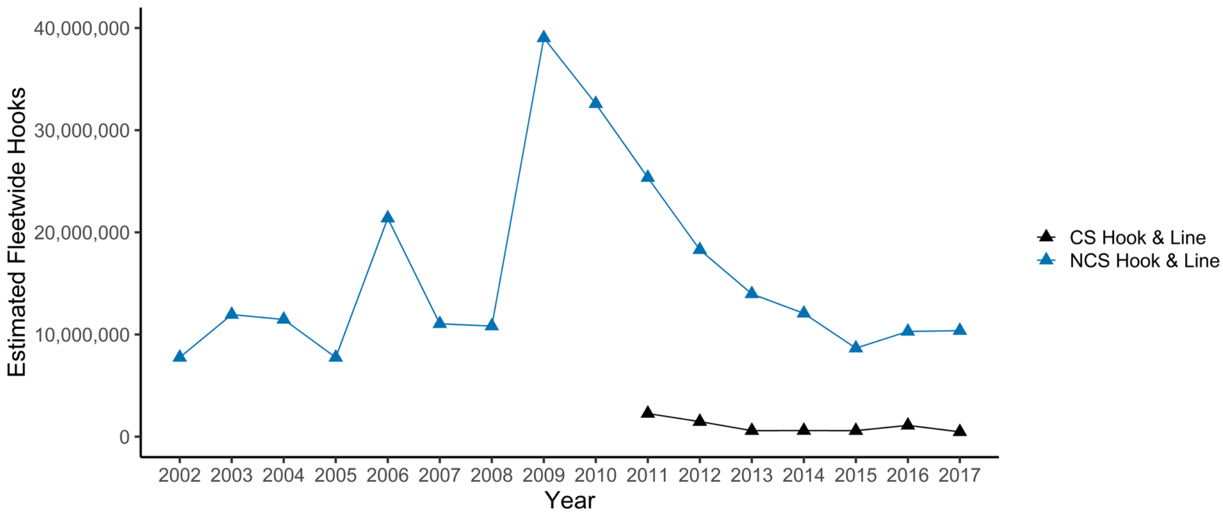


Figure 33. Annual total fleetwide gear units in hook-and-line sectors.

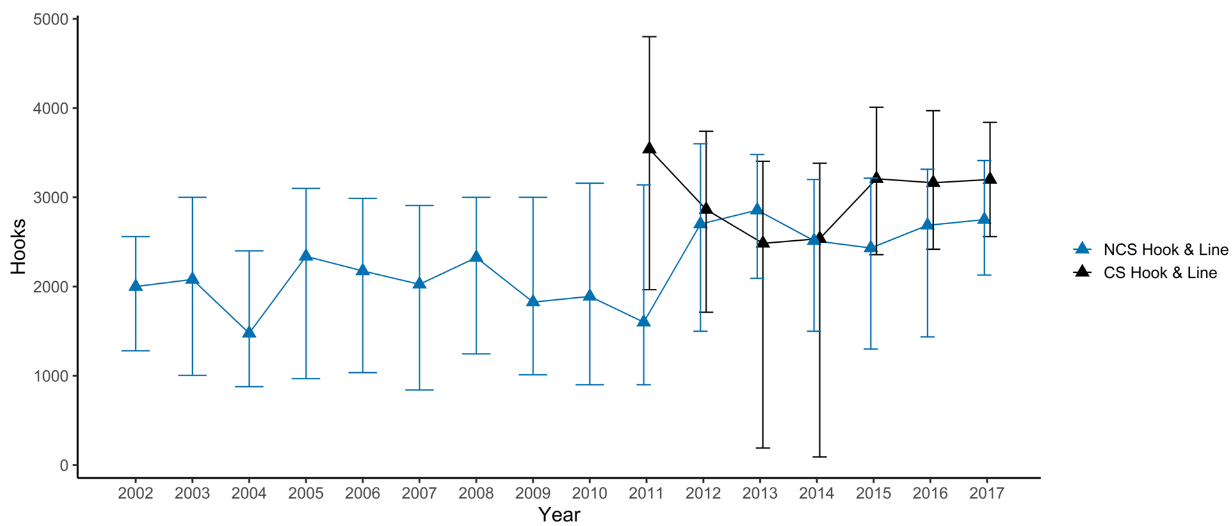


Figure 34. Gear units per haul in hook-and-line sectors. Medians and first and third quartiles for each year are shown.

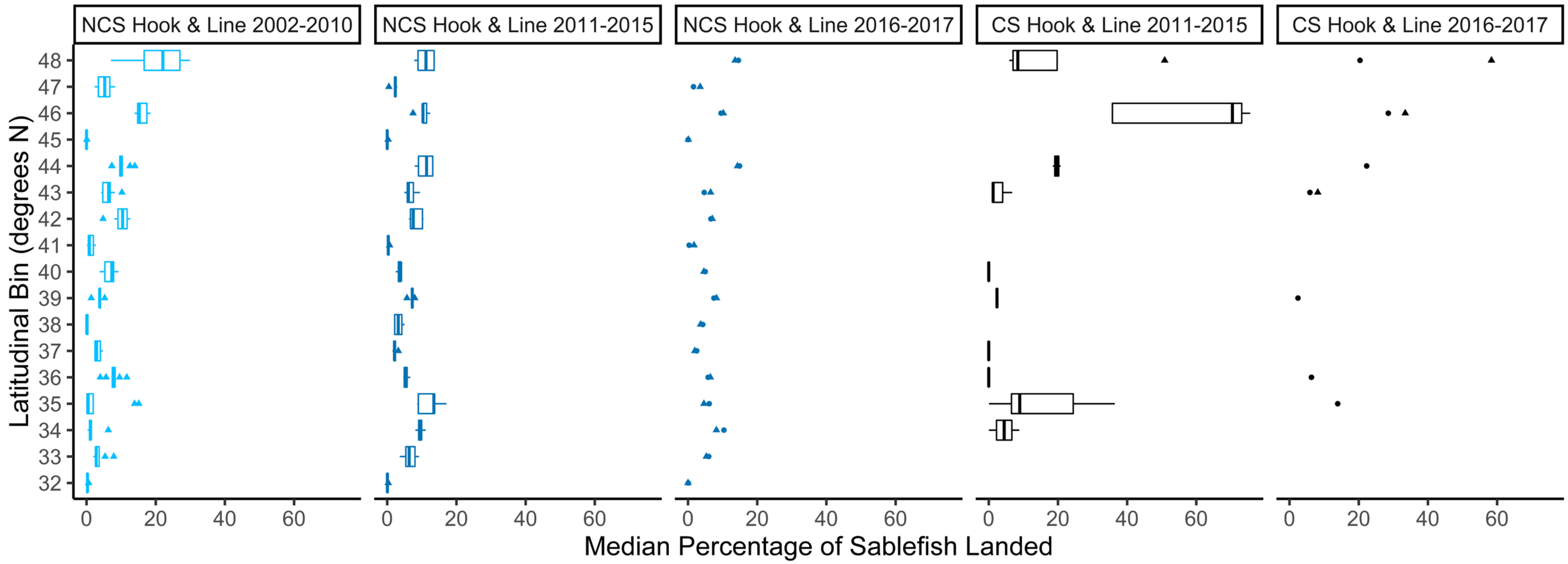


Figure 35. Percentage of retained sablefish landed in latitudinal bins by hook-and-line sectors; patterns in actual fishing activity are shown in Figures 36 and 37. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

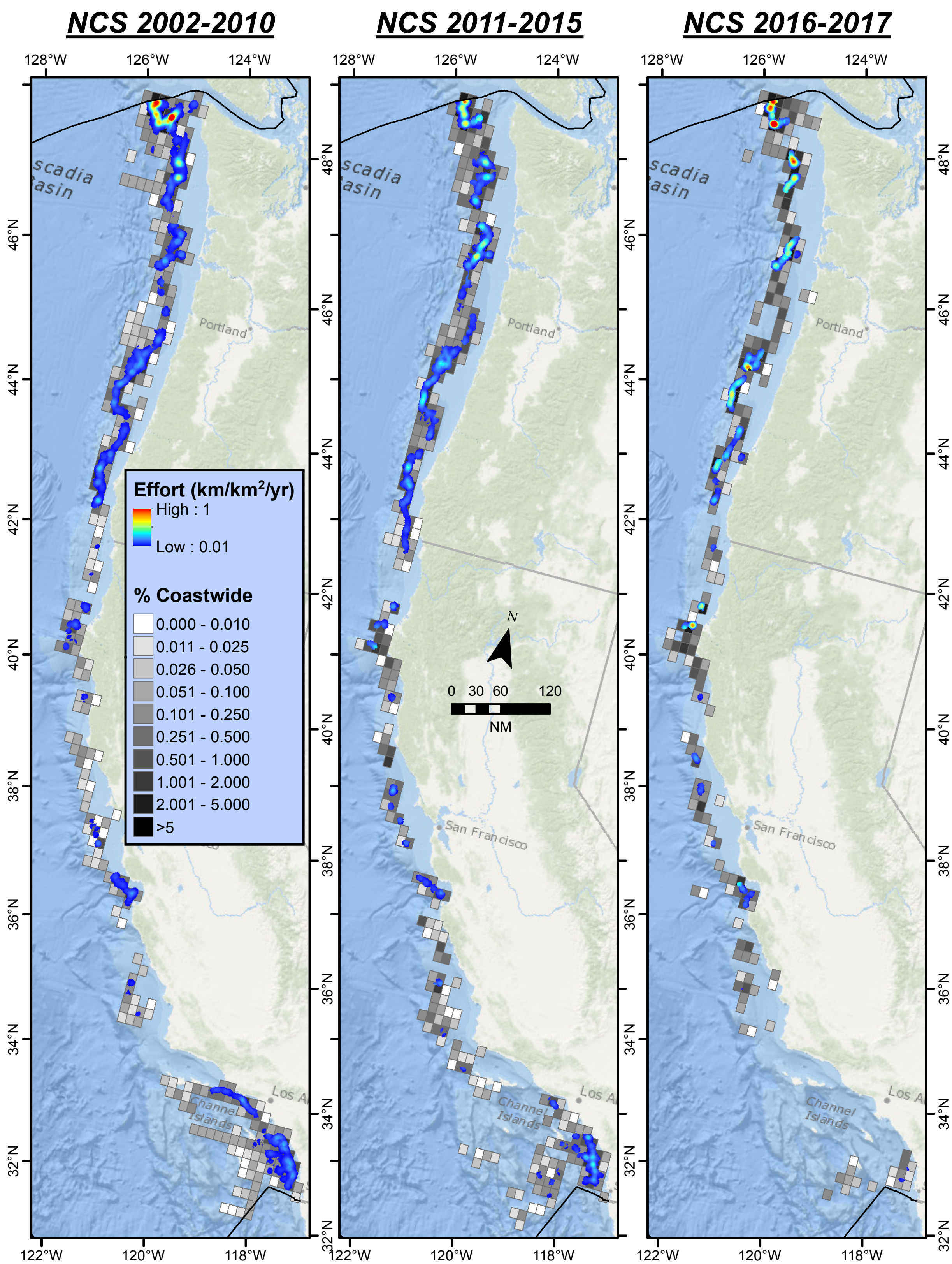


Figure 36. Spatial distribution and intensity of fishing effort by the non-catch share hook-and-line sector. Intensity (units: km/km^2/yr) is depicted by a color ramp of cool (low) to warm (high) colors. The overall footprint of fishing for each time period is depicted in grayscale, with darker (black) tones depicting a higher relative contribution to the coastwide effort within 10×10-minute cells.

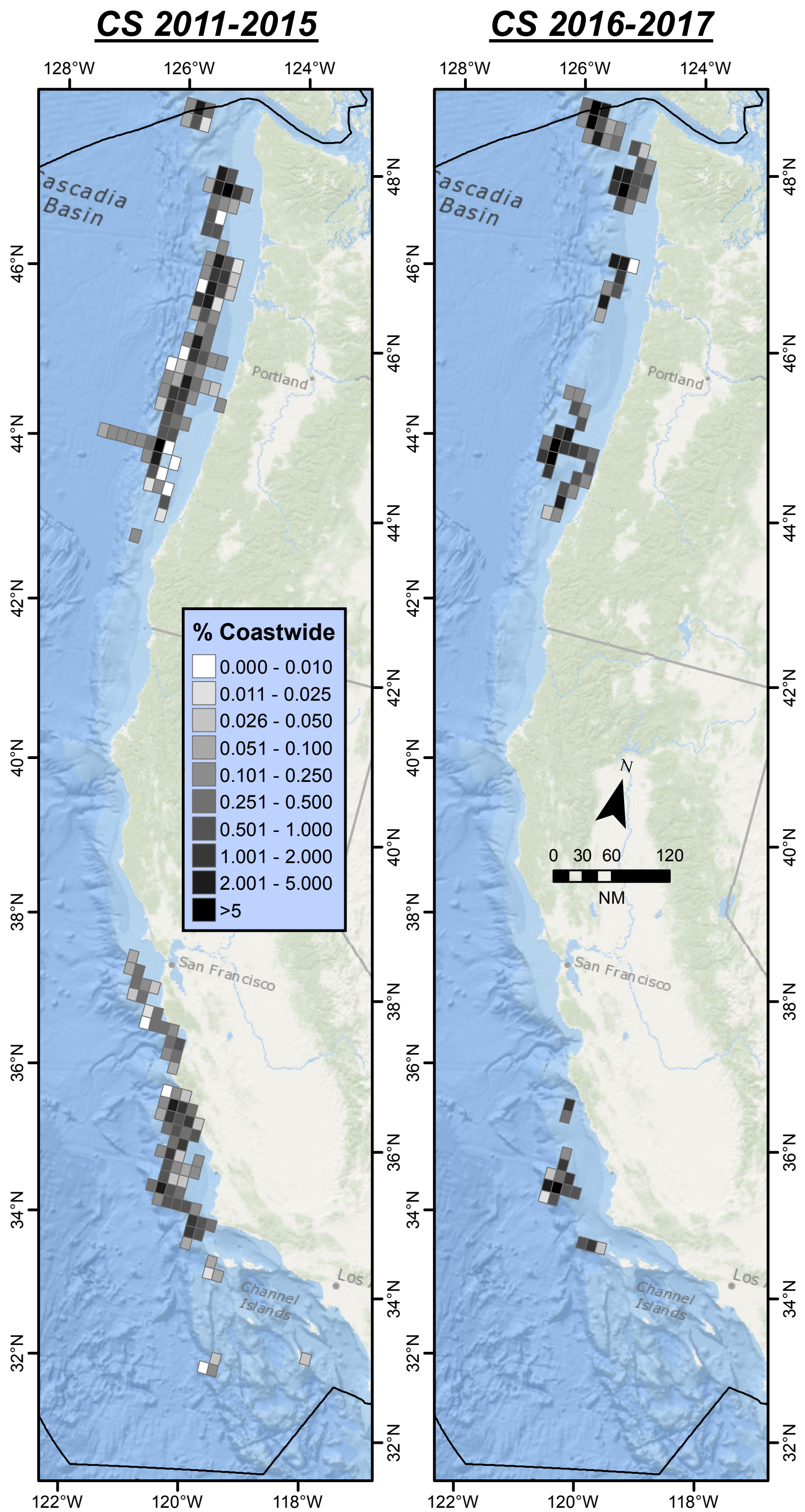


Figure 37. Spatial distribution of fishing effort by the catch share hook-and-line sector. The overall footprint of fishing for each time period is depicted in grayscale, with darker (black) tones depicting a higher relative contribution to the coastwide effort within 10×10-minute cells.

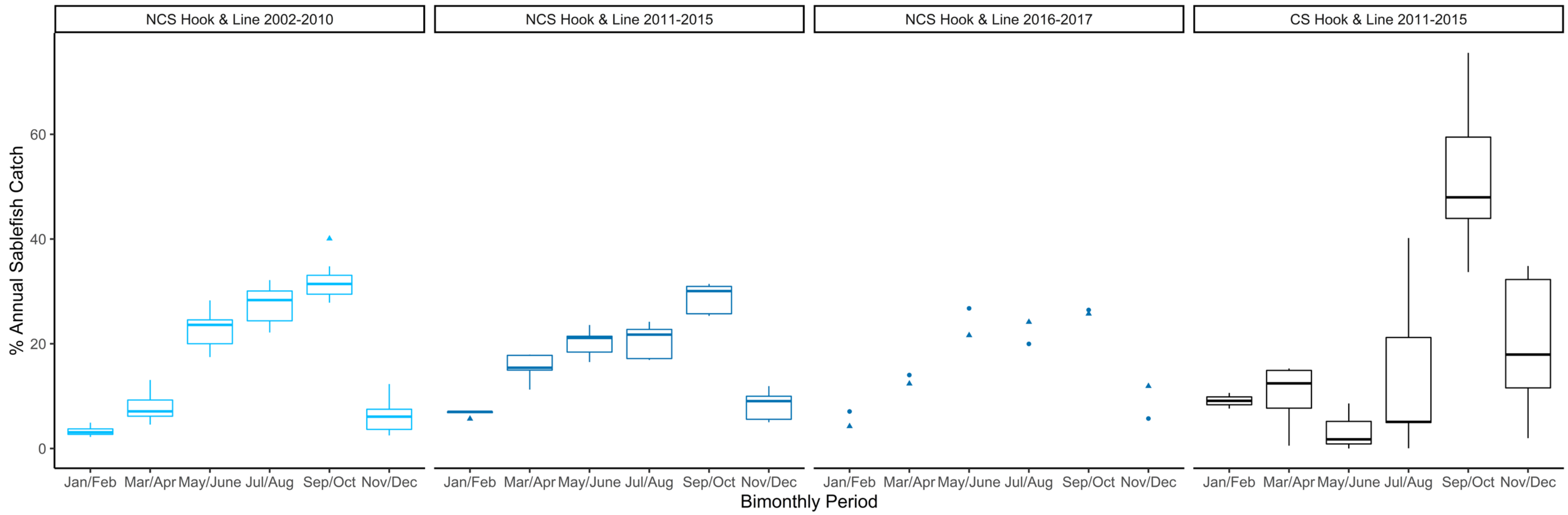


Figure 38. Percentage of retained sablefish landed in bimonthly bins by hook-and-line sectors. Catch share 2016–17 data are not shown to maintain confidentiality, because fewer than three vessels were active in some of the seasonal strata. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

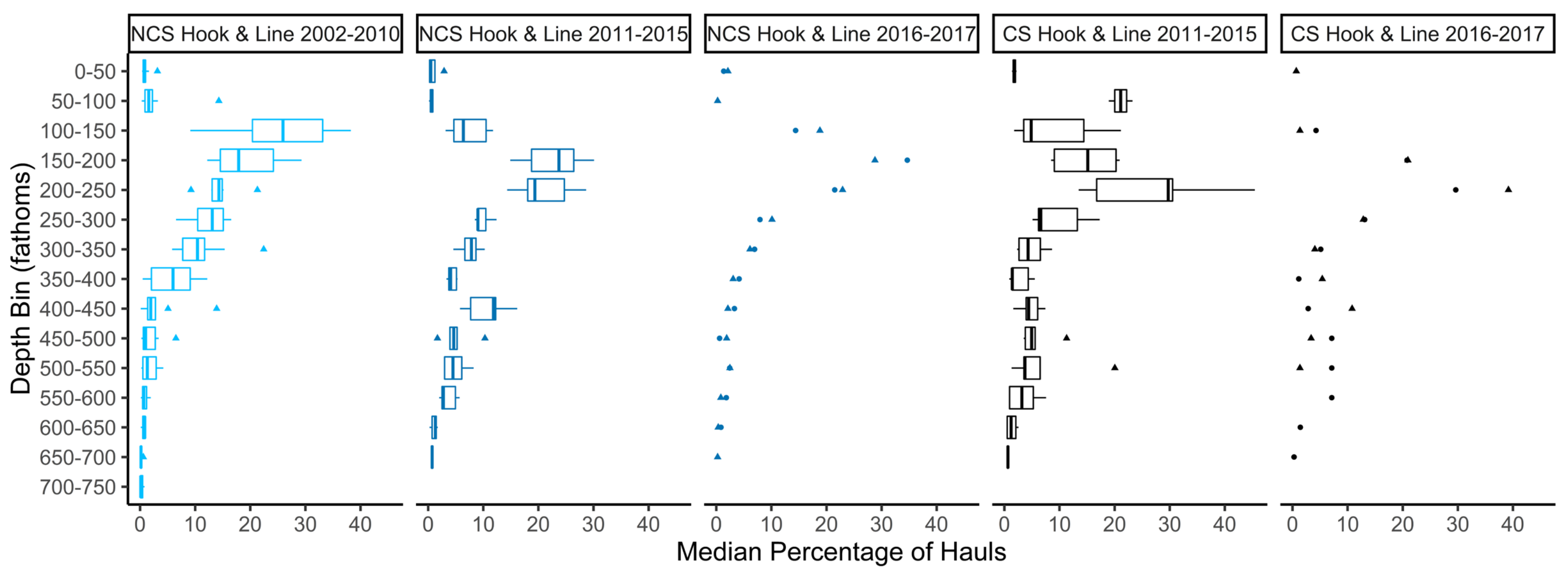


Figure 39. Percentage of observed hook-and-line hauls in 50-fathom depth bins. Medians and first and third quartiles are shown for each time period except the most recent, when circles represent 2016 and triangles represent 2017.

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List of Species

cowcod rockfish	*Sebastes levis*
Pacific hake	*Merluccius productus*
sablefish	*Anoplopoma fimbria*
widow rockfish	*Sebastes entomelas*
yelloweye rockfish	*Sebastes ruberrimus*
yellowtail rockfish	*Sebastes flavidus*

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