Accounting for and Managing All Pacific Halibut Removals

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Abstract

The International Pacific Halibut Commission (IPHC or Commission) has the responsibility for conservation and yield from the Pacific halibut resource. In 2014, the Commission requested that the staff prepare a discussion paper on the biological and management issues involved with managing the removals of all sizes of Pacific halibut, particularly the explicit accounting for mortality of halibut less than 26 inches in length (U26). This report develops a conceptual extension to the current harvest policy which allows for direct evaluation of U26 mortality, and uses the 2013 results to compare harvest policy calculations with alternative distributions of removals among bycatch and the directed fishery.

Current harvest policy calculations do not respond to changes in projected annual U26 bycatch mortality; however, changes in bycatch removals (including both the O26 and U26 mortality) are found to have an approximate pound-for-pound effect on directed fishery yields when all other sources of mortality are considered. These effects are quantified and included in projection tables that summarize all sources and sizes of halibut mortality. This report outlines relevant management considerations, procedural constraints, and promising paths for future IPHC processes. Major sources of uncertainty relating to various components of these analyses are discussed, and potential data improvements that could reduce this uncertainty are also identified.

Introduction

The International Pacific Halibut Commission (IPHC or Commission) has the responsibility for conservation and yield from the Pacific halibut resource. All removals from the halibut resource are in the form of either directed (commercial, recreational, subsistence, ceremonial) or non-directed (bycatch mortality from releases of fish in non-target fisheries and incidental mortality of fish in directed fisheries that must be released by regulation, or wastage) fishing activities[1]. While mortality associated with the directed fisheries is under the management authority of the Commission, bycatch mortality is not. Rather, bycatch mortality is controlled by federal agencies of the two contracting parties (Canada and the United States).

Accounting for and managing all sizes of removals of Pacific halibut has been an increasingly important topic of discussion over the last decade, as directed fishery removals have been reduced, and non-directed removals have become relatively more important to both biological and fishery objectives. In recent years, mortality associated with bycatch in non-target fisheries as well as wastage in the commercial halibut fishery has comprised more than than 20% of the total removals (by weight) from the coastwide stock. In the Bering Sea and Aleutian Islands (BSAI), bycatch represents a much larger proportion: in Area 4CDE in 2013, 66% of the total removals were bycatch. The biological characteristics of these removals differ importantly from directed fishery landings: bycatch and wastage are predominantly comprised of fish less than 32 inches in length (U32) and, for bycatch, many are less than 26 inches in length (U26). This means that an equal weight of removals from bycatch or wastage will correspond to a much larger number of fish than in the directed commercial fishery. Commission staff have produced several analyses of the potential lost yield associated with mortality of U32 and U26 halibut, as well as the implications for equilibrium stock levels. However, previous analyses have not been framed in terms of application of the harvest policy and calculation of annual catch limits.

The IPHC's annual stock assessment, utilizing an ensemble of coastwide population dynamics models, includes complete accounting of estimated removals of all sizes of fish from the halibut stock. The results from the stock assessment have been summarized, since 2013, in a decision table evaluating the trade-off between potential benefits, in the form of fishery removals, and risks to the future stock and fisheries. An important reference component of the annual decision table is the Blue Line, or the mortality associated with the application of the IPHC's current harvest policy. The current harvest policy provides direct area-specific accounting for all removals of fish greater than 26 inches in length (O26). This has been the case since 2011, when the policy was extended from previous calculations that explicitly considered only O32 removals. In the current harvest policy mortality of U26 halibut is implicitly assumed to be present at a constant rate, which is included in the target harvest rates: the target harvest rates are lower than they would be in the absence of U26 mortality. However, U26 mortality is not included in the quantitative evaluation of annual catch limits and there has been no way to directly compare these removals with those of O26 fish. This means that the potential effects of

[1] This report uses the terms "removals" and "mortality" interchangeably to refer to dead fish. Further, all reference to bycatch and wastage indicates only the portion of those fish that subsequently die and, unless stated specifically, does not include fish that have been handled and subsequently survived.

changes in annual U26 mortality are not directly evaluated in the IPHC's annual process, and are only observed years later when they have been fully realized in the stock dynamics and are reflected in the assessment estimates of stock size and productivity. This system of accounting has not provided a clear understanding of the effects of U26 mortality to decision makers and resource users.

At its 2014 Annual Meeting, the Commission considered recent progress by its Halibut Bycatch Work Group. In particular, the Commission evaluated issues associated with levels of bycatch mortality and their impact on halibut population dynamics and yield, based on current understanding of the stock. As a result of its deliberations, the Commission requested that the staff prepare a discussion paper on the biological and management issues involved with managing the mortality of all sizes of Pacific halibut. The essence of this request is to bring the accounting for mortality of U26 fish into the same framework as that for mortality of O26 fish.

Subsequent to this direction to staff from the Commission, the North Pacific Fishery Management Council (NPFMC) began consideration of its management program for bycatch mortality of halibut in the Bering Sea/Aleutian Islands (BSAI) region. The NPFMC transmitted to the Commission a request for a summary of the status of the halibut stock and an estimate of the impacts of halibut bycatch mortality in the BSAI area on the halibut resource and its fisheries. IPHC staff had previously conducted similar analyses for the BSAI and the Gulf of Alaska (GOA) regions (Hare et al. 2012, Hare and Williams 2013). In particular, Hare et al. (2012) examined the issue of total mortality impacts on halibut stock management in a more restricted framework, involving maintenance of existing protections for stock spawning biomass afforded by the IPHC harvest policy.

The IPHC staff took the opportunity presented by the Commission request and the 2014 NPFMC request to begin development of a new total mortality accounting framework. This report extends the material prepared for the North Pacific Fishery Management Council (NPFMC or Council), and presented at its June, 2014 meeting in Nome, Alaska (Stewart et al. 2014). That document considered specifically: 1) the status of the Pacific halibut (*Hippoglossus stenolepis*) resource in the Bering Sea and Aleutian Islands (BSAI), and 2) the impact of Prohibited Species Catch (PSC, or bycatch) in the BSAI trawl and fixed-gear groundfish fisheries on halibut stock biomass, reproductive potential, and the short- and long-term yields to the directed halibut fisheries.

This report develops a conceptual extension to the current harvest policy which allows for direct evaluation of U26 mortality impacts in the context of standard harvest policy results. It uses the 2013 results for comparison of alternative distributions of removals for bycatch and the directed fishery. It also outlines potential management considerations, procedural constraints, and promising paths for future IPHC processes. Major sources of uncertainty relating to various components of these analyses are discussed, and potential data improvements that could reduce this uncertainty are identified. Updated information following the framework presented here will be provided for the IPHC Commissioners and stakeholders consideration during the 2014 annual process.

History of IPHC management

The IPHC has managed the directed commercial halibut fishery since its inception in 1923. In the early decades, management focused on fishing gear and effort rather than total fishery removals. In 1940, a five pound minimum size limit (net weight) was instituted, and this was converted into a (nearly equivalent) 26-inch minimum size limit in 1944. In 1963, this size limit was extended to the Bering Sea. In 1973, a 32-inch minimum size limit was adopted for all existing commercial halibut fisheries, which included directed longline as well as an incidental troll fishery (Myre, 1973). This management action occurred at a time when size-at-age was very large, and therefore fish grew beyond the legal size limit much more rapidly than in either earlier or later periods. With the change in the minimum size limit came increased and appreciable fishery wastage, mortality associated with released fish that could not be legally landed.

Pacific halibut are caught in several directed fisheries including commercial longline, personal use and subsistence, and sport fisheries. Regulations of the IPHC prohibit United States fishermen from retaining halibut captured with gear other than hook and line. Similar IPHC and Canadian regulations apply in Canada with the exception that allows fishers licensed to catch sablefish in waters off British Columbia, using sablefish trap gear, to retain halibut under the quota share program up to bycatch limits as defined by Canadian regulations. The allowance of sablefish trap gear is part of an integrated groundfish fishery plan where most species are under individual quota shares and fishers are responsible for the mortality of these species, regardless of whether they are retained or discarded. Regulations in both countries are designed to prevent fisheries other than the directed halibut fishery, or those other hook and line fisheries permitted under regulation, from targeting fishing effort toward halibut. However, halibut are often caught incidentally in other fisheries, and released fish may not survive injuries received during capture. Thus, the incidental catch (bycatch) represents an important source of mortality, and resulting yield losses to the directed fisheries may be substantial.

The IPHC relies largely on information collected by other agencies as the source of bycatch amounts. The most reliable information on incidental catch is from on-board observers. However, observer programs are expensive to implement in a comprehensive manner. Observations on bycatch in BSAI fisheries are among the more extensive for fisheries in Alaska, but those in the Gulf of Alaska (GOA), although improving, are among the least extensive. The trawl and hook-and-line fisheries in British Columbia operate under a fully integrated system using video monitoring, onboard observers, and port-based sampling to ensure that individual vessel quotas are effective. In Area 2A, the groundfish trawl fisheries have operated with 100% observer coverage and individual bycatch quotas since 2011.

Total halibut removals ranged from 64 to 85 million pounds net weight (Mlb; note that the IPHC uses net weight for all calculations, this dressed, head-off weight is approximately 75% of the round weight) during the 1960s, with bycatch mortality estimated to have ranged from a high of 21 Mlb in 1965 decreasing to a low of 15 Mlb in 1969. Total removals subsequently declined, primarily due to the reduced quotas allowed by IPHC, which was in response to a decline in the abundance of halibut. However, incidental mortality remained high due to a lack of regulation and became an increasingly larger share of the total removals through the 1970s.

Halibut abundance stabilized during the mid-1970s and total removals from the resource ranged from 34 to 43 Mlb during 1974 to 1982. Bycatch mortality declined to a low of 12 Mlb, but increased to 19 Mlb in 1980, partly as a result of increased foreign fishing effort. Bycatch mortality declined as foreign fisheries operating off Alaska were curtailed and were eliminated in the GOA in 1986. However, joint-venture fishing began in the late 1970s and expanded sharply in the early 1980s, as foreign fisheries were phased out. The joint-venture and subsequent domestic fisheries were not initially subject to the same bycatch restrictions as the foreign fisheries and bycatch mortality increased, peaking at 20 Mlb coastwide, and over 10 Mlb in the BSAI region in the early 1990s. Wastage in the directed commercial fishery, likely small prior to 1973, increased during the 1980s as the fisheries were restricted to shorter seasons, encouraging less efficient fishing practices and resulting in large quantities of lost gear.

Initial restrictions on bycatch mortality in the BSAI region were implemented under the auspices of the International North Pacific Fisheries Commission (INPFC) or bilateral arrangements between the U.S. and foreign fishing nations. The IPHC Bering Sea Closed Area was created by the Commission in 1967 to protect a nursery area for juvenile halibut, in response to severe declines in halibut abundance. The current Closed Area is slightly smaller than the original definition due to reductions that occurred when Area 4 was first partitioned into separate areas in 1983 (Hoag et al. 1993), and the exclusion of Bristol Bay in 1990 (Gilroy and Hoag, 1993). The Closed Area had historically accounted for a relatively small percentage (<10%) of the directed halibut landings in the Bering Sea but was a source of significant halibut mortality from foreign vessel bottom trawling. The Commission recommended the closure to both directed halibut fishing, which was under Commission jurisdiction, and to bottom trawling, which was not under Commission jurisdiction. However, through negotiations within the INPFC and bilateral agreements with foreign governments, the Closed Area was also closed to foreign bottom trawling. Throughout the late 1960s until the early 1970s, the Closed Area provided significant protection for juvenile halibut, with bycatch mortality dropping to an estimated low of 4.2 Mlb in 1985. Coincidentally, halibut abundance improved dramatically, fuelled in part by strong year classes of the mid-1970s.

As Americanization of the Bering Sea trawl fisheries occurred in the early 1980s, following promulgation of the U.S. Extended Economic Zone, the protection to juvenile halibut afforded by the Closed Area diminished as domestic fisheries were not excluded. The NPFMC implemented control measures for bycatch mortality by instituting gear and fishery-specific limits and closures within the BSAI including the Closed Area, throughout the 1980s. However, mortality on halibut in the BSAI again increased substantially in the 1985-1991 period, reaching a peak of 10.7 Mlb in 1992. Bottom trawling within the Closed Area currently accounts for a significant proportion of the halibut mortality in the Bering Sea, and the area remains open to all fishing except directed halibut longline fishing.

As domestic groundfish fisheries developed and foreign fishing was phased out in the 1980s, federal regulations were implemented to limit bycatch of halibut so as to minimize impacts on the domestic halibut fisheries. Interception of juvenile halibut often occurs in trawl fisheries targeting other groundfish species such as rock sole, pollock, yellowfin sole, and Pacific cod. Incidental catch of halibut also occurs in groundfish hook and line and pot fisheries. Incidental 032 halibut within the longline sablefish fisheries can be retained if halibut quota share is held. In other groundfish hook and line or pot fisheries, regulations require that all halibut caught incidentally must be discarded, regardless of whether the fish is living or dead. Groundfish pot gear is exempted from halibut bycatch restrictions because the discard mortality rate and total mortality associated with this gear type is estimated to be relatively low, and existing pot gear restrictions are intended to further reduce halibut bycatch mortality. The IPHC does make estimates of this source of mortality, which are included in all analyses.

Regulations to control halibut bycatch in domestic groundfish fisheries were implemented initially as part of the BSAI groundfish Fisheries Management Plan (FMP) in 1982. These regulations reflected some of the time-area closures in effect for foreign trawl operations. Beginning in 1985, annual halibut PSC limits were implemented for the groundfish trawl fisheries, attainment of which triggered closures to bottom trawl gear. Seasonal allocations of halibut PSC limits also are authorized.

Other measures that have reduced halibut bycatch include seasonal and area allocations of groundfish quotas for selected target species, seasonal and year round area closures, gear restrictions, careful release requirements, public reporting of individual bycatch rates, and gear modifications. While the groundfish FMP's allow the NPFMC to set the season start dates to accommodate fishery interests, it has relied on the seasonal apportionments of halibut PSC limits to take advantage of seasonal differences in halibut and some groundfish fishery species distributions. Gear restrictions are specified to reduce bycatch or bycatch mortality of halibut. Restrictions include (a) requiring biodegradable panels on groundfish pots, (b) requiring halibut exclusion devices on groundfish pots, and (c) revised specifications for pelagic trawl gear that constrain the pelagic trawl fisheries for groundfish to a trawl gear configuration designed to enhance escapement of halibut.

PSC limits have been used to control the bycatch of halibut in the groundfish fisheries off Alaska since the initial groundfish FMPs were developed. PSC limits are intended to optimize total groundfish harvest, taking into consideration the anticipated amounts of incidental halibut catch in each directed fishery. They are apportioned by target fishery, gear type, and season. Essentially, these bycatch limits provide an incentive for specific fisheries to operate in times and areas where the highest volume or highest value target species may be harvested with minimal halibut bycatch. Directed fishing must stop when seasonal PSC limits are reached; all other fisheries remain unaffected. Reaching a PSC limit results in closure of an area or a groundfish directed fishery, even if some of the groundfish (particularly flatfish) total allowable catch (TAC) for that fishery remains available for harvest.

Current regulatory structure and jurisdictions

Each year the IPHC sets directed fishery catch limits (FCEYs) for each of eight major Regulatory Areas: 2A, 2B, 2C, 3A, 3B, 4A, 4B, and 4CDE. Included in those catch limits are the directed commercial fishery landings in all regulatory areas. In Areas 2A, 2B, 2C and 3A, by Catch Sharing Plan (CSP) or regulatory authority (2B) some removals from the sport fishery, personal use and subsistence, and commercial fishery wastage are also included in the FCEY. Removals regulated independently of the IPHC's annual catch limits therefore include wastage in most areas, bycatch, non-CSP sport removals as well as all personal use and subsistence removals (except in Area 2A).

Halibut in the eastern Bering Sea, Area 4CDE (including the Closed Area), are considered to be a single unit in all IPHC analyses. However, management subareas 4C, 4D, and 4E were created to serve the needs of the NPFMC's Catch Sharing Plan (CSP). Annually, the Commission adopts the Council's CSP to determine the specific catch limits for these subareas. The percentage shares to these areas, as determined by the Council, are: Areas 4C and 4D each receive 46.43% of the Commission's adopted catch limit for Area 4CDE, and Area 4E receives 7.14%. If the total catch limit for Area 4CDE exceeds 1.6576 Mlb, Area 4E receives 0.08 Mlb off the top of the total catch limit before the percentages are applied. Within Area 4CDE, the annual available halibut yield is further allocated among CDQ and IFQ fishing within subareas. The amounts allocated to CDQ by area are: Area 4C 50%, Area 4D 30%, and Area 4E 100%. There are also provisions within the CSP allowing Area 4C CDQ and IFQ to be harvested in Area 4D, and for allowing Area 4D CDQ fish to be harvested in Area 4E. All of these allocations are outside of the Commission's jurisdiction and are governed by U.S. domestic agencies.

Incidental mortality of halibut occurs in directed halibut fisheries as a result of mortality to halibut required to be released if the fish are smaller than the IPHC minimum legal size limit (32 in). For the commercial fishery this mortality is estimated by the Commission annually. Release mortality in other directed fisheries (recreational and personal use) is estimated only for recreational fisheries in Regulatory Areas 2C and 3A. Mortality of halibut in non-target fisheries is estimated by federal regulatory agencies (the National Marine Fisheries Service, NMFS, and Fisheries and Oceans Canada, DFO) which regulate non-target bycatch mortality within the two nations. However, the regulatory structure for control of non-target bycatch mortality varies by regulatory area. Detailed presentation of the bycatch management framework in each area is contained in Karim et al. (2012) and we present only a brief synopsis of this framework here.

Regulatory Area 2A (Washington-Oregon-California)

For regulatory Area 2A, non-target bycatch mortality is under the jurisdiction of the NMFS but allocative and control measures are developed by the Pacific Fishery Management Council (PFMC). Mortality of halibut occurs in non-target trawl fisheries for groundfish, hook-and-line fisheries for groundfish and salmon, and pot fisheries for sablefish. Since 2011, the PFMC has instituted individual bycatch quotas for halibut mortality within the IFQ groundfish trawl fisheries, combined with 100% observer coverage of vessel trips. In 2013, the total mortality limit for the IFQ trawl groundfish fishery was set at 0.194 Mlb (net wt.), with over 90% of this total allocated to the groundfish trawl fishery north of 40°10' N. The actual halibut mortality in this trawl fishery has been decreasing since the imposition of individual bycatch quotas and for 2012 the mortality estimate was only 0.067 Mlb.

The hook and line fishery in Area 2A does not have 100% observer coverage and an assumed discard mortality rate (DMR) of 25% is applied to the estimated halibut releases in this fishery. For 2012, the estimated mortality in this fishery was 0.059 Mlb. There is no estimate for release mortality in the recreational fishery. Mortality in the groundfish pot fisheries is low and, using a DMR of 18%, the estimated mortality of halibut in this fishery in 2012 was 0.001 Mlb. Halibut excluder devices have been required in all shrimp trawl fisheries since 2003 and halibut mortality has been assumed to be zero since 2012.

Regulatory Area 2B (British Columbia)

Halibut bycatch mortality in non-target fisheries in Area 2B is under the jurisdiction of the DFO, which is also responsible for allocative usage by different fishing sectors. Mortality of halibut in non-directed commercial fisheries occurs for groundfish trawl, shrimp trawl, crab pot, sablefish trap, and hook and line fisheries. Mortality of released fish also occurs in the recreational fishery, but no estimate of this mortality is available. Mortality of non-retained halibut is regulated in three ways: (i) direct monitoring of individual vessel bycatch limits in the groundfish trawl sector; (ii) direct monitoring and estimation of mortality in the hook and line (including directed halibut fishing) and sablefish trap sectors; and (iii) estimation of bycatch mortality in shrimp trawl and crab pot fisheries. Groundfish trawl, hook and line, and sablefish trap fishing is subject to 100% monitoring at sea, as well as 100% dockside monitoring.

Since 2006, the hook and line and trap sectors have been managed under a Commercial Groundfish Integration Program, wherein all vessels are responsible and accountable for their 032 halibut bycatch mortality. Vessels must obtain commercial halibut Individual Transferrable Vessel Quota (ITVQ) to cover both retained and discarded O32 halibut, and vessels are subject to trip limits and annual caps of halibut usage. The mortality of U32 fish associated with halibut landings is estimated from logbook discard records, and a 16% DMR; this mortality is covered under the commercial halibut ITVQ system through a pre-quota reduction. Mortality of U32 halibut for fishing activity that did not land halibut is currently unaccounted for.

Bycatch mortality in the Area 2B trawl sector is managed under a Halibut Bycatch Management Plan, as a component of the overall groundfish Integrated Fishery Management Plan. Provisions of the Bycatch Management Plan include: a total halibut mortality fleet limit of 1 Mlb; individual vessel mortality caps; and, the provision for bycatch ITQ transfer among vessels, subject to total vessel mortality caps. All vessels are subject 100% at sea monitoring and 100% dockside monitoring. Mortality is assessed from condition factors estimated by observers. Total estimated bycatch mortality in the Area 2B trawl sector for 2013 was 0.225 Mlb.

Bycatch mortality in the trawl fisheries for shrimp and pot fisheries for crab is based on only limited observer coverage and retention is prohibited in both fisheries. However, bycatch reduction devices have been mandatory in the shrimp trawl fishery since 2001/2002, and bycatch mortality is estimated to be zero, similar to Area 2A shrimp trawl fisheries. The characteristics of pots used in the Area 2B crab fishery provide limited opportunity for halibut bycatch. The target species is Dungeness crab (*Cancer magister*), a relatively small crab compared with king and tanner crabs targeted in Alaska, and the pots have small tunnels and mesh sizes which limit the capture of larger species. While direct observations of this fishery are limited, they indicate minimal occurrence of halibut over a decade-long record.

No estimates of total halibut discard mortality in recreational fisheries in Area 2B are available, although discards are known to occur in these fisheries. Discards within the ceremonial/subsistence fisheries by First Nations are assumed to be negligible.

Regulatory Areas 2C, 3, and 4 (Alaskan waters)

Non-target halibut bycatch mortality in IPHC Regulatory Areas 2C through 4 is under the jurisdiction of the NMFS but allocative and control measures are developed by the NPFMC. In addition, some monitoring and estimation processes are conducted by the Alaska Department of Fish and Game (ADF&G); however, the ADF&G does not have direct regulatory authority over halibut removals or allocation. Bycatch mortality of halibut in non-target fisheries occurs in groundfish trawl, groundfish fixed-gear, shrimp trawl, scallop dredge, and crab trap fisheries. Over 80% of the non-target halibut mortality occurs in the groundfish trawl fisheries; with fixed-gear groundfish fisheries creating approximately 10% of the halibut mortality.

Regulation of halibut bycatch mortality in non-target fisheries in Alaska is complex and is orchestrated by the NPFMC. The primary regulatory vehicle for halibut bycatch mortality control is through limits on Prohibited Species Catches (PSC). Subordinate to the PSC limits, are a host of regulatory processes that are designed to facilitate access to the maximum amount of available groundfish catches, while adhering to the PSC limits. These measures are detailed in Karim et al. (2012) and Williams (2014), and are only summarized here.

The BSAI halibut PSC limit is set in regulation and the GOA halibut PSC limit is set annually through the groundfish harvest specifications process; neither is tied to halibut abundance. Federal regulations also establish allocations of the BSAI halibut PSC limit between the community development quota (CDQ) and non-CDQ fisheries and a process for apportioning those limits among non-CDQ fisheries.

For 2013, the estimated bycatch mortality (in net weight) for halibut in Alaskan fisheries was: BSAI trawl 4.50 Mlb, BSAI fixed gear 0.71 Mlb, GOA trawl 1.82 Mlb, and GOA fixed gear 0.50 Mlb. These values, with the exception of GOA fixed gear were well below total PSC limits. The PSC mortality limits (in net weight) for halibut bycatch in 2013, were: 5.80 Mlb for BSAI trawl, 1.50 Mlb for BSAI fixed gear, 3.26 Mlb for GOA trawl, and 0.50 Mlb for GOA fixed gear. These PSC mortality limits are further subdivided into seasonal apportionments by species complexes and gears, in each area. The final subdivision of PSC bycatch mortality limits in Alaskan waters involves allocation by the NPFMC of specific halibut bycatch limits from the overall limits to fishery cooperatives that manage these allocations internally, to minimize bycatch and achieve maximum access to groundfish quotas. These include the Central Gulf of Alaska Rockfish Program, the Amendment 80 fishery cooperatives in the BSAI and GOA, the sideboard allocations to non-exempt American Fisheries Act vessels in the BSAI and GOA, and the 'other hook and line' allocations for fixed gear fisheries in the GOA. Groundfish pot and jig fisheries and sablefish IFQ fisheries are exempt from PSC limits. Mortality estimates from these fisheries are derived from observer estimates of discards paired with pre-season DMR estimates, which are updated every three years although data from observers are collected continuously.

Lastly, fisheries regulated by the State of Alaska in territorial waters are not subject to comprehensive monitoring of bycatch mortality. Fisheries within which bycatch occurs include: (i) beam trawling for shrimp and flounders in Area 2C; (ii) hook and line fisheries for sablefish in Area 2C; (iii) sablefish hook and line fisheries in Prince William Sound (Area 3A); and, (iv) king and tanner crab pot fisheries throughout the GOA and BSAI. Estimated bycatch in these fisheries had historically been estimated from research data but in 2012, the IPHC ceased using these out-of-date data and began to work with ADF&G to update estimates. Progress on this initiative has been limited and new estimates are not available for these fisheries.

Accounting and management in other fisheries

The IPHC's current harvest policy delineates between O26 removals, explicitly included in the annual catch limits, and U26 removals, not included in catch limit calculations (see full description of the harvest policy below). This approach is quite atypical in the context of similar fisheries in the North Pacific, and around the world. By the mid-1990s, fisheries reference points based on integrating all sources of mortality into estimates of Spawning Potential Ratio (SPR, described below) were in common use in the United States (Mace and Sissenwine 1993). Current catch limit calculations for the U.S. Pacific (http://www.pcouncil.org/) and North Pacific Council (http://www.npfmc.org/) processes generally include all sources of mortality and all sizes of fish. It is therefore often a prerequisite for calculation of directed fishery Optimal Yield (OY) or Total Allowable Catch (TAC) to make projections regarding other fisheries and the size structure of all removals (especially where it may differ from historical patterns). For example, TACs from the most recent Alaskan sablefish assessment (Hanselman et al. 2013) include all sizes of sablefish, both retained and discarded, from all of the long-line, trawl, and pot fisheries. Only research landings are excluded from the assessment analysis, and these represent less than 2% of the total. In this case, management of these removals includes separate NPFMC actions for the trawl fishery, the IFQ directed longline and pot fisheries, and the State managed fisheries.

Estimation of U26 Mortality

There are two components of U26 halibut mortality that are included in the stock assessment but not the standard harvest policy tables: directed fishery wastage and bycatch in non-target fisheries.

Wastage describes all mortality of halibut that occurs during the directed fishery, but that does not become part of the landed catch. There are three main sources of wastage: 1) fish that are estimated to have been captured by fishing gear that was subsequently lost during fishing operations, 2) fish that are discarded for regulatory reasons (e.g., the vessel's trip limit or harvester's IFQ limit have been exceeded), and 3) fish that are captured and discarded because they are below the legal size limit of 32 inches. Briefly, U26 (and all U32) halibut are assumed to be captured by the directed fishery at a rate equal to that observed by the IPHC's setline survey in each regulatory area. This rate provides an estimate of the number of halibut discarded by the fishery, to which a 16% DMR is applied for fisheries operating under a quota program, and a 25% DMR rate is applied to those operating under a derby system (currently only 2A). Lost gear is assumed to have encountered legal and sublegal halibut at the same rate as gear that was hauled in each regulatory area each year. For a full description of the methods used to estimate wastage see Gilroy and Stewart (2014).

Bycatch describes all halibut that have been captured and subsequently die during non-target fisheries (Williams 2014b). Bycatch includes trawl fisheries, hook-and-line fisheries other than halibut (e.g., Pacific cod, sablefish, rockfish), as well as pot fisheries. In order to estimate the mortality associated with these fisheries, the observer program first estimates the number of halibut discarded. For hook-and-line fisheries, a sample of the discarded fish is assessed based on the type of injury the fish have sustained due to hooking, and then these injuries are linked to estimates of discard mortality rate by injury type from previous analyses. For trawl fisheries a sample of the discarded halibut is assessed for condition, which is categorized and similarly assigned a DMR rate based on historical mark-recapture analysis. These values are then extrapolated to the discards estimated for the entire fishery. Bycatch estimates also include halibut that are landed and, because they cannot legally be sold, are donated to food banks. This occurs primarily in Alaska through the SeaShare program (Williams 2014c), and in the shoreside hake fishery in 2A, which is required to have full retention of all catch.

Both wastage and bycatch have fluctuated over time (Stewart 2014); in recent years wastage has totaled from one to just over three Mlb (Fig. 1) with Areas 3A and 3B comprising the majority of this source of mortality. Over the same period, bycatch has totaled from just under 8 to just over 11 Mlb, with much of that total occurring in Area 4CDE (Fig. 2). To delineate this mortality (in weight) into the U26 and O26 components, length frequencies (in numbers) and the length-weight relationship are used. The fraction of the bycatch that is U26 is much higher in all regulatory areas than the fraction estimated for wastage. The highest proportion of U26 bycatch occurs in Area 4A (43%, Fig. 3) and wastage in 4CDE (11%; Fig. 4). In 2013 U26 bycatch was estimated to be 2.83 Mlb and U26 wastage was 0.12 Mlb (Webster and Stewart 2014).

These estimates of U26 and O26 wastage and bycatch are produced annually by the IPHC. They include significant uncertainty related to the data that are currently available (See section on uncertainty below). Further, recent restructured North Pacific Observer Program reports (2013 and 2014) have included different estimates of hook-and-line discards, which are difficult to compare to IPHC estimates for several reasons: 1) The IPHC reports all estimates of removals in pounds (generally millions); the observer program reports metric tons; 2) The IPHC uses net weight (head-off and gutted, approximately 75% of round weight); the observer program uses round weight; 3) The IPHC delineates discards in the directed halibut fishery (wastage) from those in non-target fisheries (bycatch); the observer program has combined these into a single hook-and-line estimate; 4) The IPHC reports both wastage and bycatch in estimated mortality; the observer program does not apply a discard mortality rate, but reports 100% of the estimated pounds discarded for all fisheries; and 5) There has been a known error in NMFS calculations where the average fish weight for the entire catch has been assigned to the number of discarded halibut (which creates a positive bias in the pounds discarded due to the minimum size limit; i.e., the discarded fish are systematically smaller than the retained fish).

Accounting

Stock distribution and apportionment

General understanding of Pacific halibut life history and distribution indicates that the bulk of the pelagic juvenile halibut occurs in the western GOA, Aleutian Islands, and southwestern Bering Sea. Densities of 1-4 year old halibut (not frequently encountered in setline surveys or the directed fishery) are typically also very high in these areas; this has been observed in trawl surveys (Sadorus and Lauth 2014, Sadorus et al. 2014, Sadorus and Palsson 2014, Sadorus and Palsson 2014b; Fig. 5), directed IPHC trawl investigations (Schmitt 1985), and in the length-frequencies of halibut captured as bycatch in various trawl fisheries operating in these areas. Although these observations allow for some insight into the average distribution of juvenile halibut (most U26 halibut are less than 6 years old), there is no single geographically comprehensive source of annual distribution information, as the GOA and Aleutian trawl surveys alternate biennially, and DFO surveys use different trawl gear and cover only two of four strata off the B.C. coast each year. In addition, juvenile halibut appear to be highly mobile, much more so than adults, so information regarding distribution would tend to be much less relevant for predictions.

The aggregate result of historical IPHC tagging programs indicates that the Bering Sea and the near Aleutian Islands are a net exporter of halibut of all sizes to all other regulatory areas. New analysis of historical tagging projects conducted by the IPHC in the BSAI is currently underway (Webster *in prep*). Some preliminary results of this analysis indicate that juvenile halibut tagged in the BSAI tend to remain near the area of tagging for the first year at large, but then distribute broadly to the Aleutian Islands, GOA (70-90%), and Area 2 (Fig. 6). This would imply that by the time they enter the directed fishery (and are fully selected by the setline survey) halibut spending their first few years of life in the Bering Sea could be in virtually any regulatory area. A very similar pattern of dispersal was observed for juvenile halibut tagged near Unalaska (Figs. 7, 8). At present it is not possible to correct for the spatial distribution of fishing effort in these data, which may lead to an overestimate of movement rates to areas (like the GOA) with more fishing activity.

Larger halibut are also estimated to move among regulatory areas, with the net result that regulatory Area 2 tends to benefit from immigration, while Area 4 has a net emigration (Valero and Webster 2012; Table 14, Webster et al. 2013). The observed distribution of the stock available to the directed fisheries in each year will reflect not only the historical fishing effort in each regulatory area, but also the interaction of recruitment distribution and movement rates over the 6-10 years that these fish have been alive.

Apportionment, a key input to the harvest policy and catch-limit calculations, uses the distribution of observed O32 halibut catch rates in the setline survey (Soderlund et al. 2012, Henry et al. 2014, Webster 2014) to infer the distribution of the stock. This process is similar to how survey estimates are used by other agencies in the north Pacific and around the world. Survey estimates reflect the relative catch rate in each area multiplied by the total available habitat occurring in depths of 0-400 fathoms. Apportionment calculations take into account the timing of fishery removals relative to the annual survey, as well as competition among halibut (of all sizes) and other species for the finite number of hooks deployed. These calculations are also smoothed, using the most recent three years to dampen the effects of sampling variability on stock distribution estimates (Webster and Stewart 2014).

Apportionment thus provides a ‘snapshot’ of how the halibut stock is distributed in each year, and this relative distribution has changed over time, with the Central and Western GOA (Areas 3A and 3B) representing less of the total stock over time, and Area 2 relatively more (Webster and Stewart, 2014). Calculations in 2013 resulted in roughly one-third of the stock estimated to be in Area 3A, 13-16% in each of areas 2B, 2C, and 3B, and smaller contributions from the other areas (Table 1). The estimate of current stock distribution (not including juveniles) is what allows for explicit consideration of area-specific removals in the harvest policy.

The current IPHC harvest policy

The IPHC's harvest policy has evolved through many levels of target harvest rate, spatial complexity, and implementation strategy. Briefly, early harvest policy implementations used higher target rates of exploitation, including values of 35%, 30%, and finally 20% in 1996 (Clark and Hare 2006). Clark and Hare (2004) provide a more detailed summary of the evolution of the IPHC's harvest policy through 2004. These early higher rates were reduced as subsequent analyses showed the stock to be less productive and the objectives of the harvest policy were broadened from targeting Maximum Sustainable Yield (MSY), to also maintaining a reasonable stock size over a range of conditions.

The target harvest rate on which the current policy is based (20%) was generated via a simulation analysis that used data from the 'core' of the halibut stock including Areas 2B, 2C, and 3A. In order to account for lower productivity and greater uncertainty in Areas 3B and 4, target harvest rates were reduced in those areas (to 15%). During both the closed-area assessment period, and the coastwide assessment period (after 2006), these target harvest rates were used to generate regulatory area-specific Total Constant Exploitation Yield (TCEY) estimates.

The target rates have a number of important properties and assumptions embedded in them. Simulation analysis found that these rates would achieve a stock size that exceeds 30% of the equilibrium stock size in the absence of any fishing ($SB_{30\%}$) with at least an 80% probability over a sufficiently long time-horizon (Clark and Hare 2006). Fluctuations in size-at-age and variable recruitment regimes were included in the original analysis, and subsequent sensitivity analyses, and it was acknowledged that a fixed harvest rate policy in combination with natural fluctuations in recruitment would lead to similar fluctuations in the fishery removals (Hare and Clark 2002). In addition, the levels of bycatch and wastage occurring during the 1980s and 1990s contributed to the estimated productivity of the stock, and therefore the target rate of exploitation. In this way, an allowance for U32 (and later U26) mortality was built in to the original harvest rate targets.

In order to better understand what is being lost via U26 (and O26) mortality in the current approach, there have been several previous IPHC analyses investigating the effects of bycatch on the halibut stock using metrics of fishery yield and lifetime spawning biomass contribution (Hare et al. 2012, Hare and Williams 2013). These analyses were conducted separately from the annual stock assessment, using equilibrium calculations based on relatively simple assumptions about growth and mortality. Results indicated that there was a 1.0-1.14 pound loss of fishery yield per pound of bycatch (O26 and U26 combined). For each pound of bycatch, the potential lifetime contribution to female spawning biomass was found to be somewhat larger than the fishery yield.

Correspondence from the IPHC to the Council and internal reports indicate that in the late 1980s and early 1990s there was a considerable effort to define and quantify the "adult equivalents" associated with halibut bycatch, attempting to clarify and understand the exchange rate between mortality of different sizes of halibut. Yield equivalents for bycatch were estimated to be 1.4-1.6 pounds of fishery yield in the 1980s; however, recalculations based on spawning output led to a pound-for-pound deduction of O32 bycatch from the TCEY through the 1990s. This reduction was done for the coastwide total, and therefore distributed in proportion to the exploitable biomass (Hare and Clark, 2007).

Analyses conducted in 2010 (Hare 2011) used Spawning Biomass per Recruit (SBR) as a measure of total fishing intensity. The calculation of SBR in that analysis is consistent with that of SPR (described in detail below). Hare (2011) first found the SBR associated with the harvest policy at the time (20% and 15% harvest rates applied to O32 removals). He then solved for the TCEY values that would result in the same SBR if removals of O26 halibut were included directly in the TCEY. In this way, he applied an extended definition of removals, but used SBR to maintain the same level of fishing intensity. The harvest rates for O26 removals were higher (21.5%), but the sum of the TCEYs was slightly (0.84 Mlb) lower, indicating only a small divergence in the biological properties of all the removals since the original simulations. That analysis also calculated harvest rates that could be applied when all sizes of removals were included in the TCEY, and concluded there was no biological basis for area-specific deduction of these removals given the highly migratory nature of juvenile halibut. A second option was presented, which distributed the U26 mortality in proportion to the exploitable biomass estimates by regulatory area. This is consistent with the logic of assuming that the effects of U26 mortality are realized equally across the O26 stock. The extended accounting for O26 halibut was adopted in 2011, and subsequent harvest policy calculations have relied on the 21.5 and 16.125% (15% scaled up by the same factor as 20% to 21.5%) rates. In aggregate, these changes brought a broader size-spectrum of mortality into the annual calculations, but retained a system of accounting that did not explicitly show U26 mortality in harvest policy tables and could not respond to future changes in U26 mortality.

Current IPHC harvest policy distributes the directed Fishery Constant Exploitation Yield (FCEY) limits for each regulatory area based on apportioned biomass estimates derived from survey catch rates, and application of fixed harvest rates (21.5% in Areas 2A-3A and 16.125% in Areas 3B-4CDE) to those estimates. The policy accounts for only O26 halibut removals from the directed and non-target fisheries in the calculation of exploitation rates and yield. Changes in O26 bycatch therefore directly translate into changes to directed fishery yields, as illustrated above, but changes in U26 mortality are not visited directly on calculations of available yield. Instead, the effects of changes in U26 mortality do not factor into the FCEY until those effects are realized through eventual changes in O26 biomass. To illustrate this gap in the current policy, it is useful to consider the hypothetical scenario where the total pounds of bycatch is increased by a million pounds, but the size distribution of that bycatch is shifted, such that all of the increase is realized on U26 halibut. It is clear that this would have an effect on the stock, as that increase in pounds would correspond to a very large number of fish. However, the application of the current harvest policy would yield identical TCEYs and FCEYs, despite the large increase in the total fishing intensity being applied to the stock. The converse would also occur: a million pound decrease in the bycatch of U26 halibut would also result in no change to the TCEYs or FCEYs. These results occur because the current harvest policy assumes a static level of U26 mortality.

Recent annual harvest policy tables (e.g., Webster and Stewart 2014) have been calculated in the following manner: 1) apportionment provides an estimate of the stock distribution, 2) the target harvest rates are applied, which generates a target distribution for the O26 harvest regardless of the scale of those removals (Table 1). The distribution of potential catch limits can then be compared to the target distribution. For example, the final adopted catch limits for 2014 resulted in TCEYs that exceeded the apportionment target in Areas 2A, 2B, 4B, and 4CDE, with the largest difference in 2B (Fig. 9). The scale of this relative distribution is then a function of the apportionment percentages applied to the coastwide total exploitable biomass (a definition created within the harvest policy reflecting a fixed selectivity schedule somewhat like the fishery at the time of the simulation analysis). The TCEY values therefore reflect the combination of stock distribution and target harvest rates by regulatory area (Table 2). In order to find the Fishery Constant Exploitation Yields (FCEYs) for each regulatory area, all O26 "other removals" are subtracted from the TCEYs. FCEY values thus represent what is 'leftover' after accounting for distribution and other sources of mortality.

To manage U26 mortality, harvest rates that account for changes in U26 removals must be dynamic, in order to maintain the same fishing intensity or protection for the spawning stock depending on annual changes in all sources and sizes of removals. A relevant metric to quantify all removals and their effect on the stock is the Spawning Potential Ratio.

Spawning Potential Ratio

It is common practice to consider fishing intensity in terms of fishing mortality: the catch as a fraction of the stock or as an instantaneous rate of mortality (per year/age). In both cases, there must be a clearly defined set of sizes or ages included in the calculations. Where multiple fisheries are present, and where these fisheries access differing size and age components of the stock, it is not possible to characterize a single fishing mortality rate for all fisheries simultaneously. In these cases, a metric that integrates the different fisheries (and therefore the mortality on different sizes of fish) is required.

Spawning Potential Ratio (SPR; Goodyear 1993) is a commonly used metric that summarizes the fishing intensity of all fisheries accessing different parts of the same population. SPR has two components: 1) the equilibrium spawning biomass in the absence of fishing and 2) the equilibrium spawning biomass given some distribution of fishing mortality at size or age. Without fishing, the spawning biomass produced by a fixed number of incoming recruits will be a simple function of individual growth, the maturity schedule, and the rate of natural mortality. Fishing just adds an additional source of mortality at each age. However, some of the fish that would have died of natural causes are caught first, such that natural and fishing mortality are not simply additive annual factors. The ratio of equilibrium spawning biomass with fishing to that without fishing is SPR. SPR can therefore range from 1.0 as fishing mortality approaches zero, to 0.0 as fishing mortality results in no fish surviving to reach maturity. SPR calculations are frequently summarized in units of one minus SPR, such that increasing fishing intensity equates to a larger value, similar to traditional metrics of fishing mortality.

This metric integrates fishing intensity across multiple sources, where selectivity may differ and traditional age-range dependent fishing mortality rate (F) or harvest fraction calculations can be misleading. Because the SPR metric includes all sources and sizes of mortality, it can be used to directly compare potential halibut fishery yield associated with different levels of total and U26 bycatch and can therefore be used to define a harvest target for the stock. This conceptual extension to the current harvest policy allows for quantification of the impacts of bycatch on the halibut stock via the yield estimates, rather than in terms of adult equivalents or equilibrium spawning biomass units. SPR is also a logical choice for defining fishing intensity for Management Strategy Evaluation (MSE) where trade-offs among fisheries and size-limits within fisheries need to be directly evaluated in a common framework.

Extended accounting for U26 mortality

SPR can be used to define the level of total fishing intensity that is consistent with current (2013) levels of mortality. This conceptual approach is identical to that used in Hare (2011), in order to include O26 mortality into the target harvest rates. The 2013 fishing intensity equates to a target SPR, which can then be used to set the scale of all removals under differing distributions of those removals among fisheries and sizes of halibut. The apportionment results and relative harvest rate targets by regulatory area still define the distribution of the TCEY. Both the target distribution of the TCEY among regulatory areas and the assumption that the effects of U26 mortality are distributed across the entire stock remain the same. This means that if there were no changes in U26 mortality, the extended accounting would produce the exact same results as the current accounting approach.

Two features of this extended accounting are important: 1) exploitable biomass is no longer necessary or relevant, as halibut mortality of all sizes is included in the calculation of SPR and, 2) the order in which the non-U26, O26 non-FCEY, and FCEY removals are calculated is no longer fixed. Specifically, the FCEY no longer represents only what is 'leftover' from the rest of the harvest policy calculations. The SPR-target and the relative distribution of TCEY from apportionment and relative target harvest rates by regulatory area can be achieved by solving for the fishery landings (and wastage) given any level of bycatch, or by solving for the bycatch given any level of fishery landings (and wastage). Changes to fishing practices that alter the projections of wastage for a given level of fishery landings can also be included. There are therefore dual entry points possible for management actions and trade-offs among fisheries can be directly evaluated.

Examples from the 2013 process

This analysis uses the 2013 stock assessment models (Stewart and Martell 2014), apportionment estimates, and current harvest policy calculations (Webster and Stewart 2014) to investigate how changes in U26 and O26 removals impact the annual TCEY and FCEY values. This is done via direct comparison with the results of the 2013 IPHC process; harvest policy calculations are repeated under different projected levels of coastwide and BSAI bycatch. For simplicity, this analysis focuses on the trade-offs between CEYs and bycatch. However, changes in wastage could be included in a similar manner. Due to the much smaller estimated magnitude of U26 wastage, the results would be very similar.

It is important to note that this analysis and annual calculations are based on the actual (2013) bycatch mortality estimates from all non-directed fishing in each regulatory area. As described above, recent bycatch levels in Alaska for both trawl and fixed-gear (except in the GOA) have been well below the PSC limits set by the NPFMC. Therefore changing the PSC limits in particular fisheries may or may not affect change in realized bycatch levels. Pacific halibut bycatch in non-target fisheries in recent years has represented a significant fraction of the total mortality of halibut due to fishing. In 2013, there was an estimated 7.9 Mlb of halibut bycatch coastwide, which represented 17% of the 46 Mlb of total fishing removals. The BSAI regulatory areas (4A, 4B, and 4CDE) contributed 5.2 Mlb, or 66% of the total.

This analysis starts from the results of apportionment and application of current harvest policy which generated the Blue Line FCEY values for 2014 (Table 2). This harvest policy table is first extended to show each of the individual components included in the TCEY, as well as all sizes of mortality by regulatory area (Table 3). Comprised predominantly of bycatch, the 2013 U26 mortality was estimated to be 2.92 Mlb, or 8% of the total 36.41 Mlb removals. In order to illustrate how changes in U26 and O26 mortality influence the TCEY and FCEY, values were recalculated using coastwide bycatch values that are 40, 20, and 10% above and below the estimates from 2013. This calculation integrates the changes in the distribution of halibut mortality among commercial, recreational, and subsistence catches, as well as estimates of wastage, associated with differing quantities of directed fishery landings.

With a 40% increase in bycatch (3.2 Mlb), the coastwide FCEY decreases from the 2013 value of 24.5 Mlb to 22.5 Mlb (Fig. 10). A 40% decrease in bycatch similarly produces a 1.9 Mlb increase in coastwide FCEY. Changes in bycatch of +/- 20% show an intermediate effect, but the results by specific regulatory area indicate that area 4CDE is the most sensitive (Tables 4-5). A 20% increase in bycatch results in the FCEY for 4CDE dropping from 0.64 (at the Blue Line) to 0.2 Mlb, and a decrease of 20% results in an increase in 4CDE to 1.07 (Tables 4-5). In Area 4CDE, for all values of estimated bycatch at least 30% greater than 2013, the FCEY would be 0 for the current harvest policy. Areas 4A and 4B are much less sensitive due to a much lower ratio of bycatch to directed fishery harvest.

For direct comparison, the same calculations are then repeated using the SPR target from the 2013 Blue Line, therefore including all the change in removals, both O26 and U26. When FCEYs are adjusted to maintain the same SPR target, changes in bycatch result in changes to directed fishery yields that are greater than just the change in O26 mortality: this is due to the effects of the U26 removals (Fig. 10). In this case, a 20% reduction in coastwide bycatch results in an FCEY of 26.0 Mlb (Table 6-7), compared to the Blue Line value of 24.5, while the reduction that did not account for U26 removals resulted in an FCEY of 25.4. These results are consistent with previous analyses finding approximately a 1:1 relationship in total lost yield due to all sizes of bycatch.

The salient points of these comparisons are that the FCEY responds only to the change in O26 removals under the current harvest policy, and the TCEY does not respond to changes in coastwide bycatch, despite potentially large changes in total mortality (Table 8). By extending the accounting to maintain the same level of fishing intensity, an increase in coastwide bycatch results in a decrease in the FCEY, TCEY and total mortality (Table 8); the converse is true as well.

To investigate the BSAI areas specifically, where much of the coastwide bycatch occurs, the same relative changes are applied only to bycatch estimates from BSAI areas. Under the current harvest policy calculations, the results are identical for the BSAI areas (Tables 9-10). There are no changes to annual removals in Areas 2A-3B, despite the change in productivity that would be expected from immigration of some of those U26 fish over their lifetime. Applying the extended accounting for total fishing intensity, changes in BSAI bycatch correspond to changes in the FCEY and TCEY values across all regulatory areas (Tables 11-13). This is due to the distributed effects of U26 mortality. The current assumption is that U26 effects are distributed in proportion to the productivity of the stock as a whole, therefore changes in the TCEY among regulatory areas are most pronounced for areas that have larger apportioned biomass estimates. The largest change occurs in Area 3A, where the FCEY goes from 9.43 Mlb at the Blue Line (and for a 20% reduction in the BSAI bycatch when U26 mortality is not accounted for) to 9.59 when the same SPR is maintained. The clear difference in these calculations is that any response to changes in bycatch in the FCEY, up or down, is of greater magnitude when all sizes of mortality are accounted for. Ongoing research at the IPHC to evaluate size-limits, discard mortality rates in the directed fishery, and the interaction of bycatch with total fishing mortality is yielding very similar results.

The results of the full range of bycatch changes (+/- 40%, Fig. 10) show that the current harvest policy is much less sensitive to changes in bycatch than the extended accounting explicitly including U26 mortality. The results have been presented in the context of the change in FCEY as a function of changes in bycatch, consistent with recent harvest policy accounting. However, the same results can be considered in the opposite direction: How much would bycatch have to be reduced to achieve a given change in the FCEY? If a 6% increase in FCEY is desired, the bycatch would need to be reduced 30% given the current harvest policy, or 17% if all mortality is accounted for (Fig. 11). If the FCEY were reduced to accommodate slightly more anticipated bycatch, a 4% reduction in the FCEY would allow a 20% increase in bycatch under the current harvest policy, but only a 12% increase if the U26 component of bycatch mortality is accounted for via a constant SPR (Fig. 11). These results include changes in the ratios of commercial landings to wastage and recreational removals under the various CSPs, and therefore represent the fully realized tradeoffs necessary to achieve a desired change in the FCEY.

There are several results of this analysis that are particularly relevant to the BSAI regulatory areas. Current (2013) halibut bycatch in the BSAI represents 66% of the coastwide total from all non-target fisheries. This also represents a significant portion of the total mortality in BSAI areas, especially Area 4CDE. In Area 4CDE, based on 2013 estimates, application of the harvest policy would result in no directed fishery yield if the estimated O26 bycatch were to increase by at least 30%, the apportioned exploitable biomass were to decrease by the same amount, or any combination of these two adding up to at least 30%. When FCEYs are adjusted to maintain the same SPR target, changes in bycatch result in changes to directed fishery yields that are greater than just the change in O26 mortality, accounting also for the effects of the U26 removals. This result is consistent with previous analyses finding approximately a 1:1 relationship in total lost yield due to all sizes of bycatch.

In 2012, the IPHC adopted a revised process for providing annual catch advice. To clearly delineate between risk assessment and management, the estimated risks associated with several alternative harvest levels have been presented to the Commission rather than just the results of the application of the current harvest policy. These results have been in the form of a decision table, including risk metrics associated with stock trend, as well as harvest policy based metrics of stock status and fishery status. Using the Blue Line results from 2013 (Table 11) as a direct comparison, the alternative distribution and magnitude of removals for the analyses reported above can be evaluated directly in the current decision-making framework. There is relatively little change in risk associated with changes in bycatch

(+/- 20%), and between the two methods of accounting for that bycatch over the next three years (Table 12). This illustrates that the projections from the ensemble of assessment models are quite robust to changes in fishery removals, despite the fact that these changes have very large implications for current fisheries. Both the extended and current harvest policy calculations suggest a very similar recent history of exploitation: rates have been above target levels based on exploitable biomass (Fig. 12) and SPR (Fig. 13) targets over the last decade. Management actions have brought these rates down appreciably over the last five years, and by either metric the 2014 adopted catch limits were the closest to the current harvest policy in recent history.

Management

Adding full accounting to the IPHC's annual process

The easiest extension of current IPHC management is the explicit consideration of the harvest policy accounting system, and the results obtained in this report. The setting of annual catch limits has historically used information from the decision-table, apportionment, the current harvest policy and target exploitation rates, as well as survey and fishery trends and stakeholder perspectives. The SPR-based comparisons possible with this extension to the current harvest policy add another piece of potentially valuable information to the annual decision-making process. Perhaps most importantly, this information allows the direct evaluation of trade-offs, by source and area, for all halibut removals.

These calculations could be added to current harvest policy calculations in the short-term, and they could replace those calculations if the IPHC chose to adopt this extended accounting system, just as was done in 2011, when O26 mortality was added to the annual calculations. Benefits of the extended accounting include: no further need for the abstract and confusing concept of exploitable biomass, consistency in the target fishing intensity despite future changes in removals among fisheries and/or changes in the size structure of removals within fisheries, a clear understanding of the direct tradeoffs between all directed and non-directed removals, and the use of SPR which provides a direct link to future output from MSE analyses.

Management of wastage

Direct management of wastage associated with the commercial fishery clearly falls under the purview of the IPHC and its annual regulations. Much of the current wastage (compared to the derby fisheries of the late 1980s and early 1990s, in Alaska) is a function of the 32 inch minimum size-limit. However, voluntary or regulatory reductions in this wastage may be possible without changes to that size limit. Fishermen may be able to avoid areas with high proportions of sub-legal fish, adjust hook- and bait-sizes to target larger halibut, and modify the timing of trips to correspond to periods when larger fish are relatively more available on the same fishing grounds. These changes in fishing behavior will require positive incentives, in contrast to current practices. Specifically, the IPHC's practice of indirect estimation of wastage (via the setline survey sub-legal catch rates applied to the directed commercial landings) provides no incentive for changes in wastage: fishermen opting to reduce wastage at their own expense in fishing efficiency (e.g., fuel to move among grounds or altering their catch rates) are faced with FCEYs the following year that are just as high as if they had not made any reductions to wastage.

The only way to reverse this situation is to create a system of improved monitoring, such that the fishery itself can see and respond to changes in actual, and not estimated, wastage. This type of system is currently in place in Area 2B, where logbook records of wastage (validated with electronic monitoring) are used by the IPHC to estimate wastage directly. This means that fleet-wide changes in behavior will result in larger FCEYs in the future.

All areas currently lack vessel-specific accounting systems for wastage. If the accounting for wastage was conducted at an individual vessel level (e.g., wastage shares or limits associated with pounds of quota), then positive incentives could operate at the vessel level in addition to the fleet level. This would mean that each individual would benefit from reduced wastage directly in their own quota – a much stronger incentive than at the fleet-level. This would only be possible with 100% monitoring of all fishing activity to ensure accurate estimates of wastage.

A second avenue for reducing commercial wastage would be to decrease the realized DMR. The IPHC already mandates the careful release of all sub-legal halibut. However, as with wastage, the current static assumption that 16% of all discarded halibut subsequently die does not create an incentive to take additional time during each release to attempt to improve this rate; there is no feedback to subsequent estimates. Specifically, if DMRs were based on an observed distribution of injury rates, and/or release methods, then improvements in handling practices would translate into positive changes in the future FCEYs. This too would require extensive monitoring to provide accurate estimates of release categories.

Changes to the current 32 inch minimum size limit, and or slot or maximum size limits would all likely result in changes to the magnitude and size structure of wastage. Specifically, reduction in the minimum size limit, allowing retention of halibut smaller than 32 inches, would likely lead to less wastage overall, but might also allow the fishery to target relatively more smaller fish, which could offset some or all of any potential catch limit reduction. Changes to size-limits would also have very strong implications for the performance of the current harvest policy. In order to understand whether such changes would be beneficial to achieving fishery objectives, it would be necessary to fully evaluate than in the context of harvest policy, and preferably a full MSE analysis. This effort is currently underway at the IPHC.

Bycatch control and reduction – collaboration among agencies

The Commission has no direct regulatory authority over the amount of halibut taken as bycatch or in the monitoring and estimation of bycatch. The Commission therefore relies on U.S. and Canadian agencies for the necessary bycatch information and management.

Bycatch is part of a national focus for the U.S. and Canada, based on specific requirements in federal legislation or policy. In the U.S., the Magnuson-Stevens Act (NMFS 2007) is the primary law for federal fisheries management. The MSA contains national standards for fishery conservation and management. National Standard 9 specifically addresses bycatch reduction, stating:

"Conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch."

In addition, the NPFMC and PFMC have adopted regulations to manage halibut bycatch, including the designation of halibut as a “Prohibited Species” within groundfish fishery management. Other fishery restrictions include bycatch limits on the amount of halibut which can be taken by the groundfish fisheries (NPFMC 2010, 2012).

In April 2013, Canada adopted a Policy on Managing Bycatch as part of its Sustainable Fisheries Framework[2]. The policy is national and it applies to all commercial, recreational, and Aboriginal fisheries licensed and/or managed by DFO under the Fisheries Act. The policy has two objectives: 1) to ensure that Canadian fisheries are managed in a manner that supports the sustainable harvesting of aquatic species and that minimizes the risk of fisheries causing serious or irreversible harm to bycatch species; and 2) to account for total catch, including retained and non-retained bycatch.

Similar philosophies exist within these national policies. Both direct that the capture of bycatch species shall be minimized *to the extent practicable.* This implies that bycatch should be reduced to the point where it balances with other competing objectives. Both policies also contain language which addresses the status of the bycatch species following release. Objective 4 in DFO’s policy states that the potential for survival should be maximized, whereas MSA National Standard 9 states that mortality should be minimized.

Since 1991, a succession of Commission-led work groups have been established to investigate various aspects of bycatch, including reviewing domestic bycatch management programs, identification of fisheries contributing to bycatch, optimal levels of bycatch, and options for reductions. The first initiative occurred in 1991, when the Commission established a Halibut Bycatch Work Group (HBWG I) to review the adequacy of management measures implemented by each country to control and reduce bycatch, examine potential measures to achieve reductions in bycatch, identify target levels of reduction, and to develop recommendations for additional Commission action (Salveson et al. 1992). The principal recommendations included the inclusion of all groundfish fisheries off Alaska into the bycatch limit management program, development of monitoring and estimation of bycatch off Washington and Oregon, a recommendation for a program to reduce bycatch limits off Alaska by a minimum of 10 percent per year, an expansion of the observer program off Canada to cover all bottom trawl fisheries, and that research should be conducted on the viability of trawl-caught halibut.

The Halibut Bycatch Work Group was re-established in 2010 (HBWG II) to review progress on reduction of halibut bycatch mortality, bycatch management programs, and to examine how best to incorporate halibut bycatch mortality into halibut assessment and management. Although the latter objective was subsequently dropped, the HBWG II compiled a comprehensive report on successful bycatch management programs and identified areas for improvement, accompanied by recommendations (Karim et al. 2012).

As a follow up, at the January 2012 IPHC Annual Meeting, the IPHC therefore approved a commissioner-led initiative focused on a better understanding of the implications of current levels of halibut bycatch

[2] http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/index-eng.htm

and to explore possible actions to address these concerns. The Commission developed and approved the following specific objectives:

- To gain a better understanding of the amount of halibut bycatch occurring in each regulatory area;
- To gain a better understanding of the impact of bycatch on the conservation and allocation of the halibut resource and on the available harvest;
- To explore options for reducing the overall level of halibut bycatch; and
- To explore options for mitigating the impact of bycatch in one regulatory area on the available harvest in other regulatory areas.

The HBWG II is reporting on progress to the Commission in 2014. The report explores options for reducing the overall level of halibut bycatch in groundfish fisheries, and for mitigating the impacts of bycatch in one area on the available harvest in other areas. The Commission will consider this report at its 2015 Annual Meeting and develop an action plan for implementation of any adopted measures.

Independently of the HBWG II, the NPFMC initiated a review of PSC limits in the BSAI region in 2012 (NMFS 2012). At its June 2014 meeting the Council passed a multi-part motion to analyze reductions of these limits from 10-35%, individually by sector. A multi-agency work group, in which IPHC staff is participating, is developing an analysis of the benefits and costs of these options, for initial consideration by the Council in February 2015.

The IPHC has the opportunity to move forward with coordinated management of bycatch in non-halibut fisheries. This effort must entail evaluating what aspects of current and potential monitoring can provide positive incentives for the reduction in halibut mortality without unduly reducing the efficiency of those fisheries. Positive incentives for bycatch reduction, like wastage, can occur at the fleet-wide level, or more effectively at the vessel-level, where the benefits of bycatch reduction are conserved within the fishing operation itself via longer seasons, more quota for target species, or simply the avoidance of individual bycatch limits. Vessel-level incentives will require comprehensive monitoring of all fishing activities, in order to accurately estimate the absolute magnitude of bycatch. Given the financial and logistical constraints of many relevant fisheries, new approaches to estimation may be needed, approaches that require less direct measurement in favor of model-based estimators that can be periodically validated. These may include video monitoring of release methods, which are then linked to injury rates (or condition codes) and therefore DMRs, rather than direct enumeration of injury/condition via human observers onboard vessels. An important aspect of positive incentive structures seen in other fisheries is a focus on the goal (reducing bycatch), rather than the means (enforced changes in gear, areas or other methodological mandates): this allows harvesters to use their considerable creativity to find the most efficient means to success.

Uncertainty and future research

There are several very important sources of uncertainty in this analysis: some of these sources are inherent to the biology and management of Pacific halibut and are not easily addressed, while others could be substantially reduced through additional data collection and analysis.

The current harvest policy (and any extension to explicitly include all sizes of halibut mortality) makes the implicit assumption that the effects of U26 mortality are distributed across the entire stock, in proportion to the total productivity. If juveniles in some areas are less likely to disperse to other areas, or if these patterns change over time with environmental conditions or stock abundance, this assumption may not be a good one. Neither the directed fishery, nor the setline survey provides clear information on juvenile abundance distribution. Some information can be inferred from NMFS and DFO trawl survey observations, bycatch rates in non-target fisheries, and encounter rates in the directed fisheries; however, all of these are subject to incomplete spatial coverage as well as many other uncertainties. The design of a targeted survey of juvenile halibut abundance and distribution is likely to be both technically unfeasible and prohibitively expensive. An extensive tagging effort could provide a 'snap-shot' of migration rates (which might allow inference about the spatial distribution of recruitment), but these rates likely to vary with stock density, environmental conditions, and other unknown factors. Again, costs would likely be prohibitive due to the large number of tag releases required to compensate for low recovery rates caused by the extended time between tagging and recovery by the commercial fishery.

Juvenile natural mortality rates are highly uncertain, but are important to any evaluation of removals to population trend and productivity. The area of greatest uncertainty is for pre-recruit juveniles and may be highest for sizes of fish that are well below those first encountered by any survey gear. For this analysis, several alternative comparisons were made assuming juvenile natural mortality rates were 1.5 and 2 times the rates estimated for adults. The relative change in SPR was found to be similar across alternatives, but the relative importance of fishing mortality was slightly less with increased juvenile natural mortality. Natural mortality rates are notoriously difficult to estimate, even for well-sampled/observed age ranges for highly-studied species, and there are few avenues for experimental or data-collection based efforts to improve our understanding of juvenile halibut mortality. Indeed, the two-year releases of Passive Integrated Transponder (PIT) tags in the most recent tagging program were designed to directly estimate natural mortality, but produced a fairly broad and uninformative estimate, which included the currently used values.

The current distribution of the stock is estimated via apportionment. This analysis utilizes the catch-rates of legal-sized halibut observed in the setline survey. It is uncertain how inaccuracies in apportionment would affect long-term stock dynamics. They may be both direct effects through the annual distribution of removals, as well as indirect effects via their influence on weighting of area-specific indices for use in the stock assessment and therefore estimates of stock size and trend. Over the next five years, planned survey expansions (Webster et al. 2014) will allow the use of improved (more direct) estimators of stock abundance in deep waters (>275 fa), shallow waters (<20 fa) and for gaps in the current station grid. Further, calibration coefficients linking the IPHC's survey to auxiliary datasets (e.g., the NMFS Bering Sea Trawl survey) will be re-analyzed. Determining whether there are sufficient removals of O26 and U32 halibut to warrant using the survey catch-rate of U26 halibut as the basis for apportionment of these fish is a topic for further investigation, as harvest policy analysis continues.

The stock assessment and application of the harvest policy relies on accurate and precise estimation of the removals from all fishing sectors, including the directed fishery, recreational, and subsistence harvests, as well as discards from these fisheries and bycatch. There is a substantial amount of uncertainty in the current treatment of bycatch due to: the estimation framework (data collection), the summary of the estimates (data processing), the DMRs applied to these summaries, and the forecasting of bycatch and its biological properties from one year to the next.

The first of these relates to the current North Pacific Observer Program. While some fisheries in the BSAI region have observer coverage of 100% of fishing trips, other fisheries have much lower coverage (particularly in the GOA) or no coverage at all (small vessels). In these cases, observer data may not be representative of all fishing activity (observed and unobserved) and therefore there is no way to be certain that the estimates are unbiased, regardless of the statistical design. Indeed, evidence indicates that the existing estimates are biased by harvester behavior (Benoît and Allard 2009, Faunce and Barbeaux 2011). This situation can only be fully ameliorated via some type of monitoring (direct observer or electronic) on all fishing activity.

In addition to the magnitude of bycatch, the size-distribution (particularly the fraction U26) of these removals is important for harvest policy accounting. Currently, estimates of the total bycatch are obtained by the IPHC from the catch accounting system. There is uncertainty in assigning these summarized estimates to specific regulatory areas due to the imperfect alignment of IPHC and NMFS statistical reporting areas. This means that not all bycatch may be attributed to the correct regulatory area in each year. Additionally, the size information collected by the observer program is transmitted to the IPHC in an unprocessed form, which allows no easy method for weighting among fishing sectors within IPHC regulatory areas. Expansion of the raw length distributions is necessary to reflect differences in sampling rates among fisheries in each of the regulatory areas, and among vessels with different levels of observer coverage. This would require a substantial amount of integration between the observer data and catch accounting system. For this reason, bycatch length frequencies have not been updated annually for all Alaskan regulatory areas. Obtaining accurate size-, age-, and sex-specific estimates of the removals of halibut from all sectors via improved observation and reporting to the IPHC may be the most tractable avenue for improving our understanding of the role of bycatch in current stock trends and productivity.

The stock assessment and harvest policy calculations rely on an aggregate bycatch selectivity assumption. However, the size distribution of bycatch varies among regulatory areas, among fisheries and even annually within fisheries, in response to many extrinsic and intrinsic factors. Further, many of the tools proposed for bycatch reduction could have large effects on the potential size-distribution of future bycatch mortality through direct effects, or changes in the discard mortality estimates by fish size. These changes are difficult or impossible to predict, and therefore current practice is to use the values from the previous year for all calculations. This approach could introduce lags in response if clear trends occur. The sensitivity to some of these factors was investigated as part of this analysis: the proportions of young and old fish in the currently assumed curve were adjusted by 20% up and down and the results recalculated. This produced only modest changes in FCEYs, slightly smaller than those produced from a 10% change in the total magnitude of bycatch (~0.5 Mlb). These changes also illustrated the expected relationship between the size-distribution of the bycatch and the long-term implications for the stock productivity: if mortality is higher on small fish for the same total pounds removed (greater numbers), the harvest of larger fish would have to be reduced to offset the greater lifetime contribution of these fish that have yet to mature. More direct estimation of bycatch selectivity would require appropriately expanded and weighted length-frequency observations not currently available and would likely have to be carried out with a more spatially disaggregated assessment approach.

In addition to bycatch, wastage in the directed commercial fishery is currently estimated indirectly, via catch-rates of U32 halibut observed on the IPHC's setline survey in each regulatory area and assumed discard mortality rates. The exception to this is Area 2B, where the number of U32 halibut discarded is taken directly from fishery logbooks. In this case, the average individual fish weight from the survey is used to convert the numbers of fish discarded into pounds of mortality. These direct estimates do compare well with the indirect estimates calculated in the traditional manner by the IPHC. Analysis of potential management actions that would influence wastage realized in the fishery (such as a change in the size-limit, regulated hook-sizes, or time-area closures) requires accurate estimates of that wastage. Current observer coverage in the Alaskan directed halibut fishery is very low, and therefore estimates of wastage are of unknown accuracy; however, improved monitoring via increased observer coverage and/or electronic monitoring offer potential for improvement in these estimates. In Area 2A, there is currently no at-sea monitoring of the directed halibut fishery. With increased monitoring, it may also be possible to improve discard mortality rates (currently assumed to be 16% for IFQ fisheries and 25% for 2A) through direct evaluation of hooking injuries, as is done for non-target hook-and-line fisheries in Alaska.

In all areas, the DMRs for both wastage and bycatch are an important source of uncertainty due to the relatively large quantity of halibut that are handled and released each year. Specifically, small changes in the realized DMR may correspond to large changes in mortality. Although there is no current evidence that the DMRs being currently applied are biased, use of direct annual observations would be required to track any changes in fishery behavior and handling. This is only possible for fully monitored fisheries.

Summary

Although the extended accounting developed in this analysis is a logical extension of the current harvest policy, it is not a re-analysis of the policy itself. Given changes in fishery selectivity, size-at-age, and other biological and anthropogenic factors, there remains a distinct need to re-evaluate the current harvest policy and determine whether it meets the current management objectives. This type of analysis is part of the MSE process. Development of a MSE at the IPHC has the potential to identify alternative management procedures that may be robust to many of the uncertainties described here, and serve as a vehicle to explore hypotheses regarding recruitment distribution, juvenile and adult migration, density dependence, spatial and temporal growth variability, and a multitude of other factors. The process is ongoing, as is the development of more spatially disaggregated assessment analyses that can also be used for future work on these topics.

SPR-based accounting provides a specific total mortality target for the entire halibut stock, consistent with the current harvest policy. This ensures the same level of protection for the stock in the future, despite changes in the relative magnitudes of target and non-target fisheries and changes within the fisheries themselves. Area-specific U26 mortality targets could be established by the IPHC; however, current understanding of juvenile distribution and migration does not support an apportionment-based approach that directly prescribes the levels of U26 removals in specific regulatory areas, as is the case for O26 mortality. Even if the distribution and migration rates for juvenile halibut were known perfectly, the mechanism for distributing this mortality would be completely conditional on fishery objectives rather than biological dynamics. However, the effects of U26 mortality can now be directly evaluated in all regulatory areas, without waiting years for those effects to become obvious.

The extended accounting, using SPR in the context of the current harvest policy, provides additional information for the annual process of setting catch limits. Accounting for halibut removals of all sizes represents a conceptual extension of the current harvest policy, but not a change in the implicit logic of the approach. This analysis does broaden the scope of the policy, providing an analog in total mortality which avoids future changes in realized fishing intensity. Further, it allows for the explicit evaluation of trade-offs between removals of halibut associated with different fisheries and potential changes in the size structure of these removals in response to management actions. All sources of mortality are now 'on the table' for consideration in the same units. This analysis can therefore serve as the basis for direct comparisons within and among regulatory areas of the 'exchange rate' among fisheries in terms of both pounds of halibut removals and potential dollars earned via those removals or the removals of target species other than halibut. This approach should serve to elevate the discussion regarding such trade-offs; however, it does not presuppose any changes to current management by the U.S. Councils, DFO, or the IPHC.

Finally, the staff would like to thank the Commissioners for the opportunity to explore this topic in detail. A large amount of historical and recent analysis has addressed the harvest policy and specifically the treatment and management of various sources of mortality. The request from the 2014 Annual meeting has allowed us to perform a comprehensive review of the information available, the gaps in our current understanding of important processes, and the promising paths for future progress. The context provided here will be helpful as the Commission moves forward with annual decision making as well as ongoing long-term harvest policy and management strategy evaluation.

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Tables

Table 1. 2013 IPHC setline survey legal-size biomass distribution (apportionment), area-specific harvest rate targets based on the current harvest policy, and the resulting target TCEY distribution.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
Apportionment	2.4%	15.6%	14.9%	32.9%	13.6%	5.7%	4.2%	10.6%	100.0%
HR targets	21.5%	21.5%	21.5%	21.5%	16.1%	16.1%	16.1%	16.1%	19.7%
Target TCEY Dist.	2.6%	17.1%	16.3%	36.0%	11.1%	4.7%	3.5%	8.7%	100.0%

Table 2. Apportionment and harvest policy table from 2013 based on the Blue Line (current IPHC harvest policy). All biomass values are reported in millions of net pounds (From: Webster and Stewart 2014).

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
Exploitable bio.	4.03	26.64	25.44	56.07	23.14	9.69	7.23	18.06	170.29
Percent of total	2.4%	15.6%	14.9%	32.9%	13.6%	5.7%	4.2%	10.6%	100.0%
Harvest rate (%)	21.5%	21.5%	21.5%	21.5%	16.1%	16.1%	16.1%	16.1%	19.7%
Total CEY	0.87	5.73	5.47	12.05	3.73	1.56	1.17	2.91	33.49
Other removals	0.14	0.74	1.31	2.63	0.90	0.71	0.34	2.27	9.04
Fishery CEY	0.72	4.98	4.16	9.43	2.84	0.85	0.82	0.64	24.45

Table 3. Projected 2014 removals (millions net pounds) based on the Blue Line (current IPHC harvest policy) from 2013.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
U26									
Wastage	0.00	0.01	0.01	0.02	0.04	0.00	0.00	0.00	0.08
Bycatch	0.01	0.04	0.00	0.51	0.26	0.47	0.13	1.42	2.83
Total U26	0.01	0.04	0.01	0.52	0.30	0.48	0.14	1.42	2.92
O26 Non-FCEY									
Wastage	0.02	0.14	NA	NA	0.24	0.05	0.02	0.02	0.49
Bycatch	0.12	0.19	0.01	0.93	0.62	0.63	0.32	2.23	5.05
Non-CSP Sport	NA	NA	0.90	1.44	0.02	0.03	0.00	0.00	2.39
Pers./Subs.	NA	0.41	0.40	0.25	0.02	0.01	0.00	0.03	1.11
Total Non-FCEY	0.14	0.74	1.31	2.63	0.90	0.71	0.34	2.27	9.05
O26 FCEY									
Wastage	NA	NA	0.08	0.33	NA	NA	NA	NA	0.41
CSP Sport	0.31	0.61	0.76	1.78	NA	NA	NA	NA	3.47
Pers./Subs.	0.03	NA	NA	NA	NA	NA	NA	NA	0.03
Fishery Landings	0.38	4.37	3.32	7.32	2.84	0.85	0.82	0.64	20.54
Total FCEY	0.72	4.98	4.16	9.43	2.84	0.85	0.82	0.64	24.45
TCEY	0.87	5.72	5.47	12.05	3.73	1.56	1.17	2.91	33.49
Total Mortality	0.87	5.77	5.48	12.58	4.04	2.04	1.30	4.33	36.41

Table 4. Projected 2014 removals (millions net pounds) based the Blue Line and a 20% increase in coastwide bycatch.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
U26									
Wastage	0.00	0.01	0.01	0.02	0.04	0.00	0.00	0.00	0.08
Bycatch	0.01	0.04	0.00	0.61	0.31	0.57	0.16	1.70	3.40
Total U26	0.01	0.05	0.01	0.63	0.35	0.57	0.16	1.70	3.48
O26 Non-FCEY									
Wastage	0.02	0.14	NA	NA	0.23	0.04	0.02	0.01	0.46
Bycatch	0.14	0.23	0.01	1.12	0.74	0.76	0.38	2.68	6.06
Non-CSP Sport	NA	NA	0.90	1.44	0.02	0.03	0.00	0.00	2.39
Pers./Subs.	NA	0.41	0.40	0.25	0.02	0.01	0.00	0.03	1.11
Total Non-FCEY	0.16	0.78	1.31	2.81	1.01	0.83	0.41	2.71	10.02
O26 FCEY									
Wastage	NA	NA	0.08	0.32	NA	NA	NA	NA	0.40
CSP Sport	0.31	0.61	0.76	1.75	NA	NA	NA	NA	3.42
Pers./Subs.	0.03	NA	NA	NA	NA	NA	NA	NA	0.03
Fishery Landings	0.37	4.34	3.32	7.17	2.72	0.73	0.76	0.20	19.61
Total FCEY	0.71	4.95	4.16	9.24	2.72	0.73	0.76	0.20	23.46
TCEY	0.87	5.72	5.47	12.05	3.73	1.56	1.17	2.91	33.49
Total Mortality	0.88	5.77	5.48	12.68	4.08	2.13	1.33	4.61	36.97

Table 5. Projected 2014 removals (millions net pounds) based the Blue Line and a 20% reduction in coastwide bycatch.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
U26									
Wastage	0.00	0.01	0.01	0.02	0.04	0.00	0.00	0.00	0.09
Bycatch	0.00	0.03	0.00	0.40	0.21	0.38	0.11	1.13	2.27
Total U26	0.00	0.03	0.01	0.42	0.25	0.38	0.11	1.14	2.35
O26 Non-FCEY									
Wastage	0.02	0.15	NA	NA	0.25	0.05	0.02	0.03	0.53
Bycatch	0.10	0.15	0.01	0.74	0.50	0.50	0.26	1.78	4.04
Non-CSP Sport	NA	NA	0.90	1.44	0.02	0.03	0.00	0.00	2.39
Pers./Subs.	NA	0.41	0.40	0.25	0.02	0.01	0.00	0.03	1.11
Total Non-FCEY	0.12	0.70	1.31	2.44	0.78	0.59	0.28	1.84	8.07
O26 FCEY									
Wastage	NA	NA	0.08	0.33	NA	NA	NA	NA	0.41
CSP Sport	0.32	0.62	0.76	1.82	NA	NA	NA	NA	3.52
Pers./Subs.	0.03	NA	NA	NA	NA	NA	NA	NA	0.03
Fishery Landings	0.39	4.40	3.32	7.47	2.95	0.97	0.88	1.07	21.45
Total FCEY	0.75	5.02	4.16	9.61	2.95	0.97	0.88	1.07	25.42
TCEY	0.87	5.72	5.47	12.06	3.73	1.56	1.16	2.91	33.49
Total Mortality	0.87	5.76	5.48	12.48	3.98	1.95	1.27	4.05	35.84

Table 6. Projected 2014 removals (millions net pounds) based the Blue Line and a 20% increase in coastwide bycatch accounting for U26 mortality by maintaining the same fishing intensity (SPR).

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
U26									
Wastage	0.00	0.01	0.01	0.02	0.04	0.00	0.00	0.00	0.08
Bycatch	0.01	0.04	0.00	0.61	0.31	0.57	0.16	1.70	3.40
Total U26	0.01	0.05	0.01	0.62	0.35	0.57	0.16	1.70	3.48
O26 Non-FCEY									
Wastage	0.02	0.14	NA	NA	0.22	0.04	0.02	0.00	0.45
Bycatch	0.14	0.23	0.01	1.12	0.74	0.76	0.38	2.68	6.06
Non-CSP Sport	NA	NA	0.90	1.44	0.02	0.03	0.00	0.00	2.39
Pers./Subs.	NA	0.41	0.40	0.25	0.02	0.01	0.00	0.03	1.11
Total Non-FCEY	0.16	0.77	1.31	2.81	1.00	0.83	0.41	2.71	10.01
O26 FCEY									
Wastage	NA	NA	0.08	0.31	NA	NA	NA	NA	0.39
CSP Sport	0.30	0.59	0.74	1.70	NA	NA	NA	NA	3.33
Pers./Subs.	0.03	NA	NA	NA	NA	NA	NA	NA	0.03
Fishery Landings	0.36	4.24	3.23	6.99	2.65	0.70	0.74	0.15	19.06
Total FCEY	0.69	4.83	4.05	9.00	2.65	0.70	0.74	0.15	22.82
TCEY	0.85	5.61	5.36	11.82	3.65	1.53	1.15	2.86	32.83
Total Mortality	0.86	5.66	5.37	12.44	4.01	2.10	1.31	4.56	36.30

Table 7. Projected 2014 removals (millions net pounds) based the Blue Line and a 20% reduction in coastwide bycatch accounting for U26 mortality by maintaining the same fishing intensity (SPR).

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
U26									
Wastage	0.00	0.01	0.01	0.02	0.04	0.00	0.00	0.00	0.09
Bycatch	0.00	0.03	0.00	0.40	0.21	0.38	0.11	1.13	2.27
Total U26	0.00	0.03	0.01	0.42	0.25	0.38	0.11	1.14	2.36
O26 Non-FCEY									
Wastage	0.02	0.15	NA	NA	0.25	0.06	0.02	0.03	0.54
Bycatch	0.10	0.15	0.01	0.74	0.50	0.50	0.26	1.78	4.04
Non-CSP Sport	NA	NA	0.90	1.44	0.02	0.03	0.00	0.00	2.39
Pers./Subs.	NA	0.41	0.40	0.25	0.02	0.01	0.00	0.03	1.11
Total Non-FCEY	0.12	0.71	1.31	2.44	0.79	0.59	0.28	1.84	8.08
O26 FCEY									
Wastage	NA	NA	0.08	0.34	NA	NA	NA	NA	0.42
CSP Sport	0.33	0.63	0.78	1.86	NA	NA	NA	NA	3.60
Pers./Subs.	0.03	NA	NA	NA	NA	NA	NA	NA	0.03
Fishery Landings	0.40	4.49	3.40	7.63	3.01	1.00	0.90	1.12	21.96
Total FCEY	0.77	5.13	4.26	9.83	3.01	1.00	0.90	1.12	26.01
TCEY	0.89	5.83	5.57	12.27	3.80	1.59	1.18	2.96	34.09
Total Mortality	0.89	5.86	5.58	12.69	4.05	1.98	1.29	4.10	36.45

Table 8. Comparison of coastwide projected 2014 removals (millions net pounds) based the Blue Line, alternate levels of bycatch, and current vs. extended accounting via SPR. Target TCEY distribution, based on apportionment, is maintained in all projections (Detailed results in Tables 3-7).

Alternative:	**Total U26**	**Total O26 Non-FCEY**	**Total FCEY**	**Total TCEY**	**Total Mortality**
Blue Line	2.92	9.05	24.45	33.49	36.41
<u>Current accounting</u>					
Bycatch (+20%)	3.48	10.02	23.46	33.49	36.97
Bycatch (-20%)	2.35	8.07	25.42	33.49	35.84
<u>Extended accounting</u>					
Bycatch (+20%)	3.48	10.01	22.82	32.83	36.30
Bycatch (-20%)	2.36	8.08	26.01	34.09	36.45

Table 9. Projected 2014 removals (millions net pounds) based the Blue Line and a 20% increase in bycatch in Areas 4A, 4B, 4CDE.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
U26									
Wastage	0.00	0.01	0.01	0.02	0.04	0.00	0.00	0.00	0.08
Bycatch	0.01	0.04	0.00	0.51	0.26	0.57	0.16	1.70	3.24
Total U26	0.01	0.04	0.01	0.52	0.30	0.57	0.16	1.70	3.32
O26 Non-FCEY									
Wastage	0.02	0.14	NA	NA	0.24	0.04	0.02	0.01	0.47
Bycatch	0.12	0.19	0.01	0.93	0.62	0.76	0.38	2.68	5.69
Non-CSP Sport	NA	NA	0.90	1.44	0.02	0.03	0.00	0.00	2.39
Pers./Subs.	NA	0.41	0.40	0.25	0.02	0.01	0.00	0.03	1.11
Total Non-FCEY	0.14	0.74	1.31	2.63	0.90	0.83	0.41	2.71	9.66
O26 FCEY									
Wastage	NA	NA	0.08	0.33	NA	NA	NA	NA	0.41
CSP Sport	0.31	0.61	0.76	1.78	NA	NA	NA	NA	3.47
Pers./Subs.	0.03	NA	NA	NA	NA	NA	NA	NA	0.03
Fishery Landings	0.38	4.37	3.32	7.33	2.84	0.73	0.76	0.20	19.92
Total FCEY	0.72	4.98	4.16	9.43	2.84	0.73	0.76	0.20	23.83
TCEY	0.87	5.72	5.47	12.06	3.73	1.56	1.17	2.91	33.49
Total Mortality	0.87	5.76	5.48	12.59	4.04	2.13	1.33	4.61	36.80

Table 10. Projected 2014 removals (millions net pounds) based the Blue Line and a 20% reduction in bycatch in Areas 4A, 4B, 4CDE.

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
U26									
Wastage	0.00	0.01	0.01	0.02	0.04	0.00	0.00	0.00	0.08
Bycatch	0.01	0.04	0.00	0.51	0.26	0.38	0.11	1.13	2.43
Total U26	0.01	0.04	0.01	0.52	0.30	0.38	0.11	1.14	2.51
O26 Non-FCEY									
Wastage	0.02	0.14	NA	NA	0.24	0.05	0.02	0.03	0.52
Bycatch	0.12	0.19	0.01	0.93	0.62	0.50	0.26	1.78	4.41
Non-CSP Sport	NA	NA	0.90	1.44	0.02	0.03	0.00	0.00	2.39
Pers./Subs.	NA	0.41	0.40	0.25	0.02	0.01	0.00	0.03	1.11
Total Non-FCEY	0.14	0.74	1.31	2.63	0.90	0.59	0.28	1.84	8.43
O26 FCEY									
Wastage	NA	NA	0.08	0.33	NA	NA	NA	NA	0.41
CSP Sport	0.31	0.61	0.76	1.78	NA	NA	NA	NA	3.47
Pers./Subs.	0.03	NA	NA	NA	NA	NA	NA	NA	0.03
Fishery Landings	0.38	4.37	3.32	7.33	2.84	0.97	0.88	1.07	21.15
Total FCEY	0.72	4.98	4.16	9.43	2.84	0.97	0.88	1.07	25.06
TCEY	0.87	5.72	5.47	12.06	3.73	1.56	1.16	2.91	33.49
Total Mortality	0.87	5.76	5.48	12.59	4.04	1.95	1.27	4.05	36.00

Table 11. Projected 2014 removals (millions net pounds) based the Blue Line and a 20% increase in bycatch in Areas 4A, 4B, 4CDE accounting for U26 mortality by maintaining the same fishing intensity (SPR).

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
U26									
Wastage	0.00	0.01	0.01	0.02	0.04	0.00	0.00	0.00	0.08
Bycatch	0.01	0.04	0.00	0.51	0.26	0.57	0.16	1.70	3.24
Total U26	0.01	0.04	0.01	0.52	0.30	0.57	0.16	1.70	3.32
O26 Non-FCEY									
Wastage	0.02	0.14	NA	NA	0.24	0.04	0.02	0.00	0.46
Bycatch	0.12	0.19	0.01	0.93	0.62	0.76	0.38	2.68	5.69
Non-CSP Sport	NA	NA	0.90	1.44	0.02	0.03	0.00	0.00	2.39
Pers./Subs.	NA	0.41	0.40	0.25	0.02	0.01	0.00	0.03	1.11
Total Non-FCEY	0.14	0.74	1.31	2.63	0.89	0.83	0.41	2.71	9.65
O26 FCEY									
Wastage	NA	NA	0.08	0.32	NA	NA	NA	NA	0.40
CSP Sport	0.31	0.60	0.75	1.75	NA	NA	NA	NA	3.41
Pers./Subs.	0.03	NA	NA	NA	NA	NA	NA	NA	0.03
Fishery Landings	0.37	4.31	3.26	7.20	2.79	0.71	0.75	0.16	19.55
Total FCEY	0.71	4.92	4.09	9.27	2.79	0.71	0.75	0.16	23.40
TCEY	0.85	5.65	5.40	11.90	3.68	1.54	1.16	2.87	33.05
Total Mortality	0.86	5.69	5.41	12.42	3.98	2.11	1.32	4.57	36.36

Table 12. Projected 2014 removals (millions net pounds) based the Blue Line and a 20% reduction in bycatch in Areas 4A, 4B, 4CDE accounting for U26 mortality by maintaining the same fishing intensity (SPR).

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
U26									
Wastage	0.00	0.01	0.01	0.02	0.04	0.00	0.00	0.00	0.09
Bycatch	0.01	0.04	0.00	0.51	0.26	0.38	0.11	1.13	2.43
Total U26	0.01	0.04	0.01	0.53	0.30	0.38	0.11	1.14	2.52
O26 Non-FCEY									
Wastage	0.02	0.15	NA	NA	0.24	0.06	0.02	0.03	0.52
Bycatch	0.12	0.19	0.01	0.93	0.62	0.50	0.26	1.78	4.41
Non-CSP Sport	NA	NA	0.90	1.44	0.02	0.03	0.00	0.00	2.39
Pers./Subs.	NA	0.41	0.40	0.25	0.02	0.01	0.00	0.03	1.11
Total Non-FCEY	0.14	0.74	1.31	2.63	0.90	0.59	0.28	1.84	8.44
O26 FCEY									
Wastage	NA	NA	0.08	0.33	NA	NA	NA	NA	0.41
CSP Sport	0.32	0.62	0.78	1.81	NA	NA	NA	NA	3.53
Pers./Subs.	0.03	NA	NA	NA	NA	NA	NA	NA	0.03
Fishery Landings	0.39	4.44	3.38	7.45	2.88	0.99	0.90	1.11	21.53
Total FCEY	0.73	5.06	4.24	9.59	2.88	0.99	0.90	1.11	25.50
TCEY	0.88	5.80	5.55	12.22	3.78	1.58	1.18	2.95	33.94
Total Mortality	0.88	5.84	5.56	12.74	4.08	1.97	1.29	4.09	36.46

Table 13. Comparison of coastwide projected 2014 removals (millions net pounds) based the Blue Line, alternate levels of bycatch in the BSAI (Areas 4A, 4B, 4CDE), and current vs. extended accounting via SPR. Target TCEY distribution, based on apportionment, is maintained in all projections (Detailed results in Tables 3, 9-13).

Alternative:	**Total U26**	**Total O26 Non-FCEY 2A-**	**Total O26 Non-FCEY BSAI**	**Total FCEY 2A-3B**	**Total FCEY BSAI**	**Total TCEY 2A-3B**	**Total TCEY BSAI**	**Total Mortality**
Blue Line	2.92	5.72	3.32	22.13	2.31	27.84	5.64	36.41
<u>Current accounting</u>								
BSAI Bycatch (+20%)	3.32	5.72	3.95	22.13	1.69	27.84	5.64	36.80
BSAI Bycatch (-20%)	2.51	5.72	2.71	22.13	2.92	27.84	5.64	36.00
<u>Extended accounting</u>								
BSAI Bycatch (+20%)	3.32	5.71	3.95	21.78	1.62	27.48	5.57	36.36
BSAI Bycatch (-20%)	2.52	5.72	2.71	22.50	3.00	28.23	5.71	36.46

Table 14. Final 2013 decision table results.

				Stock Trend				Stock Status				Fishery Trend				Fishery Status
				Spawning biomass				Spawning biomass				Fishery CEY from the harvest policy				Harvest rate
				in 2015		in 2017		in 2015		in 2017		in 2015		in 2017		in 2014
2014 Alternative	Total removals (M lb)	Fishery CEY (M lb)	Harvest rate	is less than 2014	is 5% less than 2014	is less than 2014	is 5% less than 2014	is less than 30%	is less than 20%	is less than 30%	is less than 20%	is less than 2014	is 10% less than 2014	is less than 2014	is 10% less than 2014	is above target
No removals	0.0	0.0	0.0%	5/100	<1/100	23/100	4/100	3/100	<1/100	1/100	<1/100	0/100	0/100	0/100	0/100	0/100
FCEY = 0	11.4	0.0	5.0%	31/100	<1/100	32/100	18/100	3/100	<1/100	2/100	<1/100	0/100	0/100	0/100	0/100	<1/100
	20.0	8.5	10.1%	33/100	<1/100	37/100	24/100	4/100	<1/100	3/100	<1/100	<1/100	<1/100	<1/100	<1/100	<1/100
	30.0	18.2	15.9%	39/100	<1/100	66/100	41/100	4/100	<1/100	5/100	<1/100	5/100	2/100	8/100	4/100	7/100
Blue Line	36.4	24.5	19.7%	56/100	1/100	82/100	63/100	5/100	<1/100	6/100	1/100	43/100	20/100	74/100	47/100	50/100
Final adopted	39.6	27.5	21.5%	67/100	1/100	87/100	72/100	5/100	<1/100	8/100	1/100	80/100	46/100	95/100	81/100	89/100
	40.0	28.0	21.8%	68/100	1/100	87/100	73/100	5/100	<1/100	8/100	1/100	85/100	52/100	96/100	84/100	92/100
	45.0	32.8	24.7%	82/100	4/100	93/100	83/100	6/100	1/100	10/100	1/100	>99/100	95/100	>99/100	99/100	>99/100
status quo	48.5	36.1	26.7%	88/100	8/100	95/100	87/100	6/100	1/100	13/100	1/100	>99/100	>99/100	>99/100	>99/100	>99/100
	55.0	42.6	30.5%	95/100	23/100	98/100	94/100	6/100	1/100	19/100	2/100	>99/100	>99/100	>99/100	>99/100	>99/100
	60.0	47.5	33.5%	98/100	38/100	99/100	97/100	7/100	1/100	26/100	2/100	>99/100	>99/100	>99/100	>99/100	>99/100
				a	b	c	d	e	f	g	h	i	j	k	l	m

Table 15. Comparison of alternative 2013 decision table results based on changes in bycatch and U26 mortality accounting: row a) 2013 Blue Line, b) 20% reduction in coastwide bycatch in 2014, c) 20% reduction in coastwide bycatch in 2014 maintaining target SPR, d) 20% reduction in 2014 bycatch in areas 4A, 4B, and 4CDE, and e) 20% reduction in 2014 bycatch in areas 4A, 4B, and 4CDE maintaining target SPR. Rows correspond to apportionment and harvest policy tables above and are ordered by increasing total mortality.

				Stock Trend				Stock Status				Fishery Trend				Fishery Status
				Spawning biomass				Spawning biomass				Fishery CEY from the harvest policy				Harvest rate
				in 2015		in 2017		in 2015		in 2017		in 2015		in 2017		in 2014
2014 Alternative	Total removals (M lb)	Fishery CEY (M lb)	Harvest rate	is less than 2014	is 5% less than 2014	is less than 2014	is 5% less than 2014	is less than 30%	is less than 20%	is less than 30%	is less than 20%	is less than 2014	is 10% less than 2014	is less than 2014	is 10% less than 2014	is above target
b	35.8	25.4	19.7%	55/100	1/100	82/100	63/100	5/100	<1/100	6/100	1/100	55/100	26/100	81/100	57/100	49/100
d	36.0	25.1	19.7%	55/100	1/100	82/100	63/100	5/100	<1/100	6/100	1/100	50/100	23/100	78/100	53/100	49/100
a	36.4	24.5	19.7%	56/100	1/100	82/100	63/100	5/100	<1/100	6/100	1/100	43/100	20/100	74/100	47/100	50/100
e	36.5	25.5	19.9%	57/100	1/100	83/100	64/100	5/100	<1/100	6/100	1/100	52/100	24/100	80/100	55/100	51/100
c	36.5	26.0	20.0%	58/100	1/100	83/100	65/100	5/100	<1/100	6/100	1/100	57/100	27/100	83/100	59/100	50/100

Figures

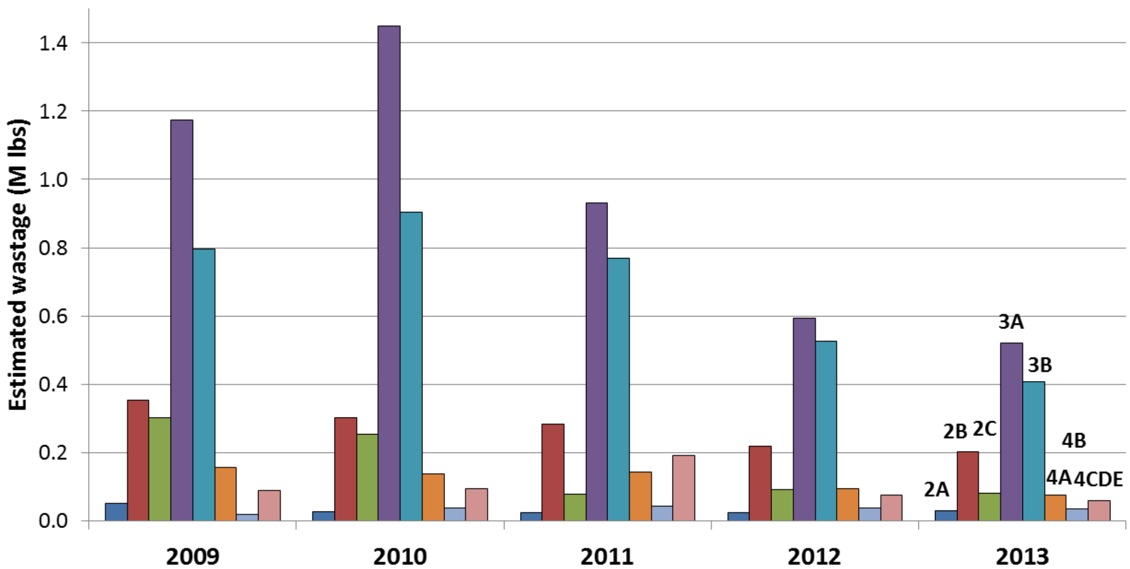

Figure 1. Wastage estimates by IPHC regulatory area over the period 2009-2013.

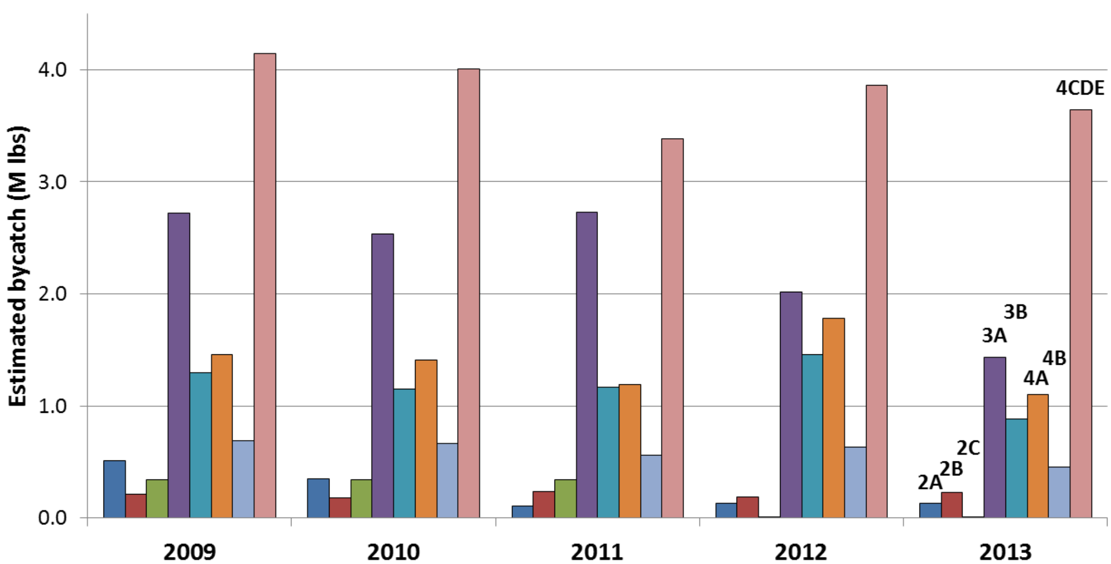

Figure 2. Bycatch estimates by IPHC regulatory area over the period 2009-2013.

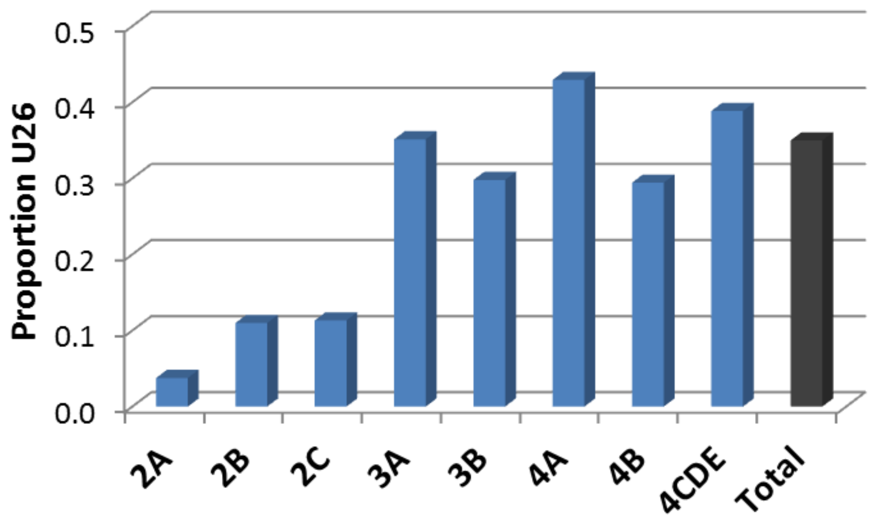

Figure 3. Estimated proportion of U26 halibut bycatch by regulatory area averaged over the period 2009-2013.

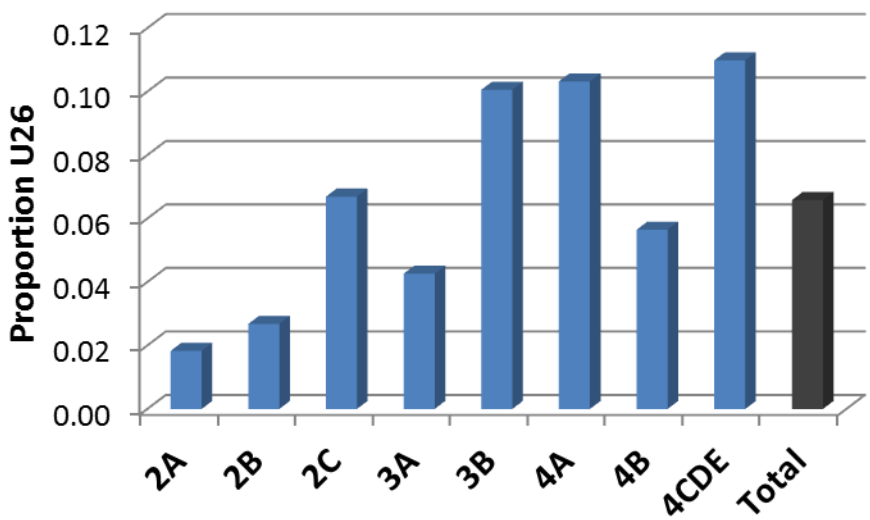

Figure 4. Estimated proportion of U26 halibut wastage by regulatory area averaged over the period 2009-2013.

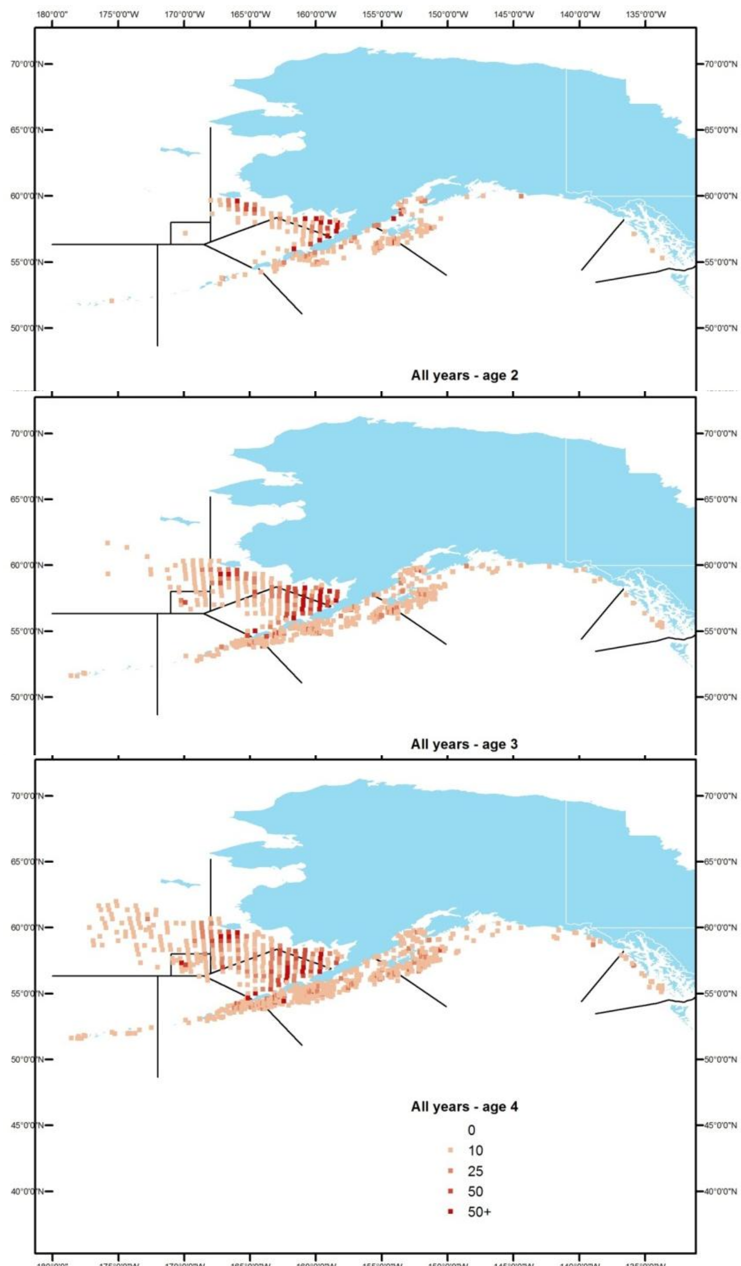

Figure 5. Distribution of aggregate halibut catch for age 2 (top panel), age 3 (middle panel) and age 4 (lower panel) from all available NMFS Bering Sea, Aleutian Islands, and Gulf of Alaska trawl surveys.

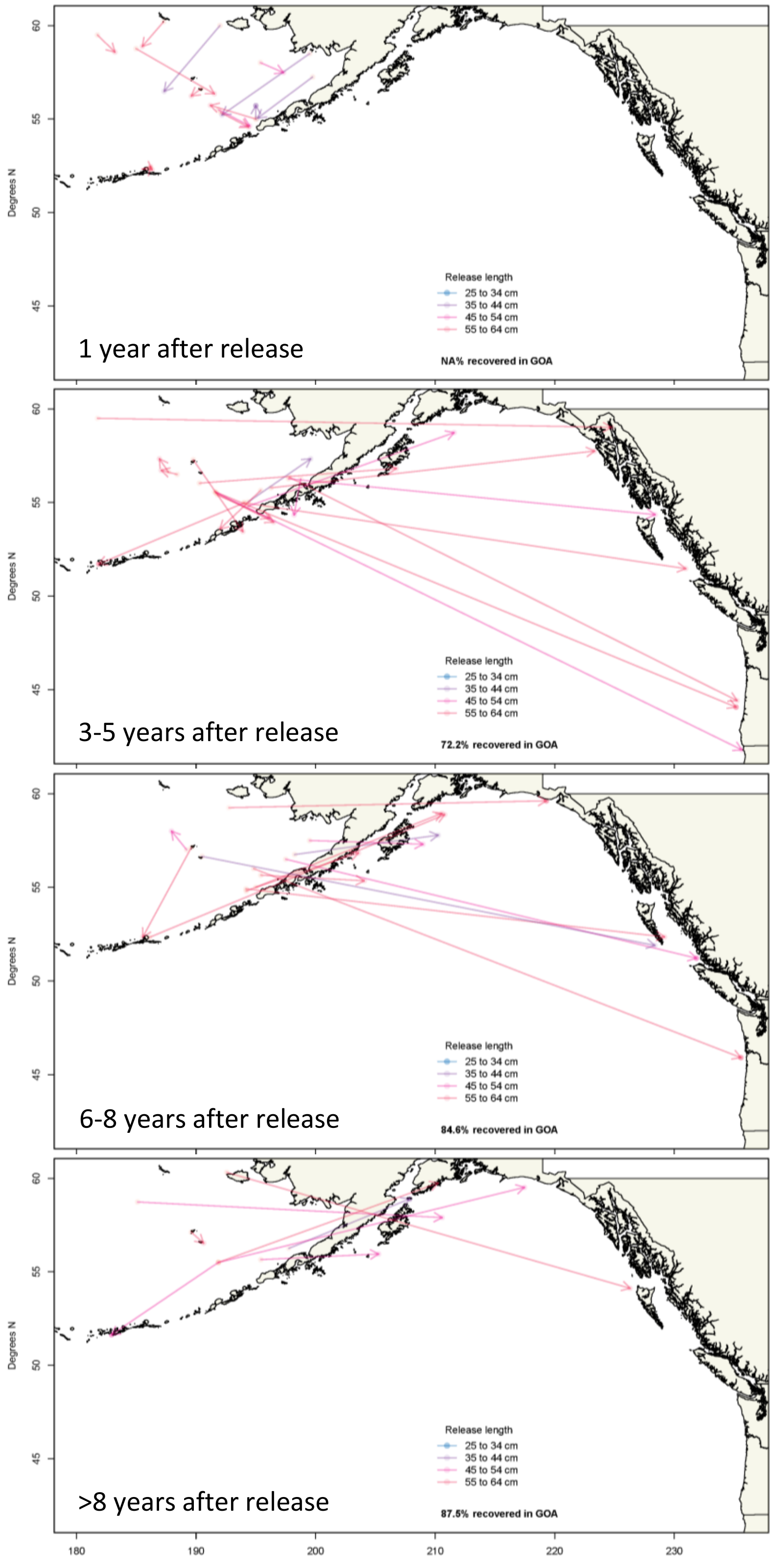

Figure 6. Release and recovery locations for juvenile halibut tagged in the Bering Sea, grouped by time at large (From: Webster, *in prep.*)

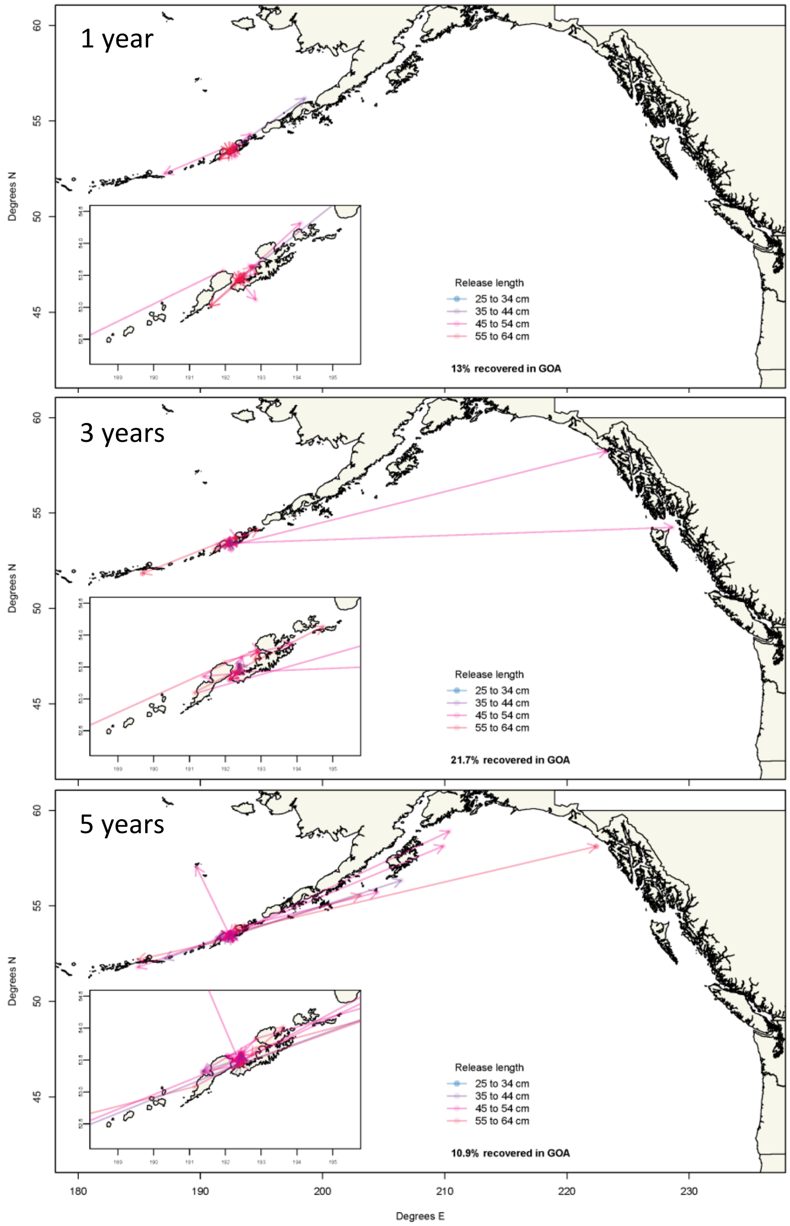

Figure 7. Release and recovery locations for juvenile halibut tagged near Unalaska, grouped by time at large (also see next figure; From: Webster, *in prep.*).

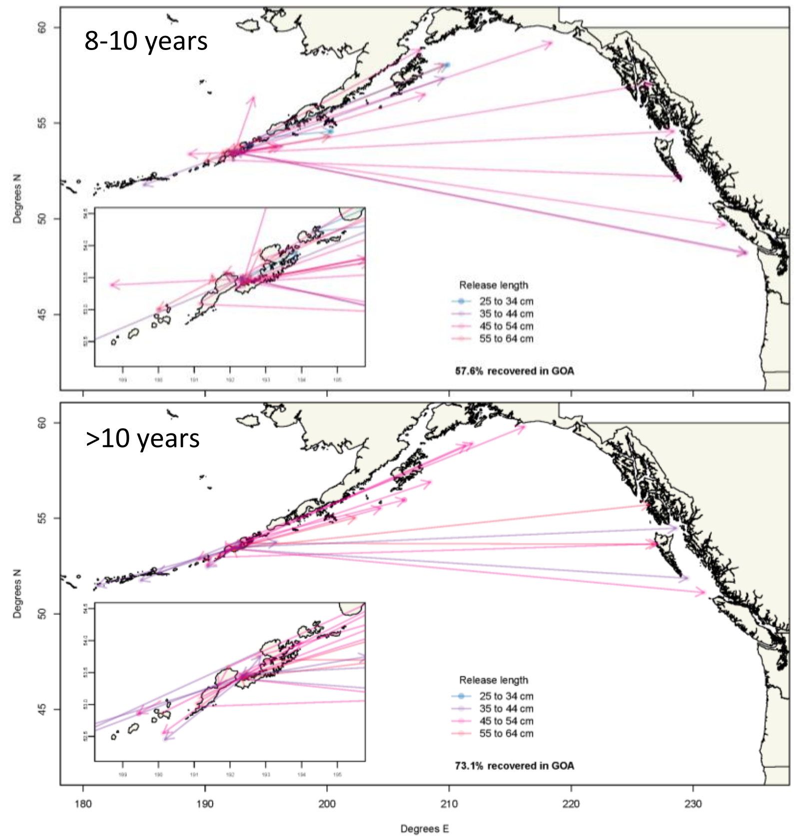

Figure 8. Release and recovery locations for juvenile halibut tagged near Unalaska, grouped by time at large (also see previous figure; From: Webster, *in prep.*).

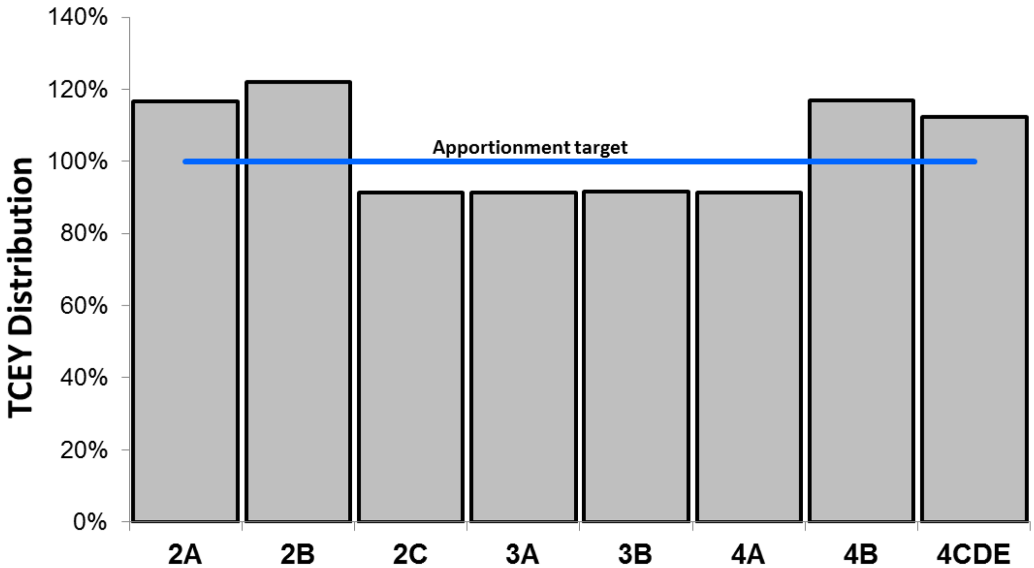

Figure 9. Relative distribution of the TCEY from the 2014 adopted catch limits.

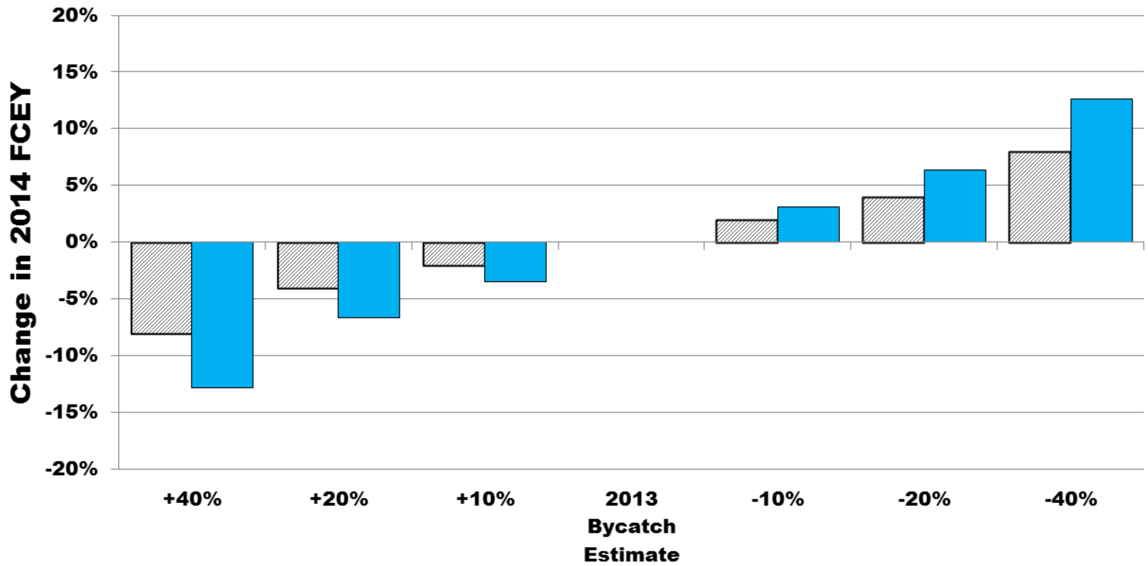

Figure 10. Change in projected coastwide 2014 FCEY in response to changes in coastwide halibut bycatch. Gray bars (left) indicate the application of current harvest policy directly accounting for only O26 mortality, darker blue bars (right) indicate an extension of this policy explicitly accounting for all mortality by maintaining the same level of fishing intensity (SPR) for all scenarios.

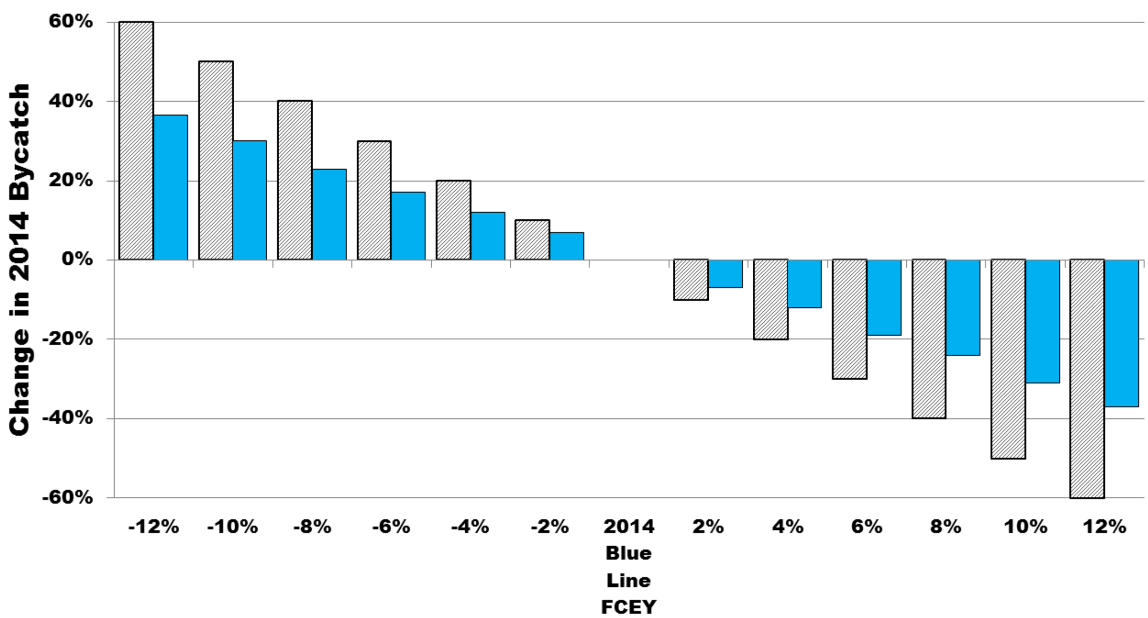

Figure 11. Change in projected coastwide 2014 Bycatch in response to different coastwide halibut FCEYs. Gray bars (indicate the application of current harvest policy directly accounting for only O26 mortality, darker blue bars indicate an extension of this policy explicitly accounting for all mortality by maintaining the same level of fishing intensity (SPR) for all scenarios.

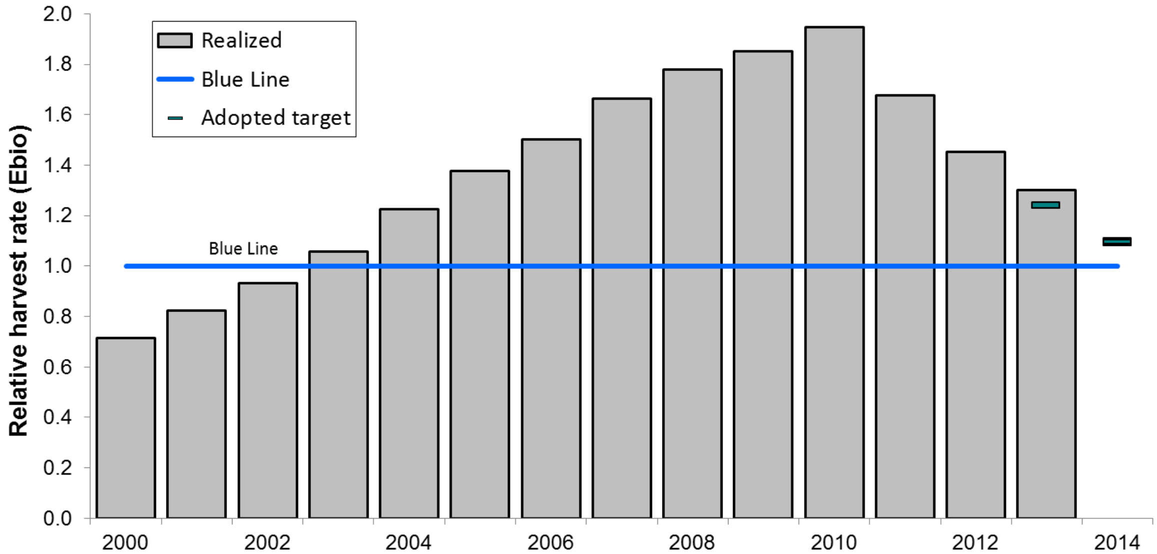

Figure 12. Recent relative harvest rate trends estimated via O26 removals and exploitable biomass.

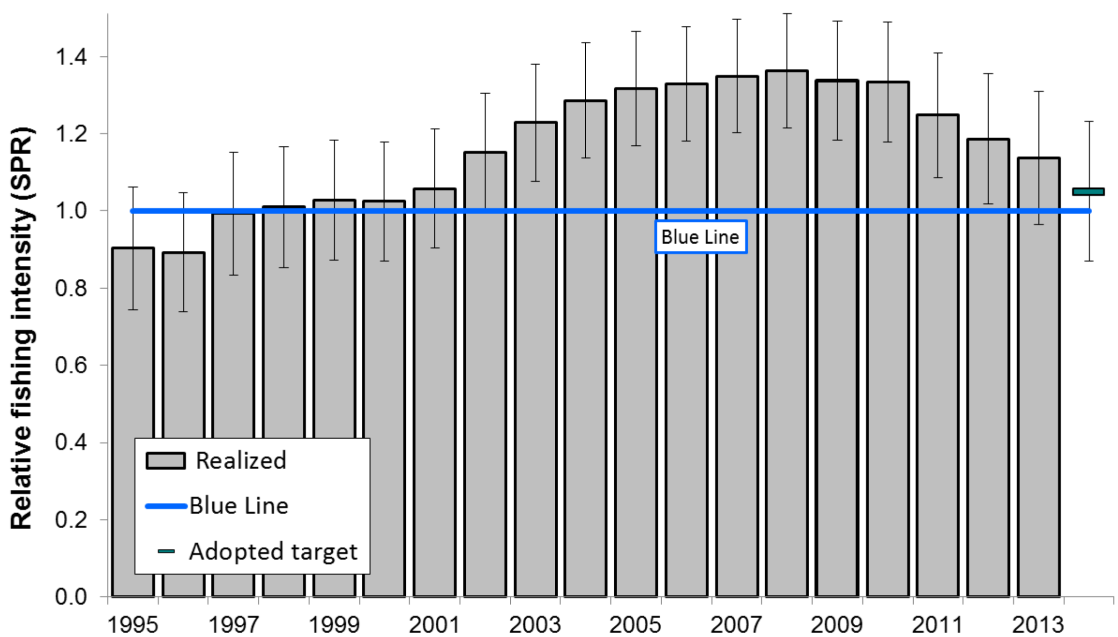

Figure 13. Recent relative harvest rate trends estimated via SPR calculated using the long-time series model from the 2013 stock assessment ensemble.