CANADA

British Columbia Groundfish Fisheries and Their Investigations in 2021

April 2022

Prepared for the
Technical Sub-Committee of the Canada-United States Groundfish Committee

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I. Agency Overview

Fisheries and Oceans Canada (DFO) has its regional headquarters office (RHQ) for the Pacific Region (British Columbia and Yukon) in Vancouver, British Columbia, with area offices and science facilities at various locations throughout the Region. Groundfish fishery management is conducted by the Groundfish Management Unit within the Fisheries Management Branch at RHQ, while Groundfish stock assessment and research is conducted by Science Branch at the Pacific Biological Station (PBS) in Nanaimo, and at the Institute of Ocean Sciences (IOS) in Sidney. Within Science Branch, a variety of programs are responsible for delivering groundfish stock assessments and research and for providing science advice to fishery managers, species at risk coordinators, marine spatial planners, etc. Directors, division managers, and section heads are as follows:

Fisheries and Oceans Canada Minister: The Honourable Joyce Murray

Regional Headquarters Office (RHQ)

Regional Director General: Rebecca Reid

Fisheries and Aquaculture Management Branch

Regional Director of Fisheries Management:	Neil Davis
Regional Director of Resource Management:	Julia MacKenzie
Regional Manager of Groundfish:	Adam Keizer

Science Branch

Regional Director of Science:	Andrew Thomson
Strategic Science Initiatives Division (SSID):	Al Magnan (Acting)
• Centre for Science Advice – Pacific:	Lisa Christensen
• Strategic Partnerships and Programs:	March Klaver
Stock Assessment and Research Division (StAR):	John Holmes
• Groundfish Section:	Dana Haggarty (Acting)
• Quantitative Assessment Methods Section:	Chris Rooper
• Fisheries and Assessment Data Section:	Shelee Hamilton
• Marine Invertebrates Section:	Ken Fong
• Salmon Assessment:	Antonio Velez-Espino
• Salmon Coordinator:	Diana Dobson
Aquatic Diagnostics, Genomics & Technology Division (ADGT):	Jon Chamberlain (Acting)
• Applied Technology:	Kathryn Berry (Acting)
• Genetics:	John Candy
• Aquatic Animal Health:	Mark Higgins
Ocean Science Division (OSD):	Kim Houston

- Ecology and Biogeochemistry: Neil Dangerfield
- Modelling & Prediction: Di Wan
- State of the Ocean: Gwyn Lintern

Ecosystem Science Division (ESD): Eddy Kennedy
- Marine Spatial Ecology & Analysis: Miriam O
- Aquatic Ecosystem & Marine Mammals: Sean MacConnachie
- Freshwater Ecosystems: Jeffery Lemieux
- Nearshore Ecosystems: Cher LaCoste
- Regional Ecosystem Effects on Fish & Fisheries: Kim Hyatt

Canadian Hydrographic Service (CHS): Mark LeBlanc

Groundfish research and stock assessment work is conducted amongst the Groundfish, Fisheries and Assessment Data, and Quantitative Methods Sections within StAR. Groundfish specimen ageing and genetics are conducted in the Applied Technologies and Genetics Sections in ADGT. Acoustic fisheries research and surveys are led by the Ecology and Biogeochemistry Section in OSD. Ecosystem studies, marine protected areas research and planning, and habitat research is undertaken in collaboration with staff in the Ecosystems Science Division (ESD).

Fishery Managers and other clients receive science advice from StAR through the Canadian Centre for Scientific Advice Pacific (CSAP) review committee. Groundfish subject matter experts (SMEs) meet periodically throughout the year to provide scientific peer review of stock assessment working papers and develop scientific advice. Every peer review process involves both internal (DFO) and external reviewers. The resulting Science Advisory Report summarizes the advice to Fishery Managers, with the full stock assessment becoming a Research Document. Both documents can be viewed on the Canadian Stock Assessment Secretariat website: http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm. The frequency of review meetings and production of stock assessment advice for fisheries managers varies depending on departmental, branch and regional priorities.

The Canadian Coast Guard operates DFO research vessels. These research vessels include the J.P. Tully, Vector, Neocaligus, and the Sir John Franklin. The Sir John Franklin, replacement for the W.E Ricker, was deployed for its inaugural field season in 2020 but only a limited number of surveys (and no groundfish surveys) were completed due to the COVID pandemic. A full suite of surveys was planned for 2021 but there was a major electrical failure mid-way through the season that sidelined the vessel. A commercial fishing vessel was chartered to complete the remainder of the surveys.

The Groundfish Trawl, Sablefish, Rockfish, Lingcod, North Pacific Spiny Dogfish, and Halibut fishery sectors continue to be managed as an integrated fishery with Individual Vessel Quotas (IVQs). IVQs can be for specific areas or coastwide. Within the general IVQ context, managers also use a suite of management tactics including time and area specific closures and bycatch limits. The 2021 Groundfish Integrated Fisheries Management Plan v.1.3 (IFMP) is available from the Federal Science Library: https://waves-vagues.dfo-mpo.gc.ca/Library/40990151.pdf.

Allocations of fish for financing scientific and management activities are identified in the Groundfish IFMP. Use of Fish Collaborative Agreements were developed for 2021-22 between Fisheries and Oceans Canada and Wild Canadian Sablefish (multi-year agreement to the end of 2023), Pacific Halibut Management Association of BC, and the Canadian Groundfish Research and Conservation Society to support groundfish science activities through the allocation of fish to finance the activities. These agreements will be updated for 2022-23.

II. Surveys

A. Databases and Data Acquisition Software

GFBioField is a data acquisition software application created in-house by DFO staff in the Groundfish Surveys Program at the Pacific Biological Station in Nanaimo British Columbia. GFBioField was designed for real-time data capture and data entry during at-sea surveys but can also be used for dockside sampling and office-based data entry. Modified versions have been developed by Groundfish Surveys staff for use by other programs such as the Marine Invertebrates Section within the StAR Division, and the Aquatic Ecosystems and Marine Mammals Section and Regional Ecosystem Effects on Fish and Fisheries Section in the Ecosystem Science Division. GFBioField uses a client-server architecture employing Microsoft SQL Server 2016 for the back-end data storage and business logic along with a Microsoft Access 2016 front-end.

GFBio is an oracle database developed in-house by DFO staff in the 1990s, which houses groundfish research survey and commercial biological data collected in British Columbia from the 1940s to the present. GFBio now includes 29,328 trips and approximately 11.9 million individual fish specimens. In 2021, data entry activities concentrated on input of current-year groundfish research cruises, fish ages, and lingcod creel survey biological samples for 2013-2019.

B. Commercial Fishery Monitoring and Biological Sampling

Groundfish commercial fisheries in British Columbia are subject to 100% catch monitoring. This requirement is met either through an at-sea observer program (ASOP) or through the use of an electronic monitoring (EM) system on each trip. In addition, a dockside monitoring program (DMP) validates all commercial landings. EM systems must meet standards specified by DFO, must be functional for the duration of any fishing trip, and are subject to an audit following every trip. The combination of fisher logbooks with ASOP/EM and DMP are intended to provide an accurate and complete record of all fishing that takes place under a commercial groundfish fishing licence.

Prior to the COVID-19 pandemic, Groundfish hook and line and trap fisheries were permitted to use either an ASOP or EM system to satisfy 100% monitoring requirements, while the majority of the groundfish trawl fleet were required to use ASOP. On April 2, 2020 the Minister of Fisheries and Oceans Canada suspended the use of at-sea observers due to the COVID-19 pandemic. On April 10, 2020, an emergency Electronic Monitoring (EM) pilot program was introduced for groundfish trawl trips in order to ensure continued comprehensive and independent catch monitoring of the groundfish trawl fleet. Effective October 29, 2020, the emergency EM measures were expanded to require an upgraded version of the EM system as

well as the installation and use of video-monitored fixed measuring grids for all releases of lingcod and sablefish which are subject to size limits. Alternatively, vessels were once again permitted to carry an at-sea observer (subject to availability and applicable COVID-19 guidelines); however, all vessels opted to continue with the EM measures. In consultation with harvesters and service providers, improvements to the EM program were implemented on August 15, 2021 which include enhanced EM equipment standards and an improved audit program to ensure the accuracy of fishing logs. Consequences for non-compliance with EM audit standards began on February 21, 2022 to provide time for fishers to learn the new standards. Consequences may include partial or 100 per cent replacement of fisher logbook data with EM estimates when audits do not meet standards.

Commercial fishery data from observer logs, fisher logs, and DMP are captured electronically in the groundfish modules of the Fishery Operations System (FOS) database, maintained by the Fisheries and Aquaculture Management Branch of DFO. Groundfish Science maintains GFFOS, which contains the groundfish FOS data, reformatted to be useful for scientific purposes.

Prior to the COVID-19 pandemic, in addition to monitoring catches at sea, the ASOP also provided biological samples of halibut, salmonids, and a variety of important commercial groundfish species from the observed trawl fishery. Biological samples were also collected from the hake fishery as part of the DMP. For the duration of the pandemic at-sea sampling has been suspended and minimal sampling has occurred during DMP; however, improved dockside sampling protocols are being implemented in 2022 for Pacific Hake and Longspine Thornyheads. Work is also underway to develop an interim biosampling program for other commercial groundfish species while Science conducts a larger review the numbers and types of biological samples needed to support groundfish stock assessment and research on an ongoing basis. Additional commercial biological samples may also be collected by DFO staff at the dockside from sablefish trips or other trips that would not otherwise be sampled. Commercial biological samples are uploaded to GFBio on an annual basis, or more frequently as required.

C. Research Surveys

The Fisheries and Oceans, Canada (DFO) Groundfish section of the Stock Assessment and Research Division conducts a suite of fishing surveys using bottom trawl, longline hook, and longline trap gear that, in aggregate, provide comprehensive coverage for all offshore waters of Canada's Pacific Coast. The core surveys include the Multispecies Synoptic Bottom Trawl, Hard Bottom Longline Hook, and Sablefish Longline Trap surveys (Figure 1).

Data from the synoptic bottom trawl surveys and hard bottom longline hook surveys are published annually to the Government of Canada Open Government Portal and to OBIS:

- Open Government Portal
  - Synoptic Bottom Trawl Surveys
  - Hard Bottom Longline Surveys
- OBIS
  - Queen Charlotte Sound Bottom Synoptic Trawl Survey
  - West Coast Vancouver Island Synoptic Trawl Survey
  - Hecate Strait Synoptic Trawl Survey

- West Coast Haida Gwaii Synoptic Trawl Survey
- Strait of Georgia Synoptic Trawl Survey
- Inside North Hard Bottom Longline Survey
- Inside South Hard Bottom Longline Survey
- Outside North Hard Bottom Longline Survey
- Outside South Hard Bottom Longline Survey

All the core surveys follow similar random depth-stratified designs and have in common full enumeration of the catches (all catch sorted to the lowest taxon possible), size composition sampling for most species, and more detailed biological sampling of selected species. Most of the surveys are conducted in collaboration with the commercial fishing industry under the authorities of various Collaborative Agreements. In addition to these randomized surveys, a fixed-station longline hook survey targeting North Pacific Spiny Dogfish in the Strait of Georgia is completed every three years. The Groundfish section also routinely participates in the Canadian portion of the Joint Canada US Hake Acoustic Survey and collects groundfish information from a DFO Small-Mesh Bottom Trawl Survey (Figure 2).

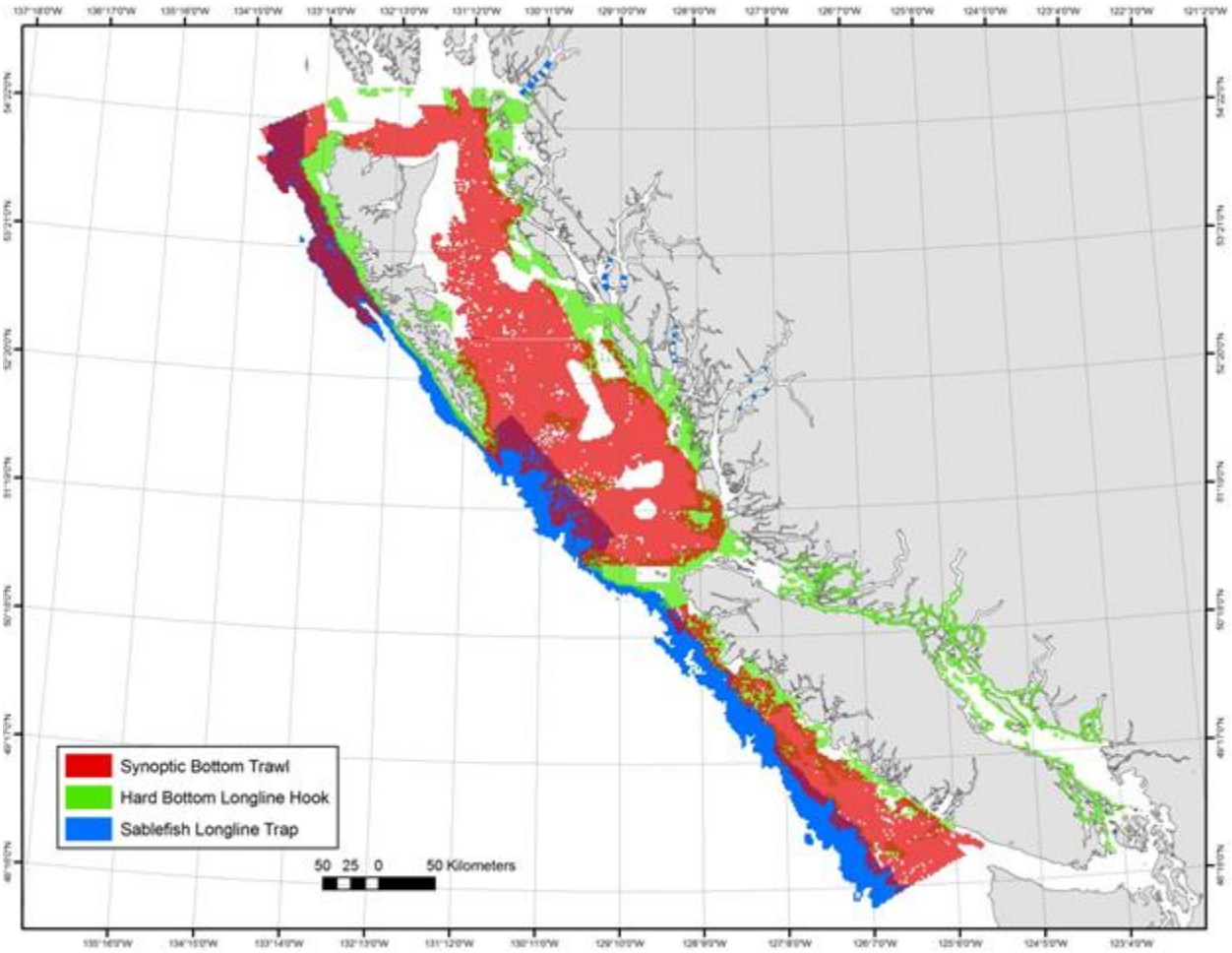

Figure 1. Random depth-stratified survey coverage.

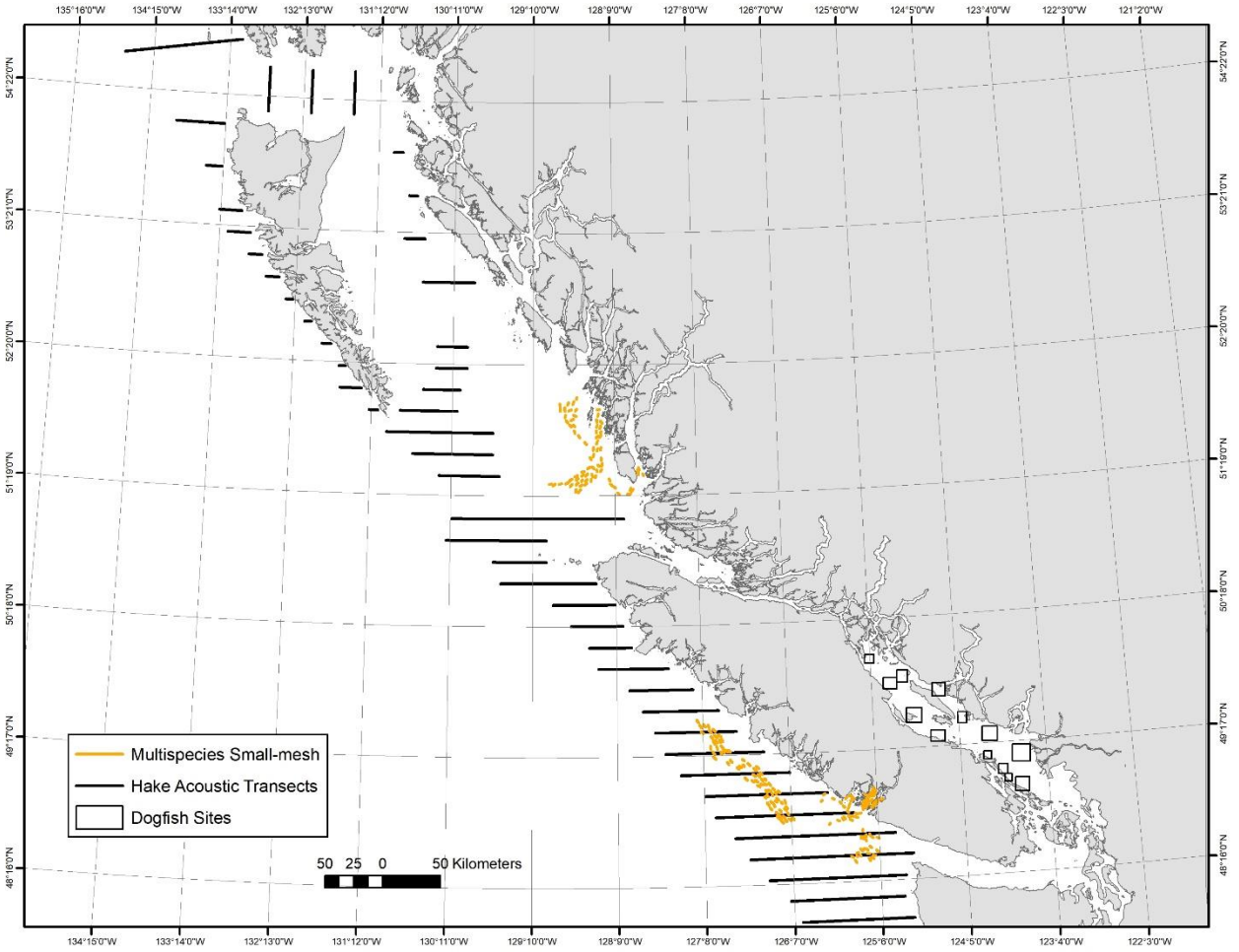

Figure 2. Non-random depth-stratified surveys that form part of the Groundfish fishing surveys program including the Multispecies Small-mesh Bottom Trawl Survey, the Pacific Hake Acoustic Survey, and the Strait of Georgia Dogfish Longline Hook Survey.

The **Multispecies Synoptic Bottom Trawl Surveys** are conducted in four areas of the BC coast with two areas surveyed each year such that the whole coast is covered over a two-year period. Typically, the West Coast of Vancouver Island (WCVI) and West Coast of Haida Gwaii (WCHG) are surveyed in even-numbered years while Hecate Strait (HS) and Queen Charlotte Sound (QCS) are surveyed in odd-numbered years (Figure 3). An additional synoptic bottom trawl survey has been conducted twice in the Strait of Georgia (SOG) but vessel availability and staffing constraints have precluded establishing a regular schedule.

These surveys are conducted under a collaborative agreement with the Canadian Groundfish Research and Conservation Society (CGRCS) and, in typical years, one survey occurs on a Canadian Coast Guard Vessel with DFO staff while one survey occurs on a chartered commercial fishing vessel with a mix of DFO staff and contracted technicians. In aggregate, the surveys provide coast-wide coverage of most of the trawlable habitat between 50 and 500 meters depth.

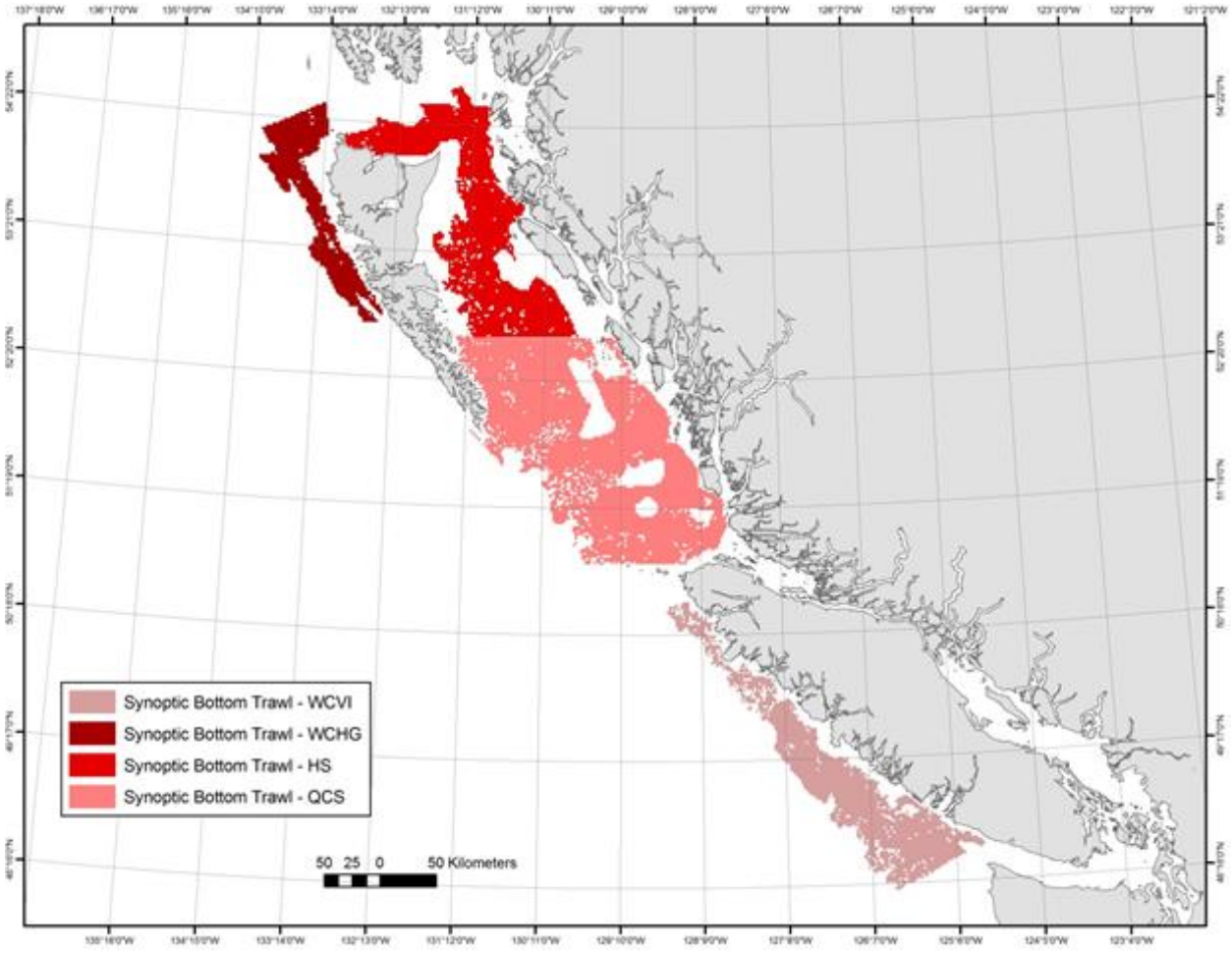

Figure 3. Multispecies Synoptic Bottom Trawl Survey coverage.

The HS, WCVI, and QCS Synoptic Bottom Trawl surveys were all conducted in 2021. The WCVI survey was originally scheduled for 2020 but was postponed to 2021 due to the COVID-19 pandemic. The HS survey was completed on the research vessel Sir John Franklin from mid-May to mid-June while the WCVI and QCS surveys were completed on the chartered commercial trawl vessel Nordic Pearl from mid-May to mid-June and early July to mid-August, respectively. A total of 478 successful tows were completed over the three surveys with 116 in HS, 169 in WCVI, and 193 in QCS (Figure 4). The dominant species in the HS survey catches were Spotted Ratfish (*Hydrolagus colliei*), Dover Sole (*Microstomus pacificus*), Arrowtooth Flounder (*Atheresthes stomias*), and Rex Sole (*Glyptocephalus zachirus*). The dominant species in the WCVI survey catches were Sablefish (*Anoplopoma fimbria*), Sharpchin Rockfish (*Sebastes zacentrus*), Pacific Ocean Perch (*Sebastes alutus*), and Arrowtooth Flounder (*Atheresthes stomias*). The dominant species in the QCS survey catches were Pacific Ocean Perch (*Sebastes alutus*), Silvergray Rockfish (*Sebastes brevispinis*), Arrowtooth Flounder (*Atheresthes stomias*), and Redstripe Rockfish (*Sebastes proriger*).

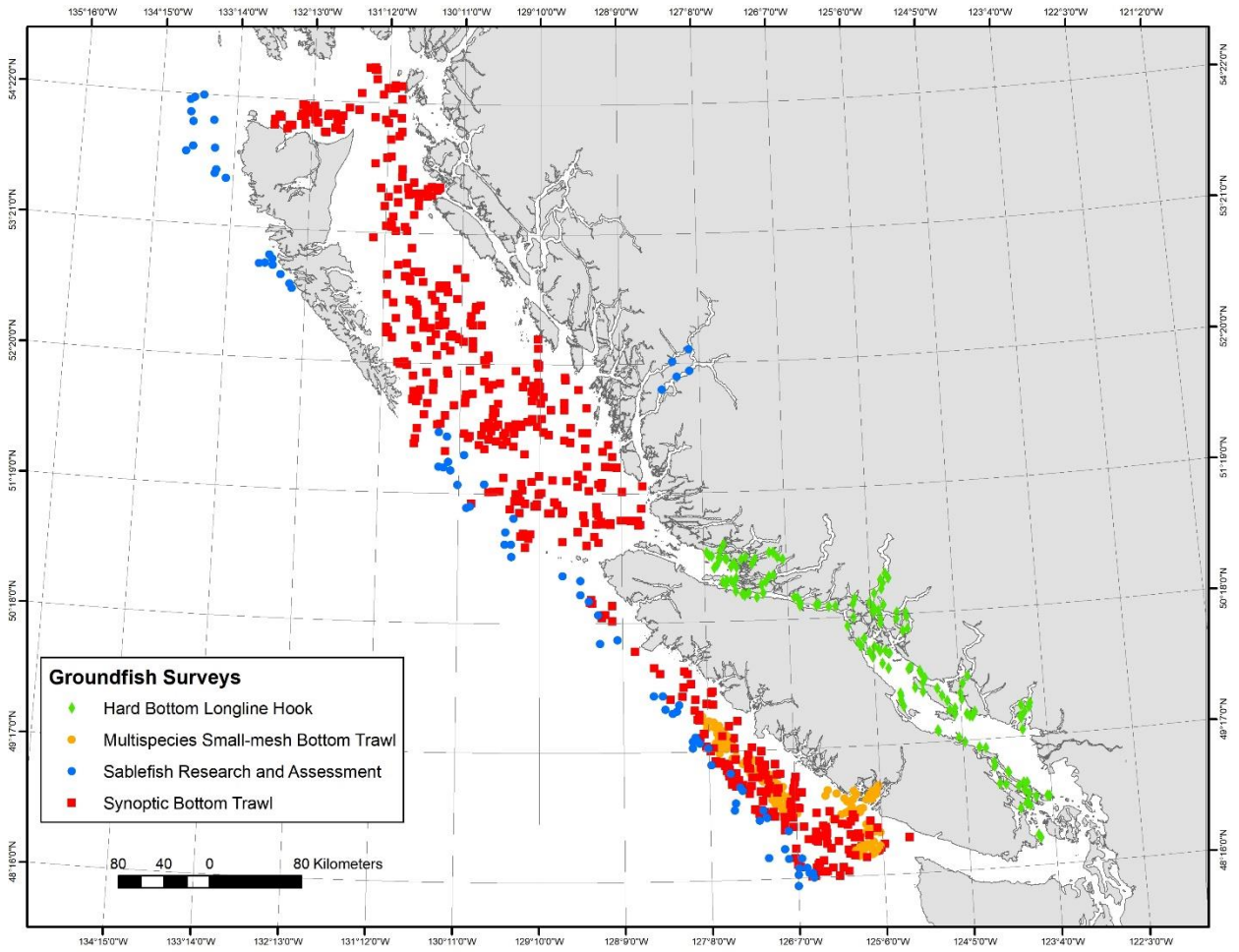

Figure 4. Fishing locations of the 2021 Groundfish surveys. The results from the Hard Bottom Longline Hook survey in the outside area were not finalized at the time of writing and have not been included.

The **Hard Bottom Longline Hook (HBLL) Surveys** are conducted annually in "outside" waters (not between Vancouver Island and the mainland) and "inside" waters (between Vancouver Island and the mainland). Both the "outside" and "inside" areas are divided into northern and southern regions and surveys annually alternate between the regions such that the whole coast is covered over a two-year period. The outside surveys are conducted under a collaborative agreement with the Pacific Halibut Management Association (PHMA) and occur on chartered commercial fishing vessels with contracted technicians. The inside surveys are conducted by DFO and occur on a Canadian Coast Guard vessel with DFO staff. In aggregate, the HBLL surveys provide coast-wide coverage of most of the untrawlable habitat between 20 and 220 meters depth.

In 2021 the northern region of the outside area and both the northern and southern regions of the inside area were surveyed (Figure 4). The 2020 inside area survey was scheduled for the northern region but was postponed to 2021 due to the COVID-19 pandemic. The outside HBLL survey was conducted on the chartered commercial longline vessels Banker II, Borealis 1, and Western Sunset from late July to mid-August. A total of 197 sets were completed. The data from the outside surveys has not been finalized at the time of writing. The inside surveys were

conducted on the research vessel Neocaligus and the northern region was surveyed in August while the southern region was surveyed in September. A total of 144 sets were completed and the dominant species in the catch were North Pacific Spiny Dogfish (*Squalus suckleyi*), Quillback Rockfish (*Sebastes maliger*), and Yelloweye Rockfish (*Sebastes ruberrimus*).

The **Sablefish Research and Assessment Survey** is an annual longline trap survey targeting Sablefish. This survey releases tagged Sablefish at randomly selected fishing locations in offshore waters as well as at fixed stations in four mainland inlets. The survey also provides catch rates and biological data for use in stock assessments. The survey is conducted under a collaborative agreement with the Canadian Sablefish Association and occurs on a chartered commercial fishing vessel by a mix of DFO staff and contracted technicians. This survey covers the depth range of 150 m to 1250 m for the entire outer BC coast as well as a number of central coast inlets.

In 2021, the survey was conducted on the commercial fishing vessel Pacific Viking from early October to late November. The survey experienced an unprecedented number of days lost to poor weather. A total of 72 of the 91 intended sets were completed in the offshore areas while only 5 of the intended 20 sets in the inlet portion of the survey were completed (Figure 4). In addition to the offshore and inlet sets, the survey included a research program designed to investigate gear interactions with the substrate and 4 sets designed to simulate commercial fishing were conducted. The most abundant fish species in the catch were Sablefish (*Anoplopoma fimbria*), North Pacific Spiny Dogfish (*Squalus suckleyi*), and Lingcod (*Ophiodon elongatus*).

The **Multispecies Small-mesh Bottom Trawl Survey** is an annual fixed-station survey of commercially important shrimp grounds off the West Coast of Vancouver Island that was initiated in 1973, and occurs on a Canadian Coast Guard Vessel with DFO staff. Catch rate indices generated by the survey have been used to track the abundances of several groundfish stocks. Groundfish staff provide assistance in catch sorting and species identification and also collect biological samples from selected fish species. The 2021 survey was conducted onboard the research vessel Sir John Franklin from April 26 to May 18, 2021 and a total of 119 usable tows were completed (Figure 4). The most abundant species in the catch were Rex Sole (*Glyptocephalus zachirus*), Pink Shrimp (*Pandalus jordani*), and Eulachon (*Thaleichthys pacificus*).

The **International Pacific Halibut Commission** (IPHC) conducts an annual stock assessment longline survey in waters from California to Alaska, including British Columbia (BC) waters. The survey's main goal is to provide data on Pacific Halibut (*Hippoglosus stenolepis*) for stock assessment purposes. However, data are also recorded on other species caught, making it the longest ongoing groundfish survey in BC waters and hence a valuable source of data for many species. The gfiphc R package (https://github.com/pbs-assess/gfiphc), developed at PBS and updated annually, contains much of the relevant data (and enables extraction from **GFBio** for the rest) It also includes code for deriving relative biomass index trends for non-halibut groundfish species within BC, based on methods that take into account the changing survey methodologies (see Anderson et al., 2019). Results for 113 species are directly viewable at http://htmlpreview.github.io/?https://github.com/pbs-

assess/gfiphc/blob/master/vignettes/data_for_all_species.html, and are incorporated into the groundfish synopsis report (see below).

III. Reserves

Canada has surpassed its marine conservation target commitment of protecting 10 percent of coastal and marine areas through effectively managed networks of protected areas and other effective area-based conservation measures by 2020, a commitment made under the United Nations Convention on Biological Diversity (UN CBD) Aichi Target 11. Approximately 14% of Canada's EEZ are now protected. Marine Conservation initiatives in British Columbia are illustrated in Figure 5.

In the Pacific Region, an initiative is underway to develop a network of Marine Protected Areas (MPAs) in BC's Northern Shelf Bioregion (NSB). A draft MPA network scenario was released for comment by stakeholders on the advisory committee on February 28, 2019, and consultation on this plan is ongoing. In 2020, the partners continued to work through outstanding questions including scope and level of detail for the action plan, approach to phased implementation, and principles that will guide future governance and implementation. The Marine Protected Area Technical Team (MPATT) will consider all spatial advice received and work towards a revised network scenario and a socio-economic analysis will be completed on a revised scenario. A revised draft scenario will be shared with stakeholders, local governments and the public for review and comment in 2021.

The Hecate Strait/Queen Charlotte Sound Glass Sponge Reefs MPA that was designated under Canada's Oceans Act in February 2017 to protect glass sponge reefs in Hecate Strait and Queen Charlotte Sound will be part of the NSB MPA network, as will the Gwaii Haanas National Marine Conservation Area Reserve (NMCAR) and Haida Heritage Site. The Scott Islands marine National Wildlife Area (NWA), an area that conserves a vital marine area for millions of seabirds on the Pacific coast, will also be part of the NSB MPA. Fishing activity is currently not prohibited in the NWA.

Parks Canada and the Archipelago Management Board have introduced new zoning to the NMCAR which includes multiple use zones (IUCN protection level IV-VI) as well as high protection zones (IUCN Ib-III) and two small restricted access zones that are intertidal/terrestrial. These zones came into effect on May 1, 2019. The two Rockfish Conservation Areas that were formerly within the NMCAR boundaries have been rescinded and replaced with the new zoning. Parks Canada is also still working to establish an NMCAR in the Salish Sea.

Another major initiative is the designation of the Offshore Pacific Seamounts and Vents Closure. The Area of Interest (AOI) was designated in 2017 and an offshore groundfish fishing closure was put into place to protect seamount and vent communities (Figure 5). The Endeavour Hydrothermal Vents MPA, designated under Canada's Ocean Act in 2003, is within the Offshore AOI. The Endeavour MPA was designated to ensure the protection of hydrothermal vents, and the unique ecosystems associated with them. The regulation to establish the MPA prohibits the removal, disturbance, damage or destruction of the venting structures or the marine organisms associated with them while allowing for scientific research that will contribute to the understanding of the hydrothermal vent ecosystem.

The SGaan Kinghlass-Bowie Seamount MPA, which was designated in 2008, protects communities living on Bowie Seamount which rises from depths to 3000 m to within 24 m of the surface, as well as two other seamounts and adjacent areas (https://dfo-mpo.gc.ca/oceans/mpa-zpm/bowie-eng.html).

The other 162 Rockfish Conservation Areas (RCAs) designated as fishery closures between 2004-2007 (Yamanaka and Logan, 2010), remain in place. The Glass Sponge Reef Conservation Areas are closed to all commercial and recreational bottom contact fishing activities for prawn, shrimp, crab and groundfish (including halibut) in order to protect the Strait of Georgia and Howe Sound Glass Sponge Reefs (http://www.dfo-mpo.gc.ca/oceans/ceccsr-cerceef/closures-fermetures-eng.html).

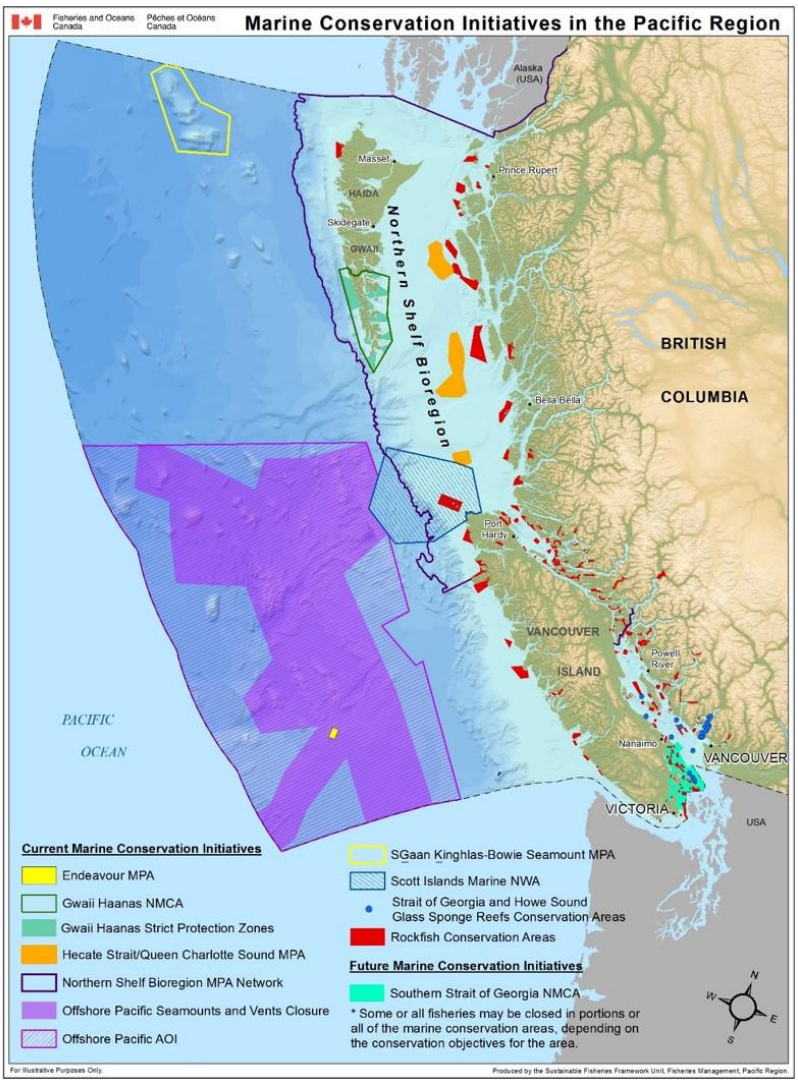

Figure 5. Marine Conservation Initiatives in the Pacific Region (Map by F. Yu).

IV. Review of Agency Groundfish Research, Assessment and Management

A. Hagfish

1. Research

No new research in 2021.

2. Assessment

Nothing to report.

3. Management

There is currently no fishery for Hagfish in BC.

B. Dogfish and other sharks

1. Research

i) North Pacific Spiny Dogfish

Data collection continued in 2021 through the annual groundfish multispecies trawl and longline surveys. Due the suspension of the At Sea Observer Program no biological samples were collected from the commercial fishery in 2021. Several indices of relative abundance for North Pacific Spiny Dogfish in BC waters have declined over the last decade despite relatively little catch compared to historical levels and no directed fishery in recent years. Dr. Lindsay Davidson is a postdoc leading a research project (with Drs. Sean Anderson, Philina English, Jackie King, and Paul Grant, and NOAA collaborators Drs. Cindy Tribuzio, Vladlena Gertseva, and Ian Taylor) examining these declines and evaluating the evidence for possible explanations including climate, predator-prey interactions, seasonal distribution shifts, population declines from historical harvesting, or changes to survey timing.

ii) Other Shark Species

Other species of shark are sampled opportunistically during annual groundfish multispecies trawl and longline surveys. In 2021, two Bluntnose Sixgill Shark and three Tope Shark were sampled. Due the suspension of the At Sea Observer Program no biological samples were collected from the commercial fishery. Anecdotal information on encounters with other shark species is also collected through the Shark Sightings Network (https://www.dfo-mpo.gc.ca/species-especes/sharks/info/sightings-eng.html).

2. Assessment

i) North Pacific Spiny Dogfish

North Pacific Spiny Dogfish were last assessed in 2010. No new assessment is currently scheduled. However, Dogfish are scheduled to be “batched in” as a Major Stock under the Fish Stocks provisions of the *Fisheries Act* and so an assessment is likely within the next 2-3 years, likely following the research project mentioned above.

In 2011, the Committee on the Status of Wildlife in Canada (COSEWC) assessed the conservation status of North Pacific Spiny Dogfish as Special Concern, citing low fecundity, long generation time (51 years), uncertainty regarding trends in abundance of mature individuals, reduction in size composition, and demonstrated vulnerability to overfishing as the causes for concern. Nevertheless, COSEWIC acknowledged that the population remains relatively abundant, and overfishing is currently unlikely.

COSEWC status reports are available at https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports.html.

ii) Other Shark Species

As no directed commercial fisheries for sharks other than North Pacific Spiny Dogfish exist in British Columbia, there have been no requests for any stock assessments.

The Committee on the Status of Wildlife in Canada (COSEWC) has assessed the conservation status of a number of British Columbia shark species, and three species are listed under the Canadian Species at Risk Act (SARA):

- Basking Shark: Designated Endangered in 2007. Status re-examined and confirmed in 2018. Listed under SARA.
- Bluntnose Sixgill Shark: Designated Special Concern in 2007. Currently being re-examined. Listed under SARA.
- Tope Shark: Designated Special Concern in 2007. Currently being re-examined. Listed under SARA.

Blue Shark (North Pacific population) was examined by COSEWIC in 2016 and designated Not at Risk. White Shark and Brown Cat Shark were considered in 2006 and 2007 and placed in the Data Deficient category.

COSEWC status reports are available at https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports.html.

3. Management

i) North Pacific Spiny Dogfish

North Pacific Spiny Dogfish are managed as part of the integrated mixed species multi-gear groundfish fishery under the Integrated Fisheries Management Plan (IFMP), and are permitted to be retained in the recreational fishery. There is currently no targeted fishing for Dogfish. Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

ii) Other Shark Species

Currently, there is no directed commercial fishery for other shark in Canadian Pacific waters; only Salmon Shark are permitted to be retained in the recreational fishery. Species at Risk Act

prohibitions only apply to species listed as extirpated, endangered or threatened; thus, they do not apply to species of special concern. Nevertheless, commercial fisheries are no longer permitted to retain Species at Risk Act listed shark species − all bycatch for these species is to be released at sea with the least possible harm. Catch limits for the recreational fishery have been reduced to “no fishing” for all species listed under the Species at Risk Act, and “zero retention” (catch and release) for all other shark species except Salmon Shark. Codes of conduct have been developed for encounters with Basking Sharks (https://www.dfo-mpo.gc.ca/species-especes/publications/sharks/coc/coc-basking/index-eng.html) and other sharks (https://www.dfo-mpo.gc.ca/species-especes/publications/sharks/coc/coc-sharks/index-eng.html).

C. Skates

1. Research

Data collection continued in 2021 through trawl and longline surveys. Most individual skates encountered on groundfish research surveys are sampled (length, weight if feasible, sex) and released alive if possible. Due the suspension of the At Sea Observer Program no biological samples were collected from the commercial fishery in 2021.

Species sampled in 2021 through groundfish surveys include Aleutian Skate (n=13), Big Skate (n=180), Sandpaper Skate (n=245), and Longnose Skate (n=862).

2. Assessment

Big Skates and Longnose Skate were assessed in 2013 (King et al 2015). No new assessment is currently planned. No other skate species in British Columbia are assessed.

3. Management

Big and Longnose Skates are currently managed under sector and area TACs. For all other species of skate there are no management measures in place.

Big and Longnose Skates are IVQ (individual vessel quota) species managed as part of the integrated mixed species multi-gear groundfish fishery under the Integrated Fisheries Management Plan (IFMP). Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

Literature Cited:

King, J.R., Surry, A.M., Garcia, S., and Starr, P.J. 2015. Big Skate (*Raja binoculata*) and Longnose Skate (*R. rhina*) stock assessments for British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/070. ix + 329 p. https://waves-vagues.dfo-mpo.gc.ca/Library/362171.pdf

D. Pacific Cod

1. Research

Data collection continued in 2021 through trawl and longline surveys. Due the suspension of the At Sea Observer Program no biological samples were collected from the commercial fishery in 2021.

2. Assessment

The last full assessments of Pacific Cod stocks were done in 2018, using the same delay-difference model that was used in 2013. The Research Document (Res Doc 2020/70) is available at https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2020/2020_070-eng.html. The Science Advisory Report (SAR 2019/008) is available at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2019/2019_008-eng.html.

Four stocks are defined for management purposes in BC: Strait of Georgia (4B); West Coast Vancouver Island (3CD); Queen Charlotte Sound (5AB); and Hecate Strait (5CD). Historically, each area has been assessed separately; however, for the 2018 assessment, data from Areas 5AB and 5CD were combined into a single stock assessment due to the lack of biological evidence for separate stocks and improved fits to the combined data compared to data from area 5AB alone. Area 3CD was assessed separately. Area 4B was not assessed as there is no directed commercial fishery there.

Both 3CD and 5ABCD stock assessments were updated in 2020 and published as a Science Response (https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2021/2021_002-eng.html), following an approximate 75% drop in the synoptic survey index in 2018 in 3CD, accompanied by three years of commercial catches well below average. There was an estimated 2-10% probability that the 3CD stock would fall into the Critical Zone in 2022 under a range of 2021 catch levels. There was an estimated < 0.01% probability that the 5ABCD stock will fall into the Critical Zone in 2022.

Groundfish bottom trawl surveys resumed in the West Coast Vancouver Island, Queen Charlotte Sound and Hecate Strait areas in 2021. Compared to the 2019 index, the median swept area survey index increased by 25% in Hecate Strait and by 15% in Queen Charlotte Sound, representing the third year of increases in Hecate Strait and the second year of increases in Queen Charlotte Sound. Although not included in the stock assessment, the West Coast Haida Gwaii index also increased, with a 132% increase in the median swept area index, compared to 2018. However, the stock continued to decline in the West Coast Vancouver Island Survey, with a 22% decrease in the median swept area index compared to 2018.

Given the decreases in the 2018 and 2021 West Coast Vancouver Island survey index, an update to the 3CD stock assessment is scheduled to occur once the 2022 survey data are available in Fall 2022.

3. Management

Pacific Cod is an IVQ (individual vessel quota) species, managed as part of the integrated mixed species multi-gear groundfish fishery under the Integrated Fisheries Management Plan

(IFMP). Commercial TACs and landings for 2020 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. Following the 2020 assessment update, the commercial TAC in Area 3CD was reduced to 300 metric tonnes. See Appendix 1 for details. In addition, winter spawning closures are in effect in both Areas 3CD and 5CD.

E. Walleye Pollock

1. Research

There was no work conducted directly on Walleye Pollock in 2021 but ongoing data collection continued through the Groundfish Synoptic Surveys. Due the suspension of the At Sea Observer Program no biological samples were collected from the commercial fishery in 2021.

2. Assessment

The most recent stock assessment (2017) is publicly available on the CSAS website (Research Document 2021/004, Science Advisory Report 2018/020, Proceeding 2021/048).

3. Management

Walleye Pollock is an IVQ (individual vessel quota) species, managed as part of the integrated mixed species multi-gear groundfish fishery under the Integrated Fisheries Management Plan (IFMP). Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

F. Pacific Whiting (Hake)

1. Research

There are two commercially harvested and managed stocks of Pacific Hake. The offshore stock is the principal target of the commercial fishery comprising the bulk of landings year over year. A smaller and discrete stock residing within the Strait of Georgia is targeted episodically when market demand is sufficient, and the available fish are large enough for processing.

i) Offshore Hake

Triennial (until 2001), then biennial acoustic surveys, covering the known extent of the Pacific Hake stock have been run since 1995. An acoustic survey, ranging from California to northern British Columbia is currently run in odd-numbered years, to continue the biennial time series. The last survey used in the assessment model took place in 2019. The sail drone survey was run again in 2020, and research is being done to determine appropriateness of using these data to construct a biomass index using commercial trawl samples as the ground truthing method.

In addition to the hake acoustic survey, biological samples were collected in 2021 through groundfish trawl surveys. Due the suspension of the At Sea Observer Program no biological samples were collected at sea from the commercial fishery in 2021. Only five dockside samples were collected.

ii) Strait of Georgia Hake

There has been a biennial acoustic survey for Pacific Hake in the Strait of Georgia since 2011. Methods are currently being developed to calculate a biomass estimate for these surveys, which will then be used as the primary index of abundance for the stock assessment.

2. Assessment

i) Offshore Hake

As in previous years, and as required by the Agreement Between the Government of Canada and the Government of the United States of America on Pacific Hake/Whiting (the Pacific Whiting treaty), the 2021 harvest advice was prepared jointly by Canadian and U.S. scientists working together, collectively called the Joint Technical Committee (JTC) as stated in the treaty. The assessment model used was Stock Synthesis 3 (SS3). The 2021 model had the same model structure used in 2020, with updates to catch and age compositions. Standard sensitivities requested by the Scientific Review Group showed little difference when compared with the base model. The largest cohort caught in the fishery was age-4's, followed by age 6's which represent the large cohorts for 2016 and 2014 respectively.

ii) Strait of Georgia Hake

There has not been an assessment of Pacific Hake in the Strait of Georgia, although the recent increases in catch may warrant one.

3. Management

Canadian commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details

i) Offshore Hake

Management of Pacific Hake has been under a treaty (The Agreement) between Canada and the United States since 2011. The stock is managed by the Joint Management Committee (JMC) which is made up of fisheries managers and industry representatives from both the U.S. and Canada. These managers receive advice from the JTC and the Scientific Review Group (SRG), which is a committee responsible for the scientific review of the assessment.

The final decision on catch advice for the 2021 fishing season was made at the Joint Management Committee (JMC) meeting online on Mar. 15 – Mar. 17, 2021. Despite extensive deliberations, a TAC was not agreed upon by the two countries' JMC members for 2021, so Canadian managers chose a TAC of 104,480 t, which is the same as the TAC for 2020.

The final assessment document and other treaty-related documents are posted at: https://www.fisheries.noaa.gov/west-coast/laws-and-policies/pacific-hake-whiting-treaty.

ii) Strait of Georgia Hake

Management of Strait of Georgia Pacific Hake has been implemented as ad-hoc quota allocation for the history of the fishery. Typical catch for the Strait has been approximately 10 - 40 metric tonnes for many years, but has seen an increase of several orders of magnitude in the last few years.

G. Grenadiers

1. Research

There is no directed work conducted on Grenadiers. Opportunistic sampling occurs on groundfish trawl surveys, but no Grenadiers were encountered in 2021.

2. Assessment

Grenadiers are not commercially harvested in BC and are rarely encountered during commercial fisheries. Consequently, there are no assessment activities planned for these species.

3. Management

There are no management objectives or tactics established for these species. These species are caught incidentally in the deep-water rockfish (Rougheye/Shortraker/Thornyhead) and Dover Sole fisheries and in the Sablefish trap fishery. 100% of the catch is discarded.

H. Rockfish

1. Research

Biological samples are collected on an ongoing basis from annual trawl, longline, and trap surveys. Due the suspension of the At Sea Observer Program no biological samples were collected from the commercial fishery in 2021.

i) Inshore Rockfish

Dr. Dana Haggarty continues to collaborate with other scientists at DFO, Dr. Philina English, Dr. Sarah Dudas and Dr. Stephan Gauthier, as well as external Scientists: Dr. Francis Juanes (UVic), Dr. William Halliday (Wildlife Conservation Society Canada), and Dr. Francis Mouy (NOAA) to continue to develop passive acoustic monitoring (PAM) of rocky reef fishes. Based on the successes of a SPERA funded project, they were awarded Canadian Science Research Funding for three years of study. With this grant, they will support some post-doctoral work of Xavier Mouy who will continue to develop and refine an automatic detector of fish (and hopefully rockfish) calls. They have also brought on a Ph.D. student, Darienne Lancaster, co-supervised by Drs. Francis and Haggarty at UVic who will refine methods to collect passive and active acoustic data of rockfishes.

Dr. Haggarty is also collaborating with colleagues at UVic and Ball State University as well as industry (Angler’s Atlas) to improve and monitor compliance in Rockfish Conservation Areas (RCAs) and Marine Protected Areas (MPAs). Angler’s Atlas has already upgraded their smart

phone app, MyCatch, to include the location of all RCAs and to provide users with warnings when they are in an RCA. The app works by employing the cell phone's internal GPS and with downloaded maps, so users do not need to be on cell networks for it to function. There is also a function to collect data on the use of descending devices for rockfishes and an outreach program associated with this. This project was funded by the BC Salmon Restoration and Innovation Fund (BCSRIF) until the end of 2022-23. We think that the up-take of the MyCatch app by anglers was affected by the COVID19 pandemic; however, we are hoping to increase awareness about the app in 2021. Dr. Paul Venturelli and his students are continuing work that Dana and collaborators have done to assess recreational compliance in RCAs using creel overflight data.

Dana is also working with a graduate student at the University of Victoria, Hailey Davies, with collaborator Dr. Francis Juanes. Hailey is studying survival of rockfish following the use of a descending device by using a tag-recapture experiment as well as the use of camera systems to record the release. Despite tagging a total of 352 rockfishes from 9 species, we have only had two tag recoveries. One recovery was a Copper Rockfish that had been at large for a month, and the other was a Yelloweye Rockfish that was recovered by a recreational angler in late February which had been tagged and released in mid-October. We have collected additional data on barotrauma symptoms by species and are planning on writing a meta-analysis on the subject. A photo essay on the field work is in review in Fisheries.

Dana has also collaborated with DFO iREC (Internet Recreational Effort and Catch) staff to develop a questionnaire on the use of descending devices by anglers. The survey is a voluntary add-on to the annual iARC (Internet Annual Recreational Catch Reporting program) survey. The survey runs April 1-23, 2022.

ii) Offshore Rockfish

The Offshore Rockfish program in 2021 continued with one DFO person working in collaboration with an industry-sponsored scientist. All efforts were devoted to stock assessment. To facilitate stock assessment, the Offshore Rockfish program maintains a suite of PBS R software packages (https://github.com/pbs-software). The Groundfish Surveys program coordinates all sample collections (otoliths, genetic tissues, morphology measurements, etc.) and the Sclerochronology Lab researches ageing protocols and methods, in addition to performing production ageing for BC finfish stock assessments.

2. Assessment

i) Inshore Rockfish

British Columbia (BC) "Inside" stocks are generally those occurring in Area 4B (Queen Charlotte Strait, Strait of Georgia, and Strait of Juan de Fuca), while "Outside" stocks occur outside Area 4B (West Coast Vancouver Island, West Coast Haida Gwaii, Queen Charlotte Sound, Hecate Strait, Dixon Entrance).

Outside Yelloweye Rockfish

The Outside population of Yelloweye Rockfish was designated as Threatened in December of 2020 by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC). DFO is now responsible for completing a Recovery Potential Analysis which will be completed in 2022 drawing from the results presented in the 2019 rebuilding plan analysis (Cox et al 2020).

Cox, S.P., Doherty, B., Benson, A.J., Johnson, S.D., and Haggarty, D. 2020. Evaluation of potential rebuilding strategies for Outside Yelloweye Rockfish in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/041.

Inside Yelloweye Rockfish

The Inside population of Yelloweye Rockfish was designated as Threatened in December of 2020 by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC). DFO is now responsible for completing a Recovery Potential Analysis which will be completed in 2022 drawing from the results presented in the 2020 rebuilding plan analysis (Haggarty et al in press).

Haggarty, D.R., Huynh, Q.C., Forrest, R.E., Anderson, S.C., Bresch, M.J., Keppel, E.A. In press. Evaluation of potential rebuilding strategies for Inside Yelloweye Rockfish (Sebastes ruberrimus) in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2022/nnn. vi + 142 p.

Quillback Rockfish

The Inside and Outside management units of Quillback Rockfish were last assessed in 2010 after the Committee On the Status of Endangered Wildlife In Canada (COSEWIC) designated them as threatened in November 2009.

Quillback is due to be reassessed in 2022-2023 in advance of a COSEWIC reassessment. In preparation to do so, we have begun analyzing data for the inside and outside stocks and have developed initial operating models for the inside stock. We also held a series of workshops to discuss the decision context and to develop objectives to be used for the Quillback Rockfish stocks in a Management Procedure (MP) framework analysis. A technical report describing the workshop results will be available soon. We have applied for funding to continue this work which is being led by Dana Haggarty and Matt Siegle and conducted by consultant Quang Huynh at Blue Matter Science. We expect to complete work on the both stocks in 2022-23. Completion of work on the outside stock is delayed due to the COVID19-related shut-down and subsequent reduced capacity of the PBS Sclerochronology lab as well as delays in establishing a contract with Blue Matter Science.

Yamanaka, K.L., McAllister, M.K., Etienne, M.-P., and Flemming, R. 2011a. Stock assessment and recovery potential assessment for Quillback Rockfish (*Sebastes maliger*) on the Pacific coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/135: vii + 151 p.

Other Inshore Rockfish Species (Copper, China, Tiger, Brown, Black, Deacon Rockfishes).

Inshore Rockfishes were assessed as a group in 2001, but none of these other inshore species have been assessed individually by DFO.

ii) Offshore Rockfish

Bocaccio

Bocaccio was assessed in 2019 (Science Advisory Report 2020/025, Proceedings 2021/014), and a very large 2016 cohort was predicted to elevate the stock from the DFO Critical Zone to the Healthy Zone by 2023. An update of the stock assessment model using new survey and commercial CPUE indices was requested for 2021 (Science Response 2022/001).

The updated model had no difficulty in fitting each survey series, including the new 2020 and 2021 indices. The capacity of the model to fit the four new survey index points indicated that these new observations were consistent among each other and with the model estimates of recruitment strength for the 2016 cohort. The updated length frequency distribution data showed that the 2016 cohort of Bocaccio remained the single dominant year class. Length frequency distributions were available from each survey, independently corroborating the presence on this cohort and demonstrating that the increased Bocaccio abundance in each survey was entirely attributable to this cohort.

The composite base case, comprising three pooled Markov Chain Monte Carlo (MCMC) runs, was used to calculate a set of parameter estimates and derived quantities at equilibrium and those associated with MSY. The composite base case population trajectory from 1935 to 2022 and projected biomass to 2032 (Figure 6), assuming a constant catch policy of 500 t/y, indicates that the median stock biomass exceeded the upper stock reference (USR) in 2022, which was sooner than predicted by the 2019 assessment.

The Bocaccio stock has been in the Critical zone since the late 1990s, but has now moved into a current (2022) position that lies well inside the Healthy zone at B_{2022}/B_{MSY} = 1.499 (0.625, 3.416), u_{2021}(trawl) /u_{MSY} = 0.24 (0.106, 0.487), and u_{2021}(other) /u_{MSY} = 0.006 (0.003, 0.013).

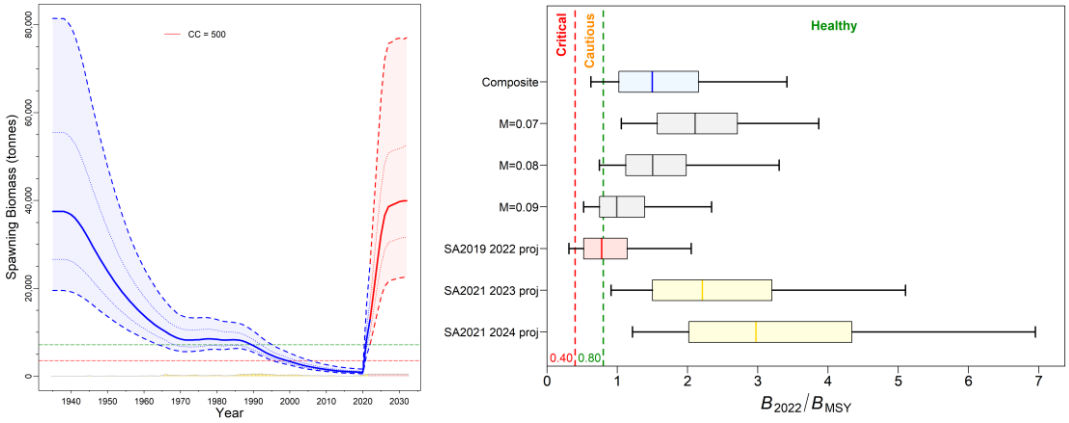

Figure 6. ***Left****: composite estimate of Bocaccio spawning biomass (tonnes) from three model posteriors pooled to form the base case. The median biomass trajectory appears as a solid curve surrounded by a 90% credibility envelope (quantiles: 0.05-0.95) in light blue; projected biomass appears in light red. Also delimited is the 50% credibility interval (quantiles: 0.25-0.75) delimited by dotted lines. The horizontal dashed lines show the median LRP and USR.* ***Right****: spawning stock status at beginning of 2022 relative to the PA reference points of* $0.4B_{MSY}$ *and* $0.8B_{MSY}$ *for the base case. The top quantile plot shows the composite distribution and below are the three contributing runs. Also shown are projected stock status for the composite base case in the 2019 stock assessment (red, assuming constant catch = 200 t/y) and for the current composite base case at the beginning of 2023 and 2024 (yellow, constant catch = 500 t/y). Quantile plots show the 0.05, 0.25, 0.5, 0.75, and 0.95 quantiles from the MCMC posteriors.*

Canary Rockfish

In 2007, Canary Rockfish along the Pacific coast of Canada was designated as 'Threatened' by COSEWIC, with commercial fishing identified as the primary threat. The Canary Rockfish stock assessment was last updated in 2009 (Science Response 2009/019). In 2017, DFO prepared a summary of available information on Canary Rockfish in preparation for a re-assessment by COSEWIC. A new full stock assessment by DFO is planned for 2022/23.

Darkblotched Rockfish

In 2009, Darkblotched Rockfish along the Pacific coast of Canada was designated as 'Special Concern' by COSEWIC. The last review of this species occurred in 2008 (Research Document 2008/056). Currently, there is no stock assessment planned.

Pacific Ocean Perch

The most recent stock assessment (2017) is publicly available on the CSAS website (Research Document 2018/031).

Redbanded Rockfish

The most recent stock assessment (2014) is publicly available on the CSAS website (Research Document 2017/058, Proceedings 2015/032).

Redstripe Rockfish

The most recent stock assessment (2017) is still awaiting translation; however, a summary report is available (Science Advisory Report 2018/049).

Rougheye/Blackspotted Rockfish

The most recent stock assessment (2020) is publicly available on the CSAS website (Science Advisory Report 2020/047, Proceedings 2022/004).

Shortraker Rockfish

The most recent stock assessment (1998) is publicly available on the CSAS website (Research Document 1999/184).

Silvergray Rockfish

Silvergray Rockfish were last assessed in 2014. The assessment is publicly available on the CSAS website (Research Document 2016/042; Science Advisory Report 2014/028).

Widow Rockfish

The most recent stock assessment (2019) is publicly available on the CSAS website (Research Document 2021/039, Science Advisory Report 2019/044, Proceedings 2021/049).

Yellowmouth Rockfish

The most recent stock assessment (2021) is publicly available on the CSAS website (Science Advisory Report 2022/001, Proceedings 2022/003).

A stock assessment for Yellowmouth Rockfish (YMR) along the BC coast was conducted in 2021. This marked a departure from rockfish stock assessments conducted since 2009 by adopting the Stock Synthesis 3 (SS) generic stock assessment platform maintained by NOAA. This platform provides more flexibility than models used in past BC rockfish assessments despite a time-consuming learning curve.

The SS model was tuned to four fishery-independent trawl survey series, a bottom trawl CPUE series, annual estimates of commercial catch since 1935, and age composition data from survey series (25 years of data from four surveys) and the commercial fishery (28 years of data). The model started from an assumed equilibrium state in 1935, the survey data covered the period 1967 to 2020 (although not all years were represented), and the CPUE series provided an annual index from 1996 to 2020.

The model was implemented in a Bayesian framework (using the Monte Carlo Marko Chain [MCMC] ‘No U-Turn Sampling’ procedure) to estimate five models which fixed natural mortality (models estimating M were not stable) to each of five levels (0.04, 0.045, 0.05, 0.055, 0.06), spanning a range that was considered plausible and which returned acceptable MCMC diagnostics. The parameters estimated by these models included average recruitment and

annual year class deviations over the period 1950-2012, and selectivities for the four surveys and the commercial trawl fleet. These five model runs were combined into a composite base case which covered the plausible range of the major axis of parameter uncertainty in this stock assessment. Fourteen sensitivity analyses were performed relative to the central run (M=0.05) of the composite base case to test the effect of alternative model assumptions.

Figure 7 (left) shows the estimated annual spawning biomass (mature females only) relative to spawning biomass at MSY for the coastwide YMR stock depicted by the composite base case. The stock has fluctuated based on four good recruitment years (1952, 1962, 1982 and 2006), increasing to a level above the equilibrium biomass associated with average recruitment (B_0) over four decades (1965-2005) before declining to a low point in 2014. Thereafter, the spawning biomass increased to approximately 15,000 tonnes.

Figure 7 (right) shows the stock status for the YMR composite base case, as well as each base component run, relative to the DFO limit and upper stock reference points of $0.4B_{MSY}$ and $0.8B_{MSY}$, respectively. These reference points define the 'Critical', 'Cautious' and 'Healthy' zones. The YMR composite base case spawning biomass at the beginning of 2022 was estimated to be above the limit reference point (LRP) with probability $P(B_{2022} > 0.4B_{MSY}) = 1$, and above the upper stock reference (USR) point with probability $P(B_{2022} > 0.8B_{MSY}) = 1$ (i.e., no probability of being in the Cautious or Critical zones based on the set of MCMC posterior samples).

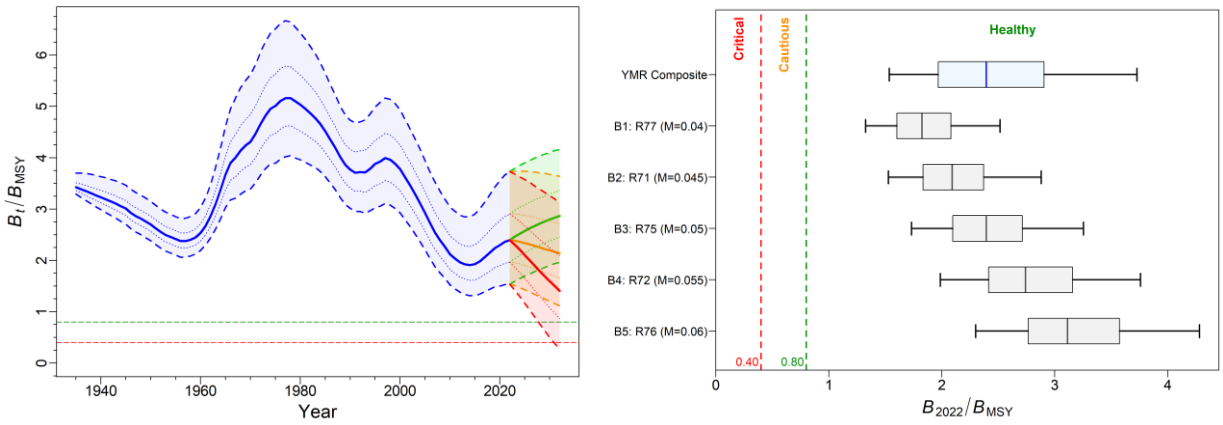

Figure 7. ***Left****: estimates of spawning biomass B_t relative to B_{MSY} from the model posteriors (10,000 samples) of the YMR composite base case. The median biomass trajectory appears as a solid curve surrounded by a 90% credibility envelope (quantiles: 0.05, 0.95) in blue and delimited by dashed lines for years t=1935–2022; projected biomass using constant catch appears in green (no catch), orange (1250 t/y), and red (2500 t/y) for years t=2023-2032 (10 years). Also shown is the 50% credibility interval (quantiles: 0.25–0.75) delimited by dotted lines.* ***Right****: Stock status of the YMR base case and its component base runs relative to the DFO Precautionary Approach (PA) provisional reference points of $0.4B_{MSY}$ and $0.8B_{MSY}$ for t=2022. Boxplots show the 0.05, 0.25, 0.5, 0.75 and 0.95 quantiles from the MCMC posterior projections.*

Yellowtail Rockfish

The most recent stock assessment (2014) is publicly available on the CSAS website (Science Advisory Report 2015/010, Proceedings 2015/020).

3. Management

i) Inshore Rockfish

Inside and Outside Yelloweye Rockfish still fall under a rebuilding plan that is documented in Appendix 9 of the 2020 IFMP (https://waves-vagues.dfo-mpo.gc.ca/Library/40765167.pdf). Most inshore rockfish are managed with Total Allowable Catches under the Individual Transferable Quota system.

Commercial TACs and landings for 2020 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2020 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

Recreationally, the retention of Yelloweye Rockfish in inside and outside waters is prohibited. In outside waters, recreational fishers are limited to 3 rockfishes daily, only 1 of which may be a China, Tiger or Quillback Rockfish; possession limits are twice the daily limits, and the season runs from April 1 – November 15. In inside waters (4B), recreational fishers can take 1 rockfish daily, possession limits are twice the daily limit and the season runs from May 1 – October 1. A condition of the recreational license is that: “Anglers in vessels shall immediately return all rockfish that are not being retained to the water and to a similar depth from which they were caught by use of an inverted weighted barbless hook or other purpose-built descender device.”

ii) Offshore Rockfish

Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

I. Thornyheads

1. Research

Data collection continued in 2021 through trawl and longline surveys. With the suspension of the At Sea Observer program due to COVID-19, there was no commercial sampling.

2. Assessment

Longspine Thornyhead was designated ‘Special Concern’ by COSEWIC in 2007. An assessment has been requested but not yet scheduled. In 2022, the WCVI synoptic survey will be adding 10-20 tows in a deep stratum (800-1300 m), specifically to assess/sample Longspine Thornyhead.

Shortspine Thornyhead was assessed in 2015 (Research Document 2017/015; Science Advisory Report 2016/016; , Proceedings 2016/040).

3. Management

Longspine and Shortspine Thornyhead are both IVQ species. Commercial TACs and landings for 2020 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2020 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

J. Sablefish

The Sablefish management system in British Columbia is an adaptive approach in which three pillars of science – hypotheses, empirical data, and simulation - play a central role in defining management objectives and in assessing management performance relative to those objectives via Management Strategy Evaluation (MSE).

The MSE process is used to provide management advice each year that supplements the stock assessment process by providing a way to explicitly evaluate harvest strategies given a set of stock and fishery objectives and uncertainties/hypotheses about Sablefish fishery and resource dynamics. Fisheries and Oceans Canada (DFO) and Wild Canadian Sablefish Ltd. have collaborated for many years on fisheries management and scientific research with the aim of further supporting effective assessment and co-management of the Sablefish stock and the fishery in Canadian Pacific waters.

1. Research

Collection of biological data continued in 2021 through trawl and trap surveys. With the suspension of the At Sea Observer program due to COVID-19, there has been no commercial sampling from the trawl fishery since March 2020. However, commercial sampling has continued in the directed trap and longline fisheries through a voluntary biosampling program supported by industry. A head-only sampling program was initiated in 2018 whereby commercial fishers follow specific instructions to collect specimens at stepped intervals of their overall cumulative catch for the year (ie., every 50,000 lbs). Males and females are marked by cutting the operculum and then the heads are frozen to be sampled on shore. Unpublished work has shown a strong relationship between head morphometric measurements and fork length, so frozen head samples are measured on shore to collect estimated length data. Otoliths are also retrieved from frozen heads for ageing. A technical report is being developed for 2022 to describe this new sampling procedure and document the relationship between head morphometrics and fork length.

2. Assessment

Sablefish stock status is regularly evaluated via the MSE process. An operating model (i.e., representation of alternative hypotheses about ‘true’ Sablefish population dynamics) is used to simulate data for prospective testing of management procedure performance relative to stock and fishery objectives. The current Sablefish operating model (OM) was revised in 2015/16 to account for potential structural model misspecification and lack-of-fit to key observations recognized in previous models (DFO 2016). Specific modifications included: (i) changing from an age-/growth- group operating model to a two-sex/age-structured model to account for differences in growth, mortality, and maturation of male and female Sablefish, (ii) adjusting model age- proportions via an ageing error matrix, (iii) testing time-varying selectivity models,

and (iv) revising the multivariate-logistic age composition likelihood to reduce model sensitivity to small age proportions. These structural revisions to the operating model improved fits to age-composition and at-sea release data that were not well-fit by the previous operating model. Accounting for ageing errors improved the time-series estimates of age-1 Sablefish recruitment by reducing the unrealistic auto-correlation present in the previous model results. The resulting estimates clearly indicate strong year classes of Sablefish that are similar in timing and magnitude to estimates for the Gulf of Alaska. Two unanticipated results were that (i) time-varying selectivity parameters were not estimable (or necessarily helpful) despite informative prior information from tagging and (ii) improved recruitment estimates helped to explain the scale and temporal pattern of at-sea release in the trawl fishery. The latter finding represents a major improvement in the ability to assess regulations (e.g., size limits) and incentives aimed at reducing at-sea releases in all fisheries.

The status of the Sablefish stock is judged on the scale of the OM which was last updated in 2019 (DFO 2019). Based on the 2019 assessment, the current point estimate of Sablefish spawning stock biomass in Canada is 16,300 t. This spawning biomass is at the transition from the Cautious to Healthy zones under the DFO FPA Framework (i.e., $B_{2018}/B_{MSY} = 0.8$). The updated stock status of Canadian Sablefish depended on the absolute size of the 2015-year class, the raw estimate of this which was about eight times the historical average. This created the impression of the largest recorded recruitment from one of the lowest spawning biomasses ever observed in Canada. However, this estimated recruitment is highly uncertain, and both the timing and magnitude of the year-class size should be better estimated as several more years of fishery and survey data accumulate.

In 2019 the updated operating model was used to generate simulated data to test the current and alternative management procedures (MPs). The joint posterior distribution of spawning biomass and stock-recruitment steepness was used to generate five scenarios that captured a range of hypotheses related to current spawning biomass and productivity. These feedback simulations showed that the current MP (no limits on at-sea releases) meets biological objectives but ranked near the bottom in terms of catch performance and revenues compared to MPs with at-sea release management measures. A no size limit (i.e., full retention) MP performed best for both biological and fishery objectives, followed by MPs that included caps on sub-legal releases. These simulations also showed that the largest conservation risk is tuning the maximum target harvest rate in MPs assuming large 2015 recruitment, but then it fails to materialize.

The revised operating model continues to assume that the BC Sablefish stock is a closed population, despite evidence of movements among Sablefish stocks in Alaska and US waters south of BC (Hanselman et al. 2014) and little genetic evidence of population structure across these management regions (Jasonowicz et al. 2017). These movements may have implications for the assumptions made about Sablefish stock dynamics in BC (i.e., recruitment, productivity) that are not currently captured by the revised OM or reflected in MP performance evaluations. The collaboration between DFO, NOAA and ADFG identified above in the research section is working towards the development of a coastwide Sablefish OM to understand the potential consequences of the mismatch between Sablefish stock structure and management by simulation testing current, and potential future, MPs to quantify their performance against a range of conservation and fishery objectives.

The next scheduled update to the BC Sablefish operating model is November 2022, at which time the operating model will be updated with new data and transitioned to a new modelling platform. A comparison of the performance of the current Sablefish management procedure with a re-tuned version of the current procedure given updated estimates of key management parameters (F_{MSY}, B_{MSY}) will also be completed as part of the update. A more thorough simulation-evaluation of a wider range of management procedures based on the updated operating model is scheduled for 2023/24.

Literature Cited:

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3. Management

The MP that is currently in place for the Canadian Sablefish fishery was last evaluated in 2019 through the Sablefish MSE (see Assessment section above). This MP is based on a surplus production model fit to time-series observations of total landed catch, and the fishery independent survey CPUE, to forecast Sablefish biomass for the coming year. The surplus production model outputs are then inputs to a harvest control rule to calculate the recommended catch of legal Sablefish in a given year. This MP includes a 3-year phased-in period to a new maximum target harvest rate of 5.5% in 2022.

Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

K. Lingcod

1. Research

Data collection continued in 2021 through trawl and longline surveys and recreational creel surveys. With the suspension of the At Sea Observer program due to COVID-19, there was no

commercial sampling. Additional biological samples (length, weight, sex, maturity and fins for ageing) were collected on the Outside HBLL survey done in collaboration with industry. We are currently preparing fins for aging in order to inform survey selectivity in our next stock assessment. We are also collaborating with the Sclerochronology lab at PBS by collecting paired otolith and fin rays on our surveys in order to compare ageing structures.

2. Assessment

Inside, the waters within the Strait of Georgia, and Outside, the rest of the BC Coast, Lingcod populations are assessed and managed as separate units. Outside Lingcod were scheduled to be assessed in the spring of 2019; however, the assessment has been pushed back due to other program demands as well as the desire to have some age-data to inform the catchability of the longline surveys. Fins collected on the IPHC, trawl surveys and Outside HBLL surveys are currently being processed. Inside Lingcod were last assessed in 2014.

3. Management

Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

L. Atka Mackerel

The distribution of Atka mackerel does not extend into the Canadian zone.

M. Flatfish

1. Research

Ongoing data collection in support of the flatfish research program, inclusive of Arrowtooth Flounder, Petrale Sole, Southern Rock Sole, Dover Sole, and English Sole continued in 2021 through surveys. With the suspension of the At Sea Observer program due to COVID-19, there was no commercial sampling after March 2020.

2. Assessment

Arrowtooth Flounder

Arrowtooth Flounder was last assessed in 2016. The final assessment was finalized and published through the Canadian Science Advice Secretariat (CSAS) in 2017. The research document and science advisory report are available at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2017/2017_025-eng.html and https://waves-vagues.dfo-mpo.gc.ca/Library/365131.pdf.

Concerns expressed by industry participants regarding localized depletion on several the historic fishing grounds have led to a request from fisheries management for an updated assessment. Efforts are underway to deliver that assessment.

Petrale Sole

Petrale Sole was last assessed in 2007. In response to a request for updated harvest advice from fishery managers, aging of otoliths was completed in 2020. Planning is currently underway to deliver an updated assessment.

Southern Rock Sole

Southern Rock sole was last assessed in 2013. No request for updated advice has been received, but aging of otoliths was undertaken in 2019 in anticipation of an updated assessment.

Dover Sole

Dover sole was last assessed in 1999. Aging of otoliths was completed in 2020 in anticipation of an updated assessment.

English Sole

English sole was also last assessed in 2007. No request for updated advice has been received, but aging of otoliths is scheduled for 2021/22 in anticipation of an updated assessment.

3. Management

Arrowtooth Flounder, Petrale Sole, Southern Rock Sole, Dover sole, and English Sole are all managed by annual coastwide or area specific TACs and harvested primarily by the IVQ multi-species bottom trawl fishery. Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

N. Pacific Halibut & IPHC Activities

Biological data were collected in 2021 on trawl and longline surveys. With the suspension of the At Sea Observer program (ASOP) due to COVID-19, there has been no commercial sampling since April 2020. Current trawl-based halibut mortality is estimated using area-based average weights that were determined using historical ASOP data. DFO is currently working with industry reps and service providers to develop a biosampling program to address gaps created from the suspension of ASOP; halibut length sampling will be considered along with other species in its development.

Commercial TACs and landings for 2021 are provided in Appendix 1.

O. Other Groundfish Species

Nothing to report at this time.

V. Ecosystem Studies

A. Data-limited Species

The Fisheries and Oceans Canada (DFO) Sustainable Fisheries Framework (DFO 2009) lays the foundation for an ecosystem-based and precautionary approach to fisheries management that enables continued productivity of Canada's fisheries.

In recent decades, DFO groundfish stock assessments have focused on data-rich species, resulting in a subset of stocks with full stock assessments, while many stocks with less informative data remain unassessed. Consequently, quotas assigned to rarely assessed or unassessed stocks may result in catch rates that are too high, may restrict harvesting opportunities to catch target species, or may result in failure for fisheries to meet seafood certification standards.

Starting in 2015, work was initiated to address this gap. Instead of a tiered approach as is used in other jurisdictions around the world, the approach eventually adopted for BC groundfish stocks considers data-richness on a continuous scale and focuses on simulation testing multiple management procedures on a stock-by-stock basis to choose an approach that best meets fisheries risk objectives.

Groundfish Data Synopsis

The first phase consisted of a groundfish data synopsis, as described in the 2019 TSC report. The synopsis provides a visual snapshot of temporal trends and spatial distributions of commercial catches and survey indices, growth and maturity characteristics, and data availability for over 100 BC groundfish stocks. The synopsis was peer reviewed through a Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) process in 2018 and published in 2019 as a Research Document (Anderson et al. 2019). An article described the approach to a wider audience (Anderson et al. 2020). An updated synopsis with all available data since the original Research Document will be published shortly (DFO, in press).

Management Procedure Framework

The second phase is the development of a framework for applying a management-procedure (MP) approach to data-limited groundfish stocks in British Columbia. Data-limited stocks are defined here as those with insufficient data to reliably estimate stock status or estimate abundance or productivity with conventional stock assessment methods such as statistical catch-at-age models. The MP framework was reviewed through a CSAS RPR process in June 2020. Specifically, the MP framework tests the performance of a suite of data-limited management procedures against conservation and fishery objectives. This is done using an existing closed-loop simulation framework that includes building appropriate operating models, testing suites of management procedures, and determining management procedures that best meet conservation and fishery objectives for one or more case-study stocks. The framework uses the open source R package DLMtool (Carruthers and Hordyk 2018), developed at the University of British Columbia, in partial partnership with DFO.

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VI. Other related studies

Nothing to report at this time.

VII. Publications

A. Primary Publications

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B. Other Publications

C.

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Appendix 1: British Columbia commercial groundfish TACs, landings, and research allocations for 2021.

Table 1. British Columbia Groundfish Total Allowable Catch (TAC) and commercial landings in metric tonnes (t) for the 2021 fishing year. Except where noted, TACs are from the 2021 Groundfish Integrated Fisheries Management Plan (https://waves-vagues.dfo-mpo.gc.ca/Library/40990151.pdf). Landings are from the Dockside Monitoring Program.

Species or Species Group	Trawl Sector (t)		Combined Line Sectors (t)		Total (t)	
	TAC	Landings	TAC	Landings	TAC	Landings
Sharks And Skates						
North Pacific Spiny Dogfish	4,480	88	9,520	0	14,000	88
Big Skate	914	178	118	9	1,032	187
Longnose Skate	195	91	263	54	458	145
Pacific Cod	1,250	708	0	7	1,250	715
Walleye Pollock	4,935	8,588	0	0	4,935	8.588
Pacific Hake [1]	7,000 gulf & 104,480 offshore	64,757	0	0	111,480	64,757
Rockfishes						
Rougheye/Blackspotted Rockfish Complex	614	452	463	165	1,077	617
Pacific Ocean Perch	5,192	2,727	1	0	5,193	2,727
Redbanded Rockfish	295	148	284	180	579	328
Shortraker Rockfish	126	40	111	78	237	118
Silvergray Rockfish	1,945	1,355	254	31	2,199	1,386
Widow Rockfish	2,500	2,264	46	0	2,546	2,264
Yellowtail Rockfish	5,440	5,082	60	4	5,500	5,086
Quillback Rockfish	4	1	147	84	151	85
Bocaccio	414	606	0	8	414	614
Canary Rockfish	965	764	135	9	1,100	773
Redstripe Rockfish	1,550	702	43	0	1,593	702
Yellowmouth Rockfish	2,364	1207	78	5	2,442	1,212
Yelloweye Rockfish	3	6	126	128	129	134
Copper, China, And Tiger Rockfish	1	1	60.3	38	61.3	39

Table 1. Continued.

Species or Species Group	Trawl Sector (t)		Combined Line Sectors (t)		Total (t)	
	TAC	Landings	TAC	Landings	TAC	Landings
Thornyheads						
Shortspine Thornyhead	736	170	34	73	770	243
Longspine Thornyhead	405	6	20	0	425	6
Sablefish	241	253	2,510	2,705	2,751	2,958
Lingcod	2572	514	1168	759	3,740	1,273
Flatfishes						
Arrowtooth Flounder	5000	3,676	0	0	5,000	3,676
Petrale Sole	900	765	0	0	900	765
Southern Rock Sole	1,552	248	0	0	1,552	248
Dover Sole	3,073	1,662	0	0	3,073	1,662
English Sole	822	379	0	0	822	379
Pacific Halibut [2,3]	454	6	2,350	2,396	2,804	2,402

[1] Hake TAC provided by Chris Grandin and Deirdre Finn

*[2] Halibut weights are dressed, head-off, where dressed, head-off weight = round weight * 0.75.*

[3]The groundfish trawl fishery has a bycatch mortality cap of 454 tonnes that is not part of the allocated commercial TAC. Halibut caught while fishing under the authority of a groundfish trawl licence cannot be retained and must be returned to the water as quickly as possible

Table 2. British Columbia Groundfish research allocations in metric tonnes (t) for 2021. Except where noted, research allocations are deducted from the fish available to the commercial fishery by sector prior to the definition of commercial TACs. Values are copied from the 2021 Groundfish Integrated Fisheries Management Plan (https://waves-vagues.dfo-mpo.gc.ca/Library/40990151.pdf).

Species or Species Group	Trawl surveys (t)	Longline surveys (t)	Sablefish surveys (t)	Total (t)
Sharks And Skates				
North Pacific Spiny Dogfish	1.1	--	--	1.1
Big Skate	0.8	--	--	0.8
Longnose Skate	0.5	--	--	0.5
Pacific Cod	2.1	--	--	2.1
Walleye Pollock	3	--	--	3
Pacific Hake	0.2	--	--	0.2
Rockfishes				
Rougheye/Blackspotted Rockfish Complex	1.0	20.6	--	21.6
Pacific Ocean Perch	20.8	--	--	20.8
Redbanded Rockfish	1.7	11.6	--	13.3
Shortraker Rockfish	0.0	5.4	--	5.4
Silvergray Rockfish	9.5	12.7	--	22.2
Widow Rockfish	0.1	--	--	0.1
Yellowtail Rockfish	2.3	2.0	--	4.3
Quillback Rockfish	0.4	5.8	--	6.2
Bocaccio	0.6	--	--	0.6
Canary Rockfish	1.8	6.5	--	8.3
Redstripe Rockfish	1.1	--	--	1.1
Yellowmouth Rockfish	5.9	3.0	--	8.9
Yelloweye Rockfish	0.0	16.6	--	16.6
Copper, China, And Tiger Rockfish	0.2	2.8	--	3.0
Thornyheads				
Shortspine Thornyhead	1.3	0.9	--	2.2
Longspine Thornyhead	0.0	0.0	--	0.0

Table 2. Continued.

Species or Species Group	Trawl surveys (t)	Longline surveys (t)	Sablefish surveys (t)	Total (t)
Sablefish	3	0.4	85	88.4
Lingcod	0.4	3.6	--	4.0
Flatfishes				
Arrowtooth Flounder	12.7	0.0	--	12.7
Petrale Sole	0.7	--	--	0.7
Southern Rock Sole	1.7	--	--	1.7
Dover Sole	5.7	--	--	5.7
English Sole	6.7	--	--	6.7
Pacific Halibut [1]	2.5	27.2	--	29.7

[1] The halibut poundage for the groundfish trawl survey is part of the trawl fishery's halibut bycatch mortality cap. The groundfish trawl fishery has a bycatch mortality cap of 454 tonnes that is not part of the allocated commercial TAC.