CANADA

British Columbia Groundfish Fisheries and Their Investigations in 2010

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Compiled by
R. D. Stanley
Fisheries and Oceans Canada
Science Branch
Pacific Biological Station
Nanaimo, British Columbia
V9T 6N7

REVIEW OF AGENCY GROUNDFISH RESEARCH, STOCK ASSESSMENT, AND MANAGEMENT

A. Agency overview

Fisheries and Oceans Canada (DFO), Science Branch, operates three principal facilities in the Pacific Region: the Pacific Biological Station (PBS), the Institute of Ocean Sciences (IOS), and the West Vancouver Laboratory (WVL). These facilities are located in Nanaimo, Sidney and West Vancouver, B.C., respectively. Dr. Laura Richards is the Regional Director of Science. The Divisions and Sections are as follows:

Division Heads in Science Branch reporting to Dr. Richards are:

Canadian Hydrographic Service	Dr. Denis D'Amour
Ocean Science	Mr. Robin Brown
Salmon & Freshwater Ecosystems	Mr. Mark Saunders
Marine Ecosystems & Aquaculture	Dr. Laura Brown

Section Heads within the Marine Ecosystems & Aquaculture Division (MEAD) are:

Groundfish	Mr. Greg Workman
Invertebrates	Mr. Graham Gillespie
Pelagic Fish Research & Conservation Biology	Mr. Jake Schweigert
Applied Technologies	Mr. Ken Cooke
Aquaculture and Environmental Research	Dr. Steve MacDonald

Groundfish research and stock assessments are conducted in the Groundfish Section. Groundfish specimen ageing and hydroacoustic work are conducted in the Applied Technologies Section. The Canadian Coast Guard operates DFO research vessels. These research vessels include the *W.E. Ricker, J.P. Tully, Vector*, and *Neocaligus*. A replacement vessel for the *W.E. Ricker* has been delayed until 2014 or beyond.

The Pacific Region Headquarters (RHQ) of Fisheries and Oceans Canada is located at 401 Burrard Street, in Vancouver, BC, V6C 3S4. Management of groundfish resources is the responsibility of the Pacific Region Groundfish Coordinator (Ms. Tamee Mawani) within the Fisheries and Aquaculture Management Branch (FAM). Fishery Managers receive assessment advice from MEAD through the Canadian Centre for Scientific Advice Pacific (CSAP) review committee. The Chair of CSAP (Ms. Marilyn Joyce) advises the Regional Management Committee on stock status and the biological consequences of fisheries management actions and works in consultation with the Canadian Stock Assessment Secretariat (CSAS) in Ottawa. Research documents can be viewed on the CSAS website http://www.dfo-mpo.gc.ca/science/advice-avis/index-eng.html.

The trawl, sablefish, rockfish, lingcod, dogfish, and halibut fishery sectors continue to be managed 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. Details for the 2010/2011 2009/2010 integrated fisheries management plan can be viewed at http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/MPlans.htm~ #Groundfish.

A shift in the funding of industry collaborations, particularly in conducting cooperative surveys, was required after the *Larocque* court decision of June 23, 2006. Prior to the *Larocque* decision, compensation provided to fishers for their data collection services took the form of the proceeds of the unavoidable fish kills in the research surveys, less any samples retained for detailed scientific analysis. In instances where these proceeds did not cover the cost of the research survey, the department allowed fishers to catch additional fish for payment purposes. Post-*Larocque* these "top up" payment for fishing activities are no longer possible. Larocque Relief Funding, to replace fish allocations, was provided in 2007 and will continue to fund surveys through March 2012. Details on Larocque Relief Funding can be found at http://www.dfo-mpo.gc.ca/Science/newpoli-polinouv/guidance-conseils-eng.htm.

B. Multispecies or ecosystem models and research

1. Ecological Risk Assessment for the Effects of Fishing (ERAEF)

In 2010, Groundfish Science staff continued to work on a pilot application of the Ecological Risk Assessment for the Effects of Fishing (ERAEF) model developed for Australian Fisheries. The pilot study is focussed on a portion of the bottom trawl fishery in Hecate Strait and includes 25 groundfish species captured by the fishery (primarily flatfish, gadids, and elasmobranchs). ERAEF assesses the impact posed by a fishing activity on the ecosystem using a hierarchical approach to risk assessment that moves from a comprehensive but qualitative analysis of risks at Level 1, through to a more focused and semi-quantitative approach at Level 2, and finally to a highly focused quantitative "model-based" approach at Level 3. Assessments only extend to the next level if risk is judged to be above a threshold, which allows the three levels to act as a series of filters to efficiently screen out low risk activities. ERAEF has the potential to serve as a basis for ecosystem-based management since risk can be assessed for ecosystem components extending beyond traditional target species (e.g., bycatch species, habitats). The goals of the pilot study are to (i) investigate how the Australian framework could be adapted to the context of BC groundfish fisheries, (ii) promote learning among groundfish scientists, manager, and stakeholders about how the method works, and (iii) explore how relative risk scores could be used to help schedule assessment activities based on ecosystem considerations.

2. Strait of Georgia Ecosystem Research Initiative Project

Groundfish Staff continued to participate in the Strait of Georgia Ecosystem Research Initiative Project in 2010. The Central Theme of this Ecosystem Research Initiative is "The Strait of Georgia in 2030", i.e. what might the Strait of Georgia be like in 2030. The research conducted within this Initiative is designed to align with the Departmental goals of ensuring a healthy and productive aquatic ecosystem in the Strait of Georgia, and to support sustainable fisheries and aquaculture in the Strait. This research initiative currently comprises over thirty research projects and involves over fifty researchers. Details can be found at http://www-sci.pac.dfo-mpo.gc.ca/sogeri/default_e.htm. This 5-year project will be concluded in 2012.

3. NSERC Canadian Capture Fisheries Research Network (CCFRN)

Starting in 2010, Groundfish staff are paritcipating in the National Sciences and Engineering Research Council of Canada's (NSERC) *Canadian Capture Fisheries Research Network*. The CCFRN is a collaboration of academic researchers, the fishing industry, and government researchers and managers from across Canada. The Network includes 33 academics from 13 universities, working with collaborators in the Canadian fishing industry, DFO, and provincial governments. The Network is industry-driven and focussed on projects that have the active collaboration of each sector. The Network will link with other strategic networks and coordinate with DFO programs, where appropriate.

The vision of the Network is to re-shape fisheries research in Canada, bringing together industry, academia and government on priority research questions and linking existing research so that it is useful to industry and management. The research of the Network is aimed at increasing knowledge that will enhance the ecological sustainability, socio-economic viability and management of Canadian fisheries. Specifically, the research objectives are to:

- overcome information gaps for important commercial fisheries and improve the use of industry information in assessment and management;
- enhance ecological sustainability while achieving operational efficiency; and improve the basis for the ecosystem approach to fisheries management.

The Network will provide a forum for sharing research objectives and results that will build capacity in each sector; as well as establish a tradition of collaborative, strategic fisheries research in Canada that is expected to extend beyond its timeline. In addition, the Network will train a cohort of new researchers that will be equipped to meet the research challenges of a new fisheries management regime.

The information and technological advances gained through the research of the Network will have a significant impact on the sustainability, viability and competitiveness of Canada's capture fisheries industry, and will provide environmental and socio-economic benefits. The research will build upon and inform the development of policies and strategies for the management of capture fisheries in Canada and internationally. Details can be found at: http://www.nserc-crsng.gc.ca/Partners-Partenaires/Networks-Reseaux/CCFRN-CCRRN_eng.asp.

C. By species

1. Pacific cod

i Research program

390 dorsal fin rays from the 2009 Hecate Strait synoptic survey were analysed for aging in 2010. Age and length data are now available in the groundfish database.

ii. Stock Assessments

No new stock assessments for Pacific cod were conducted in 2010 and none is planned for 2011. Dr Robyn Forrest and Mr Rob Kronlund are preparing background materials and potential models for an assessment in 2012. Dr Forrest joined the Groundfish Section and Pacific cod/Hake program in 2010 as a Research Scientist. Among many responsibilities, it is expected that Dr Forrest will take the lead role in Pacific cod and hake, research, and stock assessment.

2a. Rockfish – slope

i. Research programs

Originally, the Slope Rockfish Program focused on the assessment of rockfish species living on the marine continental slope of British Columbia (BC). Over the past decade our group has morphed into a multi-purpose body that tackles a variety of issues: stock assessment, COSEWIC listing requirements, oceanographic exploration, software development for the R statistical platform, and scientific research in marine ecological modelling. There is a fair degree of inter-program collaboration.

The Groundfish Section at the Pacific Biological Station (PBS) conducts a mosaic of synoptic surveys that covers most of British Columbia's ocean bottom ecosystems, including those on the continental shelf and slope. The survey team gathers information on abundance and biology (lengths, weights, maturity, otoliths, etc.). The Slope Rockfish Program, headed by Dr Andrew M. Edwards (PBS research scientist) and including Rowan Haigh (PBS research biologist), focuses on the development of models and software tools for the analysis of data pertaining to groundfish and other species. We also retain the interest of two eminent scientists – Jon T. Schnute (PBS scientist emeritus) who contributes considerable time and expertise; and Paul J. Starr who works for the Canadian Groundfish Research and Conservation Society and plays an integral role in the stock assessments assigned to our program.

In 2010, work continued on maintaining and upgrading the suite of PBS packages for the R statistical platform:

PBSmodelling
http://cran.r-project.org/web/packages/PBSmodelling/index.html
http://code.google.com/p/pbs-modelling/
PBSmapping
http://cran.r-project.org/web/packages/PBSmapping/index.html
http://code.google.com/p/pbs-mapping/
PBSadmb
http://cran.r-project.org/web/packages/PBSadmb/index.html
http://code.google.com/p/pbs-admb/
PBSddesolve
http://cran.r-project.org/web/packages/PBSddesolve/index.html
http://code.google.com/p/pbs-ddesolve/
PBSfishery
http://code.google.com/p/pbs-fishery/

Contract work involving Alex Couture-Beil (M.Sc. computer science, Simon Fraser University) with the help of Jon Schnute worked towards a significant integration of PBSadmb with the products available from the AD Model Builder project (http://admb-project.org/).

Additionally, our group employed a co-op student, Stephanie Keightley (4th year biology and environmental studies, University of Victoria), to investigate the use of multivariate autoregressive (MAR) models for groundfish communities. Under the guidance of Andrew Edwards and Carrie Holt (PBS research scientist), Stephanie tested how several indices and abiotic time series might drive recruitment for three groundfish species – Pacific ocean perch (*Sebastes alutus*), canary rockfish (*S. pinniger*) and sablefish (*Anoplopoma fimbria*) – using MAR models through a MatLab toolkit called LAMBDA (http://conserver.iugo-cafe.org/user/e2holmes/LAMBDA).

ii. Stock assessment

In 2010, our group presented the first British Columbia stock assessment of Pacific ocean perch (*S. alutus*) since 2001. The assessment focussed on Queen Charlotte Sound, which contains the primary habitat of this rockfish along the BC coast.

Pacific ocean perch supports the largest rockfish fishery in BC with an annual coastwide TAC (total allowable catch) of 6,148 t. The trawl fishery receives 99.98% of the coastwide TAC, with the rest allocated to the hook and line fishery. Stock status was assessed using an annual two-sex catch-at-age model tuned to three fishery-independent trawl survey series (Goose Island Gully historic, Queen Charlotte Sound synoptic and Queen Charlotte Sound shrimp), annual estimates of commercial catch since 1940, and age composition data from two of the survey series (8 years) and the commercial fishery (29 years).

Results are reported for the two accepted model runs (the first estimated natural mortality and the second kept it fixed); numeric ranges refer to the 5 to 95% credible intervals derived from Bayesian output).

Spawning biomass (mature females only) at the beginning of 2011 is estimated to be in the range of 12-43% or 8-24% of the equilibrium unexploited value. Annual exploitation rates have increased since the 1980s, and are approaching or have reached the historic high levels associated with the large catches by foreign fleets in the late 1960s. The exploitation rate for 2010 is estimated to be in the range 0.041-0.152 or 0.089-0.224.

Based on the DFO *Sustainable Fisheries Framework*, Precautionary Approach compliant limit and upper reference points of $0.4B_{MSY}$ and $0.8B_{MSY}$ were calculated (where B_{MSY} is the spawning biomass at the maximum sustainable yield). The spawning biomass at the start of 2011 has a probability of 0.96 or 0.82 of being above $0.4B_{MSY}$, and of 0.68 or 0.24 of being above $0.8B_{MSY}$.

Constant catch projections at 3,500 t/year (which is the average catch from 2006 to 2010) over 5 years predict that the spawning biomass at the start of 2016 would have a probability of 0.91 or 0.57 of remaining above $0.4B_{MSY}$, and of 0.63 or 0.15 of remaining above $0.8B_{MSY}$.

Both model runs estimate that since 1981 there have been no recruitment events as large as those observed in the early 1950s and late 1970s. There is evidence that an above average recruitment event occurred in the early 2000s, although there have been insufficient observations of this year class to be confident of its size.

iii Research activities for 2011

In 2009, COSEWIC (the Committee on the Status of Endangered Wildlife in Canada) assessed yellowmouth rockfish (*S. reedi*) as "threatened". This obliges our group to produce a Recovery Potential Assessment (RPA) document that comprises a stock assessment of yellowmouth rockfish along the BC coast, Precautionary Approach (PA) reference points, and decision tables that incorporate harvest options and their affect on the population with respect to the reference points. The RPA will look very much like PA-compliant stock assessments that DFO routinely produces. The major difference is that the population projection must extend further ahead than the typical five years. In the case of yellowmouth rockfish, the projection will be roughly ½ generation, or 15 years.

In 2011, we also plan on hiring a computer programmer to enhance the PBS suite of R packages. PBSmapping in particular needs upgrading to take advantage of the functionality in other R-packages.

2b. Rockfish – shelf

i. Research Programs in 2010

Dr. Murdoch McAllister of U.B.C. and Rick Stanley published a paper on modeling trawl survey catchability for B.C. bocaccio (*Sebastes paucispinis*): a combined expert driven – empirical approach. This paper combined fisher opinions of trawl catchability of bocaccio with a Bayesian surplus production model to conduct a stock assessment of bocaccio.

In conjunction with the Alaska Fisheries Science Centre (NMFS), work is ongoing to establish a consistent and low-priced genetics assay to distinguish between rougheye and blackspotted rockfish. U.S. and Canadian surveys are now collecting genetics samples in order to develop relative abundance indices for each of the species. It is important to note that as long as it is not possible to identify the species in the field, the survey will incur ongoing post-survey genetics assay costs.

A long delayed study of yellowtail genetics was re-initiated in conjunction with Washington State colleagues. The intent of this study was to look for stock delineation prior to the next stock assessment.

Dr Nathan Taylor joined the Groundfish Section and Shelf rockfish program in July of 2010 as a Research biologist. Dr Taylor's post-graduate and post-doctoral experience focussed on stock assessment and included mathematical modelling of tuna populations.

ii. Stock assessments in 2010

A synchronous assessment of five rockfish (splitnose, sharpchin, harlequin, redstripe, and greenstriped rockfish) was initiated in 2010. The intent of this assessment to provide a cost-effective means for providing adequate assessment advice on relatively data limited species in a timely manner.

iii. Research activities planned for 2011

Genetics work on rougheye/blackspotted rockfish and yellowtail rockfish will continue in 2011.

iv. Stock assessments planned for 2011

The 5-rockfish assessment will be completed in 2011 and be reviewed in the fall of 2011. An update of the bocaccio assessment is also planned for the fall of 2011.

2c. Rockfish – inshore

i. Research programs in 2010 and planned for 2011

a) Surveys

1. Inside (PMFC Area 4B)

A research longline survey designed for the Inside waters East of Vancouver Island and initiated in 2003, was conducted in the northern half of the study area in 2010. Survey coverage alternates between the northern and southern portions, annually. Hard bottom areas were identified through bathymetry analyses, inshore rockfish fishing records and fishermen consultations. The hard bottom survey areas were then overlain with a 2 km by 2 km grid and survey blocks were stratified by area and depth (41 – 70 m and 71 – 100 m) and selected for sampling at random. Twenty-one days of DFO ship time are allocated in August for this survey in 2011.

A Phantom HD2+2 remotely operated vehicle (ROV), acquired by DFO Science in 2007 has been used to develop visual survey methods for inshore rockfish. A forward looking video camera (paired lasers), DIDSON sonar unit, scanning sonar, and ultra-short baseline (USBL) underwater acoustic positioning are standard equipment used on the ROV for visual surveys. Surveys to assess inshore rockfish stocks in and adjacent to the Rockfish Conservation Areas (RCAs) were conducted in August 2010 in the northern inside waters and in February 2011 in portions of the southern west coast of Vancouver Island. ROV surveys will continue in 2011 in northern portions of the west coast of Vancouver Island.

2. Outside (PMFC Areas 3CD, 5ABCDE)

Since 2003, a third technician has been deployed on the annual International Pacific Halibut Commission (IPHC) Area 2B setline survey to collect hook-by-hook catch data and conduct biological sampling of non-halibut catch (Yamanaka et al. 2004, 2007, Lochead et at. 2006,

Obradovich et al. 2008). The third technician has been supported by Larocque funds since 2007 and will continue in 2011.

In collaboration with the halibut industry, a research longline survey was designed and conducted in the outside BC coastal waters in 2006. Hard bottom areas were identified through bathymetry analyses, inshore rockfish fishing records and fishermen consultations. The hard bottom survey areas were then overlain with a 2 km by 2 km grid (matched with the adjacent trawl survey grid) and survey blocks were stratified by area and depth and chosen at random. Approximately 200 survey sets are targeted annually. The survey covers the coastwide Outside waters over two years, alternating annually between the north and the south. Three chartered fishing vessels conduct this survey between August 15 and September 15. In 2010, the northern portion of BC was surveyed and plans for a 2011 are to survey in the southern region. This survey is supported by Larocque funds.

b) Collaborative research

Three years of NSERC funding (2009 – 2011) (National Sciences and Engineering Research Council of Canada) has been awarded to Dr. Jon Shurin of the University of British Columbia (UBC), in collaboration Parks Canada, Pacific Halibut Management Association (PHMA) and DFO, to conduct research to assess the effectiveness of RCAs in maintaining and enhancing inshore rockfish stocks in BC. Two MSc students and a PhD student began their field work on projects related to the assessment and management of RCAs for inshore rockfish in BC. MSc students will complete their projects in 2011.

Dr. Marie Etienne from the AgroParisTech in France was on sabbatical in 2010 with Dr. Murdoch McAllister at UBC and working on various projects in her field of expertise: spatial statistics. Dr. Etienne completed work, together with Dr. McAllister's PhD student Shannon Obradovich and the inshore rockfish program to develop an abundance index from research longline catch data that accounts for hook competition and the return of empty hooks (Etienne et al. *in review*). The catch data from the Inside longline surveys as well as directed hook-timer experiments are being used to test various models and help differentiate between competing scenarios.

ii. Stock assessment

The National Advisory Process (NAP) and Committee On the Status of Endangered Wildlife In Canada (COSEWIC) status reports were prepared for yelloweye and quillback rockfishes (Yamanaka et al. 2006a, 2006b). COSEWIC reviewed the status of yelloweye rockfish in November 2008 and recommended a Special Concern status. Quillback rockfish was also reviewed by COSEWIC in the fall of 2009 and COSEWIC has recommended a Threatened status. http://www.cosewic.gc.ca/eng/sct1/searchform_e.cfm

An inside yelloweye rockfish stock assessment was presented to the Canadian Science Advisory Process (CSAP) in April 2011. A coastwide quillback rockfish assessment will be presented to CSAP in May 2011.

iii. Management

In 2007, the RCA strategy was completed with 20% of rockfish habitat closed in Outside waters and 30% of rockfish habitat closed in Inside waters. RCAs are used as a spatial management tool to protect inshore rockfish. Fishing activities likely to catch rockfish are prohibited within these areas http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/fisheriesmgmt/rockfish/~default_e.htm

3. Sablefish

i. Research activities in 2010 and planned for 2011

The Sablefish Research and Assessment Survey Program includes the following program components:

a) A **Traditional Standardized Program** (1990-2010)

This program includes standardized sets at nine (9) offshore fishing localities and biological sampling. Starting in 1990, one set was made in each of five (5) depth intervals in each locality. Since 1999, additional shallower and deeper depth intervals have been added, removed and changed. However, the 5 core intervals have remained the same over time. Catch rates from these core sets extend a stock abundance index series and sablefish are sampled for data on size and growth.

b) A **Traditional Tagging Program** (1991-2007, hiatus in 2008-2010)

This program captures sablefish for tagging and release at historical tagging locations. Sets are made in the 9 traditional standardized program localities as well as five (5) tagging-only localities. The protocol for this program is to release a specified number of tagged fish in each locality. Low catch rates in some areas in previous years have resulted in survey vessels being required to re-set additional strings in an area. Tag-recoveries from these sets can be used for studying movement, obtaining estimates of gear selectivity, and deriving an index of tagging-based abundance.

c) A **Randomized Tagging Program** (2003-2010)

This program captures sablefish for tagging and release following a depth and area stratified random survey design. The catch rate data can be used to derive an index of stock abundance. Tag-recoveries can be used for deriving estimates of gear selectivity, studying movement, and deriving an index of tagging-based abundance. The survey also provides biological samples.

c) An **Inlets Program** (1995-2010)

This program includes standardized sets at four (4) mainland inlet localities. Sablefish are tagged and released from inlet sets and are sampled for biological data.

The annual Research and Stock Assessment Survey Program will be conducted in the fall of 2011, but will include only the randomized program (c) and the inlets program (d).

ii. Stock assessment activities in 2010 and planned for 2011

A sablefish assessment was conducted in 2010 (Cox et al. 2011, in revision). Sablefish stock assessment and management in British Columbia is conducted collaboratively by DFO and the Canadian Sablefish Association. The collaboration is formalized as a Joint Project Agreement that identifies the respective responsibilities of the two parties and provides a mechanism for joint contributions to fishery management and science activities for sablefish. Annual survey activities are conducted using fishing vessels chartered from the sablefish longline trap fleet.

Fishery reference points are based on a target spawning biomass at maximum sustained yield, B_{MSY}, with limit and upper stock reference points at $0.4B_{MSY}$ and $0.8B_{MSY}$, respectively. Conservation objectives relate to (*i*) maintaining the spawning biomass above the limit reference point of $0.4B_{MSY}$ in 95% of years projected over two sablefish generations (~36 years), and (*ii*) implementing an acceptable probability of stock decline over 10 years that scaled from 0.5 at the target biomass to 0.05 at the limit reference point. A multi-gear, age-structured, catch-at-age model was fitted to historical data to create stock scenarios that captured uncertainty in natural mortality, growth, and future recruitment variability. Stock reconstructions suggest stock status is currently below B_{MSY} for all scenarios. A closed-loop feedback simulation approach was used to evaluate the relative performance of candidate management procedures that are distinguished by the choice of survey data, assessment model assumptions, harvest control rule specifications, and future regulations related to at-sea release of sub-legal sablefish. Candidate management procedures were robust to the uncertainties considered as indicated by a consistently low probability ($p < 5\%$) of breaching the limit reference point over two sablefish generations (~36 years) regardless of the management procedure or stock scenario. Expectations for stock growth toward the target reference point over two sablefish generations range from B_{MSY} or greater to levels near, but not above B_{MSY} under the more pessimistic scenarios.

Performance of management procedures based on the stratified random trap survey alone suggested the legacy standardized trap survey could be discontinued without creating a conservation concern, and could also achieve reduced catch variability relative to the use of both surveys. Increases in expected conservation and catch performance due to adopting an avoidance option for sub-legal sablefish, or a full retention option, were small relative to the performance attained by the existing size limit tactic, but these effects are likely underestimated due to suspected violations of assumptions related to trawl gear selectivity. The coast-wide quota was set at 2,300 t for 2011/12 fishing year, unchanged from the 2010/11 fishing year. Sablefish is next scheduled for a stock assessment in 2012.

Development of the management strategy evaluation for BC sablefish in 2010 added modeling of retained and released catches to the age-structured operating model. A 55 cm fork length minimum legal size limit in British Columbia means that sub-legal fish are released by regulation. Work in 2011 will focus on improvements to the modeling of releases by gear sector and simulation evaluation of the B_{MSY}-based reference points. The longline trap and longline hook sectors of the sablefish fishery in BC received Marine Stewardship Council certification on

July 29, 2010. Certification was award upon conditions related to (*i*) assessment of stock status relative to fishery reference points and in particular whether the stock is fluctuating around the target reference point, (*ii*) evaluation of the impacts of bycatch of the rougheye/blackspotted rockfish complex, (*iii*) evaluation of existing sea-bird bycatch data and improvement of seabird bycatch monitoring data collection.

4. Flatfish

i. Research program in 2010

Jeff Fargo retired from DFO at the end of 2010 after 32 years conducting research on flatfish biology, ecology and stock assessment. Kendra Holt joins DFO as the new program head for flatfish research and will lead the flatfish program in 2011.

Ongoing data collection in support of the flatfish research program continued in 2010 with samples being collected during two Groundfish synoptic bottom trawl surveys, the first off the west coast of Vancouver Island in June and the second off the west coast Haida Gwaii (Queen Charlotte Islands) in August – September. Additional samples were collected by port samplers in Vancouver and Prince Rupert as well as by At Sea Observers (ASOP) deployed on bottom trawl vessels. During surveys biological data were collected from all flatfish species encountered, including non-commercial species. Sampling included collecting aging structures and determining maturity stage.

Two technical reports were prepared during 2010:

Fargo, J.J. In press. Dynamics of marine fish assemblages in Hecate Strait, British Columbia. Can. Tech. Rep. Fish Aquat. Sci. xxxx: xx + 69p.

Fargo, J.J. and S.J. Westrheim. In press. Tagging mortality, recovery rate and mortality rate of English sole (*Parophrys vetulus*) tagged in Hecate Strait, June 9-18, 1983, and records of other migrations elsewhere. Can. Tech. Rep. Fish Aquat. Sci. xxxx: xx + xxxp.

ii. Stock assessments in 2010

No flatfish stock assessments were prepared in 2010.

iii. Research programs planned for 2011

Biological data collection for all flatfish species will continue in 2011 with fishery independent samples coming from two synoptic surveys the first in Hecate Strait in June and the second in Queen Charlotte Sound in July.

Seventeen flatfish species in British Columbia have been included in a pilot study implementation of an Ecological Risk Assessment for the Effects of Fishing to a portion of the BC bottom trawl fishery in Hecate Strait (see section D – ERAEF Pilot). A productivity susceptibility analysis (PSA) will be applied to each of these species in 2011 to estimate potential risk from bottom trawl

fishing in this area. PSA methods have been taken from methodology developed by NOAA (http://nft.nefsc.noaa.gov/PSA_pgm.htm). Flatfish species included in the analysis include a wide range of directed (e.g., dover sole, petrale sole) and non-directed (e.g., speckled sanddab, deepsea sole) species.

In preparation for future stock assessments, Jeff Fargo (Retired - alumnus biologist) will complete a technical report in 2011 summarizing life history characteristics, biomass estimates, and fisheries reference points for several BC flatfish species.

5. Pacific hake

i. Research program

Triennial (until 2001), then biennial acoustic surveys, covering the known extent of the Pacific hake stock have been done since 1995. 2010 was an intra-survey year during which the survey team responded to questions raised by the Stock Assessment Review (STAR) panel in 2010. The first issue was potential bias due to the protocol for sampling schools of hake. One reviewer had felt that schools would likely be stratified by size and age and that the conventional approach of taking a "dip" from the top or side of a school to verify the lengths of fish estimated in the acoustic signal would likely be biased. Survey teams onboard the US vessel *Miller Freeman* and Canadian *W.E. Ricker* fished several hake aggregations where they were able to tow the net through the top, middle and bottom and across the length and width of a school and found no obvious pattern of size stratification. Scientists also intended to test the acoustic target strength of Humboldt squid (*Dosidicus gigas*) which were abundant during the 2009 survey, contaminating 39% of the acoustic transects with an unknown quantity of squid backscatter. This problem could not be resolved in the 2010 field season due to the absence of Humboldt Squid during the 2010 survey.

ii. Stock Assessment in 2011

The majority of the Hake catch for the 2010 season was taken from the LaPerouse area in the third quarter (July-Sept), however the shift in temporal and spatial distribution of Pacific hake was still apparent with much of the catch being taken from Queen Charlotte Sound (PMFC 5A and 5B). The increased fishing in the Strait of Juan de Fuca seen in the 2009 fishery was not apparent in 2010; word has spread amongst the fishing community that the fish caught there in 2009 were too small for processors to handle.

The 2011 harvest advice was prepared jointly by Canadian and US scientists, with considerable efforts by the two teams to align data and assumptions in the two assessment models. The models were SS and TINSS, respectively prepared by the US and Canadian assessment teams. Results from the two assessments were combined within a single document that was reviewed by the Pacific Hake Stock assessment review (STAR) panel. Notably, for the first time, decision tables incorporated results from both models, thus presenting uncertainty arising from model-choice to be presented in a consistent format. The review panel accepted both models as equally plausible and recognised the large step forward that had been taken in US-Canadian collaboration on the hake assessment.

Note that in 2009 survey results were badly contaminated by huge numbers of Humboldt squid that occurred all along the Pacific coast. It had not been possible to distinguish squid from hake acoustically and the STAR panel had recommended that the 2009 survey abundance index be removed from the assessment entirely. Re-analysis of the acoustic survey data by NOAA's acoustic team during 2010 enabled confidence intervals to be placed on the 2009 estimate of hake abundance. The acoustic team also re-analysed all the raw acoustic data since 1995 and applied a kriging methodology to recalculate indices of abundance with confidence intervals. Addition of confidence intervals that could be attributed to the presence of Humboldt squid to the 2009 index led to the decision to re-instate this data point (with CV) into the assessment. All survey data prior to 1995 were removed from the analysis, as these were known to contain bias due to subjective inflation factors that had been applied to account for the fact that these surveys did not cover the same extent (spatially or depth-wise) as surveys since 1995. Furthermore, raw data were no longer available for the earlier surveys and it was therefore impossible to apply the same kriging methodology to recalculate the index of abundance. The review panel supported the removal of pre-1995 survey data and re-instatement of the 2009 data.

A notable feature of both assessments was the appearance of an apparent strong 2008 year class in the 2010 commercial catch data. This apparent above-average recruitment event, along with evidence for relatively large 2005 and 2006 year classes, was strongly influential on model results. The strength of the 2008 year class was highly uncertain in the assessments, as it had only been seen once in commercial catch data. This year class has not yet been seen in survey data, as there was no survey in 2010 and the survey does not sample one year old fish, precluding its appearance in the 2009 survey. The uncertainty in the size of the 2008 year class led to extreme uncertainty in model results and was treated as the major axis of uncertainty in the decision tables. The assessment authors noted that a change in fishing practices could also lead to a greater proportion of two-year olds in the catch but were unable to evaluate this hypothesis without fishery-independent information (i.e., survey data). Survey data from 2011 and future years will hopefully confirm whether or not the high proportion of two year old fish in the 2010 catch was indeed the result of a very large recruitment event.

Scientists from Canada were invited to attend the Pacific Fisheries Management Council’s (PFMC) meeting in Vancouver, WA, in March, 2011 to jointly present the assessment results (with US scientists) to the Science and Statistics Committee (SSC) of the PFMC. Dr Robyn Forrest presented the TINSS results, while Dr Ian Stewart (NOAA) presented the SS and combined SS-TINSS decision tables. The SSC forwarded both sets of results to the PFMC as equally plausible and recommended an overfishing limit (OFL) based on the mean of the combined posterior results from both models. Drs Stewart and Forrest also presented the results to the PFMC's Groundfish Management Team (GMT) and Groundfish Advisory Panel (GAP). They re-iterated their concerns that the size of the 2008 cohort is extremely uncertain and age-composition data could be partly a result of an unknown change in fishing practices. After hearing the testimony of the SSC, GMT, GAP and several stakeholders, the PFMC came to a consensus on a TAC of 393,750 mt. This was based on a previous environmental impact assessment that recommended the TAC should not be more than 1.5 times the previous year's TAC (262,500 mt).

6. Elasmobranchs

i. Research programs in 2010

Two shark tagging surveys were undertaken in 2010. In late July 2010, a pelagic longline survey was conducted offshore of Barkley Sound on the west coast of Vancouver Island. Four blue sharks (*Prionace glauca*) were tagged with archival satellite tags all providing real-time data; approximately 200 were tagged with conventional tags. Two tope sharks (*Galeorhinus galeus*) were tagged with archival satellite tags, with pop-up dates for July 2011. A bottom longline survey was conducted in March 2011 in the Strait of Georgia. Eight sixgill sharks (*Hexanchus griseus*) were tagged with satellite tags, with pop-up dates set for March 2012.

Aerial surveys for basking sharks (*Cetorhinus maximus*) were conducted monthly May to September in 2010 in two areas of historic high abundance: Barkley and Clayoquot Sounds; and Rivers Inlet. No sharks were sighted. Two basking shark sightings were received through the basking shark Sightings Network (toll-free number or online form). Tri-national collaboration between Canada, US and Mexico on critical habitat modeling and tagging programs was implemented in 2010.

ii. Stock assessment(s) in 2010

A stock assessment of the spiny dogfish (*Squalus acanthias*) for both the inside stock (Strait of Georgia, PMFC 4B) and outside stock (PMFC 3C through 5E) of spiny dogfish was reviewed and accepted by the CSAP.

iii. Management

There are no directed fisheries allowed for sharks (excluding spiny dogfish, *Squalus acanthias*) in BC waters; therefore sharks are bycatch only. For the upcoming groundfish commercial fishing season, retention of shark bycatch in the hook and line fishery is not permitted and the sale of shark products is not permitted by the trawl sector. To aid in fisher and on-board observer identification of sharks, an identification guide “Sharks of British Columbia” was produced and distributed to all licence holders.

New management measures will be put in place in the recreational fishery in 2011, with non-retention of all shark species other than spiny dogfish and salmon shark (*Lamna dirtopis*). A daily limit of 4 and an annual possession limit of 8 will be implemented for spiny dogfish. A daily limit of 1 and an annual possession limit of 2 will be implemented for salmon shark. Previously the daily limit for all shark species was 20 per species, with an annual possession limit of 40 per species.

Basking shark was formally listed as Endangered under the Species At Risk Act, affording this species complete protection within Canadian waters. The Recovery Management Strategy has been completed. It is currently in the final 30 day comment period with the public SARA Registry, and will likely be accepted by summer 2011. The tope shark and sixgill shark were listed as Special Concern. A combined Management Plan has been drafted and is currently in the DFO regional and national review process.

iv. Research activities for 2011.

In collaboration with the Alaska Fisheries Science Center and Moss Landing Marine Labs, a collaborative project on bomb dating for age validation of big skate (*Raja binoculata*) and longnose skate (*R. rhina*) will be initiated. A population genetics study for blue shark and salmon shark in the North Pacific is underway with collaborators from California, Alaska, Hawaii and Japan. A population genetics study of sixgill sharks in BC will be conducted, and is to include the investigation of polyandry.

7. Lingcod

Kendra Holt began work on the lingcod program in 2010, and will continue working with Dr. Jackie King on the program in 2011.

i. Research programs in 2010

A lingcod (*Ophidodon elongatus*) egg mass survey was conducted by DFO SCUBA divers at Snake Island Reef and Entrance Island Reef in the Strait of Georgia between February 15th and February 25th, 2010. This survey was undertaken to add to the existing time series from Snake Island Reef, one of the primary index sites, and to provide an ongoing source of biological and relative abundance information for Strait of Georgia lingcod.

ii. Stock assessment(s) in 2010

Stock assessments for four different management units of outside lingcod (southern west coast Vancouver Island, northern west coast Vancouver Island, Queen Charlotte Sound, and Hecate Strait & the west coast of Haida Gwaii [Queen Charlotte Islands]) were undertaken in 2010 using a Bayesian surplus production model. The assessments were approved at an April 2011 meeting of the CSAP, and an assessment document will be published in the CSAS series with a 2011 publication date.

iii. Research activities for 2011

Lingcod research activities in 2011 will focus on Strait of Georgia lingcod, including updating the stock assessment methodology and management framework developed as part of the 2005 *Management Framework for Strait of Georgia Lingcod.* This work will be undertaken in preparation for a stock assessment in 2012 or 2013. An update of the 2005 framework will require the reference points, management objectives, and harvest control rule identified in the 2005 framework to be re-evaluated in light of DFO's 2009 *Decision-making Framework Incorporating the Precautionary Approach*. A management strategy evaluation approach (MSE) to providing management advice has been identified as a useful tool for evaluating trade-offs among these choices. The feasibility of developing a management strategy evaluation for Strait of Georgia lingcod will be evaluated in 2011.

D. Other related studies

1. Statistics and Sampling

i. Biological sampling and database work in 2010

Principal Statistics and Sampling activities in 2010 included the ongoing population of the groundfish biological database (GFBio). This database now includes almost 9 million specimens. Data entry activities continue to concentrate on the input of current port sampling and observer biological data and recent research cruises. The groundfish trawl fishery continues to be covered by 100% dockside and virtually 100% observer coverage. These observers also provided 218 length/sex/age samples and 169 length samples in 2010. Port samplers provided an additional 101 samples, 91 samples with ageing structures (length/sex/age/weight) and 10 without structures (length/sex/weight). The focus of their sampling efforts was from those fisheries not covered by at-sea observers.

ii. Catch monitoring in 2010

Staff continued to play a key role in development a new Regional Catch Monitoring information system as well being actively involved in the Groundfish Hook and Line Catch Monitoring Program and a Recreational catch monitoring working group. The Region is considering a more formal approach to identifying accountabilities for catch monitoring in the Region. The outcome of this review may lead to the Science/Groundfish Section assuming a much greeter role and workload with respect to the collection and management catch monitoring data.

In September 2010, staff co-authored a presentation at the ICES annual symposium on the use of an audit opposed to census approach for review of catch video imagery. This paper has been accepted for publication in the ICES journal with a 2011 publication date.

Related to the above issue, one staff member was invited to give a presentation and participate in the discussions at a European Fisheries Commission workshop in Copenhagen. This workshop focussed on uses, applications, and operational elements involved in the collection and analysis of video imagery from catch monitoring.

iii. Field work in 2010

Staff participated on various bottom trawl surveys including the West Coast Vancouver Island and West Coast Haida Gwaii groundfish trawl surveys, the West Coast Vancouver Island and Queen Charlotte Sound shrimp trawl surveys, as well as the Pacific hake hydroacoustic surveys, and lingcod dive survey. This group also included the port sampling activity (1.8 person-years) in the Vancouver and Prince Rupert areas. Staff continued to enhance GFBioField, the integrated (paper-less) data capture system for surveys.

iv. Proposed field and database work for 2011

Port sampling will continue in 2011, as will staff participation in the bottom trawl surveys to Hecate Strait and Queen Charlotte Sound as well as the shrimp trawl surveys in Queen Charlotte Sound and lingcod dive survey in the Strait of Georgia.

Starting in 2011 staff will begin to develop "GFCatchAll" as comprehensive database that will include all known sources of groundfish catch (1900-present). This project is expected to be 90% complete but usable by the end of 2013.

APPENDIX 1. REVIEW OF CANADIAN GROUNDFISH FISHERIES

1. Commercial fisheries

All catch figures for the 2010 calendar year are preliminary. Canadian domestic trawl landings of groundfish (excluding halibut) in 2010 were 77,198 t, a decrease of 10% from the 2009 catch. The major species in the trawl landings were Pacific hake (62%), Pacific ocean perch (7%), yellowtail rockfish (6%), and walleye pollock (5%). Trawl production was distributed amongst areas 3C (45%), 3D (20%), 5B (12%), 5D (6%), 5A (5%), 5E (4%), 4B (3%), and 5C (2%).

Canadian landings of groundfish caught by gear other than trawl in 2010 totalled 7,380 t. Landings of sablefish by trap and longline gear accounted for 2,834 t, approximately 29% by trap gear, 70% by longline gear and 1% by unspecified. Landings of species other than sablefish by trap, longline, handline and troll gear accounted for 4,546 t (36% rockfish, 34% dogfish, 17% lingcod and 12% skates) (see IPHC-TSC submission for estimates of halibut catches).

2. Recreational fisheries

Each year, Fisheries Management Branch of DFO conducts creel surveys of the recreational angling fishery in the four south coast regions. For the Strait of Georgia, in 2010, these surveys covered the months of March to October. Provisional estimates of 2010 catches, landings and releases, for this 8-month period were 22,551 fish for lingcod, 22,750 fish for all rockfish species, 126 fish for halibut, 5,066 fish for rock sole, 1,198 fish for starry flounder, 4,896 fish for dogfish, 2,784 fish for greenlings, 2,262 fish for Pacific cod and 1,793 fish for other groundfish species.

For the Strait of Juan de Fuca, catch estimates have been generated from creel surveys and fishing lodge reports for the months of March to September. Provisional estimates for this 7-month period are 21,642 fish for lingcod, 14,521 for all rockfish species, 5,614 fish for halibut, 2,155 fish for rock sole, 1,041 fish for other flatfish species, 14,006 fish for dogfish, 4,536 fish for greenlings, and 2,225 fish for other groundfish species.

Along the west coast of Vancouver Island catch estimates have been generated from creel surveys and fishing lodge reports. Data are available for June to September. Provisional estimates of 2010 catches were 16,787 fish for lingcod, 21,364 fish for all rockfish species, 16,428 fish for halibut, 2,347 fish for dogfish, 452 fish for greenlings, and 1,137 fish for other groundfish species.

In Johnstone Strait catch estimates have been generated from creel surveys and fishing lodge reports for June to August. Provisional estimates of 2010 catches were 4,040 fish for lingcod, 11,613 fish for all rockfish species, 4,852 fish for halibut, 1,287 fish for flatfish species, 1,006 fish for greenlings, 662 fish for dogfish and 1,511 fish for other groundfish species.

3. Joint-venture fisheries

In 2010, 13 Canadian catcher vessels delivered Pacific hake and incidental species to a single processing vessel in a co-operative fishing arrangement. This fishery took place mainly off the southwest portion of Vancouver Island (area 3C). A total of 8,243 t of Pacific hake was processed by the one American vessel. The estimated catch breakdown by area was 78% from area 3C, 19% from area 5B, and 3% from area 3D. The quotas and catches are outlined below:

Nation	Species	Quota (t)	Catch (t)
Poland	Hake	8,500	8,243
	Pollock	incidental	3
	Rockfish	incidental	185
	Other	incidental	11

4. Foreign fisheries

There were no national or supplemental fisheries for Pacific hake off British Columbia in 2010.

APPENDIX 3. GROUNDFISH STAFF IN 2010

Greg Workman	Section Head
Schon Acheson	Technician, Groundfish port sampling
Bill Andrews	Technician, Flatfish
Kristina Anderson	Technician, Groundfish port sampling
Karina Cooke	Technician, Database and Surveys, Inshore and Shelf Rockfish
Andrew Edwards	Program Head Slope Rockfish, Statistical and mathematical modelling, stock assessment
Jeff Fargo	Program Head Flatfish stock assessment and biology
Rob Flemming	Biologist, GIS specialist, Inshore rockfish
Robyn Forrest	Research Scientist, Stock assessment, Hake, Pacific Cod
Chris Grandin	Program Head Hake
Rowan Haigh	Biologist, Statistical and exploratory data analysis, Slope Rockfish
Kendra Holt	Biologist, Stock assessment, ERAEF
Gail Jewsbury	Technician, Data, Health and Safety
Jackie King	Research Scientist, Lingcod, Elasmobranchs, Climate studies
Brian Krishka	Biologist, database support and analysis, Flatfish
Rob Kronlund	Program Head Sablefish, analytical programs
Lisa Lacko	Biologist, GIS specialist and database manager
Romney McPhie	Biologist, Lingcod, Elasmobranchs
Brock Medlar	Technician, Sablefish

Wendy Mitton	Technician, Sablefish
Norm Olsen	Biologist, programmer/GIS, groundfish statistics, Shelf rockfish
Kate Rutherford	Biologist, database manager, groundfish statistics, Shelf rockfish
Rick Stanley	Program Head Shelf rockfish assessment and biology, statistics.
Nathan Taylor	Biologist, Stock assessment
Malcolm Wyeth	Biologist, Groundfish surveys and Port sampling
Lynne Yamanaka	Program Head Inshore rockfish research and stock assessment

APPENDIX 4. PARTIAL LIST OF GROUNDFISH RELATED REPORTS WITH 2010 PUBLICATION DATES.

PRIMARY

Dulvy, N.K. and R.E. Forrest. 2010. Life histories, population dynamics and extinction risks in chondrichthyans. Ch. 17 In Sharks and their Relatives II. Biodiversity, Adaptive Physiology and Conservation. Edited by J. Carrier, J. Musick and M. Heithaus. CRC Press, Boca Raton. pp.639-679.

Forrest, R.E., McAllister, M.K., Dorn, M.W., Martell, S.J.D., and Stanley, R.D. 2010. Hierarchical Bayesian estimation of recruitment parameters and reference points for Pacific rockfishes (*Sebastes* spp.) under alternative assumptions about the stock–recruit function. Can. J. Fish. Aquat. Sci. 67: 1611–1634.

McAllister, M.K. R.D. Stanley and P. Starr. 2010. Modeling trawl survey catchability for B.C. bocaccio (*Sebastes paucispinis*): a combined expert driven – empirical approach. Fishery Bulletin 108:282-304.

Taylor, S., Sardell, R., Reid, J., Bucher, T., Taylor, N.G., Arcese, P., Keller, L. 2010. Inbreeding coefficient and heterozygosity–fitness correlations in unhatched and hatched song sparrow nestmates. Molecular Ecology. doi: 10.1111/j.1365-294X.2010.04824.x

Taylor, N. and Walters, C. 2010. Estimation of Bioenergetics Parameters for a Stunted Northern Pikeminnow Population of South Central British Columbia. The Open Fish Science Journal. 3:110-121

Yamanaka, K.L., Logan G. 2010. Developing British Columbia's Inshore Rockfish Conservation Strategy. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 2:28–46.

OTHER PUBLICATIONS

Edwards, A.M., Starr, P.J., and R. Haigh. 2010. Stock assessment for Pacific ocean perch (*Sebastes alutus*) in Queen Charlotte Sound, British Columbia. Canadian Science Advisory Secretariat, Research Document 2010/xxx.

Grandin, C., K. Cooke, and J. Holmes. 2010. Pacific Hake (*Merluccius productus*) distribution and abundance along west coast of Canada and the United States. Pg 92-96 in Crawford, W.R., and J.R. Irvine (eds) State of physical, biological, and selected fishery resources of Pacific Canadian marine ecosystems in 2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/053.