CANADA

British Columbia Groundfish Fisheries and Their Investigations in 2009

May 2010

Prepared for the 51st Annual Meeting of the
Technical Sub-Committee of the Canada-United States Groundfish Committee
May 5-6, 2010, Nanaimo, British Columbia, Canada.

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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. Jim Boutillier
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 and groundfish 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 2013 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 Pacific Scientific Advice Review Committee (PSARC). The Chair of PSARC (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

Trawl, sablefish, rockfish, lingcod, dogfish and halibut fisheries 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.

Managers implemented a "Canadian Groundfish Integration Pilot Project" in the 2006/2007 fishing season as a three year pilot. This pilot has now been incorporated into fisheries management. The program focuses on 100% at-sea monitoring and 100% dockside monitoring, individual vessel accountability for all catch, both retained and released, individual vessel quotas and reallocation of these quotas between vessels and fisheries to cover catch of non-directed species. Details can be viewed in the 2009/2010 integrated fisheries management plan 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 fishing activities are no longer possible. Larocque Relief Funding, to replace fish allocations, was provided in 2007 and will continue to fund surveys through 2012. Details at http://www.dfo-mpo.gc.ca/Science/newpoli-polinouv/guidance-conseils-eng.htm

B. Multispecies or ecosystem models

Groundfish Staff participated in the Strait of Georgia Ecosystem Research Initiative Project during a two week hydroacoustic/trawl survey during February of 2009.

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. Responding to this challenge of ***imagining the future***, or ***constructing scenarios***, involves: 1) understanding how this ecosystem works, 2) identifying the various drivers of change most likely to determine future conditions, and finally 3) analyzing the future responses of the system under the influences of these drivers of change. 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 initative currently comprises over thirty research projects and involves over fifty researchers. Details at http://www-sci.pac.dfo-mpo.gc.ca/sogeri/default_e.htm

In a separate unrelated research project the relationship between reduced oxygen concentration in BC coastal waters and the distribution of groundfish species was investigated. Concurrent with the shallowing of the oxygen minimum layer in coastal waters there has been a shift in groundfish species distributions to shallower waters. The change is most pronounced for species normally found below 150 m depth and is areas most exposed to the open ocean, e.g. the west coasts of Vancouver Island and the Queen Charlotte Islands.

C. By species

1. Pacific cod

i Research program

Dr. Robin Forrest is a new Research Scientist hired on in 2009 with the retirement of Alan Sinclair. No new research was conducted on Pacific cod in 2009. Collection of ageing structures is planned for 2010.

ii. Stock Assessments

No new stock assessments for Pacific cod were conducted in 2009 nor planned for 2010.

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. 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 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 Andrew Edwards and including Rowan Haigh, 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 Schnute (scientist emeritus) who contributes considerable time and expertise; and Paul Starr who works for the Canadian Groundfish Research and Conservation Society (CGRCS) and plays an integral role in the stock assessments assigned to our program.

In 2009, we spent a great deal of time automating rockfish catch reconstruction back to 1911. This exercise appears simple enough, but disparate data sources, incomplete information, multiple fisheries, and various computer storage platforms made the process time consuming. A complicated function programmed in R that taps into various DFO databases (SQL and Oracle) now reconstructs catch history for any rockfish species in approximately four minutes. The code is ever-changing as we discover new quirks and hidden bugs. However, this new algorithm offers an efficient alternative to collating all the information by hand in a bewildering Excel spreadsheet. Interested parties can download the R code from: http://code.google.com/p/pbs-fishery/source/browse/#svn/branches/buildCatch.

Another major undertaking saw an upgrade to our R package *PBSmodelling*. Rob Kronlund (DFO Groundfish), who is now a co-author of the package's User Guide, provided numerous

ideas for design extension to the Graphical User Interface (GUI) component after using it to evaluate fishery management strategies with his colleagues Sean Cox (Simon Fraser University, BC) and Jaclyn Cleary (DFO Pelagics). *PBSmodelling* now includes various new widgets (`droplist`, `table`, `spinbox`, `include`, `notebook`, `image`, `progressbar`), bug fixes, and other improvements that give users greater control over GUIs designed for exploring and demonstrating analyses with R. The upgrade also includes greatly enhanced versions of our functions to support project development (e.g., an option manager) and creating interactive lectures (via XML scripts in the *talk description files*). Alex Couture-Beil, who now pursues graduate studies in robotics at Simon Fraser University, added the new programming code that contributes to this significant upgrade. *PBSmodelling* can be found on CRAN at: http://cran.r-project.org/web/packages/PBSmodelling/index.html.

ii. Stock assessment

In 2009, our team continued work on a catch-at-age population model for Pacific ocean perch (*Sebastes alutus*, a.k.a. POP) in Queen Charlotte Sound (QCS). Meetings with a DFO steering committee resulted in a decision to expand the study area from the traditional Goose Island Gully to the entire QCS basin. Two other potential areas for assessment – west coast Queen Charlotte Islands and west coast Vancouver Island – will be assessed at a future time once we settle on some standard methodologies. Data on growth shows that female L_∞ remains consistently 4 cm larger than that for males; therefore we employ a two-sex model. Ages from the commercial fishery and those from research cruises are treated separately. The commercial ages are weighted by trip catch weight within quarters and by quarterly commercial catch within years. Historical survey indices of abundance are linked to modern indices through defensible manipulation.

iii Research activities for 2010

At some point the team plans on hiring a Co-op student to work on a project of interest to the group. This may entail implementing an MSE (management strategy evaluation) framework for either POP or for data-limited species. Additionally, a separate summer student may help to reformat some of our example GUIs using a recently implemented notebook widget in *PBSmodelling*.

In 2010 we will complete the POP assessment. Preliminary work has been done using Coleraine (an interface for the program ADMB). The two data source (abundance indices and proportions-at-age) are iteratively re-weighted depending on CVs. Currently, the equations and resulting ADMB code from the 2001 assessment are being modified to deal with several issues (e.g. two sexes, not using unreliable surface-ageing data). Meanwhile, groundfish management has indicated that the next assessments will focus on redbanded rockfish (*S babcocki*) and yellowmouth rockfish (*S. reedi*). The latter is facing scrutiny by COSEWIC and may be listed as "threatened".

The PBS suite of R packages continues to grow in size and functionality. See the summary page by Jon Schnute and the "Links" to PBS package development repositories on Google Code: http://code.google.com/p/pbs-software/.

R packages compiled and ready to roll can be found on CRAN: http://cran.r-project.org/.

2b. Rockfish – shelf

i. Research Programs in 2009

In collaboration with Dr. Murdoch McAllister and Dr. Robyn Forrest at the University of British Columbia and Dr. Martin Dorn of the National Marine Fisheries Service, a meta-data analysis of steepness of rockfishes was completed. This paper has been accepted with revisions by the Canadian Journal of Fisheries and Aquatic Sciences. Results have been incorporated in the 2009 stock assessment update of canary rockfish.

ii. Stock assessments in 2009

The canary rockfish stock assessment was updated and approved at a December 2009 meeting of the Pacific Science Advisory Review Committee. It will be published in the CSAS series with a 2010 publication date.

The update was consistent with the previous assessment indicating a rebuilding trend from low levels observed in about 2004. Additional rebuilding is indicated and now estimates that the population is most likely in the healthy zone as defined by DFO PA, unlike the previous assessment where it was estimated to within the cautious zone. Over the longer term, spawning biomass will continue to increase if annual harvests are kept below 900 t/y. The authors comment that, as with many assessments, the results are highly uncertain. The assessment also did not attempt to reconstruct bycatch estimates from other historical fisheries. Inclusion of additional historical catches will lead to lower estimates of current biomass relative to target and limit reference points and to higher estimates of long-term yield. Furthermore, while three surveys have shown a recent upturn, the length of the upturn is short and may not be sustained.

Science staff continued to collaborate with management staff in the preparation of briefing notes for the Minister regarding whether to accept the threatened listings for canary rockfish and bocaccio. The committee on Status of Endangered Species in Canada (COSEWIC) had recommended a “threatened” designation for both populations based on earlier work. The Government of Canada is currently considering the recommendations and must publish a final decision by the fall of 2010.

iii. Research activities planned for 2010

Staff continued to work with Dr. Murdoch McAllister on a study of the adequacy of the current survey array. Using the a Recovery Strategy for bocaccio as a case example, the study attempts to determine if the precision of the current array of surveys will provide adequate indexing to support a Recovery Strategy, or, stated differently, how precautionary does the management control have to be within the Recovery Strategy given the imprecision of survey indices that will be used to monitor the recovery.

iv. Stock assessments in 2010

No shelf rockfish assessments are planned for 2010.

2c. Rockfish – inshore

i. Research programs in 2009 and planned for 2010

a) Surveys

1. Inside (PMFC Area 4B)

A research longline survey was designed for the Inside waters East of Vancouver Island in 2003. 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. The longline survey is now designed to cover the Inside waters (4B) over three years. Two series of surveys throughout the Inside waters were completed in 2009. Twenty-five days of DFO ship time are allocated in August and September for this survey in 2010.

A Phantom HD2+2 remotely operated vehicle (ROV) was acquired by the DFO and 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 February and November 2009 in the southern portion of the Inside waters. ROV surveys will continue in 2010 in the northern portion of the Inside waters.

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 2010.

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 2009, the southern portion of BC was surveyed, completing two full cycles of the BC survey. There are plans for a 2010 survey in the northern region. This survey is supported by Larocque funds.

b) Collaborative research

Three years of NSERC funding (2009 – 2011) 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 in the summer of 2009 and winter of 2009/2010.

Dr. Marie Etienne from the AgroParisTech in France is on sabbatical with Dr. Murdoch McAllister at UBC and is working on various projects in her field of expertise: spatial statistics. Dr. Etienne has been working 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 saturation. 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

A yelloweye rockfish (Inside stock) stock assessment is due to be presented to the Pacific Science Advice Review Committee (PSARC) in July 2010. A coastwide quillback rockfish assessment will be initiated in the Fall 2010.

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 2009 and planned for 2010

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

(a) A **Traditional Standardized Program** (1990-2009) that 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 2008-2009) that 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** (2003-2009) that 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. These sets were introduced in 2003 and are being assessed for their ability to serve as a replacement for the traditional standardized survey and tagging programs.

(d) An **Inlets Program** (1995-2009) that 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 2010.

ii. Stock assessment activities in 2009 and planned for 2010

Sablefish is scheduled for a stock assessment in 2010; no assessment was conducted in 2009 following the 2008 assessment (Cox and Kronlund 2008, Cox et al. 2009, Cox and Kronlund 2009). 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.

Catch rates from the fall 2009 standardized survey declined by ~33% from 2008, and are ~26% of the most recent high observed in 2003. The 2009 stratified random survey declined ~33% from 2008, which followed a ~30% increase from 2007 to 2008. Since 2003, declines in these indices suggest that sablefish in British Columbia may be approaching the low abundances experienced in 2001 to 2002 when a quota reduction from 4,000 t to 2,450 t was implemented. Subsequent to the 2002 reduction, the quota was increased to 3,000 t for the directed sablefish 2003/2004 fishing year (Aug 1-Jul 31) and reached 4,600 t for the 2005/2006 fishing year as trap

fishery and survey catch rates increased. The quota for the 2006/07 fishing year was reduced to 3,900 t and was similarly reduced to 3,300 t for the 2007/08 fishing year mainly as a result of declining survey indices of abundance and tagging estimates of exploitable biomass. The quota was set at 2,450 t for the 2008 fishing year. The 2008/2009 sablefish fishing year was adjusted to start February 21, 2008 and end February 20, 2009 to establish a common fishing year for all groundfish sectors. The quota was set at 2,300 t for the 2010/11 fishing year.

Stock assessment modeling in 2010 will continue work to support the management strategy evaluation process used in 2008 by extending the operating model to account for (*i*) sablefish population dynamics, (*ii*) fishery monitoring systems including two fishery-independent surveys, fishery catch-per-unit-effort for each commercial gear type, and biological sampling of age-proportions for both surveys and fisheries (where available); and (*iii*) retained and discarded catch by fishing gear. Fishery reference points will be developed to ensure the conservation objectives are aligned with the new Canadian Sustainable Fisheries Framework policy and eco-certification processes (sablefish in British Columbia are currently under Marine Stewardship Council review for eco-certification).

4. Flatfish

In 2009-10 the flatfish program includes the addition of Brian Krishka and Bill Andrews.

i. Stock Assessment in 2009

No new flatfish stock assessments were prepared in 2009

ii. Research programs planned for 2010

Program staff will participate in the Groundfish Synoptic trawl surveys off the west coast of Vancouver Island in June and the west coast Gwaii Haanas (Queen Charlotte Islands) in September. Biological data will be collected for all groundfish species caught. Vessels involved are the *CCGS W.E. Ricker* off the west coast of Vancouver Island and a chartered commercial vessel off the west coast Gwaii Haanas.

In preparation for stock assessment, data from the commercial fishery and research surveys will be compiled for all commercial flatfish species. Age composition data will be assembled for all flatfish species and samples for ageing in 2010/11 have been selected for the ageing lab. The Program Head will produce a summary of life history characteristics, biomass estimates and fisheries reference points for flatfish species by the end of 2010. This will facilitate flatfish stock assessment after Jeff Fargo retires at the end of 2010. A report summarizing historical and current information on commercial flatfish species in the Strait of Georgia is also being compiled.

5. Pacific hake

i. Stock Assessment in 2010

The 2010 harvest advice was prepared jointly by Canadian and US scientists. There were two assessments reviewed by the Pacific Hake Stock assessment review (StAR) panel; one prepared

by Canada and one by US scientists. Each assessment employed a model to generate harvest advice. Canadians used a less complex age structured production model (TINSS) while US scientists used Stock Synthesis 3 (SS3).

When evaluating the assessments and available data sources, the StAR panel decided to discard all survey catch-at-age data, due to the lack of a formal acoustic backscatter sub-sampling protocol. The StAR panel also discarded the 2009 acoustic survey biomass index due to the difficulty in distinguishing the acoustic signatures of Humboldt squid and Pacific hake resulting in a highly uncertain 2009 estimate.

The shift in temporal and spatial distribution of Pacific hake has continued with the majority of catch taking place in the third quarter (July-Sept) in Queen Charlotte Sound (PMFC 5A and 5B). Historically, the Canadian fishery occurred off the west coast of Vancouver Island (PMFC 3C and 3D) and although there was some catch there, the numbers are much smaller than in the years preceding 2007. A significant number of vessels continue to fish in the Strait of Juan de Fuca, targeting smaller, younger fish. There is no sign of a significant upcoming recruitment event.

Scientists from Canada were invited to attend the Pacific Fisheries Management Council's (PFMC) meetings in Sacramento, CA, in March, 2010 to present their assessment results to the Science and Statistics committee of the PFMC. Dr. Steve Martell from the UBC, Fisheries Centre, presented an overview of the TINSS model, while Ian Taylor present the results of the SS3 model. The SSC forwarded both sets of results to the PFMC as equally plausible states of Nature. Greg Workman addressed the council and advocated precaution in selecting a coast wide TAC given that the stock is currently at its lowest level on record, has been subject to very high levels of fishing mortality over the preceding five years, that current recruitment appears to be average or below average and that the impact of Humboldt squid, on the abundance of Pacific hake is unknown. After hearing the testimony of several stakeholders the panel came to a consensus on an Allowable Biological Catch (ABC) of 455,000 metric tonnes and an optimal yield of 262,500 mt. These values were arrived at by averaging the results of the two assessments.

6. Elasmobranchs

i. Research programs in 2009

From 2003-2006, over 18,000 big skate (*Raja binoculata*) were tagged and released in three regions in British Columbia. Generally, 75% of the recaptured fish were recaptured within 21km of the tagging location. Long-range movements (up to 2340 km) were undertaken by a small percentage (1.5%) of the recaptured fish. Tagged big skate were recaptured in waters off of Oregon, Washington, throughout the Gulf of Alaska and the Bering Sea. In 2009, these data were published in King and McFarlane (Fisheries Research 101 (2010) 50–59).

i. Stock assessment(s) in 2009

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 completed in collaboration with Vincent Gallucci and Ian Taylor of the School of Aquatic and Fisheries

Sciences. This stock assessment employed generalized Schaefer and Pella-Tomlinson surplus production models to estimate the current biomass of each stock. Model runs using intermediate *r* values and allowing the model to estimate *K* were recommended for consideration in assessing the status of the inside and outside stocks and selecting yield limits. This stock assessment will be reviewed through PSARC on May 17, 2010.

ii. Management

There are no directed fisheries allowed for sharks (excluding spiny dogfish, *Squalus acanthias*) in BC waters; therefore sharks are bycatch only. There is no immediate concern regarding the bycatch of sharks in BC fisheries, therefore no specific recommendations are made. However, the bycatch is monitored by species and area in order to ensure that the future productivity of BC sharks is not compromised.

Increases in directed catch of skate prompted management to examine options for the 2002/2003 and subsequent fishing years. This resulted in a catch "cap" of 850 t on Hecate Strait (PMFC 5C/D) big skate in 2002/03, which was continued in 2006/2007 through to 2010/2011. Out of this cap, the trawl fleet has a quota of 567 t, with no quota for the hook and line/trap fleet (N/A). No quotas are in effect in other areas. In April 2004, a monthly landing limit (coastwide) of 5.7 t was implemented for longline vessels.

iii. Research activities for 2010.

Age and growth characteristics of big skate (*Raja binoculata*) and longnose skate (*Raja rhina*) are being evaluated in collaboration with Chris Gburski from the Alaska Fisheries Science Centre. Specifically, age discrepancies found between big skate in BC and Alaska and published in two recent papers (McFarlane and King 2006; Gburski et al. 2007) have raised questions regarding potential differences in process and interpretation of rajid vertebral centra between research groups, as well as the possibility of real differences in life history parameters between regions. Big skates in BC were found to reach a much greater maximum age (26 years) than those in the Gulf of Alaska (15 years). Questions of geographical differences in growth and of differences in sampling or age estimation criteria between studies will be examined by ageing a random subset of sectioned centra from Alaska (n = 31 big skate, n = 27 longnose skate) and comparing growth curves obtained by researchers from BC with those obtained previously by researchers from Alaska. Attempts are also being made to locate archival skate vertebrae from museum collections for validation using bomb radiocarbon analysis. Reference chronologies are available for the northeast Pacific showing peaks in radiocarbon concentrations in Pacific halibut and rockfish otoliths in the late 60s and early 1970s. A comparison of radiocarbon levels from growth rings milled from archived skate vertebrae with reference chronology values might be possible to verify formation dates, provided suitable skate specimens can be located. Obtaining a better understanding of age and growth of big and longnose skate and how parameters might change among regions is important to the future management of all species of skate in BC waters.

The basking shark (*Cetorhinus maximus*) was listed as endangered under Canada's Species at Risk Act (SARA) on March 17th, 2010. As part of the recovery strategy, efforts to increase the number of reported sightings were started in March 2010. A phone-in and web-based sightings

network was implemented in 2007 and is on-going. Sightings posters and letters inviting private businesses, visitor centres, Fisheries and Oceans offices, First Nations, and other interest groups to participate in reporting have so far been mailed to over 200 addresses this year. Also new this year, "basking shark business cards" were created so that sightings network information might be readily at-hand for those working and playing on the water. Multiple presentations on the ecology, history, and current status of the basking shark are planned in order to increase awareness of the both DFO sightings network and our ongoing efforts towards research and recovery. Greater collaboration with established marine mammals monitoring and sightings programs will also hopefully yield greater reporting of basking sharks in BC waters.

A blue shark (*Prionace glauca*) tagging survey will be conducted off the west coast of Vancouver Island in July/August 2010 using archival satellite tags. Two fin-mounted SPOT5 (smart position or temperature transmitting tags) and four WC-MINIPAT 1xAA Argos-linked Pop-Up Archiving tags will be deployed on male blue sharks. This augments a 2007 survey which was able to deploy 10 tags on females. The anticipated duration of the current program with CLS America for use of the Argos collection system (Argos DCS) is 24 months, with a possibility of extension.

Life history studies have been started on brown cat shark (*Apristurus brunneus*) and the spotted ratfish (*Hydrolagus colliei*), both species of Chondrichthyes for which little biological information is available worldwide. The overall objectives of the brown cat shark study are to (1) describe the reproductive and maturity characteristics of the brown cat shark in BC waters, (2) determine age and growth characteristics of the brown cat shark in BC waters, and (3) use demographic analyses to determine the susceptibility of this species to decline in BC waters based on current mortality estimates. For the spotted ratfish, a study is underway to help elucidate some questions on the general reproductive biology, distribution, and catch of spotted ratfish in Canadian Pacific waters. Efforts will also be made to age the spotted ratfish using dorsal spines.

7. Lingcod

i. Research programs in 2009

A surplus production model for five management units of outside lingcod (*Ophiodon elongatus*) were developed in 2009. The data used and model outputs (along with WINBUGS coding) are publised as Cuif, McAllister and King, 2009. Canadian Technical Report of Fisheries and Aquatic Sciences 2861. These models were not used to provide management advice, but will be updated for stock assessment advice for November 2010.

ii. Stock assessment(s) in 2009

No assessments were conducted on lingcod stocks in 2009. A lingcod outside stock assessment using surplus production and catch-age models is underway for November 2010.

iii. Research activities for 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, as recommended in the 2003 stock assessment framework.

D. Other related studies

1. Statistics and Sampling

i. Biological sampling and database work in 2009

Principal Statistics and Sampling activities in 2009 included the ongoing population of the groundfish biological database (GFBio). This database now includes almost 8,400,000 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 265 length/sex/age samples and 112 length samples in 2009. Port samplers provided an additional 84 samples, 79 samples with ageing structures (length/sex/age/weight) and 5 without structures (length/sex/weight). The focus of their sampling efforts was from those fisheries not covered by at-sea observers.

ii. Catch monitoring

The Groundfish Integrated Pilot Project continued in year 4 in 2009, and was designated a permanent program. The process, which includes 100% at-sea monitoring and dockside monitoring for hook and line vessels, successfully monitors all catch, both landed and discarded. A review of the catch data accuracy for yelloweye rockfish has been published in Marine and Coastal Fisheries Journal. Operational elements and aspect of data quality were presented at the ICES Annual Symposium in Berlin in September 2009. Staff also continued to play a key role in development a new Regional Catch Monitoring information system.

Since 2007 all regional groundfish harvest data have been stored in the Fisheries Operations System (FOS) database. Groundfish Science staff have now developed a view of the FOS database that transforms and simplifies selected groundfish catch and effort data. The view (GFFOS) facilitates access and standardizes extractions for science and groundfish management staff. GFFOS is structured like a database which maximizes the flexibility of staff in developing ad hoc queries. It follows the same model as other Groundfish databases currently in use to simplify extractions and improve understanding of the data. GFFOS includes data from fisher logbooks, observer logbooks, electronic monitoring of fishing vessels, and dockside monitoring of landings. Staff also developed an MS Access frontend for the GFFOS "database" and a users' manual.

ii. Field work in 2009

Staff participated on various bottom trawl surveys including the Hecate Strait and Queen Charlotte Sound groundfish trawl surveys, the West Coast Vancouver Island and Queen Charlotte Sound shrimp trawl surveys, as well as the Pacific hake hydroacoustic surveys. This group also included the port sampling activity (1.8 person-years) in the Vancouver and Prince Rupert areas.

Staff continued to develop GFBioField, adding integrated GIS capabilities and enhanced ability to capture and summarize GPS and net sensor data. The system is now being evaluated for adoption in the Maritime, Newfoundland, and Quebec regions. It was demonstrated to DFO staff from the East Coast as well as at the TSC sponsored workshop on electronic data capture hosted by Mark Wilkins of NMFS in March 2009.

iii. Proposed field work for 2010

Port sampling will continue in 2010, as will staff participation in the bottom trawl surveys to the west coast of Haida Gwaii (Queen Charlotte Islands) and the West Coast of Vancouver Island Charlotte Sound, as well as shrimp trawl surveys in Queen Charlotte Sound and the west coast of Vancouver Island, and the lingcod nest survey in the Strait of Georgia.

iv. Proposed catch monitoring research and development in 2010

Staff will continue to participate in regional catch monitoring and database management activities. Staff will also be collaborating with Dr. Robyn Forrest (Groundfish-DFO) and Dr. Marie Etienne of the Paris-Agricol University in France on a study of whether fishery independent trawl surveys and fishery dependent catch data (trawl CPUE) can be blended to provide enhanced estimates of relative abundance over time.

2. Ecological Risk Assessment for the Effects of Fishing

In 2010, Groundfish Science staff will be exploring how the Ecological Risk Assessment for the Effects of Fishing (ERAEF) model developed for Australian Fisheries could be used to set priorities for science activities within the Groundfish Section. This approach is based on the premise that the relative risk incurred by groundfish stocks and their ecosystems due to human-induced impacts (e.g., fisheries) should be an important consideration when scheduling the provision of science advice. 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). To investigate how the Australian framework could be adapted to the context of BC groundfish fisheries, a pilot study ERAEF analysis will be conducted for a portion of the bottom-trawl fishery in Hecate Strait, BC in 2010.

3. Deep water corals

In June 2009, DFO participated in the "Finding Coral Expedition" funded by the Living Oceans Society (www.findingcoral.com). Thirty (30) Nuytco Deep Worker submersible dives were conducted at eight (8) locations from Queen Charlotte Sound to Dixon Entrance. Research objectives were to: document species richness and abundance of deep sea corals, document occurrences of deep sea corals, identify fish and invertebrates associated with deep sea corals and document and identify habitat perturbations in areas with coral records.

Sixteen species of coral were recorded, the most frequently encountered was red tree coral (*Primnoa pacifica*), other corals included bubblegum (*Paragorgia spp*), sea fan (*Swiftia spp*) and bamboo (*Isidellae spp.* and *Lepidisis spp*). Hydrocorals (*Stylaster spp*), cup corals, sea pens and sea whips were also common.

Invertebrates from several taxa were observed in association with deep water corals, including crabs, shrimp, sea stars, anemones, brittle stars, and feather stars. Nudibranch eggs were found attached to a red tree coral colony, and both the orange peel nudibranch (*Tochuina tetraquetra*) and southern spiny star (*Hippasteria spinosa*) were observed feeding on red tree coral polyps.

In high relief rocky habitats three species of rockfish were observed in close association with red tree coral including blackspotted rockfish (*Sebastes melanostictus*) , shortraker rockfish (*Sebastes borealis*), and redbanded rockfish (*Sebabstes babcocki*). In low relief cobble habitats smaller (juvenile) rockfish including redbanded, rosethorn (*S. helvomaculatus*), sharpchin (*S. zacantrus*), and rougheye rockfish (*S. alutianus*) were noted in association with small hydrocorals. On soft bottom the most frequently observed species were the shortspine thornyhead (*Sebastelobus alaskanus*) and Arrowtooth flounder *(Atheresthes stomias).*

Human impacts were noted at five of the dive sites. These impacts included multiple trawl tracks on a known trawling ground (Mid-Moresby Gully), suspected trawl tracks at three others, as well as pieces of lost fishing gear including trawl wire, longline groundline, and downrigger cable.

APPENDIX 1. REVIEW OF CANADIAN GROUNDFISH FISHERIES

1. Commercial fisheries

All catch figures for the 2009 calendar year are preliminary. Canadian domestic trawl landings of groundfish (excluding halibut) in 2009 were 86,206 t, a decrease of 12% from the 2008 catch. The major species in the trawl landings were Pacific hake (65%), yellowtail rockfish (5%), Pacific ocean perch (5%), and walleye pollock (4%),. Principal areas of trawl production were 3C (31%), 5B (17%), 4B (17%), 3D (11%), and 5A (9%).

Canadian landings of groundfish caught by gear other than trawl in 2009 totalled 9,848 t. Landings of sablefish by trap and longline gear accounted for 3,006 t, approximately 47% by trap gear, 50% by longline gear and 3% by unspecified. Landings of species other than sablefish by trap, longline, handline and troll gear accounted for 6,842 t (52% dogfish, 27% rockfish and 13% lingcod).

2. Recreational fisheries

Each year, Fisheries Management Branch of DFO conducts creel surveys of the recreational angling fishery in the Strait of Georgia. Principal target species are chinook and coho salmon. In 2009 these surveys covered the months of February to September. Provisional estimates of 2009 catches, landings and discards, for this 8-month period were 18,493 fish for lingcod, 23,601 fish for all rockfish species, 367 fish for halibut, 4,085 fish for rock sole, 5,457 fish for starry flounder, 8,168 fish for dogfish, 3,164 fish for greenlings, and 3,569 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 entire year. Provisional estimates of 2009 catches are 11,395 fish for lingcod, 15,329 for all rockfish species, 5,957 fish for halibut, 1,943 fish for rock sole, 2,063 fish for other flatfish species,11,694 fish for dogfish, 4,007 fish for greenlings, and 3,191 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 2009 catches were 14,424 fish for lingcod, 28,251 fish for all rockfish species, 29,497 fish for halibut, 2,770 fish for dogfish, 901 fish for greenlings, and 795 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 2009 catches were 2,118 fish for lingcod, 13,028 fish for all rockfish species, 5,701 fish for halibut, 1,072 fish for rock sole, 793 fish for other flatfish species, 1,050 fish for greenlings, 625 fish for dogfish and 2,806 fish for other groundfish species.

3. Joint-venture fisheries

There were no joint-venture fisheries for Pacific hake off British Columbia in 2009.

4. Foreign fisheries

There were no national or supplemental fisheries for Pacific hake off British Columbia in 2009.

APPENDIX 2. PARTIAL LIST OF GROUNDFISH RELATED REPORTS PUBLISHED IN 2008/09.

PRIMARY

Cox, S.P. and A.R. Kronlund. 2008. Practical stakeholder-driven harvest policies for groundfish fisheries in British Columbia, Canada. Fisheries Research 94(3), p. 224-237.

Cuif, M, M. McAllister, and J.R. King. 2009. Development of a Surplus Production Model Applicable to British Columbia Offshore Stocks of Lingcod (*Ophiodon elongatus*). Canadian Technical Report of Fisheries and Aquatic Sciences 2861. 86 p.

Edwards, A.M. 2008. Using likelihood to test for Lévy flight search patterns and for general power-law distributions in nature. *Journal of Animal Ecology*, **77**: 1212-1222.

Forrest, R.E., M.K. McAllister, M.W. Dorn, S.J.D. Martell, and R.D. Stanley. *In press* Hierarchical Bayesian estimation of productivity and reference points for Pacific rockfishes (Sebastes spp.) under alternative assumptions about the stock-recruit function. Can. J. Fish. Aquat. Sci.

Gross, T., Edwards, A.M., and Feudel, U. 2009. The invisible niche: weakly density-dependent mortality and the coexistence of species. *Journal of Theoretical Biology* **258**: 148-155.

King, J.R. and G.A. McFarlane. 2009. Movement patterns and growth estimation of big skate (*Raja binoculata*) based on tag-recapture data. Fish. Res. 101: 50-59.

McAllister, M.K., R.D. Stanley and P. Starr. *In press* Modeling trawl survey catchability for B.C. bocaccio (*Sebastes paucispinis*): a combined expert driven – empirical approach. Fish. Bull.

Stanley, R.D., N. Olsen, and A. Fedoruk. 2009. The accuracy of yelloweye rockfish catch estimates from the British Columbia Groundfish Integration Project. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1:354–362.

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

Cooke, K. and Yamanaka K. L. 2009 Preliminary Catch Summary from the Northern Portion of the Pacific Halibut Management Association Research Surveys in 2006 and 2008. 31 p. Presented to the PHMA for their annual general meeting.

Cox, S.P. and A.R. Kronlund. 2009. Evaluation of interim harvest strategies for sablefish (Anoplopoma fimbria) in British Columbia, Canada for 2008/09. DFO. Can. Sci. Advis. Sec. Res. Doc. 2009/042. 87 p.

Cox, S.P., Kronlund, A.R., and M.R. Wyeth. 2009. Development of precautionary management strategies for the British Columbia sablefish (Anoplopoma fimbria) fishery. DFO. Can. Sci. Advis. Sec. Res. Doc. 2009/043. 161 p.

DFO. 2009. Recovery Potential Assessment for bocaccio (*Sebastes paucispinis*). Can. Sci. Advis. Sec. Sci. Adv. Rep. 2009/040.

DFO. 2009. Recovery Potential Assessment for canary rockfish (*Sebastes pinniger*). Can. Sci. Advis. Sec. Sci. Adv. Rep. 2009/041.

Haigh, R. and Starr, P. 2008. A review of yellowmouth rockfish *Sebastes reedi* along the Pacific coast of Canada: biology, distribution, and abundance trends. *Canadian Science Advisory Secretariat, Research Document* 2008/055. 97 pp.

Haigh, R. and Starr, P. 2008. A review of darkblotched rockfish *Sebastes crameri* along the Pacific coast of Canada: biology, distribution, and abundance trends. *Canadian Science Advisory Secretariat, Research Document* 2008/056. 88 pp.

Obradovich, S.G., Yamanaka, K.L., Cooke, K., Lacko, L.C., and Dykstra, C. 2008. Summary of non-halibut catch from the Standardized Stock Assessment Survey conducted by the International Pacific Halibut Commission in British Columbia from June 4 to July 7, 2007. Can. Tech. Rep. Fish. Aquat. Sci. 2807: x + 83 p

Olsen, N., Rutherford, K.L., Stanley, R.D., and Wyeth, M.R. 2009. Queen Charlotte Sound groundfish bottom trawl survey, July 7th to August 8th, 2009. Can. Manuscr. Rep. Fish. Aquat. Sci. 2899. vi + 69p.

Olsen, N., Rutherford, K.L., Stanley, R.D., and Wyeth, M.R. 2009. Hecate Strait groundfish bottom trawl survey, May 22nd to June 19th, 2007. Can. Manuscr. Rep. Fish. Aquat. Sci. 2900. vi + 48p.

Olsen, N., Rutherford, K.L., Stanley, R.D., and Wyeth, M.R. 2009. West Coast Vancouver Island groundfish bottom trawl survey, May 26th to June 22nd, 2008. Can. Manuscr. Rep. Fish. Aquat. Sci. 2902. vi + 50p.

Olsen, N., Rutherford, K.L., Stanley, R.D., and Wyeth, M.R. 2009. Hecate Strait groundfish bottom trawl survey, May 26th to June 21st, 2009. Can. Manuscr. Rep. Fish. Aquat. Sci. 2901. vi + 49p.

Stanley, R.D., P. Starr, and N. Olsen. 2009. Stock assessment for canary rockfish (*Sebastes pinniger*) in British Columbia waters. Can. Sci. Advis. Sec. Res. Doc. 2009/013.

Stanley, R.D., L. Lacko, R. Kronlund, K. Rutherford, N. Olsen, M. Wyeth. 2008. Data quality in FOS-Groundfish. Paper commissioned by Gary Logan, GMU.

Stanley, R.D., M. McAllister, P. Starr, and N. Olsen. 2009. Stock assessment for bocaccio (*Sebastes paucispinis*) in British Columbia waters. Can. Sci. Advis. Sec. Res. Doc. 2009/055.

Starr, P.J. 2009. Petrale sole (*Eopsetta jordani*) in British Columbia, Canada: Stock Assessment for 2006/07 and Advice to Managers for 2007/08. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/070. ii + 134 p.

Starr, P.J. 2009. English Sole (*Parophrys vetulus*) in British Columbia, Canada: Stock Assessment for 2006/07 and Advice to Managers for 2007/08. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/069. ii + 149 p.

Yamanaka, K. L. and L. C. Lacko. 2008. 2004 Research Catch and Effort Data on Nearshore Reef-fishes in British Columbia Statistical Area 12. Can. Tech. Rep. Fish. Aquat. Sci. 2803: ix + 45 p.

Yamanaka, K.L., Obradovich, S.G., Cooke, K., Lacko, L.C., and Dykstra, C. 2008. Summary of non-halibut catch from the Standardized Stock Assessment Survey conducted by the International Pacific Halibut Commission in British Columbia from May 29 to July 22, 2006. Can. Tech. Rep. Fish. Aquat. Sci. 2796: viii + 58 p

APPENDIX 3. GROUNDFISH STAFF IN 2009/10

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 modeling, stock assessment
Jeff Fargo	Program Head Flatfish stock assessment and biology
Rob Flemming	Biologist, GIS specialist, Inshore rockfish
Robin 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 stock assessment and biology, groundfish statistics.
Greg Workman	A/Section Head
Malcolm Wyeth	Biologist, Groundfish surveys and Port sampling
Lynne Yamanaka	Program Head Inshore rockfish research and stock assessment