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Proceedings of the State of the Pacific Ocean: 2012 Workshop

February 15-16, 2012
Victoria, BC

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

The Pacific Region supports important resident and migratory populations of invertebrates, pelagic and ground fish, marine mammals and seabirds. Significant changes have occurred in recent years in the physical and biological oceanographic conditions and the state of fishery resources in this Region. Annual State of the Pacific Ocean reports provide an overview of oceanographic conditions and are used by Fisheries and Oceans Canada to inform resource assessments and risk-based management decisions. In addition, the publications address a growing public interest in the state of the Northeast Pacific Ocean. The report on the State of the Pacific Ocean 2011 (the 13th such annual report) was presented by members of the Fisheries and Oceans Canada (DFO) Fisheries and Oceanography Working Group (FOWG) and other contributing organizations at the Vancouver Island Conference Centre in Nanaimo, BC on February 15 - 16, 2012. This Canadian Science Advisory Secretariat, Regional Advisory Process meeting was chaired by Jim Irvine and Bill Crawford of Fisheries and Oceans Canada. The goal of the meeting was to develop a synopsis of the physical and biological state of the ocean off Canada's Pacific coast in a workshop setting. Participants include representatives from DFO Science and other sectors as well as non-DFO representatives from academia, other Canadian and American federal and provincial agencies, and the NGO community.

These Proceedings summarize the presentations and discussions that occurred during the meeting and key conclusions arising from those discussions. Additional publications, including a Science Advisory Report and Research Document, will be posted as they become available on the DFO Science Advisory Schedule.

Compte rendu de l’Atelier 2012 sur l'état de l'océan Pacifique

SOMMAIRE

La Région du Pacifique soutient d’importantes populations résidentes et migratoires d’espèces d’invertébrés et pélagiques, de poissons de fond, de mammifères marins et d’oiseaux de mer. Dans cette région, les conditions biologiques et physiques des océans ainsi que l'état des ressources halieutiques ont subi d'importants changements au cours des dernières années. Les rapports annuels sur l’état de l’océan Pacifique donnent une vue d’ensemble de ces conditions océanographiques et sont utilisés par Pêches et Océans Canada pour éclairer les évaluations des ressources et les décisions en matière de gestion fondées sur le risque. En outre, les publications tiennent compte de l'intérêt croissant du public à l'égard de l'état du nord-est du Pacifique. Le rapport sur l’état de l’océan Pacifique de 2011 (le treizième rapport annuel de ce type) a été présenté par les membres du Groupe de travail sur les pêches et l’océanographie (GTPO) de Pêches et Océans Canada (MPO) ainsi que par d’autres organismes participants au Vancouver Island Conference Centre de Nanaimo, en Colombie-Britannique, les 15 et 16 février 2012. Cette réunion du processus de consultation scientifique régional du Secrétariat canadien de consultation scientifique a été présidée par Jim Irvine et Bill Crawford, de Pêches et Océans Canada. Son but était de créer une synopsis de l'état physique et biologique de l'océan Pacifique au large du littoral canadien dans le contexte d'un atelier. Parmi les participants se trouvaient des représentants du Secteur des sciences et d'autres secteurs du MPO ainsi que d'autres représentants du milieu universitaire, d'autres organismes fédéraux et provinciaux canadiens et américains, et d'organisations non gouvernementales.

Ce compte rendu résume les exposés présentés et les discussions tenues pendant la réunion ainsi que les principales conclusions découlant des discussions. Les autres publications, y compris un avis scientifique et un document de recherche, seront versées, dès qu'elles deviendront disponibles, sur le site du calendrier des avis scientifiques du MPO.

INTRODUCTION

Pacific Canadian waters lie in a transition zone between coastal upwelling (California Current) and downwelling (Alaskan Coastal Current) regions, and experience strong seasonality and considerable freshwater influence. Variability is closely coupled with events and conditions throughout the tropical and North Pacific Ocean, which experience frequent El Niño and La Niña events, particularly over recent decades. The region supports important resident and migratory populations of invertebrates, pelagic and ground fish, marine mammals and seabirds.

Monitoring of the physical and biological oceanographic conditions and fishery resources in this region is carried out by Fisheries and Oceans Canada in partnership with other government departments, academic institutions and organizations to understand the natural variability of these ecosystems and how they respond to both natural and anthropogenic stresses. The Fisheries and Oceanography Working Group (FOWG), in conjunction with the regional Centre for Science Advice Pacific (CSAP) and the Canadian Science Advisory Secretariat (CSAS) in Ottawa, provides annual reporting on the state of the Pacific Ocean. Presentation of the annual State of the Pacific Ocean report to the FOWG provides an opportunity for group members and other attendees to review and discuss the data from these monitoring programs and to provide input to the Science Advisory Report (SAR) prepared by the co-Chairs.

The Chair for Day 1 (Jim Irvine) opened the meeting by welcoming the participants, especially those who had not attended a SOTO Workshop before (these included representatives from the Department of National Defence, Environment Canada, DFO Oceans, Simon Fraser University, the University of Victoria, and the BC Provincial Government). The Chair summarized the goals of the workshop, stating that the short (10- to 15-minute) presentations are intended to focus on the most up to date information, and that each presentation may be followed by short discussion period. The Chair also described the 3 publications (Research Document, Science Advisory Report and Proceedings) arising from this meeting, emphasizing that the Research Document for the SOTO Workshop is not peer-reviewed. Day 2 was chaired by the other workshop co-Chair (Bill Crawford) who, following a general discussion after the final talk, outlined the information that each presenter should provide for inclusion in the SAR.

The following summarizes the information presented and reviewed during the 2012 FOWG Meeting, from which the accompanying Research Document and SAR were prepared.

REVIEW

The average global temperature in 2011 was warmer than average almost everywhere, but not in the eastern Pacific Ocean, where cool waters have been present in almost every year since 2008, part of a Pacific-wide weather pattern associated with La Niña conditions of these years. These La Niña conditions were most active in winter, with a stronger North Pacific High Pressure System and stronger, cool westerly winds over the ocean west of British Columbia. This pattern of cool ocean surface water was interrupted only briefly in the winter of 2010, when El Niño winds brought warmer waters to this region.

The North Pacific Current increased its eastward flow speed in the eastern North Pacific Ocean through the winter of 2011 to 2012, with normal flow otherwise. This current is expected to carry tsunami debris from Japan. Although some objects have already arrived, it is expected that the main part will arrive next winter or through 2013.

Sea surface measurements from shore stations along the coast of British Columbia, and in the Strait of Georgia, confirm that ocean conditions were cooler in 2011 than in 2010. Relatively fresh surface waters within the Strait of Georgia in 2011 were at least partly a consequence of a

heavy snow pack. Ocean surface waters on the British Columbia continental shelf were fresher than normal in the summer of 2011.

Weather conditions in late winter and early spring determine the timing and intensity of growth of phytoplankton, which supply the food chain that provides the necessary prey for juvenile fish at a critical time in their life. The spring bloom of phytoplankton in the Strait of Georgia in 2011 was later than normal, due to stronger winds in March, but once it began the growth was unusually strong. Observations of this bloom by satellite and by ship-based surveys reveal that it peaked in June and extended into July, and had unusually high biomass of the harmful algae *Heterosigma akashiwo.* Blooms of this phytoplankton have been observed in previous years in nearshore waters of the Strait of Georgia during May through October and have been postulated as perhaps adversely affecting juvenile sockeye salmon during their seaward migration.

Studies of zooplankton are undertaken along the west coast and in the Gulf of Alaska. These tiny drifting animals feed mainly on phytoplankton, and in turn are prey for many juvenile fish. The species composition of zooplankton and their biomass are useful predictors for fisheries. The copepod community of zooplankton on the Oregon continental shelf was dominated by lipid rich “northern” copepods in 2011. Although other factors are important, this observation, by itself, indicates strong survivals for coho and Chinook salmon returning to the Columbia River in 2012 and 2013.

Further north, off the west coast of Vancouver Island, the zooplankton community was of normal composition, except for a summer shift to warm-water oceanic zooplankton seaward of the southern Vancouver Island shelf. In deep-sea waters, zooplankton indices were consistent with cool ocean conditions. When the zooplankton community composition is combined with other environmental indicators for the west coast of Vancouver Island and Oregon, 2011 conditions for juvenile salmon migrating to sea were rated as average. This rating affects Columbia River salmon as well as those from Vancouver Island itself.

Within the Strait of Georgia, conditions in 2011 were generally favourable for juvenile sockeye salmon from the Fraser River, whereas poor returns are projected for coho salmon returning in 2012, Chinook salmon returning in 2013 and 2014, and chum salmon returning in 2013.

An estimated 5 million Fraser River sockeye returned to British Columbia coastal waters in 2011, well within the range of predictions provided the previous year. This number contrasts with the record high of about 30 million in 2010 and record low of 1 million in 2009. Lower returns in 2011 compared to 2010 are attributed mainly to reduced survival of young salmon in freshwater. The primary estimator of sockeye returns is based on the number of parent spawners four years earlier, because most sockeye return to their natal river at age four, after spending two years at sea and two years in freshwater. On this basis, the prediction for 2012 returns is 0.7 million to 7 million, at the 10% to 90% probability distribution. These numbers are lower than average, due to fewer spawning sockeye in 2008. Fraser River sockeye returns in 2013 might be lower than average as well, due to fewer parent spawners in 2009, combined with generally favourable conditions in the Strait of Georgia in 2011, noted previously.

As part of ongoing research into year-to-year changes in ocean conditions and their impact on salmon survival at sea, scientists have examined survivals of a single stock of sockeye, from Chilko Lake in the Fraser River basin. By comparing returns of the small numbers of those returning at age five with the larger numbers returning at age four, they have revealed a sharp pattern break in 1990, when the trend in marine survival changed from increasing prior to 1990 to decreasing after 1990. In contrast, marine survivals for Fraser pink salmon were without trend, and recent increases in pink salmon returns were determined to be primarily the result of reduced fishing. Another research effort, using ecosystem models that include most marine species and climate variability in the Strait of Georgia, identified a shift to lower growth rate of

phytoplankton beginning in 1990 and continuing to present that is attributed to stronger wind speeds in spring and summer since 1990. This lower primary production is manifested in the model as declines, after 1990, of coho and Chinook salmon, herring, dogfish, and killer whales.

Other biological findings in 2011 include decreased pink shrimp biomass west of Vancouver Island from higher values in 2009 and 2010, likely as a result of warmer waters in spring two years previously when the shrimp were young.

Biomass indices for most ground fish species in Hecate Strait and Queen Charlotte Sound are trending upwards after several years of decline.

Eulachon populations coast-wide are at low levels, while Pacific sardine biomass off the west coast of Vancouver Island increased in 2011 compared to 2010. Herring biomass forecasts for Haida Gwaii and Central Coast stocks are below fishery thresholds, while for Strait of Georgia and Prince Rupert stocks, forecasts are above thresholds.

Length-at-age and weight-at-age of post-recruit herring has decreased in all BC populations since the 1970s, including herring populations not fished during the herring roe fishery. Similar changes have occurred in California and some, but not all SE Alaska herring populations. Because size-at-age has decreased in areas not fished, this decrease is not believed to be due to fishing.

Birds can be effective indicators of the state of marine ecosystems because their large breeding aggregations can be relatively easily counted. Breeding success of Triangle Island Cassin's Auklets is strongly temporally matched with the phenology of an important prey species, the copepod *Neocalanus cristatus*. Breeding success of these auklets in 2011 was better than the long-term average and well above that of 2010.

In Pacific Rim National Park Reserve, 2011 seabird abundance remained high and similar to 2010. Most species displayed stable or improving population trends over the past 4 to 5 years. Intertidal bivalve population abundances in the Barkley Sound part of this reserve were about average relative to previous years. Manila clams continue to decline while there appears to be no spatial displacement of this species by the recently introduced varnish clams. SARA-listed Olympia oyster has displayed a recovering trend for the past 7 years but the numbers are still below those observed in late 1990s.

Persistent, bioaccumulative and toxic contaminants present a health risk to aquatic biota, notably those at the top of food web such as killer whales and seals. Recent analyses of biopsy samples taken from young harbour seals live-captured in the Salish Sea reveal that polychlorinated biphenyls (PCBs) declined by 81% between 1984 and 2009. In contrast, the concentration of polybrominated diphenyl ethers (PBDEs) increased, with indication of a peak in PBDE levels in seals between 2003 and 2009 followed by a decline. This pattern would be consistent with the 2004 phase-out of two of the three PBDE products in Canada and the USA

Airborne surveys for oil on British Columbia waters have operated with increased efficiency since 2006, when more accurate sensors were added to the surveillance aircraft flights by Transport Canada, as part of the National Aerial Surveillance Program. Observations by this program, together with modelling and analyses of these observations from 2006 to 2010 by the Canadian Wildlife Service, reveal that the highest relative likelihood of detecting oil discharges occurred close to shore and, in particular, in the Strait of Georgia, the inside passage of the central coast, near Prince Rupert, and in Alberni Inlet. Although results are preliminary, they suggest that marina densities and intensity of local vessel activity (as opposed to international shipping) generally determine oil discharge patterns in the Pacific Region. There is some evidence that oil discharges have declined since the program was enhanced in 2006.

Scientists have reported alarmingly low oxygen concentrations in near-shore waters of the Oregon coast in summer, beginning in 2002 and most severely in 2006. High crab mortalities on

the ocean bottom took place in these summers. Low oxygen concentrations (less than 1 ml/L) have also been observed off southwest Vancouver Island since 2002, with concentrations of 0.7 ml/L at 150 metres depth recorded in 2006 and 2009, the lowest in the 50-year record. Oxygen concentrations were 1.0 and 1.1 ml/L in 2010 and 2011, respectively. Hypoxia on the Canadian shelf is much less severe than off Oregon and Washington, and mortality of bottom life has not been reported.

Deep water in the North Pacific Ocean is already the most acidic water in the global ocean and the British Columbia continental shelf might see negative impacts of this feature sooner than most oceanic waters.

Scientists hope to collaborate in the next year to produce more quantitative ocean indices to rank the health of the ocean and its marine species, as part of an ongoing ecosystem approach to management (EAM). This will require scientists to develop a new suite of tools and products to advise resource managers on the impact and management options for human activities in the marine environment. Subsequent State of Ocean workshops and reports are expected to report on the continued development of ecosystem indicators.

DISCUSSION

Attendees were invited to comment on each presentation during the 2-day meeting and to participate in open-forum discussions at the conclusion of each day. Talks were grouped under three main headings: General/Gulf of Alaska; mostly West Coast Vancouver Island/PNCIMA; and mostly Salish Sea (Appendix A). Questions and comments pertaining to the oceanography and biology talks in each group are summarized below, along with the discussions held at the end of each day.

GENERAL/GULF OF ALASKA

Oceanography

The whole eastern Pacific was colder than average in 2011, continuing the cooling trend of recent years. Both the Pacific Decadal Oscillation (PDO) and the North Pacific Index (NPI) of air pressure are in a ‘blue’ phase, with winds driving lower ocean temperatures. This contrasts with the upward global trend in land and ocean temperatures, suggesting that the next shift to warm local winds may bring ‘pent- up’ ocean warming and associated issues (e.g. aquatic invasive species, sea-level rise) to this region. Salinity was generally fresh in 2011 (as it was in 2010) while dissolved oxygen (DO) remains relatively low, as it has been since 2000 (particularly in 2006 and 2009), especially along the coast (the California Current continues to lose oxygen and, when upwelled, loses further oxygen due to mineralization of dissolved organic carbon). A question as to whether the PDO is about to switch phases was addressed with the comment that, although this is not known for certain, winter 2011 temperatures were among the coldest on record. In response to the question of how DO varies with latitude, it was noted that the west coast of Vancouver Island (WCVI) is protected by currents whereas DO minima are lower off California and much lower off Oregon. Regarding the California undercurrent, it was suggested that unless this picks up oxygen from North Pacific intermediate water it will remain low in DO when upwelled.

The collection and analysis of naval meteorological and oceanographic (METOC) data to study ocean properties was a new theme at this year’s workshop. Four associated systems and ~20 products are used for operational oceanography, and to generate 3-D ocean models for areas of interest by combining meteorological, oceanographic, intelligence and acoustic information (including *in-situ* and historic bathythermographic data). The ocean workstation system (OWS) is the most widely used, and provides basin- and meso-scale sea-surface temperature (SST)

based on Advanced Very High Resolution Radiometry (AVHRR). Polar Epsilon also provides SST and chlorophyll information using satellite data, while the Spaceborn Ocean Intelligence Network (SOIN) uses AVHRR for SST, MERIS for chlorophyll, and MODIS for SST and true colour. Although developed for naval operations (e.g. chlorophyll measurements for diver visibility, RadarSAT/polarization imagery for detecting ships/ship wakes) these products can also be used for non-military applications (e.g. chlorophyll as a bioindicator, thermal water patterns for fisheries monitoring) and collaboration with DFO on (RadarSAT) monitoring of SST in the Pacific Ocean is already underway. Future initiatives include a new 3-D OWS and the possible incorporation of Argo information into METOC. (Questions as to how long the various systems have been in operation, and how to access the data, should be directed to the presenter/DND).

Long-term trends in temperature and salinity measured at BC lighthouse stations showed significant freshening during 2011, which is consistent with greater snowmelt than in previous years. Salinity anomalies relative to 1980-2010 (the current normalization period) are generally trending downwards, especially in the longer term datasets (e.g. Departure Bay, Langara Island). Five stations have shown temperatures below the historical average for two years running, despite a long term warming trend in temperature anomalies. With respect to climatology, all stations in the Strait of Georgia show a lag in the mean temperature cycle. In response to a question as to whether this lag in mean temperature is related to La Niña, it was stated that such a link has not been established, although the lag does appear to be consistent.

Regarding meteorological and oceanic conditions on the west coast, 2011 began and ended with signature conditions for La Niña: the Aluetian Low was weaker/further west and the North Pacific High stronger/further north than usual, resulting in equatorward (upwelling-favourable) rather than poleward (downwelling-favourable) winter winds along the BC coast. Dramatic swings in monthly mean sea-level pressure (SLP) were noted for January (upwelling), February (downwelling) and March (upwelling-favourable conditions), preconditioning the west coast for a productive spring. Wind stress and water levels were about average, but alongshore current were stronger and more poleward than usual. In answer to a question as to whether or not daily average SST shows a bimodal (i.e. El Niño vs. La Niña) distribution it was stated that this has not yet been looked into. As to why the reversal of winds and currents (normally expected in March/April) had been emphasized, it was noted that this was unusually pronounced in 2011 and although it has happened before (e.g. in 2005) it occurred much later (in May) and coincided with relative poor productivity.

Biology

Mezoplankton biomass, as determined by continuous plankton recording (CPR), was relatively high in 2011 compared with 2010, reaching a fairly level and sustained peak following the spring bloom, which is typical for cooler conditions. Both the length of the season and season midpoint (which is significantly correlated with the PDO) were typical for *Neocalanus plumchrus* (a large copepod and good food source) in 2011, whereas smaller *Pseudocalanus* species predominated in 2010. Some taxon-specific anomalies were noted in the spring of 2011; in particular, salps were found in unusually high numbers (genetics would be needed to differentiate between the different species present). These planktonic tunicates filter out phytoplankton and are themselves food for other species (mainly fish but also certain birds and mammals).

The development of SOTO Ecosystem Indicators as performance metrics for meeting DFO Strategic Objectives (including sustainable aquatic ecosystems) has become a national priority, and terms of reference (TOR) are being developed. Two major themes are the general status of aquatic species and a consolidated index of aquatic ecosystem health, which include a national summary of the status of managed populations (with CSAS advice on past stock status) and

national indices of changes in trophic structure and species. The TOR specify that indicators must be responsive to management actions within DFO's mandate, and over timeframes that can inform management decisions. Fisheries, Aquaculture, SAR and Oceans managers are all asking for these indicators. Challenges include costs and ensuring that surveys collected the required information on aquatic ecosystem health. In response to the comment that productivity is thought to be decreasing and that there should be indicators for monitoring productivity, it was noted that the intention is to include such indicators in future stock assessments.

An overview of invertebrate species in 2011 noted that invertebrates are normally among the top 5 species in terms of commercial fishery ranked value, and that shellfish tend to rank highest in commercial fishery landings. Dungeness crab landings are indicative of stock, and 2011 appears to be at the tail end of a very high landing trend in PNCIMA, whereas Salish Sea is showing an upward trend. The opposite is true for prawns whereas WCVI prawn stocks appear to be holding steady. Geoducks (a dive fishery) appear to show a recent drop-off, when recruitment is back-calculated, although predation by sea otters (which also affects other invertebrate stocks) has decreased significantly (by 53%) since 2000. Manila clam stocks (PNCIMA) are variable and show a cyclic component. Razor clams (Haida fishery) are also variable but peaked in 2000, declined in 2003, and are now quite low. Butter clam stocks (Seal Island) are currently low, but have spiked occasionally in the past. Pink shrimp (over 30 management areas) spiked in 2010 and decreased slightly in 2011. Green sea urchins are generally increasing, except in the Salish Sea. SARA-listed species include Northern abalone, which is still low but steady, and Olympia oyster, for which we do not yet have much data but which, as a re-introduced species, looks promising. Regarding aquatic invasive species (AIS) the Salish Sea has a relatively large number of these, many of them Atlantic species (aquaculture?). In response to a question about the habitats in which AIS are looked for it was noted that monitoring often takes the form of opportunistic surveys but that intertidal and sub-tidal species are being monitored.

Lunch Break

MOSTLY WEST COAST VANCOUVER ISLAND (WCVI)/PNCIMA

Biology

A review of WCVI euphausiids and fish production mentioned that over 162,000 euphausiids and 90,000 zooplankton have been measured and weighed during 177 cruises since 1991. Biomass of adult euphausiids is highly variable and correlated with the biomass of 3-year-old herring (5 major populations). Herring tend to select *T.spinifera* larger than 17 mm, August being the critical feeding period (need the right food at the right time), and 2011 saw a good match in terms of prey availability, suggesting increased growth and adult herring survival. Coho select *T.spinifera* larger than 19 mm in May, but timing was not good in 2011 (return variability for Carnation Creek coho is related to female spawner abundance, stream discharge and, to a lesser extent, *T.spinifera* biomass). Sockeye select *T.spinifera* 3 to 5 mm in length in May but again, timing was poor in 2011. Euphausiid-based hindcasts for WCVI sockeye returns work well up until 2010 (euphausiid biomass was particularly high in 2008, and 2010-11 saw an unusual predominance of 5-year-old as opposed to 3-year-old sockeye). This model did well in predicting recent returns for Smith Inlet sockeye (which underwent a catastrophic decline in 1995). It also predicted the low 2009 return of Fraser River sockeye (18 different populations), which show a range of responses to the effects of stock and *T.spinifera* abundance, suggesting that conventional forecasting methods may be inaccurate. The influence of euphausiid biomass, which is currently low, tends to be coast-wide for herring and regional for sockeye, but WVCI herring recruitment and BC herring growth and survival should increase with increasing biomass of *T.spinifera*, if/when this occurs at the right time. In response to the question of whether some

of the observed variation could be due to sampling different parts of the population in particular years, and whether more predictable runs could be used to test this hypothesis, it was noted that data have been collected during years in which all fish have out-migrated together within the sampling period.

A review of ground fish in 2011 was based on surveys in Queen Charlotte Sound (QCS) and Hecate Strait (HS), during which CTD data were also collected. About 200 species were identified in each area. The Canadian Groundfish Research and Conservation Society (CGRCS) was contracted to carry out a supporting survey in QCS. Ground fish biomass in HS increased slightly in 2011, though there has been little change in the most dominant species from 2007 to 2011. Dissolved oxygen in 2011 was similar to that in 2009 at most depths, but lower than in 2007 (DO has been measured since 2006). Of 28 species selected, more were found in deeper water in 2011 and 2007 than in 2009 (DO levels were relatively low in 2011 except for the deepest water). In QCS 18 of 25 species selected showed an increase in biomass from 2009 to 2011, and more were found in deeper water in 2011 and 2009 than in 2007. Again, DO levels were lower than in previous years. In response to the comment that more patterns may be seen if the data can be analyzed by trophic level, in was noted that no trophic roll-up had been done for the species observed, though this might be possible based on feeding groups. The comment was also made that abundance in shallow water could be driven by factors other than tolerance to low oxygen, and that a longer time series might help to address uncertainties in this regard.

WCVI small mesh bottom trawls included Nootka and Tofino grounds, where pink shrimp are resident and for which results are likely to be more consistent/biologically relevant than for e.g. dogfish, hake and English sole, which can move in and out of the survey area and tend to have low autocorrelation. Shrimp recruitment is at 2 years of age and appears to be largely influenced by temperature, which (along with hake predation) is a key driver of shrimp biomass (e.g. higher SST at Amphitrite Point correlates with lower shrimp biomass, and vice versa). Pink shrimp biomass fell in 2011, along with other key (flatfish) species, whereas dogfish numbers appeared to rise slightly (though these were not well sampled). It was noted that surveys tend to cluster chronologically based on catch, with post-2001 surveys differing from those pre-2001 in terms of the relative abundance of core taxa (of which those that cluster together show similar patterns of variability). WCVI landings of hake increased in the late 1980's and were high in 2010 while mean trophic levels are increasing for commercial landings, though unchanged for the surveyed fish community. It was also noted that the discard rate from the commercial fishery has been declining since 1996 and that information on WCVI fisheries and oceanography is posted on the Indicators for the Seas program website (IndiSeas.org). In response to the comment that much has been made of trophic level as an indicator, and the question of how critical is the value assigned to a particular species, it was noted that surveys include information for both juveniles and adults (which tend to drive the mean trophic levels down or up, respectively) but that trophic levels (including fractional levels) can be derived from these data, that mean levels can be useful indicators if global standard values are used (time series will be relevant if this is done).

An update was provided for the NE Pacific sardine population, which extends from the Mexican border to Canada but forages in BC waters outside the spawning season, peaking in January-April, with the largest and oldest fish migrating furthest to feed. The annual WCVI sardine trawl survey (using a mid-water trawl at 45 knots) is carried out in July/August, but sardines are also picked up during the High Seas salmon survey in June/July. The catch density distribution in 2011 was 41 out of 68 sets, and biomass estimates showed a slight recovery in 2011 vs. 2010. Sardine abundance tends to correlate with SST and chlorophyll, the unusually low temperatures off the northern tip of Vancouver Island affecting sardine catches in 2011, although the WCVI migration rate was up slightly. The 2009 (2-year-old) year class appears to have above average recruitment, and 2012 catch limits are expected to be higher than for 2011 (i.e. 26 vs. 22 kT).

Questions about chlorophyll, temperature and sampling range were addressed with confirmation that habitat mapping shows sardine abundance to be strongly correlated with Chl and SST, that higher SST favours sardines (i.e. opposite to the trend for herring), and that although there is no targeted sampling in the Strait of Georgia, sardines are sometimes obtained from other trawls.

The update for eulachon and herring began by describing 3 main indicators for eulachon, these being a Fraser River egg and larval survey, the offshore catch from a survey of WCVI and QCS, and a commercial catch. The 2011 egg/larval survey showed the opposite trend to the offshore survey. Eulachon stock composition is dominated by Columbia River stock whereas eulachon spawning biomass in the Fraser River (now listed under COSEWIC) remains low, though no single cause has been identified. A Recovery Potential Assessment is looking at possible threats to eulachon, including ground fish and shrimp trawl fisheries. Eulachon spawn in ~40 rivers and different stocks have different status under COSEWIC. Five of the main stocks showed good or average recruitment in 2011. With regard to herring the Haida Gwaii, Central Coast and WCVI stocks remain low, though no cause has been established. Only the Prince Rupert and Strait of Georgia (SoG) biomass were regarded as above the threshold for commercial fishing. Recruitment is good or average for 2008 (3-year-old) herring in all areas, and is predicted to be good for SoG herring (but poor for WCVI) in 2012, based on the comparison of age-0 herring catch with age-3 recruits. However, weight-at-age has been declining in the 5 main herring stocks since the 1980's. The question of how to separate populations was addressed with the comment that this is not necessary, since fish spawning in different areas are assumed to mix proportionately. In response to questions about the magnitude and potential impact of by-catch, it was noted that shrimp trawlers have by-catch restrictors but that any net passing through the water has the potential to impact non-target/endangered species, even if they are not caught and/or observed.

A presentation on herring demographics noted that both weight-at-age and length-at-age are decreasing, although length-to-weight is unchanged (i.e. no decline in condition) and stocks are high in some areas (particularly the SoG). It was noted that water temperature has been increasing and dissolved oxygen decreasing at the same time. The same decreasing trend in size-at-age has also been observed in California, for herring and other species, even in areas where fishing has not occurred (which argues against density-dependence, or size-selective fishing gear as a possible cause). The length at which fish stop growing (L-infinity) has also dropped in herring, even though northern populations tend to be larger, faster growing and longer lived than southern populations (i.e. less older, larger herring now). Possible factors include declining resources and intra- or inter-species competition, although the latter seems unlikely over such a broad area. At the same time, the gonad-to-somatic weight ratio (a.k.a. gonosomatic index, GSI) is increasing in both males and females, implying that relatively more energy is available for/being put into reproduction. This is more pronounced in southern (California) than in northern (BC) populations and could reflect the metabolic cost of dealing with higher temperature and/or lower oxygen, which would be expected to impact somatic rather than gonadic tissues. In response to the question of whether or not egg size is measured, it was noted that this is indeed being done and that the eggs of southern populations and smaller than those in the north.

WCVI zooplankton populations were close to long term averages for most crustaceans in 2011, despite the cool conditions, although lower than in 2008-2010. Community composition data from the South Vancouver Island (SVI) time series showed a continued gradual decline for 'boreal shield' and sub-Arctic copepods but continued recovery for pteropods (which are susceptible to ocean acidification), with euphausiids and both cool- and warm-water chaetognaths at or above average numbers in 2011 compared with 2008-2010. Data from the North Vancouver Island (NVI) time series showed boreal copepods (which are large and a good food source) remaining at above average numbers and southern copepods below average. Data from 2007-2011 shows that the sign of the anomaly for these copepod species often

changes across the shelf break, whereas previously shelf and offshore trends were similar, suggesting that exchange between these sub-regions has reduced. Along the Oregon coast, copepod biomass tends to be dominated by a more diverse population of smaller, low-lipid species when conditions are cool, and vice versa when they are warm. The switch between cool and warm periods, due to the Pacific Decadal Oscillation (PDO), appears to be occurring more rapidly than in the past, with a lag of about 2 months between a switch in the PDO and the resulting biological response. The year 2011 started with intense downwelling, but upwelling started at around day 105 and continued to strengthen, bringing cold, salty, nutrient-rich, low oxygen water onto the Oregon coast. The deep water has been intermediate between El Niño (warmer, fresher) and La Niña (cooler, more saline) conditions in recent years. A question as to whether large bodied copepods are observed in Oregon was answered by stating that the same species of large copepod are observed as in BC, but that the replacement rate is higher (80-90%) than for WCVI (40-50%) as our big copepods don't disappear as quickly in the relatively cold water.

A presentation on persistent, bioaccumulative and toxic (PBT) contaminants in BC harbour seals and killer whales noted that the exposure of marine mammals to these chemicals is determined by a combination of biological, chemical and geographical factors, and that the trans-boundary capture of harbour seals since 1996 has provided a basis for contaminant research and monitoring (including spatial, temporal and health trend analysis). Harbour seals, which are not protected by SARA but by Marine Mammal Regulations (MMR) under the Fisheries Act, are long-lived, non-migratory, omnivorous, predatory, high trophic level organisms that feed on e.g. hake, herring and salmon, and can accumulate PBT contaminants like PCBs and brominated flame retardants or PBDEs (of which up to 206 congeners maybe detected in harbour seals). Seals in Puget Sound are more contaminated with many PBT compounds (e.g. 7-fold higher in PCBs and up to 2-fold higher in PBDEs) that those in Canadian waters, reflecting the greater number of spills, effluent inputs and residence times in Puget Sound than in the Georgia Strait. Monitoring reveals both positive environmental responses to legislation (e.g. decreasing, though still-significant levels of PCBs; stabilizing of PBDE levels in response to source control) and emerging concerns. A new tool box is being developed to monitor the health of killer whales (which are protected under SARA) using real-time quantitative PCR to monitor the expression of specific genes (e.g. AhR, metallothionein) in biopsy samples. Principle component analysis of such data has identified PCBs and age as significant factors influencing gene expression (33% and 19%, respectively) in killer whales. Results show a clear relationship between PCB exposure and key biological endpoints, and despite the banning of these compounds it will be ~2060 before PCB concentrations in killer whales fall below levels of concern. In response to a question about population dynamics for harbour seals in Puget Sound vs. SoG in was noted that while that analysis has not been done there is an increased incidence of disease, and anecdotal reports of deformities, in Puget Sound populations (better researched in the St Lawrence and the Baltic Sea). Regarding any new flame retardants that may be of concern, HDCDD could be a candidate, and although there are new (CEPA) regulations aimed at controlling, banning or avoiding potentially dangerous chemicals (e.g. those with high K_{ow} values, which tend to concentrate in fatty tissues) we don't yet have analytical methods for all of them.

Regarding the early survival of tagged Fraser sockeye, some changes to monitoring took place in 2011, with more receivers placed in the Chilko and Chilcotin Rivers, which have clear water compared with the turbid waters of the Fraser River (where there are no problems with fish passing the receiver arrays). Scaling survival based on the amount of time fish are observed in a particular area was also introduced in 2011. Nevertheless, mortality was apparently higher in the Chilko than in the Fraser River in 2011, although survival was generally good compared with 2010, when there was a rapid drop-off in early migration from the Chilko/Chilcotin. However, fish transported past the area where mortality occurred showed higher survival rates. Outer coast

survival was generally better in 2011 than in 2010, reflecting ship-based ocean indicators (colder water, fatter copepods) in Oregon and southern BC, and mirroring changes for Columbia River chinook. Survival rates in Discovery Passage/QCS are more variable than for the SoG, which have been relatively stable across 6 years of measurements. Nevertheless, substantial marine mortality is evident, and the comment was made that, whatever the conditions, only about 20-25% of migrating Fraser River sockeye will make it to Johnson Strait. In response to questions regarding the lifetime of the arrays and the sample size in 2011, these were estimated at 5 years and 600 fish (less than in previous years). Regarding the length of time it takes for the fish to reach the north end of Texada Island/SoG, this can be estimated from a migration speed of ~3km/day.

An update for Albacore tuna mentioned the existence of two stocks (north and south) for this highly migratory species, and that all data are fishery-dependent. The total catch of Albacore in 2010 was average for all countries (Canada and the US catch mostly Albacore tuna, whereas Japan alternates between albacore and skip jack). The 2011 catch was down 15% compared with 2010, but effort was 16% greater. Albacore tend to track the Transition Zone Chlorophyll Front (TZCF), and in 2011 97% of the catch occurred when water temperature was between 14 and 18 C. All in all, 2011 was an average year for albacore in Canadian waters. As to whether there is a correlation between the movement of sardines and tuna, it is unknown whether sardines track the TZCF like tuna, but the latter will feed on hake and other species as well as sardines.

On the breeding of seabirds at Triangle Island, hatch date (time of breeding) for Cassin's auklets tends to correlate with SST anomalies, though in high SST years food is sometimes so low (exacerbated by temporal mismatch between breeding and availability of their main prey, the copepod *N.cristatus*) that birds cannot get enough to breed (2010 was a disastrous year, though mass at 25 days was good in 2011). Adults may also die (esp. females) which, for such long-lived species, can be a greater determinant of population impact (Cassin's auklet is being considered for listing under COSEWIC). A drier climate may also affect the ability of auklets to burrow (habitat loss). For Rhino auklets, the availability of their main prey (sand lance) can again be a major factor in breeding success. This also correlates with SST for Black Oystercatchers, which bred well in 2011. Cooler SST generally correlates well with breeding success for these birds, due mainly to the matching of prey availability with hatch date. The comment was made that these bird populations provide a good opportunity to study trophic levels, for example, using ^{15}N isotope measurements of bird tissues/eggs/chicks to discriminate between offshore vs. onshore food sources, etc. The question of male/female ratio was addressed with the comment that some demographic estimates have been made in connection with COSEWIC assessments and suggest a 50/50 ratio.

Day 1 Discussion

The discussion at the end of Day 1 focussed on looking for themes and linkages that may be emerging from the enormous amount of diverse information presented so far. It was mentioned that ground fish are declining in size and age, and so are herring, and that something broader may be going on. This has not yet been looked at in great detail (no species-specifics) and not all species are well documented, but the comment was made that there certainly seems to be a consistent decline. It was noted that 2011 was a bad year for Albacore tuna, which track the transition zone, and that sardine distribution was a month later this year. Many of these things reflect some of the natural variability, but now this information is available the question is how to start integrating it into management, and how to manage other threats. We are beginning to get information that shows endocrine systems kicking in. How is that redistributed in the food chain, and what questions should we be asking in the future to help managers regarding climate and productivity? With regard to endocrine disruptors in the food chain (and gonads in herring?) it

was noted that some classes of contaminants (PCBs) are going down. A question was raised about longer lived species, and whether some species are responding to endocrine factors and/or spring transition in a different way (shift in ecosystem or trophic structure). It was noted that, compared with other years, this year does seem to be showing a consistent story for the whole BC coast and that maybe we are moving to a different, coast-wide regime. Given that the last 5 years have seen relatively cool ocean conditions (which may be responsible for the apparent harmonization of conditions along the BC coast), the question was raised as to whether any of the observed fish conditions might be related to this. We have seen warm/cold/warm/cold cycles in previous years, but is there anything we should be predicting if we are moving into a mostly warm period? The group was reminded that not all sockeye respond in the same way, but it was noted that juvenile hake were very late or did not make it into Canadian waters this year (the bulk of biomass was off Oregon this 2011), and that aggregate statistics are coming. It was pointed out that a fairly high weight is placed on the presence and absence of forage fish, and it was asked whether there are any differences in species given that we now have sardines, when we didn't have them before. The response was that this is hard to tell because many factors are currently changing (no whaling, no marine mammal hunting, etc.). Furthermore, if sardines are going up something else is going down, so the situation is more complicated. It was noted that fishing pressure is the main topic on the east coast (less annual variability, so don't have a meeting like SOTO), whereas on the west coast we focus on climate change. The response was that we see some impacts of fishing on our stocks too but we have more year to year variability. It was mentioned that a lot of stock assessments on the east coast do include environmental forcing, and the question was asked as to why this is not done on the west coast (particularly in view of the great variability due to El Niño/La Niña). There is a report that looks at fishing above and below optimal levels, which suggests that west coast fisheries are actually better managed than on the east coast (fisheries managers do read SOTO reports). It was suggested that there is scope for using environmental co-variates rather than just latitude and longitude in fisheries management. Can/should we be putting effort into developing some formal ocean indices based on the knowledge we now have of time-series data (e.g. NEPTUNE now as dissolved oxygen sensors at each node, so interannual cycles can be defined)? There has been some discussion about how to integrate climate and fisheries management. However, there are many things to consider on the west coast; for example, migrating species are affected by different/confounding factors acting on different timescales (e.g. anadromous fish like salmon; the absence of Humboldt squid this year), whereas time scales on the east coast tend to be similar. In addition, species that we care about on the west coast are much more wide-spread and large scale, whereas east coast species (lobster, crabs) are more sessile and operate at much smaller scales (i.e. we need to incorporate considerations of scale into our conversations). It was noted that VENUS sensors are being updated (including oxygen sensors at the Barkley Sound node) and other datasets can be expected, and it would be helpful if we could tell Environment Canada and other organizations how and why we can use this data (we can't do this all alone, and we do have strong allies in our universities). It was noted that small forage fishes (surf smelt, eulachon) that really are being impacted aren't being looked at because they are not commercial species, and we need information on non-commercial species over a broader area. Regarding potential indices, asymptotic lengths and weights were put forward as good candidates (these can be obtained in several ways, not always requiring age data, and can be revealing for many species). In terms of choosing the best areas to monitor chlorophyll signals, it might be a good idea to choose areas known to be productive for certain species (e.g. the transition zone chlorophyll front for Albacore tuna). In conclusion, there was general agreement on the need to identify important ecosystem indicators that should be looked at on an annual basis, and that despite the large number of groups already working on such indices, the SOTO process should have a minimum number of consistent reported-on indicators (possibly developed by a SOTO working group over the winter). The Day 1 discussion finished off with the workshop co-Chair

(Bill Crawford) stating that this year's Science Advisory Report will be limited to a few pages to encourage wider readership, and that each presenter will be asked to provide the 2 most important/robust points from his/her talk for inclusion in the SAR (to be discussed in more detail tomorrow). These two summary points are in addition to the 2- to 3-page presenter reports required for inclusion in the Research Document (which will be reference by the SAR).

Day 2 Discussion

Day 2 of the workshop began with a talk on the northward migration of Pacific grey whales between Vancouver Island and SE Alaska. These whales, of which there are 2 main populations, are found only in the North Pacific Ocean and prefer shallow waters, where they feed in the benthos. This makes them easy to kill, and they were almost wiped out until becoming protected in 1937. Pacific grey whales currently number about 20,000 but are still listed as a species of special concern under SARA (due partly to threats in Russian waters). Migration is thought to follow the coast from the Baja to the Bering Sea at about 2 knots/day northbound (4 knots/day southbound), but the tracking of 5 migrating whales using 'limpet' tags in 2009-2011 shows that the migration route cuts through coastal mainland waters inside Haida Gwaii. Spotters placed at Bonilla Island and Langara Island reported 111 sightings and 10 whales, respectively. This gives rise to conservation concerns, since the Hecate Strait/Dixon Entrance corridor goes past Kitimat, and there is high potential for anthropogenic impacts including ship strikes, noise from potential construction/operation of offshore wind energy installations, and entanglement due to major crab fishery (although the latter happens after migration). Nearshore migration of mothers and calves, which occurs during the second of two migration phases, is likely driven by the vulnerability of calves to killer whale predation in open water. Questions about the southward migration were addressed with the comment that new information obtained using satellite tags suggests that the whales cut across Gulf of Alaska and make landfall midway down Haida Gwaii, and move faster than when northbound because they are well fed. Regarding the importance of feeding during northward migration, it was noted that a few hundred animals feed at one or two locations and that this might be a distinct summer population (which could be confirmed by an upcoming COSEWIC assessment). Additionally, grey whales have sometimes been sighted in the SoG (may become confused during migration).

A talk on long term trends and annual variation in the Pacific Rim National Park was divided into various sections. The first section (about bivalves) focused on Manila clams, which have shown an average decline of 12% per year over the last 15 years. A possible reason for this decline (which seems to be steepest in Nettle Bay and Joe's Bay) is competition by varnished clams, which appeared in the 1970's, but there is as yet no clear explanation. Populations of littleneck and butter clams remain stable, and Olympia oysters showed signs of recovery in 2011 (e.g. in Joe's Bay) despite an overall downward trend, which also applies to Japanese oysters. Eelgrass communities were tested for annual trends and effects of covariance (SST, SSS, fluorescence, biomass, nitrate and epiphyte load), showing synchronization of regional trends (i.e. for Clayoquot Sound and Barkley Sound) and a 'meadow' effect that explained up to 60% of the variance in fish numbers. Overall species richness is highly variable but seems to be declining. Rockfish and sea perch showed no annual trend, whereas flatfish appear to be in decline (superimposed on high variability). Eel-like fishes were the only ones that showed regional differences, with numbers higher in Barkley than in Clayoquot Sound. The comment was made that these data are a fantastic addition to SOTO workshop reporting, since lack of information about this area (likely due to their being no fisheries in the park) had been considered a major deficiency in previous annual reviews. In response to various questions about this talk it was stated that the term 'decline' was used with reference to abundance, that no distinction was made between eelgrass species (although one species dominates in the park), and that meat weight/shell weight could not be determined for bivalves because park organisms cannot be

destroyed for the purposes of this survey. Regarding the two oyster species surveyed in Joe's Bay, it was suggested that the inverse relationship observed between the two in 2011 could result from competition for nutrients.

Oceanography

A talk on oil in Canadian waters began by listing average inputs from various sea-based activities during 1988-1997, including ships (457 kT/year), offshore oil and gas exploration (20 kT/year), coastal facilities (115 kT/year), small craft activity (53 kT/year) and natural seeps (600 kT/year). Intentional rather than accidental discharges from shipping are a major source of oil, but it is the timing and location rather than the quantity of input that are of most concern in terms of environmental impact. Models developed for looking at these impacts include an oiled seabird mortality model (OSMM) developed in Newfoundland, a spatial risk analysis model that plots the likelihood (prediction of spatial/temporal patterns) vs. consequence (vulnerable species, critical habitat) of an oil spill/discharge, and a National Aerial Surveillance Program (NASP) that uses ~3 aircraft to deploy a wide array of detection systems. The NASP is run by Transport Canada and feeds into spatial risk modelling and reviews by the Oil in Canadian Waters (OCW) expert panel. Surveillance data (normalized for effort) show the Maritimes and Pacific Regions as areas of particular concern. Pacific areas where oil is most likely to be found include the SoG, Barkley Sound, Johnstone Strait and the Central Coast (spills are frequently observed at Prince Rupert, which has implications for migrating grey whales, as previously noted). In response to the question as to how small a volume of oil can be detected, it was noted that 500 mL covers a large area and that volumes smaller than this can be detected. In terms of resolving different types of oil (e.g. crude vs. refined products) the technology to do this already exists but has not yet been put into operation. It was noted that vegetable oil spills can be persistent and potentially damaging.

MOSTLY SALISH SEA

Oceanography

The session dealing mostly with the Salish Sea began with a review of temperature and salinity measurements at lighthouses in this area. At Nanoose Bay the cold pulse normally seen in winters was not observed in 2010, whereas the warmth of subsurface waters in 2010 was slightly decreased by a 2011 cold spring intrusion, suggesting an El Niño winter. However, the 2011 temperature anomaly at Nanoose was close to zero compared with the 1971-2000 reference period. The low frequency variability in temperature for the SoG reflects that in the NE Pacific, and is closely tied to temperatures along Line-P. Empirical Orthogonal Function (EOF) analysis of BC coastal lighthouse data shows that all EOF weights have the same sign and that SSS and SST co-vary over the entire coast, though with less coherence in variability for SSS, with Fraser River discharge driving SSS anomalies at Entrance Island/SoG (which were strongly negative in 2011). SST tracks closely with PDO, especially during the last decade. It was confirmed that cold water moves into the SoG in certain years, with surface water temperature being driven by local processes. In response to the comment that individual lighthouse measurement contain outliers that don't always show up in the data, it was noted that quite a bit of smoothing takes place (e.g. 9-month triangular filter) and that this is justified by the high level of local variability (e.g. tidal mixing) that occurs (and Race Rocks tends to be an outlier anyway).

The next talk described near-bottom conditions in Saanich Inlet and the SoG using 2011 data from the VENUS cabled observatory, which has been collecting data from one depth (100m) in Saanich Inlet for 6 years and from three depths (incl. 170 and 300m) in the SoG for 4 years. Temperature, salinity, density and oxygen traces were presented for the station in Saanich Inlet. These show a cooling/ventilation period from late fall through winter (with high variability in

2011 due to a cold intrusion) and a warming period from spring onwards (one month of which occurs in steps due to water 'pulsing in' on the weakest neap tide), with about 80% of the variability in density being driven by salinity. Variable cooling/ventilation and stepped warming were also observed at the (170m) mid-water station in the SoG, where density does not show much of an annual signal (temperature and salinity cancel out?) but the deep water intrusion responsible for pulsing can clearly be seen. Dissolved oxygen (DO) measurements show cold air from the atmosphere being drawn down/entrained into deeper water during the ventilation period, then cut off in the summer, when DO drops. The deepest (300 m) SoG station lags the shallower station with the coldest temperatures being recorded in May rather than March. Not as many excursions are seen at the deep station, but when they occur they can be as large as the entire annual cycle (~2 C.). An upwelling event on August 22 resulted in deep water renewal and a drop in DO. Although earlier ventilation events were not referred to as renewal events, the point was raised that these 'bigger ventilations' could/should be regarded as renewals even if the observed density changes were not as great. In response to the comment that DO levels at 170 m in the SoG seem unusually low and that turbidity might be an issue, it was noted that a DO concentration of 0.3 mL/L might be anticipated at mid-depth based on water circulation in the SoG. As to whether DO is lower than it used to be and could be affecting the sockeye run (which occurs at between 30 and 130 m depth), this is not certain at present.

Regarding chlorophyll fluorescence measurements in the Salish Sea, using weather buoys and satellite data, it was noted that the chlorophyll maximum in 2008 (probably due to the deposition of volcanic ash) still stands out when the 2011 data are added to the time series. Chlorophyll fluorescence is good for determining when plankton blooms start, and surface water brightness is good for tracking coccolithophore blooms (spring bloom start date appears to be correlated with SST rather than wind). SoG blooms can be monitored using fluorometers on the Spirit of Vancouver Island ferry and the Halibut Bank buoy. There was no early bloom in 2011, but the fluorometer at Egmont showed a later bloom centred on March 27, and the Halibut Bank fluorometer on April 7/8. Jervis and Sechelt Inlets may be seeding these later blooms in the SoG (they are known to seed early spring blooms) but we are still learning about this process. Fluoresence measurements (e.g. MERIS satellite data) from which the chlorophyll signal at 681 nm can be obtained seem to give cleaner results than direct chlorophyll measurements (4-km, 8-day averages from MODIS Giovanni satellite data provide additional detail). An unusually intense heterosigma bloom was also observed in June 2011, the Maximum Chlorophyll Index (MCI) peak at 709 nm being a universal indicator of such blooms worldwide. 'Brightwater' coccolithophore blooms (which appear greenish in true-colour images) were also observed using MERIS fluorescence data, with an intense MCI signal centred on September 3, 2011. Offshore buoys showed a definite cooling trend in SST throughout 2011 while others remained cool, the historical trend being a decrease in SST since the early 1990's (the longest time series being for the buoy 46004, which dates from 1977). Interest was expressed in being able to identify historical heterosigma blooms, since these have been linked to salmon kills, but while this can be done for blooms in general (based on spectral data dating back to 2002) the analysis of water samples collected at the time would be necessary to identify the plankton in each bloom.

A talk on the timing of spring phytoplankton blooms centred around a station (S3) in the middle of the SoG. Use was made of a 1-D mixing model incorporating estuarine circulation (all 2-D effects must be parameterized) and requiring light and nitrate for growth. The present study defines the date of a bloom as being when nitrate drops to zero rather than when chlorophyll fluorescence spikes (the latter should predate the former). Using this model the 2011 spring bloom was predicted to be (and hindcast to be) in late March; however, the predicted date falls before the date on which bloom started according to (Halibut Bank) fluorescence data, which is problematic. A comparison of model and empirical data suggests that the earliest possible, average, and latest possible dates on which a spring bloom might be expected to occur are

February 21, March 12, and April 5, respectively. It is possible that early blooms may be linked to water temperature at 40 m. Modeling of the 2012 spring bloom is being run every morning based on weather updates, and currently suggests an early bloom unless the weather deteriorates significantly. Regarding the possibility of predicting the start of a bloom from the peak (i.e. date of zero nitrate) determined using the model, uncertainty was expressed as to how one might model what a satellite sees at the surface. As to whether a climate warming scenario might lead to earlier spring blooms, it was noted that late spring blooms could still occur but that the possibility of earlier blooms could exist due to the greater climate variability. It was also noted that the model can be used to predict blooms of zooplankton and other plankton classes, and that biological parameters are input at the beginning of the year whereas physical parameters can be updated based on e.g. current weather conditions. As to the best way of monitoring spring blooms, it was suggested that a ferry-based system similar to the one already installed on the Spirit of Vancouver Island be used but on a ferry that follows a diagonal course.

Biology

As a complement to talks on the remote observation and modeling of phytoplankton blooms, a presentation on phytoplankton in the SoG and Juan de Fuca Strait made use of actual measurements of phytoplankton from field samples collected four times a year (in April, June, September and November) during short ~5-day cruises. It was noted that we really have a blooming season in the Salish Sea, not just peaks, and that blooms can occur whenever nutrients are brought to the surface within a couple of days. CTD measurements of nitrate and chlorophyll from 2005 to 2011 were presented from a vertical section along the main axis of the estuary. The highest chlorophyll concentration was that due to the 2011 heterosigma bloom mentioned previously, although there was also evidence for a spring bloom in 2011 (April 13-20) similar to the one observed in 2009 (April 11-15). The characteristic drop in nitrate during the 2011 bloom season was in line with the 2010 average, even though blooms observed on certain cruises were larger than average. It was noted that field observations are not adequate to study inter-annual variability in phytoplankton biomass, and that observed difference in chlorophyll could be due to intra-seasonal variability (a problem when sampling over short periods that vary from one year to another).The use of phytoplankton pigment composition measurements to determine which species are present was also described. Spring populations are typically mixed with little interannual variability, whereas summer populations show greater variability and differ from the spring populations, fall being similar to summer. Pigment analysis for summer 2011 showed significant amounts of certain pigments (associated with *Heterosigma akashiwo*?) that had not been seen much before, coinciding with the highest observed chlorophyll levels (10-15 mg/m^3) in the SoG. In response to a question about how widespread the heterosigma bloom was, it was noted that this bloom was observed almost everywhere in the SoG in 2011 (including at all axial stations). As to whether differences might be expected between summer and fall populations, it was noted that diatoms tend to dominate spring blooms but that those in summer and fall would be expected to be similar.

A presentation on the use of satellite-based methods to support fisheries management in the SoG talked about the provision of data and models for accurate mapping of chlorophyll and plankton blooms, and linking primary productivity with higher trophic levels. A Fisheries Management Model incorporates the timing, magnitude, location and duration of (harmful algal) blooms based on Chl-a measurements. Remote-sensing and in-situ data are obtained from satellites (SeaWifs, MODIS , MERIS), ships (e.g. ferry box) and cabled observatories (VENUS, NEPTUNE), and atmospheric calibration of satellite imagery (i.e. AERONET) is also performed. Turbidity can affect near-IR bands and chlorophyll measurements, since it varies with depth. Preliminary results for 2007-2008 show early spring and late fall blooms in 2007 and a later but more sustained spring bloom in 2008. It was pointed out that the chlorophyll time series measurements don't look much like those presented earlier, and there is uncertainty as to how

to bridge the gap. The point was also made that fish don't eat phytoplankton so this needs to be taken into consideration (e.g. time correlations are needed). An offer was made to provide references that explain how to deal with multiple peaks in a given year. It was also noted that estimates have shown spring bloom productivity to be half that of later blooms, although this could be different at depth. A chlorophyll persistence index has been developed for the California Current system and this seems to work well with respect to sea birds, although getting point data for biological measurements is a challenge.

Regarding temporal shifts in SoG food webs, the ecological/ecosystem modelling software Ecopath with Ecosim (EwE) was run for the year 1860, 1960, 1985, 2010, and 2035. The 3 main drivers were freshwater (carries DOC and POC, mostly from forestry rather than sewage, and drives circulation and flushing), wind (affects the surface layer), and seawater (provides nutrients). Observations include intrusion (at 100 m) and mixing of new water from the Strait of Juan de Fuca, warming trend (about 1.6 ºC/century) in Jervis and Saanich Inlets (at 200 m), and increasing April discharge from the Fraser River as climate changes. The latter is significant since 3,600 m^3/s is enough to exchange the water in the SoG in 11 days vs. 40 days at 1,100 m^3/s. Meso-zooplankton show a very large signal in 1999 (but were anomalously low when the wind data was low), and the abundance of larger lipid-rich copepods correlates with fish recruitment. From 2010 onwards, humpback whales are predicted to flourish, which could result in reduced herring stocks. With Ecopath, the modelling becomes more and more developed over time and can address questions like "where did the energy go in 1960 when populations crashed?", "how did we get to where we are now?", and "what will happen if certain things occur in the future?". In response to the question of why there is a 50% reduction in primary productivity from 1860 to 2035 it was noted that there were cooler temperatures and more wetland in 1860 and that the 2035 numbers reflect habitat degradation and global warming. The point was also made that the system seems to be very sensitive to primary production, even though this has high seasonal variability, and that such a huge drop should result in a completely different food web, in response to which it was noted that both physical drivers and top-down controls are in effect and that the model attempts to balance existing biomass boxes, even though there would be big changes in species as well as biomass (the link between modelled productivity and climate change is through a complicated 'black box'). The importance of *Neocalanus plumchrus* was questioned as only salmon are large enough to eat a fully-fledged copepod, whereas other larval species can only eat smaller organism. However, because the model considers feeding until the fall, spring blooms may not be as important as they seem. Regarding estimates of carrying capacity, 800 kT of herring is probably high and better estimates could be obtained from (Alaska) trawl data. It was also noted that the system is not closed and that the rate of import/export can be highly variable (e.g. herring don't eat in the SoG), to which the response was that the EwE model does attempt to balance these (with e.g. imported biomass/energy).

Lunch Break

A talk on top-down and bottom-up mechanisms influencing managed species in the SoG described an ecosystem model (Ecosim) designed to simulate changes in the SoG as they related coho and chinook salmon. The model covers the food web from top to bottom, but is more detailed in the upper trophic levels, using biomass, production, diet composition, and fisheries to build a complete picture. The presenter raised the question of how to simulate change, and how to fit hindcasts to what is already known. Diets don't stay static through time, and prey don't make themselves freely available at all times. Need to include some bottom-up dynamics to account for climate-driven changes by simulating annual anomalies in primary production. At the moment, primary production is hindcast to what it must have been to satisfy the model, but in future the intention is to use models like the 1-D mixing model mentioned earlier to explain the observed primary production. Also need to add top-down dynamics to account for predation effects on mortality in prey species, and a climate forcing function.

Comparing spring winds in the SoG to hindcast data shows that lighter winds model periods of higher production, whereas stronger winds give lower production. The correlation is strongest in March, April and May (maybe even stronger for the average of these three). In terms of predation mortality, seals and sea lions may have as much of an influence as orca on chinook. Regarding ecosystem indicators, these need to have thresholds and be intuitive/make sense in order to be useful to other scientist and managers. Big changes in biomass are very straightforward and intuitive. The proposed strategy includes identifying trophic level changes in the SoG (catch/vertebrates/predators), developing scenarios linked to climate models (e.g. ROMS), developing ecosystem indicators from BC ecosystem models, and using indicators and reference points to guide simulation of future ecosystem configurations and management profiles. The comment was made that the ecosystem model may show where we need better management models, raising the question of what key things need to be done better in terms of management. In response, it was noted that chinook and orcas are frequently mentioned and that this is a key point, because a small change in seal diets can have a profound impact on other species. We are at the stage where we need to link the top to the bottom (i.e. we need diet and predator-prey information), but this is not currently being done in stock assessments. The point was also raised that the model shows an inflection for regime shift in 1990 but not in the 1970's when there was a really big regime change. The response was that the SoG is its own ecosystem and not necessarily driven by coast-wide mechanisms, or what is happening in the North Pacific (there are also many things that we don't study). Why the SoG appears to act as an independent unit is definitely something that can be examined.

A talk on zooplankton trends in the SoG described a reconstructive effort to combine historic data from multiple sources, requiring simplification of taxonomic descriptions (perhaps more than might be considered ideal). Many species are strong vertical migrators either daily or seasonally. Differences in the way different people classify different things led to a switch from trying to work at the taxonomic level to looking at major groups and size classes. Zooplankton biomass is dominated by a few major taxa (copepods, euphausiids). The SoG is mostly occupied by Arctic and oceanic rather than coastal or warm water species. It is also very enclosed and relatively shallow with a large freshwater input (i.e. it is an estuary, with water heading out at surface and in at depth). Therefore, things are continuously being exported at the surface and imported at depth, and because of freshwater input the surface waters can be colder than below. Inter-annual variability at depth is very small in the ocean, but currently very large down to 400m in the SoG, which has seen warming at all depths over the last 30 years. The spring freshet in getting earlier and the spring bloom is tending to get earlier and more variable. With regard to zooplankton, large (3-5mm) and medium (1-3mm) copepods were high in 1990 but low in 1994-1995. Euphausiids, the other dominant species in the SoG, were very low in 2003-2007 but, unlike the copepods, have recovered in 2008-2010. Using multivariate analysis (PCA) to look at inter-annual variability shows that the leading principal competent accounts for about half of the observed variation in biomass (all have positive co-variance). Most zooplankton time series correlate with temperature, but the North Pacific Gyre Oscillation (NPGO) was often the strongest predictor (not PDO, local taxon, nor local wind). This may be because the NPGO is linked to the source and nutrient content of the deep water that enters the SoG (very little correlation between the SoG and WCVI zooplankton populations). In any case, changes in zooplankton are likely to have contributed to low growth and survival of planktivorous fish in 2007. An apparent 6-month lag in the data was explained as being due to the use of environmental indicators for October through March. In response to questions about amphipods and megalops (planktonic early life stage in crabs), both are major dietary components for juvenile salmon, the former showing a similar trend to zooplankton (though 2007 was a bad year) whereas the latter are not well-sampled.

A presentation about survey abundance estimates/catch per unit effort (CPUE) for juvenile Pacific Salmon in the SoG, and how these are used to calculate projections every year, noted

that Fraser River flows (which were high in the 1990's) have been lower for the past 3 years than the average for the past ten, and that the abundance of chum salmon in 2011 was the lowest for the past 15 years, which is likely to lead to very poor returns in 2014, although forecasts are good for this year and fair for 2013 (pink salmon are only seen in the SoG in even years). As well, DNA analysis now provides evidence for distinct populations. To summarize, the very large CPUE for chum salmon suggests a strong return in 2012, but coho are likely to be poor, as are chinook (with the exception of the south Thompson stock, which will be good). Fraser River sockeye returns in 2012 are expected to be poor based on the low CPUE in the 2010 survey, and Harrison Lake sockeye (which return as year 4 rather than year 3 fish when they enter the SoG) are likely to be extremely poor. In response to the question of whether a retrospective analysis has been carried out for the CPUE indicator, it was noted that it is hard to get good escapement data for pink and chum salmon, though this is easier for coho, and for sockeye (July surveys were designed for coho and Chinook salmon). The use of 'stoplights' (red/green/yellow) to forecast the data was commended. Regarding interactions between pink and chinook salmon, it was mentioned that a sequence of 4 or 5 interactions might be observed but then nothing, and that there are huge numerical effects for pink salmon that need to be worked out. Regarding the possibility of earlier surveys for pinks and Fraser sockeye (June/July being too late), it was noted that there are plans to do an earlier (June) survey for pink salmon and that this is already being done on a small scale for sockeye, which are in the SoG during the last week in May and peak around June 12 (so a June survey should provide a good representation of Fraser River stock). It was also noted that sockeye take about 4 to 5 weeks to get through the SoG and that DNA work should provide an interesting perspective on this story.

Following a presentation on high seas salmon, it was noted that survival of these salmon is positively correlated with lipid-rich indicators (northern copepods) and higher N/C ratios. It was also mentioned that some are taking different routes, and a lot are being caught in inlets. As to why salmon size appears to be decreasing except in 2005, it was noted that 2005 was actually a bad year for all salmon stocks on the coast so the high seas data need to be looked at again. A question as to how growth rate was calculated was answered by saying that this was done using average fork length determined from summer and fall surveys (based on the assumption that these are the same stocks).

The final talk of the 2012 SOTO workshop was an overview of productivity for the Fraser River sockeye salmon. The Fraser contains multiple runs, which were originally designated based on return time, and managed and assessed based on return groups (now use conservation units, which are much more discrete). Harrison fish are 3-year fish whereas most sockeye are 4-year fish, having survived for 4 years (first year as an egg) of which 2 are spent in fresh water (2008/9) and 2 at sea (2010/11) before outmigration (2012). The fact that these fish spend time in two different environments makes it difficult to come up with one environmental indicator, or to make accurate predictions. Declines in the productivity of Fraser sockeye started in the 1950's for some populations and in the 1990's for others (e.g. Chilko), though no decline has been observed for the Shuswap Lake population. The Harrison population (which goes to sea as fry) is an outlier, showing an increase in productivity. Regarding 2011 forecasts and preliminary returns, it was noted that a forecast is not a number but a probability distribution, and that freshwater post-smolt survival of Chilko salmon is increasing whereas marine survival is decreasing. Regarding 2012 forecasts and beyond, the aim is to try to start including environmental co-variates for survival (e.g. Fraser River discharge, SST). There is a 50% chance that the 2012 return will fall at or below the specified forecast value. Returns were poor in 2009, so would not expect a lot of sockeye in 2013, but returns in 2010 were exceptional so would expect a lot of sockeye in 2014. Nevertheless, sockeye are difficult to predict since there are as yet no leading environmental indicators. In response to a question as to whether there are ocean type sockeye other than the Harrison population, it was noted that there are about 6 other CUs that are ocean type sockeye. Regarding survival patterns for Fraser sockeye and

pink salmon, these show a period of increasing survival up into 1989 and then decreasing survival after this (whether or not the data are smoothed). However, things have been changing in the last two years things (including standardized wind data for the SoG, which is measured at four different airports). Pink salmon have a two-year life history, with odd- and even-year runs. These are genetically isolated populations, with virtually no gene flow even if they are spawning in the same water shed (i.e. they are different species). Estimates of escapement, catch, and fry outmigration show no pattern with the trend in the marine survival, although there is a decreasing trend in fresh water survival that appears to be density-dependent. Nevertheless, pink salmon appear to show increasing returns, largely due to declines in fish mortality, since the fishery has been shut down. Even-year runs are generally doing less well than odd-year runs. To summarize, Chilko survivals have decreased since 1989, while shifts in sockeye survival appear to be related to ecosystem changes caused by shifts in wind patterns. Recent escapements of pink salmon are due to reduced exploitation, and even-year pink survivals are lower than odd-year survivals. In response to a question about the strong CPUE throughout the SoG and Gulf Islands in 2009 (which was generally a poor year for salmon returns) it was pointed out that this was due to Harrison fish. It was also noted that since the 1991-93 court case regarding access to commercial fisheries there have been huge changes in fisheries management, especially for Fraser sockeye. A related question about what contributes to the survival rate was addressed with the comment that salmon survival to adult includes fish caught in the fishery, which are added to those that spawn to get total catch (if they are caught and recorded). A discussion about how separate populations/conservation units are defined (some of them being quite small) identified two different approaches based on life history (e.g. by river- or ocean-type, as per COSEWIC) and/or genetic evidence. It was noted that there is going to be some discussion on an integrated approach using datasets from various sources after the forthcoming sockeye meeting, and hope was expressed that a ‘stoplight’ approach will be used.

Day 2 Discussion

The general discussion at the end of Day 2 began with a summary of what the workshop is attempting to achieve. There are two processes that are intended to provide advice to fisheries managers within DFO. One of them involves Integrated Fisheries Management Plans (IFMP’s/ stock assessments), which take place within management; these are the official predictors for the upcoming season and indicate what species and what stocks should be harvested. The other is State of the Ocean (SOTO), which is a scientific process in which management is less engaged; consequently, managers aren’t getting the information from this process, nor incorporating it into the IFMP’s. It was proposed that more formal process be implemented for passing along information from SOTO to management. There could be an initial meeting with managers followed by a workshop involving people from science and management. It was also suggested that science advice be presented in a way that is more useful to managers. It was noted that Newfoundland Region don’t have SOTO but have a large meeting that includes managers, science and industry/fishers; however, we would need a much larger table for the west coast, one that includes sport-fishers, NGO’s and First Nations (this used to be done for ground fish and it was wondered if this could be done for other species, although it was suggested that salmon might not be included). It was noted that the presence of representatives from DFO Oceans at this workshop is partly in recognition of the need to bridge gaps between science and large oceans management, and that it was good to see the Province represented as well. It was suggested that we should be taking a more ecosystem based approach to management, and that there should be two distinct aspects; impact of fisheries on environment, and of the environment on fisheries. Right now it looks like everything is really starting to show up in stock assessments, and that it is incumbent on the individual assessment person to reach out to others who have that information; for example, bring in the pelagic folks with the salmon folks. The observation was made that this is really more of a science than a management

exercise, and it seems that science is waiting for management and vice versa ('chicken and egg' situation, due to a disconnect between management and science, and even between IOS and PBS). It was noted that those working on PNCIMA are trying to make those linkages in support of integrated ecosystem-based management, and that bringing forward the processes that are happening, conservation objectives, etc. may help to identify data gaps and drive the science. Having DFO Science provide advice on indicators and objectives while still holding SOTO meeting would be great. It was noted that interpreting and translating information from SOTO is a challenge for management, making it difficult for them to incorporate that information into their plans. Being able to interpret and translate the data would be helpful to management in addressing the risk-component of decision-making, particularly in terms of identifying factors that are more conservative and/or known with higher confidence, although we are getting there. It was pointed out that the annual State of the Ocean reports are a great success and that we should carry on with that, but work on taking the information to management. It was noted that this may take time and that managers need to be exposed to the information that is available. The example was given of several ecosystem conditions from SOTO being incorporated by management into a decision to reduce total allowable catch (TAC) in Alaska. Because all those ecosystem indicators were down, the decision to reduce TAC was not based on stock assessments (this kind of information is slowly being incorporated into the general knowledge base). It was noted that such information could/should be brought into the assessment review, that different people can bring different pieces of the puzzle, and that it would be a good idea to get some groups together to move in that direction.

The final discussion period drew to a close with the workshop co-Chair (Bill Crawford) providing additional information about the proposed content of the Science Advisory Report, asking for presenters to send two bullets each on their most important/robust findings. It was noted that a similar approach had been taken with report cards for the Eastern Bering Sea, which include bullets on various observations: for example; environmental and ocean highlights in the context of large scale ocean patterns; time series of data trends; and symbols (up, down, same) on the right hand side to indicate trends with respect to the mean over the last 5 years. Indicators are based on a long-term process of discussion (there is now a working group to do this). This is a good example of how ecosystem indicators can be synthesized and incorporated into a report, which (like the SOTO report) includes goals and implications (must have goals to produce indicators, otherwise will end up with hundreds!). It was agreed that this kind of approach is very accessible and makes it possible for managers to understand what is going on, without things getting over-complicated. It was noted that it might be necessary to produce three such reports, one for each of the major ecosystems on the west coast. It was also stated that there is no point in having an indicator unless you need to make a decision, and for that we need goals. In response, it was noted that for the East Bering Sea the ecosystem goals are outlined in their report, with the indicators listed underneath. It was suggested that indicators need to be something like ecosystem health index that means something to managers, and that they will want to look at indicators that are important to their species (one number would be lovely but probably won't suffice). It was pointed out that there has been a lot of talk about ecosystem based management (EBM) but that no clearly articulated goals have been provided for this, although it was suggested that these are now coming from PNCIMA. What managers need is an explanation as to what, for example, 'PDO' indicates or captures (e.g. WCVI responds quite strongly to changes in temperature). It was agreed that goals need to be associated with these things but that, as scientists, we should be offering up this sort of information and starting to suggests what the goals might be (EBM needs integration from all Sectors). Some surprise was expressed that although we are talking about EBM it is e.g. SAR that appear to be calling the shots, to which the response was that SARA and EB both protect biodiversity and are not working against each other. It was suggested that we need to include environmental factors to even start thinking about defining variability in some of our stock assessments. It was also

proposed that Science should be taking a lead position on EBM and should be indicating to management what the questions are. It was noted that PNCIMA represents the conservation sector, but that although EBM is always being promoted as a conservation tool it seems that the goals coming out of PNCIMA are too lofty to be measured. If you can identify a measureable value, like mortality for example, then you can decide what level (of mortality) is okay, but you need enough science to determine targets and make them measureable. There are examples of how this can be done; for example, the approach of Hobday *et al.* which starts with high level objectives and then unpacks them (as has been done for ground fish). Notice was given of a Wild Salmon Policy meeting in the week following this SOTO workshop, which will cover objectives for salmon enhancement and risk assessment for WCVI. Regarding a paper on sable fish, it was noted that productivity may not be as great under certain conditions, and that managers might need to be more aware of specific indicators. As to whether such information would be used, it was suggested that managers are really approachable and that they want to hear about the research. They understand the need to look elsewhere to explain variation not captured in stock assessments, and for a risk-based approach for PNCIMA/MPA's/local impacts. It was emphasized that before we get too far down the road with indicators of "good times" or "bad times" (and one could argue that times have been bad since 1989) we should recognize that some species will win and others will lose out in a given scenario (a good example being chinook salmon and marine mammals), even if we see a turnaround in key species. One can try to think in terms of being able to predict who are going to be the winners/losers, and the effect of bringing in a competitor, but it isn't realistic to want to expand everything. There will have to be trade-offs between species and these trade-offs will need to communicated, along with the rationales for them.

Returning to SOTO reporting for 2011, in response to a question as to what the main ocean theme should be this year, the suggestion was 'middling cold' and not too different from past years. WCVI ground fish did well this year, but a few more years are needed before a pattern is likely to emerge. It was noted that dissolved oxygen has been measured for many years and that shallowing of oxygen minima is usually commented on. However, surprise was expressed at how low the levels were at 170 m (as recorded by VENUS), although it was suggested that changes at this mid-water depth (which can now be measured continuously) were not that great compared with past measurements. It was assumed that salmon wait at some depth before entering the river, but doubt was expressed that this could be below 100 m based on the measure oxygen levels (though it was noted that the fish aren't waiting as long as before). It was mentioned that a paper is now out describing the impacts of oxygen levels on benthic fish. Regarding the potential impact of changes at mid-depth, it was noted that herring and other clupeids (e.g. sardines) are sensitive to oxygen but cannot detect changes in oxygen levels (which sometimes leads to herring deaths in the Saanich Inlet). Furthermore, herring eggs don't do well beneath fish farm due to depressed oxygen levels. It was suggested that this is a source of concern and that not enough people are studying it. Regarding pH and ocean acidification, it was noted that this may have a bigger impact that hypoxia (e.g. on spawning/fish eggs), that small changes in pH can make a big difference, and that we need to start thinking about acidification in the long run as it is clearly going to have a bigger impact in the future. It was also noted that we seem to be overdue for a warming event (and possibly a sustained warming period) since the last warm year was 2006 and, if anything, conditions have been on the cool side recently. Species like whales and otters seem to be more prevalent in cooler periods, whereas warm years tend to bring different species (e.g. Humboldt squid), so we can expect to see significant changes with a warming event, including shifts in timing. A better understanding of which phytoplankton species are blooming at what time, which of them are toxic, and what the biological impacts might be at higher trophic levels was thought to be important, and there is a need for more sampling (for zooplankton as well) and for discussion as to how samples are

collected, as well as additional processing of the data to uncover more of the information that we think is out there.

The co-Chairs wrapped up the meeting by asking the participants each to contribute a 2- to 3-page summary for the Research Document, and 2 bullets for the SAR, by the end of March.

RECOMMENDATIONS

1. A Science Advisory Report that includes one or two key points from each presentation will be drafted by meeting co-Chairs J. Irvine and W. Crawford for review by the participants.
2. J. Irvine and W. Crawford will compile the 2- to 3-page summaries of the presentations provided by individual presenters in the Appendix of a Research Document and write an introduction that synthesises the key findings.
3. DFO scientists aim to collaborate during the next year to produce more quantitative ocean indices to rank the health of the ocean and its marine species as part of an ongoing ecosystem approach to management (EAM).
4. DFO scientists also aim to develop a new suite of tools and products to advise resource managers on potential impacts and management options for human activities in the marine environment.

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APPENDIX A: AGENDA

2012 CSAS State of Ocean Workshop Nanaimo BC
Vancouver Island Conference Centre, 101 Gordon St., Nanaimo BC

Day 1 - 15 February 2012

9:30 Coffee and Tea

10:00 Welcome and Introductions

10:15	**General/Gulf of Alaska**	**Presenter**
	Changes in water properties in BC waters and the Gulf of Alaska	Bill Crawford
	Zooplankton in the Gulf of Alaska	Sonia Batten
	State of the ocean indicators	Jim Boutillier
	Qualitative analysis of data sources/processes for use in derivation of thermal ocean properties	Dan Roy
	Long term trends in temperature and salinity observed at lighthouses in BC, 2011	Peter Chandler
	Meteorological and oceanic conditions on the west coast during 2011	Roy Hourston
	Invertebrate overview	Graham Gillespie

12:00 **Lunch**

1:30	**Mostly WCVI/PNCIMA**	
	Groundfish overview	Greg Workman
	WCVI euphausiids and fish production	Ronald Tanasichuk
	Small-mesh bottom-trawl surveys off the WCVI: 2011 in the context of surveys since 1973	Ian Perry
	Sardine update	Linnea Flostrand
	Climate-change impacts on demographics and spatial distribution of BC herring	Doug Hay

2:45 **Break**

3:00		
	Zooplankton in coastal oregon and the West Coast of Vancouver Island	Dave Mackas/Bill Peterson
	Regional overview of trends and 2011 returns of sockeye salmon indicator stocks	Kim Hyatt
	What's "normal" for albacore tuna?	John Holmes
	Seabirds at Triangle Island	Mark Hipfner
	New insights into the northward migration of grey whales between Van Isle and SE Alaska	John Ford

4:30 **Discussion**

5:00 **Adjourn Day 1**

Day 2 - 16 February 2012

8:30 **Start**

	Mostly WCVI/PNCIMA (continued)	Presenter
	Persistent contaminants in BC harbour seals and killer whales	Peter Ross
	Oil in canadian waters (OCW)	Patrick O'Hara
	Long-term trends in populations of marine birds (and other?) in Pacific Rim National Park	Yuri Zharikov
	Mostly Salish Sea	
	Temperature and Salinity in the Salish Sea	Diane Masson
	Near bottom conditions (t, sal, den, DO2, zoopl) for Saanich Inlet and the southern SoG	Richard Dewey

10:00 **Break**

10:15	Chlorophyll, buoys, and dragons	Jim Gower
	Timing of the spring phytoplankton bloom in the SoG	Susan Allen
	Phytoplankton in the SoG and Juan de Fuca	Angelica Peña
	Satellite-based method for aiding fisheries	Maycira Costa

11:30 **Discussion**

12:00 **Lunch**

1:30	Top-down and bottom-up mechanisms influencing managed species in a SoG ecosystem model	Dave Preikshot
	Zooplankton trends in the SoG	Dave Mackas
	Juvenile pacific salmon in the SoG in 2010	Rusty Sweeting
	Direct measurement of early marine survival of Fraser (Chilko & Cultus) sockeye	David Welch
	Fraser sockeye	Sue Grant/Jim Irvine
	Sockeye/pink salmon survival patterns	Jim Irvine
3:00	**Discussion**	
4:00	**Adjourn Day 2**	

APPENDIX B: PARTICIPANTS

Last Name	First Name	Affliliation
DFO Participants		
Archibald	Sarah	DFO
Boldt	Jennifer	DFO Science
Boutillier	James	DFO Science
Brown	Robin	DFO Science Director
Brown	Laura	DFO Science
Carolsfeld	Wolfgang	DFO Science
Chandler	Peter	DFO Science
Cleary	Jaclyn	DFO Science
Crawford	Bill	DFO Science
Cronkite	George	DFO Science
Davies	Sarah	DFO Science
de Mestral Bezanson	Louise	DFO Science
Dedeluk	Nic	DFO CSAP
Edwards	Andrew	DFO Science
Finney	Jessica	DFO Science
Flostrand	Linnea	DFO Science
Ford	John	DFO Science
Gillespie	Graham	DFO Science
Godbout	Lyse	DFO Science
Gower	Jim	DFO Science
Grant	Sue	DFO SA
Heloise	Frouin	DFO Science
Holmes	John	DFO Science
Hourston	Roy	DFO Science
Irvine	Jim	DFO Science
Joyce	Marilyn	DFO CSAP
King	Stephanie	DFO Science
Lake	Diane	DFO Science
Mackas	Dave	DFO Science
Mar	Amy	DFO Science
Martone	Rebecca	DFO Science
Neville	Chrys	DFO Science
Nichol	Linda	DFO Science
O	Miriam	DFO Science
Olesiuk	Peter	DFO Science
Olivier	Riche	DFO Science
Peña	Angelica	DFO Science
Perry	Ian	DFO Science
Phelan	Deborah	DFO
Preikshot	Dave	DFO Science
Ross	Andrew	DFO Science
Ross	Peter	DFO Science
Sweeting	Ruston	DFO Science
Tanasichuk	Ronald	DFO Science
Thiess	Mary	DFO Science
Wenghofer	Cal	DFO Ottawa
Workman	Greg	DFO Science

Last Name	First Name	Affliliation
Morris	John	DFO Science
Rasmussen	Glen	DFO Science
Williamson	Kent	DFO Science
Waddell	Brenda	DFO Science
External		
Akenhead	Scott	Ladysmith Institute
Allen	Faron	UVic
Allen	Susan	UBC
Argue	Sandy	Province of BC
Batten	Sonia	SAHFOS, Nanaimo
Bertram	Doug	EC at IOS
Blackbourn	Dave	DFO Retired
Bodtker	Karin	Living Oceans Society
Carswell	Tyson	Uvic
Chalmers	Dennis	Province of BC
Cliff	Robinson	Parks Canada
Crawford	Greg	VIU Nanaimo
Dewey	Richard	UVIC/Neptune
Douglas	Karen	NEPTUNE Canada
Hay	Doug	DFO Retired
Haycroft	Carly	Province of BC
Jefferies	Marlene	UVIC/Venus
John	Esme	Province of BC
Jones	Greg	Environment Canada at Institute of Ocean Sciences
Li	Lingbo	UBC
MacRaild	Fiona	Province of BC
McIsaac	Jim	PNCIMA IOAC
McKinnell	Skip	PICES
O'Hara	Patrick	EC at IOS
Pearsall	Isobell	Pacific Salmon Foundation
Ravindran	Ajaya	UVic Neptune Canada
Roy	Daniel	Canadian Forces
Snauffer	Evgeniya	UBC
Welch	David	Kintama
Wright	Kim	Living Oceans Society

APPENDIX C: TERMS OF REFERENCE

STATE OF THE PACIFIC OCEAN: 2012 WORKSHOP

Pacific Regional Science Advisory Process

February 15-16, 2012
Pacific Biological Station, Nanaimo, B.C.

Chairpersons: Jim Irvine and Bill Crawford

Context

Annual state of the ocean reporting in the Pacific Region is provided by the Pacific Region Fisheries and Oceanography Working Group (FOWG), in conjunction with the regional Centre for Science Advice Pacific (CSAP) and the Canadian Science Advisory Secretariat (CSAS) in Ottawa.

Significant changes have occurred in recent years in physical and biological oceanographic conditions and the state of fishery resources. Annual monitoring and reporting provides a synopsis of current status, how it is changing, and how these changes may affect commercial and non-commercial resources in the region.

The influences of ocean conditions are an important component of fishery resource assessment. The annual State of the Pacific Ocean Report provides an overview of these conditions, which can then be used by DFO Science Branch in resource assessments. DFO Fisheries Management Branch and Ecosystem Management Branch incorporate information provided in the annual State of the Ocean publication to inform risk-based management decisions.

In addition, the publications address to a growing public interest in the state of the Northeast Pacific Ocean.

Objective

To develop a synopsis of the physical and biological state of the ocean off Canada's Pacific coast in a workshop setting. Focusing on 2011, relevant scientific information will be provided in short (~15 minute) presentations followed by discussion.

Expected publications

- CSAS Research Document
- CSAS Science Advisory Report
- CSAS Proceedings

Participation

Participants (approximately 70) will include DFO Oceans and Resource Assessment sectors primarily within Science, and external participants from academia, other Canadian and American federal and provincial agencies, and the NGO community.

References Cited

Published advisory reports and research documents from previous years are available on the Fisheries and Oceans Canda, Oceans and Climate website.