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Science Sciences
Pacific Region
Canadian Science Advisory Secretariat
Science Advisory Report 2007/019

STATE OF THE PACIFIC OCEAN 2006

Figure 1. Location of regions described in this report. Ocean conditions are monitored along Line P, which extends from the mouth of Juan de Fuca Strait to Ocean Station Papa at 50°N, 145°W.

Context:

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, experiencing frequent El Niño and La Niña events particularly over the past decade. The region supports important resident and migratory populations of invertebrates, groundfish and pelagic fishes, marine mammals and seabirds.

Monitoring the physical and biological oceanographic conditions and fishery resources of this region is done semi-regularly by a number of government departments, to understand the natural variability of these ecosystems and how they respond to both natural and anthropogenic stresses. Support for these programs is provided by Fisheries and Oceans Canada, and Environment Canada. Contributors to this report are members of the Fisheries and Oceanography Working Group of the DFO Pacific Centre for Science Advice, with additional contributions from scientists of the U.S. National Marine Fisheries Service.

Canada

SUMMARY

This section summarises the physical and biological state of the marine ecosystems of Canada's Pacific Region in 2006 and early 2007 based on individual contributions presented in the Appendix of this report. New for this year are invited reports from American scientists, describing conditions along the west coast of Oregon and southern Washington State. The full report (and for previous years) can be found at www.pac.dfo-mpo.gc.ca/sci/psarc/OSRs/Ocean_SSR_e.htm .

This report is the eighth in an annual series describing the state of physical, biological, and selected fishery resources of Pacific Canadian marine ecosystems. This region has seen dramatic changes in atmospheric and ocean conditions over these years, all of which affect resident and migratory marine populations in B.C., many of which are of significant commercial importance. Monitoring and reporting on these conditions annually provides a brief synopsis of their present state and how they are changing, and how these changes might affect commercial and non-commercial living resources in this region.

Top Stories of 2006

- Global warming continued and the West Coast seas remained warm in early to mid-2006
- Storms of late 2006 were the worst to hit southern BC, cooling ocean waters in autumn
- "Warm-ocean pattern" of marine life continued into summer 2006
- Juvenile coho and seabirds along Vancouver Island rebounded from very low numbers
- Where were the herring? Numbers declined all through BC waters
- Where were the hake? Few found west of Vancouver Island for first time in several years
- Returns of sockeye salmon were weak due to poor ocean conditions when they were young
- Oxygen concentration continued to decline in subsurface waters in the northeast Pacific
- Strait of Georgia stayed warm in 2006
- Fraser River was warm for returning sockeye salmon
- Biggest plankton bloom ever observed in BC waters from space was in summer 2006

ASSESSMENT

Global warming continued, and the West Coast seas remained warm in early to mid-2006

Global warming of air and water temperatures continued during 2006 (Fig. 2). This ongoing and cumulative warming trend is beginning to exceed the warm conditions that were experienced during previous El Niño events. In 2006, the annual global air temperature (including land and ocean) was 0.54°C above average, making it the 5th warmest year since the start of coordinated measurements in 1880.

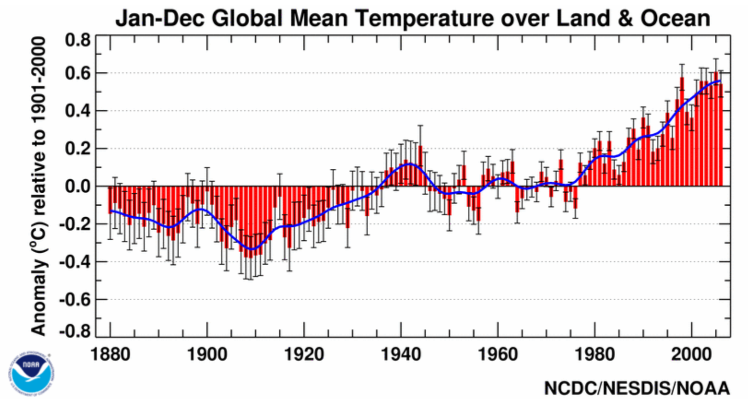


Fig. 2 Global annual average air temperatures over land and ocean from 1880 to 2006. Plot shows differences (anomalies) of annual temperatures from the average over the period 1880-2006. Plot courtesy of NOAA http://www.ncdc.noaa.gov/oa/climate/research/anomalies/anomalies.html

Along the Pacific coast of Canada, average annual **air** temperatures in 2006 were 0.5°C above average, making it the 23rd warmest year since 1948, and therefore close to this period's average. Precipitation along coastal BC in 2006 was 5.6% below average, making it the 18th driest year since 1948. The summer of 2006 was especially dry.

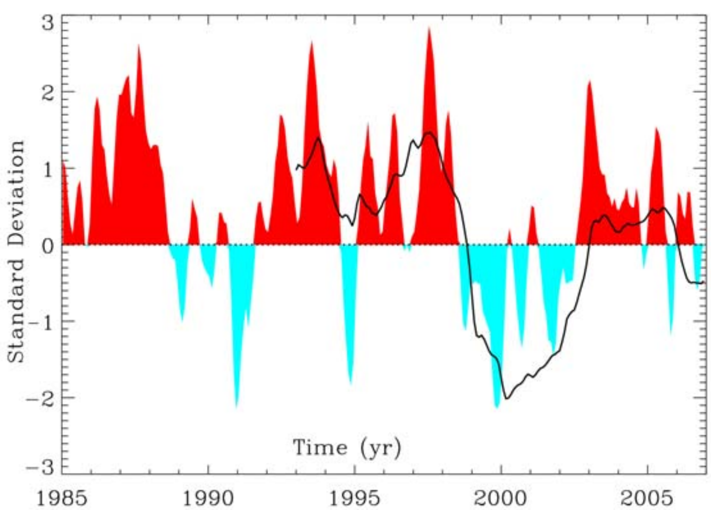


Figure 3. The solid red/blue curve gives the recent history of the Pacific Decadal Oscillation index (from http://jisao.washington.edu/pdo/PDO.latest). The solid black line is a measure of upper ocean variability over the NE Pacific based on the first principal component of sea surface height over the region [Source for figures 3 and 4: P. Cummins. See report on "Sea surface height over the northeast Pacific in 2006" in the Appendix.]

Within this general global warming, however, smaller regions can experience different conditions. The Pacific Decadal Oscillation (PDO) identifies oscillations in sea surface temperature across the North Pacific and has been used to define warm and cool regimes in the ocean climate of this region. From late 2002 to early 2006 the PDO was positive, bringing generally warmer waters to the Pacific Region of Canada. However, the PDO became negative in 2006, as noted in Figure 3, bringing cooler waters to the West Coast. This change in ocean conditions was also detected in sea surface heights in deep-sea waters. The black line in Figure 3 denotes the PDO pattern as detected in sea levels, which represent the amount of heat over greater depths than does the PDO and is therefore a more robust indicator of interannual changes. This signal became negative in 2006 and remained there to year-end. The extent to which this impacted British Columbia, Washington and Oregon waters is revealed in Figure 4. The two panels show sea surface height anomalies for the first and second quarters of 2006.

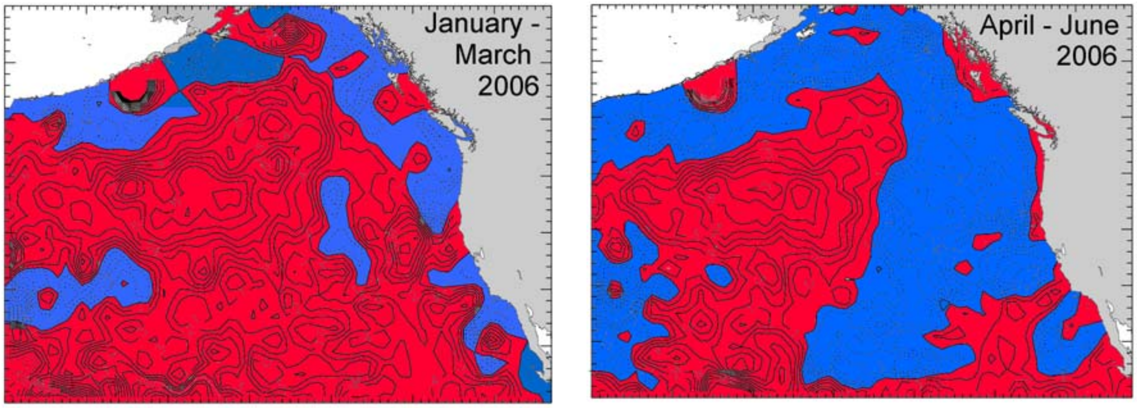


Figure 4. Differences in sea surface height from average conditions (anomalies) over the northeast Pacific Ocean (taken as 180-113°W; 25-60°N). The contour interval is 1 centimetre, with red denoting high sea level and blue denoting low sea level. Each panel presents a three-month average of monthly anomalies, based on measurements by TOPEX/POSEIDON and Jason-1 satellites. Measurements began in 1992 and monthly anomalies are determined relative to the years 1993 to 2006.

Notice how the region of high sea level in Figure 4 (red shading denoting higher-than-average values) shrank in size between the first and second quarters of 2006. This change marks the shift from positive PDO to negative PDO and from generally warm waters to cooler than normal temperatures in the eastern Gulf of Alaska. This pattern persisted to at least the end of 2006.

El Niño is a coupled atmosphere-ocean phenomenon that originates in the tropical Pacific Ocean and can affect global climate. The multivariate index used to identify El Niño conditions in the tropical Pacific indicated a weak El Niño occurred through the last half of 2006, but ended in early 2007. El Niño conditions often bring warmer winters to southern British Columbia, but the 2006 El Niño had little impact here. By April 2007, Pacific equatorial conditions were closer to those of La Niña (cool water) and were expected to remain in this state for several months.

Coastal sea levels were also average for the year 2006, but overall sea levels continue to rise by about 10 cm/century at Victoria and Prince Rupert. The southern coast of BC experienced relatively strong downwelling-favourable (blowing from the SE) winds during winter 2006, and stronger upwelling-favourable (blowing from the NW) winds during summer, compared with average conditions. The seasonal switch between these dominant winter-summer wind directions, called the Spring Transition and representing the start of the productive summer season, was near average (early April) in 2006 compared with 2005 which had the latest Spring Transition on record (June).

Temperature conditions at the surface and at depth along the outer coasts of BC during 2006 can be characterised into two states: near or above average during the first half of the year, followed by cooling from mid-summer to fall and winter 2006/2007. Figure 5 tracks this cooling at lighthouses and shore stations in British Columbia.

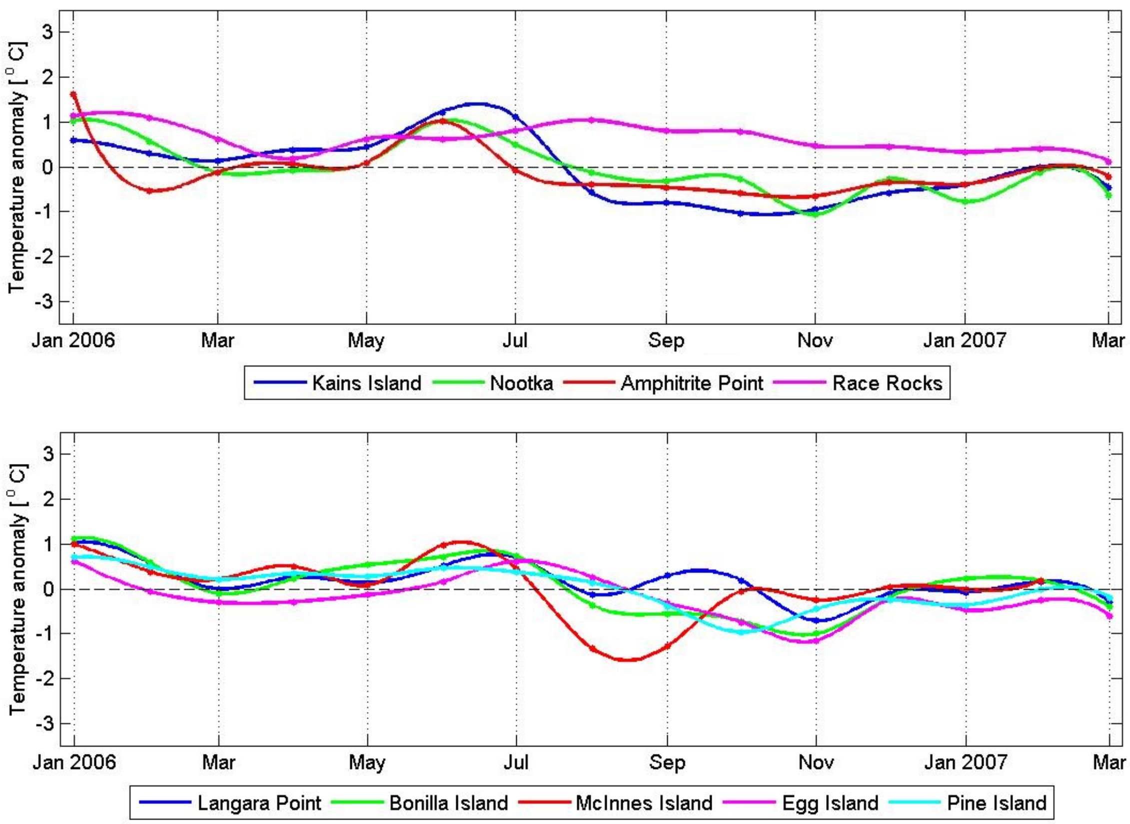


Figure 5. Sea surface temperature anomalies measured at lighthouse stations along the BC coast. Values are the differences of monthly average temperatures in 2006 and early 2007 from the long-term (generally since the 1930s) average for that month. Note that all locations had below average temperatures during fall 2006. [Source: P. Chandler, see the report on "Long-term temperature and salinity at BC Lighthouses" in the Appendix]

Storms in late 2006 were the worst to hit southern BC oceans, cooling these seas by early 2007

The significant weather story for coastal BC in 2006, however, was the series of frequent and very intense storms that occurred in late fall, mostly in November. Ten major storms hit southern Vancouver Island that month, approximately one every three days, and 149 weather warnings (for rain, snow, and/or wind) were issued, which is considerably more than in previous years. Windy conditions continued into December 2006, with monthly average wind speed records set or almost set (within 1%) at six meteorological buoys in coastal BC waters. Many residents spent nervous days and nights without power, often listening to falling trees.

These storms further cooled sea temperatures all along the outer BC coast, so that temperatures were below average by the end of 2006 and even cooler in early 2007 (Fig. 5). In addition, deep-sea temperatures plunged through late 2006 and early 2007, and by March 2007 the entire Gulf of Alaska was below normal temperature. The blue area near BC and Alaska in Figure 6 shows how unusually cold our local ocean was in March 2007.

As a result, the vertical stratification of the Gulf of Alaska (between the surface and 75 m depth) was close to average, after several years of very strong stratification that likely reduced the vertical mixing of nutrients into the surface layers. The increased vertical mixing appears to have carried more essential plant nutrients from deep to near-surface waters in the NE Pacific, with nitrate concentrations that were measured in February 2007 being typical of a cool winter with deep vertical mixing. This may lead to stronger and longer-lasting plankton growth in deep sea waters in spring 2007.

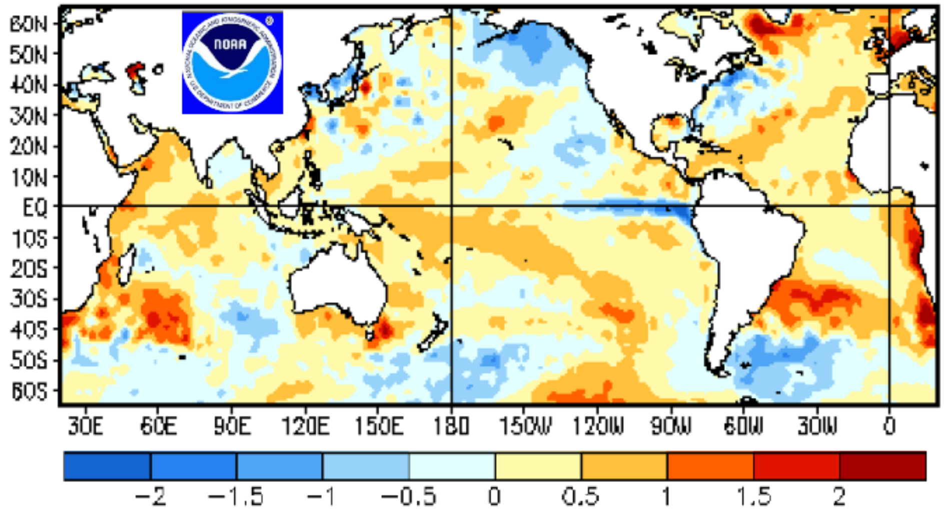


Figure 6. Sea surface temperature anomalies (Degrees Celsius) for 11 March 2007 to 7 April 2007. Although most regions were warmer, the entire Gulf of Alaska was significantly cooler than normal. [Source: B. Crawford, see report on "Cooling ocean from summer 2005 to winter 2006/2007" in Appendix. Figure source is http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf]

"Warm-ocean pattern" of marine life continued into summer 2006

Marine life in deep-sea waters in the Gulf of Alaska maintained many of the warm-water features of the preceding two years. The timing of the development of the large sub-arctic copepods, which are important food items for higher animals such as fish and whales, was early in 2006 (April-May) and similar to that in 2004 and 2005. This happens when conditions are warmer, and is in contrast to 2000-2003 when conditions were cooler and copepod development was later (June). Closer to shore, the amount of phytoplankton, which forms the base of the main food web, has been monitored along the BC coast since 1997 using satellites. Monthly data indicate a somewhat later start to the spring bloom (May) in 2006 compared with previous years (April).

Most marine animals along the outer coast of BC during 2006 continued to be affected by the very warm conditions of 2005 and the warm conditions of early 2006. A composite analysis including zooplankton, temperature, and predatory fish and seabird species suggests that 2005 was a very bad year for the productivity and survival of many BC species (comparable to conditions during the 1997/1998 El Niño), whereas 2006 was near average but with mixed signals of cooler temperatures and continued "warm ocean" effects on marine life. The species composition and seasonal development of zooplankton, which are critical components of the marine food web and important food for many fishes and seabirds, continued in a "warm ocean" pattern off Vancouver Island. There were high abundances in BC waters of zooplankton that are normally centered off California (Fig. 7) and relatively low abundances of euphausiids, another key group of zooplankton which are important as food for fish. In addition, the peak occurrences of the typical cold water species (copepods) in the surface waters of BC were among the earliest recorded (early May), which is consistent with warm ocean conditions. The amount of smooth pink shrimp off Vancouver Island continued to be low, also consistent with warm conditions.

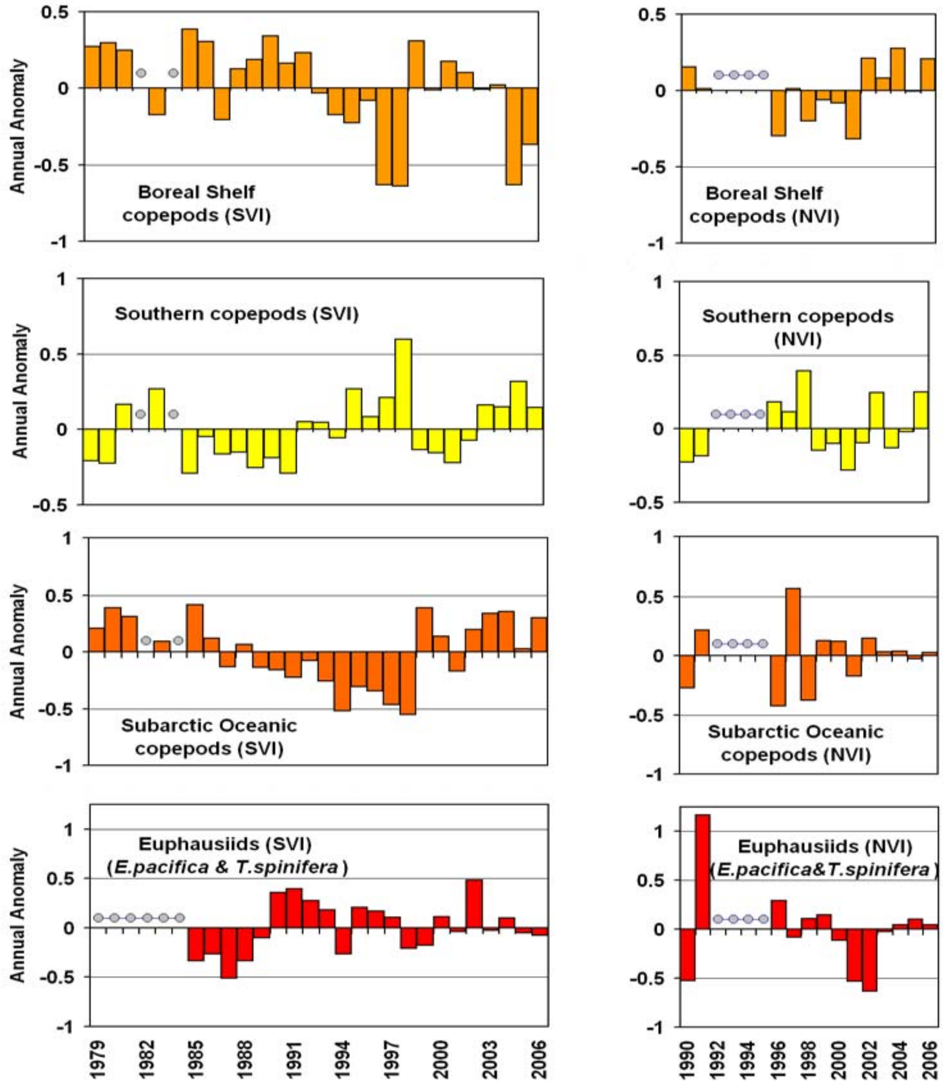


Figure 7. Time series of differences of zooplankton biomass from their average values (measured since 1979) for four groups of zooplankton off southern Vancouver Island (left) and northern Vancouver Island (right). [Source: D. Mackas; see section on "Zooplankton in a 'warm-ocean' pattern off Vancouver Island, despite cooling in 2006" in the Appendix]

The patterns that were observed during 2006 in Canadian waters are similar to those observed to the south off Oregon until July 2006. Both southern Vancouver Island and Oregon marine waters are part of the California Current large marine ecosystem, so some similarity of events is to be expected. Warmer-than-average temperatures occurred off Oregon from late 2002 until June 2006. Beginning in July 2006, sea surface temperatures became cooler than normal and remained below normal into spring 2007. Initial observations of zooplankton species composition off Oregon in late 2006 and early spring 2007 indicate the zooplankton are dominated by species which prefer colder water; this represents an important change from previous conditions which were dominated by warm water species. If this shift took place along Vancouver Island, it happened after the final plankton survey of the year in September 2006.

Juvenile coho and seabirds rebounded from very low numbers in 2005 along Vancouver Island

The growth of juvenile coho salmon off Vancouver Island and SE Alaska has been monitored during early summer and late fall surveys since 1998. Overall, marine survival of coho salmon off the west coast of Vancouver Island is expected to be high when the growth rates of juvenile coho are high. The growth of juvenile coho in 2006 off Vancouver Island increased from the lowest recorded in 2005 to near the 1998-2004 average (Fig. 8). Surveys for yearling coho and Chinook salmon off southern Washington State and Oregon in summer had higher catches of these species in 2006 compared with 2004 and 2005.

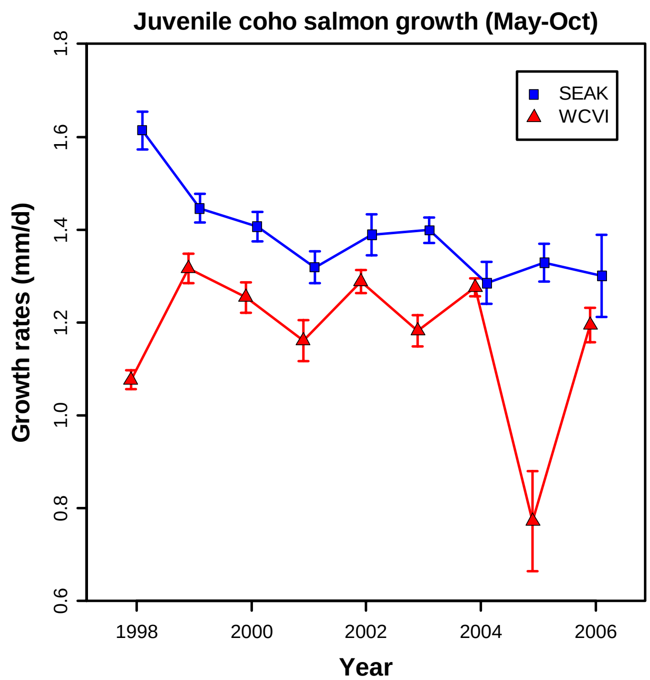
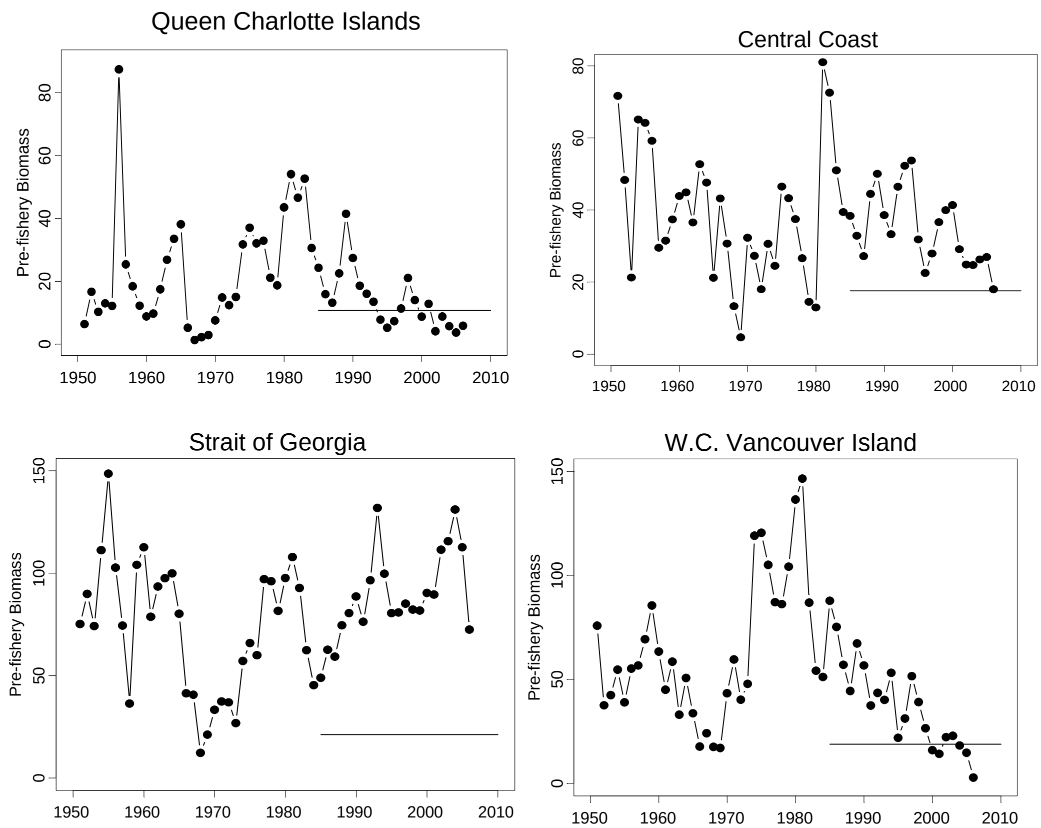


Figure 8. Growth rates (May-October) of juvenile coho salmon off the west coast of Vancouver Island (WCVI red triangles) and Southeast Alaska (SEAK blue squares). Juvenile coho generally grow faster off SE Alaska, and growth rates appear to have been relatively stable there since 2004, in comparison with the west coast of Vancouver Island. [Source: M. Trudel; see report on "Average growth conditions for coho salmon in southern BC" in the Appendix]

Marine birds are good indicators of the state of marine ecosystems because they are readily observed and because they feed on a range of species from zooplankton to fish. Seabird breeding success is also closely tied to the availability of key prey and therefore can vary widely among years, depending on ocean conditions and prey concentrations. In spring 2006, the reproductive timing and breeding success of sea birds off northern Vancouver Island were close to their long-term (since 1975) averages. This indicates that food availability and feeding conditions during spring 2006 were about normal. Breeding success for these birds in 2006 was also close to their long-term averages, in contrast to the worst ever breeding year of 2005.

Where were the herring? Numbers declined through BC waters

Small pelagic fishes such as Pacific herring and Pacific sardine are important food for many species of larger fishes. Herring spawn in all BC waters and prefer cooler conditions; sardine spawn mostly off of California and migrate into BC waters with warm conditions. The total pre-fishery biomass of herring in all regions of BC has declined over the past few years. This declining abundance is related to successive years of poor recruitment, which continued in 2006. Herring biomass off the west coast of Vancouver Island in 2006 was very low, having declined further from the low biomass recorded in 2005 (Fig. 9). This low biomass is related to successive years of poor recruitment, possibly caused by warm ocean conditions, low zooplankton food, and increased predation by Pacific hake. Despite declines in pre-fishery biomass in the past two



years, the Strait of Georgia herring fishery is reasonably healthy.

Figure 9. Pre-fishery biomass (1000 tonnes) of Pacific herring in four of the five management areas of British Columbia. [Source: J. Schweigert; see report on "Small pelagic fishes" in the Appendix]

Where were the hake? Few were found west of Vancouver Island for first time in several years.

Pacific hake is an important predatory and commercial fish that spawns off California and migrates into BC waters each summer; more hake migrate further north when conditions are warmer. Although the overall biomass of Pacific hake appears to be increasing because of strong recruitment in 1999, their distribution in BC in 2006 was unusual. They arrived in Canadian waters in May and supported the usual fishery off southern Vancouver Island, but by mid-June these fish had moved north and were being fished in Queen Charlotte Sound. Their distribution reversed the usual state of more hake off Vancouver Island than in northern BC. This behaviour may be related to the reduced abundances of their preferred euphausiid prey, and perhaps the cooling conditions that started during summer 2006.

Returns of sockeye salmon were weak because of poor ocean conditions when they were young

Returns of sockeye salmon in 2006 to the Central and South Coasts of BC were below average, but near to above-average for North BC coast and Alaska Trans-boundary stocks, respectively (Figure 10). This reflected the ocean conditions of southern BC waters and cooler conditions in the north at the time they went to sea as smolts in 2003 and 2004. Barkley Sound sockeye salmon returns were well below their long-term averages in both 2005 and 2006, as anticipated by high sea temperatures and El Niño-like conditions. Sockeye salmon returns in 2006 to Rivers and Smith Inlets on the Central BC coast were also below average.

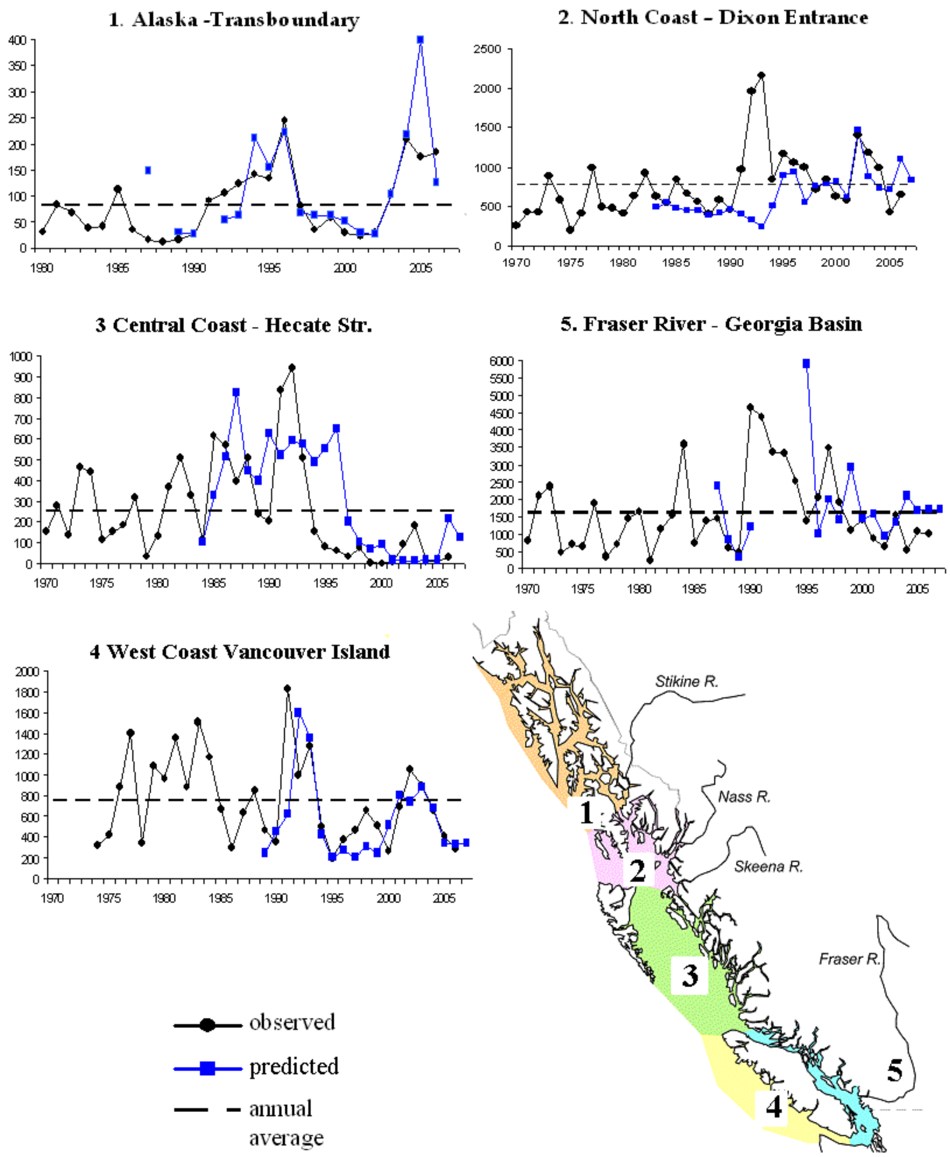


Figure 10. Trends in total returns and forecasts for British Columbia sockeye index stocks, 1970 - 2006, including: 1. Tahltan, 2. Nass, 3. Smith's Inlet, 4. Barkley Sound and 5. Chilko Lake sockeye salmon. Y-axis represents returns in thousands of fish. [Source: Kim Hyatt. See report "Sockeye salmon index stocks" in Appendix]

Oxygen declined in summer coastal waters

Oxygen levels have declined by 22% in subsurface waters (100 to 600 m) at Ocean Station P (P26) in the past 50 years. This decline is accompanied by a temperature increase that is somewhat greater than that observed in the global atmosphere. Coastal waters from California to southern Alaska are seeing similar or higher rates of oxygen decline in waters found between 100 and 400 m below the ocean surface (e.g. Fig. 11). At station P4 (also on Line P, Fig. 1) on the continental slope of southern BC, oxygen is declining at about 1% per year at depths of ~250 m, faster than is being observed at P26. The northward flowing California Undercurrent waters are losing oxygen at a rate similar to P4 and strongly influence the southern coast of BC.

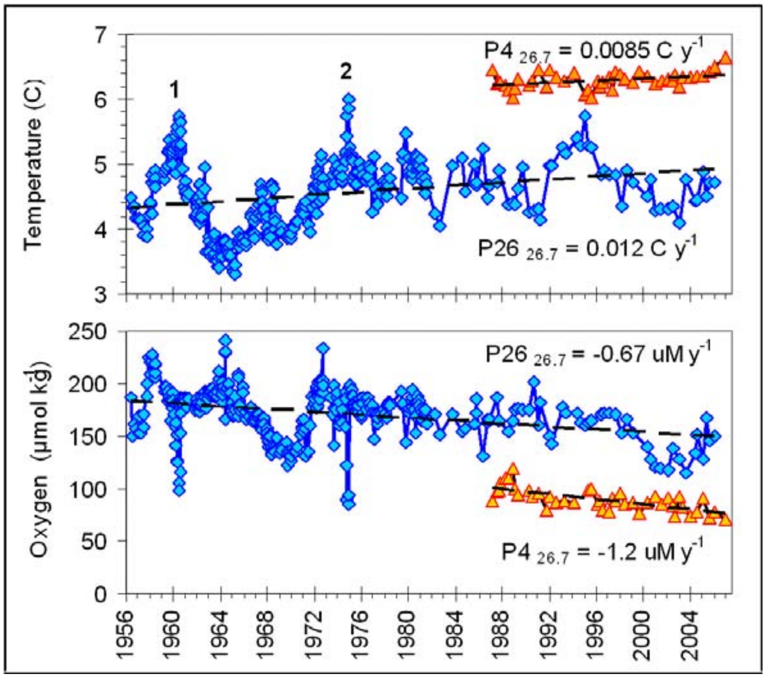


Figure 11. Oxygen and temperature on the 26.7 isopycnal surface at stations P4 and P26 on Line P. Note the steady decline in oxygen at P4 since monitoring began in 1988. Two mesoscale eddies (1 & 2) at P26 are identified in the upper panel. (Source: F. Whitney and M. Robert; see report on "Open ocean observations from Line P and Skaugran surveys" in Appendix)

Deadly low oxygen levels were observed on the Oregon continental shelf in 2006 and in the previous four years, but new in 2006 was a likely dead zone on the continental shelf west of the Olympic Peninsula and much closer to Canadian waters (http://www.piscoweb.org/files/archive-august-11-2006.pdf). This event was the closest occurrence of hypoxia to the continental slope waters of BC ever observed, although marine biota have been killed by low oxygen in coastal inlets like Howe Sound when annual flushing of basin waters does not occur. Because we have an incomplete understanding of processes that cause declines of oxygen concentrations off Oregon and Washington to lethal levels, we cannot rule out such events reaching Canadian waters in future years. Low oxygen levels kill bottom life such as crabs and clams. Fish usually escape by rising to shallower depths, although fish kills were recorded in Washington when low oxygen levels were transported to the surface in summer 2006, and about 33% of the ling cod stock in the lower reaches of Hood Canal in Washington State were killed when they lost their shallow water refuge during wind induced upwelling in 2006.

Strait of Georgia stayed warm in 2006

The Strait of Georgia and Georgia Basin are the major exception to the pattern of warm conditions during early 2006 followed by cool conditions in late 2006. The warm conditions that began in the Strait of Georgia in 2003 continued during 2006, with the heat penetrating to deeper depths. Temperatures, however, were slightly cooler than the excessive warm conditions of 2005 (Fig. 12). Past observations suggest that conditions in the Strait of Georgia lag those offshore by about 1 year, therefore the warm conditions in the Strait of Georgia in 2006 are expected to cool further during 2007.

Sampling of zooplankton in spring in the Strait of Georgia suggests that abundances of the major large copepod *Neocalanus plumchrus* in 2006 and 2007 were the third and second lowest, respectively, observed since 2001. The lowest abundance was observed in 2005. Pacific herring had been doing well in the Strait of Georgia until 2004, but the population biomass declined in 2005 and again in 2006 (Fig. 9), which appears to be due to the declining recruitment of young herring of the past few years. Some salmon populations in the Georgia Basin did well in 2006, whereas others did poorly, depending on when during 2005 and 2006 they entered the marine environment and the growth conditions that they experienced. The size of juvenile coho and their catches in surveys in the Strait of Georgia during 2006 were among the highest observed in the past 10 years, suggesting they should experience improved survival. In addition, there continues to be a decline in the percentage of hatchery-reared coho and an increase of wild coho in these surveys. This may reflect improved survival of wild coho which enter the Strait of Georgia earlier (and therefore into a more productive feeding environment), than hatchery-reared coho which are released into the ocean later in each year.

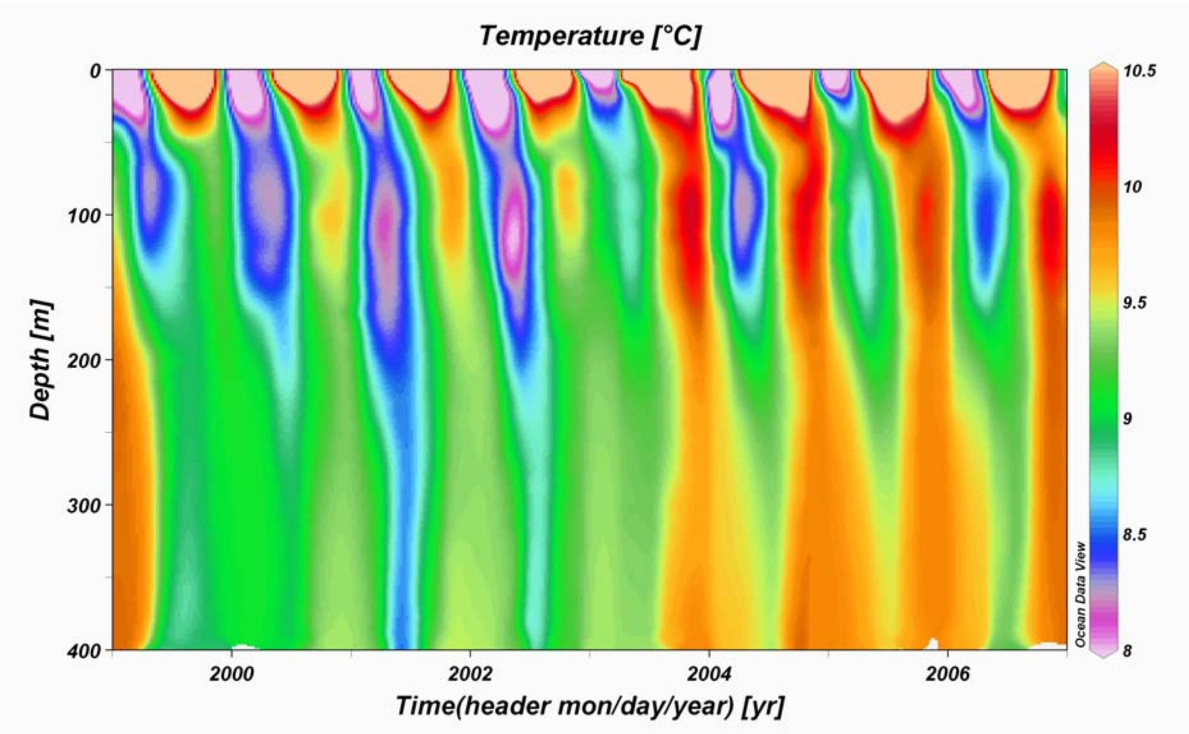


Figure 12. Strait of Georgia temperature by time (bottom axis) and depth (left axis). Colours display temperature, which has been warm during summers over the past few years. [Source: D. Masson; see report on "Strait of Georgia" in the Appendix]

Fraser River was warm for returning sockeye salmon

In the Fraser River, high flows and warm water can be detrimental to the spawning success of sockeye salmon during up-river migrations to their spawning grounds. 2006 was an exceptional year in the Fraser River, with temperatures well-above average throughout the entire salmon migration season. In addition, flows peaked early (28 May) but fell rapidly to record or near-record lows which lasted until early November. These adverse conditions caused elevated mortalities to summer and late-run sockeye salmon which were above the long-term average but lower than the highest values observed over the past 10 years.

Plankton bloom in summer 2006 was largest ever observed in BC waters from space

BC coastal waters were in the world media spotlight after NASA posted an image collected by their MODIS satellite on June 25, 2006, showing an extensive bloom west of Vancouver Island and Washington State (Fig. 13). Samples collected from the Canadian Coast Guard Ship *John P. Tully* confirm that this was due to a coccolithophore species of phytoplankton. Visual observations described the patterns in the water as very dramatic. This was the largest such bloom ever observed in these waters. These phytoplankton are not the harmful type that produce toxic conditions along the coast.

Figure 13 A "true colour" image of the ocean surface taken by the NASA satellite MODIS on 25 June 2006. (Source: J. Gower; see report on "Bright plankton blooms off the BC coast" in the Appendix)

Outlook for 2007

The cooling sea temperatures at the end of 2006 and which have continued into early 2007 suggest an end to the very warm conditions of 2004 and 2005. In addition, the U.S. Climate Prediction Center's El Niño bulletin (issued 10 May 2007; see footnote[1]) indicates that a transition from neutral El Niño to La Niña conditions is possible within the next 2 to 3 months. The Pacific Decadal Oscillation is also expected to be below average for the next several months[2]. This is all consistent with an outlook for cool sea temperatures to persist well into 2007. In addition, the cool temperatures, strong vertical mixing and higher nutrient concentrations in the Gulf of Alaska in winter 2006-2007 should permit increased primary production during spring 2007, if the weather is relatively clear and calm. If these cool conditions remain throughout 2007, and the primary productivity is high in spring, they imply a decline in southern zooplankton and improved growth conditions off BC for large subarctic copepods, Pacific herring, seabirds, and most salmon species that spend time in the waters of the BC continental shelf. However, the results of these improved growth conditions will not be observed until those species return to spawn in 2008-2010.

The outlook for cool water fish in 2007 and 2008 remains dominated by the poor growth conditions these animals experienced during 2005. Off the west coast of Vancouver Island, herring is at an historically low level. Recent conditions have been unfavourable for herring survival, and continued weak recruitment to the stock over the next couple of years is expected, although their growth may improve if cooler conditions bring more cold-water zooplankton. On the Central and North coasts of BC, the increased abundances of Pacific hake in 2005 and 2006 may have negatively affected herring recruitment and stock biomass, suggesting that herring declines in northern BC waters may persist into 2008.

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.pdf

[2] SST Anomalies Forecast data provided by the CIRES/Climate Diagnostics Center and Physical Science Division/ESRL/NOAA, Boulder, Colorado (Alexander, M.A., Matrosova, L., Penland, C., Scott, J.D., and Chang, P. (2006) Forecasting Pacific SSTs: Linear Inverse Model Predictions of the PDO) from their Web site at http://www.esrl.noaa.gov/psd/.

Pacific salmon abundance forecasts have been made for populations returning to many major rivers and fisheries throughout Pacific Region by DFO for decades. Uncertainties in forecasts occur because of real variations in fish survival and environmental conditions, and uncertainties in data and models used for forecasting. Index salmon stocks entering continental shelf waters with strong ocean influences (such as the Central Coast and west coast of Vancouver Island) appear to be affected more strongly by La Niña (cool conditions leading to better survival) and El Niño (warm conditions leading to poor survival) than stocks entering protected inside and Strait of Georgia waters. As a result of the persistent El Niño-like (warm) conditions during 2003 to 2005, salmon returns are expected to remain below average in 2007 for Central Coast and west coast Vancouver Island sockeye, Carnation Creek coho, and Robertson Creek coho and Chinook. Returns of sockeye salmon to the west coast of Vancouver Island may improve in 2008 if cool conditions continue through 2007.

The Strait of Georgia experienced warm conditions through 2006, although the Strait was cooler than during 2005. The Strait of Georgia tends to lag conditions on the continental shelf of BC by about one year, therefore cooling of the Strait of Georgia is expected to continue through 2007. The declining trend in herring recruitment during the past four years will result in reduced abundances of herring over the next few years.

There are large variations in estimates of salmon survival among sockeye populations from the Fraser River system. This suggests that environmental factors within the Fraser River system and perhaps the different times that these fish enter the Strait of Georgia as juveniles may cause much of this variability in survival. For example, fisheries research cruises in 2005 found the juvenile Fraser River sockeye to be larger than normal in size, so returns could be higher than normal based only on this factor. This sampling does not take into account variations among individual Fraser River sockeye stocks, because the stock to which these juveniles belonged could not be determined. Therefore, we cannot predict which of the many sockeye stocks of the Fraser River may have large returns.

A different approach uses sea temperatures in the Gulf of Alaska and long time series of data from the Chilko Lake stock of sockeye salmon in the Fraser River system. A study of the impact of ocean temperatures on the survival of this stock suggests they fare better when outgoing juveniles encounter cooler-than-normal water in the Gulf of Alaska, and when the returning adults swim through a warmer-than-normal ocean. Based only on this factor, it is expected that numbers of returning Chilko Lake sockeye in 2007 will be lower than normal, since the ocean was very warm in 2005, and is expected to remain cool in 2007.

Juvenile coho in the Strait of Georgia return from the ocean one year before juvenile Chilko Lake sockeye, so the number of returning coho can be used to predict the impact of marine conditions on this sockeye run. This factor also predicts low returns of Chilko Lake sockeye in 2007, since the number of coho returning in 2006 was very low.

However, it is difficult to extrapolate this 2007 prediction of Chilko Lake sockeye numbers to other Fraser river sockeye. A detailed study compared the number of Fraser River sockeye spawning in each stream with the number of their progeny returning from the ocean to spawn as adults, and found large variations from stream to stream over the past 50 years. Climate change impacts on salmon will increase uncertainties in pre-season abundance forecasts. A significant challenge is to understand how environmental and ecosystem processes affect the productivity of salmon under these changing conditions.

Contributors to this Report

Sonia Batten	SAHFOS[1]	Roy Hourston	DFO	Angelica Peña	DFO
Richard Beamish	DFO[2]	Karen Hunter	DFO	Ian Perry (Editor)	DFO
Jim Boutillier	DFO	Kim Hyatt	DFO	Bill Peterson	NMFS
Edmundo Casillas	NMFS[3]	Jackie King	DFO	Paul Rankin	DFO
Al Cass	DFO	Dave Mackas	DFO	Marie Robert	DFO
Peter Chandler	DFO	Diane Masson	DFO	Jake Schweigert	DFO
Bill Crawford (Editor)	DFO	Gordon McFarlane	DFO	Margot Stockwell	DFO
Patrick Cummins	DFO	Skip McKinnell	PICES[6]	Rusty Sweeting	DFO
John Dower	U.Vic[4]	Cheryl Morgan	NMFS	Ron Tanasichuk	DFO
Howard Freeland	DFO	John Morrison	DFO	Richard Thomson	DFO
Jim Gower	DFO	Chrys Neville	DFO	Marc Trudel	DFO
Mark Hipfner	EC[5]	Ian Okabe	EC	Frank Whitney	DFO

[1]Sir Alister Hardy Foundation for Ocean Science, Plymouth, UK
[2]Fisheries and Oceans Canada
[3]United States National Marine Fisheries Service
[4]University of Victoria
[5]Environment Canada
[6]PICES is North Pacific Marine Sciences Organization

SOURCES OF INFORMATION

On-Line access to this full report with appendices:
http://www.pac.dfo-mpo.gc.ca/sci/psarc/OSRs/Ocean_SSR_e.htm

DFO Links
Ocean Science Division : http://www-sci.pac.dfo-mpo.gc.ca/osap/default_e.htm
Marine Ecosystems and Aquaculture Division: http://www.pac.dfo-mpo.gc.ca/sci/aqua/default_e.htm
Salmon and Freshwater Ecosystems Division: http://www-sci.pac.dfo-mpo.gc.ca/fwh/index_e.htm
Canadian Hydrographic Service: http://www-sci.pac.dfo-mpo.gc.ca/charts/tides/home_e.htm
Pacific Scientific Advice Review Committee: http://www.pac.dfo-mpo.gc.ca/sci/psarc/Default_e.htm

Environment Canada
Green Lane: http://www.ec.gc.ca/default.asp?lang=En&n=FD9B0E51-1

National Marine Fisheries Service: http://www.nmfs.noaa.gov/

FOR MORE INFORMATION

Contact: Bill Crawford
Institute of Ocean Sciences
Fisheries and Oceans Canada
P.O. Box 6000
Sidney, B.C. V8L 4B2
Tel: 250-363-6369
Fax: 250-363-6746
E-Mail: CrawfordB@pac.dfo-mpo.gc.ca

or

Ian Perry
Pacific Biological Station
Fisheries and Oceans Canada
3190 Hammond Bay Road
Nanaimo, B.C. V9T 6N7
Tel: 250-756-7137
Fax: 250-756-7053
E-Mail: PerryI@pac.dfo-mpo.gc.ca

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Centre for Science Advice (CSA)
Pacific Region
Fisheries and Oceans Canada
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, British Columbia
Telephone: (250) 756-7208
Fax: (250) 756-7209
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