2004 Pacific Region State of the Ocean

Summary

Warm surface waters spread all through the British Columbia continental shelf in spring and summer; in some cases they set record highs, with major impacts. For example, Fraser River waters reached record high temperatures in August. These warm flows were a contributing factor to the low sockeye spawning returns observed in 2004. Low-oxygen waters, at 200 metres depth or more, crept toward the BC coast from mid-Gulf of Alaska. Hake were sighted in Dixon Entrance, much farther north than in 2003. Southern species of zooplankton increased in abundance and the dominant northern oceanic zooplankton species bloomed earlier in spring. Cold water species such as shrimp declined in numbers off Vancouver Island. For the first time an exotic (Atlantic origin) zooplankton species *Acartia tonsa* successfully invaded BC waters on the open continental shelf. Many jumbo squid were observed in BC and Alaska, a first for this warm-water species. Herring presented a mixed response to warming. Hecate Strait and west coast Vancouver Island stocks recruited at lower levels and the Georgia Strait stocks recruited at average levels. Juvenile coho grew larger in Northern BC and west of Vancouver Island. It was a successful year for breeding auklets on Triangle Island north of Vancouver Island.

We attribute this summer warming to abnormal weather in British Columbia and the Gulf of Alaska in spring and summer 2004, as well as to general warming of the global lands and oceans. Global land and ocean temperatures were close to record highs in 2004.

Background

This report, the sixth to date, collects individual observations and interpretations by scientists into a single summary publication. Almost all observations rely on federal funding for continuing observations, and for this we acknowledge financial support from Fisheries and Oceans Canada and Environment Canada, and ship time provided by Canadian Coast Guard. Contributing scientists are listed below. All are members of the Fisheries and Oceanography Working Group (FOWG) of the Pacific Scientific Advice Review Committee (PSARC).

Bill Crawford (Chair)	DFO	Moira Galbraith	DFO	Patrick Cummins	DFO
Chrys Neville	DFO	Jake Schweigert	DFO	Richard Beamish	DFO
Dave Mackas	DFO	Jim Cosgrove	RBC Museum	Richard Thomson	DFO
David Welch	DFO	John Morrison	DFO	Ron Perkin	DFO
Diane Masson	DFO	Ken Cooke	DFO	Ron Tanasichuk	DFO
Frank Whitney	DFO	Kim Hyatt	DFO	Roy Hourston	DFO
Howard Freeland	DFO	Marie Robert	DFO	Ruston Sweeting	DFO
Ian Perry	DFO	Mark Hipfner	EC	Skip McKinnell	PICES
Jackie King	DFO	Marc Trudel	DFO	Sonia Batten	SAHRF

DFO Links: Past Ocean Status Reports | Ocean Science Division
Marine Ecosystems and Aquaculture Division | Canadian Hydrographic Service
Salmon and Freshwater Ecosystems Division
Environment Canada Link: Green Lane
Royal BC Museum Link: Royal BC Museum

Table of Contents

Global Climate and North Pacific Indices

Warmest land temperature ever recorded, warm ocean too

The surface temperature of the earth is usually quoted as the best indicator of climate. It varies on all time scales and from a variety of causes, both natural and man-made. Accurate global temperature records can be used to track temperatures for only about 150 years into the past. For intermediate time scales, bore-holes and tree rings can be used and various kinds of sediment records have been used to span the longer time scales. Recently, Moberg et al. (*Nature* 433, 613-617, 2005) published a reconstruction of the temperature record going back to the year AD 1.

An interesting conclusion from this work is that the temperature difference between the Little Ice Age (~1600 AD) and the Medieval Warm Period (~1050 AD) was about 0.7 ºC, within the uncertainty of previous estimates, but more than previously thought. If this methodology is verified, it gives us an idea of the magnitude of temperature changes that can produce effects like glacier advances and crop failures that have been documented in our history.

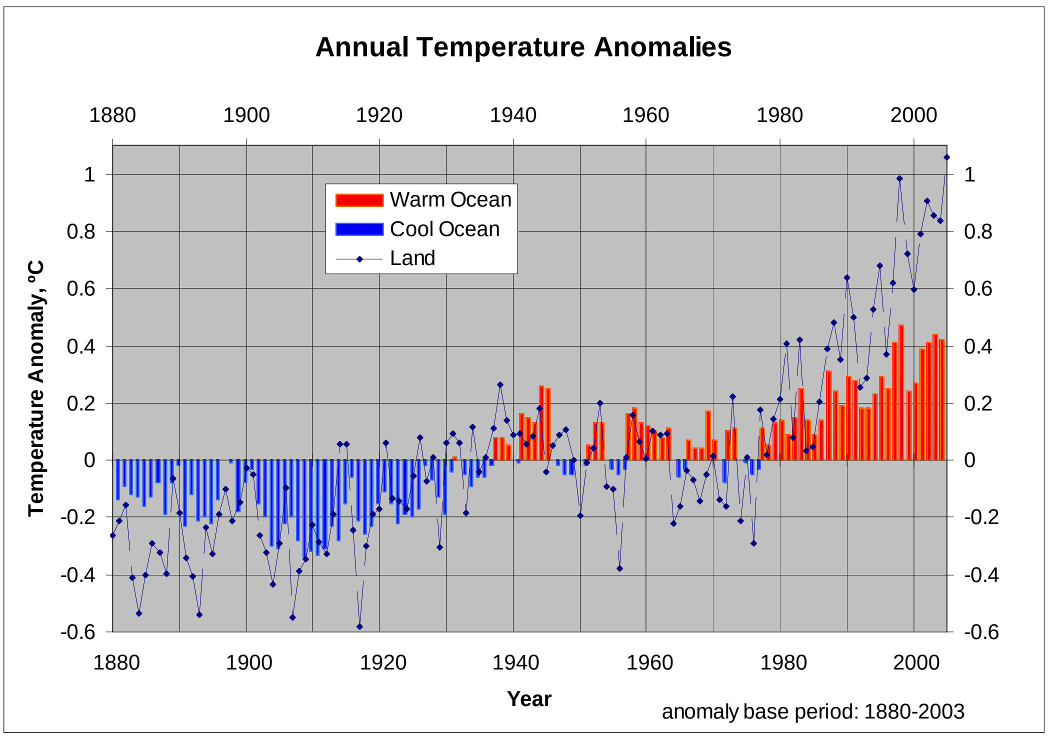


Figure 1: Global temperature anomalies relative to the 1880 – 2003 mean.

Compare that temperature change with the changes in the recent instrument record in the figure above. The land and ocean anomalies are plotted separately. In the first part of the record, the world was still climbing out of the Little Ice Age so an increasing temperature is not surprising. However, since 1970, global land temperatures have climbed by about 1 ºC, which is more than the difference between the climate extremes of the past 2000 years. Although short term changes like this can be viewed as noise on a long-term record, the size of the change is extraordinary. If the ocean continues to warm as the land has, we can expect to see invasions of warm water species, coral reef damage and loss of habitat for cold water species such as salmon.

Links Global climate in Ocean Status Report 2003 (pg 11)
NODC Land and Sea Temperatures
DFO Contact: Ron Perkin

Pacific Decadal Oscillation weakened in early 2004

The Pacific Decadal Oscillation (PDO) is defined as the first component of an EOF analysis of November through March sea surface temperature anomalies for the Pacific Ocean to the north of 20°N latitude (Figure 1, PC1) It has generally been associated with only two states; a 'positive phase' that is associated with warming of surface waters in the eastern North Pacific and cooling in the central and western North Pacific; and a 'negative phase' with opposite thermal patterns. These two states are correlated to an east-west spatial pattern in sea surface temperature. Recently, climatologists have used the second component to represent the north-south spatial pattern in sea surface temperature (Fig. 1, PC2) (Bond *et al.*, 2003). In 1977, the PDO (Figure 1, PC1) switched from a negative east-west phase to a positive east-west phase. Since 1990, the PC2 (Figure 1) has exhibited a greater amplitude of variability and is the dominant pattern. The PC2 remained negative throughout the 1990s, and shifted to a positive phase in 1998. It has remained in a positive north-south phase through 2004, though values have been moderate, or closer to zero (King, 2005).

In winter 2003-2004 the North Pacific was warm, yet the pattern of warmth did not resemble either of the PDO weather patterns. Information on the PDO is provided by Nathan Mantua of the University of Washington, through this Internet site: http://jisao.washington.edu/pdo/

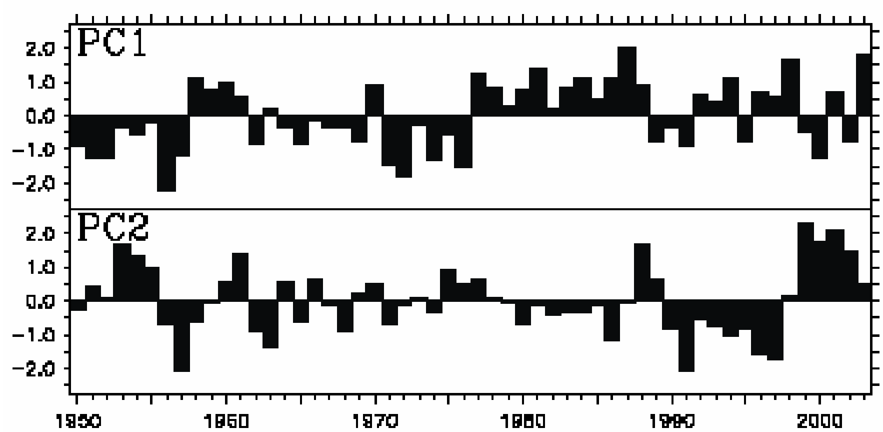


Figure 1: The first component (PC1, top) from a principal component analysis of North Pacific winter (November-March) sea surface temperature fields north of 20°N, which represents the Pacific Decadal Oscillation Index (PDO) pattern. The second component (PC2, bottom) is a second pattern of sea surface temperature variability and shows a shift to a large amplitude since the 1990s, with a shift to positive values in 1998. From Bond et al., 2003.

Bond, N.A., J.E. Overland, M. Spillane and P. Stabeno. 2003. Recent shifts in the state of the North Pacific. Geo. Res. Lett. 30: 2183-2186.

King, J.R. (ed.). 2005. Report of the Study Group on Fisheries and Ecosystem Responses to Recent Regime Shifts. PICES Sci. Rep. No. 28. 163 pp.

Links Pacific Decadal Oscillation in Ocean Status 2003 Report (pg 13)
Story on the two PDO modes
DFO Contact: Jackie King

Aleutian Low Pressure Index (ALPI) reveals a persistent Aleutian Low

The Aleutian Low atmospheric pressure system is a semi-permanent feature of the North Pacific whose relative intensity has been linked to patterns in marine productivity (Beamish *et al.*, 1997). Following the 1989 regime shift, the Aleutian Low exhibited a moderate intensity as measured by the Aleutian Low Pressure Index (ALPI, Figure 1). In 1998, the Aleutian Low was extremely intense and ALPI remained positive through 2002. In 2002, the ALPI value was extremely high, indicating a strong Aleutian Low. While the ALPI value in 2003 was not as high as 2002, it still reflects of a strong Aleutian Low (Figure 1).

The Aleutian Low in 2004 was similar to 2003 (Figure 1). Overall, the ALPI suggests that through 2004, the regime initiated in 1998 is characterized by a high degree of variability, but by relatively intense Aleutian Lows.

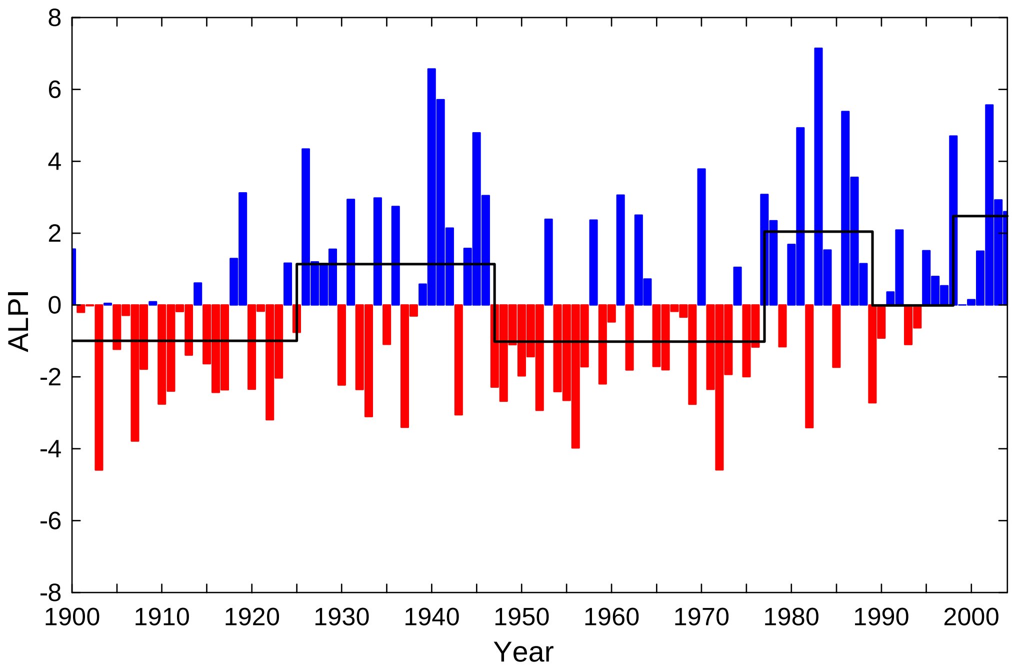


Figure 1: The Aleutian Low Pressure Index (ALPI). Solid line represents the average index value for a given regime period. Since the 1998 regime shift, the Aleutian Low Pressure system has been relatively strong as indicated by the continuance of mainly large positive values. Data available from http://www.pac.dfo-mpo.gc.ca/sci/sa-mfpd/climate/clm_indx_alpi.htm.

Beamish, R.J., C.E. Neville and A.J. Cass. 1997. Production of Fraser River sockeye salmon (*Oncorhynchus nerka*) in relation to decadal-scale changes in the climate and the ocean. Can. J. Fish. Aquat. Sci. 54: 543-554.

Links ALPI in Ocean Status 2003 Report (p15)
ALPI background information
DFO Contact: Jackie King

Atmospheric Forcing Index (AFI) remained positive through 2004

The Atmospheric Forcing Index (AFI) is a composite index based on three aspects of climate and ocean conditions: the Aleutian Low pressure system, the spatial sea surface temperature patterns captured by PC1 of the Pacific Decadal Oscillation index, and the North Pacific wide atmospheric circulation patterns. (McFarlane et al., 2000).

The AFI has been linked to decadal-scale changes in environmental conditions and marine fish productivity. In general, positive values represent intense Aleutian lows, above average frequency of westerly and southwesterly winds, cooling of sea surface temperatures in the central North Pacific in winter, and warming within North American coastal water in winter.

Since the 1998 regime shift, AFI has been dominated by positive values (Figure 1). This condition persisted through 2004. The AFI has been linked to decadal-scale changes in environmental conditions and marine fish productivity such as changes in the abundance and ocean survival of salmon (*Onchorhynchus* spp.), distribution and spawning behaviour of hake (*Merluccius productus*) and sardines (*Sardinops sagax*) and in recruitment patterns of several groundfish species.

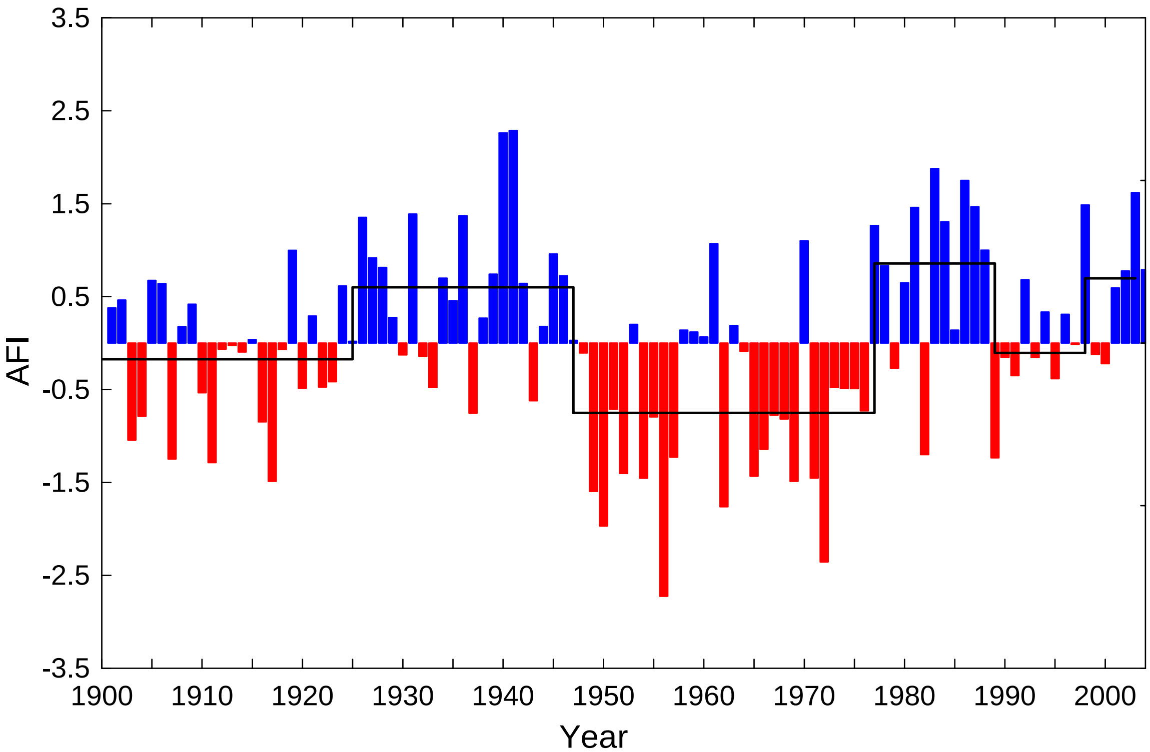


Figure 1: The Atmospheric Forcing Index (AFI). Solid line represents the average index value for a given regime period.

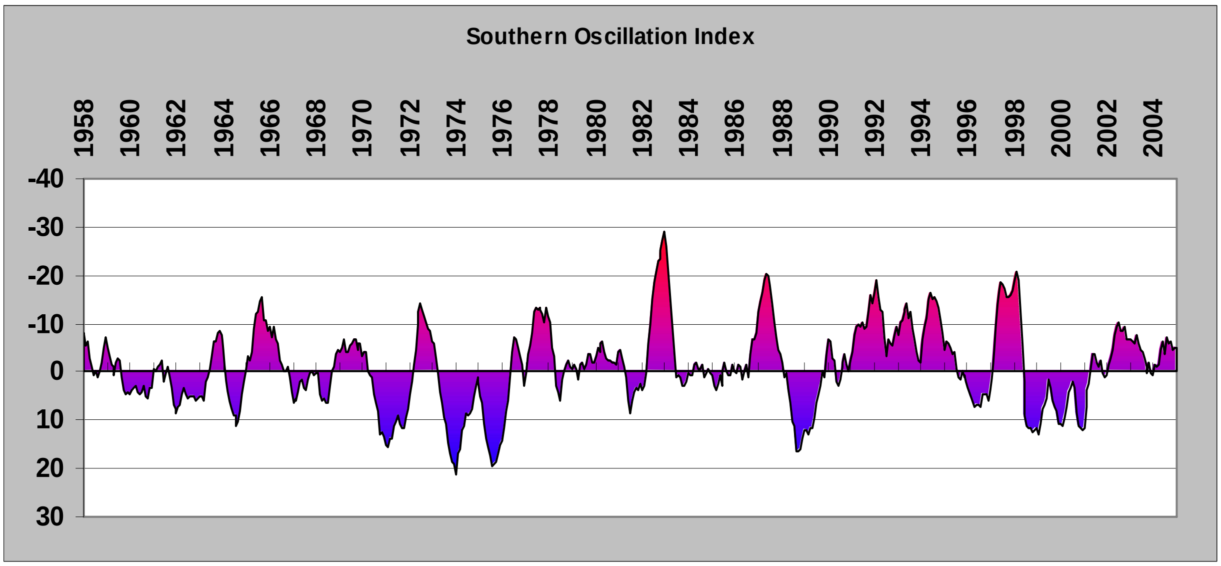
Links [Background information on AFI]
[DFO Contact: Jackie King]

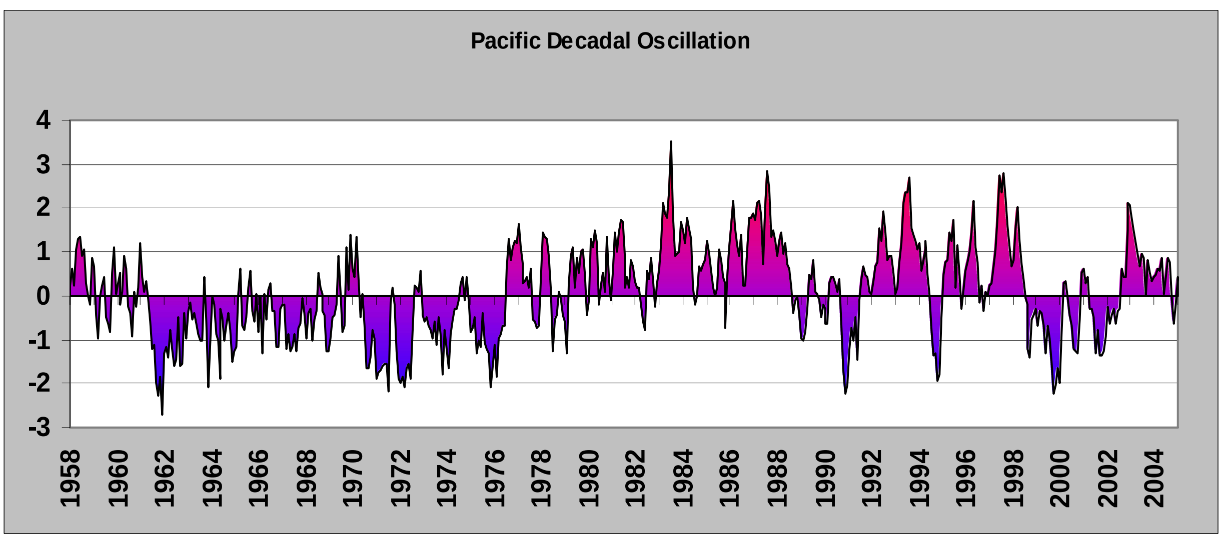
Reference:

McFarlane, G.A., J.R. King and R.J. Beamish. 2000. Have there been recent changes in climate? Ask the fish. Progr. Oceangr. 47: 147-169.

Northeast Pacific temperature indices: Neutral or weak indices, but ocean warming continues

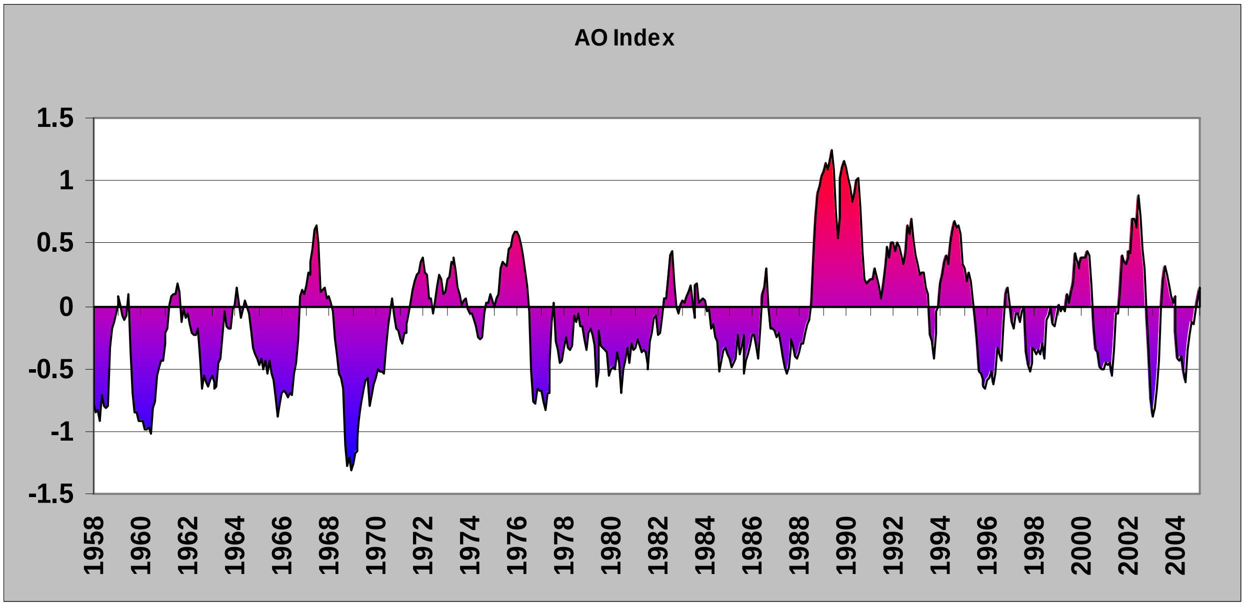
It is now generally accepted that patterns in fish abundance can be linked to patterns in climate-ocean conditions. These conditions can be relatively stable on decadal scales, but can shift abruptly from one state to another. The figure below shows the major climate indices relevant to the northeast Pacific. They are the **Southern Oscillation Index** which tracks El Nino events, the **Pacific Decadal Oscillation (PDO)** which tracks variations in the dominant temperature pattern in the North Pacific and the **Arctic Oscillation** which tracks the distribution of low and high air pressure in the annular region surrounding the Arctic.





The **Southern Oscillation Index** (above) suggests that we have been in a weak El Niño for the past year and it is expected to continue.

The Pacific is considered to be in **PDO cool phase** although it has, for the last few years, shifted to a warm pattern. Generally, the PDO signal has been weak for the past several years.



The Arctic Oscillation (**AO above**) is near-neutral so we might expect normal storm activity.

Overall, the climate indices for the North Pacific indicate near normal conditions but the general increase in global temperatures puts an upward pressure on what would be considered normal.

In addition, there are local warm and cool spots due to wind pattern and storm track anomalies. Alaska had a record warm summer with a statewide temperature of 2.6° C above the 1971-2000 mean. May, June, July and August were all record breaking for the state. On land, much of the west coast of Canada also had record high or near-record high temperatures for the summer of 2004. The coastal waters of B.C. were above normal for 2004. So climate indices are part of the story but don't tell you everything.

Links: NOAA climate anomalies
PDO host site
NOAA climate research perpsectives
Arctic Oscillation
DFO Contact: Ron Perkin

Gulf of Alaska

Mesozooplankton in the Gulf of Alaska in 2004: Biomass peaked earlier than in previous years

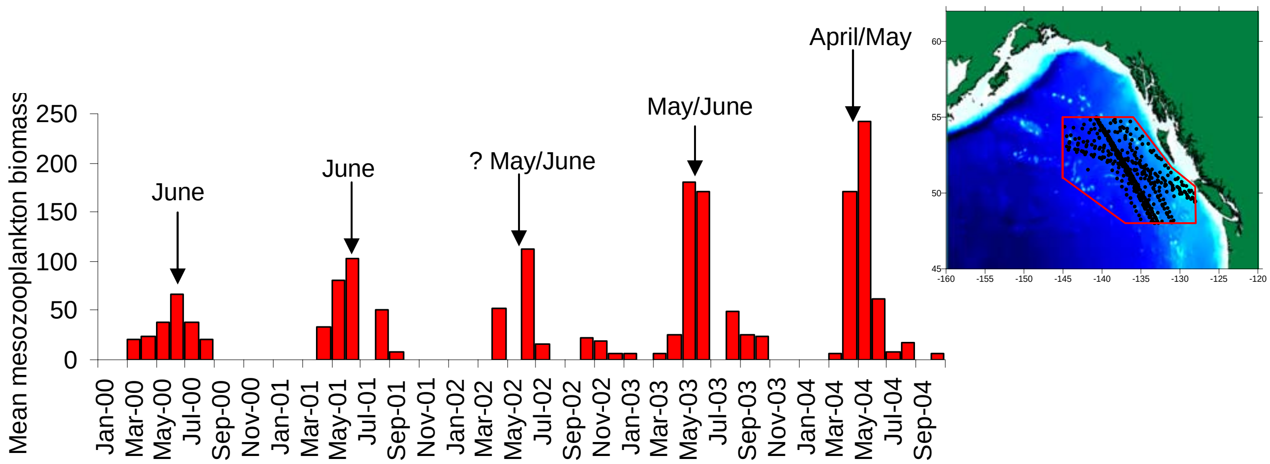


Figure 1. Time series of mesozooplankton biomass as mean monthly biomass in mg dry weight per sample (~3m^3) from Continuous Plankton Recorder sampling (which occurs approximately monthly between March and September) in the off-shore Gulf of Alaska area shown to the right. The time when peak biomass occurred in each year is indicated by the arrows.

The 5-year time series of monthly biomass in Figure 1 gives the impression that spring biomass has been increasing. However, variability has not been shown and only 25% of the data are so far available for 2004, so caution must be used in interpretation. What is clear, however, is that the peak in biomass occurred earlier in 2004 than in previous years**.** The peak in biomass shifts according to surface water temperatures; in 2000 and 2001 temperatures were somewhat cool and peak biomass occurred in June. Surface waters in 2004 were the warmest yet recorded in some areas and peak biomass occurred in late April/early May, about one month earlier.

Mesozooplankton biomass in spring is dominated by *Neocalanus plumchrus/flemingeri* copepods which account for, on average, 40% of the biomass of each CPR sample. Juvenile copepodites appear in surface waters in late winter and mature through to the sub-adult stage where they accumulate lipid and then descend to deep diapause depths in summer. The time taken to develop from early copepodite stages to sub-adult CV is temperature dependent. Copepodite stages II-V in CPR samples are separately counted and in 2004 their development rate was the fastest seen (from 2000 to 2004). This led to a peak in their biomasss some 3 weeks earlier in 2004 than in 2000 (according to Mackas *et al.*, 1998, peak biomass occurs when 50% of the population is at the CV stage, *Can. J. Fish. Aquat. Sci.* **55**: 1878-1893). It seems likely that the one month advance in peak mesozooplankton biomass was at least partially caused by the more rapid development of *Neocanalus* copepodites although other invertebrate development could have been similarly affected by the warm surface waters.

This advance has implications for those higher trophic levels that time their migration or reproduction to take advantage of the peak in mesozooplankton.

Links: Background information on CPR program
Contacts: Sonia Batten, Scientist at Sir Alistaer Hardy Research Foundation. For Ocean Science

Changes in life history timing of subarctic oceanic copepods: Early spring biomass maximum

Large copepods in the genus *Neocalanus* make up most of the zooplankton biomass in the oceanic subarctic Pacific and in the "subarctic oceanic copepods" group. They have an interesting annual life cycle that includes a brief growing season from spring into early summer followed by departure from the surface layer for a prolonged dormancy much deeper in the water column (between 400-1500 m).

The annual biomass maximum, and maximum availability as food for upper ocean predators, is brief (about 3-4 weeks) and occurs just before the start of this dormant period. About 10 years ago, we realized that timing of the biomass maximum is also quite variable, moving earlier in the year if the upper ocean is warm and stratified, or later if the upper ocean is cold and deeply mixed.

Fig. 1 shows the updated trends in life cycle timing for *Neocalanus plumchrus* at Stn P in the central Alaska Gyre, and along the Vancouver Island continental margin. Biomass maximum was very early in the spring in 2004, at dates observed only a few times before.

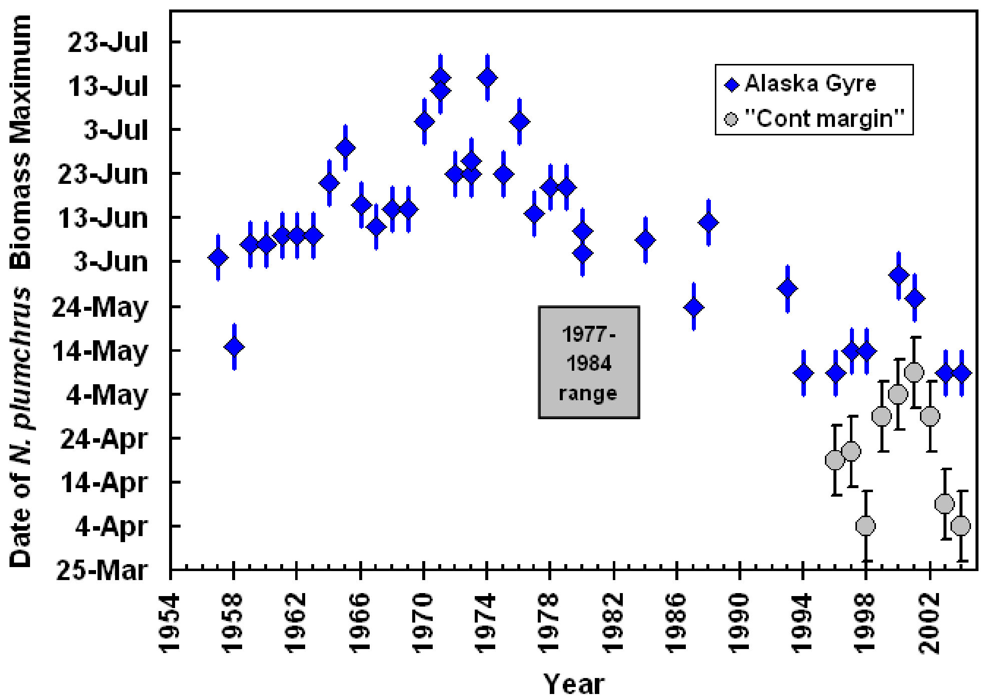


Figure 1. Changes in the date of the surface layer biomass maximum of Neocalanus plumchrus at Ocean Station Papa (blue). and along the Vancouver Island continental margin (grey). Most estimates before 1981 are based on frequent sampling of total biomass, most later estimates are based on age structure of the copepod population.

Mackas, D.L., R. Goldblatt and A.J. Lewis. 1998. Can. J. Fish. Aquat. Sci. 55:1878-1893.

Bertram, D.F., D.L. Mackas, and S.M. McKinnell. 2001. Progr. Oceanogr. 49:283-307.

Links: Plankton Ecology Group at Institute of Ocean Sciences
DFO Contacts: Dave Mackas, Moira Galbraith, Steve Romaine

Unusual appearance of jumbo squid in BC and Alaska

The jumbo flying squid, *Dosidicus gigas*, also known as Humboldt squid, is endemic to the eastern Pacific Ocean and normally ranges from northern California (40°N) to southern Chile (45°S) (Nigmatullin, 2001, *Fish. Res.* 54: 9-19). They are short lived and are the largest ommastrephid squid, measuring up to 1.0-1.2 m (dorsal mantle length) and weighing up to 30-50 kg (Nigmatullin, 2001). The jumbo flying squid feed on a variety of prey, ranging from zooplankton and fish larvae in juveniles *D. gigas*, to fish and squid in adults (Nigmatullin, 2001). They are also an important component of the sperm whale diet (Ruiz-Cooley et al. 2004. *Mar. Ecol. Prog. Ser.* 277: 275-283).

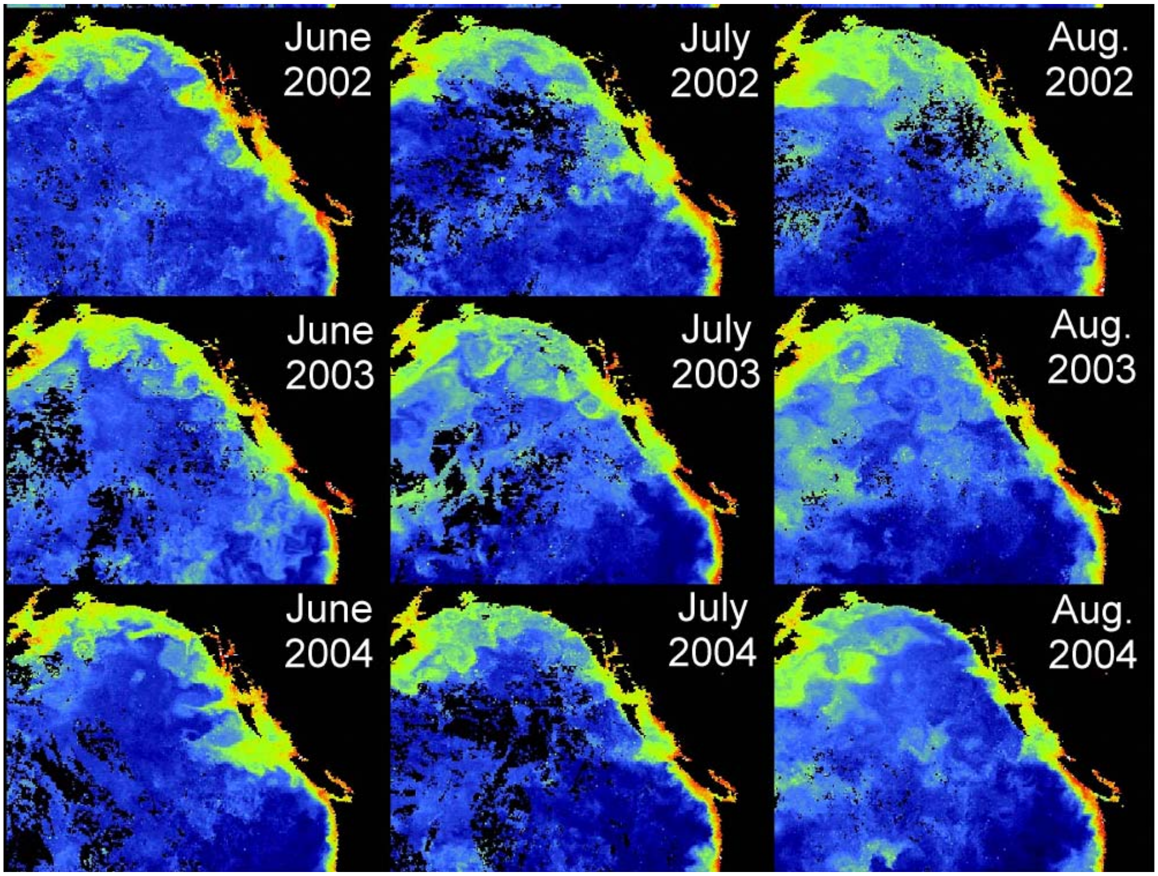
Figure 1. A jumbo flying squid, Dosidicus gigas, one of ten caught at the surface off Quatsino Sound on October 25, 2005, during a juvenile salmon survey. This specimen weighed 10 kg.

Until 1997, none had been reported in coastal waters north of Oregon. In August-October 2004, several jumbo flying squid were captured incidentally by commercial fishermen and by research surveys throughout British Columbia and as far north as Sitka in Alaska (Figure 1). Interestingly, necropsy showed that all the collected specimens were sexually immature. Many were observed but not caught in Washington and Oregon. Although relatively few jumbo flying squid have been caught (ca. 30), witnesses reported seeing hundreds if not thousands of jumbo flying squid at the surface off the west coast of Vancouver Island and in southeast Alaska. Thousands of jumbo flying squid were washed ashore on the Oregon and Washington coast in 2004.

It is unclear what prompted jumbo flying squid to migrate this far north, though the warmer sea surface temperature might have played a role. Whatever the cause might be, the large number of jumbo flying squid reported from Oregon to Alaska indicates a profound change in coastal ecosystem. Due to their fast growth rate, jumbo flying squid are expected to consume large quantities of forage fish such as herring and sardines, and possibly juvenile salmon. Hence, they may have serious impacts on coastal ecosystems in British Columbia and elsewhere. This indicates the need to consider climate change and ecosystem functioning in coastal fisheries management.

DFO Contact: Marc Trudel
Royal BC Museum Contact: Jim Cosgrove

Ocean chlorophyll measured from space



The green, yellow, and red regions of the images above show relatively high concentrations of chlorophyll in the surface ocean and indicate relatively high levels of ocean plant life that provide food to zooplankton and fish. Coastal regions of British Columbia are rich in this marine life, which in turn support rich fisheries and habitat for marine mammals. Here the chlorophyll images for the months June, July, August are compared for the last 3 years. Patterns appear roughly comparable in both spatial extent and seasonal timing, showing no major changes in plant life over these three summers. Many of the offshore patterns of chlorophyll distribution are formed by large eddies in the Gulf of Alaska.

The images are derived from the SeaWiFS satellite sensor, which provides water-leaving radiance and near-surface chlorophyll concentration data. Composites are formed by NASA from the full global data set at a variety of resolutions and time scales. Data from this satellite are available at 1 km resolution for Local Area Coverage from stations such as the one operated at the Institute of Ocean Sciences (IOS), at 4 km resolution for global data recorded on the satellite and at 10 km resolution as weekly or monthly global composites. MODIS satellite replaced SeaWiFS as the primary ocean colour source in December 2004.

Links : Satellite images
SeaWiFS
Ocean Colour satellite MODIS
DFO Contact: Jim Gower

Near-surface summer temperature in the Gulf of Alaska: Warm all over

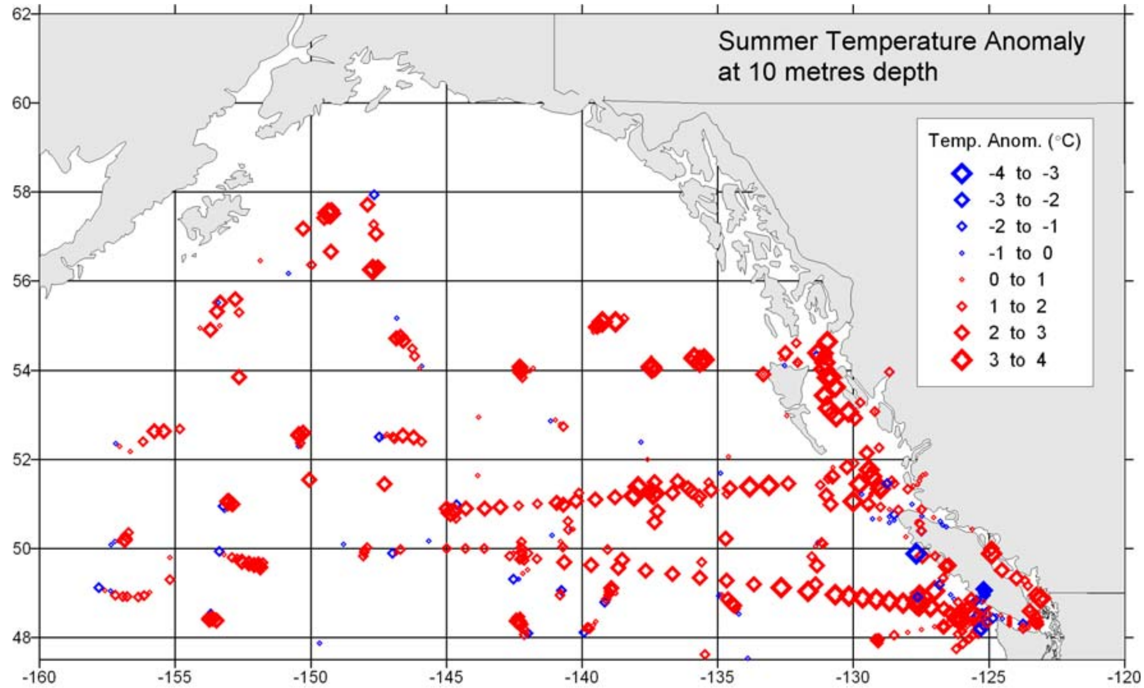
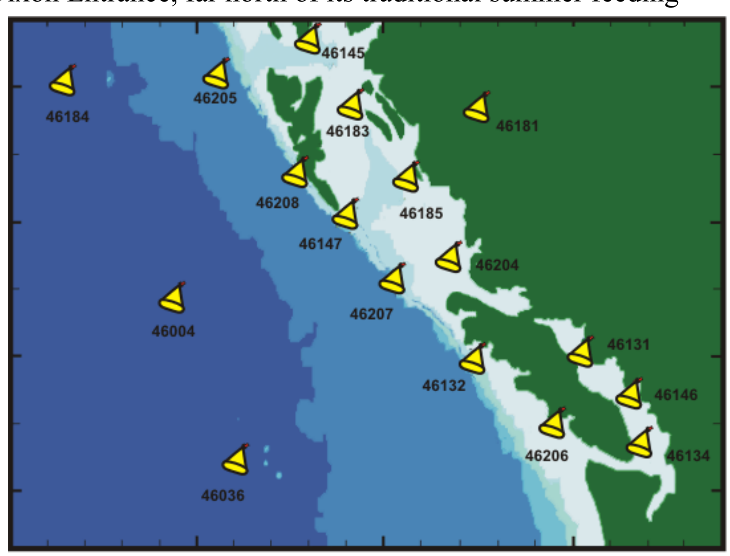


Figure 1: Temperature anomalies, measured from surface to ocean depths are taken by a variety of sensors and ships, including Fisheries and Oceans Research Fleet, Canadian and US naval vessels, some commercial Volunteer Observing Ships, and autonomous Argo floats. ***Red denotes warm anomalies****;* ***blue denotes cold.*** *These agencies and individuals send in records to one or more Canadian and American ocean data archives, where they are stored, and from which they are easily recovered to plot in the figure above. Average conditions were computed from more than 170,000 profile records in these archives.*

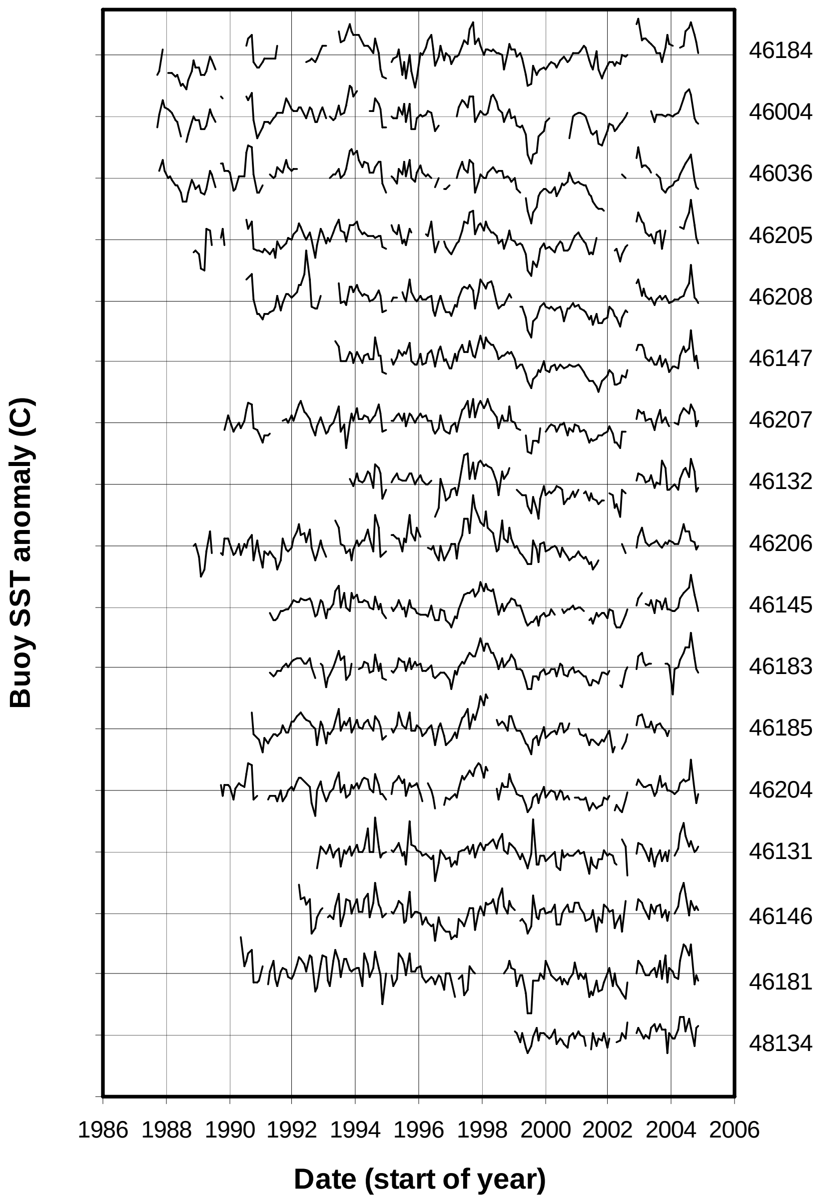
Temperature measurement all through the Gulf of Alaska in July, August and September revealed a nearly continuous pattern of very warm water, in some cases the warmest observed to date. Few areas of the British Columbia continental margin reported any cooler-than-normal surface waters. This warming likely led to the sighting of Pacific hake in Dixon Entrance, far north of its traditional summer feeding range. Juvenile fish of most species are thought to be most sensitive to warming, due to changes in timing and quantity of food, and presence of predators. The impact of this warm summer might appear in future years when these juveniles enter the fishery.

DFO Contact: Bill Crawford

Measurements at weather buoys provide a historical perspective of this warming. West coast meteorological buoys, at locations in the map at right, show an anomalously warm May to August in 2004. These 17 buoys provide wind, wave, and surface temperature data.



Three locations are 400 km offshore (46184 to 46036, north to south on the figure below). The remainder are along the exposed west coast (46205 to 46206), and in sheltered waters (46145 to 46134). Anomalies are offset 4°C per buoy.



The plots show that the anomaly was comparable in magnitude to that observed at the time of the 1997-98 El Niño, but of shorter duration. The pattern of the anomaly as observed at different buoys was different for the summer of 2004 as compared to the El Niño. The summer 2004 anomalies showed warming at all buoys, with more warming offshore and to the north. The El Niño anomalies were strongest at southern buoys on the continental shelf and small or zero in the Strait of Georgia and at the offshore locations. Long term (1990 to 2005) SST trends are close to zero for all buoys, as shown.

Links: Weather buoys
DFO Contact: Jim Gower

Index of northeast Pacific sea level anomalies

As described in the two previous State of the Ocean reports, an index of ocean variability for the northeast Pacific Ocean may be constructed based on data collected from satellite altimetry. This index complements the standard Pacific Decadal Oscillation (PDO) index, which is based on sea surface temperature (SST) observations. Satellite altimeters measure changes in sea level over the world ocean. On interannual time scales, sea level indicates the vertically integrated effects of anomalies in temperature and (to a lesser degree) salinity over the upper ocean, meaning nominally the top 300 metres.

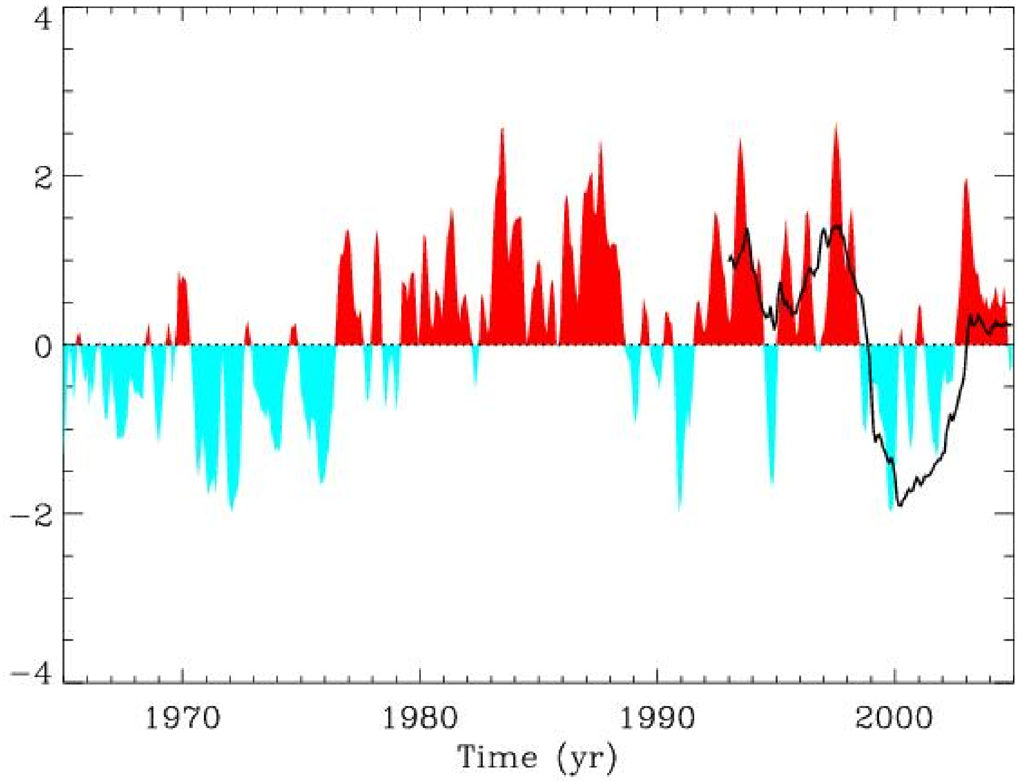


*Figure 1: The PDO index is shown in solid **blue** and **red**. **Blue** indicates the PDO cold phase and **red** the warm phase. The solid **black** curve gives the SSH index with positive values indicating elevated sea level off the west coast of North America and sea level anomalies of opposite sign in the central Pacific. During 2003 and 2004 the SSH index was close to zero indicating that the northeast Pacific has not returned to a strongly warm phase of the PDO.*

The index based on sea surface height (SSH) is defined in terms of the leading principal component of the altimeter data after the climatological seasonal cycle has been removed. This is analogous to the PDO, which is the leading principal component of SST over the extra-tropical North Pacific. The time series resulting from this analysis provides information on the dominant mode of SSH variability over the period of the Topex/Poseidon-Jason satellite altimeters which now extends over the 12 year period beginning in January, 1993 through December, 2004.

Figure 1 shows the recent history of the PDO and SSH indices. The latter is based on altimeter data from northeast Pacific, a region delimited by the west coast of North America and the dateline with a southern boundary along 25N. While the PDO and SSH indices are clearly related, the SSH index is less subject to high frequency variability, which is preferable for an index characterizing long term changes in the state of the ocean.

Both of the indices in Figure 1 indicate that significant changes in the state of the North Pacific occurred during 1998/99 and that these changes persisted until 2002. These changes were marked by colder SST and lower SSH over the northeast Pacific, which is characteristic of a change to the cold phase of the PDO. There has been wide discussion on whether these changes in 1998 constituted a new “regime shift” to a persistent cold phase of the PDO. This would reverse the persistent shift to the warm phase that occurred in 1976/77.

In early 2003 a weak El Nino event occurred in the equatorial Pacific that produced anomalously warm SSTs over the northeast Pacific along with positive SSH anomalies. This reversed conditions that had prevailed over the preceding four years and may be that the recent cold phase of the PDO was a relatively short lived event. In 2003 and 2004, our index based on SSH has not varied greatly, remaining close to neutral and just slightly positive. The cold phase that started in 1998 appears then to have ended. However, the northeast Pacific has not changed to a state characterized by a pronounced PDO warm phase as occurred following the 1976/77 regime shift.

Links: Ocean Status Report 2003 (page 16)
DFO Contact: Patrick Cummins

Ocean currents in the Gulf of Alaska: More normal in 2004-2005

Background

Growth of Argo

At the start of 2004 there were about 1100 autonomous profiling floats operating in the global ocean, transmitting data every 10 days to all listeners. By the start of 2005 this had increased to almost 1700 oceanographic robots profiling the oceans to 2000 metres depth. Argo is a global program with floats presently supplied by 20 nations. International deployments are continuing, though Canadian deployments are presently suspended until the future of funding becomes apparent.

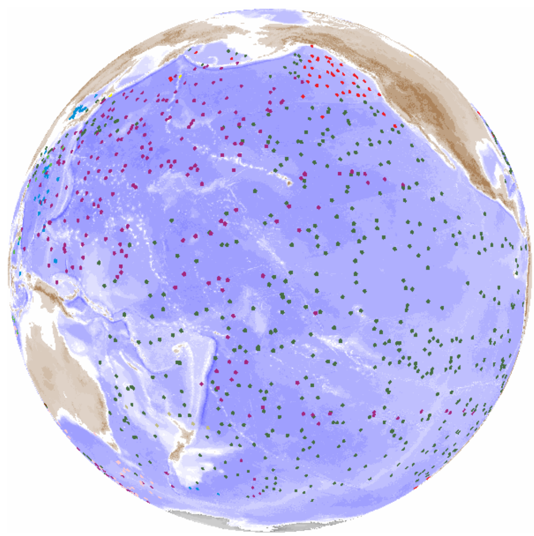


Figure 1: The distribution of Argo floats in the Pacific Ocean, April 2005.

As Figure 1 shows, the array is now quite impressive and in the Gulf of Alaska has allowed ocean conditions to be mapped since about mid-2002.

Circulation Changes

Figure 2 shows the general circulation of the N.E. Pacific for the month of October 2004. This shows the general eastward flow of the North Pacific Current roughly along 40°N. This bifurcates into the Alaska Current heading northwards and the California Current heading southwards. During 2002 and running into 2003 the N. Pacific Current was significantly farther northwards than we believe to be normal.

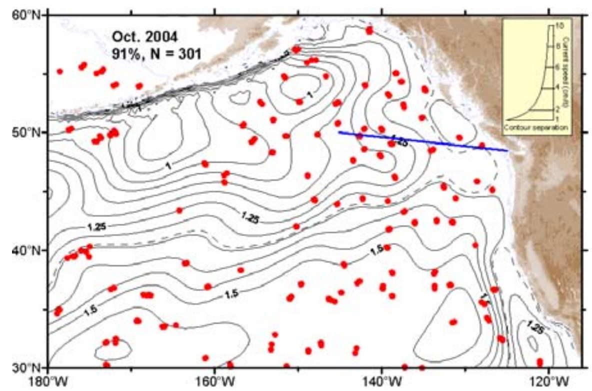


Figure 2: The circulation of the N.E. Pacific during October 2004. ***Line-P is shown in blue****. Flow is along contours and is faster as contours get closer together.* ***Red dots*** *show the Argo profiles on which this circulation field is based.*

We believe that those unusual circumstances are related to a shift in the prevailing winds in the Gulf, and to the very shallow winter mixed layers of the winters 2002/03 and 2003/04. Since that time, the circulation of the Gulf of Alaska appears to have steadily returned towards what we believe to be normal. This transition is illustrated in Figure 3 below.

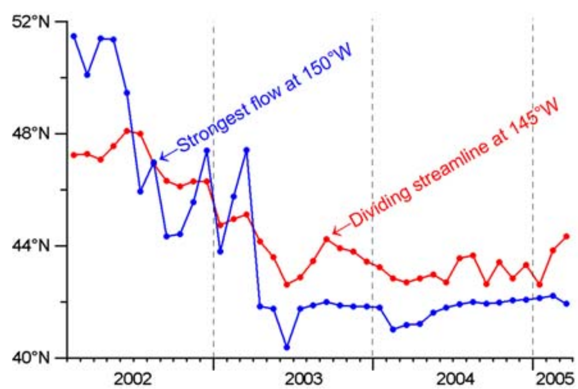


*Figure 3: The latitude of the N. Pacific Current at 150ºW (**blue line**) and the latitude of the dividing streamline (**red line**).*

Since mid-2003 Figure 3 suggests that the circulation of the Gulf of Alaska has been extremely stable and close to what we believe to be normal. This is somewhat uncertain as we have not been able to monitor the circulation fields for very long.

Conditions in the Gulf of Alaska

Pacific oceanographers have been sampling along Line-P since the early 1950s, which means that we have a good and thorough description of the average conditions along Line-P and the variability in average conditions through the year. Since mid-2002 we have been using Argo observations to interpolate onto Line-P stations and so create artificial surveys along Line-P, once per year. This type of artificial survey captures only the dynamic variables, temperature and salinity.

The diagram in Fig. 5 shows the deviations from normal along Line-P in July 2004. The low-temperature intrusion previously reported just below the main pycnocline has vanished but the very warm near-surface water is still present. The large surface warming is not compensated by higher salinities, so this results in a significant reduction in the density of the surface waters. For this reason we have been monitoring the stratification of the upper part of the water column in the Gulf of Alaska.

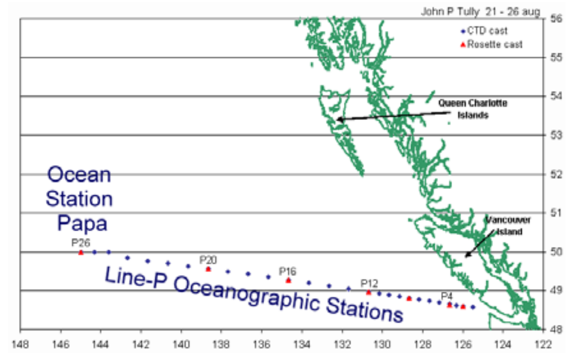


Figure 4: Line-P in the Gulf of Alaska

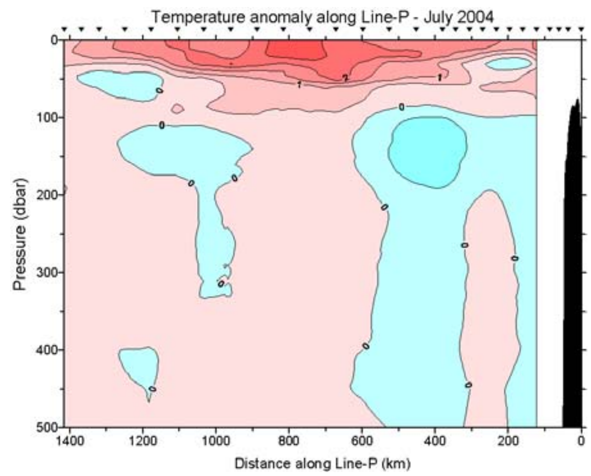


Figure 5: Temperature anomalies along Line-P for July 2004.

Links: Line-P
Project Argo
N. Pacific Current anomalies
DFO Contact: Howard Freeland

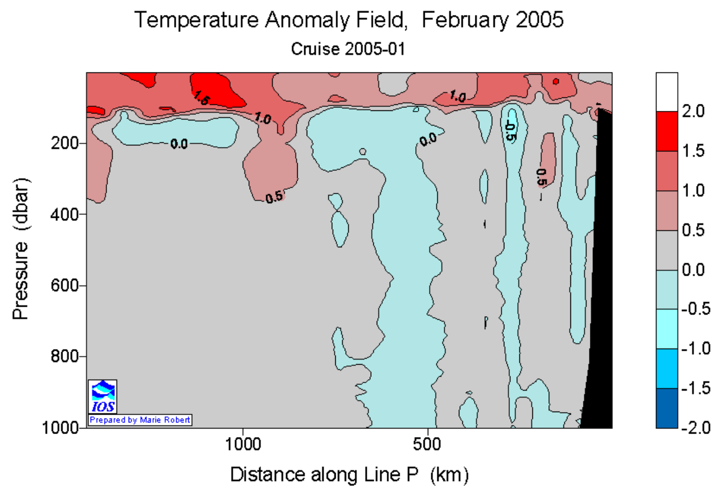
Warm surface waters along Line-P in winter 2005

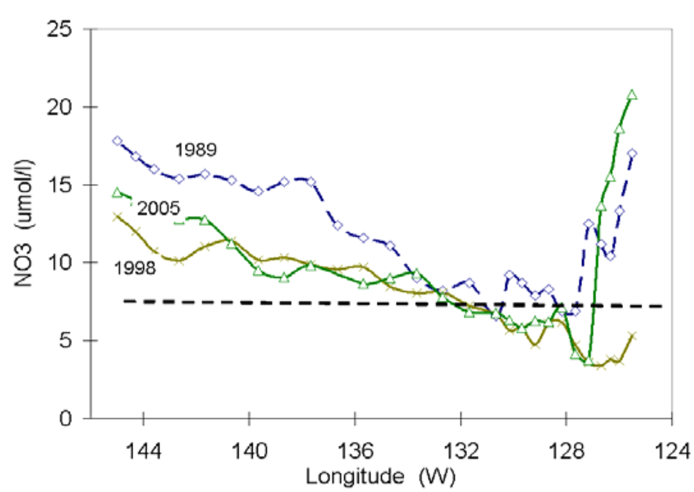
The waters of the Gulf of Alaska along Line-P, from the surface to 100-150 metres, were warmer than average by 0.5 to 2.0 °C (Fig. 1 at right). (Averages are computed over the years 1956 to 1991.)

Surface nutrient concentrations were typical of warm years of 1995 to 1998 and lower than in cool years such as 1989 or 1999 (Fig. 2, middle right).

Nitrate (NO3) depletion was widespread along Line P from 1994 to 1998 and has returned to more normal conditions over the past few years near the BC coast. In waters from the coast at 124 W to ~133 W, nitrate supply determines the level of primary production in spring.

The mixed layer depth at Ocean Station Papa was deeper in February 2005 than during the last 2 years (Fig. 3, bottom right), which relaxes the strong stratification that was present while the mixed layer depth was shallower. This slackening of the stratification suggests that the upwelling of deeper waters is made easier, bringing more nutrient rich waters to the surface. This should in turn result in greater primary productivity, as can hopefully be studied during upcoming cruises.





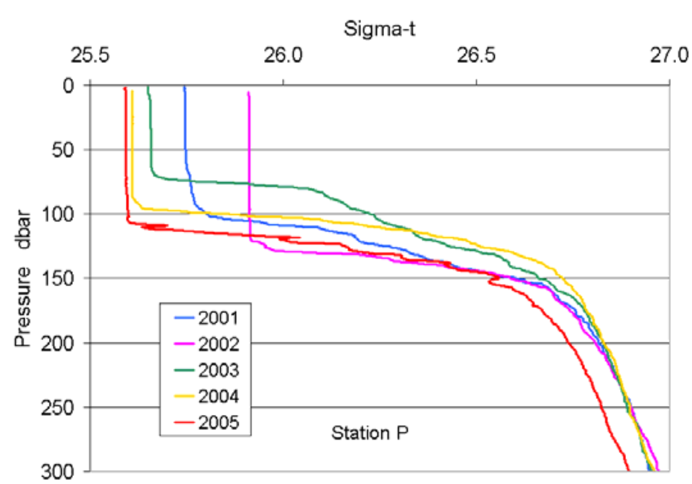


Figure 1: (top right)*: Temperature anomalies along Line P in February 2005, with respect to averages from 1956 to 1991.*

Figure 2: (centre right): *Nitrate levels along Line-P in February 2005 were lower than normal, resembling winter concentrations observed during the 1997/98 El Niño. Before the warm decade of the 1990s, winter nitrate was higher in oceanic waters (e.g. Feb. 1989). The dashed line shows the usual level of seasonal nitrate drawdown.*

Figure 3: (lower right)*: February density at station Papa, 50° N, 145° W, from 2001 to 2005. Decreased density in 2005 is a result of warmer waters.*

Links: Line-P

DFO Contact: Marie Robert

Winter 2004-05 surface mixed layer: Deeper and closer to normal

The unusual circulation events of 2002 to 2003 appear to have introduced a large amount of excess ocean surface heat to the Gulf of Alaska, which has been slowly dissipating. The result was extremely shallow mid-winter mixed layers during the winters of 2002/03 and 2003/04. Finally in the winter of 2004/05 conditions do appear to have returned to normal. This is shown in Figure 1 below, the distribution of mid-winter mixed layer depth. We see that surface water mixed down to more than 100 metres in most of the Gulf of Alaska and as deep as 120 metres in some regions.

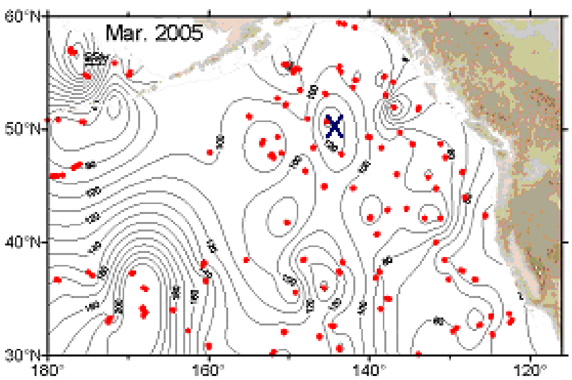


Figure 1: Distribution of surface mixed layer depth in the northeast Pacific in March 2005. Contours are in intervals of 10 metres. ***Red dots*** *show Argo float positions.* ***X*** *denotes Ocean Station Papa.*

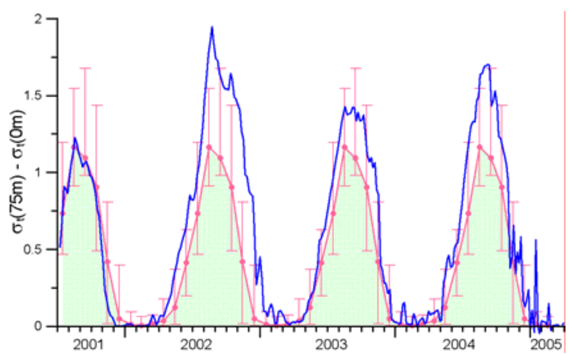


Figure 2: The stratification at Ocean station Papa through 2002, 2003, 2004 and into 2005 observed by interpolation from the Argo array.

Figure 2 above shows a plot of the stratification from 2002 to early 2005. The stratification was estimated as the difference in σ_t between 75m depth and the surface and is interpolated from the Argo array. The **blue line** is the observed near-surface stratification and the faint red line is the long-term average over all observations at Station Papa, and the 95% confidence bounds. This diagram tells us that the stratification of the upper ocean in the Gulf of Alaska was exceedingly strong during early 2002 leading into the winter of 2002/03. Some vertical mixing did occur during that winter with the result that though the stratification remained very high in 2003 and 2004 it was not close to the astonishing conditions seen during 2002. As we approached the winter of 2004/05 stratification appeared to be returning to normal.

Deepening of the surface mixed layer during the winter supplies nutrients to the upper ocean for the following spring growth. Shallow mixed layers lead to fewer nutrients in surface waters the following spring and summer. Warm summers and fresh surface waters, together with fewer storms in winter, all lead to shallower mixed layer depths.

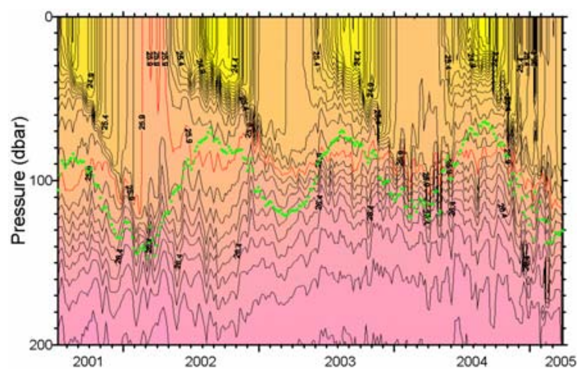
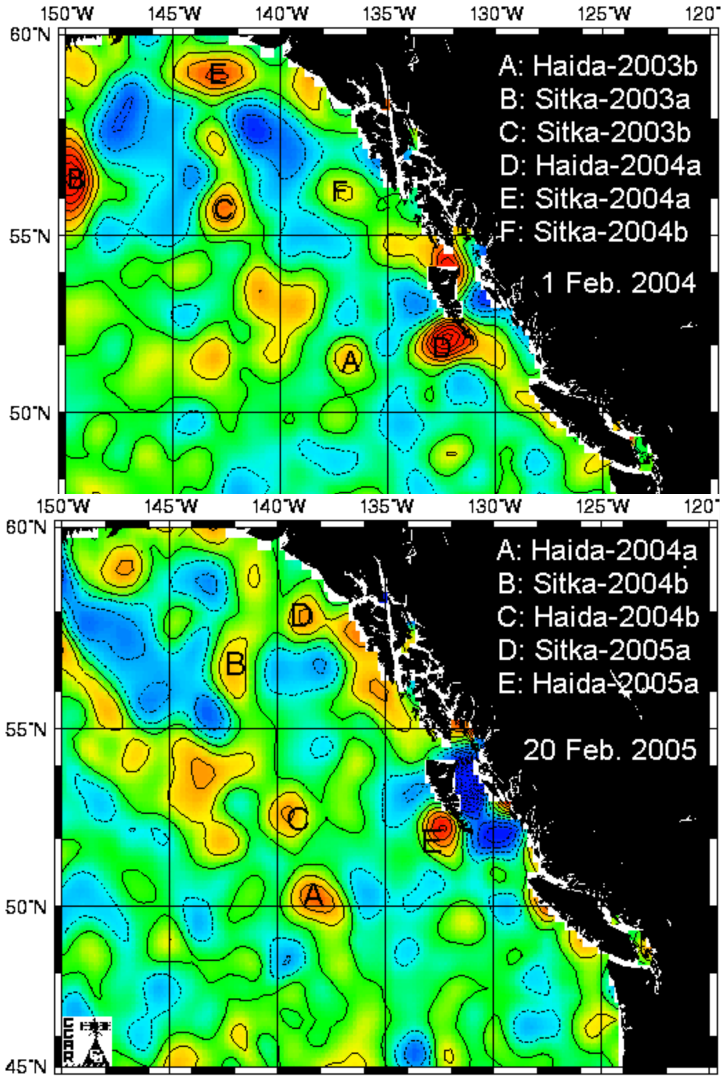


*Figure 3: The time series of density (**coloured contours**) and mixing depths (**green dots**) from 2001 to early 2005.*

Figure 3 shows the time history of the upper ocean density structure from 2001 to the present. This shows the deep mixing during the winter of 2001/02 followed by two winters characterized by unusually shallow mixing.

Links Project Argo
DFO Contact: Howard Freeland

Eddies in the Gulf of Alaska: Bigger and farther south



Scientists have been tracking large eddies in the Gulf of Alaska since 1998, using satellite measurements of sea level. The eddies, labelled Haida and Sitka for their regions of formation in winter, always rotate clockwise, are up to 350 km in diameter, and drift generally westward into the Gulf of Alaska. They form near shore, and can track more than 1500 km westward before they decay away after a few years.

Images at left display eddies (in red) during February 2004 and February 2005. These images were prepared from satellite measurements using software provided by the Colorado Centre for Astrodynamics Research. Contours show sea surface height at 4-cm intervals.

Red denotes eddies and highest sea levels
Blue denotes low sea levels

Eddies carry nutrients and coastal species into mid-Gulf of Alaska, and divert the eastward flow of surface waters. Their role in the ocean is undergoing study.

Haida Eddies west of the Queen Charlotte Islands may carry away from shore as much as 60% of the ocean heat flowing northward in winter, and 15% of autumn and winter fresh water input. (Crawford, 2005 Deep-Sea Research II)

Haida-2004a was one of the largest eddies observed since 1998, and like previous large eddies in 1995 and 1998, it drifted farther to the south than normal for Haida Eddies. Scientists on board the CCGS *John P. Tully* in February 2005 observed large populations of seabirds and killer whales along the southern flank of Haida-2004a.

Links
Haida Eddy Web Page
DFO Contact: Bill Crawford

Oxygen decline in sub-surface waters: Dangerously low levels below 250 metres depth

Oxygen levels have been steadily declining in subsurface waters at Ocean Station Papa (OSP) over the past decade as nutrient levels increase (Fig. 1 at right).

Oxygen is consumed by various organisms as they oxidize organic carbon for metabolic purposes, one of the byproducts being nitrate.

Oxygen is replenished in these waters when they come into contact with the atmosphere. Therefore, oxygen decreases indicate either increased consumption of organic matter or reduced ventilation. Since recent upper ocean stratification has been reducing nutrient supply to the upper ocean, production of organic matter has likely decreased over the past few decades.

Therefore the assumption is that strengthening stratification of the upper ocean by warming is reducing oxygenation of intermediate waters.

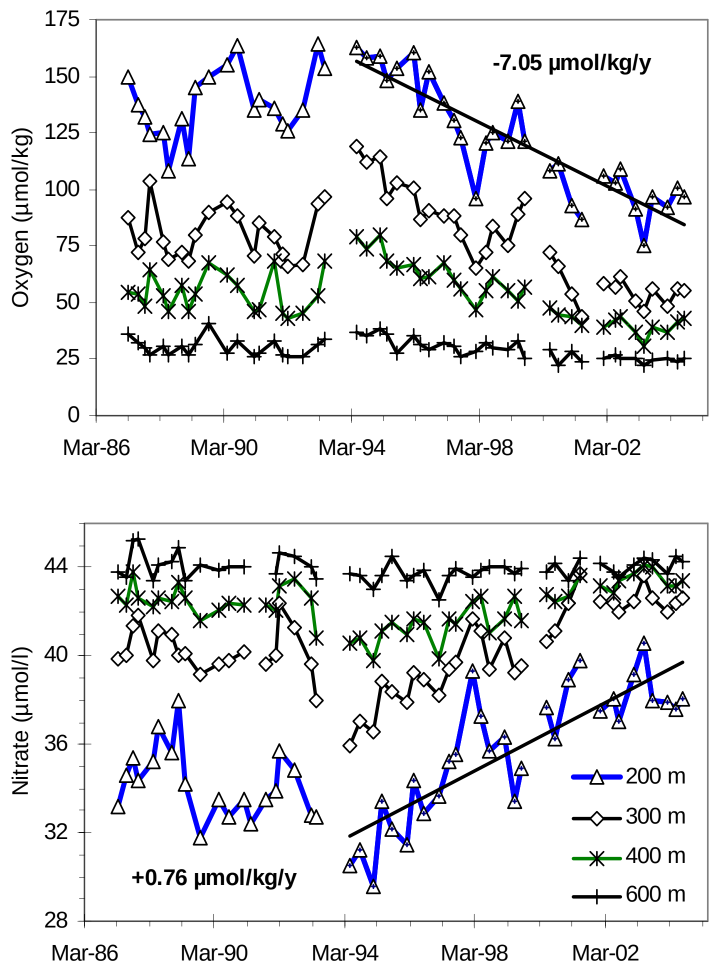


Figure 1: Oxygen and nitrate concentrations at Ocean Station Papa (50 N, 145 W) between 1987 and 2004.

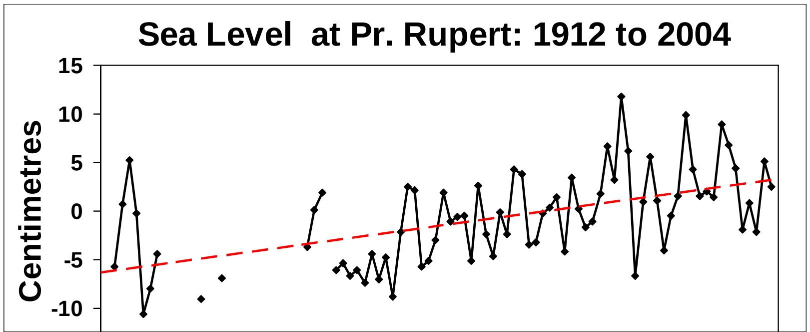
Indeed, Ono et al. (2001, *Geophys. Res. Lett.* 28) have observed declining oxygen levels off the coast of Japan starting in 1990. Since this is the major ventilation site of the subarctic Pacific, it appears that the Gulf of Alaska is being affected by basin scale processes.

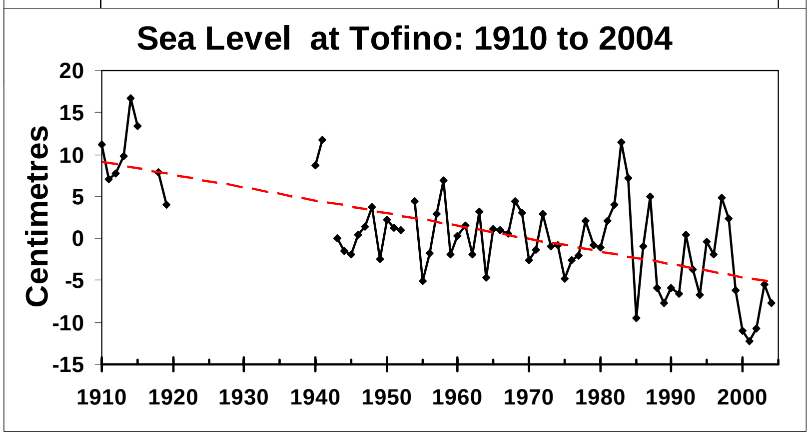
Ono et al. (2001) observe an oxygen decline of ~5 µM/y at ~190 m depth, whereas oxygen declines at Ocean Station Papa were 7 µM/y at 200 m depth between 1994 and 2004. To put these declines in context, any marine organism that could not tolerate oxygen concentrations below 60 µM (~2 mg/l) would have lost a large part of their oceanic habitat as the depth of this oxygen concentration shoaled from 400 to 250 m between 1994 and 2004.

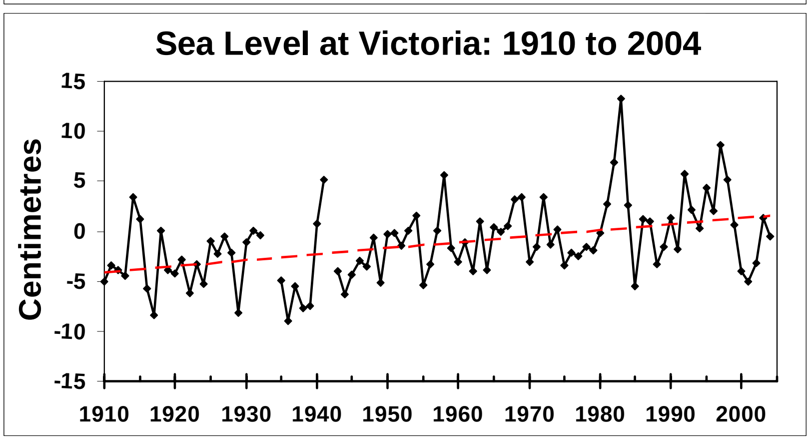
Links Water in the NE Pacific in 2004
Line-P and Ocean Station Papa
DFO Contact: Frank Whitney

West coast of Vancouver Island

Coastal sea levels: Normal in 2004, but long term rise continues.







The Canadian Hydrographic Service has monitored sea levels along the coast of British Columbia for more than 90 years.

The three records at left show deviations from long-term average levels, and trends in sea levels at three BC ports.

The **dashed red lines** show the trend over the record length, in centimetres per century:

Prince Rupert +10
Victoria + 6
Tofino - 15

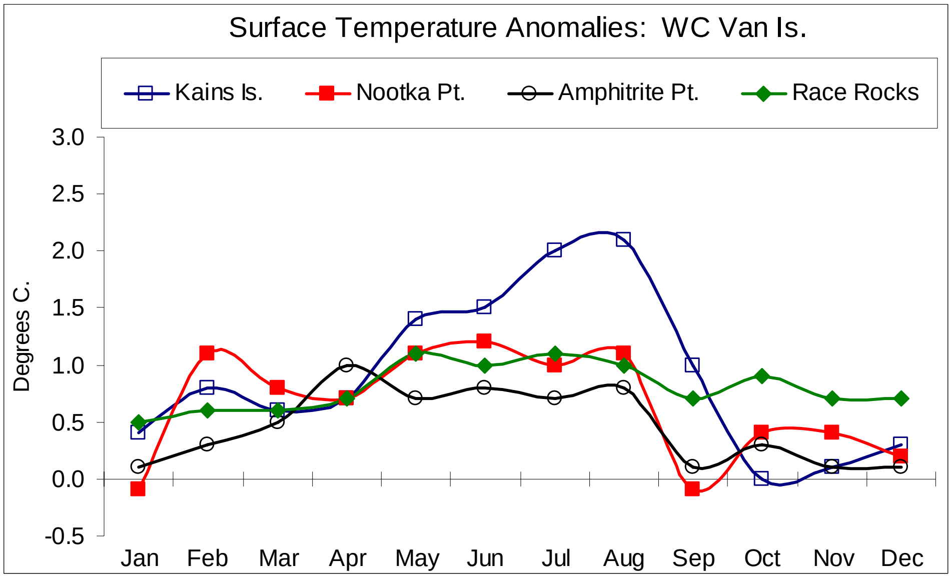
Tectonic motion is lifting the land at Tofino faster than sea level is rising, so local sea level there is actually dropping at a rate of 15 cm per 100 years.

The next Cascadia Subduction Zone earthquake will drop the land at Tofino and along the west side of Vancouver Island by a metre or so, and send a major tsunami toward the BC coast.

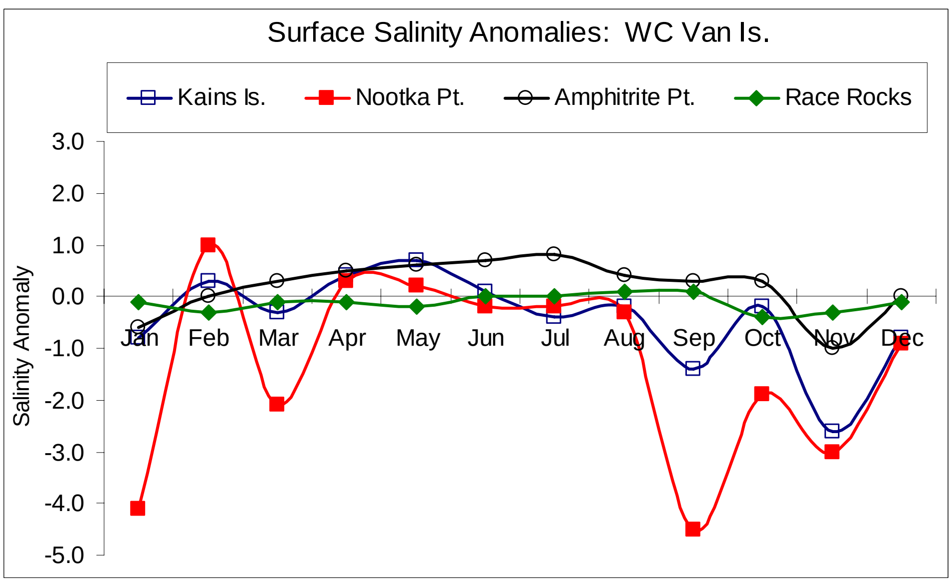
Global sea levels have risen about 10 to 20 cm over the past 100 years, and are expected to rise between 9 and 90 cm in the next 100 years.

Links: Sea Level Change in Ocean Status Report 2003 (Page 33)
Canadian Hydrographic Service
DFO Contacts: Fred Stephenson, Bill Crawford

Shore station temperature and salinity: Warm all year, fresh at Nootka Point all fall



Warm temperature hit all west coast Vancouver Island and Juan de Fuca in summer, in a pattern that extended into the Strait of Georgia and Alaska. By autumn most temperatures returned to more normal values, but Race Rocks stayed warm.

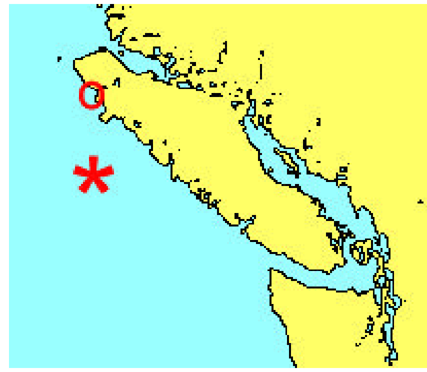


A big surprise was the fresher water in January, and September to November at Nootka Point, which dropped to lowest values recorded. Nearby Kains Island, and Egg Island to the north also freshened in September to December. Only a massive rainfall and shift in winds could have brought such fresh water into northern Vancouver Island and eastern Queen Charlotte Sound.

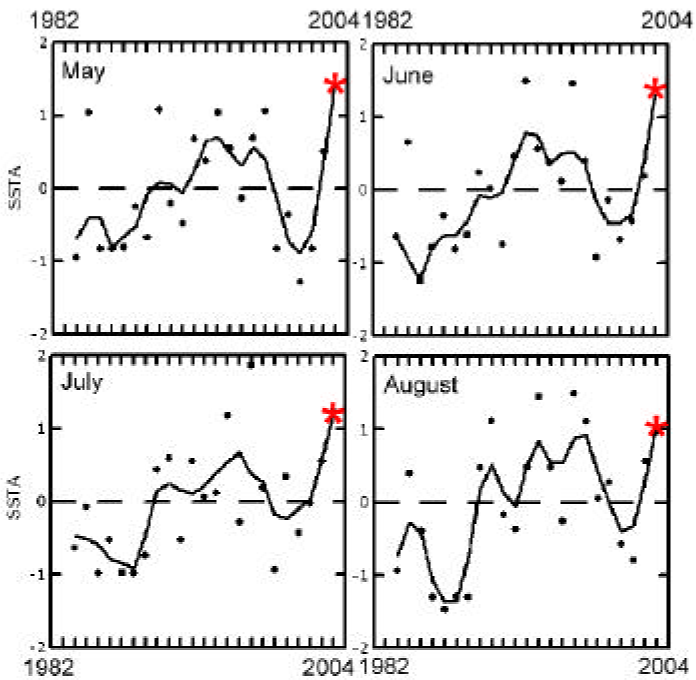
Links: BC Seawater sampling at Lighthouses
DFO Contacts Bill Crawford, Ron Perkin

Temperatures at ocean surface west of Vancouver Island: Warmest May in 22 years of observations.

Temperatures have been recorded daily at Kains Island (Red circle at right) since mid-1930s. The offshore site marked by red * at right is one of the sites monitored by NODC using satellite temperature sensors and underway ships. Monthly average temperature anomalies at this offshore site are plotted below for May, June, July and August.



At Left: Monthly temperature anomalies at 49.5N, 128W, from 1982 to 2004 (2004 anomalies in **Red ***).



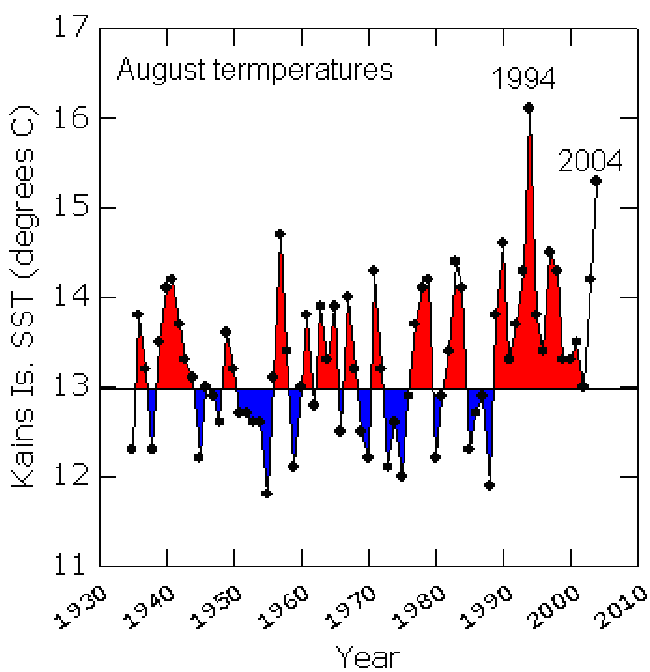
Coastal temperatures west of Vancouver Island in late spring to summer 2004 were at or near record highs, reaching or exceeding temperatures seen previously only in the warm years of 1992 to 1998.

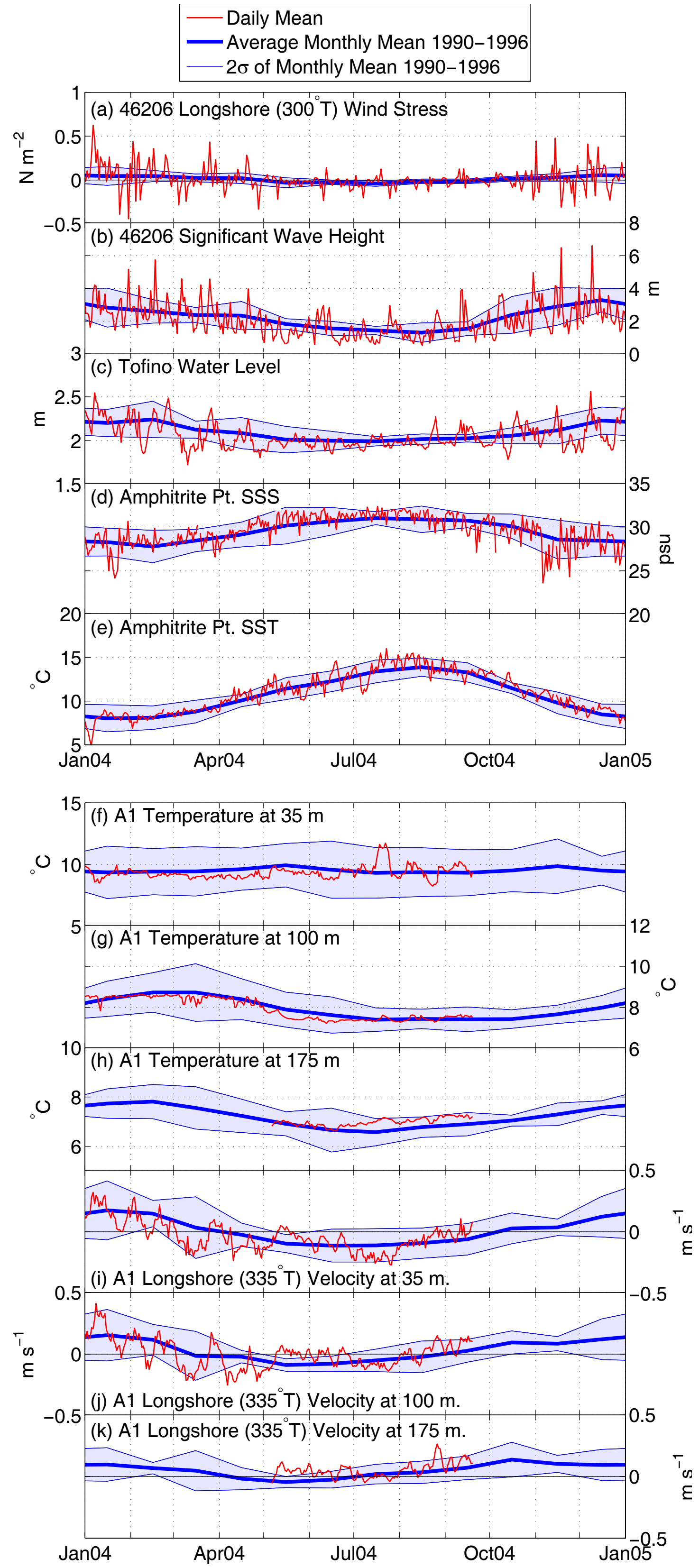
Below: Kains Island August temperatures 1935 to 2004.

Of note, since 1989 there have been no average August temperatures < 13°C at Kains Is. (**Red O above**) whereas they occurred frequently prior to that, suggesting a step-change rather than a trend; the offshore site (**Red ***) does not have this property.

Fish stocks preferring warm summers should thrive if these warm summers persist.

Links [NODC temperatures](#)
Contact: [Skip McKinnell](#)





Southwest coast Vancouver Island: Daily variability during 2004

West coast Vancouver Island sea-surface temperature (SST) anomalies of +2 °C in July-August (Fig. e) may reflect the onset of a weak El Niño, but during the rest of 2004 were near the 1990-96 average. Warmer SSTs may also have resulted from weaker upwelling in July. Downwelling-favourable winds (a) were stronger than average in January and weaker in December. Upwelling-favourable winds were stronger than average in May and October. Wave heights and water level in 2004 were near average with sub-monthly variability a response to strong wind events (b-c). Sea-surface salinity was near average, with large negative spikes in January and November likely due to large storm driven run-off events (d). Sub-surface temperatures and longshore velocities were near average (f-k). The timing of longshore current spring and fall direction reversals were average or slightly early (i-k). From May-June, the longshore current was equatorward on average but was poleward in 2004.

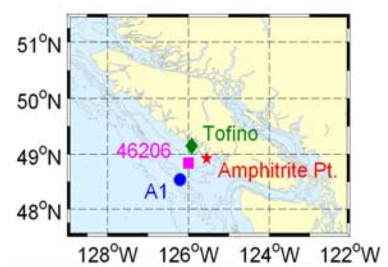
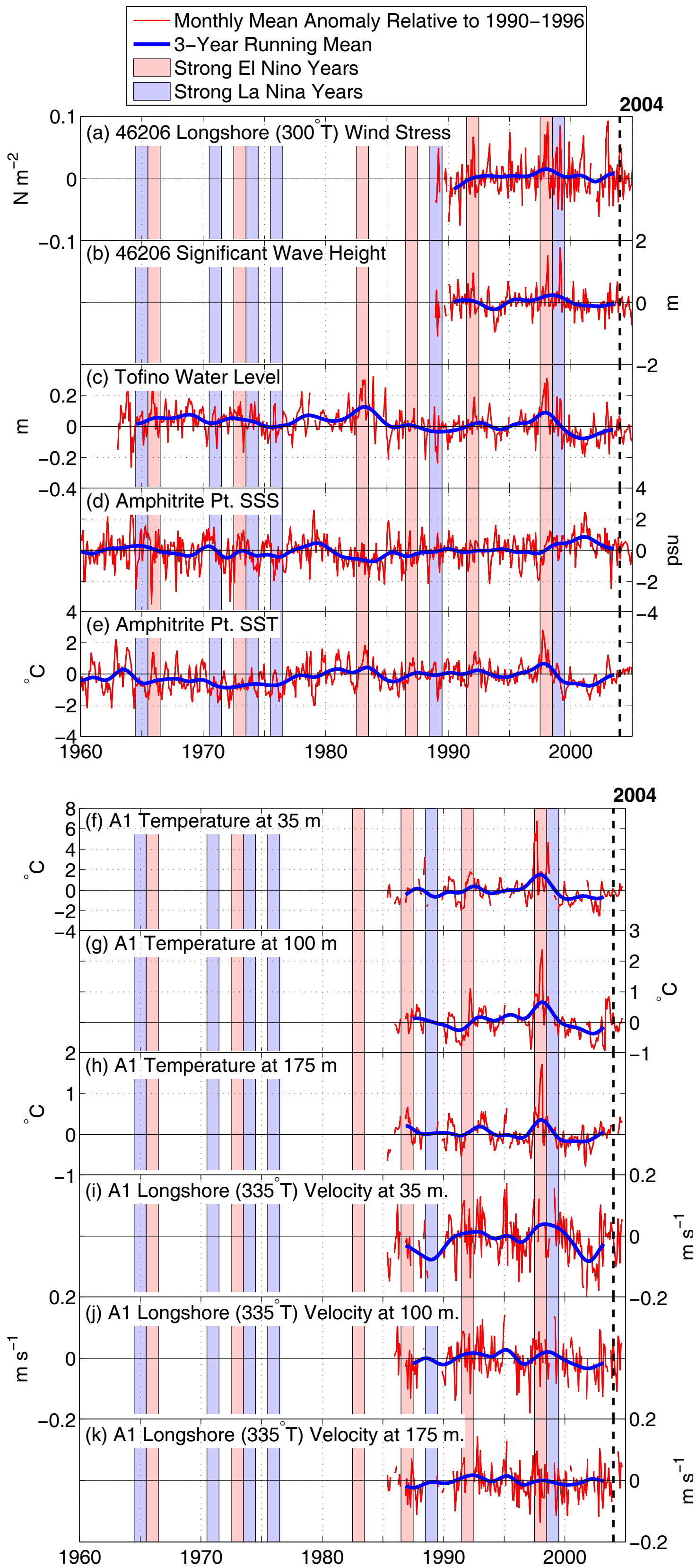


Figure Captions

Above: Map of station locations.

Left: West coast Vancouver Island daily values relative to 1990-96 average monthly means: (a) Longshore wind stress; (b) Significant wave height; (c) Water level; (d) Sea-surface salinity; (e-h) Water temperature at the surface, 35, 100, and 175 m depth; and (i-k) Longshore current velocities at 35, 100, and 175 m depth.

DFO Contacts: Rick Thomson, Roy Hourston



Southwest coast Vancouver Island: Low-frequency variability

Following the strong El Niño in 1997/98 (when the warmest West coast Vancouver Island sea temperatures on record were observed), and the subsequent La Niña (cool) event in 1998/99, there was a 4-5 year period over which many physical oceanographic anomalies off the West coast of Vancouver Island were either persistently positive or negative. This was observed for water level (lower than the 1990-96 average) (Fig. c), sea-surface salinity (higher) (d), surface to 175 m water temperature (cooler) (e-h), and longshore velocity 35 to 100 m (more equatorward) (i-k). By 2003/2004 conditions had returned to near average.

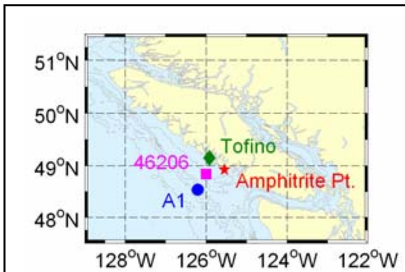


Figure Captions

Above: Map of station locations.

Left: West coast Vancouver Island monthly mean anomalies relative to 1990-96 with their three-year running mean: (a) Longshore wind stress; (b) Significant wave height; (c) Water level; (d) Sea-surface salinity; (e-h) Water temperature at the surface, 35, 100, and 175 m depth; and (i-k) Longshore current at 35, 100, and 175 m.

DFO Contacts: Richard Thomson, Roy Hourston

Southern species of zooplankton increased in abundance and the dominant northern oceanic zooplankton species bloomed earlier

Time series sampling of zooplankton has been carried out 3-6 times per year at standard locations on the continental-shelf and the adjoining deep ocean off Vancouver Island (Fig. 1). The southern Vancouver Island region (SVI, 48°-49°N) has been sampled since 1979 (standardized methods and locations since 1985), and the northern Vancouver Island region (NVI, 50º-51.5ºN) since the early 1990s (standardized methods and locations since 1996). The time series were extended in both regions through 2004. Mackas, Thomson and Galbraith (2001, *Can. J. Fish. Aq. Sci.* 58, 685-702) and Mackas, Peterson and Zamon (2004, *Deep-Sea Res*. II 51, 875-896) provide detailed descriptions of sampling and data analysis methods. These long time series allow us to estimate annual anomalies of most of the major zooplankton species, relative to their long-term baseline average annual seasonal cycle.

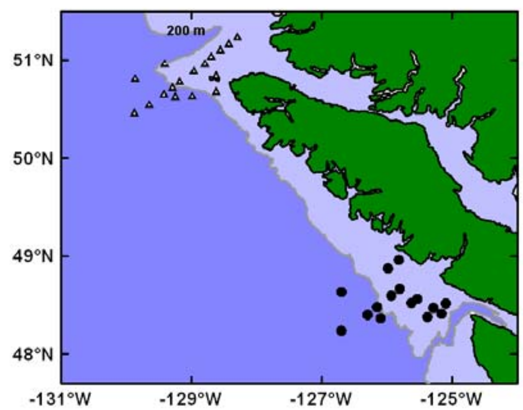


Figure 1: Zooplankton sampling locations for southern Vancouver Island (SVI, circles) and northern Vancouver Island (NVI, triangles) statistical areas. Within each region, sites are further classified as continental shelf (shallower than 200m, light blue) and offshore (dark blue).

Southern Vancouver Island (SVI)

Anomaly time series for five major SVI zooplankton groups are summarised in Fig 2, along with winter indices of large scale surface temperature variability in the North Pacific (from Bond et al., 2003, *Geophys. Res. Lett*. 30, 2083-2086 and PICES Report No. 28). Very similar patterns extended southward at least as far as central Oregon (Mackas, Peterson and Zamon, 2004, *Deep-Sea Res*. II 51, 875-896). Zooplankton anomalies are logarithmic: an annual anomaly of +1 means that the zooplankton were on average ten times more common than during the 1979-1991 reference period; –1 means they were one tenth as common. The time series show very strong (factor of 5-10 or larger) variations of all major zooplankton species groups (not just the taxa shown in Fig. 2). Shifts were particularly strong at the end of the 1980s and between 1998-1999. Through most of the 1990s, there was a strong and cumulative shift to a more 'southerly' copepod fauna, and reduction of abundance for the boreal-subarctic species. This trend reversed sharply in 1999, following the 1997-1999 El Niño-La Niña event. From 1999-2002, biomass of most zooplankton taxa along the Vancouver Island continental margin was similar to the 1979-1991 baseline period. In 2003 and 2004, the SVI zooplankton showed a partial return toward the zooplankton community of the mid-late 1990s. Southern species were significantly more abundant than average. Response of the ‘northern’ species was mixed: oceanic taxa (*Neocalanus* spp.) and shelf species that produce benthic eggs as an overwintering strategy (*Centropages* and *Acartia*) were slightly more abundant than average; other shelf species were less abundant than average.

Northern Vancouver Island (NVI)

NVI anomaly time series are shown in Fig. 3. The interannual variability of the NVI zooplankton, although significantly positively correlated with the anomalies of SVI and Oregon (Mackas et al. 2004), has been weaker off NVI. In particular, the mid 1990s replacement of boreal shelf copepods by California Current species, the reversal of this trend in 1999, and the decline of northern shelf species in 2003-04 were all less pronounced in the NVI region.

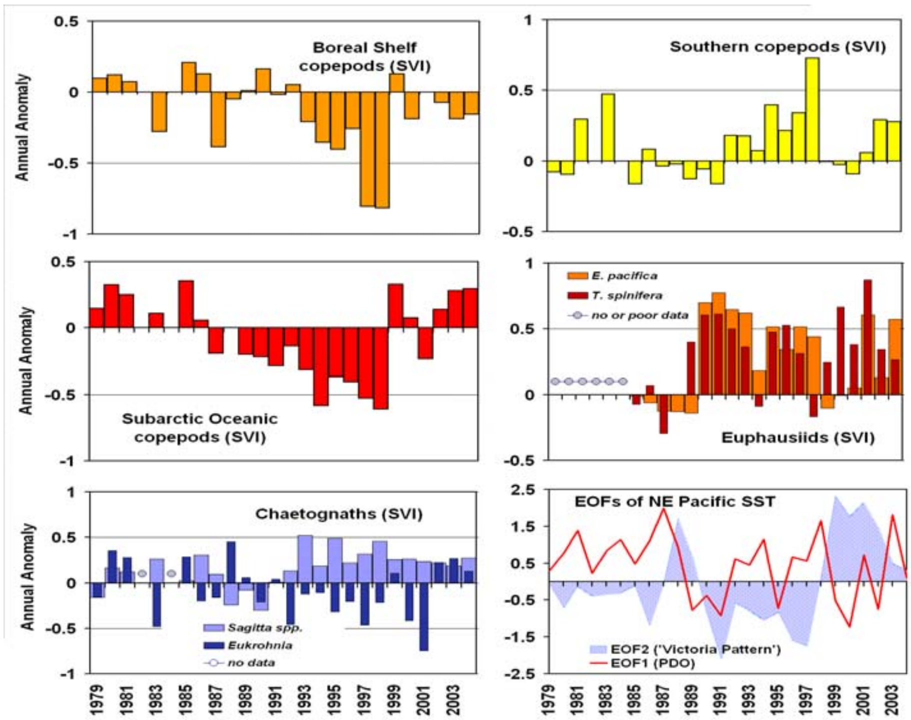


Figure 2: Southern Vancouver Island zooplankton time series: log-scale anomalies relative to the average seasonal cycle in this region from 1979-1991

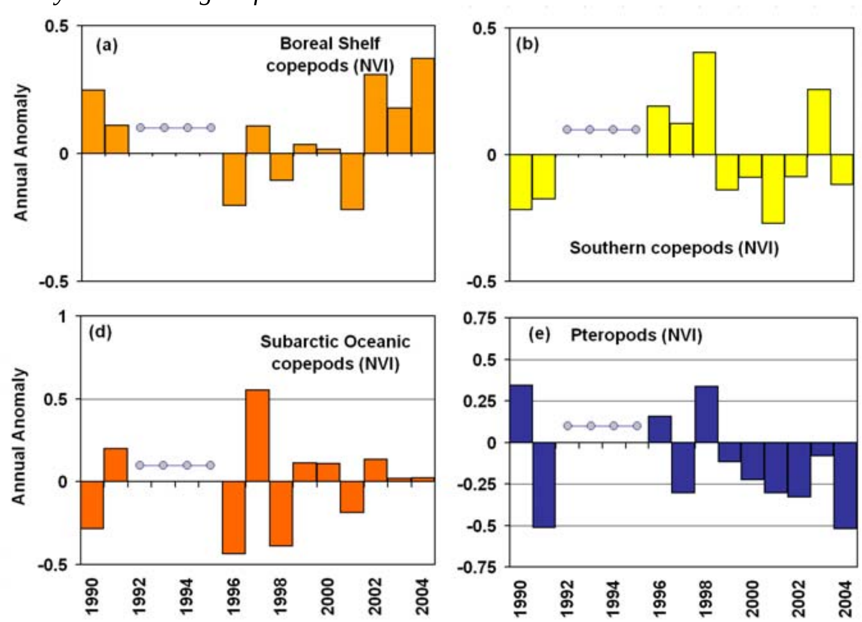


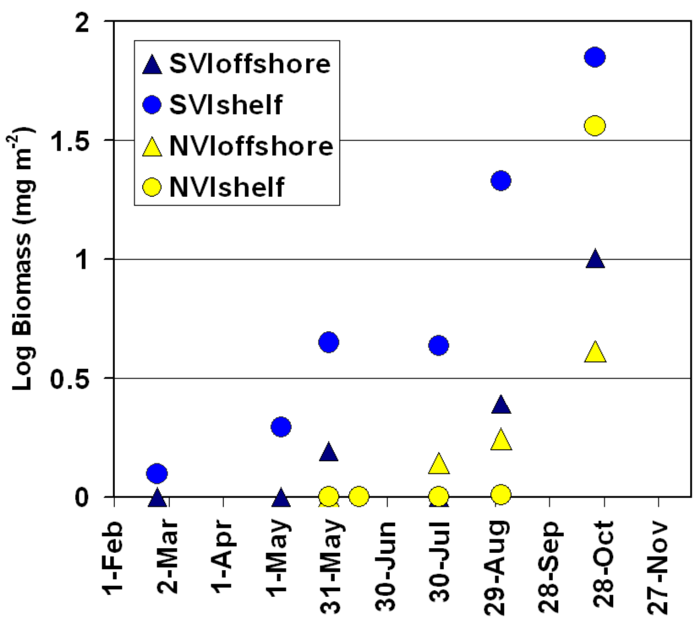
Figure 3: Northern Vancouver Island zooplankton time series: log-scale anomalies relative to the average seasonal cycle in this region from 1990-2001.

Links: Plankton Ecology Group at Institute of Ocean Sciences
DFO Contacts: Dave Mackas, Moira Galbraith, Steve Romaine

First recorded invasion of BC shelf waters by exotic zooplankton

The copepod *Acartia tonsa* is endemic to the mid-latitude Atlantic and European marginal seas, but has in the past two decades established a resident population in San Francisco Bay (J. Cordell, pers. comm.) and occurs off Oregon in low numbers during warm years with anomalously strong northward currents (W. Peterson, pers. comm.). *A. tonsa* is morphologically similar to, but slightly larger than its congener *Acartia longiremis* (Fig. 1), which has been until now the dominant *Acartia* species on this coast.

Figure 1: Side-by-side morphological comparison of adult females of Acartia longiremis (left) and Acartia tonsa (right). The background grid pattern is 1 mm. A. tonsa is larger and more robust; in other regions it also is known to be very tolerant of low salinity environments.



A. tonsa appeared in our British Columbia samples for the first time in 2003. It showed a rapid, and approximately exponential increase in biomass in 2004 (Fig. 2); by early autumn it surpassed *A. longiremis.* To date, there has been no compensating decrease of *A. longiremis*. This is the first clear evidence in our region of successful invasion of a non-estuarine environment by an exotic zooplankton species.

Figure 2: Increase during 2004 in average biomass of A. tonsa on the Vancouver Island continental margin

Links: Plankton Ecology Group at Institute of Ocean Sciences
DFO Contacts: Dave Mackas, Moira Galbraith, Steve Romaine

Euphausiids and predators on the west coast of Vancouver Island: More food for coho and sockeye, and more hake predation

One of our research activities focuses on evaluating simultaneously the influences of stock, food, and predation on the productivity of Pacific herring (*Clupea pallasi*), and coho (*Oncorhynchus kisutch*), sockeye (*O. nerka*), and chum (*O. keta*) salmon along the southwest coast of Vancouver Island. Diet analysis indicates that herring and coho prefer the euphausiid *Thysanoessa spinifera* and that these fish select prey longer than about 17 and 19 mm respectively. Sockeye prefer 3-5 mm long *T. spinifera* and chum salmon prefer 3-4 mm individuals. The 1991-2004 time series of *T. spinifera* biomass is presented in Fig. 1.

Pacific hake (*Merluccius productus*) dominates the pelagic biomass in summer and is considered to be the most important predator. Hake recruitment, as indexed by the estimate of age 2+ fish, for the 1999 yearclass was lower than only 10% of the recruitments in the 1972-2003 time series (See link to Pacific hake below). In 2004, hake from this yearclass became large enough to start consuming fish.

Historic analyses showed that recruitment to the West Coast Vancouver Island (WCVI) herring stock was negatively related to hake biomass in the Canadian zone. Results of the recent analyses suggest that recruitment to the Strait of Georgia and WCVI herring stocks is affected by stock density and hake predation. These analyses were extended to consider the three major northern herring stocks (Central Coast, North Coast, Queen Charlotte Islands). In contrast to the southern populations, recruitment is determined by hake biomass; there was no detectable stock effect. Chum productivity, as indexed by returns of Nitinat River Hatchery fish, is affected mostly by variations in hake biomass. WCVI wild coho, and Barkley Sound (Sproat and Great Central lakes) and Central Coast (Oweekeno and Long lakes) sockeye return variability can be explained by variations in *T. spinifera* biomass early in marine life. Euphausiid population dynamics is complex enough that predator-specific prey biomass must be estimated. Prey biomasses for coho and sockeye in 2004 were 10 and 80 times greater respectively than in 2003. Prey biomasses in 2004 were lower than in 65 and 44% respectively of the other years.

The following are the anticipated consequences of 2004 prey and predator biomass levels.

- Herring: recruitment to all major BC stocks should begin declining in 2007 because of the hake predation effect;
- WCVI wild coho: marine survival is forecast to increase to about 5% for the 2005 return year because of improved food availability in the 2004 smolt year;
- Barkley Sound sockeye: returns in 2005 will be low because of low food availability for ages 4 (2003 smolt year) and 5 sockeye (2002 smolt year) and increase in 2006 because of improved prey biomass for age 4 fish (2004 smolt year);
- Central Coast sockeye: returns will be low in 2005 and 2006 because of the small effect of increases in euphausiid biomass in 2004;
- Nitinat River Hatchery chum: returns should decline markedly as of 2007 because of hake predation.

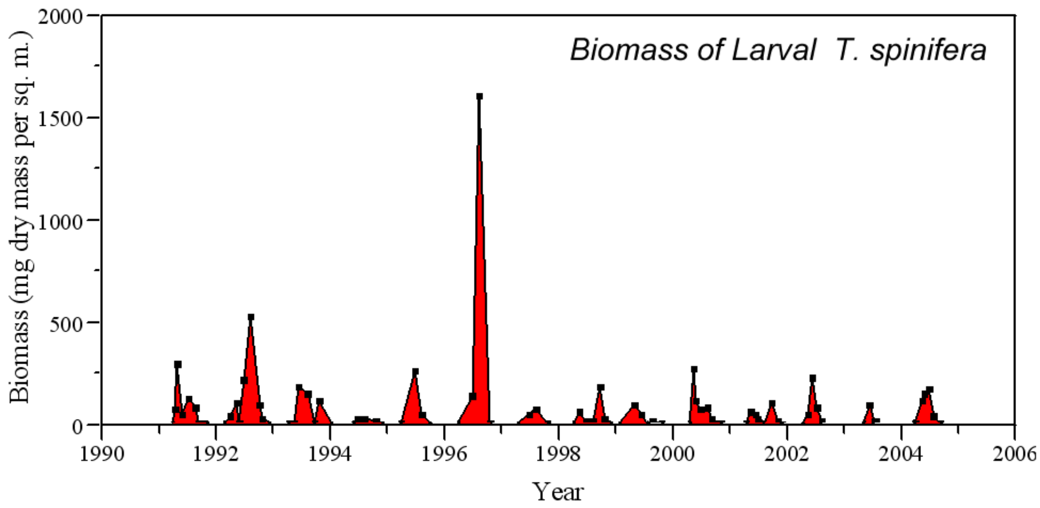
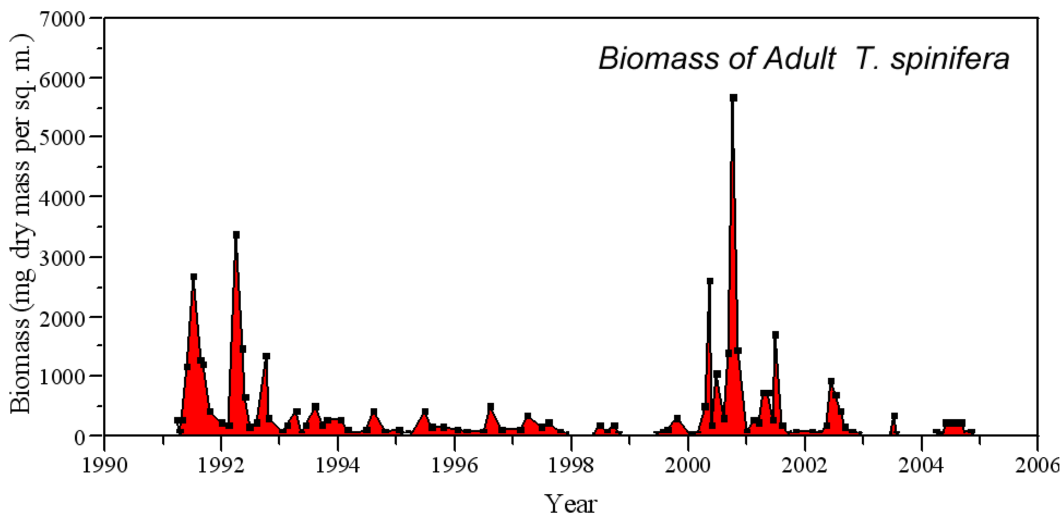


Figure 1: The 1991-2004 time series of ***larval*** *(top panel, <10 mm) and* ***adult*** *(bottom panel > 9 mm) T. spinifera biomass. Median larval and adult biomasses in 2004 were three and 10 times greater respectively than in 2003, the year of lowest larval and adult biomasses. The biomasses in 2004 were lower than 58 and 78% respectively of the other years.*



Links Pacific Hake in Ocean Status Report 2003 (page 42)
Pacific Hake in Ocean Status Report 2004 (page 49)
DFO Contact: Ron Tanasichuk

Growth and energetic status of juvenile coho salmon: Largest juveniles found since sampling began in 1998

Ocean surveys for juvenile salmon using the CCGS *W.E. Ricker* have been used to assess the growth, condition, and survival of salmon in different parts of the British Columbia coastal ecosystem since 1998. These surveys were typically conducted in June-July and in October-November. In addition, juvenile salmon have been collected during February-March since 2001. The results indicated that juvenile coho salmon caught off the west coast of Vancouver Island (WCVI) in June 2004 were the smallest on record for this area since 1998 (Fig. 1). The opposite pattern was observed for northern British Columbia/southeast Alaska (NBC/SEAK) with juvenile coho salmon reaching the largest size on record for this area since 1998 (Fig. 1). By October 2004, juvenile coho salmon caught off WCVI in 2004 were among the largest juvenile coho salmon recorded in this area during the surveys (Fig. 1). This suggests either that summer growth was exceptionally good off WCVI in 2004 or that size-selective mortality favoured faster growing fish. Juvenile coho salmon caught in NBC/SEAK during fall were generally larger than those from southern stocks in all the years, suggesting better feeding conditions during summer at northern latitudes.

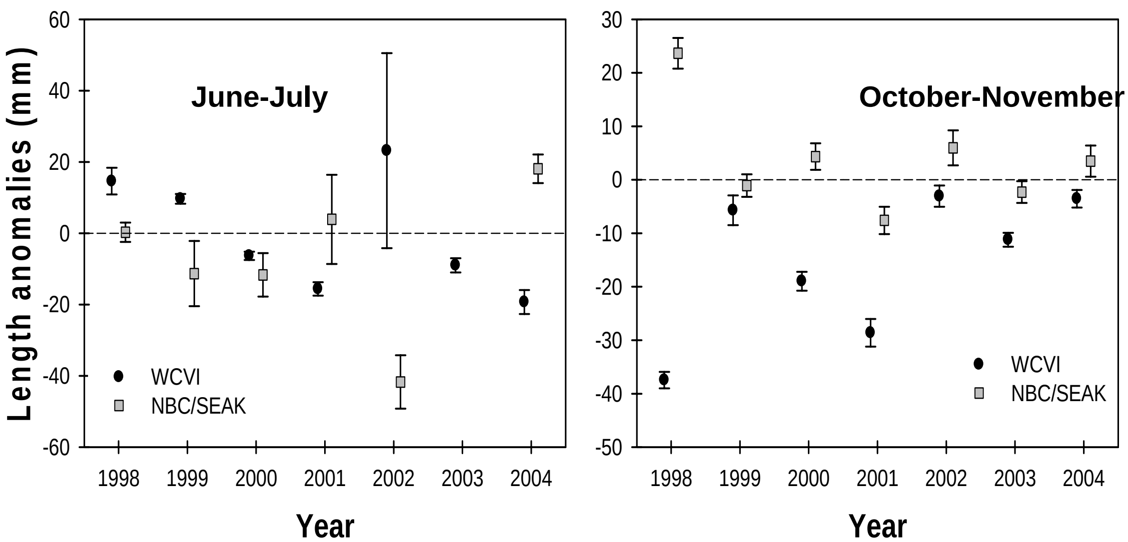


Figure 1: Summer and fall fork length anomalies of juvenile coho salmon caught during their first year at sea off the west coast of Vancouver Island (WCVI) and northern BC/southeast Alaska (NBC/SEAK). Length anomalies were calculated as the difference between observed and expected fork length, averaged across fish within a season, year, and region. The expected fork length was estimated by fitting a third order polynomial to fork length versus day of the year. We added 365 days to the day of the year for coho that were caught in their second ocean year.

Percent dry mass, which is an indicator of caloric content and lipid concentration in fish (Trudel et al., 2005, N. Am. J. Fish. Manag. 25: 364-390) has been measured in a sub-sample of the juvenile coho salmon collected during fall and winter. Off WCVI, percent dry mass of juvenile coho salmon has been increasing almost consistently every year and reached the highest observed levels in 2004 (Fig. 2). Except for October 1999, the percent dry mass of juvenile coho salmon were consistently higher in NBC/SEAK than off WCVI (Fig. 2), suggesting that juvenile coho salmon from northern latitudes not only grow faster but are also in better condition at the end of the growing season. This could potentially explain the higher marine survival of SEAK coho salmon (13.6%) compared to southern BC stocks (3.5%). Percent dry mass also decreased over winter (Fig. 2), suggesting that juvenile coho salmon rely in part on energy reserves accumulated during the growing season to fuel their metabolic rates during the low productive winter months.

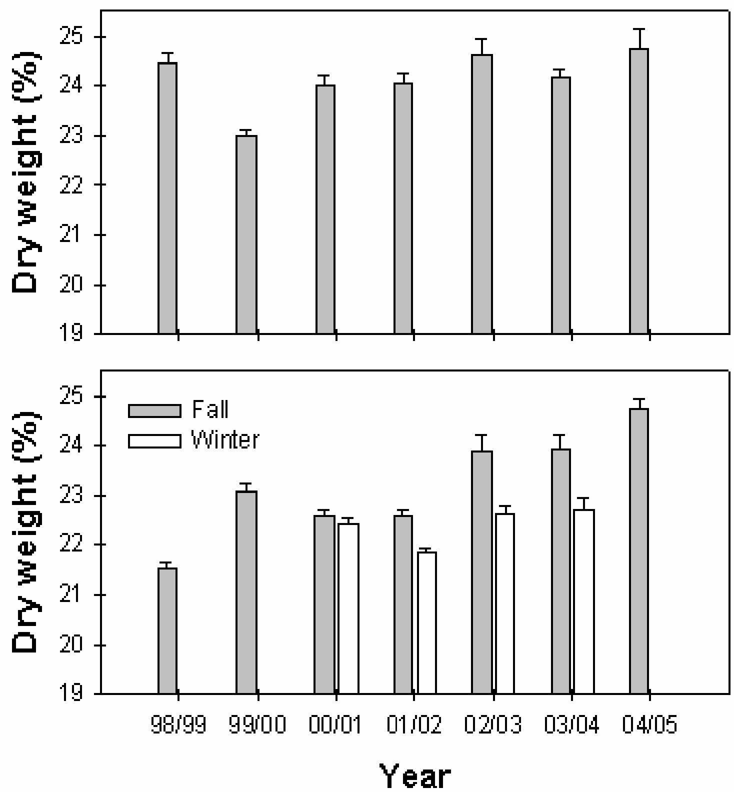


Figure 2: Percent dry mass of juvenile coho caught off the west coast of Vancouver Island (WCVI) and northern BC/southeast Alaska (NBC/SEAK) during fall and winter. Since 2001, only two juvenile coho salmon have been caught north of Vancouver Island during winter, preventing this over-winter comparison for NBC/SEAK.

The general assumption of this work is that marine survival is expected to be high when salmon are rapidly growing and are in good condition and low in years of poor growth and condition. Hence, marine survival is expected to be positively correlated to indicators of growth rate such as attained size in summer and fall.

Marine survival was negatively correlated with summer fork length in three out of seven coho salmon stocks from southern British Columbia, though this relationship was only significant for the Quinsam River hatchery (Fig. 3). In contrast, marine survival was positively correlated to fall size in Robertson Creek hatchery coho salmon (Fig. 4). In general, survival of different hatchery coho stocks was not well-correlated between stocks, or with observed marine sizes. The mechanism generating these varying relationships is poorly understood and will require further investigation, but the different survival rates suggest that the stocks may not all be located in the same area.

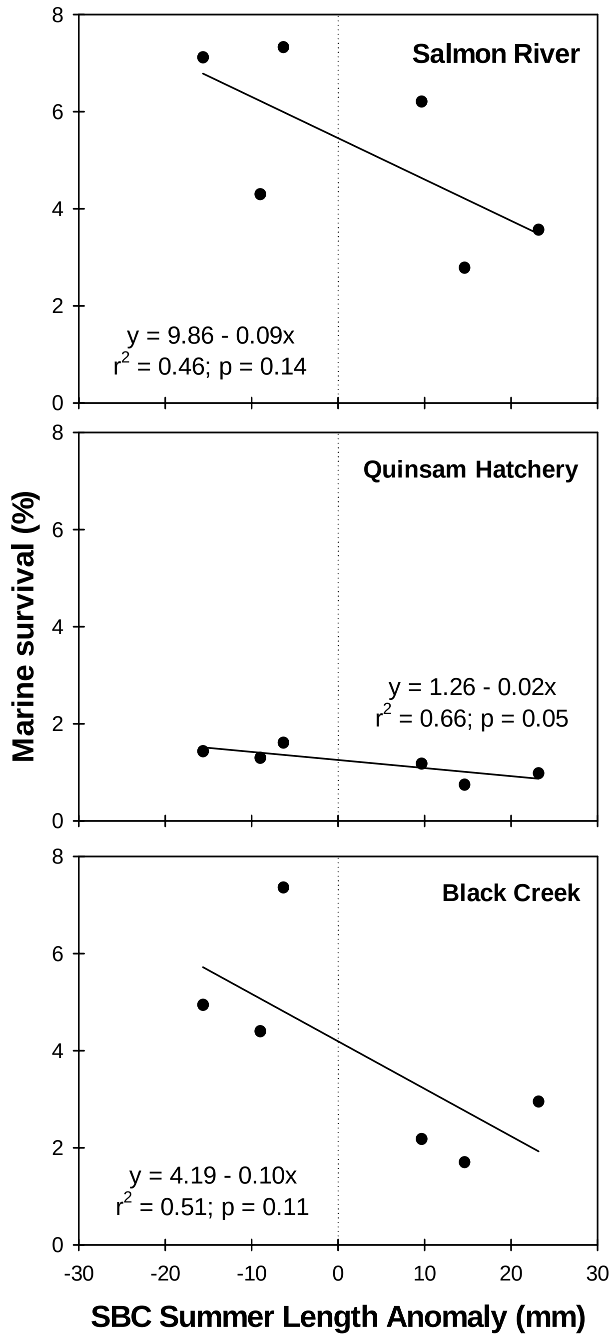


Figure 3: Stock-specific relationship between marine survival and summer fork length anomalies off the west coast of Vancouver Island for Quinsam River Hatchery coho.

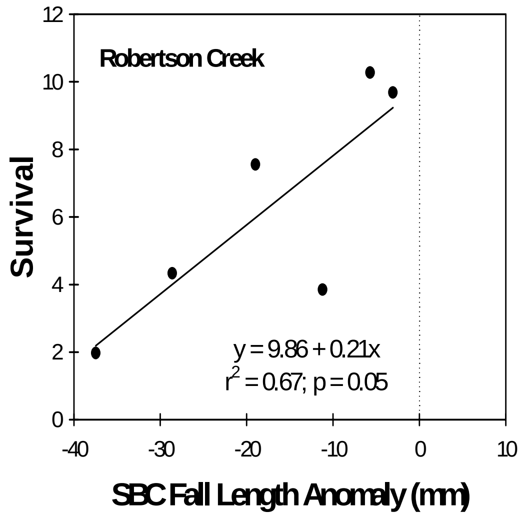


Figure 4: Stock-specific relationship between marine survival and fall fork length anomalies off the west coast of Vancouver Island for Robertson Creek hatchery coho.

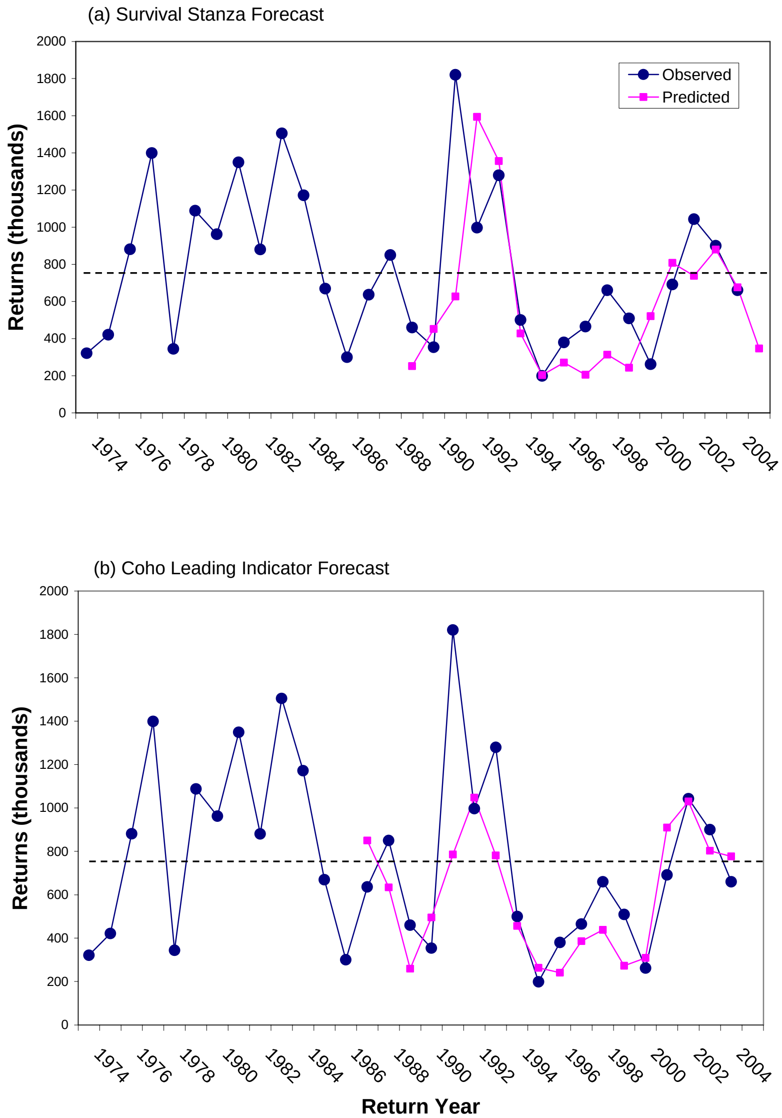
Links DFO coho web page
DFO contact: Mark Trudel

Barkley Sound sockeye recruitment: Variations, ocean state changes and year 2004 performance

Barkley Sound (BkSd) sockeye on the west coast of Vancouver Island (WCVI) exhibit annual recruitment variations that alter abundance patterns by more than an order of magnitude within intervals as short as 2-3 years (Figure 1.). Thus, a peak return of 1.7 million sockeye in 1991 was followed by a minimum return of only 113,000 adult sockeye three years later. Large production variations exhibited by BkSd salmon confer a "boom and bust" character to native, recreational and commercial fisheries. To complicate matters further, BkSd sockeye abundance changes do not occur with the same predictable regularity associated with cyclic dominance patterns exhibited by Fraser River sockeye. Studies to determine the biophysical mechanisms and origins (i.e. freshwater or marine environment) of BkSd sockeye production variations have a long history (Hyatt and Steer 1987) and, more recently, have clarified their basis as follows: (1) on average, annual changes in freshwater and marine environmental conditions each account for about 50 % of observed production variations (Hyatt and Steer 1988), (2) production variations originating in freshwater exhibit no obvious temporal trend but those originating in the marine environment co-vary "periodically" in association with physical changes (temperature and/or salinity) in the latter, (3) changes to dominant predator and prey communities that BkSd sockeye encounter on the continental shelf during the early portion of their seaward migration drive major changes in survival (Hyatt, unpublished results), (4) a simple two-state, "survival stanza", model (SStM, Hyatt and Steer 1988) in which smolt-to-adult survival rates alternate between a relatively high mean level (5 %) when ocean conditions are favourable (i.e. SST > 30 yr average during smolt migration) and a lower mean level (2.5 %) when ocean conditions are unfavourable (i.e. SST < 30 year average during smolt migration) has been used since 1988 to successfully predict (Figure 1a.) stock collapses (late 1980's, mid-1990's) and recoveries (early 1990's, 2000's) associated with strong El Nino and La Nina events respectively. These predictions have been critical to planning annual openings or closures of various fisheries supported by Barkley Sound sockeye (Hyatt et al. 2003), (5) WCVI ecosystem state changes not only influence BkSd sockeye marine survival variations but also have similar effects on other WCVI salmon populations (e.g. Hobiton Lake sockeye, Hyatt unpublished data; Kennedy Lake sockeye, Robinson and Hyatt 1999; Robertson Creek coho, Hyatt et al. 2000; and Roberston Creek Chinook salmon, Hyatt et al. unpublished results), (6) Robertson Creek coho mature and return to freshwater a year earlier than sockeye salmon so marine survival variations observed for the former may serve as the basis for an annual Coho Leading Indicator (CLI) Forecast of BkSd sockeye returns (Figure 1b., Dobson et al. 2005).

Given the observations above, time series changes in recruitment variations and annual returns of Barkley Sound sockeye salmon may be considered as part of an integrated suite of potentially useful biophysical indicators (temperature, salinity, abundance of major prey taxa e.g. euphasiids, Robertson Creek coho salmon survival) of significant historic or future state changes to WCVI coastal marine ecosystems. Sockeye returns fell just below the long term average in 2004 but were very close to levels predicted by both the SStM and CLI models (Figure 1.). This reflected a combination of conditions that first favoured higher and then lower marine survivals experienced by WCVI juvenile salmon during their 2001 (SST and multivariate ENSO index negative) and 2002 (SST and multivariate ENSO index positive) ocean entry years respectively. In 2004, SST at Amphitrite Point (Crawford, this report) and the NOAA multivariate ENSO index (http://www.cdc.noaa.gov/people/klaus.wolter/MEI/) added to a series of positive values initiated in 2002. Consequently, recruitment levels of several WCVI salmon stocks (all sockeye stocks originating from WCVI nursery lakes, Carnation Creek coho, Robertson Creek coho and Chinook) are likely to fall below average (e.g. Barkley Sound sockeye, Dobson et al. 2005) in return years 2005 and 2006.

Figure 1. Annual Returns and Forecasts of Barkley Sound Sockeye 1974-2004



DFO Contact: [Kim Hyatt]

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Hyatt, K. D. and G. J. Steer. 1987. Can. Spec. Publ. Fish. Aquat. Sci. 96: 435-457.

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Robinson, C. L. K. and K. D. Hyatt. in Brian Egan (ed.) Proceedings of the Helping Heal the Land Conference on Ecological Restoration in British Columbia, Nov. 5-8, Victoria, B. C. Published by the BC Environmental Network Educational Foundation. 251 p., 2 appendices.

Seabird reproductive performance on Triangle Island: A successful year for breeding auklets

Triangle Island Background and Species Natural history

Marine birds can be effective indicators of the state of marine ecosystems because they gather in large aggregations to breed and because, as a group, they feed at a variety of trophic levels (zooplankton to fish). Seabird breeding success is closely tied to the availability of key prey species, and as a result, can vary widely among years, depending on ocean conditions. Triangle Island (50°52' N, 129°05' W) in the Scott Islands off Northern Vancouver Island supports the largest and most diverse seabird colony along the coast of British Columbia. Since 1994, researchers from the Centre For Wildlife Ecology (a partnership between the Canadian Wildlife Service and Simon Fraser University), have visited Triangle Island between late March and late August to collect annual time-series information on seabird demography and ecology. This report presents key indicators of seabird breeding at Triangle Island in 2004, focusing on species belonging to the family Alcidae, and place 2004 results within the context of the 1994-2003 time series.

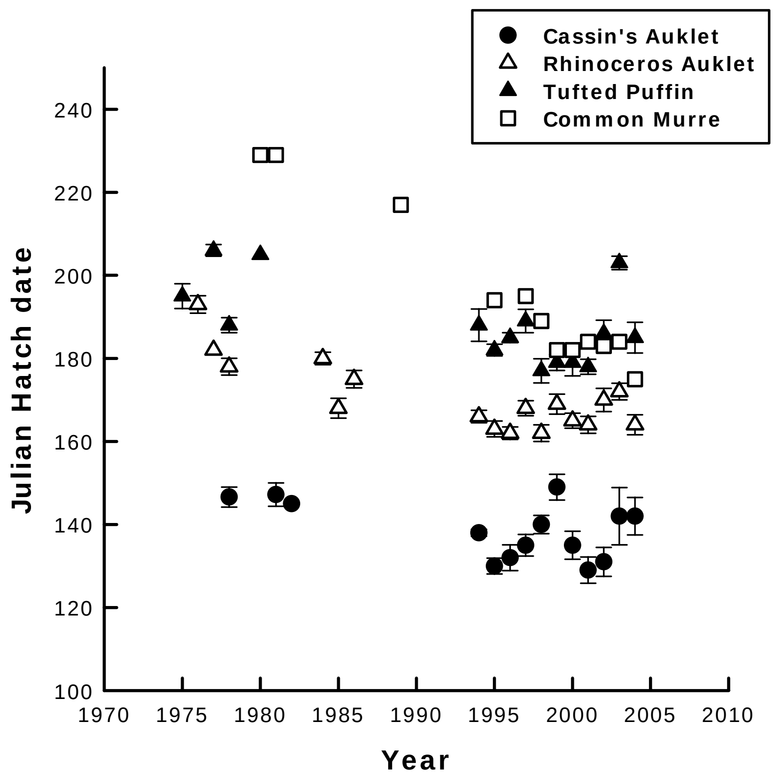


Figure 1: Timing of breeding for seabirds on Triangle Island, British Columbia, 1975-2004.

Reported are mean hatching dates, with 95% confidence intervals, for Cassin's Auklets, Rhinoceros Auklets and Tufted Puffins, and dates when nestlings were first seen for Common Murres.

All four species bred early (very early in the case of Common Murres), or at about the normal time.

Timing of breeding

Timing of avian breeding is thought to be determined primarily by female condition prior to and during the period of egg formation, which is itself related to food availability early in the season. In general, the timing of breeding among the alcids was early to normal in 2004, compared to previous years (Fig. 1). This suggests that food was readily available early. Of particular note, the timing of laying among Common Murres was the earliest yet recorded

Breeding success

All species of alcids bred successfully at Triangle Island in 2004. In both Cassin's Auklets and Rhinoceros Auklets (our primary study species), breeding success was as high or higher than in any other year since 1994, and considerably higher than predicted from early season sea surface temperatures recorded at Pine Island (Fig. 2). Of note, the high success rate in 2004 occurred in the absence of several factors associated with previous successful seasons: for Cassin's Auklets, nestling diets included less *Neocalanus cristatus* than had been observed in a number of previous successful years (notably 1999 and 2000), while euphausiids (especially *Thysanoessa inspinata)* and larval fish were both quite important; and for Rhinoceros Auklets, nestling diets included less Pacific sandlance (*Ammodytes hexapterus*) than in many previous successful years, and the bulk of the sandlance, including age 0+ individuals, appeared quite late. Salmon and rockfish were both important components of Rhinoceros Auklet nestling diets in 2004, and juvenile rockfish was also the major item fed to nestling Common Murres. On the whole, 2004 was a successful year, but also an unusual year, for seabirds breeding on Triangle Island.

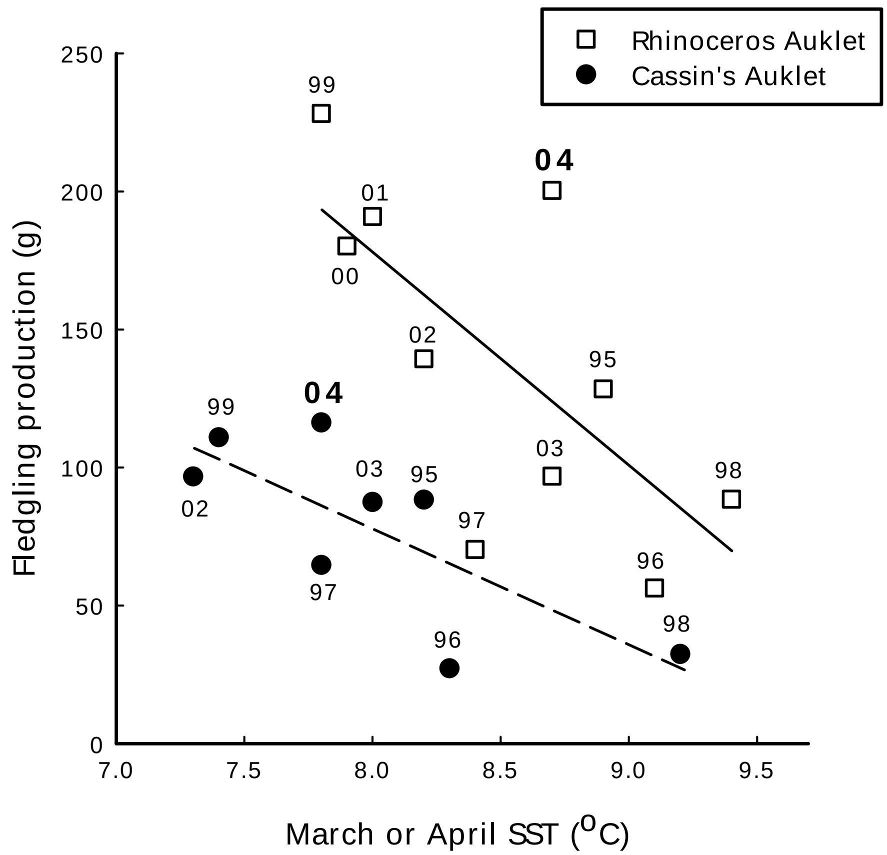


Figure 2: Consequences of April sea surface temperatures, measured at the Pine Island Lightstation (50°35'N 127°26'), for Cassin's and Rhinoceros auklets breeding on Triangle Island, British Columbia, 1994-2003. Fledgling production is calculated as: hatching success x % fledging success x mean fledging mass; or in other words, the mean mass of fledged chick produced per egg laid. Both species bred very successfully in 2004, and well above values predicted from SST recorded at Pine Island lightstation.

Links Scott Islands Marine Wildlife Area
Canadian Wildlife Service bird monitoring in BC
Seabirds in Ocean Status Report 2003 (Page 69)
Environment Canada Contact: Mark Hipfner

Herring and sardines on west coast of Vancouver Island in 2004: Average abundance of herring but fewer recruits; Sardines were late and scarce in offshore waters

Herring

Herring recruitment off the west coast of Vancouver Island declined from 1977 to the late 1990s. Abundance in 2004 was similar to the previous year but continued the recent increasing trend. Warm ocean temperatures appear to be associated with poor recruitment for herring (opposite of herring stocks in the Strait of Georgia), and an increase in summer biomass of predators. Apart from predation, ocean conditions (temperature) appear to be warming resulting in poorer herring survival that may result in reduced recruitment to the stock in 2005 and 2006.

Since about 1977, the recruitment of herring off the West Coast of Vancouver Island has been generally poor (Figure 1). The productivity of the west coast of Vancouver Island herring stock (Figure 2) has been declining since 1989, primarily because recruitment to this stock has been poor for 6 of the last 10 years (Figure 1) although there are recent signs of some recovery. In 2003, the spawning biomass (Figure 2) increased to the average for the past two decades and 2004 is similar. Research studies have shown that herring recruitment in this region tends to be negatively correlated with temperature probably reflecting: 1) poor feeding conditions for herring larvae and juveniles during their first growing season; and 2) a general increase in the mortality rate of the larvae and juveniles, due to an increase in the intensity of invertebrate and fish predation in the rearing area in warm years. Studies to measure the predation rate confirm that the negative correlation between herring recruitment and hake biomass could be caused by predation. Ocean conditions have warmed in the last few years impacting herring survival in 2002 and 2003 and could result in reduced recruitment to the stock in 2005 and 2006.

Interpretation and speculative results: Herring on the west coast of Vancouver Island are likely to remain stable or decline slightly unless ocean conditions resulting in a reduction in the abundance of predators in the area improve. Recent conditions have been less favourable for herring survival in 2002 and 2003, and we expect weaker recruitment to the stock during the next couple of years.

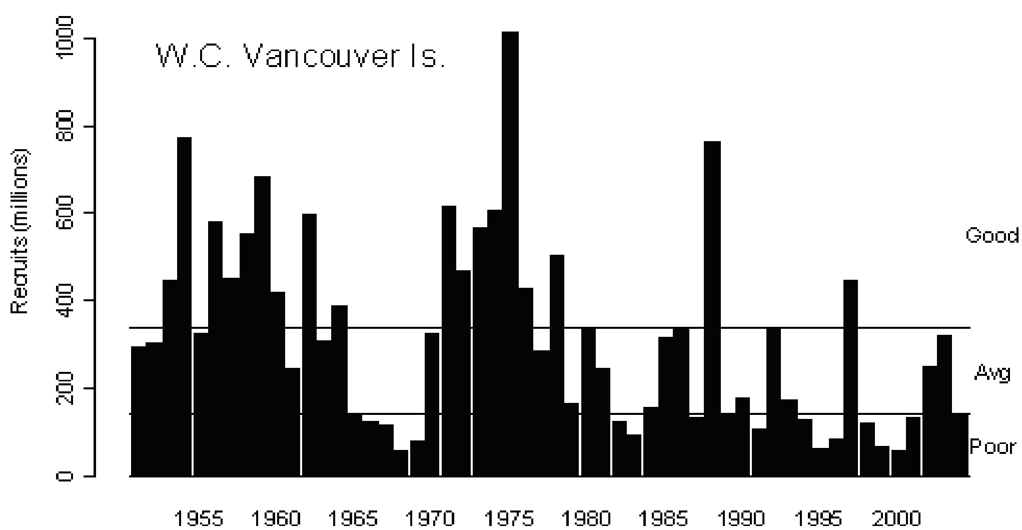


Figure 1: Interannual variability and decadal trends in recruitment to the west coast of Vancouver Island herring stock. The boundaries for 'poor', 'average' and 'good' recruitment are shown. Note that 6 of the last 10 recruitments have been 'poor'.

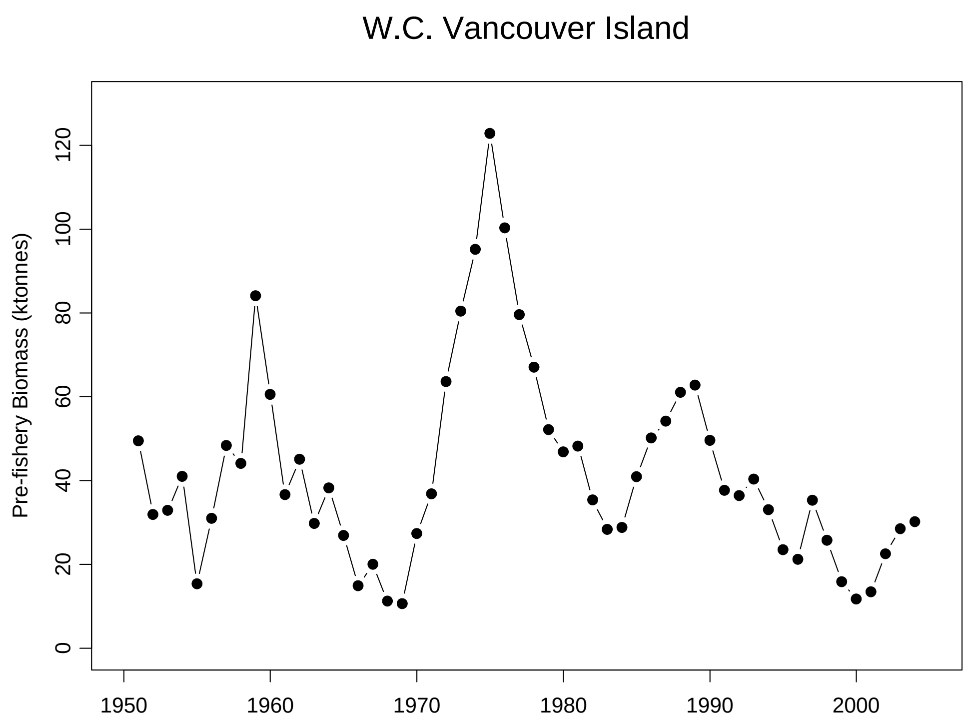


Figure 2: West Coast Vancouver Island herring abundance.

Pacific Sardine

Pacific sardine is a migratory species and when the population is healthy and ocean conditions are favourable, sardines migrate to British Columbia in the summer to feed. Most of these summer migrants make a return spawning migration in the fall to the waters off central and southern California. The sardine fishery in Canadian waters collapsed in 1947 without warning and by the early 1950s off California due to unfavourable environmental conditions. After a 45-year absence from British Columbia waters, sardines reappeared off the west coast of Vancouver Island in 1992. From 1992-1996, their distribution was limited to the southern portion of Vancouver Island. In 1997, their distribution expanded northward and by 1998 sardines inhabited waters east of the Queen Charlotte Islands throughout Hecate Strait and up to Dixon Entrance. Spawning was reported off the west coast of Vancouver Island in 1997 and 1998. In 1999 following the El Niño, sardine distribution again contracted southward. During 2003 and 2004, sardines did not appear in Canadian waters until late-July and were confined to coastal inlets along Vancouver Island and parts of the Central Coast. The most recent U.S. assessment suggests a leveling off in sardine abundance (Fig. 3). The 2004 trawl survey off Vancouver Island (Fig. 4) found virtually no sardines in the offshore waters except in the south and some concentrations at the mouth of the inlets. Fewer sardines were present than in 1997-1999 when water conditions were warmer.

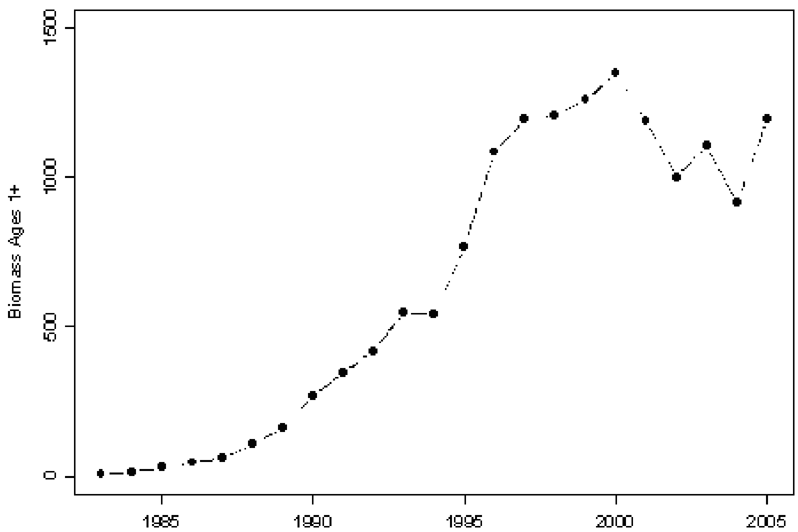


Figure 3: Time series of Pacific sardine stock biomass (x1,000 mt) of age 1 and older fish, estimated from an age-structured stock assessment model (data from Conser, R.J., Hill, K.T., Crone, P.R., Lo, N.C.H., and R. Felix-Uraga. 2004. Assessment of the Pacific sardine for U.S. management in 2005. Available from http://swfsc.nmfs.noaa.gov/frd/Coastal%20Pelagics/Sardine/Sardine_Assessment_Nov_2004_revised.pdf.)

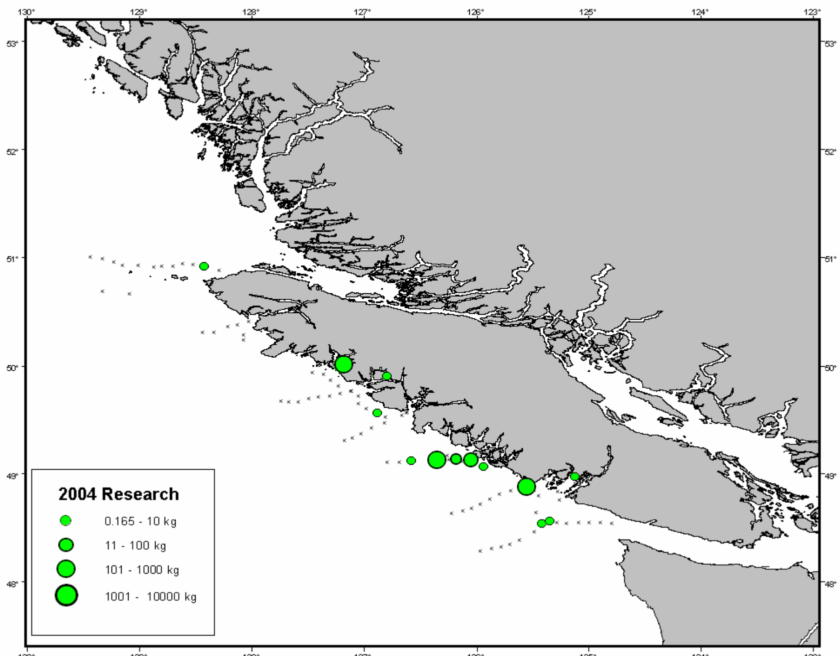


Figure 4: The distribution of Pacific Sardine was concentrated in southern inshore areas in 2004. Dots represent sets at depths shallower than 45m where no sardines were captured, and circles represent the quantity of sardines captured in the set.

***Interpretation and speculative results**:* Sardines reappeared off the west coast of Vancouver Island in 1992. During the 1990s their distribution expanded northward into Hecate Strait to Dixon Entrance. However, in 2003 and 2004, the distribution of sardines in B.C. was again reduced and limited to the inlets of Vancouver Island and offshore areas in the south.

Links DFO Pelagics Section
DFO Contact: Jake Schweigert

Summer nutrient depletion trends west of Vancouver Island: Low-nitrate surface waters were farther offshore in 2003 and 2004, but not as far as observed in the nitrate drought of the late 1990s

Nitrate is the nutrient controlling phytoplankton growth in the coastal ocean, in large part because other potentially limiting nutrients are supplied by rivers and continental shelves in large amounts (e.g. silicate and iron; Whitney et al., in press. Deep-Sea Res.).

During the mid 1990s, persistent El Niño conditions enhanced the northward transport of subtropical waters off the BC coast, resulting in a reduced winter supply of nitrate to the surface ocean for several years (Fig. 1). During this time, measurements showed that nitrate-depleted waters in summer had lower primary productivity than both coastal waters that were enriched by upwelling, and the iron-limited waters of the open ocean (Whitney et al., 1998. Mar. Ecol. Progr.Ser. 170).

Since 1999, summer nitrate depletion has been similar to that observed in the late 1980s, although winter nutrient supply remains less than that observed in the 1970s. Low-nitrate water extended farther offshore in 2003 and 2004 than in the cooler years of 2000 and 2001. Stratification of the upper ocean is the dominant control on nutrient transport from depth, into the surface ocean layer.

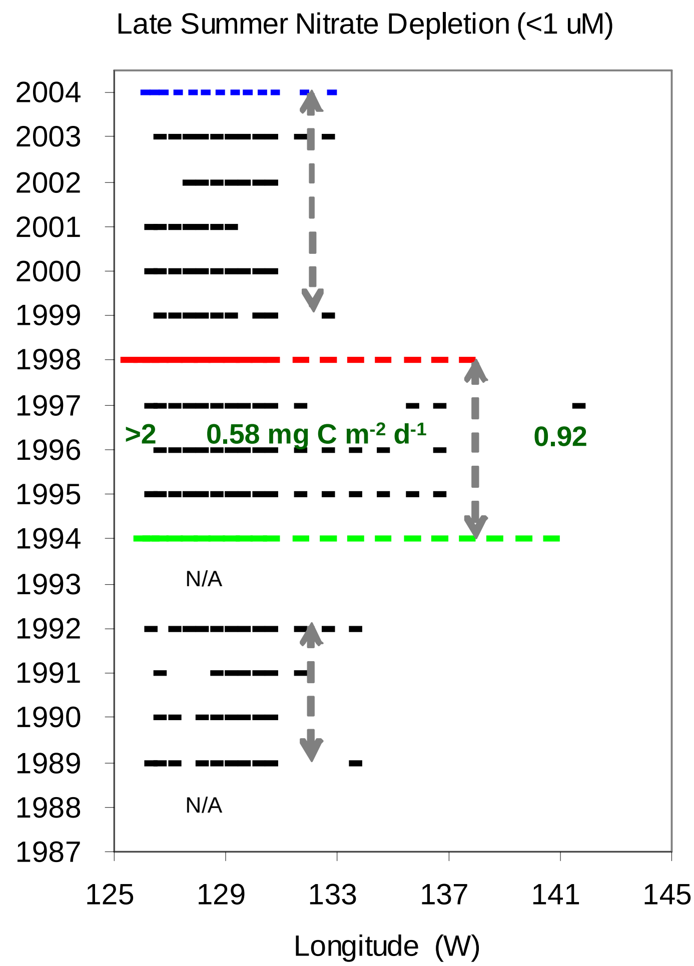


Figure 1: Nitrate depletion in surface waters along Line P in summer months. Typical primary productivity measurements for the coastal (>2 mg C m^{-2} d^{-1}), nitrate-depleted (0.58 mg C m^{-2} d^{-1}) and nitrate-replete (iron limited; 0.92 mg C m^{-2} d^{-1}) ocean regions are noted.

Links: Line-P and Ocean Station Papa
Nutrients in Ocean Status Report 2003 (page 28)
DFO Contact: Frank Whitney

Oxygen in deep water of the BC continental shelf: Continuing decline since records began in 1979

The British Columbia coast is a downstream recipient of waters coming from the weakly ventilated western Pacific and Gulf of Alaska. Coastal waters are also influenced by the California Undercurrent which can be the dominant water mass off Vancouver Island (Mackas et al., 1987. J. Geophys. Res. 92).

Oxygen trends on the BC coast show impacts of declining oxygen levels in subarctic waters. Offshore of both the Queen Charlotte Islands and Vancouver Island on isopycnal surfaces that represent depths of 150 to 300 m, oxygen is declining at ~1 µM/y over the past couple of decades. This depth range is typical of deep and bottom water on the BC continental shelf.

The fishes and marine organisms that are most sensitive to oxygen declines are those that have higher metabolic rates, including pelagic fishes, but also many early life stages of groundfish that may tolerate low oxygen as adults.

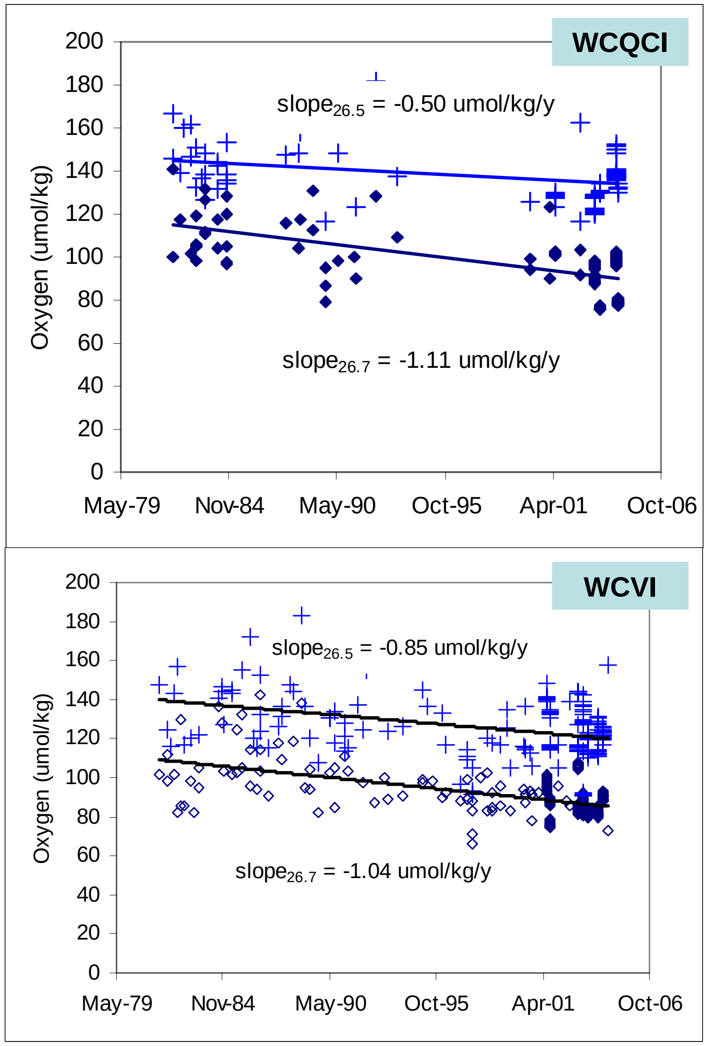
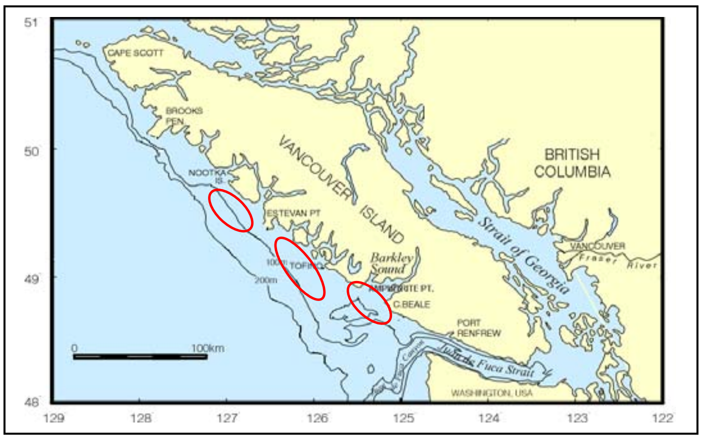


Figure 1: Oxygen concentrations on 2 isopycnal surfaces, 26.5 (~150 m) and 26.7 (250-300 m) off the southwest coast of Vancouver Island (WCVI) and the west coast of Queen Charlotte Islands (WCQCI). All data come from the IOS archive.

Links: Water in the NE Pacific in 2004
Line-P and Ocean Station Papa
DFO Contact: Frank Whitney

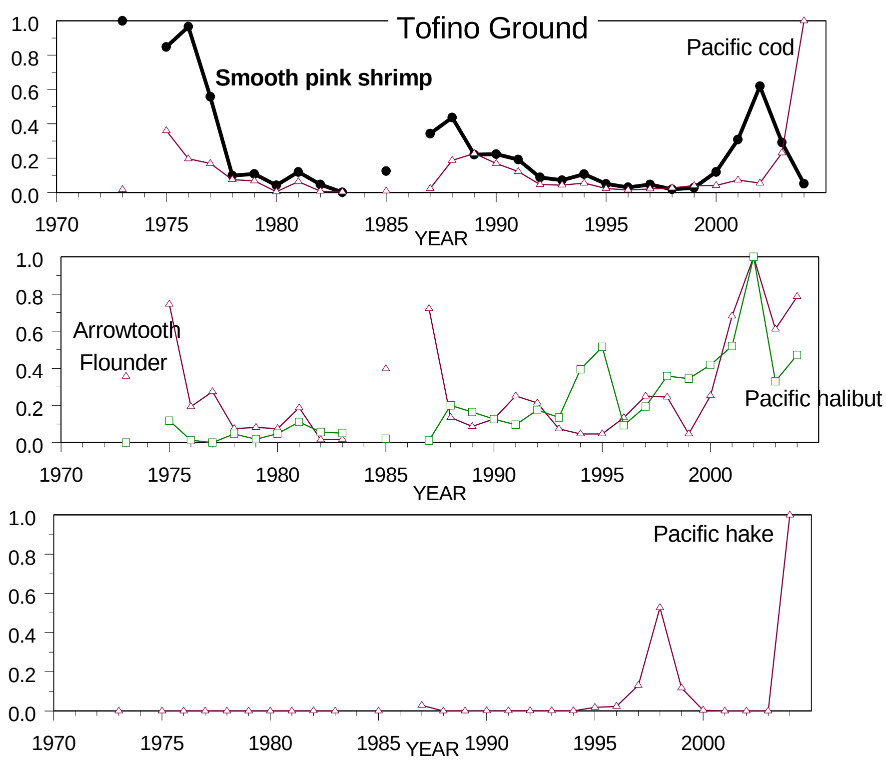
Small-mesh bottom-trawl surveys off Vancouver Island: Warmer waters in 2004 resulted in fewer shrimp, but more hake, cod, halibut and arrowtooth flounder.

Bottom trawl surveys using a small-mesh net (targeting the smooth pink shrimp *Pandalus jordani*) have been conducted during May since 1973. The survey for 2004 indicated that the *Pandalus jordani* shrimp population off of Tofino continued its decline (from the recent peak in 2002) because of declining recruitment. In contrast, strong increases in catches of Pacific cod and Pacific hake occurred in 2004, along with small increases in arrowtooth flounder and Pacific halibut (reversing their decline since 2002). In total, these changes suggest warmer water conditions in 2003 and 2004 in contrast to cooler conditions from 1999 to 2002.



__Left:__ Map showing the three main shrimp (Pandalus jordani) fishing grounds off Vancouver Island (red ovals). The Tofino Ground is the middle oval.

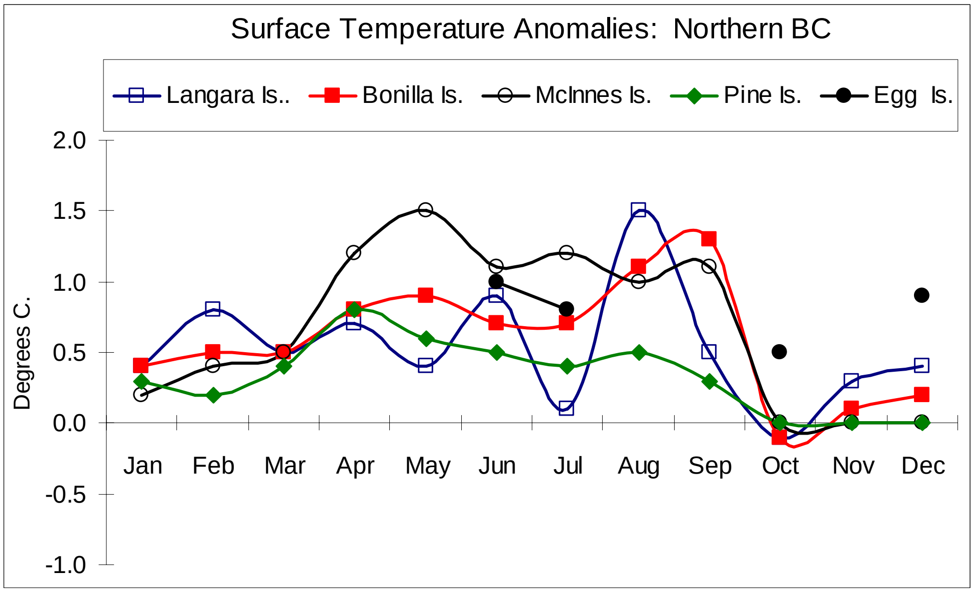
__Below__: Time series of normalised survey catches of smooth pink shrimp, Pacific cod, Pacific halibut, Arrowtooth flounder, and Pacific hake.



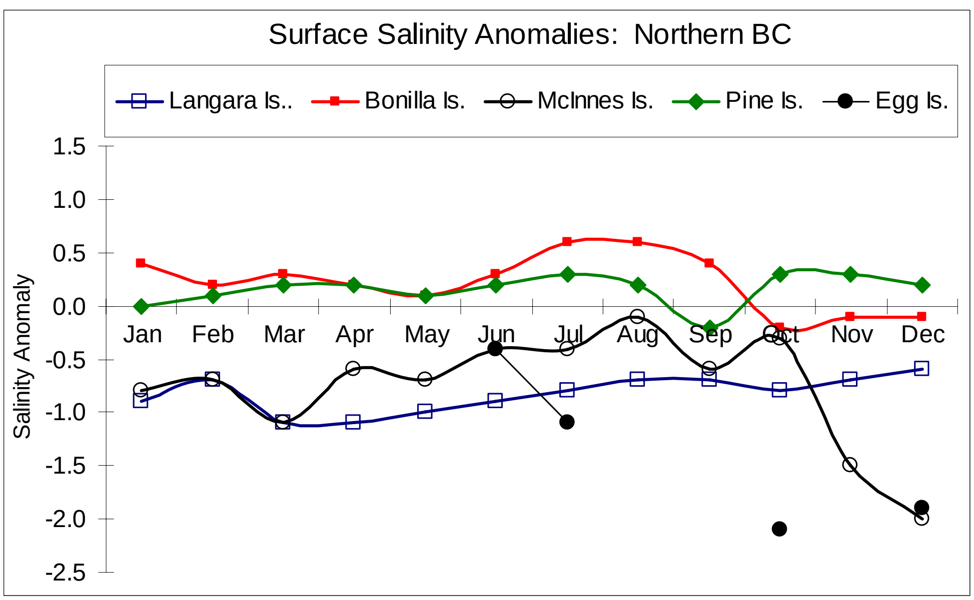
DFO Contact: [Ian Perry]

Northern British Columbia

Shore station temperature and salinity in 2004: Warm all year, and fresh at Egg Is. and McInnes Is. in fall



Except for a short drop to normal values in October, all stations saw warmer waters all year in northern BC. The anomalies passed 1 Celsius at all but Pine Island.



The surprising news, however, is the fresh water observed at McInnes and Egg Islands in autumn, reaching 2 parts per thousand below normal for that time of year. Even fresher anomalies were found at Kains Island and Nootka Point to the south through autumn.

Links: BC Seawater sampling at Lighthouses
DFO Contacts Bill Crawford, Ron Perkin

Herring in Hecate Strait: Low recruitment in 2004 could reduce abundance in Queen Charlotte Islands, Prince Rupert and Central Coast areas

Exploitable herring biomass in the north coast area is an amalgamation of migratory stocks from the Queen Charlotte Islands, Prince Rupert area and Central Coast area. Over the past decade, abundance in the Queen Charlotte Islands has been depressed whereas abundance in both Prince Rupert and the Central Coast has remained at healthy levels (Figs. 1,3,5). Levels of recruitment to the Queen Charlotte Islands have been depressed (Fig. 2) with 6 of the past 10 year-classes being 'poor' while the Prince Rupert stock (Fig. 4) has experienced a good recruitment at least every 4 years since 1980. Recruitment to the Central Coast stock (Fig. 6) has been less regular but the 'good' year-classes that have occurred were very strong. Indications are that the most recent recruitment of the 2001 year class is one of the poorest observed in the historical record. As a result,abundance may decline slightly in the three northern stocks over the next couple of years.

Fishery interpretation and speculative results

Herring stocks in the Hecate Strait area consist of migratory stocks from the Queen Charlotte Islands, Prince Rupert and Central coast areas. For the past ten years, recruitment and abundance of the Queen Charlotte Islands stock has been low while recruitment and abundance of the Prince Rupert and Central Coast stocks have been generally good. However, recruitment in 2004 was among the lowest observed and could impact short term abundance in all three northern stocks.

Links: Herring Assessment by DFO
Herring on North Coast in Ocean Status Report 2003 (page 74)
DFO Contact: Jake Schweigert

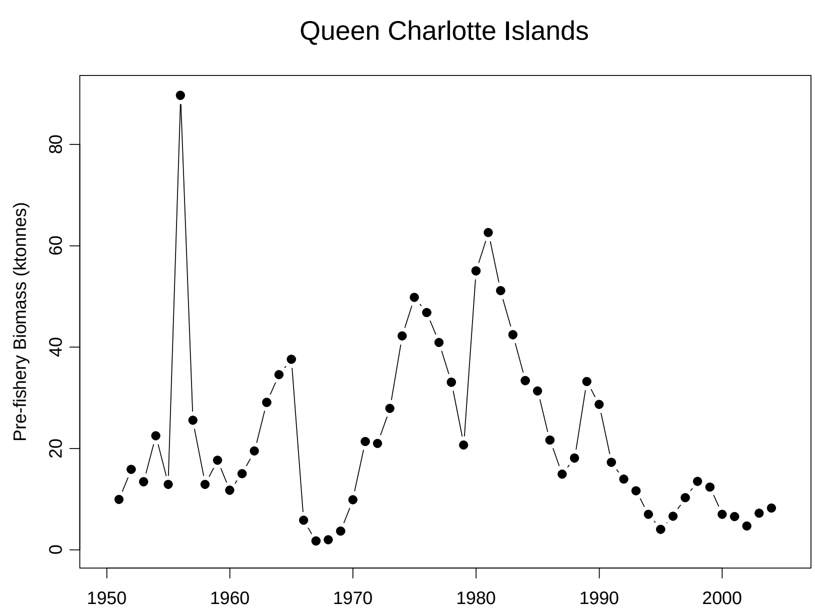


Figure 1: Queen Charlotte Islands herring abundance.

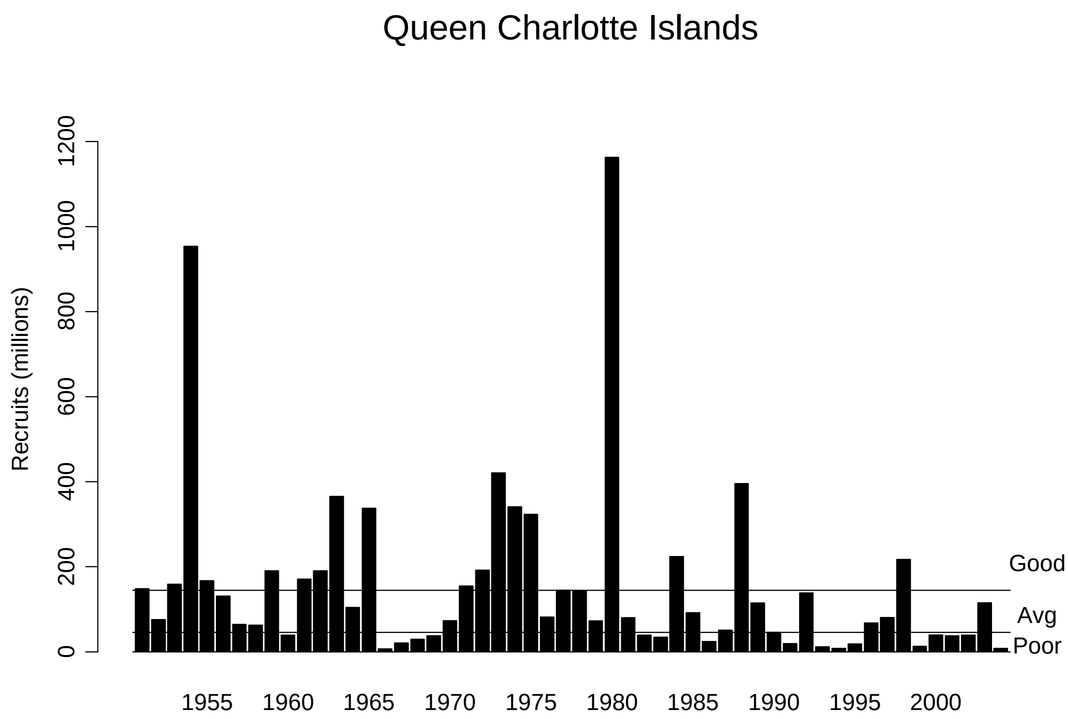


Figure 2: Interannual variability and decadal trends in recruitment to the Queen Charlotte Islands herring stock. The boundaries for 'poor', 'average' and 'good' recruitment are shown. Note that 6 of the last 10 recruitments have been'poor'.

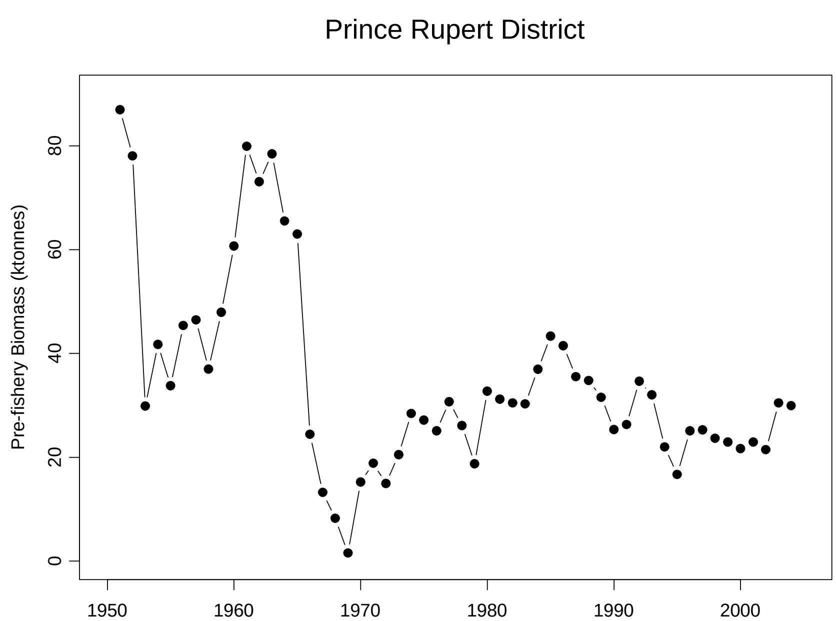


Figure 3: Prince Rupert District herring abundance.

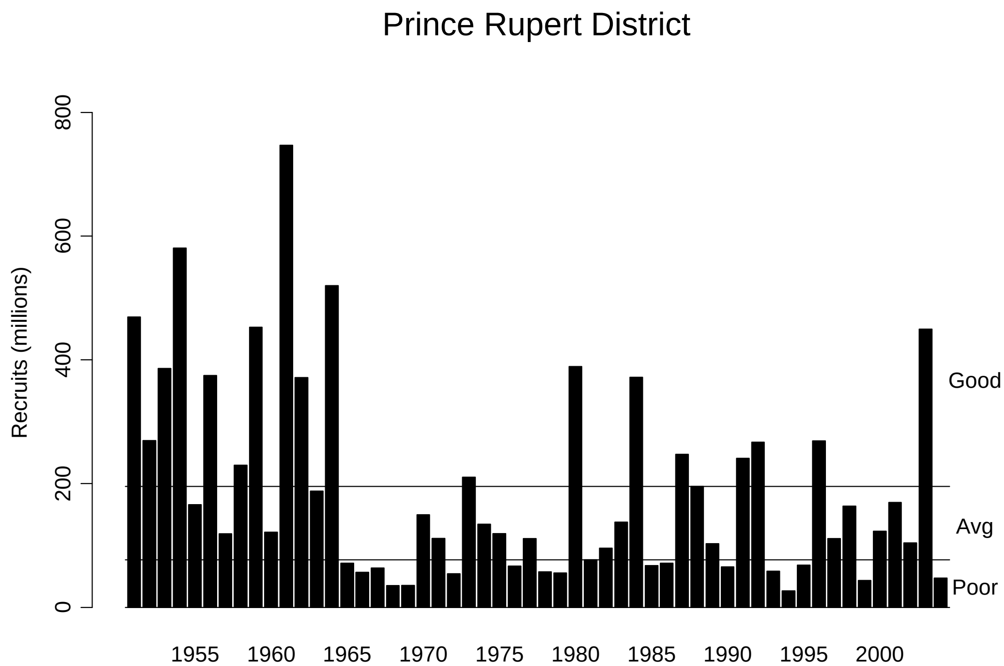


Figure 4: Interannual variability and decadal trends in recruitment to the Prince Rupert District stock. The boundaries for 'poor', 'average' and 'good' recruitment are shown. Note that 'good' recruitments have occurred almost every four years since 1980.

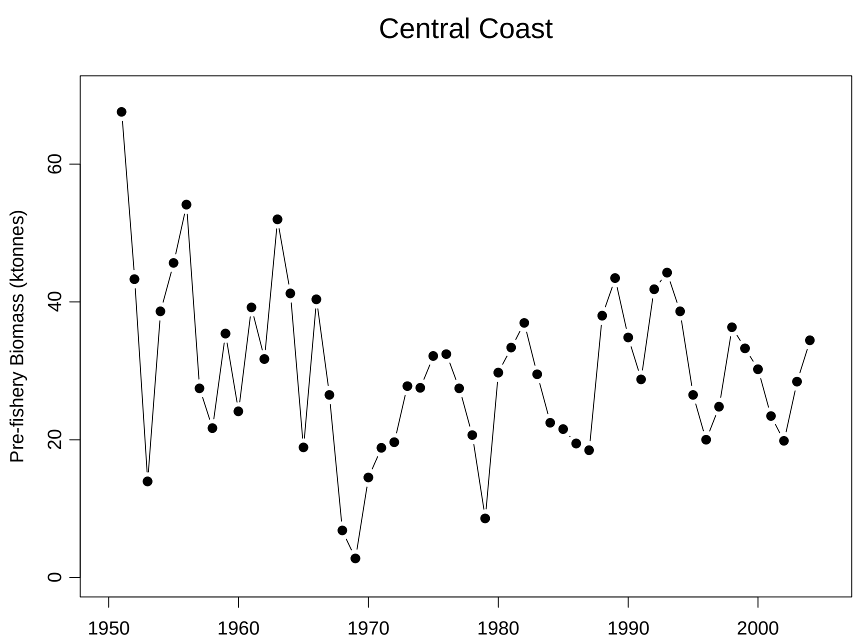


Figure 5: Central Coast herring abundance.

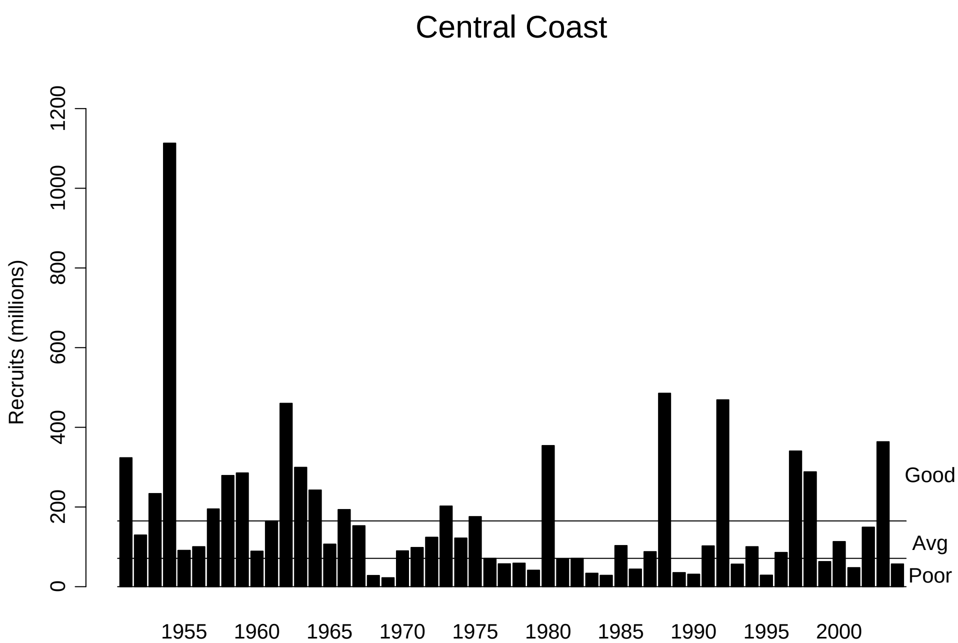
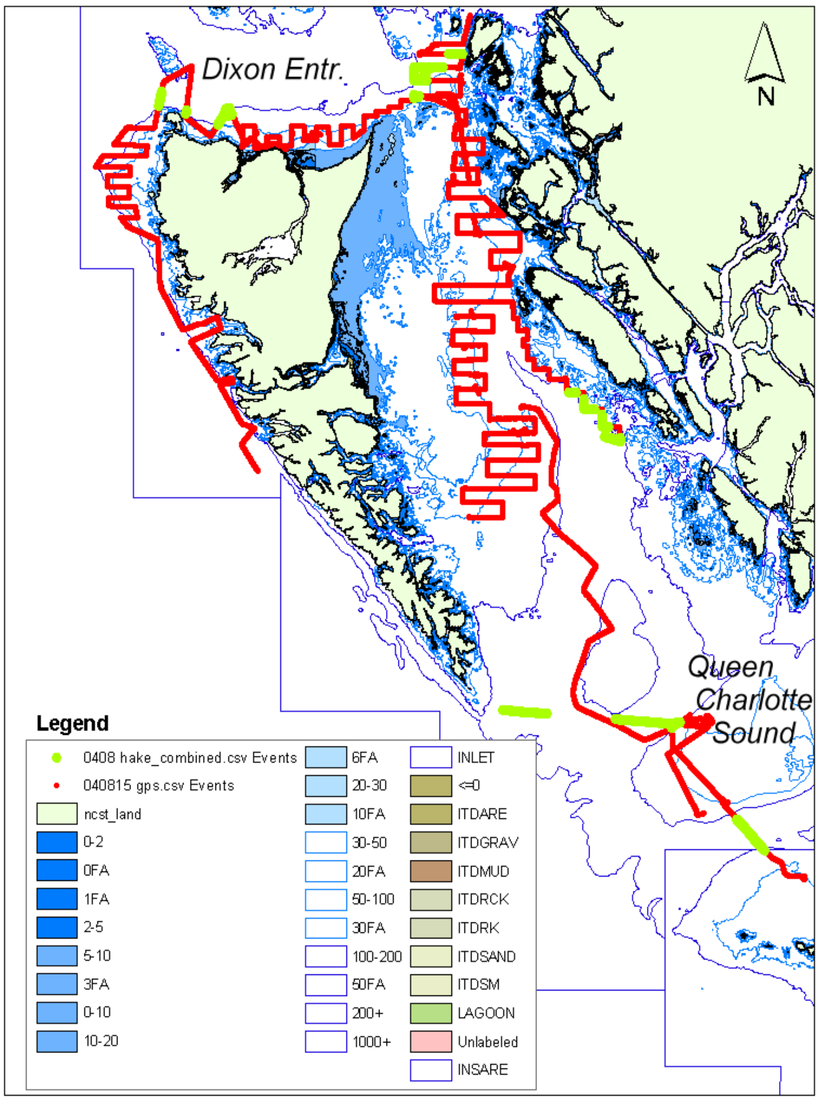


Figure 6: Interannual variability and decadal trends in recruitment to the Central Coast stock. The boundaries for 'poor', 'average' and 'good' recruitment are shown.

Pacific hake distribution along the west coast of Canada in 2004: Some sightings in Dixon Entrance suggest northward movement.

Incidental records of Pacific hake (*Merluccius productus*) were collected en route (Therriault et. al. 2004) during the 2004 Pacific herring survey. Small aggregations of hake were found along Goose Bank in Queen Charlotte Sound and in Dixon Entrance (Fig. 1). The extent of the northward migration may be indicative of warmer than normal conditions persisting from 2003. However, as no hake assessment survey was conducted in 2004, it is not clear to what extent these aggregations formed part of a larger coast wide distribution or were isolated migrants that remained in the area from 2003. Associated midwater trawl samples showed the catch was primarily older fish at an average size of 50-54 cm.



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Therriault, T., K. Cooke, M. Thomson, and K. Daniel. 2004. Cruise report on CCGS *W.E. RICKER* acoustic-trawl survey in Queen Charlotte Sound, west coast Queen Charlotte Islands, Dixon Entrance, and Hecate Strait, August 4-15, 2004. Internal report. Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, B.C. V9T 6N7

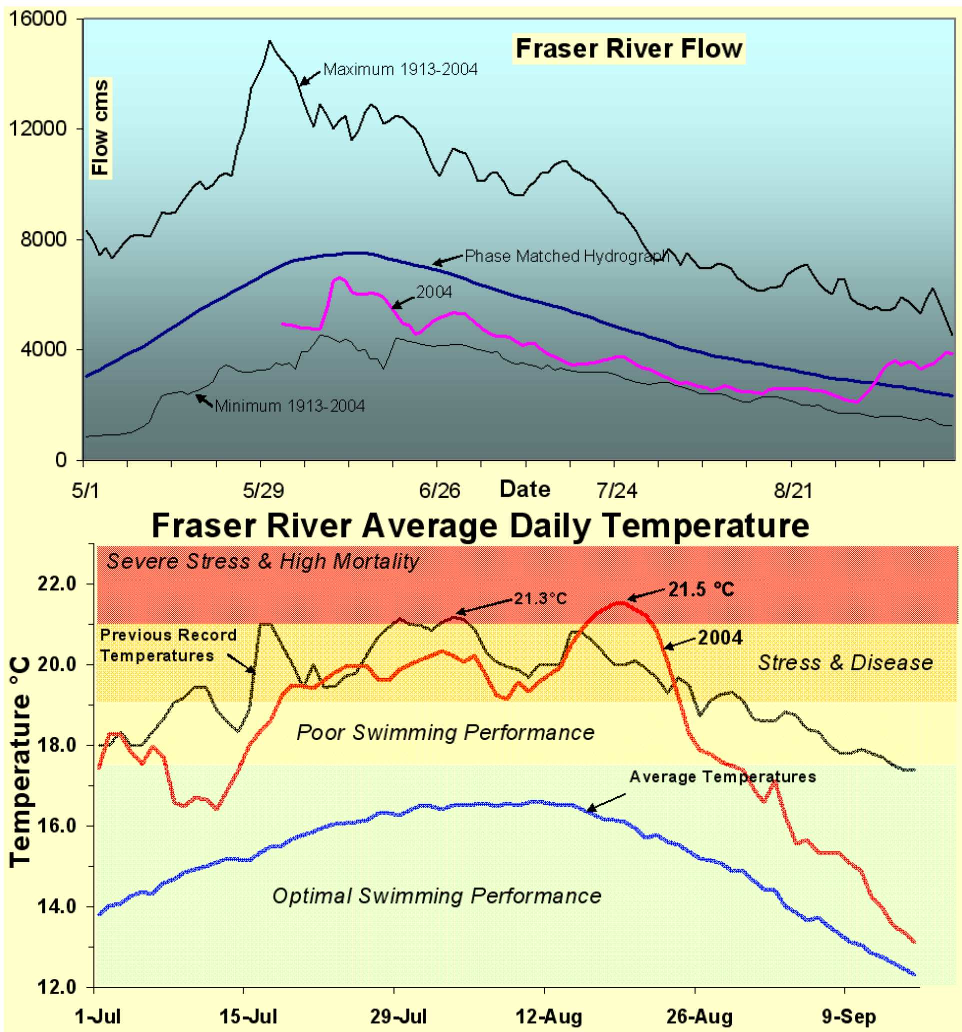
Thompson, M., Daniel, K. and Therriault, T.W. 2004. Offshore Northern British Columbia Herring Survey, August 2004. Can. Manuscr. Rep. Fish. Aquat. Sci. *2713*: v + 41 p. (*in press*).

Links: Ocean Status Report 2003 (page 42)
2003 Stock Status Report
DFO Contact: Ken Cooke

Georgia Basin and Fraser River

Fraser River in summer 2004: Record high temperature and low flow stressed returning sockeye

High flow and/or water temperature are known to be important factors that can affect the spawning success of Sockeye Salmon[1, 2]. 2004 was an exceptional year with highest temperatures in 90 years of observations, and with low flows. Temperature in the Fraser River was persistently high throughout the summer of 2004 with record highs early and mid July. A new all time record high of 21.5°C was set on Aug. 18 and 19. River flow was below average throughout the summer, with near-record low flows for all of July and August based on 60 years of observations. These warm flows were a contributing factor to the low sockeye spawning returns observed in 2004.

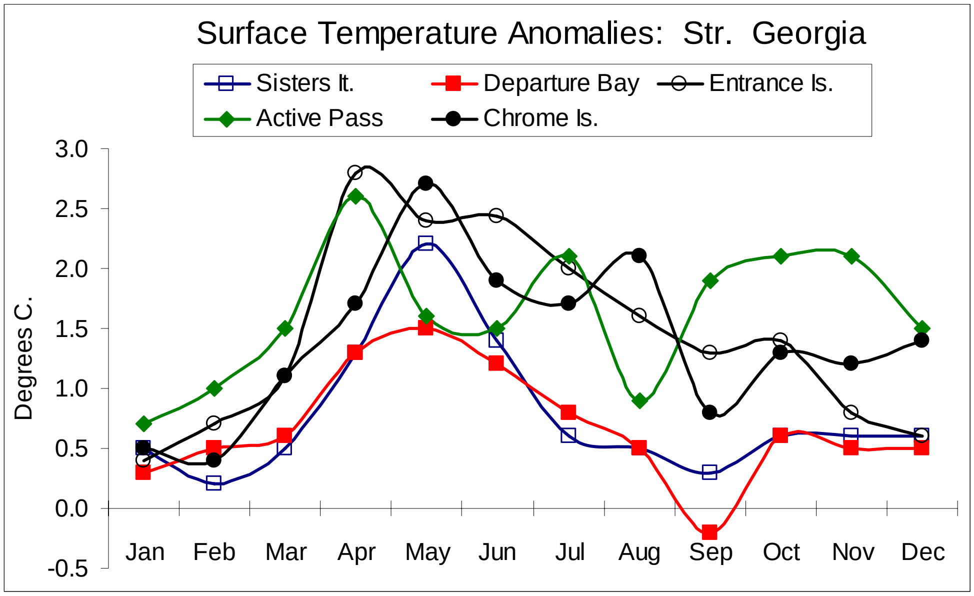


[1] Macdonald, J.S., Williams, I.V. and Woodey, J.C. 2000a. Can. Tech. Rep. Fish. Aquat. Sci. 2315: 120p.

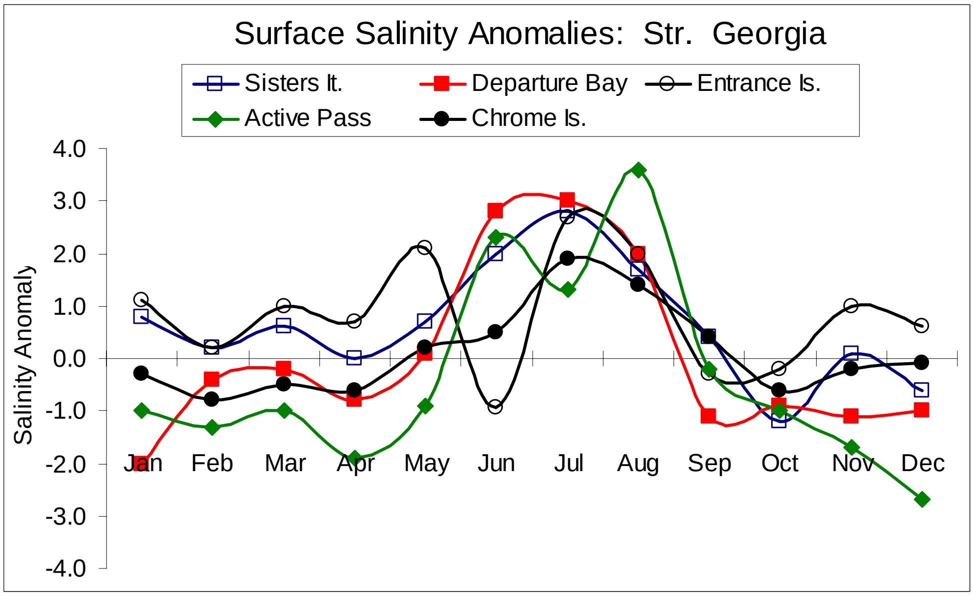
[2] Macdonald, J.S., Foreman, M.G.G., Farrell, T., Williams, I.V., Grout, J., Cass, A., Woodey, J.C., Enzenhofer, H., Clarke, W.C., Houtman, R., Donaldson, E.M., and Barnes., D., 2000b. Can. Tech. Rep. Fish. and Aquat. Sci. 2326: 117p.

Links: Williams report, released in April 2005
Fraser River temperature modelling at Inst. Ocean Sciences
DFO Contacts: John Morrison, Mike Foreman

Shore station temperature and salinity: Warm all year, and a salty summer



Temperature and salinity are measured daily by light keepers through BC waters as part of a program that began in the 1930s. Monthly averages from 5 stations in the Strait of Georgia and Active Pass show it was warm all year.



All salinity stations were saltier than normal in late spring and summer, likely due to low Fraser River freshet. In September after heavy rain, salinity dropped back to more normal values.

Links: BC Seawater sampling at Lighthouses
DFO Contacts: Bill Crawford, Ron Perkin

Strait of Georgia, 2004: Warm through the whole water column, especially at the surface in spring

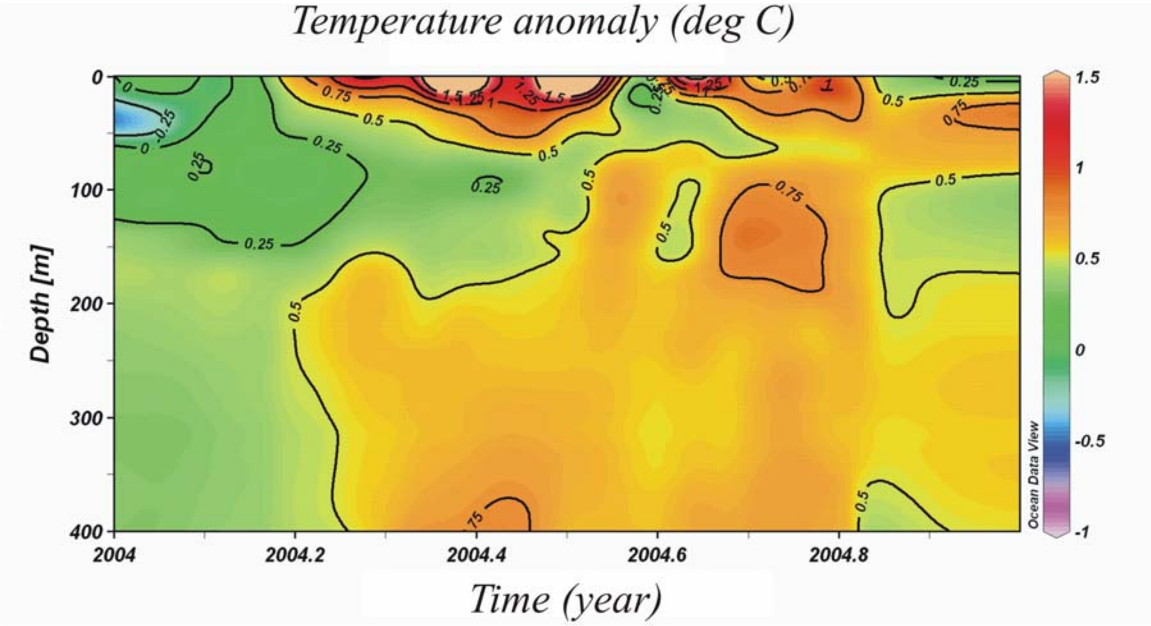


Figure 1: Temperature anomalies (deg. C) at the Navy hydrographic station off Nanoose Bay located in central Strait of Georgia. The anomalies have been computed in reference to the period 1970-2004.

The warmer conditions in the Strait of Georgia prevalent in 2003 persisted all through 2004 (Fig. 1). The temperature anomalies were particularly large near the surface in the spring. In fact, the highest monthly temperature anomaly since 1937 was recorded in April 2004 at the lighthouse station located at Entrance Island, with a value of +2.7 ^{o}C.

Links: Strait of Georgia in Ocean Status 2003 Report (page 79)
Monitoring southern BC water
Water properties of the Straits of Georgia and Juan de Fuca
DFO Contact: Diane Masson

Herring in the Strait of Georgia: Recent strong recruitment should maintain the stock at very healthy levels for the next few years

The Pacific herring stock in the Strait of Georgia migrates inshore in the fall and leaves the Strait in the spring following spawning. Survival conditions for juvenile herring in the Strait of Georgia have been unusually good during the last decade. Abundance of herring in the Strait of Georgia reached a recent high level in 2003 at just over 150,000 tonnes (Fig. 1) exceeding the historical high of 1955. Recruitment to this stock has been very strong with 7 of the last 10 year-classes being average or better (Fig. 2). Juvenile rearing conditions within the Strait of Georgia appear to be the main determinant of recruitment success for this stock since most juveniles do not leave the area until their second summer. Recent surveys of juvenile herring abundance within the Strait of Georgia indicated that the year-classes corresponding to the 2003 and 2004 recruitments should be ‘good’ but the latter is only average. Initial indications are that the recruitments for the next couple of years may also be weak. Nevertheless, the recent strong recruitments should maintain the stock at healthy levels for the next few years.

Fishery interpretation and speculative results

The abundance of herring in 2004 is slightly reduced from the historical high of more than 150,000 tonnes in 2003. Current abundance is well above the lowest abundance estimated in 1968 (11,000 tonnes) in the time series from 1951-2004. The abundance of this stock has been increasing steadily since the recent low of the mid-1980s. Recent juvenile surveys suggest the trend of recent strong recruitments appears to be ending and weaker recruitment and reduced abundance may be expected over the longer term.

Links: Herring Assessment by DFO
Herring in Georgia Basin in Ocean Status Report 2003 (page 85)
DFO Contact: Jake Schweigert

(See figures on next page)

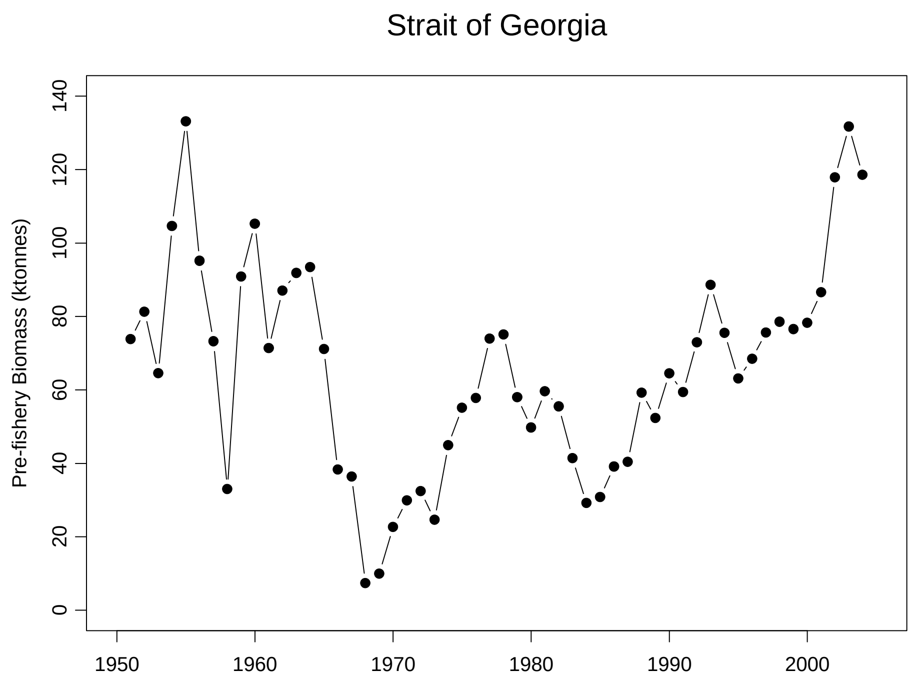


Figure 1: Strait of Georgia herring abundance.

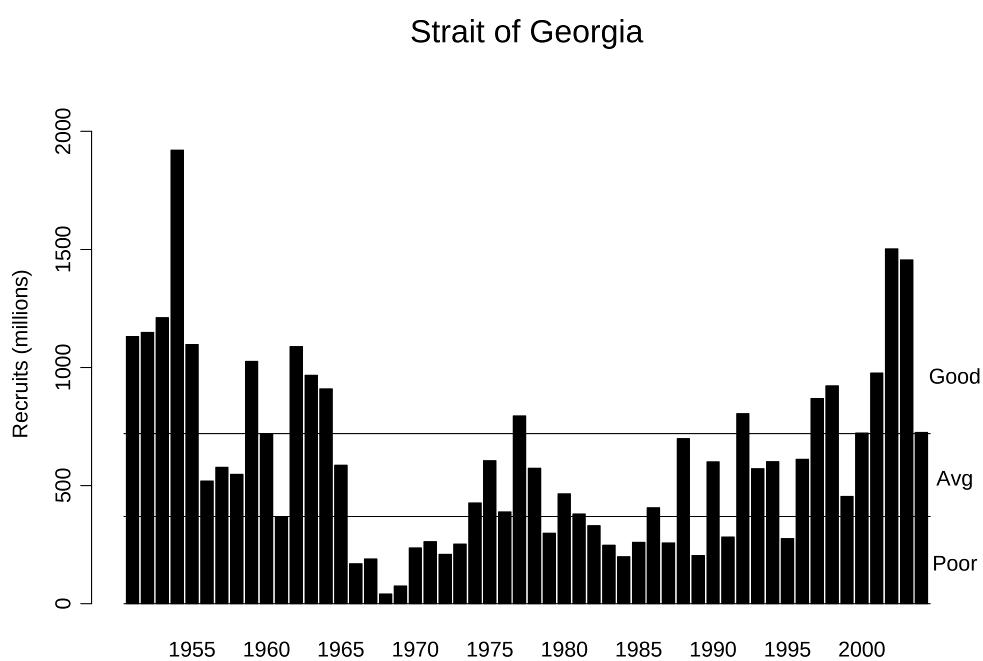


Figure 2: Interannual variability and decadal trends in recruitment to the Strait of Georgia stock. The boundaries for 'poor', 'average' and 'good' recruitment are shown. Note that 6 of the last 10 year-classes have been 'good'.

Strait of Georgia juvenile salmon: Chinook and sockeye in summer were plentiful, but much shorter in length

The **abundance** of juvenile chinook, chum and sockeye salmon July 2004 was greater than in 2002 and similar to the average abundances observed in 2001 (Figure 1 below, Sweeting et al. 2004). Juvenile pink salmon are only observed on even years and the abundance in 2004 was similar to the abundance in 2000 (Sweeting et al. 2004). The **abundance** of juvenile coho salmon in July 2004 was 4.0 million which was greater than in July 2002 (3.0 million) but still well below the 11.2 million and 9.5 million observed in 2001 and 2002 respectively (Figure 1).

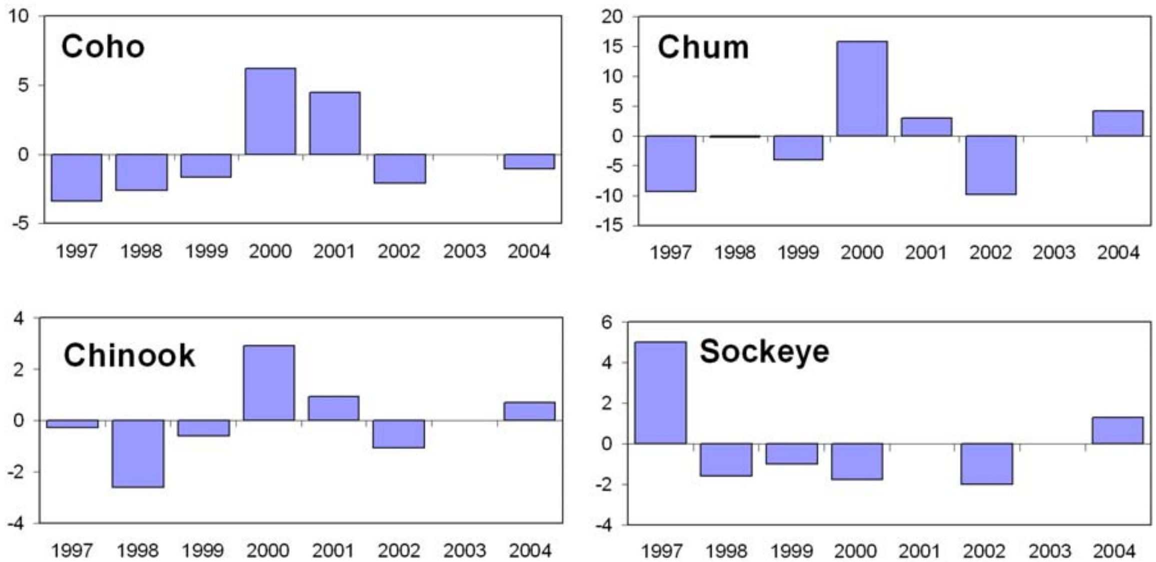


Figure 1: Abundance anomaly of juvenile coho, chinook, chum and sockeye in July of each year. Survey design and calculation of abundance is described in Beamish et al. (2000) (no survey in July 2003.)

The **average length** of juvenile chinook and sockeye salmon in July 2004 were the smallest observed in this climate regime at 120 mm and 108 mm respectively. The average length of pink and chum juvenile salmon was average for this climate regime. The **average length** of the juvenile coho was average for this climate regime and slightly larger than observed in 2002 (Figure 2 below). It is anticipated that returns of coho in 2005 to the Strait of Georgia will be better than 2002 but will remain at low abundances.

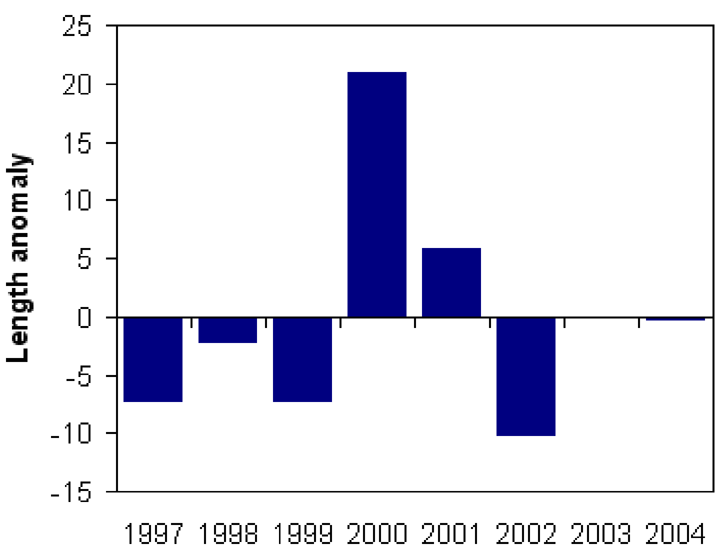


Figure 2: Juvenile coho salmon fork length (cm) anomaly for July surveys from 1997-2004. Note that these are ocean age 0 coho and that there was no July 2003 survey.

There were record returns of adult pink salmon to the Fraser River in 2001 and 2003. Based on the abundance of juvenile pink salmon in 2004 it is expected that there will also be large returns in 2005. There were exceptionally large abundances of juvenile pink salmon in Queen Charlotte Strait and based on these abundances, we expect historic high returns of adult pink salmon to the Fraser River in 2005.

Impacts of the climate regime shift that occurred in 1998 were first observed in the productivity of the Strait of Georgia in 2000 (Beamish et al. 2001, 2002, 2004) and have persisted through 2004. The average surface and 10 m water temperature remains below the average for the previous climate regime; however, both are increasing and the annual temperature at 10 meters in 2004 was the second highest recorded since 1970 (Figure 3). Average bottom water temperatures are warmer than during the previous climate regime and were the warmest for the record period in 2004.

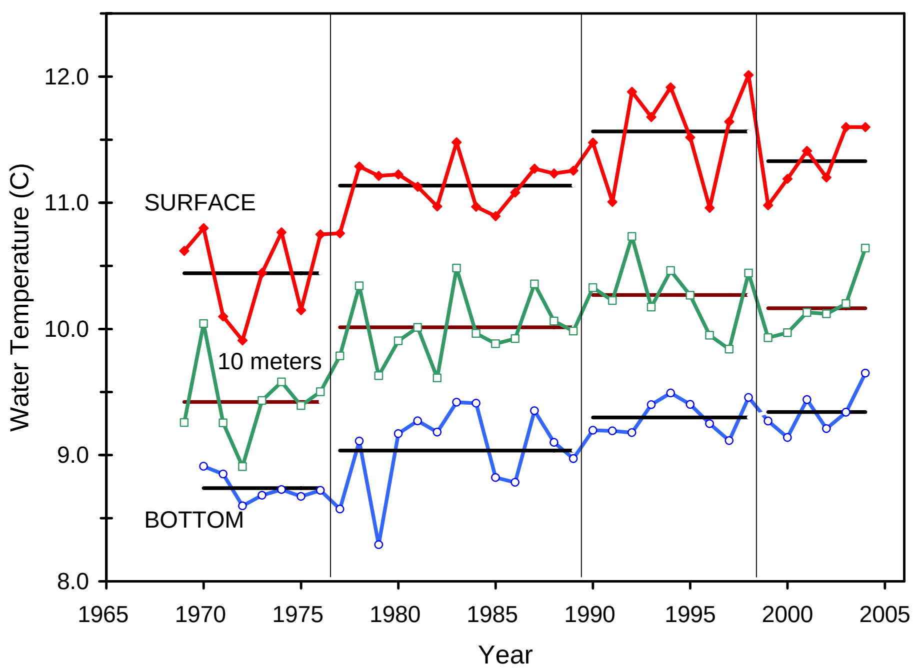


Figure 3: Annual mean water temperature profiles (surface, 10m and 395m) for 1969 to 2003, obtained from the Nanoose Bay Naval Station. Data is collected just off Ballenas Island. Vertical lines denote years of regime shifts, with average temperatures in each regime denoted by a horizontal black line.

Beamish et al (2004) demonstrated that the stock and recruitment relationship for Fraser River pink and sockeye salmon is better described by examining the data for each regime separately rather than for the entire data time period. The study covered the three climate regimes prior to 1998 identified in Figure 3. Based on the 2000 to 2004 returns of pink and sockeye salmon, this climatic period continues to be more productive for these stocks than the previous regime as evidenced by the large juvenile abundances followed by large abundances of adults.

The variation in marine survival between the salmon species in the Strait of Georgia is not understood. In addition, unlike the Strait of Georgia, coho salmon from Puget Sound has seen improved marine survival in recent years. This discrepancy between the Strait of Georgia and Puget Sound is the focus of a Pacific Salmon Commission funded study that will take place in 2005.

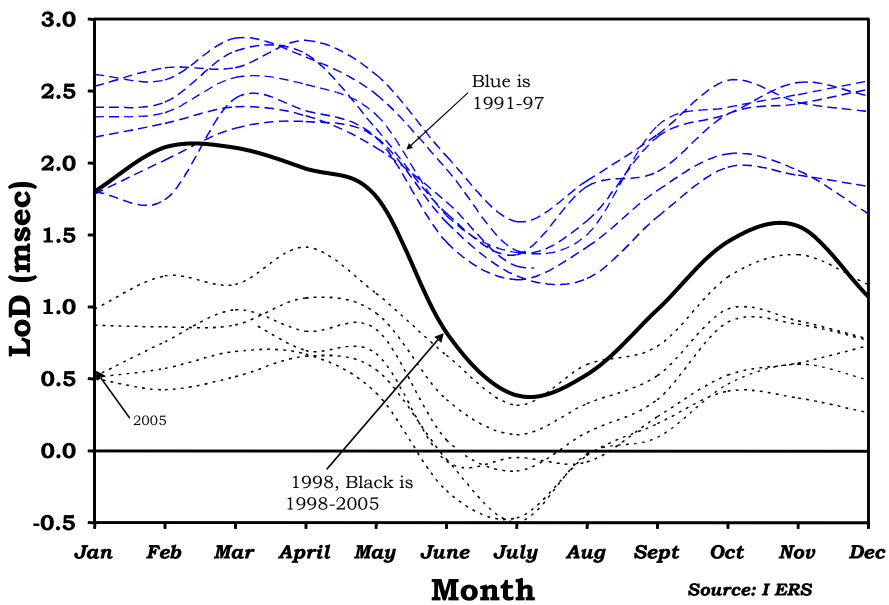


Figure 4: Length of Day (LOD) Index, showing the seasonal variation and the 1998 regime shift. The long blue dashed lines represent LOD values from 1991 to 1997, the solid black line is 1998, and the short dashed lines are 1999 to 2005. Length of Day is calculated as the difference (in ms) from 86400 (24 hours) and indicates changes in the rotational speed of the earth.

We use the length of day index as a proxy measure of atmospheric circulation trends (Figure 4) to show that the regime starting in 1998 is persisting despite variations in productivity within the Strait of Georgia in 2002 to 2004. We recognize that the use of the seasonal length of day index is experimental and can best be tested when the next regime shift occurs.

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DFO Contacts: Chrys Neville, Ruston Sweeting, Richard Beamish

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