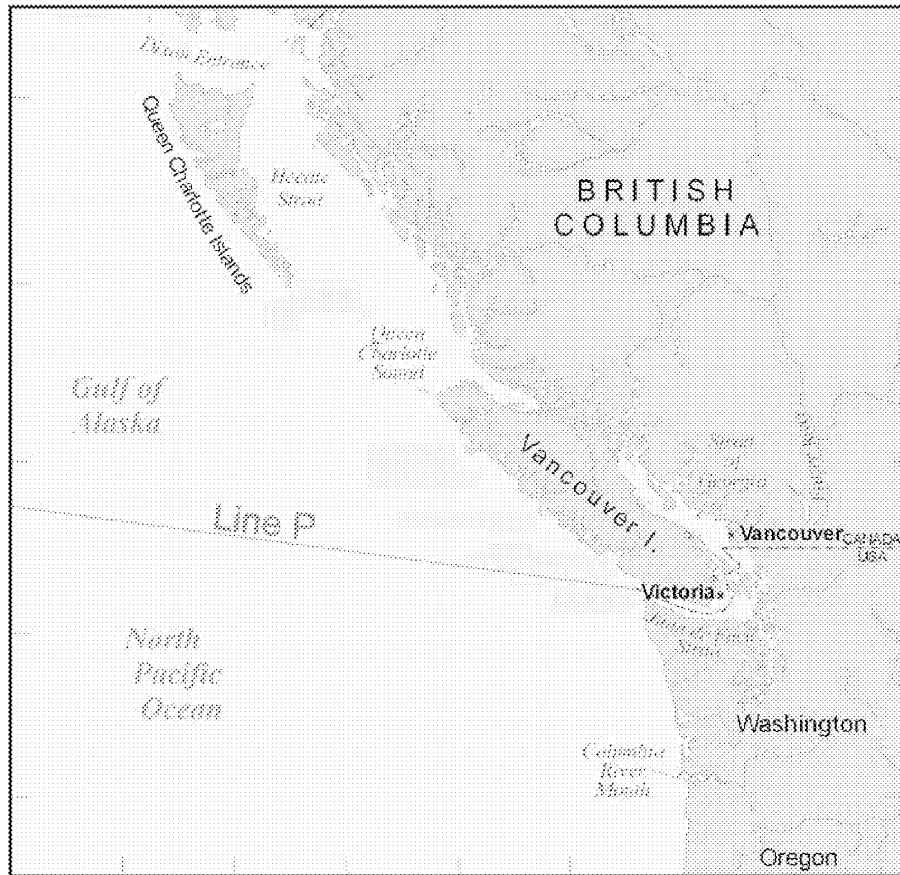




## STATE OF THE PACIFIC OCEAN 2007



### Context:

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

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

July 2008

Canada

## SUMMARY

This report is the ninth in an annual series describing the state of physical, biological, and selected fishery resources of Pacific Canadian marine ecosystems. This region has seen dramatic changes in atmospheric and oceanic conditions over these years, all of which affect resident and migratory marine populations in B.C., many of which are of significant commercial importance. Monitoring and reporting on these conditions annually provides a brief synopsis of their present state and how they are changing, and how these changes might affect commercial and non-commercial living resources in this region. Cool winter conditions in 2007 benefited some species that thrive in cooler waters, but there will be time lags before we see these benefits for others, particularly longer-lived species.

Top stories from the 2007 review of resources of Pacific Canadian marine ecosystems are:

- Our globe was warm almost everywhere, but the Northeast Pacific cooled with La Niña
- Argo observing system reaches design target
- Colder winter and warmer summer waters along the coast
- Ocean acidification: Local seas are most vulnerable
- The BC and Oregon zooplankton communities returned to 'cool-ocean' species in 2007
- Low returns of sockeye coast-wide, especially in the Fraser River
- Hake scatter in BC waters – can we blame jumbo squid?
- Sardines are back in BC, but herring, shrimp, and other species have declined

## INTRODUCTION / BACKGROUND

Except for a brief warm period in summer, local ocean waters were cooler than normal through 2007 and into 2008, in contrast to warm waters of the previous four years. These cooler temperatures were associated with La Niña conditions in spring and autumn 2007, and also to a shift in the Pacific Decadal Oscillation to a cool state. This local cooling was the global exception. Most of the world was warmer than normal with record high temperatures over land and the most reduced extent and duration of Arctic sea ice on record. The Argo Observing System launched its 3000<sup>th</sup> ocean profiler in October 2007, providing for the first time ever, real-time observations of all the oceans from surface to 2000 metres depth. This network reveals a very strong North Pacific Current flowing eastward into BC and Alaskan waters in 2007-08, and a return to deep mixed layers and cold waters in the Gulf of Alaska. Other observations reveal the oceans to the west of Canada and USA are the most vulnerable to increasing ocean acidification due to global carbon dioxide emissions.

Very young and very small marine life respond rapidly to these changes in temperature in West Coast waters. Northern and sub-Arctic zooplankton dominated in 2007, largely replacing the southern species that prevailed in previous years of warmer waters in BC and Oregon. Deep-sea zooplankton growth in the Gulf of Alaska was very focussed in 2007 with most of the spring/summer biomass (73%) occurring in May and a second smaller peak in July. Catches of juvenile (yearling) coho in June 2007 off Oregon were among the highest during the 10 year time series, but by September, catches were among the lowest. High and low numbers might be due to cool and warm temperatures of spring and summer, respectively. Surveys along the west coast of Vancouver Island (WCVI) show average growth of juvenile coho in 2007, suggesting normal marine survivals for adult coho, Chinook, and sockeye. However, biomass of the euphausiid *T. spinifera*, an important food source for juvenile salmon entering Barkley Sound, was low in 2007, indicating poor growth of salmon stocks that migrate through there and feed on this prey. The shift to a much stronger La Niña in winter 2007-08 anticipates improvement in growth and survival rates for WCVI coho, sockeye, and chinook migrating seaward in 2008.

General groundfish surveys, now into their fourth year, reported low catch weights per tow in 2007 in all regions. In Queen Charlotte Sound, in particular, an across-the-board decrease in biomass indices for almost all species was noted. Herring biomass was low in most BC waters, (except Strait of Georgia), attributed to less feed and more predators during previous warm years when herring were young and small in size. Low recruitment rates are expected in the next few years in all regions. Biomasses of pink shrimp, arrowtooth flounder, Dover sole, and Pacific halibut off the west coast of Vancouver Island in May declined, also attributed to warm waters of previous years. Hake were few in number off the west coast of Vancouver Island and scattered into many more regions in 2007 in BC waters. Reasons for the declines and scattering are not clear, but low *T. spinifera* biomass (a favourite hake food) and interactions with jumbo squid, a recent intruder are potential explanations. Interestingly, the 2007 hake survey captured these squid in Canadian waters only.

In the Strait of Georgia, surface waters were somewhat warmer than normal through the year, but deeper waters cooled to temperatures observed in 1999 to 2002. Phytoplankton biomass was higher in summer and lower in autumn. Its spring bloom arrived relatively early. Herring biomass declined from the very high levels of only a few years ago. Very few Fraser River sockeye returned to spawn in 2007, most likely due to very poor feeding conditions and/or increases in predators resulting from warm waters during the spring of 2005. Marine indicators of ocean productivity suggest that sockeye survivals in 2008 should be somewhat better than in 2007, but still below normal. Coho salmon returns to the Strait of Georgia in 2008 are predicted to be low, perhaps even lower than in 2006, based on very poor growth and low CPUE recorded in the 2007 survey in the Strait of Georgia. Chinook returns in 2008 are predicted to be below average - numbers of 5-yr olds returning from the disastrous 2005 sea entry year will probably be very low. Chum returns in 2008 are anticipated to be average, based on the average CPUEs in the July 2006 survey. It is expected that there will be a large abundance of juvenile pink salmon in the strait in 2008, which may put pressure on marine survival of other juvenile salmonids.

## ASSESSMENT AND CONCLUSIONS

### Our globe was warm almost everywhere, but the Northeast Pacific cooled with La Niña

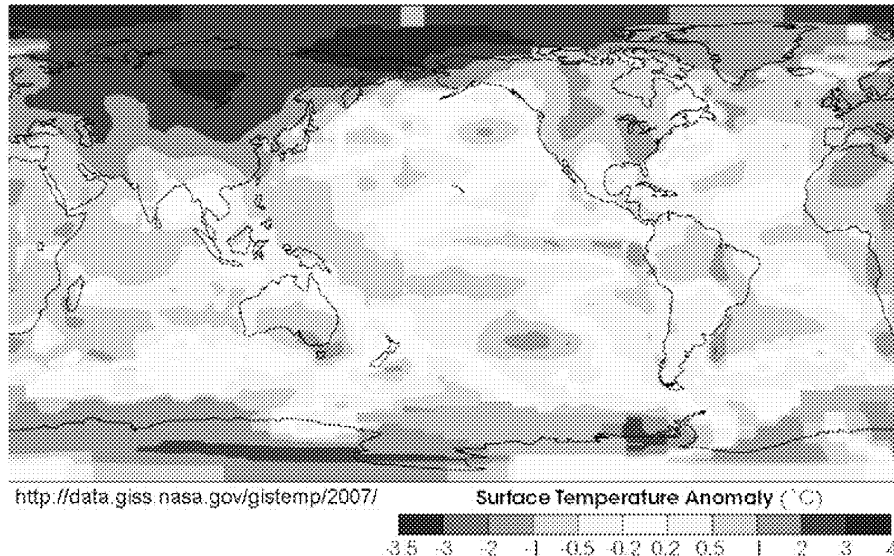


Figure 1. Surface temperature anomaly in 2007 relative to the 1951-1980 mean based on surface air measurements at meteorological stations, and ship and satellite measurements of sea surface temperature.

Source: NASA Goddard Institute for Space Sciences (<http://data.giss.nasa.gov/gistemp/2007/>).

According to the NASA Goddard Institute for Space Studies, the temperature over land and ocean in 2007 was tied with 1998 for the second warmest year in the era of instrument data, which began in the late 1800s. Land temperatures in 2007 were the highest since the beginning of instrumental record as shown in the lower panel of Fig. 2.

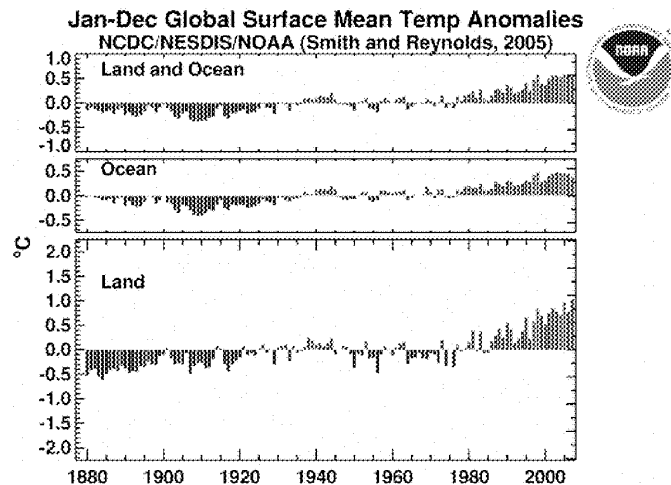


Figure 2. Time series of annual average temperature anomalies over the globe, reference to the period 1901 to 2000. Source: NOAA National Satellite and Information Service, National Climatic Data Center

(<http://www.ncdc.noaa.gov/oa/climate/research/2007/perspectives.html>)

The most anomalously warm ocean surface appeared in the Arctic Ocean north of Bering Strait, contributing to the record low ice coverage in the Arctic Ocean in late summer 2007. Land temperatures have risen steadily since the 1970s, and the moderating effect of ocean temperatures has kept the global average temperature over land and sea from rising as rapidly. But in the eastern Pacific from Cape Horn to Alaska, waters ran much cooler than normal in 2007.

So why did it happen in our waters? Blame it on La Niña. (Or thanks to La Niña if you love cold-water fish.) Other ocean indices such as PDO and its sister the Victoria Mode also track these cool waters. Wind patterns over the Gulf of Alaska often vary with the rise and decline of both El Niño and La Niña. The left panel of Fig. 3 shows an average winter, with the black arrow along isobars pointing in the direction of typical warm south-westerly winds. Winter winds in 2006-07 and 2007-08 blew from a more westerly direction, with colder temperatures. Coldest winds were in January 2008 (right panel), with isobars distorted by shifts in the Aleutian Low (L) and North Pacific High (H) in Fig. 3. Winds were forced to blow from the north-northwest.

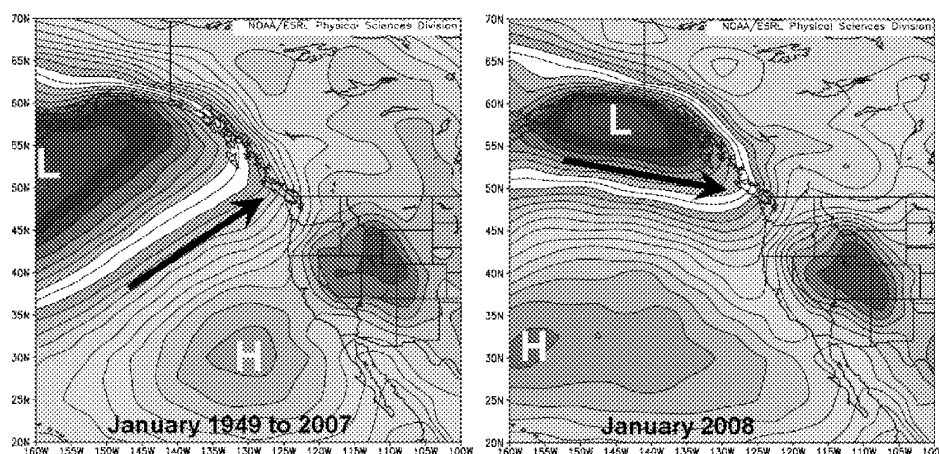


Figure 3: Average sea surface pressure for the January of 1949 to 2007 (left), and January 2008 (right). Contours are at 1 mbar intervals, with the same scale for each panel. Images provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado (<http://www.cdc.noaa.gov/>).

How cold was it? The figures below show ocean temperature anomalies in June 2007 and July 2007 from the tropical Pacific north to Alaska. Cooling near the West Coast in June 2007 did not extend to shore, due to weaker upwelling winds along the coast, but by January 2008 the entire coast from Mexico to Alaska was below normal temperatures. One analysis found the Gulf of Alaska to be the coldest in 35 years, predicting cold coastal waters into late spring 2008.

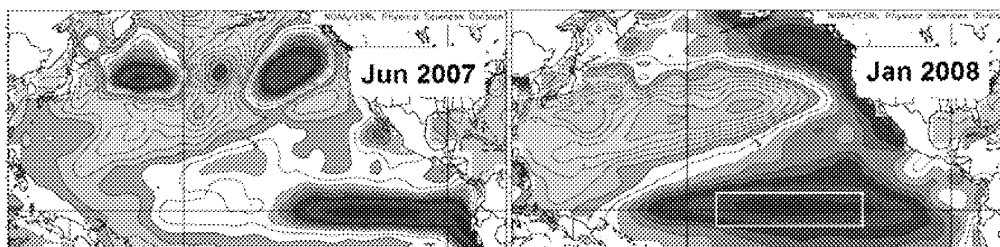


Figure 4. Anomalies of sea surface temperature over the North Pacific Ocean and tropics. Relatively cold water is shown in purple. The white box in the right panel is Niño 3.4 region along the Equator whose

temperature anomaly defines El Niño and La Niña conditions. Coldest water in this box in January 2008 indicates La Niña was most intense in this month. Yellow and orange regions are warmer than normal. The pattern of warmer water between Indonesia and central North Pacific, together with cooler water in the northwest Pacific is a classic La Niña state. Images provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado (<http://www.cdc.noaa.gov/>).

### **Argo Observing System reaches design target**

The Argo Observing System reached its target of 3000 operating ocean profilers in October 2007; providing real-time observations of all the oceans from surface to 2000 metres depth. Canada has contributed about 3% of the total number of floats in global oceans. Each profiler is an autonomous instrument that drifts through deep-seas for up to five years. Most drift at 2000 metres depth. Every ten days they rise slowly, measuring temperature and salinity all the way to the ocean surface, where these data are transmitted to shore via satellite. All measurements are available to the public within days of reception. These data are immediately entered into weather and climate models, and also sent to oceanographers to detect significant changes in ocean currents. In the Gulf of Alaska (Fig. 5), these profilers revealed an unexpected strengthening of the North Pacific Current in 2007 and 2008 (flow across line  $\Delta D_{NPC}$  below) and increased flow into the California Current (flow across line  $\Delta D_{CC}$  below). Stronger flow into the California Current may have contributed to cooling of near shore oceans observed through 2007.

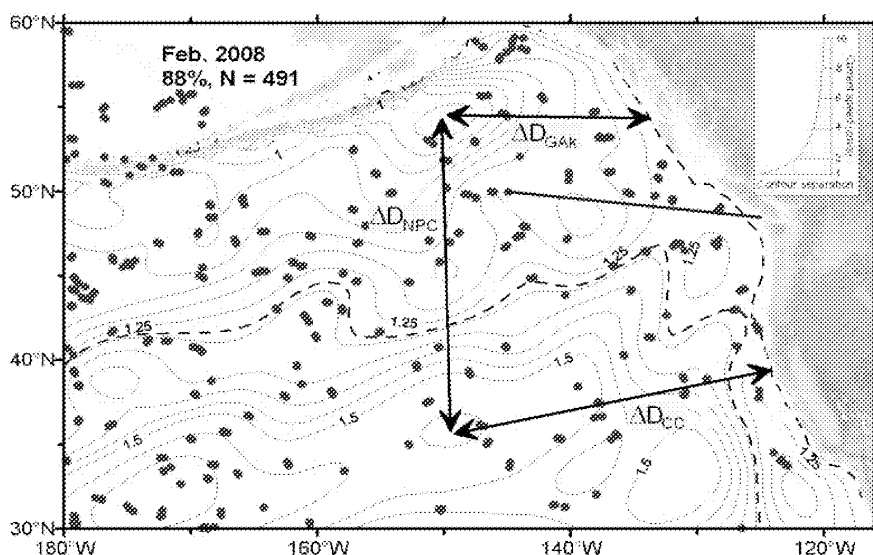


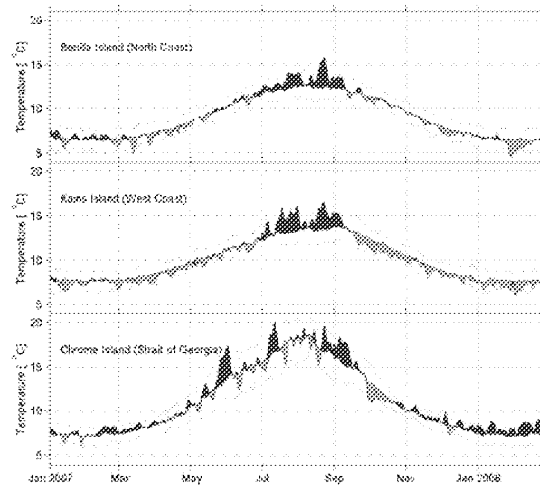
Figure 5. Each red dot is an Argo profiler. Most were launched by Fisheries and Oceans Canada and enable calculations of sea surface height and ocean current position and strength. Currents flow along contour lines with the bold-dashed line being the "dividing streamline" in the North Pacific Current that separates water that heads into the Gulf of Alaska from that which heads into the California Current system. Arrows show the points used to compute the differences in dynamic height, and so the strength of individual currents

In addition to Argo, DFO research cruises regularly sample the Gulf of Alaska. High concentrations of phytoplankton in large eddies were observed in June 2007. Sampling in February 2008 along Line P showed increased surface nutrient concentrations and a deepened mixed layer. If the mixed layer remains deep through spring (i.e. if spring remains stormy), then reduced light levels will decrease primary productivity in oceanic waters, but could enhance nutrient supply to coastal waters. This pattern was observed during the strong La Niña of 1999.

## **Colder winter and warmer summer waters along the coast**

In normal winters the winds blow from the south, bringing warm seawater along the West Coast. In normal summers an offshore high pressure system reverses the prevailing winds, pushing warm water offshore. But weather systems weakened these forces in both summer and winter 2007, giving us colder winter waters and warmer summer along the outer coast from California to northern BC. Daily measurements at lighthouses in Canada tracked these changes, as shown in Fig. 6. These observations together with measurements at weather buoys revealed a warm-summer, cold-winter pattern of anomalies. It was different within the Strait of Georgia where temperatures at Chrome Island in mid-strait were mainly warmer than normal all year (See Fig. 6). Sea surface temperatures along the outer coast in summer (for example at Kains and Bonilla) generally cooled during northerly winds and clear skies. A sunny day at Tofino in summer will have colder ocean waters. Upwelled waters carry more nutrients, so the summer winds of 2007 that favoured warmer waters were likely poor for local marine life. Weaker upwelling winds in summer 2007 were found all along the coast from California to SE Alaska, as shown in Fig. 7. Based on ocean current data, it appears that the spring transition timing for the West Coast Vancouver Island current in 2007 was later than average. However the wind records suggest a later spring transition.

SeaWiFS satellite observations of phytoplankton off west coast Vancouver Island and Washington State showed no significant anomaly until May 2007, when values were two to three times the average.



*Figure 6. Temperature anomalies in 2007-08 (in red and blue), and the annual cycle from 1971 – 2001 at three BC shore stations.*

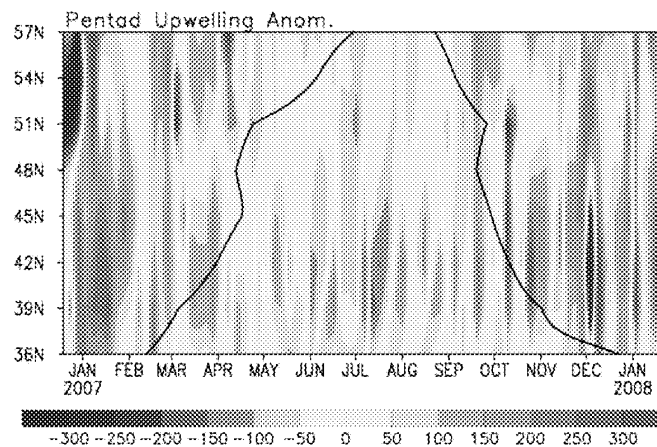


Figure 7. Upwelling anomaly between 36°N and 57°N along the West Coast of Canada and USA in 2007. The black line marks the transition between upwelling and downwelling in normal years. Note the negative upwelling anomalies at most regions in the spring-to-autumn upwelling season.

### **Ocean acidification: Local seas are most vulnerable**

The North Pacific Ocean already has the most acidic water in the global ocean. All oceans are becoming more acidic due to increasing carbon dioxide. Much of the extra CO<sub>2</sub> released by burning fossil fuels ends up in the oceans, increasing the dissolved inorganic carbon concentration, resulting in an increase in acidity and a decrease in pH. At present the average pH of seawater has decreased by about 0.1. The decrease in pH means that pteropods, corals and shellfish that produce calcite and aragonite shells or structures are threatened. In fact the aragonite saturation depth (defined as the depth below which aragonite dissolves more readily than it can form) has shoaled between 50 and 200 metres in the last century. The Line P carbon program of Fisheries and Oceans Canada has contributed critical data to make these estimations of change in the carbonate system in the Gulf of Alaska, in regions most sensitive to acidification. Fig. 8 reveals global distribution of the saturation depth of two forms of calcium carbonate: aragonite and calcite.



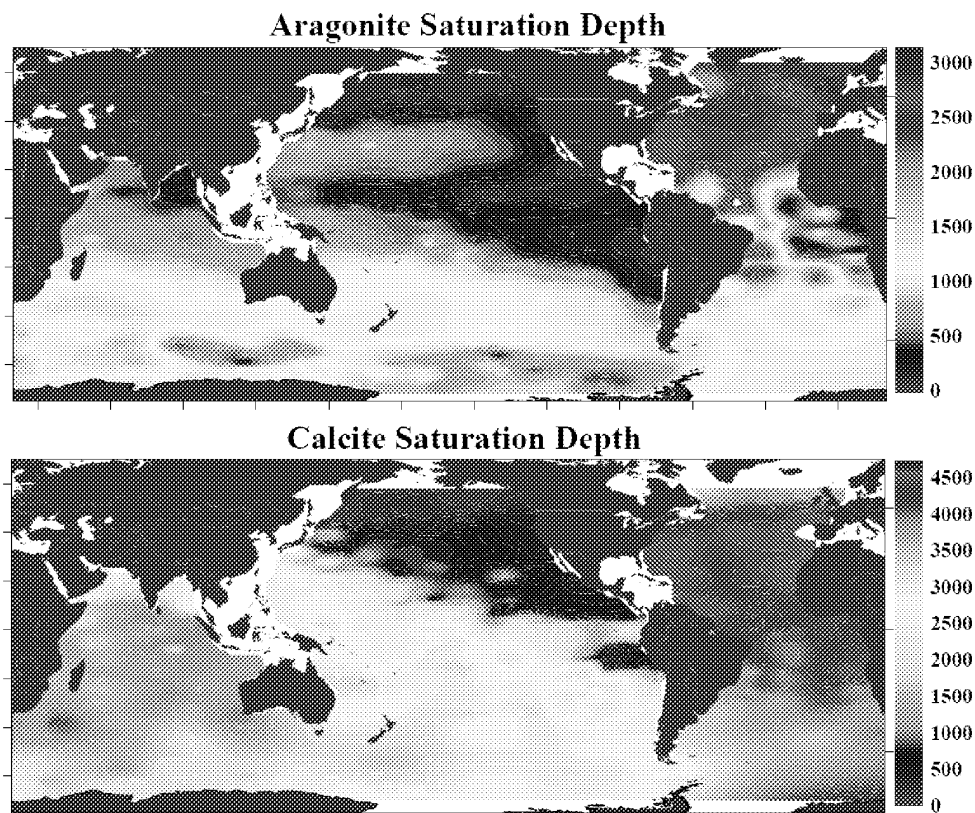


Figure 8. Saturation depth of aragonite and calcite in the global oceans. Colour scale at right denotes the depth in metres. White areas denote regions of little or no data. Figure courtesy of Richard Feely.

### **The BC and Oregon zooplankton communities returned to 'cool-ocean' species in 2007**

Although cooling began in BC southern shelf waters in 2006, recovery of the boreal shelf copepods and northern chaetognaths and decline of the southern copepods and chaetognaths were delayed until 2007. Even in 2007, the return to cool ocean biomass levels and community mix was confined primarily to the continental shelf. Offshore waters off southern Vancouver Island remained relatively unproductive.

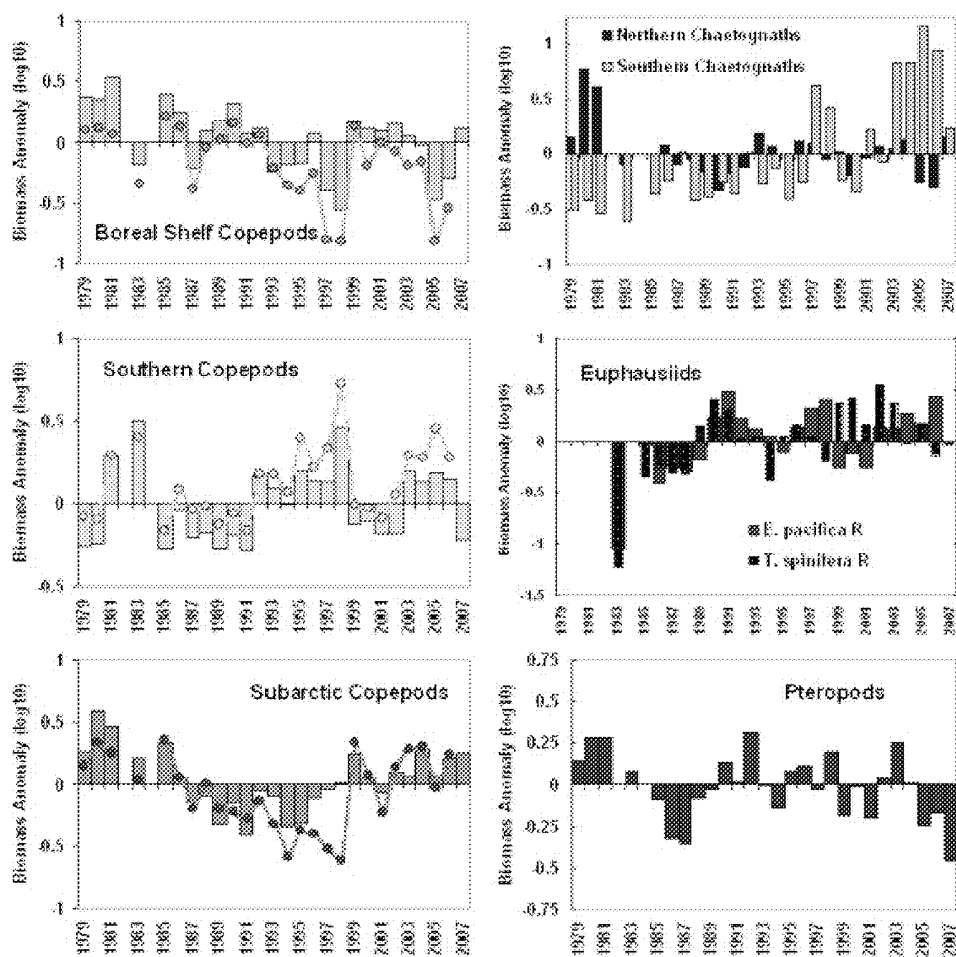


Figure 9. Zooplankton anomaly time series for southern Vancouver Island. Column bars are species group anomalies referenced to the full 1979-2005 baseline period. The years 1982 and 1984 are omitted because there were too few samples. Circles and lines in the 3 left panels show for comparison the older anomalies (1979-1991 baseline). Euphausiid anomalies have been corrected for day vs. night differences in capture efficiency, and are not reported for the first 3 years due to a change in sampling method after 1982.

The copepod community on the Oregon Shelf was a “cold water boreal” community and dominated by cold neritic species, from February through December 2007. This is in contrast to the previous three (warm) years during which warm neritic species were prominent (*Paracalanus parvus*, *Acartia tonsa* and *Calanus pacificus*), as shown in last year’s “State of the Pacific Ocean” report.

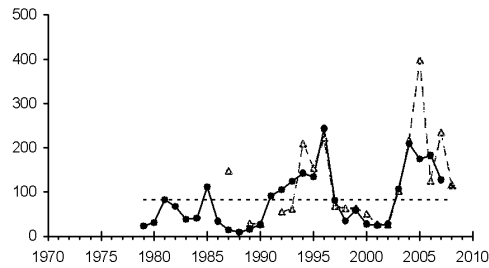
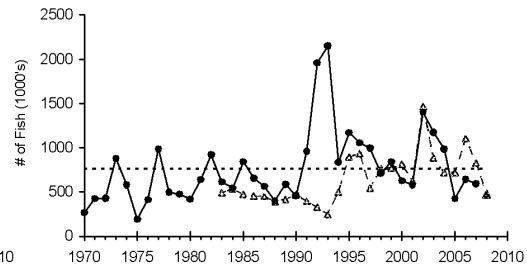
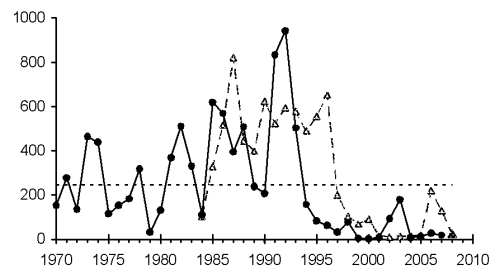
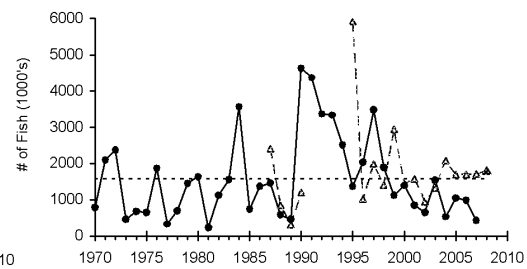
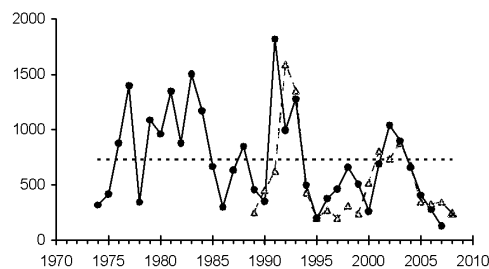
The changes in zooplankton community composition in the past two decades appear to have had large effects on fish growth and survival, probably because the ‘cool water’ zooplankton are better fish food (larger individual body size and much higher energy content). Because much of the year-to-year variability of marine survival rate of harvested fish species occurs at early life stages (for salmon, in their first year after ocean entry), recent zooplankton anomalies provide a useful index of juvenile fish nutrition and a ‘leading indicator’ for subsequent adult fish recruitment.

Total mesozooplankton biomass for the deep-sea offshore BC region (from the continental slope out to 145 °W and between 48° and 55 °N) was very focussed in 2007 with most of the spring/summer biomass (73%) occurring in May and a second smaller peak in July. Although conditions were cooler, the time of peak biomass has not yet returned to June, where it was during cool conditions in 2000/01. The 2007 *Neocalanus plumchrus* peak, which makes up the bulk of the spring biomass, was later than it was during the warmer 2004-2006 period but not as late as in 2000/01. However, the copepod biomass in July 2007 was mostly made up of the larger *N. cristatus*; high numbers of this species have not been seen this late in the year since 2001.

### **Low returns of sockeye coast-wide, especially in the Fraser**

With the exception of northern B.C., sockeye returns were generally low in 2007 (Fig. 10). Looking at the time series for various index stocks indicates:

- Since 1970, maximum returns for all populations occurred during the early 1990's immediately following the strong La Niña event of 1989.
- Central Coast, Vancouver Island (WCVI) and Fraser index-stocks all declined from early-1990s highs to persistent, sub-average returns since the mid-1990s.
- North Coast and Transboundary index-stocks declined from early-1990s highs to sub-average values by the late-1990s but since the year 2000 have exhibited a higher frequency of above-average returns than Central and South coast stocks.
- Populations entering continental shelf areas under stronger oceanic influences appear most responsive to La Niña-like (*anomalously cool, survival favourable*) and El Niño-like (*anomalously warm, survival less favourable*) conditions than stocks entering more protected estuarine waters.
- Persistence of strong El Niño-like conditions through the 2005 sea entry period by smolts was associated with low adult return rates in 2007 for Central Coast (Rivers and Smith Inlet), WCVI (Barkley Sound) and Fraser (Chilko Lake) sockeye index stocks.

**1. Alaska - Transboundary****2. North Coast - Dixon Entrance****3. Central Coast - Hecate Strait****5. Fraser River - Georgia Basin****4. West Coast Vancouver Island**

—●— Observed Returns  
 - - -△- - - Forecast Returns  
 ..... All Year Average  
 ▲ 2008 Forecast

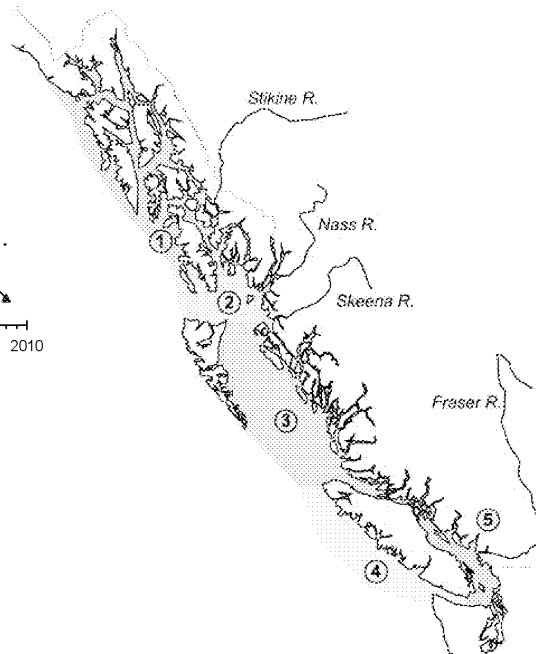


Figure 10. Trends in the total returns and forecasts for BC sockeye index stocks including: 1. Tahltan, 2. Nass, 3. Smith's Inlet, 4. Barkley Sound, and 5. Chilko. Y-axis represents returns in thousands of fish.

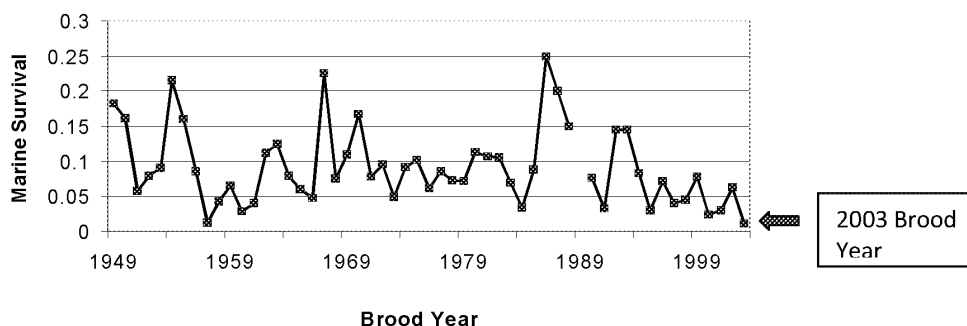


Figure 11. Marine survival of Chilko Lake run of Fraser River sockeye salmon. Data for 2003 brood year (2007 return year) are preliminary.

All four major run timing groups of sockeye salmon returned to the Fraser River in very low numbers in 2007. These low returns are almost certainly due to unusually poor ocean conditions after juvenile salmon left the river in spring 2005, a factor that hampered DFO predictions of returning numbers.

How bad were ocean conditions for Fraser River salmon? Fig. 11 shows a time series of marine survival for Chilko Lake Fraser River sockeye. The 2003 Chilko Lake brood year entered the ocean in 2005 and returned to spawn in 2007. Their marine survival was dismal, tied for the second lowest in more than 50 years of records.

Accurately forecasting salmon returns is difficult, and DFO forecast numbers were too high for all major Fraser sockeye populations in 2007, as revealed in Fig. 12. Forecast models like the ones used for Fraser sockeye assume average survival conditions based on the historical time series. Therefore, in years when survival conditions are less than what has been observed in the past, as occurred for the salmon that returned in 2007, forecasts under-estimate observed returns. Part of the challenge is to understand the relative importance of factors occurring in fresh water versus factors operating in the ocean. The Chilko stock is the only major sockeye population in the Fraser watershed where smolts are routinely counted en route to the ocean, and hence is the only population where we can separate the role of freshwater and marine factors affecting survival. Sockeye fry numbers are estimated in various lakes using hydroacoustic equipment (sounders), but significant freshwater mortality can occur between the time fry numbers are estimated and the sockeye migrate to sea nine months later as smolts. Sampling in the Strait of Georgia in June and September helps us understand what occurs during the early marine life of salmon. Observations of juveniles in the Strait of Georgia in 2005 indicated no problem with marine survival, suggesting normal returns in 2007. In 2005 relatively high surface ocean temperatures associated with reduced marine survivals existed, but higher temperatures in earlier years did not result in the extremely low marine survivals found for this brood year.

From the Georgia Basin, juvenile Fraser sockeye normally migrate through Johnstone Strait, Queen Charlotte Sound and northward along the continental shelf. It appears now that conditions in these waters were poor, based on low returns of sockeye and poor marine survival of seabirds near Vancouver Island.

Previous State of the Ocean Reports noted poor survival of juvenile coho and fledgling seabirds along the west coast of Vancouver Island in 2005, due to poor ocean conditions. Seabirds survival was the worst ever observed from California to Triangle Island off northern Vancouver Island. However, seabirds appeared fine north of this range in 2005, suggesting returns of sockeye in 2007 would be normal. Indicators of ocean productivity, such as PDO and coastal

sea surface temperatures (Table 1), suggested reduced survivals for sockeye returning in 2007.

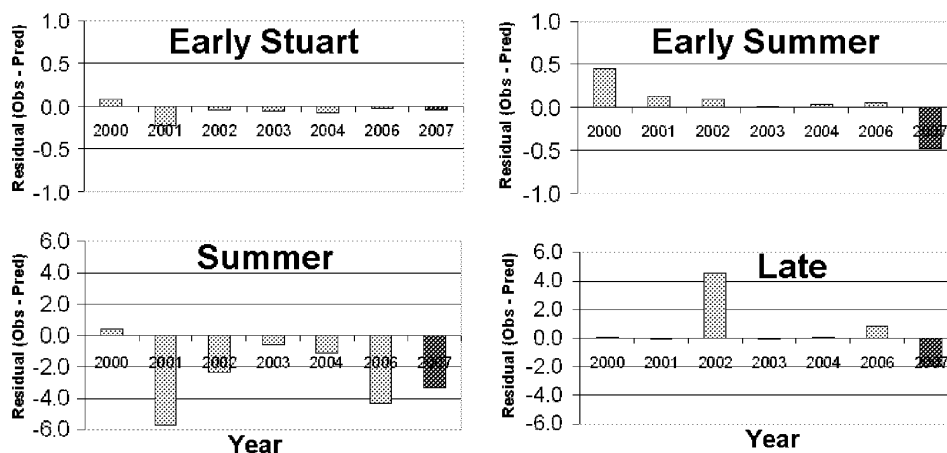


Figure 12. Forecasts success in past years for major run timing groups of Fraser River sockeye. Numbers for 2007 are highlighted – note that run forecasts were overly optimistic.

One analysis, reported in last year's report, compared Chilko Lake marine survival with ocean temperature observations for the brood years 1952-2002. These suggested that increased survivals were associated with a cooler Gulf of Alaska from January to August of ocean entry year and a warmer Gulf of Alaska from November to July of the return year. Conditions for the 2007 returning populations were just the opposite and quite extreme, pointing to poor returns. However, given past unreliability of using Chilko Lake sockeye in non-dominant years as indicators of other sockeye populations, it was not clear how to use this finding.

Future forecasts will consider how to more effectively use climatic, physical and biological oceanographic data to inform quantitative return forecasts. A possible approach presents data from previous State of the Pacific Ocean reports corresponding to the 2005 and 2006 entry years in a "report card" format (Table 1). Qualitatively, all indicators for 2005 were poor (below average), and this type of information could be used to recommend the acceptance of a conservative probability forecast. The good news is that 2006 marine indicators of ocean productivity suggest that the survivals of sockeye returning in 2008 should be somewhat better than for those that returned in 2007. Unfortunately, the number of spawners in 2004 was the lowest for this cycle year, indicating that even with near average survivals, that returns will be low in 2008.

Indicators of Ocean Productivity (State of the Ocean Reports 2005 & 2006)

	2005	2006
PDO	☒ warm (0.95 Jan-Aug) ☒ cool (-0.77 to Dec)	☒ warm (0.57 Jan-Jul) ☒ cool (-0.34 to Dec)
SST (Coast BC)	☒ warm	☒ near/above avg (Jan-Jun) ☒ below avg (Jul-Dec)
Vertical Stratification	☒ strong	○ average-weak (storms)
Upwelling	☒ weak	☒ strong (in summer)
Spring transition	☒ delayed (June)**	○ average (Early-April)
Zooplankton (warm-water spp.)	☒ high	☒ high
Large cold water euphasiids	☒ poor (peak Ap/May)	☒ poor (peak May)
WCVI Coho growth rates	☒ lowest on record	○ average
Marine bird breeding success	☒ lowest on record	○ average
Juvenile sockeye size (SOG)	☒ below average	☒ largest in past 10 yrs

Table 1. Ocean indicators for Fraser River and other southern BC sockeye salmon outbound in 2005 and 2006. The 2005 and 2006 indicators are relevant to sockeye returning in 2007 and 2008 respectively.

### Hake scatter in BC waters. Can we blame jumbo squid?

Hake were distributed from Monterey Bay (36.8° N) northwards to Dixon Entrance (54.6° N) in 2007, with typical dense shelf-edge aggregations observed off of the Washington, Oregon, and northern California coasts (Fig. 13). Further north in Canadian waters, hake distribution was sparse, with most hake in well-separated pockets along the west coast of Vancouver Island and through Queen Charlotte Sound, Hecate Strait and Dixon Entrance. Total estimated biomass of hake aged 3 and older was 0.88 million metric tons in 2007, which is a 27% decline since 2005 and similar to the lowest estimated biomass of 0.78 million metric tons recorded in 2001. The 2007 survey was conducted by the NOAA Ship *Miller Freeman* because the CCGS *W.E. Ricker* suffered a catastrophic failure of the propeller shaft two weeks prior to joining the hake survey effort. The 2007 survey covered more than 12,000 nautical miles on 133 transects and conducted 92 sampling trawls.

Historically, the areas between the mouth of Juan de Fuca Strait (48.25° N) and La Pérouse Bank (48.8° N) are the most productive fishing grounds for the Canadian hake fishery. However, hake biomass in these areas has declined substantially since 2003 (Fig. 13), which is most clearly illustrated by the 2007 data, and as a result the fishery has shifted to Queen Charlotte Sound, at the northern end of Vancouver Island. These changes in distribution and abundance between surveys are not related to differences in survey timing or methods since standardized protocols have been followed since 1995 by both Canada and the United States. The recent decline in hake abundance on traditional Canadian fishing grounds might be related to a reduction in the abundance of *T. spinifera*, a preferred food of hake.

The 2007 survey was notable for the capture of 82 jumbo squid (*Dosidicus gigas*) during biological sampling at depths exceeding 300 m offshore of the continental shelf along Vancouver Island and the Queen Charlotte Islands. Jumbo squid underwent a rapid range expansion into the southern California Current between 2002 and 2006 (Field et al. 2007). Although previous surveys have captured jumbo squid, the 2007 survey was the first survey to capture jumbo squid exclusively in Canadian waters. Based on the acoustic data, hake appeared to be more widely dispersed or less densely aggregated when jumbo squid were

captured and jumbo squid predation may have led to increased swimming activity and dispersal of hake.

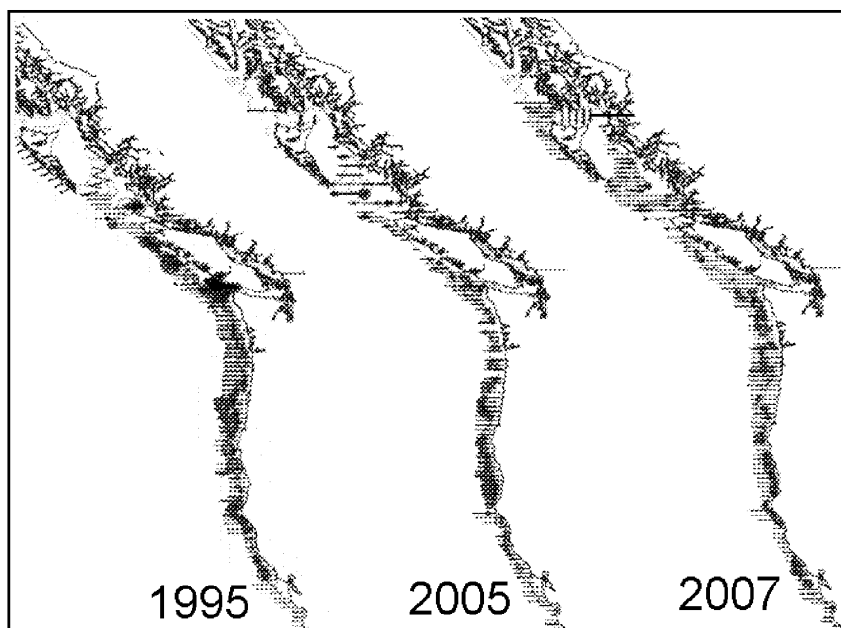


Figure 13. Offshore hake distribution and abundance estimated by the Canada-US Pacific hake acoustic-trawl survey, 1995, 2005 and 2007. Black lines show survey grid, cyan line is the 200 m depth contour (continental shelf-edge) and the red circles indicate hake acoustic backscatter along transects with size proportional to the maximum among years. Based on a figure provided by Rebecca Thomas (Nat. Marine Fish. Serv., Northwest Fish. Centre, Seattle, WA).

### **Sardines are back in BC, but herring, shrimp and other species have declined**

Sardines reappeared off the west coast of Vancouver Island in 1992. During the 1990s their distribution expanded northward from southern Vancouver Island through Hecate Strait to Dixon Entrance. In 2003 and 2004 the distribution of sardines in B.C. was limited to the inlets of Vancouver Island and offshore areas in the south. Recent warm conditions and a very strong 2003 year-class have resulted in widespread distribution of sardines throughout southern Hecate Strait and Queen Charlotte Sound in 2006 and 2007.

However, herring on the West Coast of Vancouver Island is at an historically low level and will remain so unless ocean conditions resulting in a reduction in the abundance of predators in the area improve. Recent conditions have not been favourable for herring survival in 2004 and 2005, and we expect continued weak recruitment to the stock during the next couple of years.

Herring in the Hecate Strait area consist of migratory stocks from the Queen Charlotte Islands, Prince Rupert and Central coast areas. For the past decade, recruitment and abundance of Queen Charlotte Islands herring have been low while recruitment and abundance of Prince Rupert and Central Coast herring have generally been good. Recruitment of the 2003 and 2004 year-classes was weak in all three areas resulting in moderate declines in Prince Rupert and the Central Coast.

Herring survival conditions and recruitment have been unusually good in the Strait of Georgia



for the last decade. Abundance of herring reached near historical high levels from 2002-2004 exceeding 100,000 mt. However, the 2003 and 2004 year-class are relatively weak resulting in a substantial decline in abundance in recent years. Nevertheless, the stock remains at a healthy level in the short term.

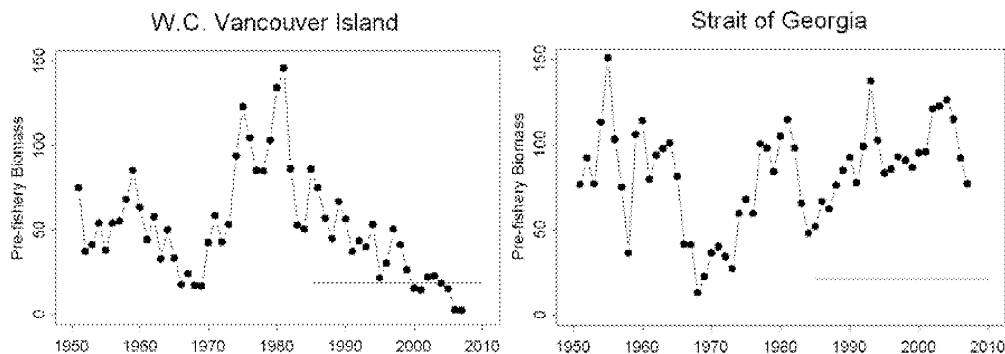


Figure 14. Herring abundance on the West Coast of Vancouver Island and in the Strait of Georgia to 2007. No commercial fishing is allowed when biomass drops below the horizontal lines in each panel. Central and North Coast biomasses were closer to this fishing limit.

Bottom trawl surveys using a small-mesh net (targeting the smooth pink shrimp *Pandalus jordani*) have been conducted during May since 1973. The survey in 2007 found that the biomass of *Pandalus jordani* shrimp off central Vancouver Island was low and similar to that from 2004 to 2006. Pink shrimp biomass continues to be affected by the warm ocean conditions from 2003 to 2005, likely a result of poor recruitment during this period and a 2-yr time lag to capture by the survey. Biomass of most other “key” indicator species continued to decline from record highs (for some species) in 2005; exceptions in 2007 were increases of both warm (Pacific hake) and cool (walleye pollock) water species.

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