Recent trends in waters of the subarctic NE Pacific – summer 2004

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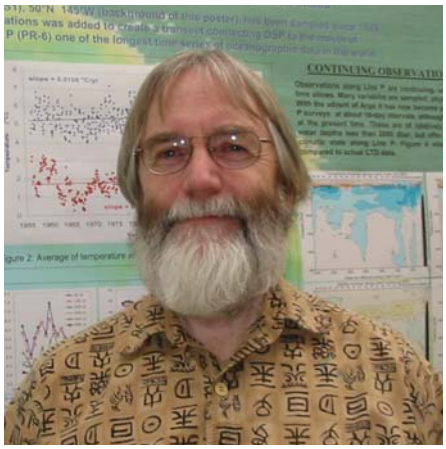

Frank A. Whitney has led the Line P program for the past 12 years, carrying out repeat oceanographic sections for WOCE (1991-97) and hosting the Canadian JGOFS program (1992-97) on these cruises. Through this time, his main research interest has been in understanding processes which control nutrient supply to the upper ocean. He has also surveyed meso-scale eddies several times in an attempt to estimate offshore transport of coastal waters in the Gulf of Alaska. Frank has been working in oceanography on the British Columbia coast since 1969.

Warmest waters in 45 years of observations

This summer, we surveyed the warmest surface waters ever observed along Line P between 127ºW and 134ºW (Fig. 1). As a reminder, Line P is the time-series program that samples along a transect extending westward from the southern coast of British Columbia to Ocean Station Papa (OSP) at 50ºN, 145ºW (Fig. 2). Waters were as much as a degree warmer than during the strong El Niño summer of 1997 in the region called the Transition Domain, and exceeded any measurements made during the 1959 to 1981 period in which Weatherships were transiting to and from OSP every 6 weeks.

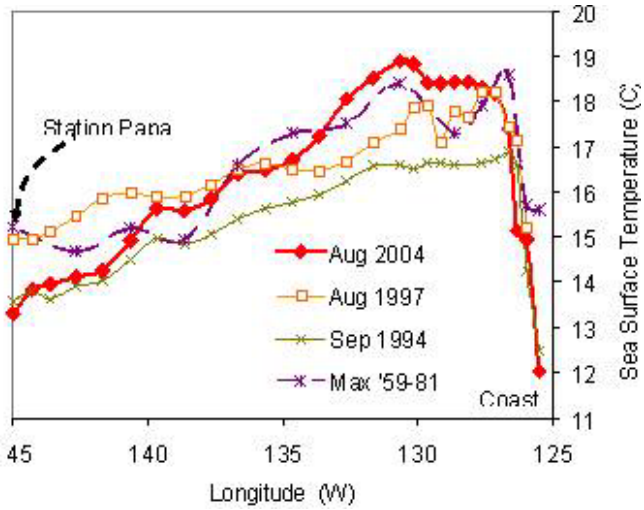

Fig. 1 SST along Line P during the warmest years of the 1990s and from the Weathership era (1956-1981).

The maximum recorded temperature this August was 18.9ºC at station P12. Warm waters persisted northward, with 17.3ºC waters being found off the southern end of the Queen Charlotte Islands (station R6). Waters cooled to the east of R6 as they did coastward of about P4 along Line P because of upwelling on the continental shelf. Toward open ocean, temperatures likewise decreased as the high nitrate, low chlorophyll (HNLC) waters of the subarctic Pacific were approached.

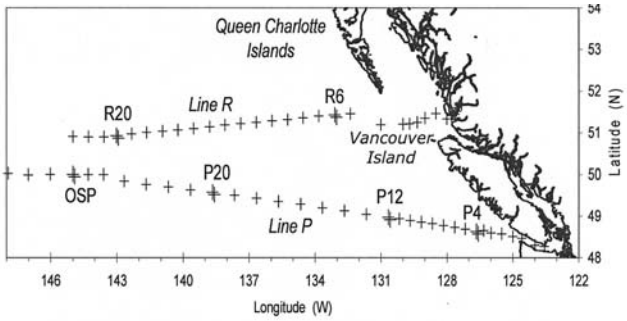

Fig. 2 Track of the August survey along Line P to Ocean Station Papa (OSP) and along line R to the southern tip of the Queen Charlotte Islands.

The Transition Domain is the region that often contains waters which are depleted of nitrate in summer, have little chlorophyll (<0.2 mg m^{-3} this August) and contain subtropical species including southern zooplankton and tuna. This summer, Moira Galbraith (Institute op Ocean sciences) found several anomalous groups of southern organisms in net tows starting at the shelf break off the BC coast and extending westward past station P12. A medusa, *Aglaura hemistoma*, which is endemic to waters south of 40ºN was abundant, as were southern euphausiids and eggs of the Pacific sardine (*Sardinops sagax*). On summer cruises, we also caught albacore tuna and saw humpback whales feeding off the shelf break in waters warmer than 16ºC. Graham Gillespie (Pacific Biological Station) reported collecting the myctophid *Symbolophorus californiensis* off Langara Island (roughly 54°10' N, 133°55' W) in September. This organism has not been found north of ~50°N previously. Through October, local people have also been finding a species of large squid that is typically found south of San Diego, California, in fishing nets and on beaches along southern British Columbia.

Marc Trudel (Pacific Biological Station) reported having caught several of these Humboldt squid (*Dosidicus gigas* Orbigny) in October off central Vancouver Island, the largest being 1.5 m long. Such oddities tend to occur during strong El Niño events. However, the Southern Oscillation Index indicated only weak El Niño conditions in 2003/04.

Sonia Batten (Continuous Plankton Recorder Program) found another consequence of the warmer surface water, the more rapid development of *Neocalanus* copepod populations. *N. plumchrus* and *N. flemingeri* typically reproduce at depth in the late winter, the early stages vertically migrate towards the surface and mature as they do so. Copepodite stages I-V are spent in the surface waters, and once CV's have accumulated enough lipid they descend again to enter diapause and over-winter at depth. Populations exist at the surface usually between February and June, peaking in biomass in May and the lipid-rich older stages are prey for a number of fish and bird species. Although the trigger for ending diapause is still unknown development through the copepodite stages is temperature-dependent. Figure 3 shows data from Continuous Plankton Recorder samples for the last 5 years. Although not all data for 2004 are available yet, it looks as though the population matured more rapidly in 2004 than any of the other years so far sampled (the line is steepest). Since peak biomass occurs when 50% of the population reaches CV (Mackas *et al.*, 1998. *Can. J. Fish. Aquat. Sci.* 55: 1878-1893), biomass would have peaked in 2004 about 3 weeks earlier than in 2000. This may have implications for predators that rely on this biomass.

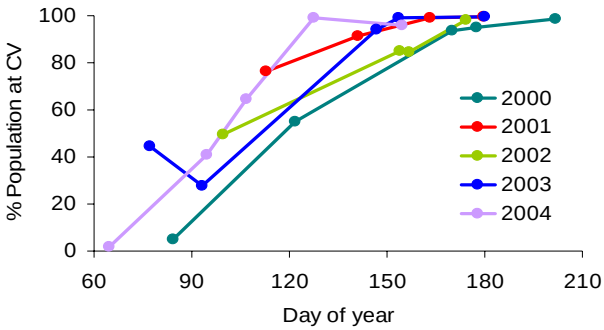

Fig. 3 Mean proportion of the Neocalanus plumchrus/flemingeri population at stage CV (stages II to V separately counted) in each year from CPR samples collected in the eastern Gulf of Alaska.

Decreasing oxygen in subsurface waters

For the past 17 years, nutrients and oxygen have been routinely measured onboard research vessels surveying Line P, providing a high quality data set. Several standard stations were repeatedly sampled at a frequency of ~3 times per year. One of the strongest trends in these data is for oxygen to decrease and nutrients to increase in subsurface waters. An example of this is shown for OSP (Fig. 4) where oxygen levels have declined from ~150 to ~100 µmol kg^{-1} at 200 m, and from ~90 to ~50 µmol kg^{-1} at 300 m over this observation period. Howard Freeland (IOS) has been tracking the mixed layer depth at this location (see *PICES Press*, Vol. 11 (2), July 2003), and has noted a shoaling of the surface layer over the past 4 decades. The winter mixed layer has been especially shallow in the past 2 or 3 years. Surface warming and perhaps a change in wind intensity appears to be the cause of this shoaling. A consequence of weaker mixing is evidently a decrease in the ventilation of thermocline waters (depth 100 to 400 m). This leads to declining oxygen and increasing nitrate as organic detritus is remineralized at depth.

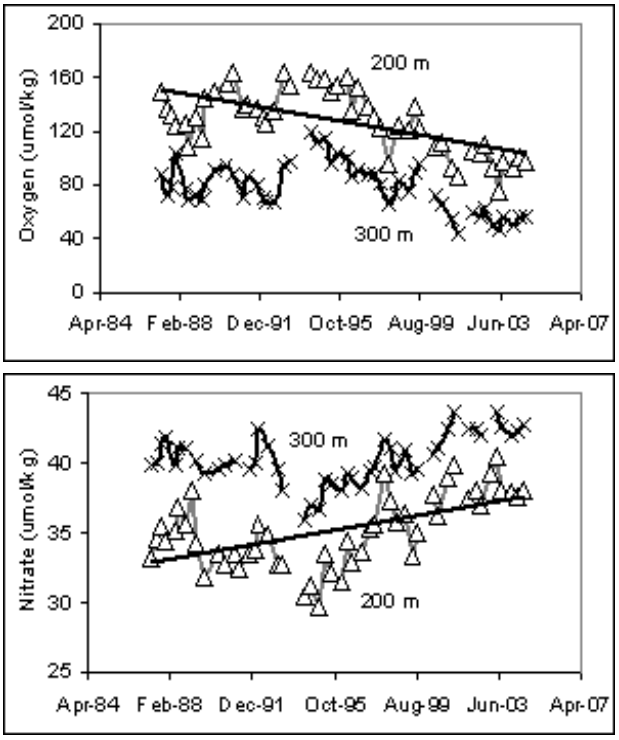

Fig. 4 Oxygen and nitrate levels at 200 and 300 m depth at Ocean Station Papa from 1987 to 2004.

Such declines in oxygen are a cause of concern. Hypoxia, a condition under which many marine organisms weaken or die, occurs at ~62 µmol kg^{-1}. Our data shows that hypoxia has spread upward from ~400 m to ~250 m at OSP over the past couple of decades. In addition, waters at ~200 m depth supply coastal upwelling regions with nutrient rich waters, stimulating the high primary productivity that supports rich fisheries. However, as the upwelled waters become oxygen poor and nutrient rich, coastal organisms may be stressed or killed by hypoxic conditions. Jane Huyer and colleagues (Oregon State University) have been following just such conditions along the Oregon coast. Over the past 3 years, hypoxia during the upwelling season has resulted in occasional kills of fish and crab populations. Such kills were not observed prior to 2002.