Impact of the 1990s El Niños on Nutrient Supply and Productivity of Gulf of Alaska Waters

Frank Whitney,[1] David Mackas,[1] David Welch[2] and Marie Robert[3]

[1] *Fisheries and Oceans Canada, Pacific Region*
Institute of Ocean Sciences
Box 6000, Sidney, B.C. V8L 4B2, Canada
e-mail: whitneyf@dfo-mpo.gc.ca

[2] *Pacific Biological Station*
Hammond Bay Rd.
Nanaimo, B.C. V9 R 5K6, Canada

Institute of Ocean Sciences
[3] *Box 6000, Sidney, B.C. V8L 4B2, Canada*

Over the past few decades, surface waters of the Gulf of Alaska have been gently warming. In the 1990s, we are also setting records for warmest waters since observations began in the 1930s. Coastal temperatures at British Columbia lighthouses (e.g. Amphitrite Point and Kains Island, Figure 1) were very warm during the summer of 1997 (Figure 2), besting previous temperature maxima by more than 1°C. The monthly averaged T at Amphitrite Point, for example, was 16.0°C in September 1997, topping the 1979 record of 14.9°C. Coastal trends generally mimic that seen in equatorial waters. In both regions, warming is measured over time, and periodic El Niños produce major warm anomalies. A notable exception is that the 1972 El Niño does not appear in Lighthouse temperature records.

In open ocean, the highest measured winter temperatures were observed in 1994. Coincident with this was a thinning of the mixed layer (a trend Freeland et al. (1997) have observed over the past 40 years at Ocean Station Papa (OSP)) and a reduction in the nutrient supply to the mixed layer (Whitney et al., 1998). As a result of reduced winter nutrient supply, nitrate depletion has become more widespread in the 1990s. Between 1989 and 1994, nitrate depletion spread from 250 km to almost 600 km offshore along Line P. This loss of nutrient has resulted in abnormally low chlorophyll levels in recent summers (Figure 3) compared with the recent average, and a substantial reduction in primary productivity in late summer (Whitney et al., 1998).

This work allowed estimates of loss of new production in an area covering 290,000 km^2 off the coast of Vancouver Island. Between 1989 and 1994, a decline of about 2 million tonnes of phytoplankton carbon was calculated. However, surveys had not been made along the coast of Alaska during this period. When it was evident that a major El Niño was building in 1997, more detailed sampling was begun both along Line P and to the north coasts of B.C. and Alaska. Over the past couple of years, we have been able to chart the area that experiences nitrate depletion in summer (Figure 1), and now see that virtually all the shelf waters in the Gulf are affected.

More frequent surveys along Line P provided much better seasonality to nutrient supply and utilization. On the shelf, 1997–98 winter nutrient levels were less than half those of an average year in the 1970s, and nitrate depletion occurred in April rather than May (Figure 4). It also appears that coastal upwelling has been much weaker through the summer of 1998, since nutrient levels remained low. This trend was also seen in open ocean stations, to at least 225 km offshore.

Assuming that nutrient deficiency is spreading in the Gulf of Alaska, much the same way it has been along Line P, then shelf productivity has been substantially impacted. B.C. juvenile salmon are known to spend several months in coastal waters as they migrate northward through spring and summer (D. Welch, unpublished data). The weakened nutrient supply suggests that they are migrating through water that may have only 50 to 60% of the primary production that was seen in the 1970s. The decline in open ocean survival (Welch et al., submitted) of some of these stocks in the 1990s may be linked to changes in coastal nutrition.

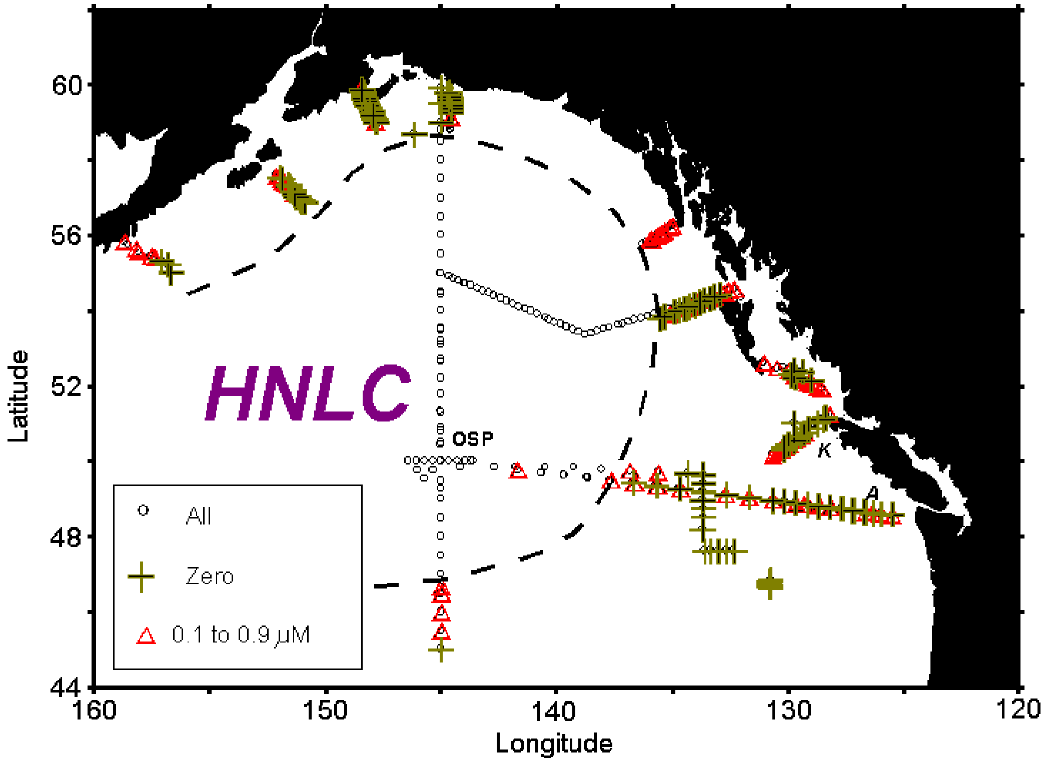

Figure 1. *Gulf of Alaska, showing surface sampling locations for summers of 1997 and 1998. The dashed line shows the approximate bounds of high nutrient–low chlorophyll (HNLC) water. Ocean Station Papa (OSP), Amphitrite Point (A) and Kains Island (K) sampling locations are marked.*

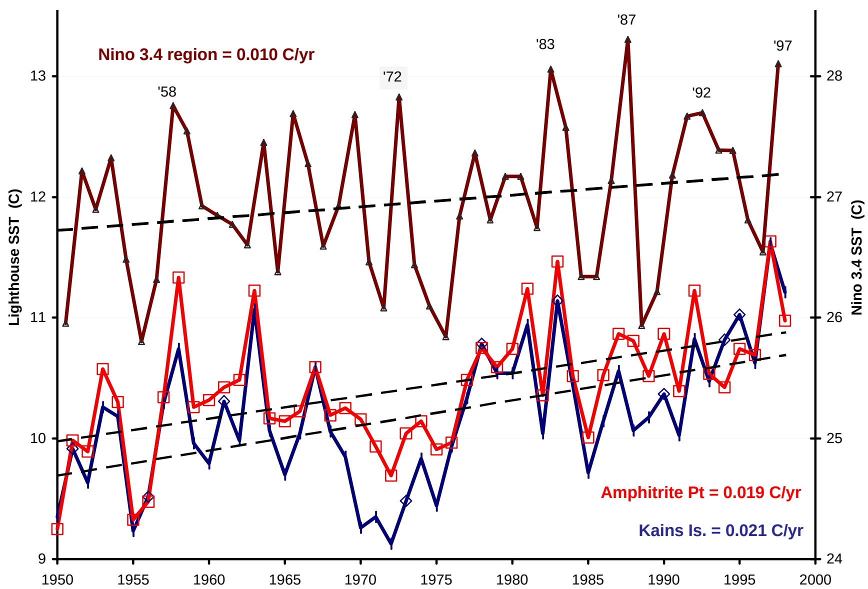

Figure 2. *SST averaged yearly for the equatorial Niño 3.4 region and two lighthouse stations. Linear regressions show a warming trend in each area.*

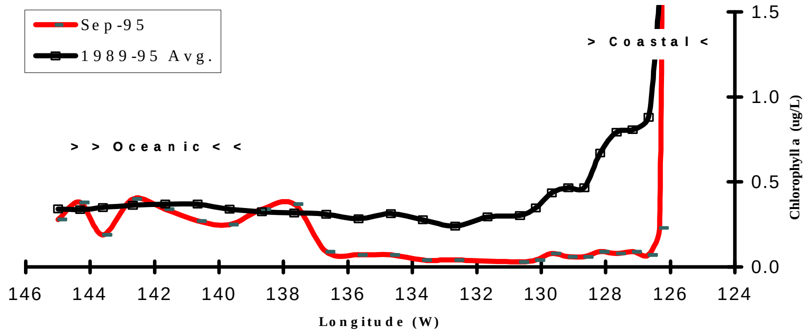

Figure 3. *Chlorophyll a levels in surface waters along Line P. Low concentrations in September 1995 correspond to nitrate-depleted waters; high coastal values to upwelling.*

A result of mixed layer thinning is the increase in average light levels that phytoplankton receive, which would advance the onset of spring growth (as suggested in Freeland et al. (1997)) and should stimulate earlier development of grazers. Mackas et al. (1998) have observed a 2 month earlier development of one of the major subarctic Pacific copepods, *Neocalanus plumchrus*, at OSP. Such shifts in communities must create mismatches in timing of predator and prey interactions.

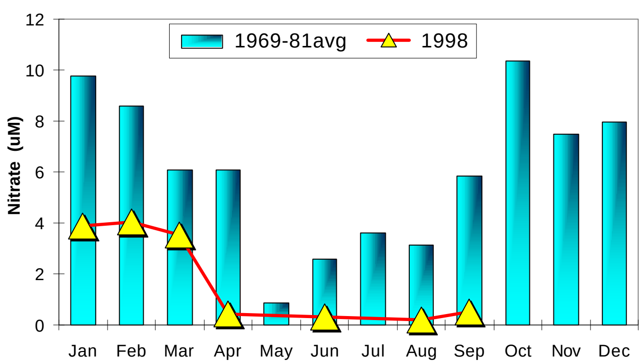

Figure 4. *Average nitrate concentration in the coastal 75 km of Line P during the 1970s and 1998.*

Thus the changes we have been observing in coastal and open ocean in the Gulf of Alaska are consistent with a warming of surface waters. The increased buoyancy of the mixed layer results in less winter supply of nutrient, which decreases the amount of phytoplankton biomass that is produced, which in turn impacts the productivity of the entire region.

References

Freeland, H.J., Denman, K.L., Wong, C.S., Whitney, F. and Jacques, R. 1997. Evidence of change in the winter mixed layer in the northeast Pacific Ocean. *Deep-Sea Res.*, *44*, 2117–2129.

Mackas, D.L., Goldblatt, R. and Lewis, A.G. 1998. Interdecadal variation in developmental timing of *Neocalanus plumchrus* populations at Ocean Station P in the subarctic North Pacific. *Can. J. Fish. Aquat. Sci.* ***55***, 1–16

Welch, D.W., Ward, B.R., Smith, B.D. and Eveson, J.P. 1999. Influence of the 1990 ocean climate shift on British Columbia steelhead (*O. mykiss*) populations. *Fish. Oceanogr.* (submitted)

Whitney, F.A., Wong, C.S. and Boyd, P.W. 1998. Interannual variability in nitrate supply to surface waters of the Northeast Pacific Ocean. *Mar. Ecol. Prog. Ser.* *170*, 15–23