

Time series of the Northeast Pacific: A symposium to mark the 50th anniversary of Line-P

By Angelica Peña

As one of the longest running ocean time series in the world, Ocean Station Papa (OSP; 50°N and 145°W) represents a unique dataset that has improved our understanding of ocean processes. Meteorological and surface ocean sampling from a weather ship at OSP began in 1949. In 1956, observations were initiated at stations along the 1425 km-long line between the coast of British Columbia and OSP. Since then, surveys along this line, now called Line-P, have been undertaken many times each year. However, Line-P is only one of the ocean time series of the Northeast Pacific, and previous research has benefited from comparisons among the various time series. To facilitate interaction and exchange of information among investigators working in the Northeast Pacific, a symposium, sponsored by Fisheries and Oceans Canada and the North Pacific Marine Science Organization (PICES), with additional support from CLIVAR, was held July 5–8, 2006, at the Victoria Conference Centre in Victoria, British Columbia, Canada. Convenors of the symposium were Howard J. Freeland and Angelica Peña. The symposium, which celebrated 50 years of oceanography along Line-P and at OSP, explored the scientific value of both Line-P and the time series of the Northeast Pacific in general. More than 80 scientists from PICES member countries attended the symposium.

The symposium consisted of plenary talks by invited speakers interspersed with contributed posters. It included: (i) overviews of specific time series of the Northeast Pacific such as CalCOFI (California Cooperative Oceanic Fisheries Investigations), the NH (Newport Hydrographic) Line, the GAK (Gulf of Alaska) Line and HOT (Hawaii Ocean Time-Series); (ii) a review of main findings from the Line-P program, including presentations of the physical variability, plankton and biogeochemical cycles, and ecosystem modelling; (iii) presentations on process studies in the Northeast Pacific, including discussion of the factors influencing gas exchange, the large-scale iron fertilization experiment (Subarctic Ecosystem Response to Iron Enrichment Study – SERIES), and the influence of eddies and mesoscale variability in the region; (iv) a panel discussion on the strengths and weaknesses of the Line-P program as it has been executed to date; and (v) a workshop to discuss the future of Line-P by those who plan on carrying out research in the Line-P program.

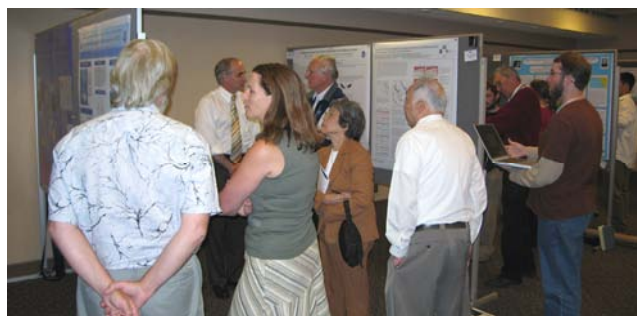
Coastal waters of the Northeast Pacific are highly productive, supporting important commercial fisheries. This is reflected in the motivation and design of the coastal time series programs such as CalCOFI, and NH and GAK Lines. For example, the goal of CalCOFI, the longest time series of the region, was to achieve an understanding of the

dynamics of fish resources off California to enable their management to be improved. After 57 years, they are able to infer confidently about phenomena of time scales ~0.25–15 years, and spatial scales ~60–500 km horizontally and ~5–500 m vertically, as well as large-scale trends. CalCOFI has become one of a few programs with data to understand processes over this range of scales, now including climate change.

Sampling of the NH Line, which extends along 44.65°N from the central Oregon coast to 160 km offshore, began in 1961. Observations show that the seasonal cycle is very strong, with rapid transitions in spring and fall. Comparison of summer regimes between two epochs: 1961–1971 and 1997–2003, indicates that the near-surface



Line-P symposium turnout.



Attendance at the poster session.



Line-P panel discussion with (left to right) Ricardo Letelier, William Crawford, Timothy Parsons, Douglas Bancroft, Diana Varela and Ed Harrison.

layer at most locations is significantly warmer and fresher during the latter period.

The GAK Line has been sampled intermittently for 35 years, with more intensive sampling taking place during the GLOBEC Coastal Gulf of Alaska program (1997–2004). The marine ecosystem in this region shows large seasonal variations and is influenced by a seasonally-varying Aleutian Low which induces large annual cycles in heat fluxes, runoff, and winds, and by a complex bathymetry and coastal orography. Cross-shelf variability in phytoplankton and zooplankton appear linked to freshwater dispersal processes and along- and cross-shelf transports. Observations in recent decades show a marked reduction in ocean cooling by the atmosphere and increasing runoff.

The subarctic and mid-latitude North Pacific and its marginal seas include several of the world's longest and richest marine zooplankton time series (**Fig. 1**), displaying large amplitude interannual to decadal changes in total zooplankton biomass, community composition, and body size and life cycle timing within individual species.



Fig. 1 Location of zooplankton time series in the Northeast Pacific.

Open oceans experience variable productivity due to mesoscale processes and interannual and decadal oscillations. Open ocean time-series sites are very valuable for monitoring biogeochemical cycles and climate change. For example, the HOT long-term records of water soluble reactive phosphorus (SRP) concentration in the North Pacific Subtropical Gyre indicate that during warm phases of the Pacific Decadal Oscillation (PDO), microbial assemblages are able to deplete SRP well below the concentrations observed during cold PDO phases. These observations, when combined with other physical and biological time-series data, suggest an increase in nitrogen fixation and the relative contribution of prokaryotic photoautotrophs to this ecosystem during warm PDO phases. As another example, the Line-P records reveal surface warming, increasing stratification (**Fig. 2**), shallowing trend in the mid-winter mixed layer, earlier maturation of spring zooplankton and decreased ventilation of the interior of the ocean during the past 50 years. There is now compelling evidence that the large-scale upper ocean variability in the Northeast Pacific is a direct response to atmospheric forcing.

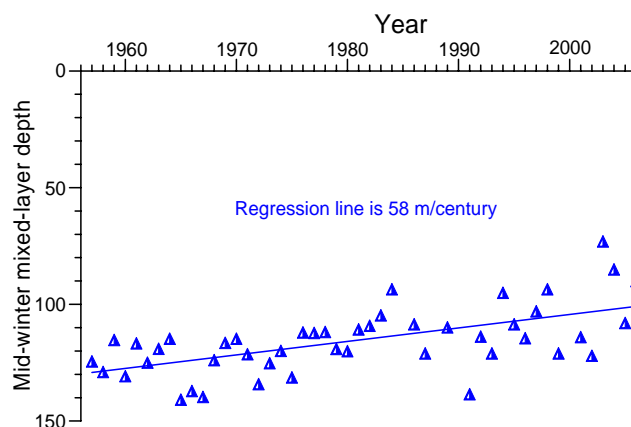


Fig. 2 Depth of the mid-winter mixed layer depth plotted against year at OSP during the period of 1956 to 2005.

Early work at OSP was critical to our present understanding of HNLC (high nutrient low chlorophyll) regions, and to the formulation of the iron limitation hypothesis where the availability of iron was proposed to be the main control on primary production and nitrogen uptake. Results from the SERIES iron fertilization experiment, conducted in the Northeast Pacific in July 2002, as part of the Canadian SOLAS program, showed an important increase in phytoplankton biomass, a moderate increase in carbon sequestration, and a decrease in DMS (dimethylsulfide) concentrations, leading to conditions that would not mitigate greenhouse warming. Modelling studies at OSP have been integral to the major cooperative ecological programs. Studies along Line-P have greatly improved our understanding of the interactions between trace metals, microbes and ocean biogeochemical cycles. Variability of nutrients and other biogeochemical parameters is much larger than first expected, and points to the importance of events as opposed to stable processes.

Satellite and ship-based observations have defined the impacts of mesoscale eddies on properties of Line-P and the Gulf of Alaska. These studies have revealed that Haida and Sitka Eddies dominate the surface chlorophyll distribution, as seen from the satellite-based SeaWiFS sensor, around the entire rim of the gulf. Several physical processes allow mesoscale eddies to carry coastal chlorophyll, macro- and micro-nutrients, and low oxygen water several hundreds of kilometres into near-surface, mid-gulf waters. Ten years of sediment trap data along Line-P show a summer seasonal peak in sediment transport, a decrease in the flux of particles with distance from the coast, and a different composition of sediments compared to the western Pacific. In the last decade, studies at the air-sea interface, including multi-year moorings and sampling of the sea-surface microlayer, have been carried out at OSP. These studies have found differences in the thickness of the microlayer between OSP and coastal waters, and that increasing gas transfer rates are coincident with increasing winds and deepening bubble penetration depth.

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Some of our most important knowledge of the ocean has come from long-term measurements at particular sites or from repeated measurements along sections. Knowing accurately the time variability in even a few locations around the world is important, as very long records are needed to determine the difference between multi-decadal cycles and climate trends. Line-P is a program highly regarded by the scientific community and has itself benefited from numerous collaborations and partnerships with the national and international research communities. Since its initiation, it has been a multi-disciplinary program including oceanic and atmospheric research, physical, chemical and biological studies of the upper mixed layer

dynamics. Another strength has been its flexibility to allow the integration of many process studies. During the panel discussion, concerns were raised regarding the continuation of Line-P given the limitation of ship time and personnel. Several challenges were identified, including continuity, innovation, funding, and the need to provide results useful for management and policy. Both academics and government scientists are needed in the Line-P program. The Canadian and international scientists at this symposium agreed on the need to continue the Line-P series indefinitely, as it is the only series of observations that allows scientists to determine climate change events and processes in the northeast subarctic Pacific.



Dr. Angelica Peña (penaa@pac.dfo-mpo.gc.ca) is a biological oceanographer conducting research on phytoplankton ecology and biogeochemical cycles. She uses field observations and models to study the dynamic relationships that exist between the planktonic ecosystem and its environment, and its response to climate change. Angelica works as a research scientist for Fisheries and Oceans Canada at the Institute of Ocean Sciences (IOS). She received her B.Sc. from the University of Concepcion, Chile, and her M.Sc. and Ph.D. degrees in oceanography from Dalhousie University, Canada. Angelica has been involved in several international programs including JGOFS, GLOBEC and ECOHAB. She is a member of the PICES Biological Oceanography Committee.