The Continuous Plankton Recorder Survey of the North Pacific

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Background

Zooplankton are a key intermediate trophic group between the primary production in the ocean and fish and larger marine organisms that form valued resources. Large scale routine sampling in the open ocean from research vessels is impractical because of the large costs involved, consequently the north Pacific has been poorly sampled to date. Observed and predicted climate changes, observed large scale changes in Pacific salmon populations and other higher trophic levels all point to a need for large scale monitoring to detect changes in the ocean. The North Pacific Marine Science Organisation (PICES) supported the initiative to begin collecting baseline plankton data at its 1998 annual meeting, through the MONITOR Task team, and has remained closely linked with this program since its commencement in 2000. The eventual aim is a multidisciplinary monitoring program that will allow explanation of the measured variability.

The initial proposal sought to make use of existing expertise in the North Atlantic, where the Hardy Continuous Plankton Recorder (CPR) has been deployed from Ships of Opportunity (merchant vessels going about their regular activities) for the last 70 years. Although designed in the 1920s, the CPR is a robust, reliable plankton sampler (Fig 1) that can be deployed and operated at the high speeds of modern commercial vessels (in excess of 20 knots). For further information on the Atlantic CPR survey and the history of the plankton recorder go to www.sahfos.org

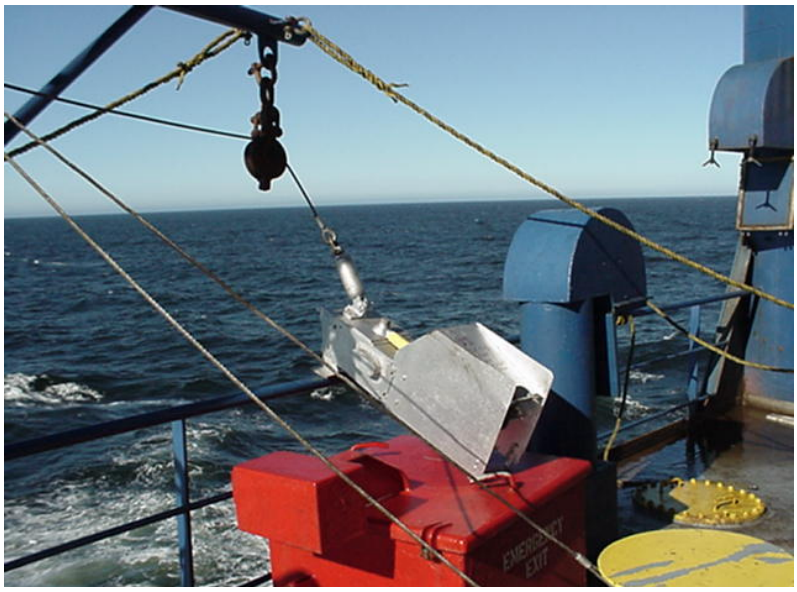

Fig 1. The CPR about to be deployed

Two years of funding approved by the North Pacific Marine Research initiative were used to acquire baseline data on a range of planktonic organisms. Specific objectives were then to assess the sampling strategy, and if necessary recommend modifications for a future monitoring program, and to analyse the collected data to begin to say something about the large scale plankton populations of the North Pacific. PICES set up a CPR Advisory Panel to contribute to the design and analysis of the program and the data.

Introduction

The Sir Alister Hardy Foundation for Ocean Science (SAHFOS), which operates the CPR survey, undertook a pilot sampling exercise in the Pacific in 1997 using an oil tanker on its route from Prince William Sound, Alaska, to Long Beach, California. This successful exercise set the framework for the NPMR funded sampling, and replicate transects were planned for spring and summer 2000 and 2001. A complimentary transect running east to west across the North Pacific, from Vancouver, Canada through the southern Bering Sea towards Japan was also initiated, although funding restricted this transect to once per year, in summer (see Fig 2).

The CPR samples at a depth of about 7m and although it samples continuously, the resulting transect was divided into discrete samples. A single CPR sample was collected over 10 nautical miles (18.5km) and represented the plankton filtered from a narrow cylinder of seawater, with a volume of about $3m^3$, a diameter of about 1.27cm and a length of 18.5km. All collected samples were archived and selected samples were microscopically processed to enumerate the plankton. Processing of samples ranged from every sample on a transect to every fourth sample only, to address a variety of issues. The resulting database contained abundances of particular plankton taxa (ranging from species level to groups) on each processed sample together with the position of the sample (at its midpoint) and the time and date of collection. A simple temperature logger was attached to the CPR on the route from Alaska to California that recorded surface temperature every 15 minutes.

We first describe the sampling methods, and success achieved, in the first two years of sampling. Other reports in this series describe some analyses with the resulting data. We also comment on some of the strengths and weaknesses of the program and some analyses that have been undertaken to assess whether the CPR adequately samples the large scale distributions. The term 'baseline data' covers a multitude of issues, from seasonal cycles to species distributions to interannual variability. We detail some of the results obtained but are by no means exhaustive. Finally, we discuss the near- and longer term future of the program.

1. Sample collection and processing

The CPR was towed 5 times in 2000 and again in 2001 on a transect from Alaska to California and once in each year from Vancouver, Canada to the western Pacific (Kamchatka in 2000, the Japanese coast in 2001). Figure 1 shows the location of the transects and Table 1 the dates of each sampling.

Two vessels operated the north-south transect, the *Polar Independence* in 2000 and the *Polar Alaska* in 2001 (and also in 1997 when it was known as the *Arco Alaska*). Both vessels were crude oil carriers operated by Polar Tankers, Inc. The east-west transect was carried out by the *Skaubryn*, a cargo vessel operated by Seaboard International Shipping Company Ltd. Both companies provided excellent help in the scheduling and operation of the CPR deployments.

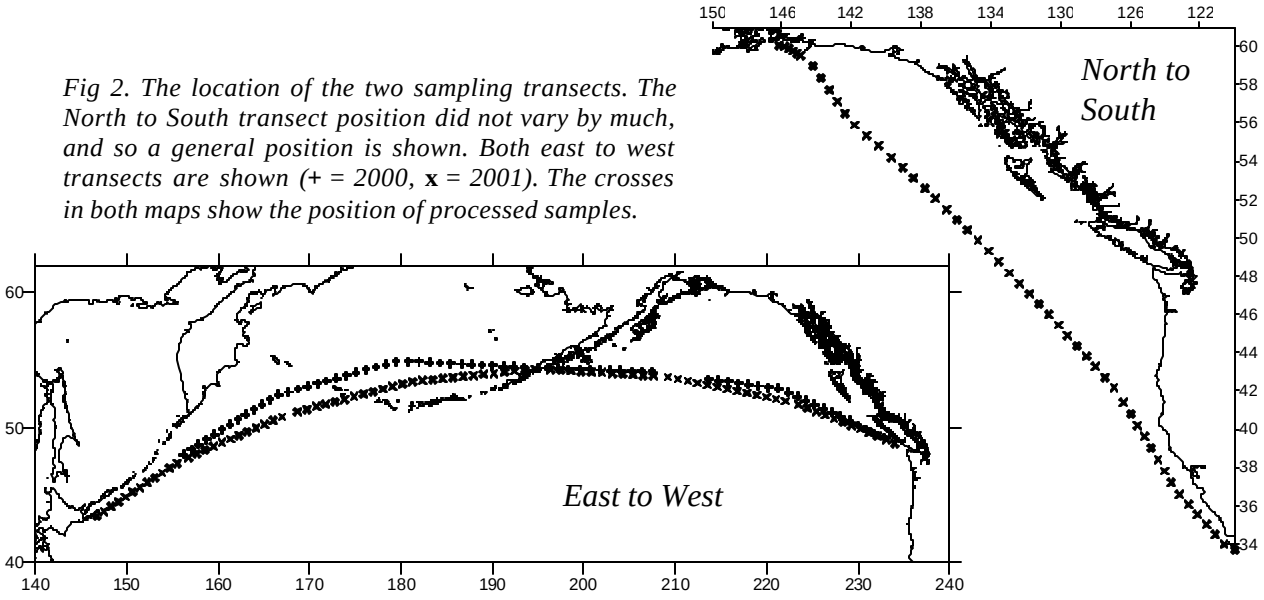

*Fig 2. The location of the two sampling transects. The North to South transect position did not vary by much, and so a general position is shown. Both east to west transects are shown (+ = 2000, **x** = 2001). The crosses in both maps show the position of processed samples.*

Table 1. The dates of each sampled transect. In addition, data are available from the trial sampling in 1997 (21st July-6th August) on the north to south transect.

Transect	**2000**	**2001**
Alaska to California (N-S)	21st –26th March	22nd-27th April
	29th April-5th May	20th-25th May
	17th-22nd June	27th June-2nd July
	19th-24th July	10th-16th August
	23rd-29th August	21st-25th September
Vancouver to Japan (E-W)	24th June-3rd July	10th-20th June

Methods

The CPR was deployed soon after the vessel was clear of coastal traffic and towed continuously at a depth of about 7m. Each internal cassette is capable of being towed for about 800km, therefore, the CPR was recovered, the cassette changed, and the CPR re-deployed 3 times on each north-south transect and 5/6 times on the east to west transect. The CPR was finally recovered as the vessel approached port. All deployments and recoveries were at the Captain's/Senior Officer's discretion.

As the CPR is towed behind the ship water, containing plankton, enters through the font 1.27cm square aperture in the nosecone of the CPR. The water is filtered through a continuously moving band of silk filtering mesh, which has a leno weave (a single thread in one direction and a double twisted thread in the other) and a mesh size of ~270µm. The interlocking nature of the weave ensures that under tension the mesh apertures do not distort significantly, as does a simple square mesh, but retain their original shape and filtering characteristics. A second band of mesh covers

the filtering layer so that a sandwich is formed with the plankton in between the layers of mesh. This sandwich is wound onto the storage spool in a tank that contains a dilute solution of borax-buffered formaldehyde (~4%) that fixes the plankton. At the end of the tow the entire machine is returned to the laboratory for unloading.

Once the CPR was returned to the laboratory the length of mesh was cut into discrete samples and then processed according to a set of standard procedures developed by the Atlantic CPR survey (Warner and Hays, 1994). The crew of the towing ship return a completed log form that details the navigational data from the tow. These data are used to calculate the beginning and end times and positions of the tow and the midpoints of the sections of the gauze representing the samples. The samples were distributed in a pseudo-random way to the team of plankton analysts. The entire samples was viewed under a microscope and the plankton identified (sometimes to species level, sometimes to higher taxonomic levels) and counted (into abundance categories).

Results

Sampling was achieved on each of the planned transects, although there were some minor incidents which reduced the total number of samples obtained. In 2000, the Captain of the *Independence* mis-read the instructions for June, and launched the CPR in May for half of the transect before realising the mistake. Only 3 of the 5 mechanisms were then available for the June sampling (4 plus one spare were loaded) and so the June sampling was reduced by one quarter. A tear in the filtering mesh meant there was reduced sampling on one section of the east-west transect, about 16 samples were lost. In 2001 when the crew were exchanging cassettes a cassette that had already been deployed was reloaded into the CPR. Although this had no effect on the samples that were already collected it meant that no new samples were collected and so one quarter of the north south transect was not sampled. This, unfortunately, happened on two occasions. We hope that better communication will prevent it occurring again.
Mechanical failure was negligible, human error accounting for most of the lost samples, but even so sampling success was > 95% (93 cassettes were deployed and 3.5 cassettes did not return samples as planned).
The actual number of samples obtained and processed on each transect is given in Appendix 1. A total of 2365 samples were collected (and have been archived) in 2000 and 2001 and of these 857 samples were processed and have data for them available. There were a further 52 samples processed from the 1997 trial sampling.

221 plankton entities were recorded on these samples, 119 zooplankton, 101 phytoplankton plus an estimate of chlorophyll biomass, known as the Phytoplankton Colour Index. The entities are mostly species, but also include subdivisions into copepodite stages for some copepods and coarser taxonomic groups. A full list of entities is given in Appendix 2.

Acknowledgements

We gratefully acknowledge the support and efforts of the officers and crew of the *Polar Independence*, *Polar Alaska* and *Skaubryn* and the considerable help of the personnel at Polar Tankers Ltd and Seaboard International Shipping Company Ltd. We also thank the NPMR program and the administrators at University of Alaska, Fairbanks all of whom have been responsible for the success of this project.

We would like to acknowledge the support of the PICES community, particularly the members of the MONITOR Task Team and the CPR Advisory Panel for their valued contributions.

Warner, A.J. & Hays, G.C. (1994). Sampling by the Continuous Plankton Recorder Survey. *Progress in Oceanography*, 34, 237-256.

Appendix 1
Samples collected and processed

Tow	Samples Collected & Archived	Samples Processed
Alaska-California		
21st –26th March 2000	177	50
29th April-5th May 2000	174	152
8th-10th May 2000	98	0
17th-22nd June 2000	133	68
19th-24th July 2000	188	49
23rd-29th August 2000	199	58
22nd-27th April 2001	172	47
20th-25th May 2001	186	51
27th June-2nd July 2001	143	75
10th-16th August 2001	141	71
21st-25th September 2001	139	73
Vancouver-Japan		
24th June-3rd July 2000	272	70
10th-20th June 2001	343	93

Appendix 2
Taxonomic entities recorded on CPR samples

Phytoplankton		Zooplankton	
Phytoplankton colour		Acartia danae	Mesocalanus tenuicornis
		Acartia longiremis	Metridia I-IV
Actiniscus pentasterias	Halosphaera spp.	Acartia spp.	Metridia okhotensis
Actinoptychus spp.	Hemiaulus spp.	Acartia tonsa	Metridia pacifica
Asterionella glacialis	Lauderia borealis	Atlanta spp.	Nannocalanus minor
Asteromphalus	Leptocylindrus danicus	Calanus I-IV	Neocalanus cristatus I_IV
Bacteriastrum spp.	Navicula planamembranacea	Calanus marshallae V_VI	Neocalanus cristatus V_VI
Bellerochea malleus	Navicula spp.	Calanus pacificus V_VI	Neocalanus plumchrus* II
Biddulphia longicruris	Neodenticula seminae	Candacia armata	Neocalanus plumchrus* III
Blepharocysta paulsenii	Nitzschia delicatissima	Candacia bipinnata	Neocalanus plumchrus* IV
Ceratium arcticum	Nitzschia longissima	Candacia colombiae	Neocalanus plumchrus* V
Ceratium arietinum	Nitzschia seriata	Candacia ethiopica	Neocalanus plumchrus** V (3.4-3.9mm) from 2001 only
Ceratium azoricum	Noctiluca scintillans	Candacia I-IV	Neocalanus spp.
Ceratium breve	Odontella aurita	Candacia pacifica	Oithona spp.
Ceratium bucephalum	Odontella sinensis	Centropages abdominalis	Oncaea spp.
Ceratium candelabrum	Oscillatoria spp.	Centropages bradyi	Ostracoda
Ceratium carriense	Oxytoxum spp.	Cephalopoda larvae	Paraeuchaeta elongata
Ceratium extensum	Paralia sulcata	Chaetognatha (large)	Paraeuchaeta spp.
Ceratium furca	Phaeocystis pouchetii	Chaetognatha (small)	Parafavella gigantea
Ceratium fusus	Phalacroma spp.	Cirrpede larva	Para-pseudocalanus spp.
Ceratium gibberum	Pinus pollen	Clausocalanus spp.	Parasites of the plankton
Ceratium horridum	Planktoniella sol	Clio spp.	Parasitic Nematoda
Ceratium lamellicorne	Podolampus spp.	Clione limacina	Pleuromamma abdominalis
Ceratium lineatum	Polykrikos schwartzii cysts	Coelenterata tissue	Pleuromamma borealis
Ceratium longipes	Prorocentrum spp.	Copepod eggs	Pleuromamma robusta
Ceratium macroceros	Protoperidinium spp.	Copepod nauplii	Podon spp.
Ceratium massiliense	Pterosperma spp.	Corycaeus spp.	Polychaeta larvae
Ceratium minutum	Rhizosolenia alata alata	Cyphonautes larva	Pseudocalanus spp. adult
Ceratium pentagonum	Rhizosolenia alata curvirostris	Decapoda larvae	Ptychocylis spp.
Ceratium pulchellum	Rhizosolenia alata indica	Dictyocysta spp.	Radiolaria
Ceratium teres	Rhizosolenia alata inermis	Doliolidae	Salpidae
Ceratium trichoceros	Rhizosolenia bergonii	Echinoderm larvae	Sapphirina spp.
Ceratium tripos	Rhizosolenia calcar-avis	Echinoderm post-larvae	Scolecithricella spp.
Chaetoceros(Hyalochaete) spp.	Rhizosolenia delicatula	Echinospira larvae	Scolecithrix spp
Chaetoceros(Phaeoceros) spp.	Rhizosolenia fragilissima	Epilabidocera amphrites	Sergestidae
Cladopyxis spp.	Rhizosolenia hebetata hiemalis	Eucalanus attenuatus	Siphonophora
Coccolithaceae	Rhizosolenia hebetata semispina	Eucalanus bungii	Spiny egg (Candacia armata egg)
Corethron criophilum	Rhizosolenia imbrica. shrubsolei	Eucalanus elongatus	Thaliacea
Coscinodiscus concinnus	Rhizosolenia setigera	Eucalanus pileatus	Thecosomata
Coscinodiscus wailesii	Rhizosolenia stolterfothii	Euchirella pseudopulchra	Tintinnidae
Cylindrotheca closterium	Rhizosolenia styliformis	Euchirella rostrata	Tintinnopsis spp.
Cystodinium spp.	Schroederella delicatula	Euphausiacea	Tomopteris

Dactyliosolen antarcticus	Scrippsiella spp.	Euphausiacea calyptopis	Tortanus discaudatus
Dactyliosolen mediterraneus	Silicoflagellatae	Euphausiacea eggs	Total Calanus
Detonula confervacea	Skeletonema costatum	Euphausiacea nauplii	Total Copepods
Dinoflagellate cysts	Stellate body (Land plant hair)	Evadne spp.	Total Harpacticoida
Dinophysis spp.	Stephanopyxis spp.	Favella serrata	Undeuchaeta bispinosa
Ditylum brightwellii	Thalassionema nitzschioides	Fish eggs	Undeuchaeta major
Eucampia zodiaca	Thalassiosira spp.	Fish larvae	Undeuchaeta plumosa
Exuviaella spp.	Thalassiothrix longis sima	Foraminifera	Unidentified Candacia spp.
Fragilaria spp.	Unidentified Coscinodiscus spp.	Gammaridea	Unidentified Centropages spp.
Gonyaulax spp.	Unidentified Nitzschia spp.	heterorhabdus robustus	Unidentified Eucalanus spp.
Gyrosigma spp.		Heterorhabdus tanneri	Unidentified Euchaeta spp.
		Hyperiidea	Unidentified Euchirella spp.
		Lamellibranch larvae	Unidentified Heterorhabdus spp.
		Larvacea	Unidentified mollusca
		Lucicutia spp.	Unidentified Pleuromamma spp.
		Macrosetella gracilis	Unidentified Undeuchaeta spp.
		Mecynocera clausi	Zoothamnium pelagicum

* This category is actually *Neocalanus plumchrus/flemingeri*

** Two size categories at stage V were noted and so from 2002 the two categories were separately counted – it is possible that the smaller category is principally *N. flemingeri* and the larger *N. plumchrus*