EVOS PROPOSAL SUMMARY PAGE

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Project Title: A CPR-based survey to monitor the Gulf of Alaska and detect ecosystem change
Submitted under the BAA

Project Period: FY 03-FY 04

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DFO 'in kind' support

Study Location: North Pacific

Trustee Agency: NOAA

Abstract:
Plankton are a critical link in the marine food chain that respond rapidly to climate change and form the link between the atmosphere and upper trophic levels. Many important marine resources in the GoA are strongly influenced by changes in ocean climate. We present evidence from recent CPR work showing that significant changes occurred in all plankton communities in the GoA, associated with the recent climate shift, and that the CPR is an appropriate tool for detecting such changes. In this proposal we will test the CPR as an almost real-time indicator of ecosystem change across the GoA (the ACC and off-shore). Ships of Opportunity are a cost-effective platform for large scale monitoring. This proposal builds on collaborative efforts measuring physical parameters and marine bird/mammal populations. Simultaneous data collection and synthesis will assist in determining the underlying mechanisms and aid the GEM program in devising its long-term monitoring strategy.

I. INTRODUCTION

This proposal seeks to continue, and to further develop, the Continuous Plankton Recorder surveys from Ships of Opportunity begun in 2000 through the North Pacific Marine Research initiative and continued through 2002 under GEM (project 02624). In this section we will first describe the project and the most significant achievements of the work to date. In subsequent sections we detail the proposed enhancements, the rationale behind them and their relevance to GEM that forms the basis of this proposal.

The premise that zooplankton respond rapidly to climate change and also provide the link between changes in the atmosphere and important upper trophic level populations, such as salmon, herring, marine birds and mammals provided the impetus for this project. The difficulty in scheduling and paying for research vessels to operate at significant distances from the coast multiple times per year led to the preference for Ships of Opportunity as a research platform. The experience of the Sir Alister Hardy Foundation for Ocean Science in operating a plankton monitoring program for 70+ years with Ships of Opportunity in the North Atlantic provided the basis for a successful program in the North Pacific. At this time, with analysed data available from 3 years (and a fourth year underway) we can discuss the strengths of the program, identify areas of improvement and focus on the products that are of particular relevance to the GEM program.

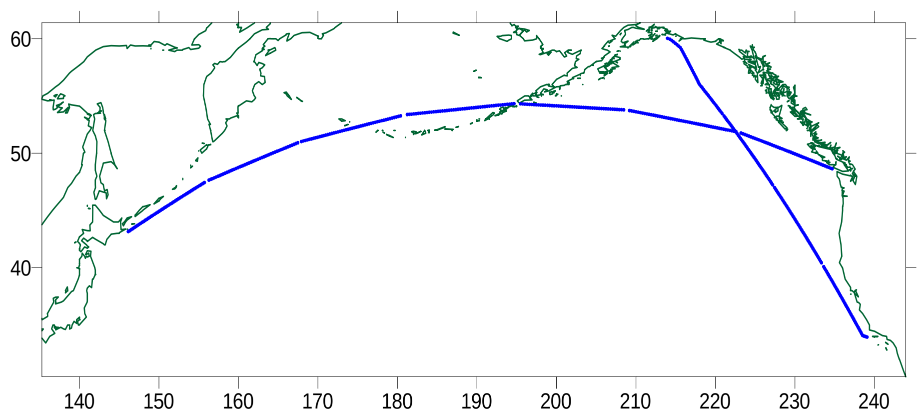


Fig 1. Example transects sampled in May and June 2001. Position varies only slightly between months.

Transects sampled in 2000 through 2002 are shown in Fig 1. The transect from Prince William Sound to San Francisco/Long Beach California is operated by an oil tanker, the *Polar Alaska*. The transect from Vancouver through the southern Bering Sea to Japan is operated by a cargo vessel, Seaboard International's *Skaubryn*. The Alaska to California transect was first sampled in summer 1997 (as a feasibility study) then 5 times between March and August 2000, 5 times between April and September 2001, and through the current GEM project (02624) 5 times between April and September 2002. Additional funding from the North Pacific Research Board (NPRB) will be used to sample the transect again in Fall and Winter 2002/03. The transect from Vancouver to Japan has been sampled once in each summer of 2000, 2001 and through the GEM project in summer 2002. The NPRB funding will also support sampling on this transect in September and November 2002.

Selected samples are processed for plankton abundance with the remainder being archived. All samples collected over the shelf are processed and then every fourth (occasionally every second) sample from open ocean areas is processed. Both phytoplankton and zooplankton are identified to the highest practical taxonomic level and enumerated. The resulting database contains counts of each taxonomic entity (currently about 200) together with time, date and location of the sample and also the individual who processed the sample and notes on any unusual items in the sample. Further details on the methods, developed in the North Atlantic, are given in Warner and Hays (1994). SAHFOS has rigorous quality control procedures that are applied to each processed sample before the data are stored in the database. All data are freely available.

Main results to date
1. Sampling success

Sampling success has been high to date, with over 95% of intended sampling achieved. Human error, mechanical failure caused by chance encounters with floating debris, and last minute vessel schedule changes have accounted for the few problems with obtaining samples but these have had a negligible effect on the quality of the data. During the three years of sampling a good working relationship has been achieved with the personnel and crew of the two companies and vessels that have been involved in the CPR deployments, a significant plus for a ship of opportunity program.

2. Interannual variability

The principle original aim of the program was to obtain baseline plankton data to describe the plankton communities of the North Pacific and their dynamics over large spatial scales. The second aim was to develop a sampling program with a sampling frequency that would be more intensive than undertaken by other programs, in order to assess the temporal variability of the plankton communities. Only with these types of data will it be possible to assess the large-scale response to climate variability and the implications for higher trophic levels.

The Pacific CPR feasibility study carried out in 1997 was during a time of anomalously warm conditions for the north east Pacific – the Pacific Decadal Oscillation (PDO) was in a positive phase (PDO index available at http://tao.atmos.washington.edu/pdo/) and 1997/1998 saw the strongest El Niño on record. Sampling in 2000 and 2001 was during a time of cooler than average conditions with the PDO in a negative phase. There is a growing consensus that the El Niño of 1997/98 marked the transition to a new ‘regime’ in the North Pacific, beginning in 1999 (Schwing and Moore, 2000). This situation provided us with the opportunity to examine the CPR data with respect to these warm and cool ‘regimes’. Although the data from the warm regime are limited to just one transect, they nevertheless provide a test of the suitability of the CPR sampling program to detecting the impacts of such climate-change scenarios.

The North Pacific as sampled by the CPR can be sub-divided into four regions, determined by the topography and the main currents; the Alaskan shelf, the Alaska Gyre (bounded to the north by the Alaskan Coastal Current and to the south by the northern diversion of the North Pacific Current into the Alaska Current), the oceanic region to the south of the Alaska Gyre; also known as the transition zone (bounded by the southern diversion of the North Pacific Current into the California Current), and the upwelling region of the Oregon and California slope and shelf. We examined the abundance of the mesozooplankton (organisms from a few hundred µm to a few mm, the size range most quantitatively sampled by the CPR) in each of these four areas over the time series (Figure 2, upper panel). Then, because a change in abundance may not reflect a change in biomass (if small organisms are replaced by larger ones for example) we estimated the biomass of each sample. This was achieved by multiplying the abundance of each taxon by a taxon-specific individual dry weight value and summing the values for each sample (Figure 2, lower panel).

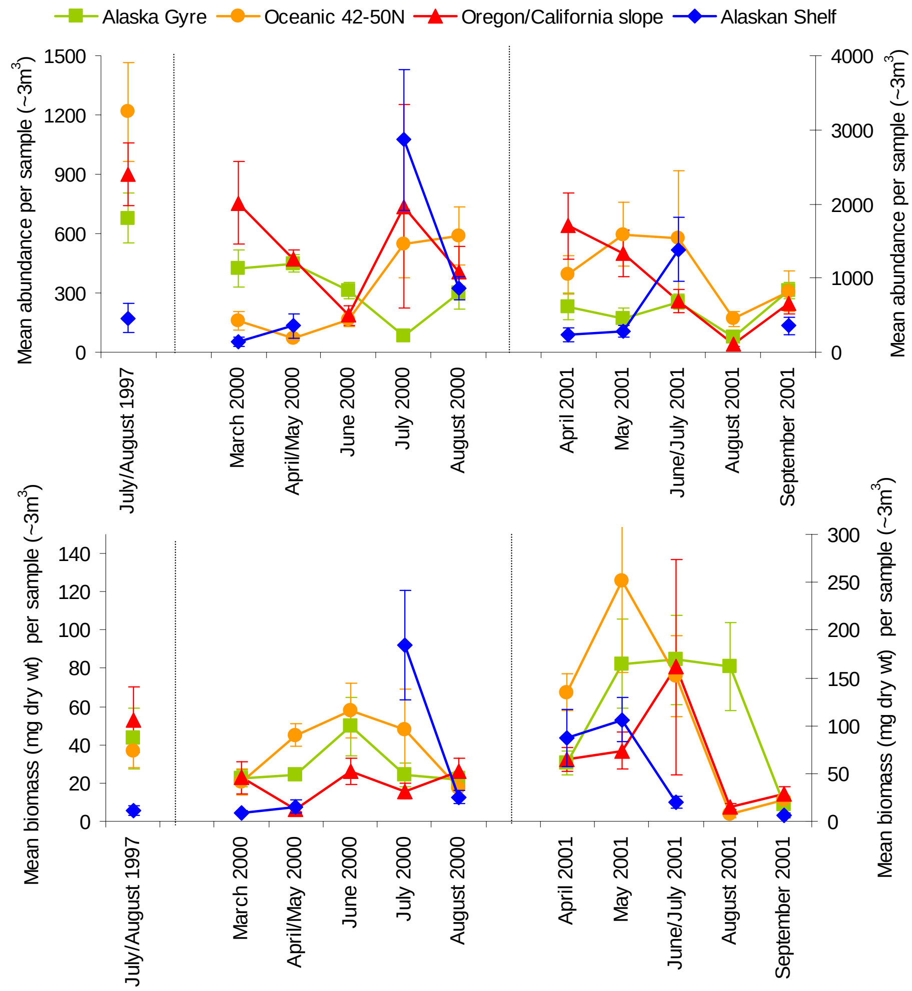


Figure 2. The upper panel shows the mean mesozooplankton abundance for each of four regions, for each sampled month. The lower panel shows the mean estimated biomass. Note that in both graphs the Alaskan Shelf values are plotted against the right-hand axis. Error bars are standard error.

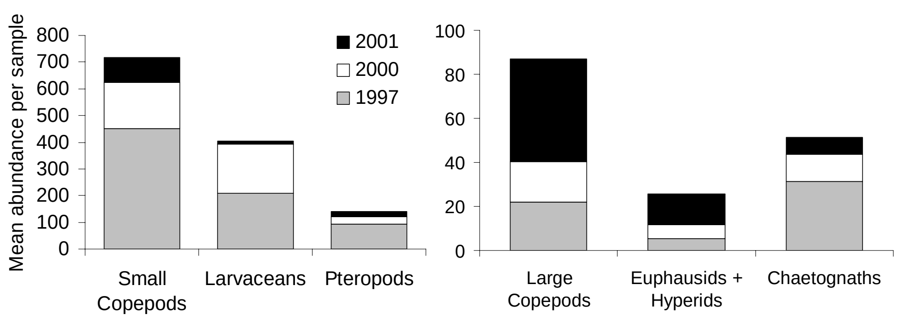
Although only one transect is available from the warm regime there are noticeable differences in the abundance and biomass of zooplankton between the warm and cool regimes (Figure 2). At no time in the cool regime, for all areas except the Alaskan Shelf, were mean abundances as high as they were in 1997. Biomass, however, reached comparable or higher levels. The two oceanic areas show a similar pattern with abundances lower in 2000 than in 1997 and lower again in 2001 while biomass is similar in 1997 and 2000 but slightly higher in 2001. The Alaskan shelf is showing an opposite signal to the oceanic areas despite gaps in the data – both abundances and biomass were very low in summer 1997, and higher in the summers of 2000 and 2001. Both abundance and biomass were more variable in the California slope area, probably owing to the heterogeneity imposed by the upwelling but the ship track also varied more at this end of the transect as sometimes a port call was made at San Francisco. By focussing on the comparable sampling periods in each year (21st July to 6th August in 1997, 19th July to 29th August in 2000, and 27th June to 16th August in 2001) we can detect where significant differences occurred between the warm and cool regimes, and within the two sampled years of the cool regime, in terms of mesozooplankton abundance and biomass (Table 1). Even allowing for the likelihood of some type-1 errors it is clear that abundances between the warm and cool regimes are generally significantly different while abundances within the cool regime years are similar (except for the California slope region where the abundance in each year was significantly different from the others). Biomass, however, is not significantly different between the two regimes (with the exception of the Alaskan shelf). A significant change in abundances without a significant change in biomass implies that there must have been a change in the species composition.

Table 1. The results (p values, 2 tailed test) of heteroscedastic t-tests for sample means. Samples from July and August from each region (rows) were compared for each pair of years (columns). Both abundance and biomass values were compared. The Alaskan Shelf portion of the transect was not sampled in August 2001 so no comparison was made between this year and the other years. Significant results are in bold, n refers to the number of samples in each year.

		1997 & 2000	1997 & 2001	2000 & 2001
Alaskan shelf	*n*	*3 & 17*		
	Abundance	***0.024***		
	Biomass	***0.021***		
Gulf of Alaska	*n*	*16 & 32*	*16 & 42*	*32 & 42*
	Abundance	***0.002***	***0.001***	0.780
	Biomass	0.229	0.103	***0.002***
Southern oceanic	*n*	*16 & 29*	*16 & 55*	*29 & 55*
	Abundance	0.309	***0.0003***	0.130
	Biomass	0.816	0.794	0.662
California slope	*n*	*17 & 29*	*17 & 41*	*29 & 41*
	Abundance	***0.028***	***0.001***	***0.018***
	Biomass	0.091	0.141	0.976

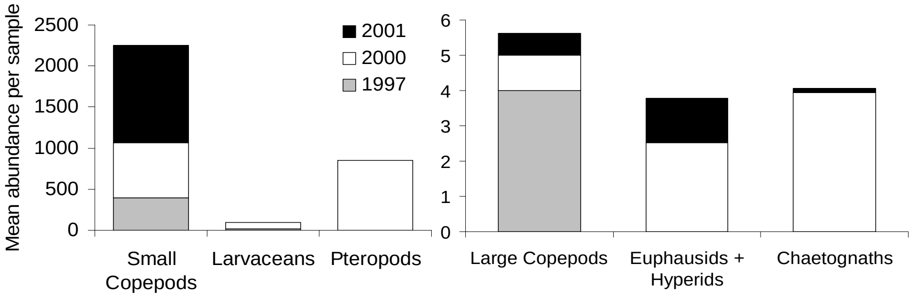
For the oceanic area of the transect (42°N to 59°N) we examined the abundance of the dominant groups of mesozooplankton in the summer of each of the three sampled years (Figure 3). During summer 1997 small copepods were very numerous, 4-5 times more numerous than in the cooler summers of 2000 & 2001. Conversely, larger copepods were at least as abundant in 2000 as in 1997 but 2-3 times more abundant in 2001 than in 1997. Larvaceans, another numerically dominant but low biomass group, were also abundant in 1997 and less so in the cooler period. The larger crustacea caught by the CPR, the euphausiids and hyperiids were more abundant in 2001 than in 1997 with 2000 abundances similar. These data suggest that the regime shift begun in 1998/99 with a change from small species to larger species out in the open ocean. 2000 appears to be somewhat of a transition year with differences between 2001 and 1997 more noticeable.

Fig 3. The mean abundance (as stacked bars) of main groups of plankton in each of 3 summers for the **oceanic section** *of the CPR*



A similar analysis for the Alaskan shelf region (Figure 4) has to be treated with caution as only 3 samples are available from summer 1997, compared to 17 in July/August 2000, and 8 in late June 2001 (every fourth sample was processed along the transect in 1997, regardless of its location whereas in the current program all shelf samples are processed). As part of this proposal we plan to process the remaining samples from 1997 to enable a better analysis. However, it is again clear that the patterns in the plankton community of the Alaskan shelf are opposite to the

Fig 4. The mean abundance (as stacked bars) of main groups of plankton in each of 3 summers for the ***Alaskan shelf****.*



open ocean. Abundances of small copepods doubled from 1997 to 2000 and doubled again in 2001 but large copepods (although few in number) declined between the warm and cooler periods.

Copepods are almost always identified to species in CPR processing and provided an opportunity to look at species level responses to the regime shift. Abundance of each copepod species (or genus if the highest level identified) was correlated with latitude for all samples collected on the Alaska to California transect, except those samples collected over the continental shelf (north of 59°N and south of 40°N). By separating the coastal samples, this eliminated the more neritic species that occurred at both extremes of the transect and which could confuse an analysis of species composition. Species that correlated positively with latitude were termed 'northern species' and those that correlated negatively were termed 'southern species' (Table 2). Southern and northern indices were calculated for each sample by summing the abundances of the respective species (Figure 5).

Table 2. Northern species are those whose abundance correlated positively with latitude, southern species correlated negatively between 40° and 59°N.

Northern Species	Southern Species
Acartia longiremis	*Acartia danae*
Acartia spp.	*Calanus pacificus*
Calanus marshallae	*Candacia armata*
Candacia colombiae	*Candacia bipinnata*
Centropages bradyi	*Candacia ethiopica*
Eucalanus attenuatus	*Clausocalanus spp*
Eucalanus bungii	*Corycaeus spp.* (note, cyclopoid not calanoid)
Eucalanus elongatus	*Euchirella pseudopulchra*
Heterorhabdus tanneri	*Euchirella rostrata*
Neocalanus cristatus	*Mecynocera clausi*
Neocalanus plumchrus/flemingeri	*Mesocalanus tenuicornis*
Oncaea spp.	*Metridia pacifica*
Paraeuchaeta elongata	*Nannocalanus minor*
Pseudocalanus spp.	*Pleuromamma abdominalis*
	Sapphirina spp.
	Scolecithrix spp.
	Undeuchaeta bispinosa
	Undeuchaeta major
	Undeuchaeta plumosa

Keeping in mind that there is just a single transect from the 'warm regime' any conclusions must be considered as provisional. However, these data clearly support the idea that there has been a shift in the copepod community since the El Niño. Abundances of southern copepods were much higher in the Alaska Gyre region in summer 1997 and abundances of northern species were much lower along the transect. Northern species were particularly abundant on the Alaskan shelf

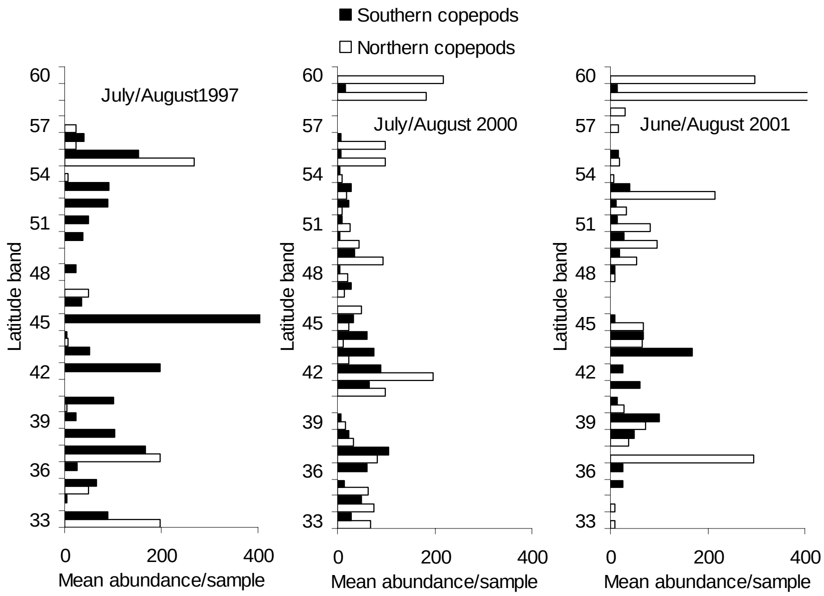


Fig 5. Mean southern and northern copepod indices for 1° bands of latitude in summer 1997, summer 2000 and summer 2001 along the Alaska to California transect.

in the cool regime, and much more frequent in the oceanic areas. This result fits very well with other, more coastal studies, undertaken in the north-east Pacific. Studies of zooplankton collected along the Newport Line (Newport, Oregon) have identified that certain copepod species can be designated as boreal or subtropical, and that their relative abundance off Newport in a given year shifts with climatic conditions (Peterson *et al.,* 2001). An increase in biomass occurred after 1998 together with a switch to colder regime species. Mackas *et al*. (2001) report that between 1990 and 1998 the zooplankton community of the British Columbia continental shelf edge consisted of southerly copepod and chaetognath species endemic to the California Current system with a corresponding decline in species endemic to the Northeast Pacific continental margin. This observed pattern changed abruptly in 1999.

In summary then, the regime shift occurring in 1999 is clearly evident in the CPR data. Before the shift, the anomalously warm oceanic water contained large numbers of small species, chiefly copepods, and these were species of a more southerly origin. Importantly, the oceanic areas appear to be as responsive to climate changes as do more coastal regions. The Alaskan shelf had very low numbers of copepods in the warm regime and the implication is that rather than northern species being replaced by southern species (as happened in the Gulf of Alaska), northern species simply failed to do well on the shelf. The coastal limit of the northern extension of the California Current copepods was probably northern British Columbia. After the regime shift the oceanic areas saw a return to larger organisms, and colder boreal species of copepods became more abundant. The Alaskan shelf saw a large increase in small boreal copepod species leading to higher recorded zooplankton abundance and biomass in the cool regime.

These changes have implications for higher trophic levels. Firstly, larger prey items are more energetically rewarding and secondly the mesozooplankton biomass levels appear to have increased across all areas since the regime shift, therefore more food is available in the larger size fractions. Evidence for the relevance of these changes to upper trophic levels can be found in the returns of Pacific salmon, which have shorter generation lengths than most other animals, and therefore respond more quickly to climatic changes. The returns of adult chinook and steelhead salmon to the Columbia River in 2001 reversed from near historic lows to reach the highest and second highest recorded levels respectively since record keeping began in 1938. These animals entered the ocean two years earlier (in 1999), just after the regime shift. Adult returns of Columbia River coho showed a similar response but starting one year earlier (in 2000), consistent with their shorter marine life cycle. Adult returns of Fraser River pink salmon also turned around and may have reached the highest levels of the century in 2001 (Even year runs of pink salmon are almost absent from the Fraser).

3. Offshore transport of coastal species in eddies.

Anti-cyclonic eddies form in winter along the eastern continental margin of the north-east Pacific. Satellite altimetry measurements during the last decade have enabled descriptions of the extent and life history of these features (Gower and Tabata, 1993), and multiyear patterns of their behaviour (Crawford et al., 2000, Crawford, 2002). Two regions that consistently generate eddies are near the Queen Charlotte Islands in British Columbia, Canada (which creates the Haida eddy) and the Alexander Archipelago of Alaska, USA (which creates the Sitka eddy). These eddies, which have a diameter of up to 200 km or more, form during the winter months and in late winter spin off the shelf and move out into the open ocean. Dedicated research cruises sampling the eddies had revealed elevated levels of entrained near-shore and slope zooplankton species that persisted within the Haida 2000 eddy for over a year (Mackas and Galbraith, submitted). The CPR transects passed through, or very close to, these eddies and raised the possibility of determining whether or not the sampling resolution was capable of detecting such mesoscale features, and also establishing the possible transport and persistence of shelf species in the open ocean.

Sea surface altimetry plots (TOPEX & ERS2, see www-ccar.colorado.edu/~realtime/global-real-time_ssh/) were used to determine the location and midpoint of each eddy at the time of each sampled transect. Distance from the midpoint of each sample to the midpoint of the closest eddy centre was calculated and the abundance of each taxon against distance examined. The relationship between abundance and distance from the eddy revealed three classes of plankton that appeared to be associated with eddies (Fig 6);

1. Diatoms: *Thalassiosira* spp., *Chaetoceros* spp. (Hyalochaete forms), *Coscinodiscus* spp. and *Cylindrotheca closterium.*
2. Zooplankton species of shelf origin: *Acartia longiremis* and *Calanus marshallae*
3. Zooplankton taxa that are also common in the open ocean: *Limacina helicina*, Chaetognaths, copepod nauplii, *Clione limacina, Neocalanus plumchrus*.

Interactions between the eddy dynamics and diel vertical migration of the zooplankton act to keep many of the organisms entrained within the eddy, however, gradually the eddies decay and these coastal species are deposited in oceanic waters. Wind driven surface currents are then the dominant transporting force. There is a weight of evidence to support the idea that the eddies play a significant role in spreading shelf species through the oceanic northeast Pacific. All of the shelf taxa were common on the north-south transect northwards of about 52°N, the section which crosses the eddy paths, but rare on the oceanic section south of this latitude. Occurrences in the western Gulf of Alaska were extremely rare (and non-existent for the shelf copepods) along the two east to west transects but more frequent on the region east of the Haida eddy. This region is generally ‘downstream’ of the Haida eddy. The CPR is not an efficient sampler of fish larvae, however, these results suggest that these eddies may be a mechanism by which fish larvae are transported from coastal waters out to the open ocean. The volume of entrained shelf water is high and from nutrient and temperature anomalies Whitney and Robert (in press) show that bottom water from Hecate Strait and Queen Charlotte Sound is entrained in the Haida eddy.

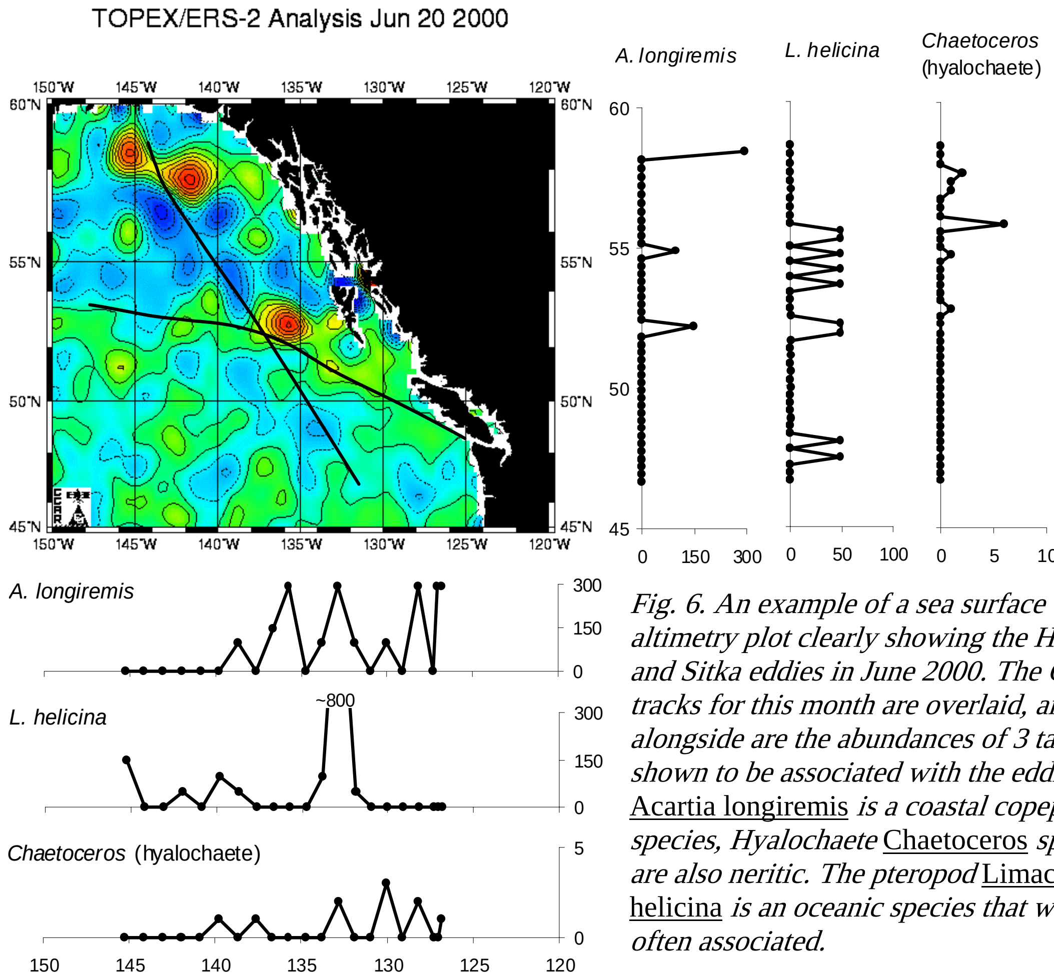


Fig. 6. An example of a sea surface altimetry plot clearly showing the Haida and Sitka eddies in June 2000. The CPR tracks for this month are overlaid, and alongside are the abundances of 3 taxa shown to be associated with the eddies. Acartia longiremis *is a coastal copepod species, Hyalochaete* Chaetoceros *spp. are also neritic. The pteropod* Limacina helicina *is an oceanic species that was often associated.*

The Haida 2001 eddy was much weaker than the Haida 2000 and it might be predicted that oceanic occurrences of coastal taxa would be less frequent in 2001. All of the associated shelf taxa showed a significant decline in oceanic occurrence in 2001 (p<0.01, paired 2 sample t-test). The 6 oceanic taxa associated with the eddy in 2000 showed no significant change in frequency of occurrence (p>0.05, paired 2 sample t-test). Interannual variability in the strength of the eddy (presumably determined by wind parameters) may cause significant variability in the structuring of open ocean plankton populations.

Current status

Funding for FY02 through GEM project (02624) is being used to sample the Alaska to California transect 5 times. At the time of writing 4 of these transects have taken place and the samples are in various stages of processing. Owing to a scheduled dry-dock period during mid-late August the vessel will not be able to complete the fifth tow until somewhat later than planned, in late September. A collaborative project funded by GEM (project 02614) fitted a thermosalinograph to the vessel which recorded its first data in July 2002. Although the fluorometer is not yet installed and there are no comparative sets of plankton and salinity/temperature data available to compare we are confident that insights will result from this data synthesis. Funding from the NPRB will enable a further two runs on this transect, approximately in October and December. This will provide four collections of plankton for which the TSG data will be available.

The Vancouver to Japan transect was towed successfully in the first two weeks of June 2002. Funding from the NPRB will enable a further two tows on this transect in approximately late September and late November. This funding also enabled a marine bird and mammal observer to be present on board collecting observations through a collaborative project with the Point Reyes Bird Observatory and the Canadian Wildlife Service. Over 1000 5' long transects (i.e. $1/12^{th}$ of a degree) were recorded during the transect and over 112,500 birds recorded. A novel survey technique was developed that should enable good estimates of populations in each area. Several species of seabird, as well as many marine mammals, feed directly on plankton with the remainder feeding on small forage fish and squid which themselves feed on plankton. Simultaneous collection of plankton quantity and composition with marine bird and mammal distributions right across the North Pacific will provide insights on trophic interactions at these higher levels never before possible on this scale.

During the fall of 2002 SAHFOS is undertaking to train technicians from the Prince William Sound, Alaska and Vancouver, British Columbia areas in CPR servicing and re-loading. This will enable the instruments to be turned around more efficiently and more economically in the future. It will then only be necessary to transport the machines back to the UK for repair in the case of serious damage, saving routine freight costs and also allowing more flexibility in meeting the variable vessel schedules. This training will also increase the level of CPR knowledge and expertise in the Northeast Pacific area, desirable for the long-term goals of GEM.

Future directions

At present, financial support for CPR sampling ends in 2002. This proposal firstly asks for continued support to collect data in 2003 and beyond. Continued sampling and acquisition of data is important for a variety of reasons. Firstly to maintain the momentum that is now present; the value of the good working relationship we now have with the ships of opportunity cannot be overstated and maintaining such collaboration is vital to a long-term ship of opportunity program. FY02 has also seen the simultaneous acquisition of data from other sources for the first time; physical data from the thermosalinograph, hopefully chlorophyll before long and also higher trophic level population estimates. Sea surface altimetry data have also been used with the CPR plankton data to describe mesoscale processes occurring in the Gulf of Alaska. During April 2002 GEM and PICES co-sponsored a workshop on acquiring data from Voluntary Observing Ships. The workshop report (summarised in PICES Press Vol 10, no. 2, pages 5-7 and soon to be available in full as a PICES report) resulted in a planned proposal to develop a Ferry-Box type instrument for Ships of Opportunity that would measure physical, optical and chemical parameters in addition to CPR surveys. A bridging proposal for this work will be submitted separately, which will build on the CPR-based observing system that has been developed to date.

Second, in order to confidently detect ecosystem change less dramatic than witnessed during a regime shift, sufficient baseline data must be available. Although we have presented evidence that an ecosystem shift occurred between 1998 and 2000 the current database contains only a few data from the previous warm regime. Better defining the extent of interannual variability is central to a confident assessment of ecosystem variability and change. Our proposal seeks support for continued data acquisition and synthesis through 2003 and, following an assessment of the approach at the end of FY03 and modifying if necessary, continued support through FY04.

During FY03 we wish to test the concept of 'fast response sample analysis'. There is increasing evidence (which we explore further in a subsequent section) to suggest that zooplankton are good detectors of ecosystem change. A subset of the CPR samples can be processed rapidly, integrated with the temperature, salinity and chlorophyll data as well as satellite-derived data and an assessment made of the ecosystem status relative to previous year's of data. This assessment will be published on a website, ideally within a month or two of sample collection, and may also be available in time for summary in the PICES Ecosystem Status Report, providing rapid distribution of evidence for sudden ecosystem change. The analysis can also be strategic because the physical data can be used to identify areas where sample processing should focus, a strong eddy or frontal feature for example. Full processing will be carried out in a routine way so that all data would be fully processed within 9 months of collection (following current practice) and more rigorous analyses made to confirm initial assessments.

II. NEED FOR THE PROJECT

A. Statement of Problem

Ecosystem regimes have a typical duration on the order of a decade and shifts in regimes may occur very rapidly – within a year. A notable regime shift occurred in the late 1970s in the eastern North Pacific but was not recognised as such for about another decade (Ebbesmeyer *et al.* 1991). The most recent shift described above occurred in 1999 (Bograd *et al.*, 2000; Schwing and Moore, 2000). Ecosystems contain species of commercial importance whose abundance, distribution and productivity differ from regime to regime. An early indication of such a shift would be of obvious advantage to the management and study of such commercial species.

It has been suggested that biological variables provide a more diagnostic signal of regime shifts than climate indices (Ebbesmeyer *et al*, 1991; Hare and Mantua, 2000) since the ecosystem may filter out some of the noise and clarify the signal. Commercial fish landings provide a useful measure of the state of the ecosystems that each species occupies, however, most fishery data are sensitive to fishing effort. Furthermore, many commercial species have relatively long life spans so that a response to a climate event is unlikely to be rapid and clear cut. This suggests that zooplankton, who have short life spans and are not directly harvested, should provide a useful way of detecting regime shifts in near real time. The International Research Institute for Climate Prediction in a recent report states that '*Zooplankton species composition appears to be a sensitive indicator of water mass changes that may be key elements in marine ecosystem regime shifts*' (IRI, 2002). The North Pacific has few zooplankton time series where samples have been processed to the species level. The time series of zooplankton information that do exist in the eastern North Pacific, off southern California, Oregon and British Columbia, have for the most part been collected in shelf or slope waters. Open ocean time series are even rarer, and in fact are limited to the data collected at Ocean Station Papa and the recent CPR sampling. Regime shift type changes have been previously identified in each of these north-east Pacific time series, primarily as changes in zooplankton biomass (Brodeur and Ware, 1992; Roemmich and McGowan, 1995; Mackas, *et al.*, 2001; Peterson, *et al.* 2001). Studies have also been published detailing the taxa, principally calanoid copepods, whose abundances have co-varied with changing oceanographic conditions (Mackas *et al.*, 2001 ; Peterson *et al.*, 2001). The Oregon and British Columbia time series have several species in common; linked as these two regions are by the equatorward California current and the poleward moving slope current, this is not surprising. The species that showed a response fell into two groups; boreal species and those that are more southern in their distributions. The two groups tended to show opposing responses to the climatic variability. The response of the southern California copepods to decadal variability has been more equivocal, but again a response to identified regime shifts was noted in some species (Rebstock, 2002). We have already shown in an earlier section of this proposal that the CPR data reveal these same changes in boreal and southern copepod species from the 1999 regime shift together with broader changes in the community composition and changes in biomass. The CPR results show that the open ocean is as responsive to such climate events as more coastal regions, and that not all coastal regions of the North Pacific respond in the same way.

Large scale changes in Pacific salmon populations in all regions of western North America have been related to climate change in this century. Although best studied in salmon, similar influences are also thought to occur for other important upper trophic level organisms. The initial cause is likely due to changes in the structure of the atmosphere and then the ocean, which then pass up the food chain through the plankton to affect the fish and mammal populations at higher trophic levels. The changes in plankton abundance have been related to the changes in salmon abundance, and reduced ocean productivity is probably the causal link leading to poor survival of salmon and other important resources in the ocean. The pattern of failure in year-class strength of western Alaska chum and chinook populations or Bristol Bay sockeye salmon, as well as other many stocks and species in British Columbia and the Pacific Northwest demonstrates that the cause of the sudden downturn has a largely marine origin (e.g. Welch *et al* 2000). However, salmon spend part of their life history in both coastal and oceanic marine environments, and are therefore subject to environmental changes occurring in both regions. These changes appear to have extended back centuries (e.g. Ware, 1995; Finney et al 2000, 2002), and to have affected a wide variety of Alaskan resources including shrimp and groundfish (e.g. Anderson and Piatt, 1999) and salmon (e.g. Finney, 1998). Higher trophic level responses to the recent 1999 regime shift are now beginning to appear, as discussed previously.
Climate change seems to have driven the overall dynamics of Pacific salmon populations in the past, and to have been as important as the effect of commercial fisheries in determining population levels. In addition, the effects of anthropogenic climate change due to global warming over the next few decades are expected to dwarf the climatic changes observed to date. We currently have little understanding of how global warming will affect the frequency and intensity of regime shift type events in the North Pacific, and the development of consistent baseline datasets will be crucial to defining how climate change or global warming will affect the food chain supporting Pacific salmon dynamics.

Continued support for CPR surveys on ships of opportunity in the North Pacific through the GEM program builds on existing work that has been endorsed by the scientific committee of PICES and the Global Ocean Observing System (the Atlantic CPR program is part of the GOOS Initial Observing System, the Pacific CPR program was endorsed by the Living Marine Resources Panel of GOOS as a pilot project).

B. Rationale/Link to Restoration

A Ships of Opportunity program originating in Prince William Sound using CPR technology makes a direct contribution to the development of GEM. The types of data acquired by the CPR and other data collections now being undertaken on the same vessels would be appropriate to evaluating hypotheses regarding sources of change in productivity from earlier restoration projects (i.e. Sound Ecosystem Assessment, SEA). In particular, the role of changes in climate in changing productivity are amenable to evaluation by CPR and related data collected from

Ships of Opportunity. Observations of climate change in the atmosphere and simple physical variables such as sea temperature and atmospheric pressure are readily available. These data show that large-scale physical changes are evident which seem to be associated with changes in ocean productivity observed in upper trophic levels (i.e. fish production). A recent study in the North Atlantic linked increasing northern hemisphere temperatures with changes in zooplankton biodiversity (from Atlantic CPR data) and commented on the implications for over-exploited North Sea fish stocks (Beaugrand *et al.,* 2002). However, correlative relationships frequently break down, and the lack of a mechanistic understanding of how the North Pacific can rapidly shift from one regime to another limits our ability to manage these resources by setting harvest rates appropriate to the productivity of the populations. The data necessary to show directly that changes in primary or secondary plankton production are occurring have not been collected in a systematic fashion in the North Pacific, and to date have largely depended on opportunistic sampling from Japanese research ships sampling a series of transects only once a year. Without detailed information on the "natural" level of variability occurring between months or over years, it will be difficult to establish whether variations in timing or abundance of plankton reflect climate driven change (e.g. interdecadal differences in the timing of a key species, *Neocalanus,* Mackas et al., {1998}) or the effect of anthropogenic influences such as oil spills (e.g. the impacts of the *Sea Empress* oil spill on plankton populations, Batten *et al* {1998}).

C. Link to GEM Program Document

The GEM document states that '*prudent use of the natural resources of the spill area requires increased knowledge of critical ecological information about the northern GOA* [Gulf of Alaska]. Plankton are a fundamental component of the marine ecosystem, upon which many of the natural resources directly depend, and monitoring their distributions and variability is crucial to GEM's mission. Furthermore, the first identified goal of GEM is to '*serve as a sentinel (early warning) system by detecting annual and long-term changes in the marine ecosystem from coastal watersheds to the central gulf*'. A monitoring program that provides an early indication of ecosystem regime shifts clearly addresses this goal. The current CPR transects cross the continental shelf regions south of Prince William Sound, the Aleutians and British Columbia as well as the oceanic Gulf of Alaska and the southern Bering Sea. We will thus be sampling two of the GEM identified habitats (the Alaska Coastal Current and the offshore) in a systematic and continuous way. A monitoring system that works seamlessly between habitats is beneficial to assessments of change and to identifying the impacts of that change.

As the GEM document recognises, the key area of interest to GEM is also connected to adjacent waters, both in terms of the origins of the water itself (the shelf and slope areas off California up to British Columbia feed in to the GEM area through the current system of the North East Pacific) and because higher trophic level animals move between many of these areas without recognising any boundaries. The data from the CPR survey presented earlier reveal that the Alaskan shelf is responding to climate influences in a different way to the open Gulf of Alaska. We will try to establish the mechanisms by integrating physical data with the biological data.

This proposal also will address the second and third goals of GEM;
By integrating the plankton data with the physical data collected on the same transect, satellite data and data on higher trophic levels we will seek to understand the forcing on the plankton communities, and the implications.

By rapidly processing a subset of the samples, comparing them to the data we already have and publishing the findings rapidly on a website we will be providing a useful summary capable of informing policy makers and other interested parties.

Although not expressly addressed in our proposal the data collected from the CPR surveys could ultimately be used in predictive models.

III. PROJECT DESIGN

A. Objectives

1. To add to the existing database of seasonal plankton data acquired by the CPR across the North Pacific on the existing transects (Fig 1, Prince William Sound to California and Vancouver to Japan) in FY03 and FY04. Also to process the remaining 1997 shelf samples.

2. To integrate physical data and fluorescence/chlorophyll data collected on the same vessel (via project 02614) with the plankton observations made from Prince William Sound to California.

3. To compare marine bird and mammal observations made on the Vancouver to Japan transect (funded by the NPRB) with the plankton data and temperature data from a temperature logger on the CPR and from XBT's (collected through NOAA's XBT program) all on the same vessel in FY03. A separate proposal to further develop a Ferry-Box type system for Ships of Opportunity will, if successful, also be added to this vessel.

4. To process a subset of samples rapidly (within 1-2 months of collection), assess plankton communities in relation to data from previous years and publish results on a web-site in a timely fashion (FY03 and FY04).

B. Procedural Methods

1. The collaborative projects that have now been implemented on the same vessels, together with the good working relationship built up with the crew of the sampling vessels and parent shipping companies during the last 3 years, confirm that the same transects should continue to be sampled.

   Standard CPR methodology

   CPRs are towed in the surface mixed layer at a depth of about 7m by commercial ships of opportunity on their regular routes of passage. Water enters the front of the CPR through a small square aperture (1.27cm), passes along a tunnel and through a silk filtering mesh (with a mesh size of 270μm) which retains the plankton and allows the water to exit at the back of the machine. The movement of the CPR through the water turns an external propeller which, via a drive shaft and gear-box, moves the filtering mesh across the tunnel at a rate of approximately 10cm per 18km of tow. As the filtering mesh leaves the tunnel it is covered by a second band of mesh so that the plankton are sandwiched between these two layers. The mesh and plankton sandwich is then wound on into a storage chamber containing preservative. At the end of the tow the machine is returned to the laboratory and the mesh processed in a routine way. The mesh is cut into separate samples (each representing 18kms of tow and about 3m^3 of seawater) which are randomly apportioned amongst the analysts for plankton analysis. (The 3m^3 sample volume analyzed is comparable to that which would be measured by an OPC towed along the same track line).

The first step is the assessment of phytoplankton colour (the greenness of the sample) which is determined by comparison with standard colour charts. It is a representation of the total phytoplankton biomass and includes the organisms that are too fragile to survive the sampling process intact but which leave an impression on the mesh. Hard-shelled phytoplankton are then semi-quantitatively determined under a microscope by viewing 20 fields of view and recording the presence of all the different taxa in each field. Small zooplankton are identified and counted into categories of abundance from a subsample (1/50 of the sample) whilst all zooplankton larger than about 2mm are counted with no subsampling. Identification is carried out to the highest practicable taxonomic level and is a compromise between speed of analysis and scientific interest. Since copepods make up the vast majority of the zooplankton most copepods are identified to species level whilst rarer groups are identified to a lower level. Although CPR sampling is continuous, the midpoint of the sample is used to label it with latitude, longitude, time and date. All of this information is stored on a relational computer database so that the questions of when, where, and how much can be answered. All of the samples are archived after analysis so that they can be re-examined at any time, for example, if a scientist with an interest in a specific group wishes to study it in more detail, or an incident occurs which warrants closer examination of the samples from that area.

The CPR is a relatively simple, rugged piece of oceanographic equipment. It can withstand being deployed from large ships moving at speeds of >20 knots and still function, and over 95% of tows successfully record plankton. It has the ability to carry instruments to record the physical environment. A high level of expertise is needed to carry out the taxonomic analysis but SAHFOS has an excellent team of analysts, some members with over 30 years of experience.

2. Integration of plankton and physical data. We are actively collaborating with Dr S. Okkonen, lead on GEM project 02614. Analysis of the physical data under project 02614 should provide our project with an understanding of the hydrodynamic features (such as fronts or eddies) and processes, the origin of the water for example, and any anomalies which we will use to explain the plankton distributions.

   During FY03 sampling the physical data will be examined after collection and a decision made as to the spacing of samples to be processed. For example, each CPR sample covers 18km and eddies typically have a diameter of 200km (although the CPR may not pass through the centre). In the region of the feature every sample can be processed to maximise the statistical rigour of the analysis. When the physical environment seems ‘stable’ then the standard practice of processing every fourth sample and every shelf sample will be employed (the statistical basis for this practice is given in a later section). Satellite-derived data will also be used where appropriate to explain the plankton distributions.

3. Integration of plankton and higher trophic level data. We are collaborating with the Point Reyes Bird Observatory and the Canadian Wildlife Service who have an NPRB funded project to collect marine bird and mammal observations along the Vancouver to Japan CPR transects in 2002 and 2003. One such simultaneous data collection occurred in June 2002, a

second is planned for September/October 2002 with three in 2003 (March, June and September). A new technique for obtaining population estimates has already been developed under this project involving counting the birds in discrete bands based on distance from the ship (0 - 99m, 100 - 199m, 200 - 399m, 400 - 799m and >800m) to provide an estimate of the probability of detecting a bird with increasing distance. Temperature data will be available through a logger on the CPR and through XBT's deployed by the vessel.

Estimates of total plankton biomass and of selected groups will be made from the CPR data. Spatial patterns along the transect will be correlated with the seabird population and species composition measurements, and with marine mammal observations where possible. This will enable the trophic linkages to be examined since plankton either directly, or indirectly through small fish and squid, support these higher trophic levels. Furthermore, these analyses will be undertaken on a seasonal basis as the birds and mammals undergo migrations through the region, the first time such a large-scale study has been proposed.

4. In order to process a subset of the samples rapidly the CPR mechanisms must first be unloaded when the vessels return to their respective ports. Training this Fall in CPR servicing will provide two centres of expertise, one at the Prince William Sound Community College and one at a DFO laboratory on Vancouver Island. Training will also be set up in mesh processing and CPR sample analysis for a technician within DFO. The mesh will then be sectioned into samples and a subset retained (~20%) while the remainder are sent to SAHFOS. The subset will be determined by comparison with the physical data in the case of the Alaska to California transect (as described above) while the Vancouver to Japan transect will have only a subset of samples from the eastern half of the transect retained. SAHFOS will process the bulk of the samples (~80%) according to its routine procedures and provide the quality control of the entire sample processing. The subset processed in Canada (at DFO) will be completed within 1-2 months of receipt and compared with the existing database. We will test the hypotheses that regime shift type events can be detected by integrating physical and biological data, and that a subset is sufficient to assess the ecosystem status relative to the baseline data. We will also test the value of such a 'fast response'. Visitors to the website will be asked to provide feedback on the value of the data analysis to their own studies and this feedback will be used to assess the success of the approach, and to make modifications in 2004.

C. *Statistical Methods*

Two analyses have been undertaken with existing CPR data to verify that the proposed sample density is valid and that the level of subsampling proposed for the 'fast response' component of this proposal is likely to be successful. These are summarised below;

i. Large scale patchiness (on the order of 10s to 100s of kms) needs to be considered as a factor that may contribute to the observed variability in the plankton data. The maximum resolution possible from CPR data is 18.5 km, however, to maximise coverage with the resources available we plan for a resolution of 74 km in the open ocean (every fourth sample being processed). Under the original NPMR funded CPR program we carried out an analysis of the CPR data to examine the size of observed patches of particular organisms. Sequentially lagging an abundance series and calculating its autocorrelation enables the decorrelation length scale to be determined, i.e. the point (distance) at which the series no longer significantly correlates with itself. At this point samples are

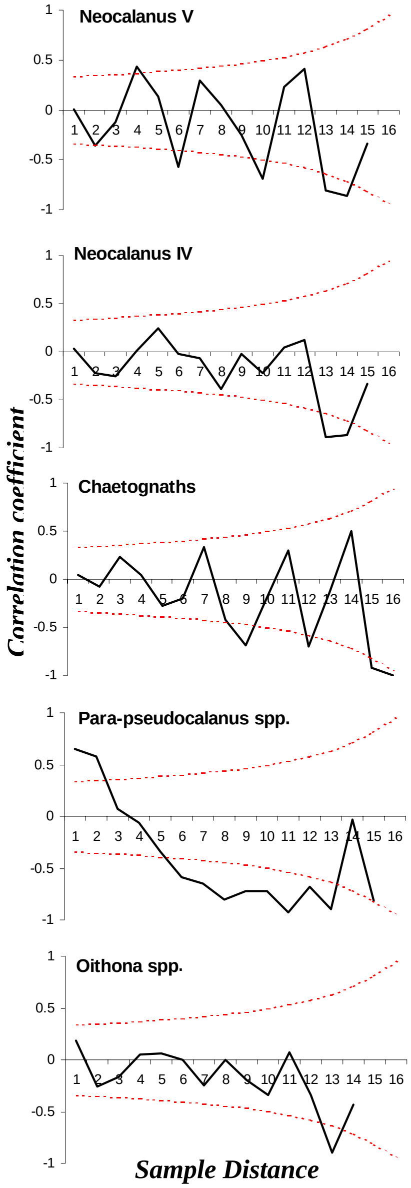


Fig 7. Autocorrelations of abundances of common taxa for the first sampling day in April 2000 along the Alaska to California transect. Only day time samples were used. Red dashed lines show 95% confidence limits.

statistically independent. The April 2000 transect was sampled as normal but every sample collected was processed instead of every fourth. Samples were therefore continuous with the midpoint of consecutive samples being 18.5 km apart. The entire transect from Alaska to California takes about 5 or 6 days to cover. For this analysis we ignored samples collected on the shelf at the extremes of the transect as the shelf break causes an abrupt change in the number and/or type of organisms present. Similarly, surface species composition often changes at twilight and dawn because of diel vertical migration by some species. More day-time samples were collected than night-time and so the analysis only used samples collected after dawn but before twilight. The oceanic section of the transect was sampled over 4 days and we have considered each day of sampling as a replicate. 15 to 18 consecutive samples were collected and processed for each of the four replicate days. For the most commonly occurring taxonomic entities on each day (ranked according to frequency of occurrence) autocorrelations of abundance were carried out by lagging the series of sequential abundances by 1 sample, 2 samples, 3 samples etc until only the first and last samples were paired. With each additional lag the number of paired samples to correlate decreases and so the threshold correlation coefficient for a significant correlation increases. For most of the taxonomic entities there are sporadic significant correlations but no clear pattern (Fig 7 is a sample of the results). This suggests that patches are occurring either at scales smaller than about 1 CPR sample (i.e. less than 20 km) or larger than 15-18 samples (larger than about 300 km). This supports the belief that the CPR sampling resolution is adequate for a synoptic large-scale survey. An individual sample will pass through small patches of plankton and so provide an 'average' of the small-scale patchiness. Samples that are spaced well apart, such as every 74 km, are likely to be representative and not likely to be within or outside of a patch.

ii. A subset of the extensive CPR data set in the North Atlantic was examined to determine the frequency of sampling in space and time required to reveal significant ecosystem changes. CPR sampling in the northeast Atlantic during the last five decades has produced more than 200,000 samples processed by standard procedures. How many of these samples would actually have been necessary to detect low frequency changes in the sampled ecosystems? The signal sought was that of the steady decline in abundance of *Calanus finmarchicus* across much of the survey area, shown to be associated with a change in the North Atlantic Oscillation (NAO) (Planque and Fromentin 1996; Fromentin and Planque 1996; Planque and Reid 1998). The Planque and Reid time series of *Calanus finmarchicus* was recreated by extracting data for the same area of the northeast Atlantic. A total of 58,768 samples was used, about 100 samples per month between 1958 and 1999. Monthly mean abundances and annual means were calculated from log transformed sample abundances, and overall annual means were calculated by averaging over seven areas. The resulting time series is essentially the same as that of Planque and Reid (correlation coefficient of 0.96). Two indices were selected to determine how well any subsampling of the data set would reproduce the signal. The first index, the r^2 value from a regression of abundance against time (the full data set has a value of 0.69), would provide information on how well the decline in abundance is measured by the subsampled data. The second index, the correlation coefficient of the subsampling time series against that of the full data set, measures how well the signal from the subsampled set compares with that from the full set.

Two strategies for subsampling were used. First a randomized approach was applied to determine the possible variability of the resulting indices. For each year fixed proportions of the original data set were randomly extracted (e.g., 90%, 80%, etc) and the areal, monthly, and annual means calculated as before, this being repeated 100 times for each proportion to find average index values and their variability. Second, in a more realistic strategy, subsampling was planned, for example spread more evenly or based on some knowledge of the system being studied. This subsampling included only odd or even months, only months between March and September, and only every fourth, sixth, eighth, etc. of the data set. Means and the two indices were calculated as before. In short, the random multiple simulations were used to determine the reliability of the subsampling indices, while the planned strategies were used to show how successful a restricted survey might be in identifying the *Calanus* decline.

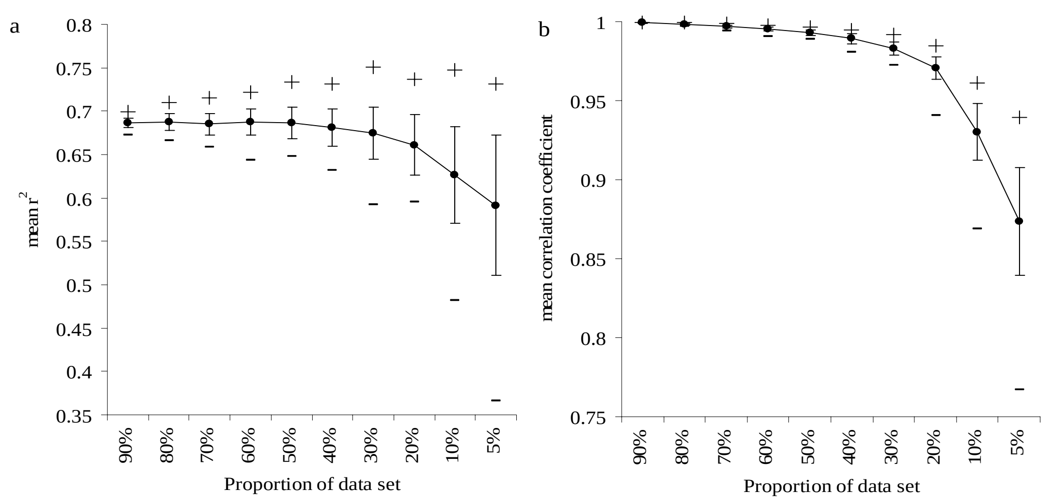


Figure 8. The resulting mean values of each index (a: r^2 of decline in abundance with time, b: correlation coefficient when test time series was correlated with original time series) after randomly selecting samples 100 times for each chosen percentage. Error bars indicate standard deviations in each case, + = maximum value of index in 100 extractions, – = minimum value of index in 100 extractions.

The results are shown in Fig. 8. Surprisingly, only a small fraction of the data was needed to reveal the signal. Even with only 5% of the samples used (about 60 or 70 samples per year across all months and the whole sampling area) each of the 100 random selections produced statistically significant declines in abundance with time, and correlated significantly with the original time series. The planned subsampling produced similar results with somewhat higher values of the indices.

These two studies have demonstrated that our proposed approach is statistically valid. The samples can be considered as independent of each other and a subset should be sufficient to detect a strong change in the ecosystem. The full processing available within 9 months of the sampling will add certainty to any earlier conclusions.

D. Description of Study Area

The project will sample waters on one transect from Prince William Sound to California. Sampling is usually carried out from south to north, commencing either in Long Beach (33.4667°N, 118.217°W) or San Francisco (38.003°N, 123.127°W) and continuing through the Hinchinbrook entrance of Prince William Sound, typically 60.117°N, 146.233°W. The second transect will follow a great circle route, beginning in the Strait of Juan de Fuca (48.867°N, 126.083°W) through Unimak Pass in the Aleutian chain to the southern Bering Sea and then to the east coast of Japan (typically 41.857°N, 143.717°E). See Figure 1 for a map of the transects. Ship tracks vary minimally from month to month.

E. Coordination and Collaboration with Other Efforts

This project first came about as a PICES initiative, following the October 1998 Annual meeting and recommendations of the Climate Change and Carrying Capacity Implementation Panel. It was financially supported during 2000 and 2001 by the North Pacific Marine Research program (final report submitted June 2002). Funding was provided for 2002 sampling by EVOS (project number 02624). Further funding has been obtained from the North Pacific Research Board to sample the fall and winter of 2002 and carry out further data analyses (funding continued until June 2003). Throughout this period, and into the future, the CPR activities continue to be endorsed by PICES which, in 2000, set up a CPR Advisory Panel.

We are actively collaborating with Dr S. Okkonen, lead on GEM project 02614. Owing to the late fitting of the TSG in field season 2002 there is only one plankton transect so far that has the simultaneous physical data (since the transect was towed in early August the samples are not yet processed). However, we anticipate an additional three transects between September and December 2002, and five during the 2003 field season. We expect the chlorophyll sensor to be fitted in October 02 which will enable us to explore the links between the physical structuring of the surface waters, chlorophyll, hard-shelled phytoplankton sampled by the CPR and the secondary producers. Analysis of the physical data under project 02614 should provide our project with an understanding of the hydrodynamic features and processes, the origin of the water for example, and any anomalies which we will use to explain the plankton distributions. The northern end of this transect crosses the Alaska Coastal Current in a similar fashion to the more western GAK-1 line (GEM project 02340). Multi-parameter repeated sampling along these two lines should provide opportunities for further analysis.

We are already collaborating with the Point Reyes Bird Observatory (Drs W. Sydenham and D. Hyrenbach) and the Canadian Wildlife Service (Dr. K. Morgan) who have an NPRB funded project to collect marine bird and mammal observations along the Vancouver to Japan CPR transects in 2002 and 2003. One such simultaneous data collection occurred in June 2002, a second is planned for September/October 2002 with three in 2003 (March, June and September). This is the first time that such large-scale higher and lower trophic level data will be collected simultaneously and on repeated seasonal transects (if this proposal is funded). Acquisition of bird and mammal population estimates and interpretation will be the responsibility of Drs Hyrenbach, Sydenham and Morgan. Acquisition of plankton distributions and interpretation will be the responsibility of Drs Batten and Welch. Data integration will be jointly undertaken. The results of the APEX projects are relevant to this collaboration since one conclusion was that the environmental conditions of the Gulf of Alaska had switched to a potentially more favourable (for many species of seabird) regime just as the experiment was concluding.

During April 2002 GEM and PICES co-sponsored a workshop on acquiring data from Voluntary Observing Ships (Ships of Opportunity). The workshop report (summarised in PICES Press Vol 10, no. 2, pages 5-7 and soon to be available in full as a PICES report) resulted in a planned proposal to develop a Ferry-Box type instrument for Ships of Opportunity that would measure physical, optical and chemical parameters in addition to CPR surveys. This type of data collection would be a huge step towards a comprehensive monitoring program. A separate proposal is being submitted to facilitate the development of a Ferry-Box proposal for implementation on Ships of Opportunity in the North Pacific.

We propose that some of the sample processing and analysis be done at DFO in Canada (the Institute of Ocean Sciences at Sidney, Vancouver Island). DFO are willing to offer support 'in kind' for this project (letter of support to follow). They will provide laboratory facilities, library facilities, desk space and administrative support. Many scientists in the PICES community are based at IOS and there is a wealth of oceanographic expertise that will enhance our data interpretation.

In 2001 SAHFOS was involved in the setting up of a new Working Group under the Scientific Committee on Ocean Research (SCOR) to develop standards for sampling, analysis and storage of data and samples obtained by high speed and extensive sampling systems. A main aim is to standardise approaches between surveys to allow better intercalibration. The outputs of this WG will be very useful in ensuring the long-term robustness of the sampling carried out under GEM.

Through the PICES meeting this Fall (the CPR advisory panel) we will seek support from Japan for some sample processing on the Vancouver to Japan transect.

IV. SCHEDULE

A. Project Milestones

1. To add to the existing database of seasonal plankton data acquired by the CPR across the North Pacific on the existing transects (Prince William Sound to California and Vancouver to Japan) in FY03 and FY04.
   Full quality controlled data set to be available by Feb 04 (FY03 collected data) and Feb 05 (FY04 collected data).

2. To integrate physical data and fluorescence data collected on the same vessel (via project 02614) with the plankton observations made from Prince William Sound to California. Seasonal integration to be completed by Dec 03.

3. To compare marine bird and mammal observations on the Vancouver to Japan transect (funded by the NPRB) with the plankton data and temperature data from a temperature logger on the CPR and from XBT's (collected through NOAA's XBT program) all on the same vessel in FY03 (and data from the Ferry-Box project, if funded). FY02-collected data synthesis to be completed by May 03. FY03-collected data synthesis (including seasonal analysis) to be completed by May 04.

4. To process a subset of samples rapidly (within 1-2 months of collection), assess plankton communities in relation to data from previous years and publish results on a web-site in a timely fashion (FY03 and FY04).
   First data and assessment to be published on website in May 03. Feedback report to be prepared by Jan 04.

B. Measurable Project Tasks

FY 03, 1st quarter (October 1, 2002-December 31, 2002)

Throughout:	Continue data analysis of 2002 field data
October 18-25:	Attend PICES annual meeting. Present results to CPR Advisory Panel and two papers in meeting sessions (already funded).
November 25:	Project funding approved by Trustee Council
Mid-December:	Place order for Microscope; begin search for CPR sample processing and plankton ID technician.

FY 03, 2nd quarter (January 1, 2003-March 31, 2003)

January 13-17:	Attend Annual EVOS Workshop
Early February:	Set up and Despatch CPRs to Pacific west coast
February:	Training in CPR sample processing and plankton ID. Source and purchase new tow wires.
March:	2 transects sampled, Prince William Sound to California and Vancouver to Japan Begin web site design

FY 03, 3rd quarter (April 1, 2003-June 30, 2003)

April:	Process first samples (ongoing hereafter). Start data analysis (ongoing hereafter).
Early May:	Sample PWS to Calif. Transect
May:	First results available on web site (ongoing hereafter).
June:	2 transects sampled, PWS to Calif. and Vancouver to Japan

FY 03, 4th quarter (July 1, 2003-September 30, 2003)

July:	Sample PWS to Calif. Transect
August:	Sample PWS to Calif. Transect
September 1:	Annual report to EVOS
September:	Sample Vancouver to Japan transect.

FY 04, 1st quarter (October 1, 2003-December 31, 2003)

October:	Return CPRs to UK for overhaul

	Attend PICES annual meeting (dates TBC). Present results to CPR advisory panel and paper in main meeting. Prepare Manuscript and submit.
December 31:	Complete processing of 2003 samples Assess 2003 sampling and modify 2004 work plan if necessary

FY 04, 2nd quarter (January 1, 2004-March 31, 2004)

(dates not yet known)	Annual EVOS Workshop
January:	Quality Control of 2003 samples Compile feedback report on website data products. Modify 2004 data analysis as required.
Early February:	Set up and Despatch CPRs to Pacific west coast
March:	2 transects sampled, PWS to Calif. and Vancouver to Japan

FY 04, 3rd quarter (April 1, 2004-June 30, 2004)

April:	Process first 04 samples (ongoing hereafter).
Early May:	Sample PWS to Calif. Transect
June:	2 transects sampled, PWS to Calif. and Vancouver to Japan

FY 04, 4th quarter (July 1, 2004-September 30, 2004)

July:	Sample PWS to Calif. Transect
August:	Sample PWS to Calif. Transect
September 1:	Annual report to EVOS
September:	Sample Vancouver to Japan transect. Return CPRs to UK.

FY 05, 1st quarter (October 1, 2004-December 31, 2004)

December 31:	Complete processing of 2004 samples

FY 05, 2nd quarter (January 1, 2005-March 31, 2005)

January:	Quality Control of 2004 samples

FY 05, 3rd quarter (April 1, 2005-June 30, 2005)

April 15	Submit final report to EVOS. Submit 2nd manuscript for publication

V. RESPONSIVENESS TO KEY TRUSTEE COUNCIL STRATEGIES

A. Community Involvement and Traditional Ecological Knowledge (TEK)

During Fall 2002 technicians at the Prince William Sound Community College will be trained in CPR servicing and setting up (as funded by the NPRB). Assuming this current request for funding is successful we then propose to subcontract the Valdez servicing to them after each sampling trip in 2003 and 2004 on this transect. Robert Benda (a biologist at PWSCC) and the PIs have been in contact to set up this training and it is hoped that this link will facilitate local dissemination of the results of the project.

Our web site, once set up in 2003, can be linked to the Trustee Council web site to further disseminate results. We would welcome any other suggestions from the Council as to how best to inform local communities.

B. Resource Management Applications

The CPR survey has already shown that it delivers data describing the abundance and type of plankton across a variety of habitats used by the resources in question. From these data it is possible to predict ocean productivity and it is believed that changes in ocean productivity are a likely cause of some of the variability in living marine resources. We can already demonstrate the effects of a climate regime shift on the plankton and through integrating the CPR data with physical and higher trophic level data the links between climate forcing, lower and higher level productivity can be more fully explored. The effects of human activities need to be addressed in the context of what changes are occurring through natural processes. For this reason, the project we describe will produce information of direct relevance to resource managers.

VI. PUBLICATIONS AND REPORTS

Manuscripts are currently in progress on the role of eddies in structuring ocean plankton populations and the interannual changes in plankton composition and biomass related to the 1999 regime shift (as described in the Introductory section). These manuscripts will be submitted (both to separate special issues of Deep Sea Research) before FY03 commences. A manuscript is planned for the end of FY03 on 'Zooplankton detection of environmental change' which will incorporate the results of the 'fast response' processing we intend to employ in FY03 and assess the value of the CPR approach to determining the status of the ecosystem. A journal such as Fisheries Oceanography would probably be appropriate. Given the wealth of data already acquired in the northeast Pacific it is likely that further manuscripts will also be produced particularly in relation to the collaborations with other projects already described. These data will also be fed into the PICES Ecosystem Status Report to provide a broader perspective on the changes that we will document and to give a quick initial look at recent events.

VII. PROFESSIONAL CONFERENCES

PICES has been instrumental in the setting up of the Pacific CPR sampling through its MONITOR Task Team since 1998 and the CPR Advisory panel that first met in 2000. This is the most significant meeting to promote the project and seek collaboration and to date, both funded collaborative projects (GEM project 02614 and the NPRB project with Point Reyes Bird Observatory) have resulted from discussions at PICES annual meetings. The 2003 annual meeting will be held in Korea in October 2003 (dates and venue to be confirmed) and we ask for support for one of the co-PIs (S. Batten) to attend. We will make a presentation to the CPR Advisory Panel and although the session topics are not yet available it is anticipated that a paper will also be given in the main meeting.

VIII. PERSONNEL

A. Principal Investigator (PI)

Dr Sonia Batten
Sir Alister Hardy Foundation for Ocean Science (Plymouth, UK)
C/o 321-2815 Departure Bay Rd, Nanaimo, British Columbia, Canada V9S 5P4
Telephone/FAX 1-250-756-7747
Email soba@mail.pml.ac.uk

Dr. David Welch
Department of Fisheries and Oceans Canada
Pacific Biological Station, Nanaimo, V9R 5K6, British Columbia, Canada
Telephone 1-250-7556-7218
Fax 1-250-756-7053
Email welchd@pac.dfo-mpo.gc.ca

Sonia Batten will take responsibility for overseeing the sampling program, processing of samples and carry out statistical analyses of the acquired data. She will co-ordinate production of the final report and publications.

David Welch will take responsibility for the DFO contribution and co-ordinating the broader scale monitoring effort amongst the Pacific science community. Will contribute to data analysis and publications.

Other Key Personnel

Captain Peter Pritchard is the operations manager of SAHFOS and has 12 years experience in liasing with shipping companies to arrange towing of CPRs. Will be responsible for co-ordinating the sampling program through regular communication with shipping agents and Masters/crew and arranging dispatch and return of equipment.

C. Contracts

The CPR servicing and reloading will be contracted out. The Prince William Sound to California transect will be serviced by technicians at the Prince William Sound Community College (Robert Benda as the co-ordinating person) and the Vancouver to Japan transect will be serviced by technicians from DFO on Vancouver Island, British Columbia (D. Welch will be responsible for co-ordination). The 'fast response' processing and website maintenance will also be undertaken at DFO. S. Batten will co-ordinate and also undertake some plankton processing and enumeration.

IX. PRINCIPAL INVESTIGATOR QUALIFICATIONS

Sonia D. Batten, PhD. Curriculum Vitae

During the past eight years I have been working with the Continuous Plankton Recorder Survey at the Sir Alister Hardy Foundation for Ocean Science, which operates and maintains the multi-decadal, basin-wide database of plankton abundance and distribution from the North Atlantic. Since 2000 I have been based in western Canada, co-ordinating the north Pacific CPR survey. My main research focus has been the mesozooplankton; their distribution, ecology and role in the upper pelagic ecosystem. I have extensive experience of analysing and interpreting CPR data and have worked on several multidisciplinary projects in European waters. I have extensive project management, data analysis and publication/presentation skills through my experience as Assistant Director of SAHFOS and as acting as a PI on numerous research projects (including the current GEM and NPRB projects in the North Pacific).

Employment History

- ***2001 and currently.*** Part-time Research Associate***. Kintama Research Corporation, Canada.***
- ***2000 and currently.*** Part-time Research Fellow***. Sir Alister Hardy Foundation for Ocean Science, UK.***
- ***1996–2000.*** Assistant Director***. Sir Alister Hardy Foundation for Ocean Science, UK***
- ***1994–1996.*** Postdoctoral Research Fellow***. Sir Alister Hardy Foundation for Ocean Science, UK***

Education

- ***1990–1994. Oceanography Dept., Southampton University, UK.***

PhD. Marine Biology **'***Correlative studies of the ecophysiology and community structure of benthic macrofauna'***.**

- ***1987–1990. Oceanography Dept., Southampton University, UK***

BSc. *Honours Degree in Oceanography with Biology*, 2(i).

Recent Research projects

- July 2002-June 2003. *A Continuous Plankton Recorder monitoring program* North Pacific Research Board (with D. Welch, DFO, Canada)
- Dec 2001-Sept 2002 *A CPR-Based Plankton Survey Using Ships of Opportunity to monitor the Gulf of Alaska.* Exxon Valdez Oil Spill Trust Fund (with D. Welch, DFO, Canada)
- August 2000 – January 2002 PI on '*Testing hypotheses on the causality of long-term changes in zooplankton abundance*. UK NERC 'Marine Productivity'
- April 2000 – June 2001 Co-PI (with Dr G. Hays, University of Wales, UK and Dr R. Harris, PML, UK) on *Increasing the utility of data from the CPR survey.* UK NERC 'Marine Productivity'
- July 1999 – November 2001 Co PI (with D. Welch, DFO, Canada) on *A Continuous Plankton Recorder Monitoring Program for the NE Pacific and Southern Bering Sea.* North Pacific Marine Research Fund
- June 1997-November 2000 PI on *The Continuous Plankton Recorder Survey of the Iberian margin, OMEX II,II.* European Union, Marine Science and Technology.

5 Selected Recent Publications

Batten, S.D., Welch, D.W., & Jonas, T. (In press). Latitudinal difference in the duration of development of *Neocalanus plumchrus* copepodites. (*Fisheries Oceanography*)

Batten, S.D., Clarke, R.A., Flinkman, J., Hays, G.C., John, E.H., John, A.W.G., Jonas, T.J., Lindley, J.A., Stevens, D.P., & Walne, A.W. (In press). CPR sampling – The technical background, materials and methods, and issues of consistency and comparability. (*Progress in Oceanography*).

Batten, S.D., Fileman, E.S. & Halvorsen, E. (2001). The contribution of microzooplankton to the diet of mesozooplankton in an upwelling filament off the north west coast of Spain. *Prog. in Oceanog.* 51, 385-398.

Belgrano, A., ***Batten, S.D.,*** & Reid, P.C. (2001) Pelagic Ecosystems. *Encyclopaedia of Biodiversity*. 4, 497-508. Academic Press.

Batten, S.D., Allen, R.J.S. & Wotton, C.O. (1998) The effects of the Sea Empress oil spill on the plankton of the southern Irish Sea. *Marine Pollution Bulletin*. 36, 764-774.

David W Welch, PhD. Curriculum Vitae

I am Program Head for the Department of Fisheries and Ocean's High Seas Salmon Program, a position I have held and developed since its inception in 1990. I am past chair of the PICES "Climate Change and Carrying Capacity" implementation program (finishing my term in 2001), under which I worked to develop improved ocean monitoring programs for the North Pacific. I am currently chair of the Alfred P Sloan Foundation "Census of Marine Life" initiative in the Pacific, POST, or the Pacific Ocean Salmon Tracking Project. The goal of this new initiative is to apply new breakthroughs in electronic technology to allow marine scientists to track animals wherever they go in the ocean. In 2000 I started my own technology development company to provide the measurements necessary to establish the validity of an ocean acoustic array. In all of these roles I have been actively involved in the identification of new research areas, and the development of the managerial and support infrastructure necessary to address the research needs as well as conducting the research. I am the author of over 100 primary scientific publications and technical reports, and have also served as an expert consultant to both governments and the private sector regarding potential societal impacts of climate change.

Employment History

- 1986–Present. ***Program Head, Dept of Fisheries and Oceans, Canada***.
- ***2000-Present.*** President and Founder, Kintama Research Corporation **.**

Education

- B.Sc., Biology & Economics, 1977. University of Toronto
- Ph.D., Oceanography, 1985. "A Study of the Effects of Density-Dependence and Age-structure on the Dynamics of Marine Fish Populations". Dalhousie University

Recent Research projects

- July 2002-June 2003. *A Continuous Plankton Recorder monitoring program* North Pacific Research Board (with S. Batten)
- Dec 2001-Sept 2002 *A CPR-Based Plankton Survey Using Ships of Opportunity to monitor the Gulf of Alaska.* Exxon Valdez Oil Spill Trust Fund (with S. Batten)
- July 1999 – November 2001 Co PI (with S. Batten) on *A Continuous Plankton Recorder Monitoring Program for the NE Pacific and Southern Bering Sea.* North Pacific Marine Research Fund
- March 2001- July 2002. "A Feasibility Study for Pacific Ocean Salmon Tracking (POST)" North-West Power Planning Council.
- March 2001-March 2003. Co PI (with George Boehlert) on Alfred P. Sloan Foundation's Census of Marine Life Project, "***POST***". (Pacific Ocean Salmon Tracking).
- Ongoing since 1999. Principle Investigator on Bonneville Power Administration Collaborative Agreement *"Canada-USA Shelf Salmon Survival Study"*.

5 Selected Recent Publications

1. Batten, S.D., ***Welch, D.W.,*** & Jonas, T. (In press). Latitudinal difference in the duration of development of *Neocalanus plumchrus* copepodites. (*Fisheries Oceanography*)
2. ***Welch, D.W.,*** B.R. Ward, B.D. Smith, and J.P. Eveson. 2000. Influence of the 1990 Ocean Climate Shift on British Columbia Steelhead (O. mykiss) Populations. Fisheries Oceanography 9(1):17-32
3. Whitney, F.A. and ***Welch, D.W.*** (In Press) Impact of the 1997-8 El Niño and 1999 La Niña on nutrient supply in the Gulf of Alaska. Prog. Oceanogr. 54:
4. ***Welch, D.W.,*** A.I. Chigirinsky, and Y. Ishida. 1995. Upper Thermal Limits on the Oceanic Distribution of Pacific Salmon (Oncorhynchus spp.) in the Spring. Can. J. Fish. Aquat. Sci. 52(3):489-503
5. ***D.W. Welch,*** Y. Ishida, and K. Nagasawa. 1998. Thermal Limits and Ocean Migrations of Sockeye Salmon (Oncorhynchus nerka): Long-Term Consequences of Global Warming. Can. J. Fish. Aquat. Sci. 55:937-948.

X. LITERATURE CITED

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EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
PROJECT BUDGET

Budget Category:	Proposed FY 03
Personnel	$85.8
Travel	$4.4
Contractual	$22.3
Commodities	$10.4
Equipment	$22.5
Subtotal	$145.4
Indirect	$35.5
Project Total	$180.9
with 9% GA ($16.3)	$197.2
Other Funds	

Comments:

NPRB funding is contributing 2.7 months of S. Battens salary ($10.2)
Indirect rate is 40% personnel and subcontracting costs
$0 for NEPA (Not Applicable)
$1.5 for Annual Workshop attendance
Salary costs for S. Batten and Researcher (to be employed) include costs for report writing and publications (2 months, $7.1)

FY03

Prepared: August 27th 2002

Project Number: 030624 (approved TC 11/25/02)
Project Title: A CPR-based survey to monitor the Gulf of Alaska and detect ecosystem change

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
PROJECT BUDGET

Personnel Costs:			Months	Monthly	
Name	Description		Budgeted	Costs	Overtin
S. Batten	Principal investigator/lead researcher		3.3	3.8	
P. Pritchard	Operations Manager		1.0	4.4	
R. Barnard/L.Gregory	Technician		1.0	3.1	
Various	Taxonomists (team of ~12 people)		10.5	3.3	
D. Stevens	Data Manager		0.5	2.8	
To be employed	Researcher		9.0	3.3	
	Subtotal		25.3	20.7	C
					Personnel To

Travel Costs:	Ticket	Round	Total	Da
Description	Price	Trips	Days	Per Die
S. Batten to attend EVOS workshop, January 03 in Anchorage and visit PV	0.8	1	5	C
Researcher travel to SAHFOS for sample processing training	0.6	1	20	C
				Travel To

FY03

Prepared: August 27th 2002

Project Number: 03624
Project Title: A CPR-based survey to monitor the Gulf of Alaska and detect ecosystem change
Name: Sir Alister Hardy Foundation for

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
PROJECT BUDGET

Contractual Costs:
Description
Leasing of Continuous Plankton Recorders ($0.9 per tow)
Transport of CPRs to and from UK at start/end of field season plus 1 contingency shipment for repair
Servicing and setting up of CPRs between tows contracted out to Prince William Sound Science Centre and DFO
Shipping of samples for processing
Computing services (these are provided by the Marine Biological Association at an agreed rate PA. Pro rata costs indicated)
Contractual To

Commodities Costs:
Description
Filtering mesh ($0.2 per unit)
Laboratory consumables
Tow wires (a 0.2 per wire)
Commodities Tot

FY03

Prepared: August 27th 2002

Project Number: 03624
Project Title: A CPR-based survey to monitor the Gulf of Alaska and detect ecosystem change
Name: Sir Alister Hardy Foundation for

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
PROJECT BUDGET

New Equipment Purchases: Description	Number of Units	U Pri
Specialty microscope for CPR sample processing, including accessories (fume hood, light source)	1	21
Computer	1	1
Indicate replacement equipment purchases with an R.		**New Equipment To**

Existing Equipment Usage: Description	Numb of Un
existing CPRs will be used. Rental costs charged above cover replacement and repair	
external bodies	
internal mechanisms	:
Existing microscopes will also be used, although an additional one has been requested	

FY03

Prepared: August 27th 2002

Project Number: 03624
Project Title: A CPR-based survey to monitor the Gulf of Alaska and detect ecosystem change
Name: Sir Alister Hardy Foundation for