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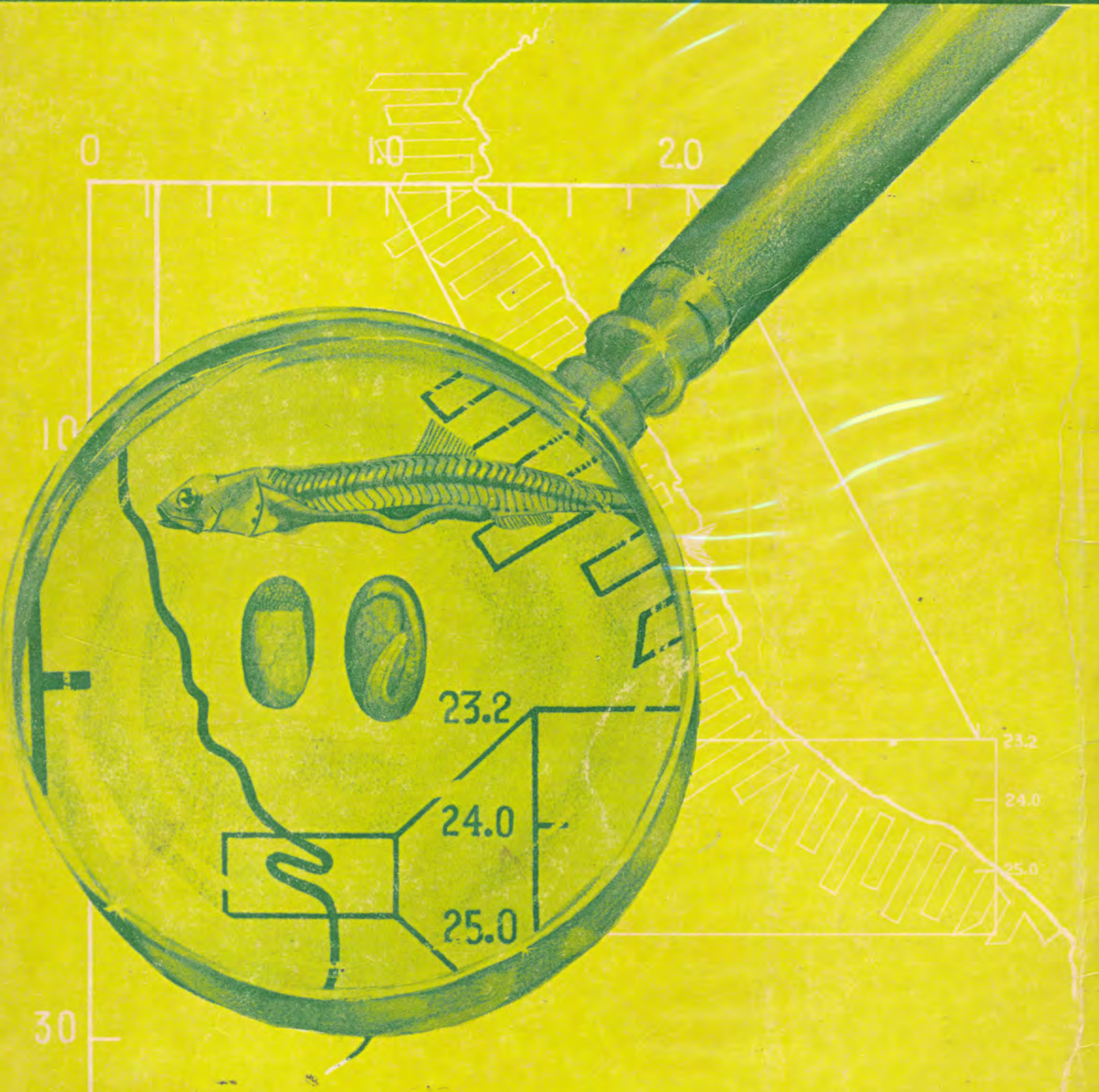



## INVESTIGACION COOPERATIVA DE LA ANCHOVETA Y SU ECOSISTEMA -ICANE- ENTRE PERU Y CANADA

CALLAO 1981 PERU

# VERTICAL DISTRIBUTIONS OF PLANKTON IN THE UPPER 35m OF THE PERUVIAN UPWELLING ZONE - APPLICATION OF A SHIPBOARD ELECTRONIC PLANKTON COUNTING SYSTEM.

D.L. Mackas[1], C.M. Boyd[2], S. Smith[3], and H. Santander[4]
1 Institute of Ocean Sciences, Sidney, B.C., Canada
2 Dalhousie University, Halifax, N.S., Canada
3 Brookhaven National Laboratory, Upton, N.Y. USA
4 IMARPE, Callao, Peru

## ABSTRACT

Using a hose intake lowered in 1 m steps through the water column, we obtained rapid (~1 hr), detailed (~2 m resolution), and repeatable realtime profiles of temperature, chlorophyll fluorescence, and zooplankton abundance. The system electronically sorts a subsample (25o/o) of the total zooplankton counts for each sample interval into eight size categories ranging between 0.3 and 1.5mm equivalent diameter, thus providing a size histogran for the sampled population. Vertical variations in the abundance profiles and in the size (i.e. species) composition of the zooplankton were consistently correlated with physical and chemical gradients in the water column. In daylight, the zooplankton maximum was nearly coincident with the fluorescence maximum, while at night the animals were at shallower depths and were spread more evenly through the surface mixed layer. The electronic sampling system seems particularly useful as a guide for the positioning of subsequent, more traditional, sampling efforts.

## RESUMEN

Mediante una manguera con toma de entrada profundizable de metro en metro en la columna de agua obtuvimos perfiles rápidos (~1 hr) y detallados (~2 m de resolución), además de repetibles y referidos a tiempo real, de la temperatura, clorofila por fluorescencia y abundancia de zooplancton. El sistema usado divide electrónicamente una submuestra (25o/o) del conteo total del zooplancton en cada intervalo en ocho categorías de tamaño desde 0.3 hasta 1.5 mm de diámetro equivalente, proporcionando así un histograma de tamaños de la población muestreada. Las variaciones de abundancia en los perfiles verticales y en la composición de tamaños (es decir, especies) del zooplancton se correlacionaron consistentemente con las gradientes físicas y químicas de la columna de agua. Durante el día el máximun de zooplancton fue casi coincidente con el máximum de fluorescencia pero en la noche los animales se encontraron en profundidades más someras y se extendieron más uniformemente en la capa de mezcla superficial. El sistema de muestreo electrónico parece especialmente útil como una guía para decidir la localidad de los muestreos tradicionales.

## INTRODUCTION

Over the past few years, oceanographers have become increasingly involved with the problem of resolving the meso- and fine-scale structure of the marine environment, both in spatial and temporal dimensions.

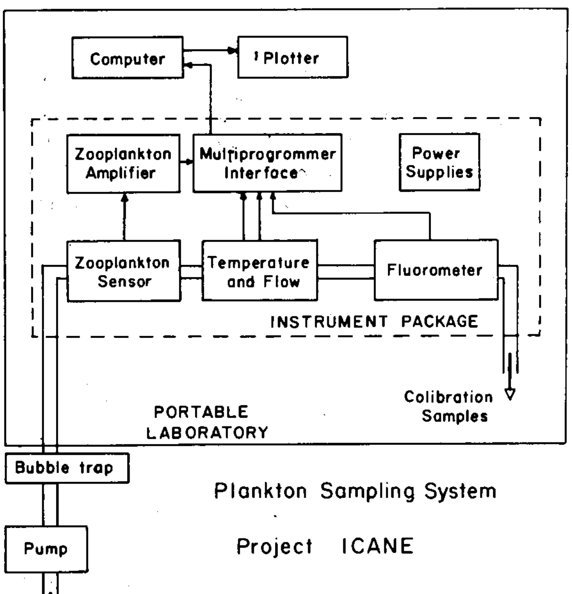
A major factor in the progress of this work has been the development of continuous sampling technologies, usually involving electronic sensing and/or amplification, and also usually generating large amounts of data to be processed by a computer. Such technologies are well established for the phsical variables such as conductivity, temperature, and water motion. For biological variables (which very possibly have the most intense spatial structure) **in vivo** chlorophyll fluorometry, an indication of phytoplankton abundance, is the best known example. However, this method only allows assessment of the lowest trophic level.

At Dalhousie University, we have developed several sampling systems which allow continuous measurement of zooplankton abundance, the next link in the marine food web (Boyd, 1973). As part of Project ICANE, we added several modifications and improvements to the original design and then used the revised sytem to study the distribution of small zooplankton in near-surface waters off Peru. This paper describes the modified sampler and presents brief examples of the type of data we were able to obtain.

## THE PLANKTON SAMPLING SYSTEM

The key element of the smapling system is an internally ratioed conductivity sensor which registers the passage through the sensor of resistive particles (animals) imbedded in a conductive fluid medium (seawater), The sensor was originally developed (Boyd, 1973) as an **in-situ** device. An attached plankton net concentrated the organisms and funneled them into the sensor mouth. To eliminate restrictions on tow duration and ship's speed (due to clogging of the net), we subsequently developed an alternative system for on-board use (Mackas and Boyd, 1979). Basically we placed four replicate sensing elements in a single plastic block and fitted the assembly with hose connections so that water could be forced through the sensor tubes under relatively high pressure. We combined this particle sensor with a Turner Designs fluoromter, a flowmeter and a thermistor (Fig. 1). A new addition to the system for the work discussed here was a pulse-height analyzer connected to one of the four particle sensing channels. This gave a size-frequency histogram for that channel - an approximate 25o/o subsample of the total particles. Outputs from all the sensors were scanned by a Hewlett-Packard 9825 calculator and the data were recorded simultaneously as graph paper plots and magnetic cassette tapes.

Fig. 1 Schematic of the sampling system. Data channels were sampled by the multiprogrammer at 5 s intervals; integrated, plotted and recorded by the computer at 30 s intervals. The system could also be switched to a through hull intake for sampling of near-surface water while the ship was underway.




The water supply for the sytem was a 3.25 cm I.D. hose driven by a reciprocating pump. Typically the flow rate was 20 liters per minute, giving an average residence time in the plumbing of 150 seconds. To obtain vertical profiles we lowered the inlet of this hose in a one meter step every 60 seconds, thus giving about 1m vertical resolution. Profiles were normally of the upper 30m. Because we did not have a pressure sensor attached to the hose inlet, our estimates of sample depth were obtained indirectly from CTD casts taken immediately prior to each of the pump profiles. The temperature vs. depth traces from the CTD casts defined an artificial depth scale against which we aligned the time series data from the pump profiles. Because the temperature gradient was strong and of constant sign throughout the upper layer, this method gave comparable resolution and better accuracy than a calculation based on surface wire angle. Because the depth scale is defined relative to isopycnal surfaces, the method also has the advantage of making invisible the transient vertical displacemtens associated with the passage of internal waves (Denman and Herman, 1978).

During the vertical profiles, we also filtered the sample discharge through a small plankton net to provide abundance and sizing calibration of the electronic sensors and information on species composition. These calibration samples were integrated over five minute periods, and thus divided the upper water column into five or six depth strata. Organisms were later sized and identified to genus level using a dissecting microscope.

## OCENOGRAPHIC CONDITIOINS

The data reported here were collected during a 36-hour drogue station (8-10 November, 1977, vicinity 9° 30'S, 78°58' W, water depth approxiimately 135m). Background oceanographic data are tabulated in detail by Doe (1978) (see also other reports in this volume). Winds had been calm for a number of days prior to the drogue station, and the region was not experiencing active upwelling. A strong thermal gradient occurred below the surface (where the temperature was ~18°C). Salinity was nearly constant at 35o/oo through the water column, so the density structure was almost entirely determined by the thermocline. Dissolved oxygen was depleted to about 0.5 ml $l^{-1}$ below 25 m. Nitrate values were low at the surface, but always easily detectable, and increased to nearly 35 ug-at $l^{-1}$ at the base of the thermocline. A broad chlorophyll maximum also occurred here and became sharper during the span of the drogue station. Superimposed on these average conditions was considerable high frequency temporal variability occurring at and near 25 m depth (almost certainly resulting from internal wave effects) plus lower frequency variations associated with advection and with diel shifts in the vertical distribution of the plankton.

## RESULTS

**a) Variability in vertical distribution**

The data from the five pump profiles can be classified into two basic patterns, shown in Figs. 2 and 3. The daytime profiles (0700 and 1530 hrs) showed distinct sub-surface ~10 m depth) maxima in both zooplankton abundance and chlorophyll fluorescence profiles (Fig. 2), with the zooplankton peak occurring slightly deeper than the chlorophyll maximum. The zooplankton peak was also coincident with the sharp gradient in dissolved oxygen concentration; this may have inhibited a deeper vertical migration by the animals.

Essentially all the animals above the zooplankton peak were copepods of the genera **Paracalanus** and **Centropages**. These genera were also present in the peak in considerable numbers along with **Calanus** and **Eucalanus**. Although a few copepods (usually **Oithona** sp.) were identified in samples from below the thermocline and in the low oxygen water, most of the (relatively rare) particles were from other taxa, principally polychaetes, ostracods and euphausiids.

Fig. 2 Typical daytime profiles (collected ~1500 hrs, 8 Nov.) of chlorophyll fluorescence, temperature and zooplankton abundance. Filled circles indicate data collected while the hose intake was being lowered; open circles are data from the up cast.

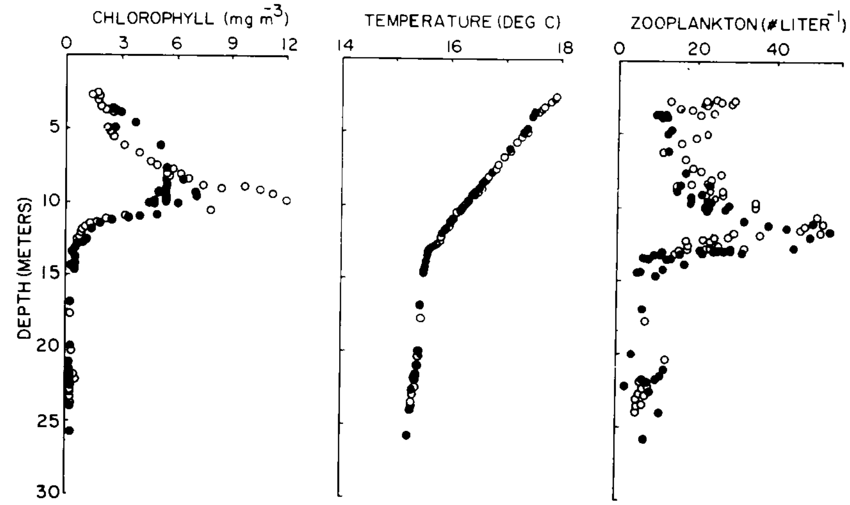
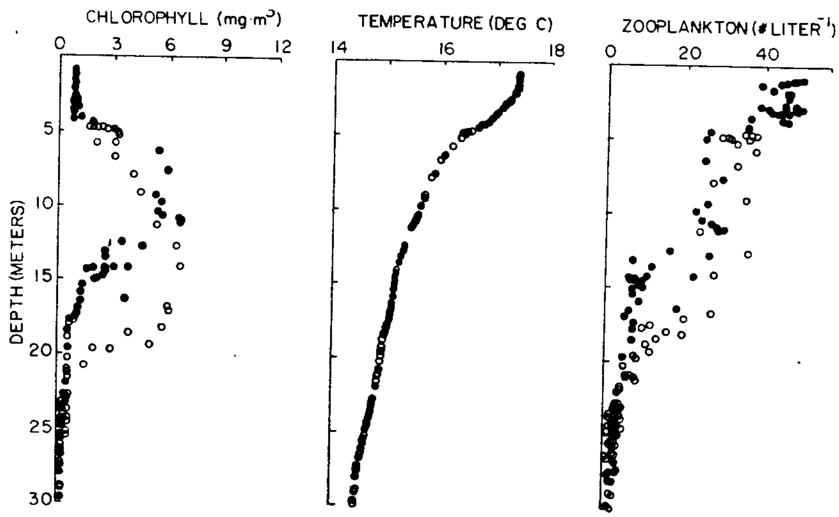



Fig. 3 Typical nighttime profiles (collected ~2000 hrs, 8 Nov.). Symbols as in Fig. 2.

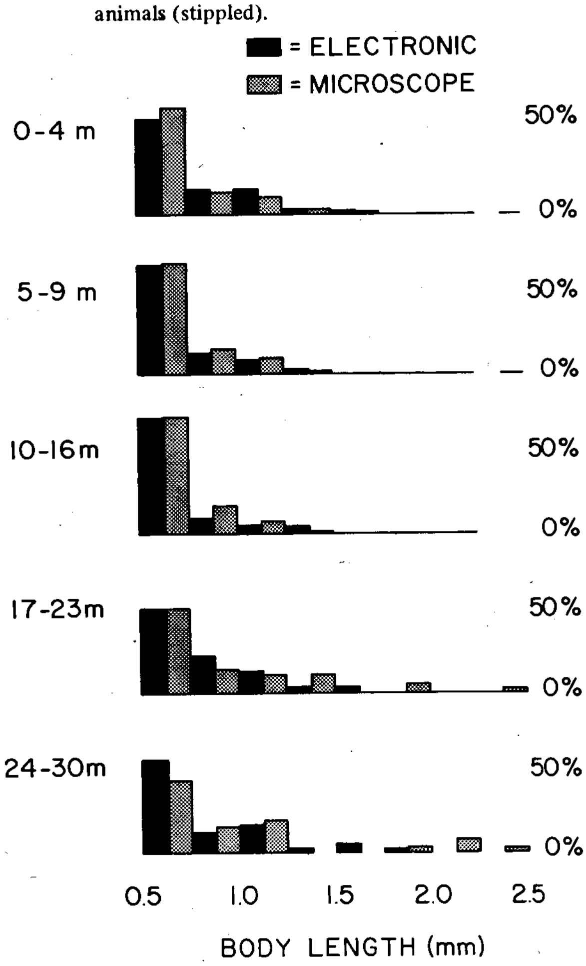



Of the three nocturnal profiles, one (0000 hrs, 10 November) showed a vertical distribution pattern similar to Fig. 2 except that the peak zooplankton abundance occurred above, rather than below, the fluorescence maximum. The remaining two profiles (2000 hrs, 8 November and 0030 hrs, 9 November) followed the pattern shown in Fig. 3. Note that the zooplankton were above the chlorophyll maximum and were present in abundance throughout the upper layer, with no clear preferred depth. Again, the thermocline and oxycline appeared to divide the upper 30 m into fairly distinct copepod and non-copepod faunal zones. Note also in Fig. 2 the downward displacement of both the fluorescence and particle distributions in the second half of the cast. Because the portrayed depths are calculated from the temperature data it is unlikely that this results from a passive displacement by internal waves of the entire water column structure. Instead, the organisms appear to be shifting their position relative to the density and temperature structure of the water. It is possible that the plankton are maintaining a true depth coordinate despite vertical displacements of the surrounding water by internal waves, and despite the absence of strong light intensity cues. Alternately, the ship may have drifted across a persistent sub-surface frontal boundary during the sampling period (nearly 1 hr duration).

**b) Size distribution of the zooplankton**

Small copepods (< 1.5 mm body length) dominated the zooplankton community in terms of both numerical abundance and biomass. This preponderance of small zooplankton appears to be the norm in a variety of coastal upwelling ecosystems (Peterson **et al.**, 1979; Blackburn, 1979). A typical series of depth stratified size-frequency histograms is shown in Fig. 4, with electronic and visual (microscope) estimates of size distribution shown for comparison. In general, the agreement between the two is good, particulary given that one estimate is based on a visual measurement of length while the other is calculated from an electronic estimate of volume and an assumed 3:1 aspect ratio for a "standard" copepod body.

Fig. 4 Size-frequency histograms within various depth strata for the data from fig. 3. Adjacent cells compare sizing estimates from the automated sampler (solid shading) and from subsequent microscope measurements of formalin-preserved animals (stippled).




In the upper layer, the two smallest size classes consist of **Paracalanus**; the next two are composed of **Centropages** juveniles and adults, while numerically rare **Calanus** and **Eucalanus** form the largest size classes. Below the thermocline, the 2 small size classes are **Oithona**, while the larger sizes are a mix of **Tomopterid** polychaetes, small medusae, ostracods, and occasional euphausiid fragments.

## AN ASSESSMENT OF AUTOMATED ZOOPLANKTON SAMPLING.

One of the goals of Project ICANE has been the transfer of Canadian oceanographic technology to Peruvian scientists. In this context it is worthwhile to present a brief discussion of the advantages (and disadvantages) of automated sampling of plankton abundance.

The advantages lie in two general areas. First and perhaps most important is the rapid availability of the data. The computer provides an initial display of the information (in time-series form) a few seconds after the water passes through the sensor package. This can be compared with the lag times of hours (or more commonly, months to years) usual for microscopic identification and enumeration. Data-adaptive modification of the sampling program becomes possible, with resulting gains in both efficiency (fewer discrete samples are needed) and information content (the discrete samples can be located more effectively). A second advantage is the feasibility with automated sampling methods, of acquiring and processing very large amounts of data with relatively minimal effort (once the system is set-up and functioning properly). This gain occurs over a wide range of spatio-temporal scales; small-scale resolution and overall coverage of the study area can usually both be increased per unit scientific effort.

The disadvantages of automated samplers are also basically two-fold. At the best of times, a sampler that sorts zooplankton into size and abundance categories will be blind to much biologically interesting information. Overlap with traditional sampling methods (as, for example, we have done with our microscope comparisons) is essential to extract the greatest value from the electronically-obtained data. A second weakness of automated systems at sea is their propensity (particularly as prototypes) for obscure and unheralded malfunction. In the hands of an experienced operator, these breakdowns are neither frequent nor of long duration (we experienced two, each shorter than 24 hrs, during the six weeks of use in Project ICANE). However, a casual and/or trusting novice could easily acquire (and possibly interpret) extensive data sets consisting primarily of instrumental "noise". Again, the best way to overcome this potential problem is simultaneously to obtain relatively frequent and careful calibrations against independent measures of the "real" world. In summary, automated sampling systems, such as the electronic plankton counter, are most effectively used as guides and supplements to more traditional methods (e.g. chemical analysis and microscopic identification of batch samples). The automated sampler provides spatial and temporal continuity between discrete samples, thereby greatly aiding both data collection and eventual interpretation.

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