WASP: A Self Contained Upward Looking Echo Sounder.

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Abstract - The increasing demands to monitor biological activity, in particular, fish stocks, has led to the development of a self-contained digital echo sounder capable of recording internally for extended periods of time. The current unit operates at 200 kHz with a 6^{o} beam angle, and utilises a 200 Mb hard drive for data storage.

Results are presented for a number of deployments requiring differing sampling strategies, ranging from a 9 month time series in the Beaufort Sea to two weeks in the Skeena River B.C.

INTRODUCTION

The use of acoustics in the ocean has a long history, and has become a well established tool for fisheries research. The decline of the cold war, with the resulting de-classification of highly sophisticated technology, promises even greater advances for the future. Faced with growing demands for an economical means of monitoring biological activity, we present here a novel application of the simple echo sounder which provides a fresh perspective on the ocean.

The advent of the lap top computer has made available a series of low power consumption, high capacity, rugged hard drives at reasonable cost. Based on this technology, we have developed a compact, self-contained digital echo sounder that can be deployed to record for extended periods of time at a fixed location. At the chosen frequency of 200 kHz, this provides a visual record of a wide range of reflectors, ranging from plankton to fish and marine mammals. When combined with the pattern recognition capability of the informed human eye, the extended records reveal patterns of both biological behaviour and oceanographic phenomena. The instrument thus provides the much needed link between conventional biological and oceanographic sampling techniques.

TECHNICAL DESCRIPTION

The unit consists of a 200 kHz digital echo sounder, coupled to a micro-processor controlled data logger, which feeds a 200 Mb hard drive via a 1Mb RAM buffer. The data logger is configured around the Xilinx PFGA (Field Programmable Gate Array) Logic Cell Array family of devices to provide some flexibility in the completed hardware. The emphasis in the design throughout has been on low noise levels, combined with low power consumption, the latter being achieved by use of the relatively slow HC11 micro-processor, and by shutting down the system between pings. The stationary mooring allows the use of relatively low ping rates (1 per second), to adequately sample the slow moving reflectors.

The unit is programmed for use with a simple portable computer equipped with a terminal emulator which allows the user to specify the following parameters:

File name.
Pulse length.
Digital sample interval.
Number of sample bins per ping.
Start of recording window.
Ping interval.
Number of pings to average.
Time to start recording.

With this range of options, the phenomena of interest can be sampled to the best advantage. A delayed turn on time can be specified where intense sampling is required at some future date.

The raw data is sampled at approximately 55 kHz with 8 bit resolution, and an average value calculated for the specified bin interval. The corresponding values in successive pings are then summed before the total is finally recorded in a 16 bit format on a 1 Mb RAM card. The contents of the RAM card are periodically written to the hard drive. This results in a slight break in the continuity of the recording, of approximately 48 seconds, during the data transfer. In most applications, this is not significant for visual presentation, but must be accounted for if quantitative analysis is applied. Each ping record starts with a header section containing the setup parameters, record date and time. Figure 1 shows the main components of the system, A being the main chassis, B the battery pack and C the 200 kHz transducer. An eighteen inch rule indicates the scale. The components are accommodated in a pressure case 5 inches in diameter and 24 inches long.

The instrument is configured with the aid of a "Dumb Terminal" or personal computer running a terminal emulator; no other special software is required to set-up the instrument or monitor its functioning. Once configured, WASP will 'ping' unattended for periods of time limited only by the capacity of the battery and the hard drive. After recovery, the data is transferred by connecting the removable hard drive directly to a portable computer.

FIELD RESULTS

Over the past three years the authors, in collaboration with colleagues from the fisheries sector, have deployed WASP under a variety of conditions to test its applicability to fisheries research. The following sections describe some representative data sets from these test deployments. The acoustic returns are shown in black against a white background; in viewing the figures, it should be borne in mind that the pictorial presentations do scant justice to the dynamic range of the original data. In practice, digital processing is used to the enhance desired features or to directly extract relevant information.

1: The Beaufort Sea Deployment 1991.

WASP was first deployed in the Beaufort Sea on March 29, 1991, at a position of 70 deg 53.27 N, 133 deg 43.84 W, It was configured with a ping interval of 3 seconds, each stored record consisting of 500 samples averaged over 30 pings. With these settings, the instrument recorded 150 days of continuous data. The deployment was designed to collect long term statistics of the hydrodynamic interaction between the deeper ice keels and the density stratified surface layer of the Arctic Ocean, important factor in understanding atmosphere/ocean transfer processes.

The period of data collection, from March through to September, covered the time of the onset of the plankton bloom, which was in this instance one of almost continuous ice cover. Figure 2 is a 36 hour segment of the record from July 16. The sharply defined edge of the black area at the top of the figure marks the underside of the ice cover, and the zooplankton layer at the base of the mixed layer is clearly visible below this. At approximately diurnal frequency, diffuse clouds of plankton migrate downwards.

The thick ice cover on the lefthand side of the figure protrudes through the surface mixed layer and is a potential site for strong flow interactions. With these instrument settings, the stronger, more mobile reflectors such as fish, will have been strongly attenuated by the 90 second averaging period, although they are expected to be relatively sparse. Long term records of this type can provide valuable information on upper ocean productivity.

2: Kootenay Lake 1993.

In August of 1993, in collaboration with the BC Fisheries Branch, WASP was deployed in the West Arm of Kootenay Lake to test its suitability for continuously tracking the vertical migration patterns of the fresh water shrimp Mysis relicta. The instrument was deployed on August 24, 1993 at a ping rate of once per second, with averaging over 5 pings. With these settings 14 days of data were recorded. Figure 3 shows a 28 hour section of a compressed image comprising every 20^{th} record. The black area above the line marking the surface results from multiple reflections, and the surface itself is obscured by reflections from bubble clouds induced by breaking waves. The image clearly shows the diurnal migration pattern; a rapid rise towards the surface at dusk, followed by a descent at dawn. During the hours of daylight the shrimp are confined to a 5m layer at the bottom. The strong signals observed about 20m from the bottom during the daylight hours are fish echoes. Figure 4 is a section of record at full resolution showing the details of the vertical distribution of the shrimp during the evening.

3: The Skeena River 1994.

WASP was deployed near the mouth of the fast flowing Skeena River, B.C., for a two week period starting July 7, 1994 as part of an investigation into the distribution of returning salmon. The instrument was bottom mounted in approximately 15m of water to test its suitability for the acoustic detection of salmon swimming close to the surface. The instrument was set to ping once per second and write the average of 3 pings per data record.

Figure 5 is section of the record starting at about 10:00 hrs on July 8, showing details of the retreat of the salt wedge on the falling tide. Individual fish are difficult to discern in this visual presentation, as the high gain setting has resulted in a digital cutoff of the stronger signals.

4: A Herring Fishery, 1995.

Figure 6 is a section of a record taken during the herring fishery at Denman Island B.C. during February 1995. The instrument is again bottom mounted in about 50 m water depth, pings once per second and stores the average of 10 pings. The record shows the nocturnal migration of strong individual reflectors superimposed on a weakly reflecting bottom layer. The surface echo is obscured by bubble clouds in this presentation, an indication of breaking waves. The strong vertical signals on the extreme right are from mammals, probably sealions or seals, diving close to the transducer; note the short scale internal waves in the lower layer generated by the intrusion of the large mammals. Figure 7 is an example of the very strong signals from schooling herring.

The persistent bottom layer provides flow visualisation for a variety of oceanographic phenomena. For example, advancing density fronts are clearly outlined as the low lying layer is raised above the intruding interface. Figure 8 shows an interesting example of what appears to be the profile of a solitary wave passing the transducer, suggesting that the fluid containing the weak reflectors is itself stably stratified.

FUTURE DEVELOPMENTS

The existing system has considerable potential for development. The self-contained nature of unit has the technical advantage of being relative free from unwanted noise arising from local electrical and acoustic interference. The high quality of the resulting recorded data is well suited to digital processing. At present, the rapid ping rate necessary to monitor fast moving targets conflicts with the averaging requirements for long term monitoring. The received acoustic signals consist of sharp returns from individual scatterers superimposed on a more diffuse background. In many applications, it is the small subset of individual targets which is of interest; however, their sampling necessitates high recording rates, which rapidly expends the available memory. On the other hand, in applications where it is the background which is of interest, long term averaged records are contaminated by strong individual targets.

The proposed solution is to extract selected returns from the background on a ping to ping basis in real time, and store these in a data file separate from the long term averaged residual background returns. In cases where only echoes from fish are of interest, lowering the frequency would eliminate much of the background information, and a simple conditional sampling data compression scheme could be employed; this would be appropriate for a dual beam unit.

The increased total capacity of modern hard drives, combined with their superior mechanical characteristics, makes it practical to expand the memory in excess of 500 Mb. When combined with the internal processing outlined above, many months of continuous high quality data could be collected.

SUMMARY

A simple battery powered digital echo sounder has been designed and built which provides the capability of recording for extended periods of time at a fixed location. Deployments under a variety of conditions, ranging from several months under arctic pack ice to two weeks in a fast flowing river, demonstrate the value of such extended records in linking together biological behaviour and oceanographic phenomena.

Although it is not claimed that the present instrument can "count fish", it provides a useful extension of monitoring techniques. The inherent low noise levels of the self-contained configuration, combined with advances in low power consumption computing and storage technology driven by the needs of the laptop computer, hold out the promise of a suite of high precision, quantitative instruments.

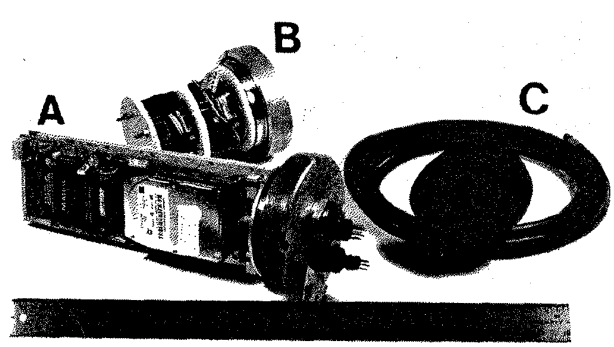

Figure 1. WASP components.

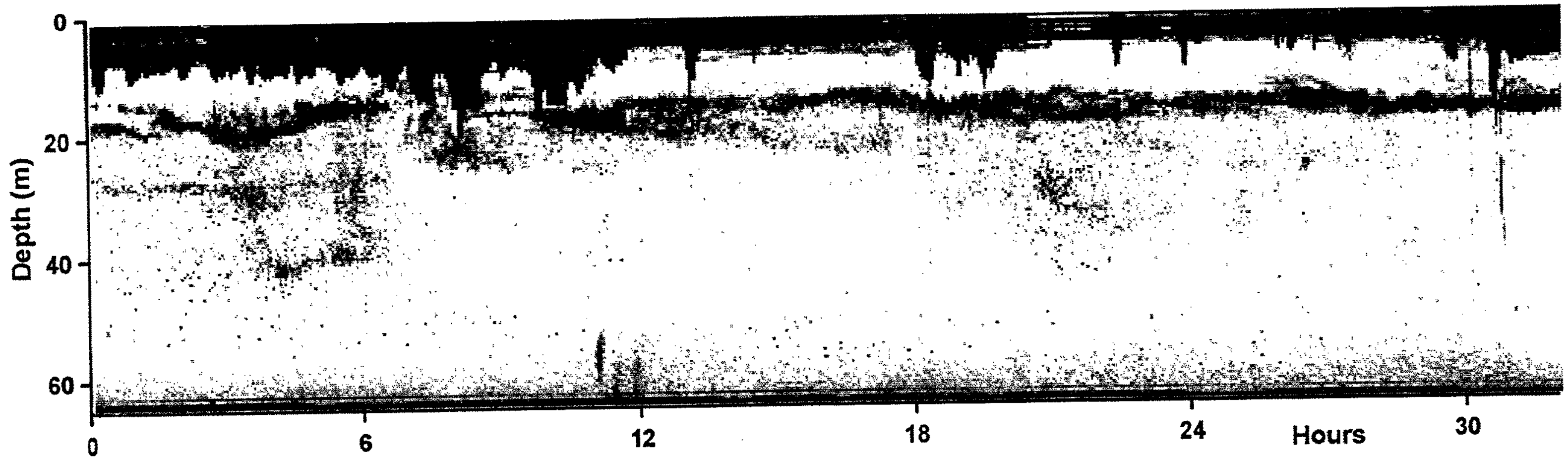

Figure 2. Plankton beneath pack ice, Beaufort Sea, July 16, 1991

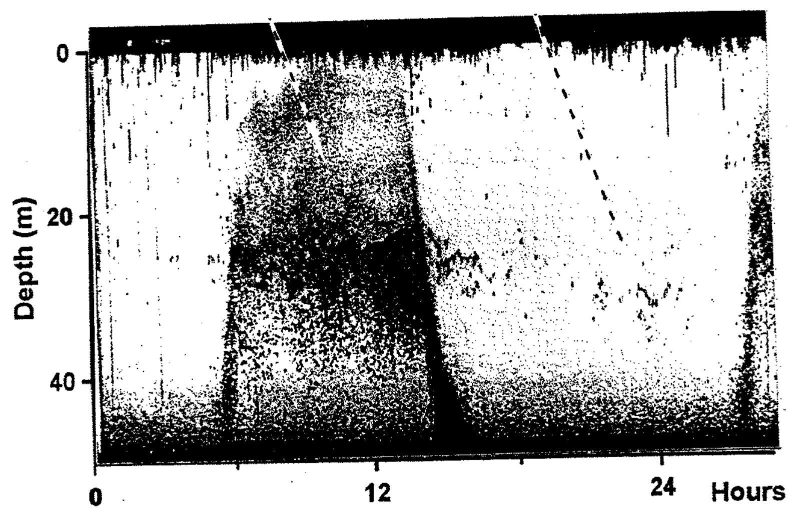

Figure 3. Mysis shrimp, Kootenay Lake, B.C.
20:1 time compression.

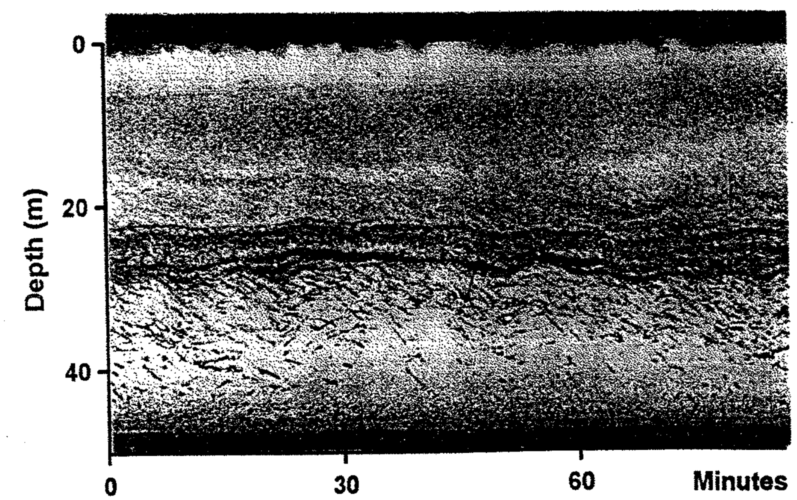

Figure 4. Mysis shrimp, Kootenay Lake, B.C.
Full resolution.

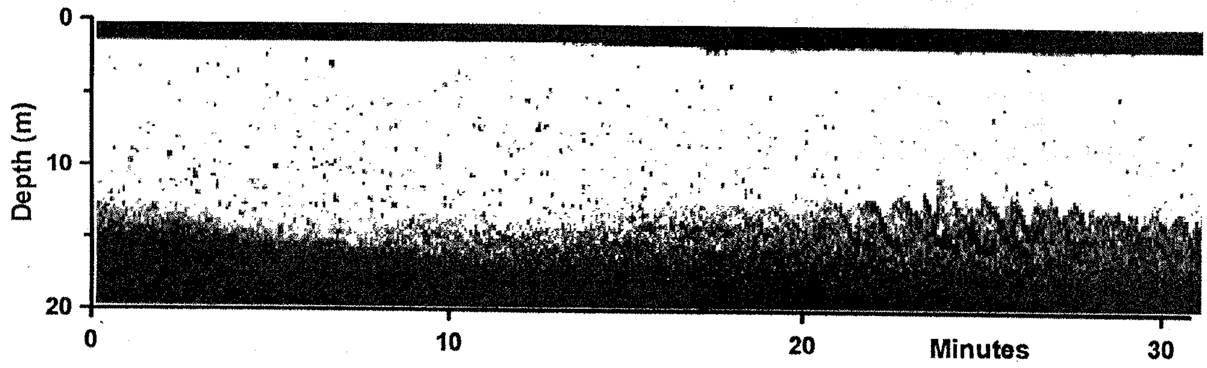

Figure 5. Retreat of the saltwedge, Skeena River, B.C.

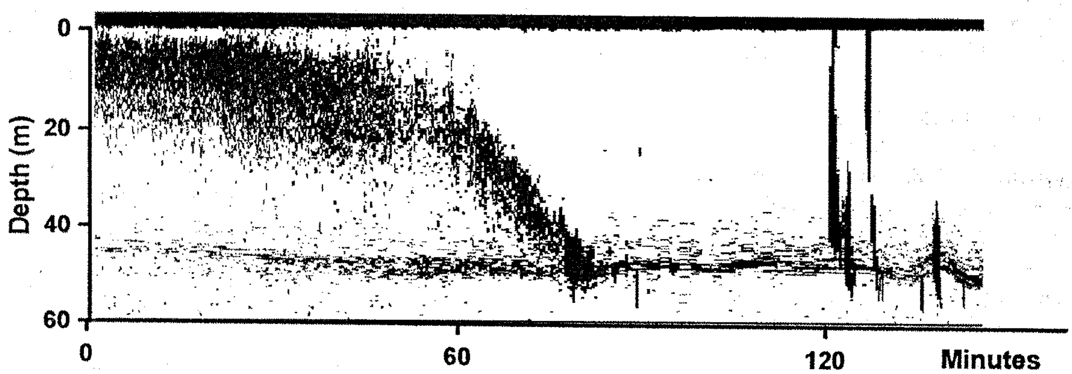

Figure 6. Early morning descent of strong reflecting layer.

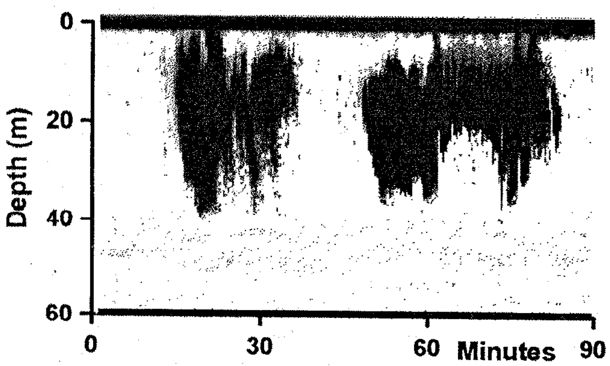

Figure 7. Schooling herring, Denman Island, B.C.

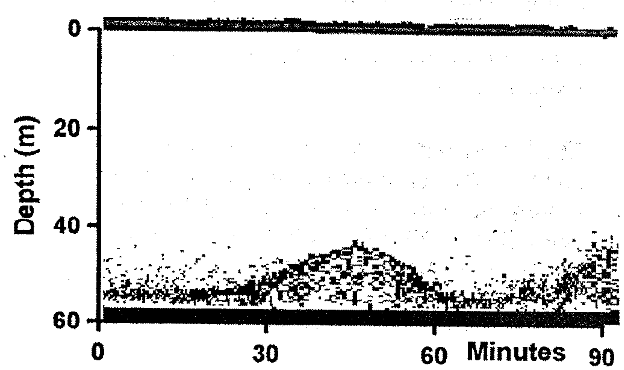

Figure 8. Solitory wave profile.