

## **The Moving Vessel Profiler (MVPI: in-situ Sampling of Plankton and Physical Parameters at 12 kts and the Integration of a new Laser/Optical Plankton Counter.**

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### **Introduction**

Long-term monitoring of our coastal waters and a continuous maintenance of resulting databases are a primary task at the Bedford Institute of Oceanography i) for studying the long-term effects of climate changes on our coastal waters and ii) responding to queries from clients (e.g. aquaculture & offshore petroleum industries) for environmental information. Our dwindling shiptime resources have always been the limitation to sampling physical and biological parameters with high spatial resolution over our broad coastal scales. The CTD (conductivity, temperature & depth) has been our prime tool for measuring physical parameters. The simultaneous requirement of water samples with CTD profiling typically restricts the operation to a ship on-station thereby restricting the areal coverage achievable with limited shiptime. Straight CTD sampling can be achieved by mounting CTDs on towed platforms such as Batfish (Dessureault 1976) which can be towed at 8-9 kts in an undulating pattern providing CTD information on vertical and horizontal spatial scales.

Sampling zooplankton is more difficult since plankton nets are required and can only be towed at 1-2 kts. Recently it has been possible to sample zooplankton (size and abundance) with towed optical plankton counters (OPCs) at speeds up to 10 kts providing real-time information over broad coastal scales ( Herman 1992). Plankton net sampling is still required for ground-truthing and calibration but can be considerably minimized by the use of OPCs.

We describe here the Moving Vessel Profiler (MVP), instrumentation and methodology for sampling from a vessel underway at 12 kts to depths of 200 m based on the original technology Dessureault and Clarke (1994). The principles of operation/deployment and design of the MVP (winch and towed fish) are described here, including results from a recent Scotian Shelf survey. In the area of plankton sampling we describe a new laser-based optical plankton counter (LOPC) replacing the first generation of optical plankton counters. The new LOPC mounted on the MVP minimizes coincidence counts and measures the shape outline of larger zooplankton. The design and principles of operation

of the LOPC are described here including data results from a recent survey. The MVP and LOPC were developed in partnership between the Bedford Institute of Oceanography and industry; Brooke Ocean Technology Ltd. and FOCAL Technologies Ltd. both in Dartmouth, N.S., Canada.

### **Moving Vessel Profiler**

#### **Operational Principle:**

The operational principle of the MVP is shown in Fig. 1. The hydrodynamic fish, weighing 100 lbs in water and constructed from aluminium, is released from the stern of a ship underway at 10-12 kts. The fish 'free falls' at an average rate of 3.7 m/sec in the upper 50m surface layers while reaching a maximum controllable depth of 200-250 m with a final rate of 2.8 m/sec. During the 'free fall' period of approx. 60 sec., about 530 m of cable were streamed from the ship in the configuration shown in Fig. 1. Upon reaching the desired depth, the fish is recovered to within 30 m of the ship's stern and re-released into another cycle.

#### **Design:**

The winch/handling system is shown in Fig.2. The winch/handling system and hydraulic power is entirely self-contained (electric motor, winch, hydraulics & reservoir) and requires an electrical power source (440 VAC). Operation of the system is controlled by a single lab-based PC. The hydraulic power source is a closed loop variable displacement pump used to control the winch, rotating boom and release of the spring-applied brake. The hydraulic pump is powered by a 10 HP electric motor. The heart of the handling system is a radial piston hydraulic motor capable of true 'freewheeling'. Retracting the motor's internal pistons provides near-frictionless rotation and rapid payout of cable. The cable drum is fitted with a Lebus shell and is configured such that the fleet angle from the first sheave block, situated directly above the drum at the boom elbow (Fig.2), is conducive to natural self-spooling. The first sheave block also contains magnetic quadrature encoder sensors used to monitor cable payout and a instrumented clevis pin used to monitor cable tension. Located at the end of the boom is a counter-balanced flagging block designed to accommodate the motion of the ship, as well as cable and boom rotation. An emergency stop switch is incorporated into the flagging block.

The 4-conductor electromechanical tow cable is constructed from braided KEVLAR and has an outside diameter of 0.24" diameter and a breaking strength of 2200 lbs. Our maximum operating loads are about 20% of breaking strength. Overall length of the cable is 630 meters. Critical positions along the cable are monitored using an inductive proximity sensor located at the boom elbow. This sensor detects the passage of stainless steel sleeves attached to the outer jacket of the cable. Two sleeves are used near the end of the cable to 'slow & stop' recovery of the fish as it approaches the ship. Four closely-spaced sleeves at the front of the cable are used as an emergency stop to indicate a near-empty drum.

#### **Control:**

At the core of the control box in Fig. 2 is an Onset Model-8 microcontroller which is used to control the 440 VAC starter & motor and all electromechanical solenoids associated with hydraulic control. The Model-8 also samples and telemeters the winch-sensor data, such as cable payout, tension etc.. Linked to Model-8 is a lab-based Pentium PC which uses a LabWindows environment i) to provide high-level control for the winch via the Model-8 and ii) to monitor all engineering and sensor data using a real-time display. The PC cable link also powers the oceanographic sensors in the fish where data is telemetered from the fish sensors directly to the PC for display and storage. The system can also be controlled manually from a control box/joystick located on the MVP frame itself.

#### Fish & Sensors:

Fig. 3 shows the MVP fish constructed entirely from aluminium and its sensor payload. The main design criteria for the fish required a weight of 100 lbs in water and that it 'free fall' at maximum rate of 4 m/sec at a tow speed of 10-12 kts while reaching a maximum depth of 200 m. Sensors mounted in the fish consist of a FSI (Falmouth Scientific Inst. Model-MCTD-DBP-S) CTD and a WETStar fluorometer mounted in the tail of the fish for easy access. The CTD temperature and conductivity sensors protrude outside the fish in open flow but are also protected by the tail fins. The LOPC is mounted centrally and accepts water flow from a 7 x 7 cm aperture/tunnel at the mouth of the fish. A side access panel allows installation/removal of the LOPC from the fish.

#### Profiling:

Fig. 4 shows the descent/ascent rates of the MVP tested in Scotian Shelf waters in the fall of '97. Upon release of the fish at a depth of about 6-7 m at tow speeds of 8-9 kts, it is seen to achieve its maximum descent rate of a 3.7 m/sec about 7-8 m later at a depth of about 14 m. Cable drag eventually slows the fish to a rate of about 2.8 m/sec as the fish approaches a depth of 200 m. On this profile the fish achieved a maximum depth of 250 m as seen from the depth trace. The ascent and recovery of the fish is about 3x longer than descent period. The profiling mode is selectable according to several criteria; i) the fish depth, ii) the fish height above bottom, and iii) the cable out. Our most common mode of operation is the fish height above bottom allowing optimization of spatial sampling.

A major requirement at the Bedford Institute is the seasonal sampling of 150 km transect (the Halifax Line) across the Scotian Shelf. The data required are sampled with a standard suite of instruments; a CTD, fluorometer (measuring chlorophyll fluorescence) and an optical plankton counter, the latter supplemented by occasional plankton net sampling on station. The Halifax line was sampled continuously by the MVP at 8-9 kts on the Parizeau cruise and the corresponding depth traces are shown in Fig. 5. Continuous performance was obtained with the MVP over a distance of 150 km while sampling some 100 profiles. Data losses that appear in some traces were due to the LOPC telemetry integrated with the CTD which occasionally lost data (approx. 3-4%) in regions of high zooplankton counts. Notwithstanding, the MVP cycled without flaw and the sampling tow proved the utility of the MVP in providing us with rapid sampling underway.

## Laser Optical Plankton Counter (LOPC)

### Operational and Measurement Principle:

An illustration of the operational principles of the LOPC is shown in Fig. 6. A laser diode mounted with a line generator produces a line beam of about 1mm width at a wavelength 670 nm. The emerging beam is focussed parallel by a cylindrical lens and then reflected 90 degrees using a mirror. The resultant beam of cross-section 1 x 34 mm is directed through an acrylic window into the seawater medium where it traverses the sampling volume over a 7 cm path. The beam is then reflected back via a prism along a path directly below the emerging light beam. The resultant cross-sectional area sampled normal to flow is defined as 7 x 7 cm. The returning beam then passes through an interference filter and impinges on a 35 element photodiode array (1 x 4 mm per element).

The output of the photodiode is multiplexed and digitized at sample rate of 1 Mhz by a digital signal processor (Texas Instruments, Model TMS320CS0). A number of software algorithms in the DSP monitor the activity of the photodiode by 'tracking' the passage of all plankton particles above the smallest detectable size of approx. 50 microns. At a scan rate of 1 Mhz, a small particle traversing the beam at a speed of 12 kts will produce 5-6 data measurements adequate for accurate measurement of size. The size of each particle is measured as simply the maximum signal produced at the photodiode. Particles larger than 1 mm overlap both the beam and adjacent elements and therefore by 'tracking' the passage of such large particles or occluded elements, we are able to combine all the information using the DSP to provide a shape outline of the particle. Examples will be presented.

### LOPC Probe:

The basic configuration of the LOPC optical geometry was installed in a two-component underwater probe consisting of a tunnel and pressure case shown in Fig. 7. The LOPC probe is approx. half the width of its predecessor (the OPC) and contains only 4 sealing surfaces; 1) the acrylic window, 2) a side access cover, 3) a back access cover, and 4) an underwater connector. Each sealing surface utilizes 2-3 'O' rings for increased reliability. The probe is constructed entirely from aluminium and the tunnel is separable from the pressure case.

### Data Results:

Figure 8 shows the size distribution of plankton measured with the LOPC lowered on station (at approx. 1 m/sec) in the Emerald Basin south of Halifax NS. Three depth ranges are plotted corresponding to the surface and deep basin layers. The 3 distributions show distinct differences in shape. The deep layer contain larger plankton typically *Calanus finmarchicus* Stages III - V where were clearly indicated by the separate peaks (heavy lines) above 1 mm in size.

Measurement of flow speed is important to the user as it is utilized i) to estimate water volume and hence particle densities and ii) to measure the shape outline of plankton. Flow

velocity is estimated simply from the measured transit time of small organisms passing over a known distance of each photodiode element (1mm). Figure 9 shows the measured flow speed through the LOPC while towed horizontally over a range of speeds from 2-10 kts. The estimated standard deviation is approx. +1- 10% over the entire velocity range.

Figure 10 shows the shape outline of zooplankton *Calanus finmarchicus* stage V measured in the Emerald Basin. The outline indicates the length of the copepod to be approx. 2 mm in length with various appendages, such as antennae.

Figure 11 shows profiles of zooplankton as measured by the LOPC mounted in the MVP. The profiles correspond to the measurement along the Halifax Line shown in Fig. 5. Only the 'down' profiles are selected since the sampling speeds average 3.3 m/sec and are within the measurement range of the LOPC. During the 'up' or recovery profiles, the instantaneous sampling speeds may exceed 5 m/sec bordering the detection limit of the LOPC. The profiles show a zooplankton layer situated within a 75 m bottom layer in the Emerald Basin, a typical feature that is measured annually in our surveys.

### **SUMMARY**

The fully instrumented Moving Vessel Profiler will become a standard sampling tool for the BIO long-term monitoring program. Its ease of deployment will enable it to be utilized on a large variety of vessels. Once automated the MVP requires a single operating technician located by a lab-based PC. The MVP operation is a passive one and it can be deployed in the midst of other 'opportunity' sampling programs and even while steaming 'enroute' to the stations of other programs. It is intended to install the MVP on all of our 'program vessels of opportunity' with the intent of securing as much 'data of opportunity' as possible within our coastal waters.

### **REFERENCES**

- Dessureault, J.-G.. (1976) 'Batfish' a depth controllable towed body for collecting oceanographic data. *Ocean Engineering*, 3:99-111.
- Dessureault, J.-G. and R.A. Clarke (1994) A system to collect temperature and salinity from vessels underway. *Proceedings of the IEEE Oceans '94 Conference*, pp. 397-401, IEEE, New York.
- Herman, A.W. (1992) Design and calibration of a new optical plankton counter capable of sizing small zooplankton. *Deep Sea Research*, 39:395-415.

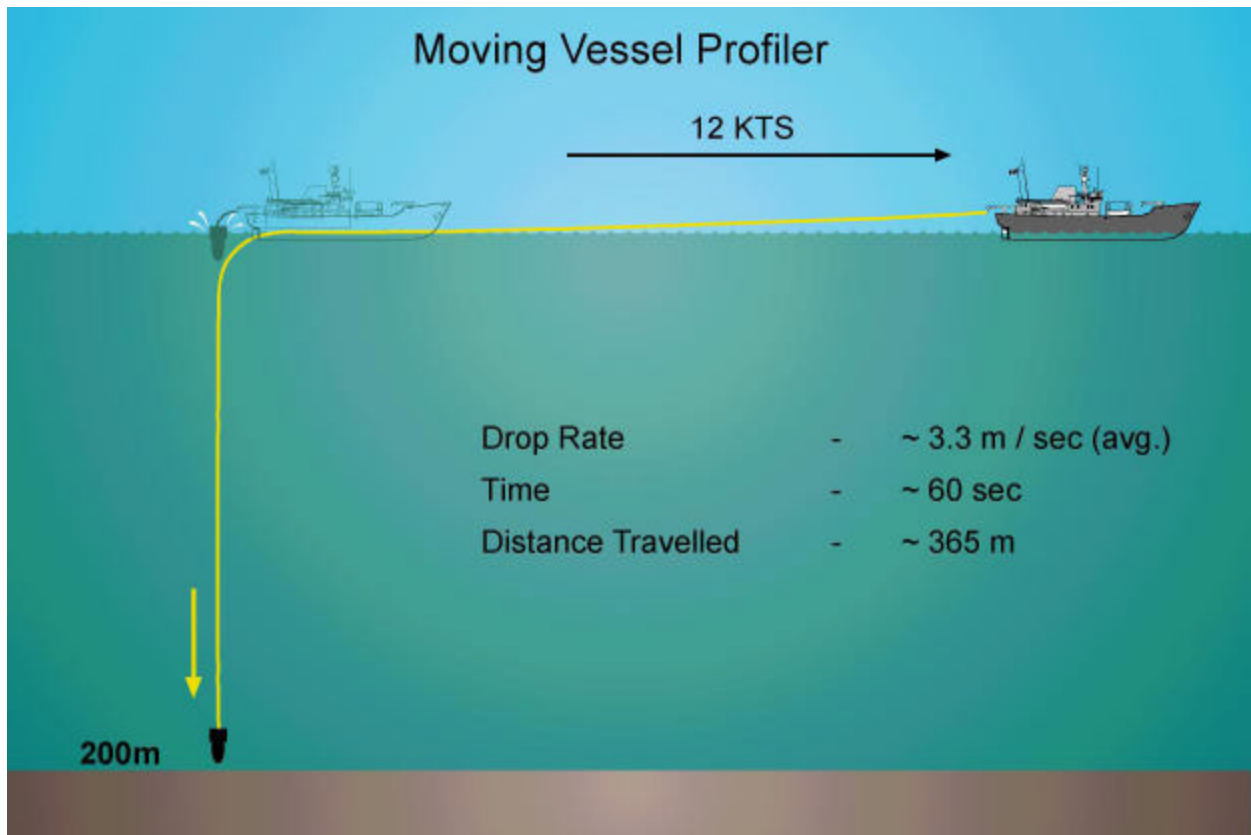


Fig.1 Deployment of the Moving Vessel Profiler. The fish 'free falls' to a depth of 250m in the configuration depicted above, is recovered by winch control and is subsequently re-released.

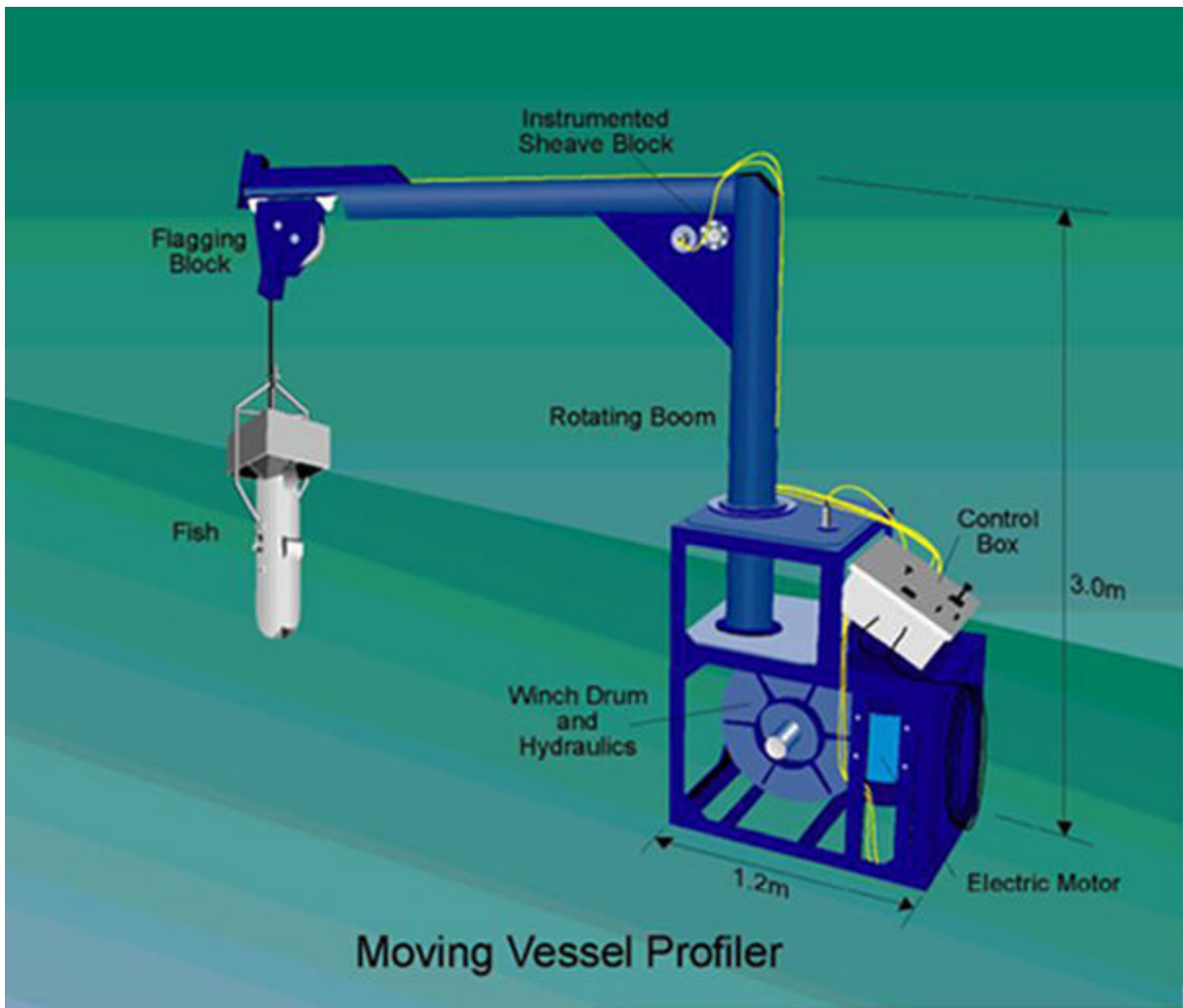


Fig. 2 The MVP winch/handling system is entirely self-contained including hydraulics and reservoir. The system can be operated from a lab-based PC or manually controlled via a control box on the frame.

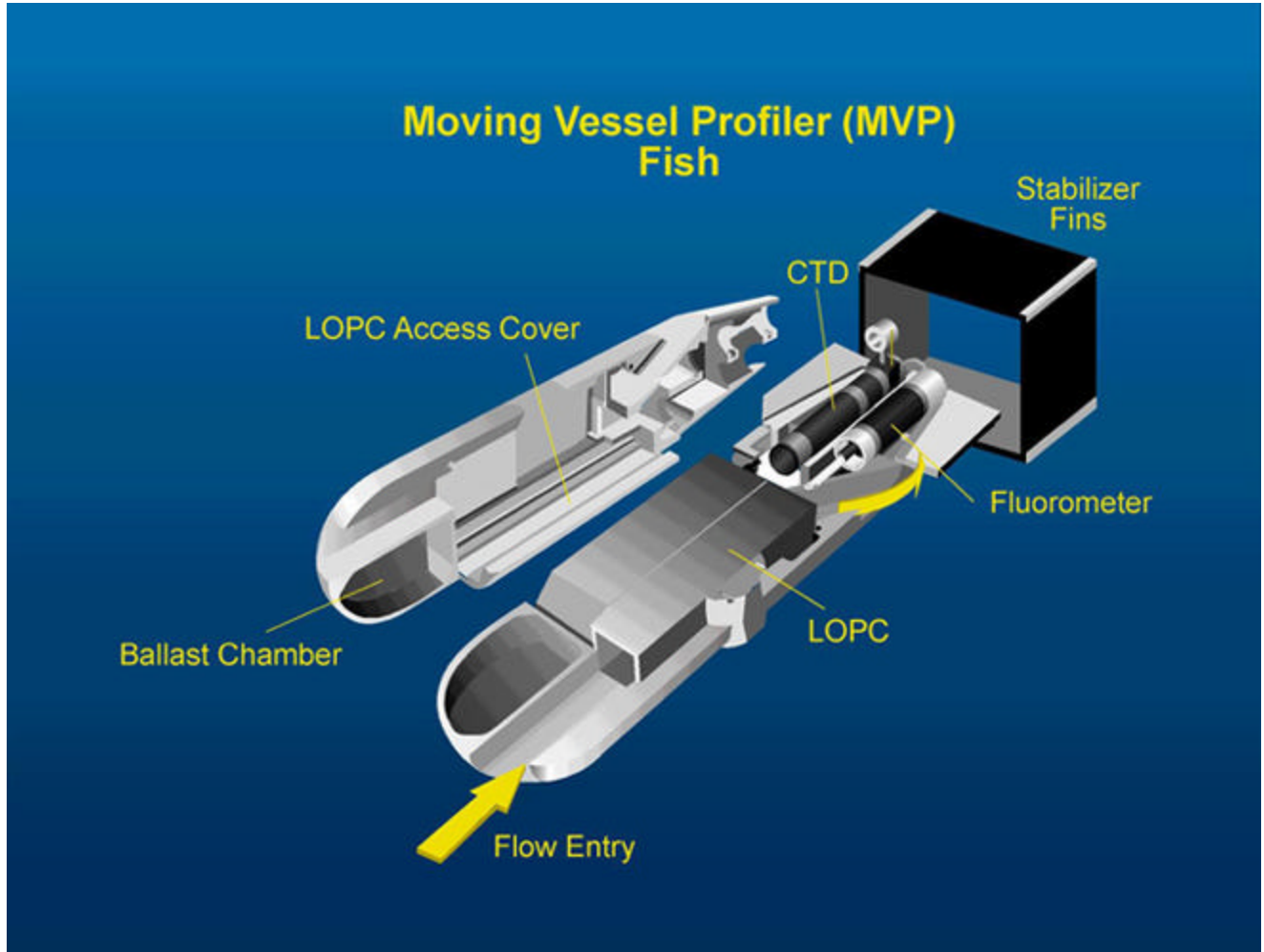


Fig. 3 The MVP aluminum fish with split halves opened illustrating the mounting of sensors, CTD, fluorometer, and Laser-OPC.

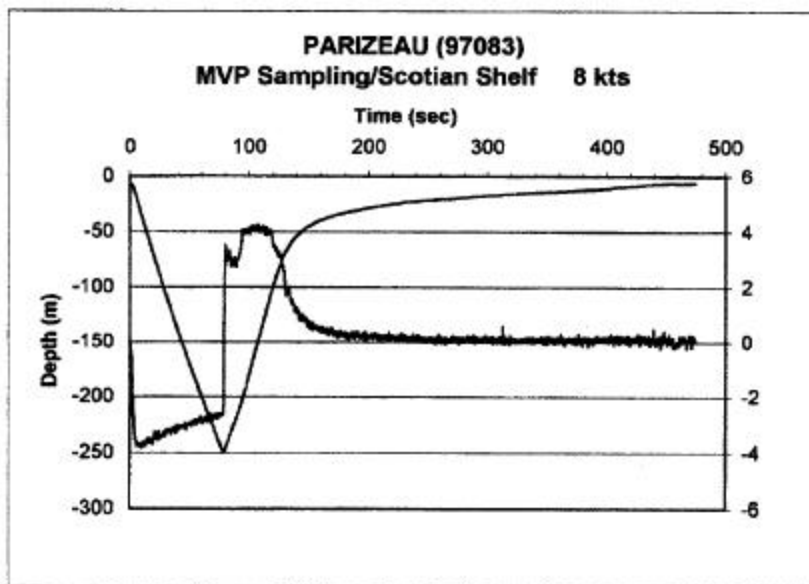


Fig. 4 The descent and ascent rates of the fish from an MVP cast at 8-9 kts. The resultant depth trace is also shown.

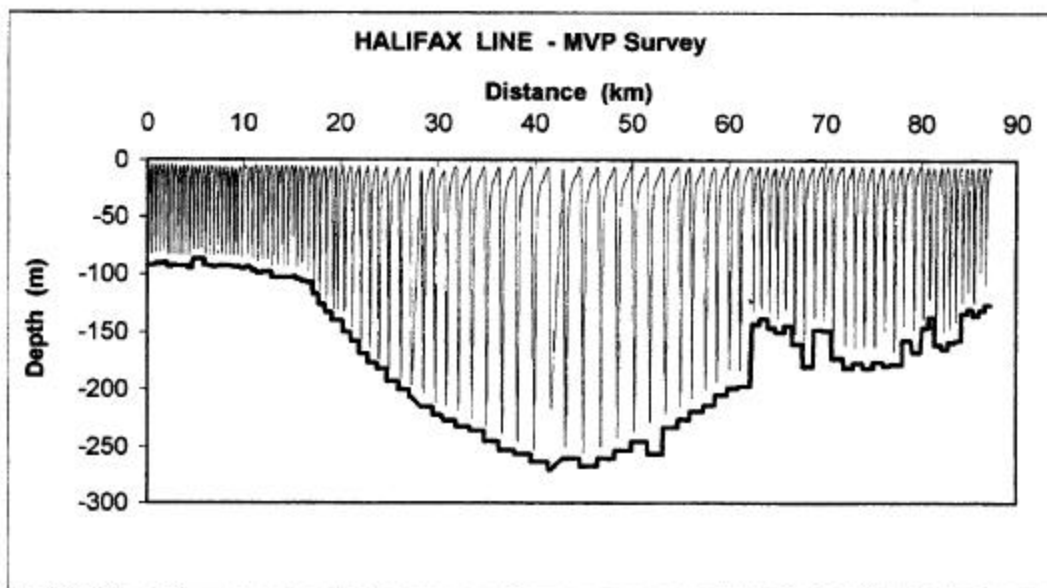


Fig. 5 Depth traces from an MVP survey along the Halifax line at 8-9 kts. The fish sampled to a depth above bottom of 10-15 m.

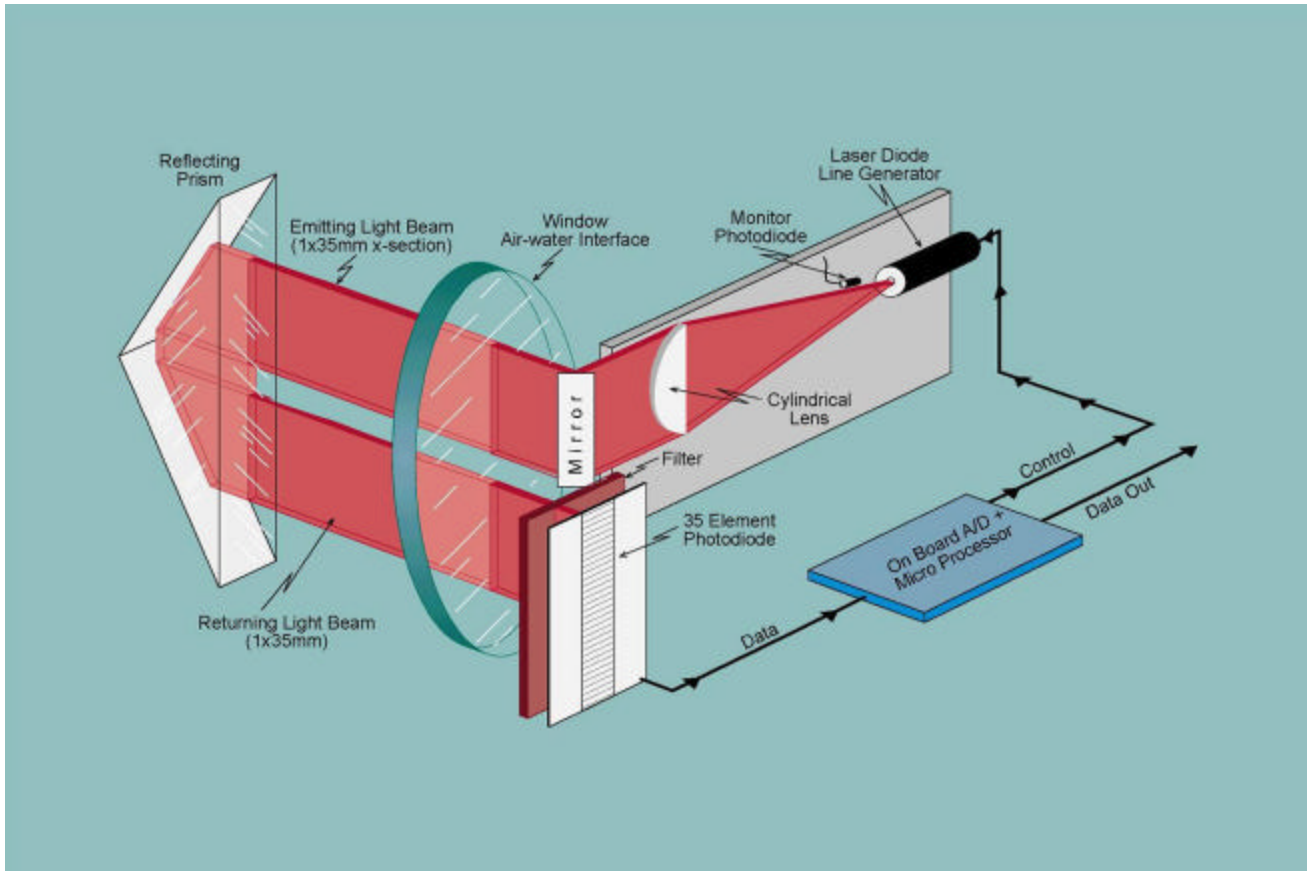


Fig. 6 The operational principle of the laser optical plankton counter. The laser beam subtending a cross-section of 1x35 mm is directed into the seawater sampling volume and reflected back to the multi-element detector.

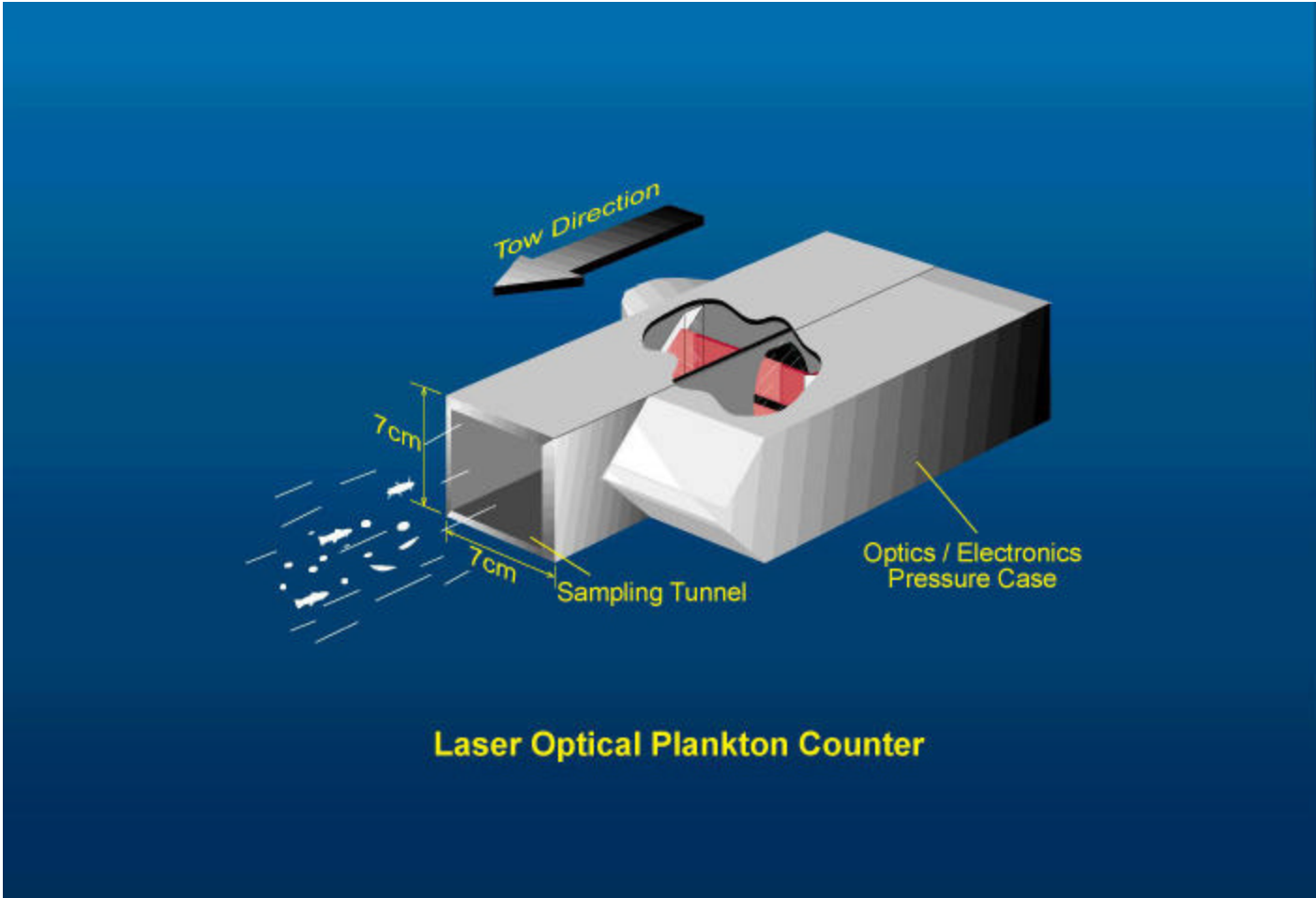


Fig. 7. The LOPC probe with cutaway showing beam orientation. The probe is fabricated from aluminum comprising a pressure case and sampling tunnel.

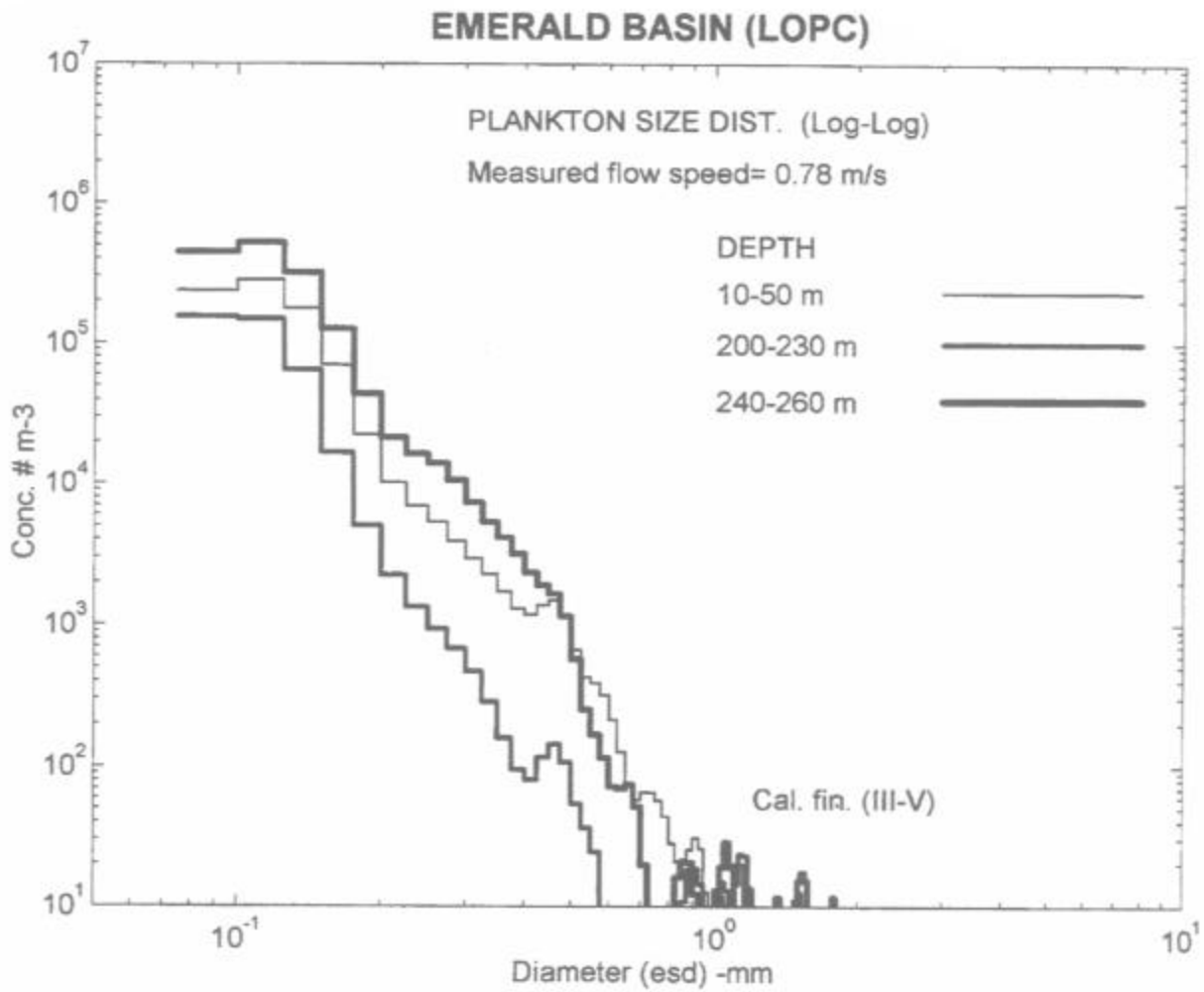


Fig. 8 A size frequency distribution of plankton sampled by the LOPC in Emerald Basin.

Fig. 9 Flow velocity estimates measured by the LOPC towed at various speed ranges from 2 to 10 kts.

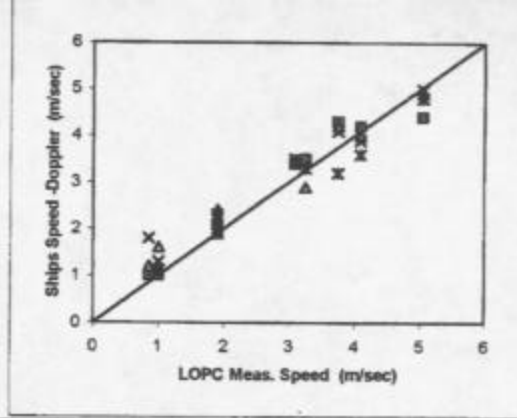


Fig. 10 Examples of the shape outline of a copepod (*Calanus finmarchicus* stage V) as measured by the LOPC. Appendages can also be seen.

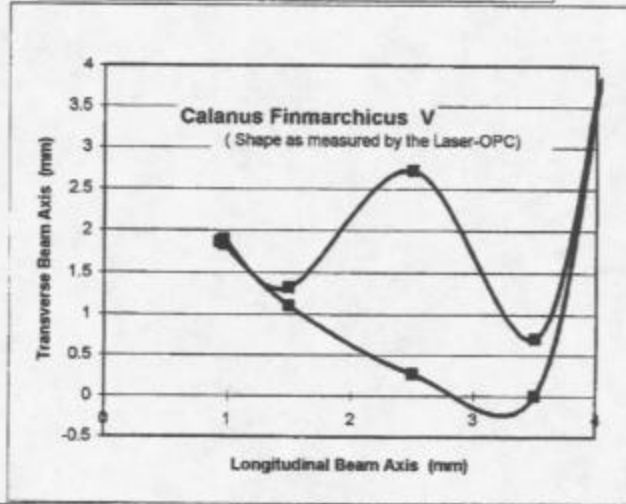


Fig. 11 Sample plankton profiles measured by the LOPC mounted on the MVP and towed at 8-9 kts along the Halifax line.

