FISHERIES RESEARCH & DEVELOPMENT CORPORATION

UNIVERSITY OF TASMANIA

Final Report, FRDC project 95/085 (reference H0007772)

Development and testing of an algal bloom monitoring buoy for the Australian aquaculture industry: proof of concept

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Abstract

A prototype of an automatic algal monitoring buoy was developed for unattended operation in shellfish and finfish farm waters. The instrument employs novel antifouling and self-calibration strategies (subject to a provisional patent) based on a battery-powered actuator extending into the seawater medium at 15 min intervals both a light source and a solid state sensor from a protective PVC cylinder. The optical sensor measures both ambient light and the signal from a high intensity LED light source, with separate readings being taken after travelling through an optical fibre reference path (internal standard) and after travelling through a 60 cm horizontal path of natural seawater. The optical system is suspended at 1 m depth (can be varied) from a float with the systems control and data acquisition system located above water. Financial constraints ($20,000 FRDC budget) prevented us to also implement a radiomodem link to laboratory computer as originally planned. We are now seeking further funds to develop the instrument to a commercial stage (estimated market value per unit Aus $10,000) and extensively test its field performance under a range of environmental and algal bloom conditions.

Background

Damage caused by algal blooms to finfish in intensive aquaculture systems and contamination of shellfish products with algal biotoxins are problems which are increasing in frequency, intensity and global distribution (Hallegraeff, 1993). If not adequately monitored and managed, the economic impacts on Australia's developing aquaculture industry and on both domestic and export markets could be devastating. An example of the first problem is the 1989 bloom event by the golden-brown flagellate *Heterosigma carterae (=akashiwo*) in Big Glory Bay, New Zealand, which killed NZ$ 12 million worth of cage-reared chinook salmon. An example of the second problem is the 1993 New Zealand outbreak of neurotoxic shellfish poisoning by the dinoflagellate *Gymnodinium* cf. *breve* (NSP; 180 illnesses, no deaths) which led to export losses of NZ $ 4.5 million in the first quarter of 1993 and a 25% decrease in domestic shellfish demand (Hallegraeff 1997).

Need

To protect finfish aquaculture there is no alternative to extensive plankton monitoring of the water column. In Tasmania such an industry-funded (SALTAS) effort covering 3 primary , 3 secondary and 7 tertiary sites has been in place since October 1993 (Jameson & Hallegraeff, 1993, 1994). However, the sensitivity of cage-reared finfish is such that even twice-weekly sampling could be insufficient warning and there clearly is a need for a continuous monitoring device.The fish farming industry along the Norwegian coastline thus is presently being protected by a sophisticated environmental monitoring system, MARINET, which uses buoys (cost US $100,000 each) with fibre optical sensors and transfers data by satellites (Dahl & Tangen 1990). An equally sophisticated Tethered Spectral Radiometer Buoy, also relying on satellite data transfer (SeaWIFS), has recently been developed by Satlantic Inc., Halifax, Canada (Cullen et al. , 1997). A much smaller scale approach appears to be more appropriate for the Tasmanian situation, but no comparable monitoring systems are available in Australia except for the water quality monitoring buoy (primarily nutrients) under development by CSIRO Division of Water Resources (Skyring & Johns ,1991).

To protect the Australian shellfish industry, compulsory biotoxin testing programmes are now in place in Tasmania and Victoria, with further programmes under development in NSW, SA and WA. These programmes, run either by State Government Departments of Health or Fisheries, lead to seasonal closures of shellfish farms (up to 6 months in TAS). Knowledge of local factors controlling seasonal algal bloom dynamics and early warning from plankton monitoring programmes (in place in TAS and VIC) can be used, however, to mitigate the impacts on industry by allowing farmers to harvest shellfish before toxin contamination occurs or to relocate stocks to emergency sites (in place in TAS). Research carried out by the principal investigator in the past 10 years indicates that in Tasmania a significant toxic dinoflagellate bloom of *Gymnodinium catenatum* can only develop within a permissive seasonal temperature window (January -June), requiring a rainfall trigger to start it off and needing periods of low windstress for sustained development (Hallegraeff et al, 1995). The addition to the proposed monitoring buoy instrument package of probes recording water column temperature, rainfall and windstress thus could contribute significantly to provide early warning of algal blooms.

When our original FRDC proposal requesting $ 275,573 was awarded as little as $20,000 for "proof of concept ", we were forced to severely limit our efforts and decided to focus on : (1) mechanisms minimising biofouling; (2) optical monitoring strategies; and (3) data acquisition .

Objectives

To improve the sensitivity of current algal watch programmes in Tasmanian waters, designed to protect shellfish and finfish aquaculture by means of frequent microscopic plankton analyses, we aim to develop a small monitoring buoy which responds to sudden increases in algal density as measured by an optical turbidity sensor . This automated monitoring aims to forewarn farmers of sudden outbreaks of algal blooms or the introduction of blooms from other areas.

RESULTS

Mechanisms minimising biofouling

Existing commercial buoy systems available from Oceanor (Trondheim, Norway) and Satlantic (Halifax, Canada) primarily operate in offshore waters and therefore have never addressed fouling problems [except for the addition of slowly dissolving bromide pills; J. Cullen, Satlantic, pers.comm.] . Our antifouling prototype (Fig.1) is based on a battery-powered actuator moving a glass rod (25 mm movement; 1 min out in every 20 min cycle) from a protective PVC cylinder (70 cm long, 15 cm diameter). Incubation trials in a 100 L aquarium tank filled with natural Derwent River seawater have shown no signs of leakage from the seals nor any visible signs of fouling of the glass rod, even after 4 months of exposure (Fig. 2) .

Optical monitoring strategies

The next stage of design has been concerned with examining existing optical monitoring technologies (fluorescence, absorbance, turbidity) and combine these with our antifouling mechanism in a form suitable to the scale of the Australian aquaculture industry (i.e. not relying on expensive satellite transmission as used in the Oceanor and Satlantic buoys). Our first prototype (Fig.3) uses a high intensity, LED light source and solid state sensor to monitor the transmission properties of sea water. This system can readily be extended to also provide spectral resolution. In laboratory experiments we controlled the system directly from a programmable Notebook computer. From extensive calibration experiments in aquarium tanks in the laboratory (path lengths tested 0 to 400 cm), we adopted a path length between light source and sensor of 60 cm to allow for the best discrimination between absorbance by water, dissolved colour and particulate matter (including algae). Experiments using known concentrations of algae such as *Tetraselmis* indicate that the instrument can discriminate between phytoplankton chlorophyll concentrations as small as 0.5 µg /L , and performs satisfactorily in the phytoplankton biomass range of 1 to 10 µg chlorophyll *a* / L typical of most Australian coastal waters and estuaries (Jeffrey & Hallegraeff, 1990). Spiking highly coloured, tannin-stained water with the same range of algal concentrations did not significantly affect the resolution of this optical system (Fig. 4). Subsequently , both the light source and the optical sensor were housed into two separate , 40cm long , waterproof PVC cylinders with battery-operated glass rod actuators as described above. The optical sensor measures both ambient light and the signal from a high intensity LED light source, with separate readings being taken after travelling through an optical fibre reference path (internal standard) and after travelling through a 60 cm horizontal path of natural seawater. While our optical system functions well for the purpose it was designed for, its large size with a weight in excess of 50kg is still cumbersome. Financial constraints prevented us from refining it beyond the stage described here.

Data acquisition

Finally, we turned our attention to systems of control and data acquisition, using an embedded microcontroller which also performs logging and communication functions. We first tested this system by logging windspeed and wind direction readings from a Tasmanian fishfarm site (Aquatas, North West Bay; Fig. 5). Average power consumption is small and in the prototype this has been augmented with a solar panel. The complete instrument including the optical probe has now (June 1997) been deployed in a McGowans dam for careful testing (Fig 6). Unattended deployment periods in excess of 12 months are expected for this prototype instrument. At present the instrument needs only be accessed in order to unload data (able to take readings every 15 min for 42 days). Financial constraints prevented us from implementing the telemetry system (radiomodem link to laboratory computers) as originally planned.

Intellectual Property

Intellectual property relating to the antifouling strategy and optical monitoring using an internal reference optical fibre, as appropriate to the current prototype and pending further development of the instrument, is protected by the lodgement of a provisional patent (FRDC project agreement, clause 7).

Benefits

The results will be of benefit to the entire bivalve shellfish and finfish aquaculture industry and will also be of immediate interest to government agencies responsible for environmental and water quality monitoring . The monitoring buoy system will enhance Australia's reputation as a clean environment for aquaculture production.

Further Development

We are seeking further funds to develop the instrument to a commercial stage (estimated market value per unit Aus $ 10,000) and extensively test its field performance under a range of environmental and algal bloom conditions. A full FRDC proposal to advance this work will by submitted to the Tasmanian Fisheries Research Advisory Board (TasFRAB) in August 1997 for forwarding to the FRDC Board by December 1997.

References

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Staff

Ass.Prof. G.M. Hallegraeff	project leader
Mr C. Ashworth	technical officer electronics
Mrs J.Marshall	technical assistant algal culturing

Final Cost

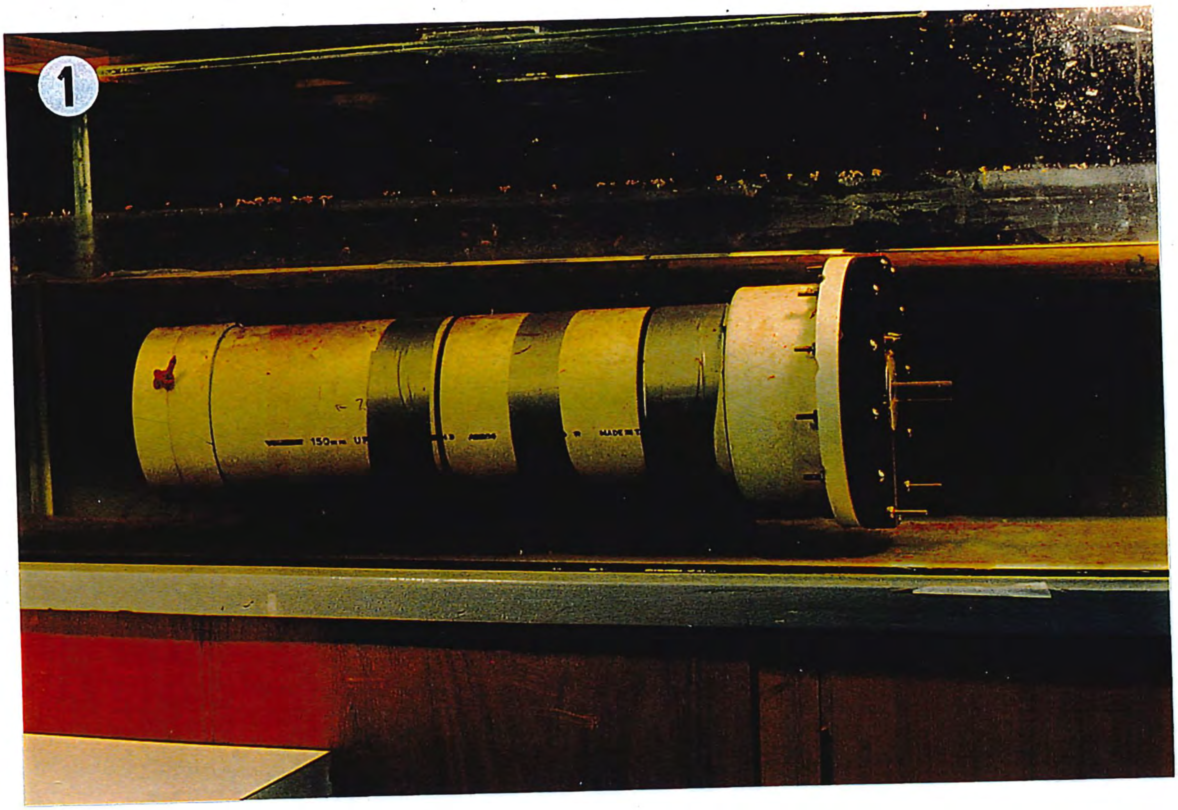
FRDC CONTRIBUTION

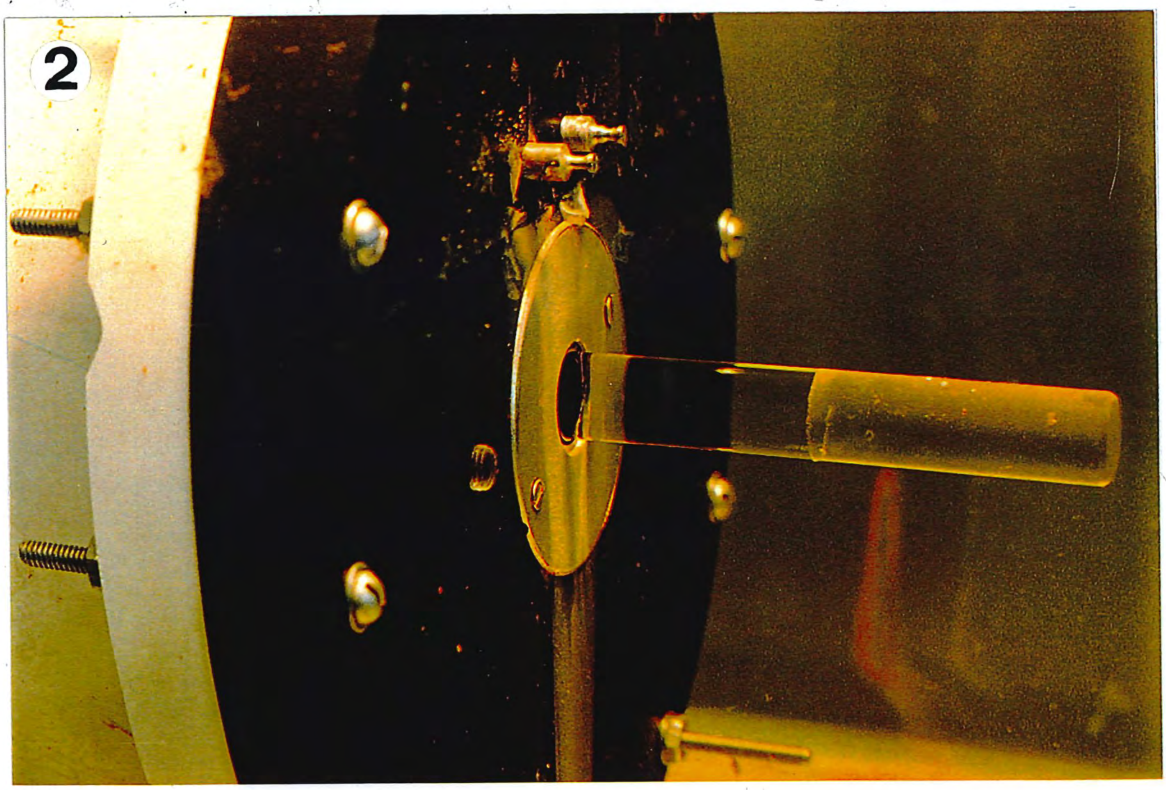
Control electronic development		$6,000
Probe housing		$4,000
Algal Cultures		$1,000
Phytoplankton field work		$1,500
Computer Processing		$2,500
Optical Sensor		$5,000
	TOTAL	$20,000

RESEARCH ORGANISATION CONTRIBUTION

Salaries and On-costs

Ass.Prof. G.M. Hallegraeff	1 month of time	$5,000
Mr C. Ashworth	5.5 month of time	$17,000
Mrs J.Marshall	1 week of time	$1,000
	TOTAL	$23,000





Antifouling strategy

Fig.1. Photographs of first prototype, demonstrating window cleaning and sealing concepts after 4 months operation in a seawater aquarium.

Fig.2. Detail of extended glass probe, demonstrating the clean surface (left) compared to a fouled reference surface (right)

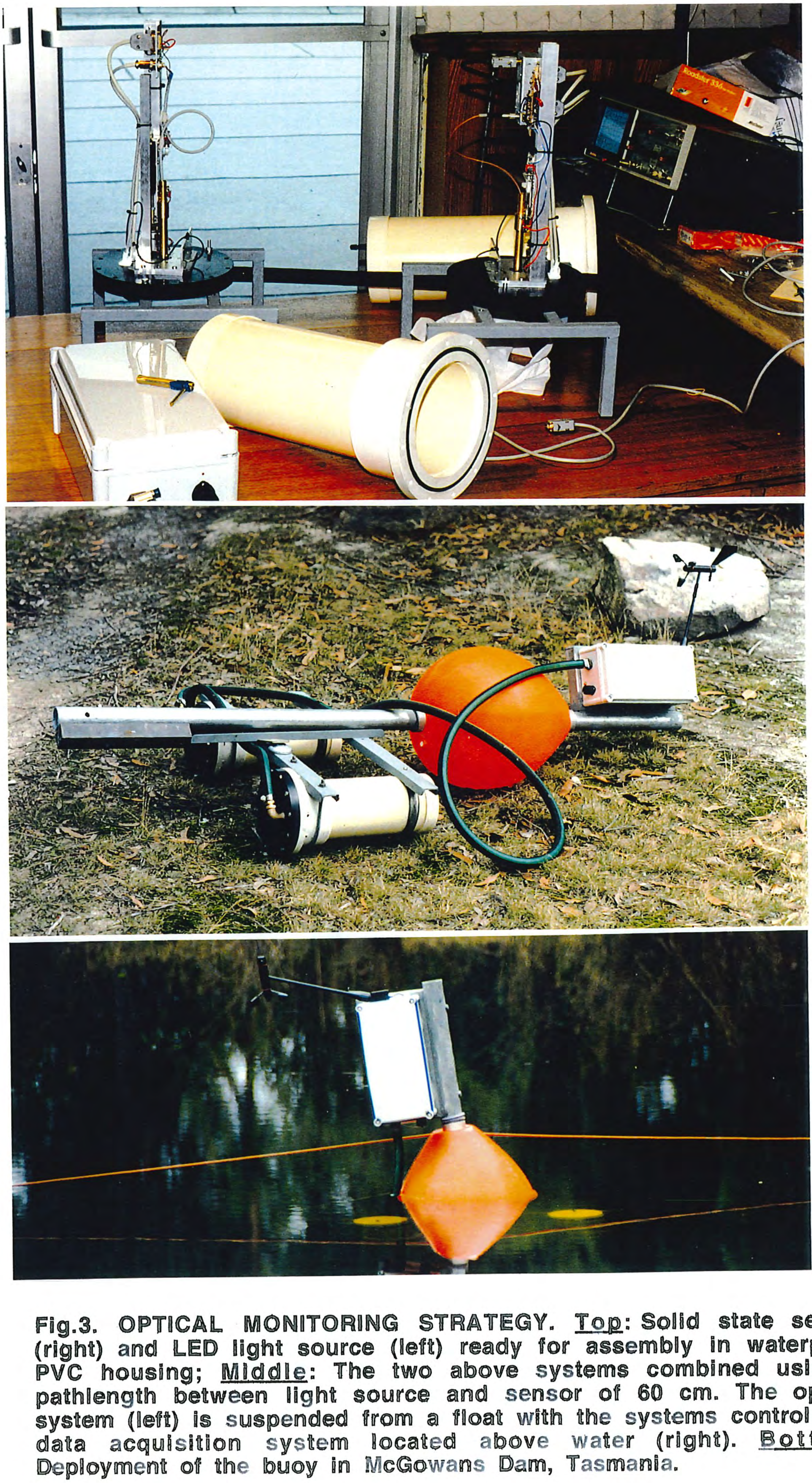


Fig.3. OPTICAL MONITORING STRATEGY. Top: Solid state sensor (right) and LED light source (left) ready for assembly in waterproof PVC housing; Middle: The two above systems combined using a pathlength between light source and sensor of 60 cm. The optical system (left) is suspended from a float with the systems control and data acquisition system located above water (right). Bottom: Deployment of the buoy in McGowans Dam, Tasmania.

Fig. 4a. Performance of the optical system (as % transmission) in the range of 0 to 10 µg chlorophyll a / L using an algal culture of *Tetraselmis suecica* .

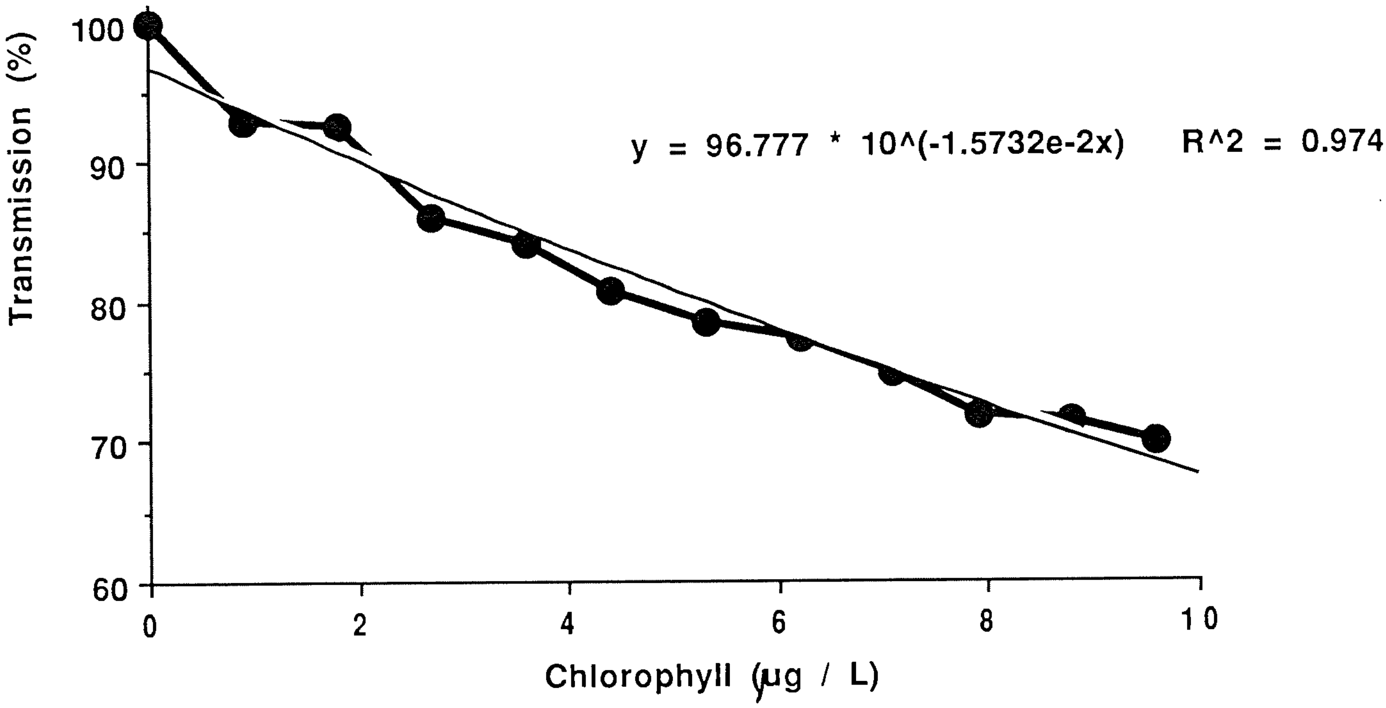
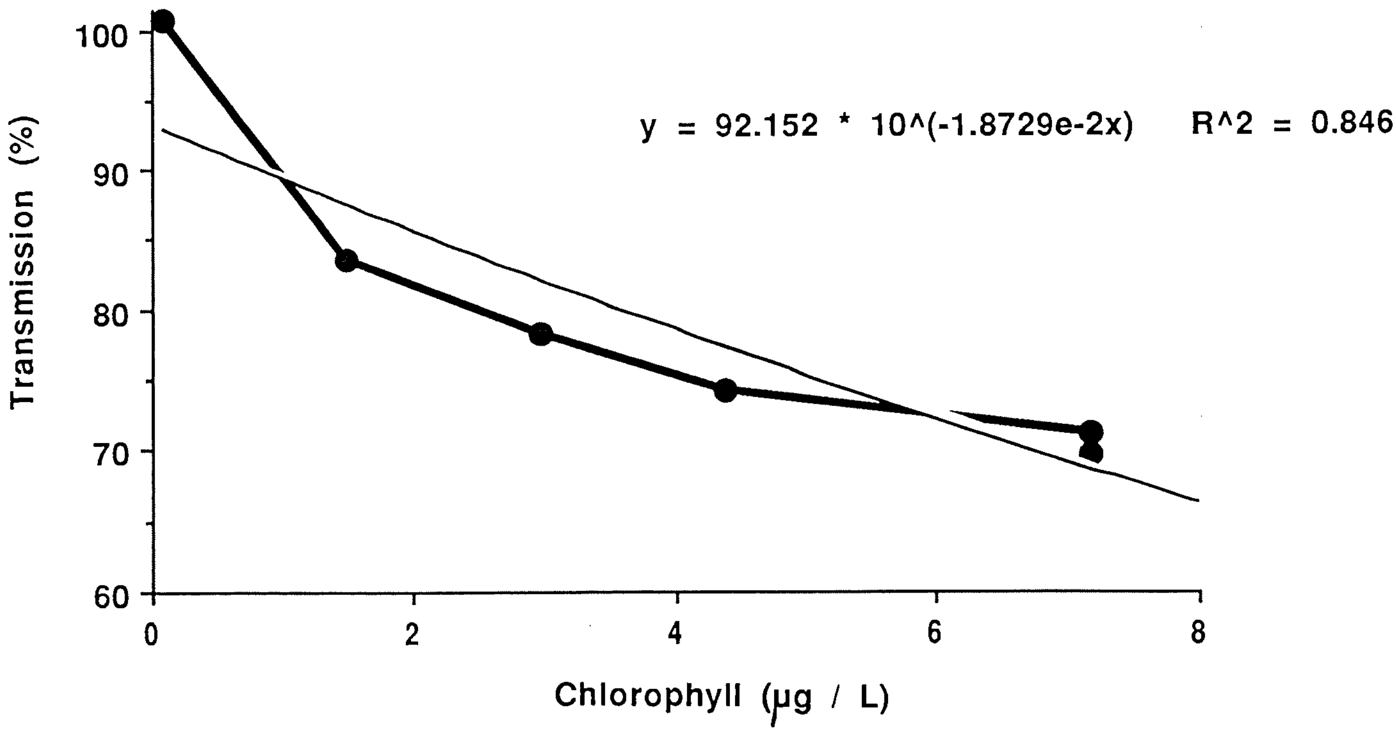
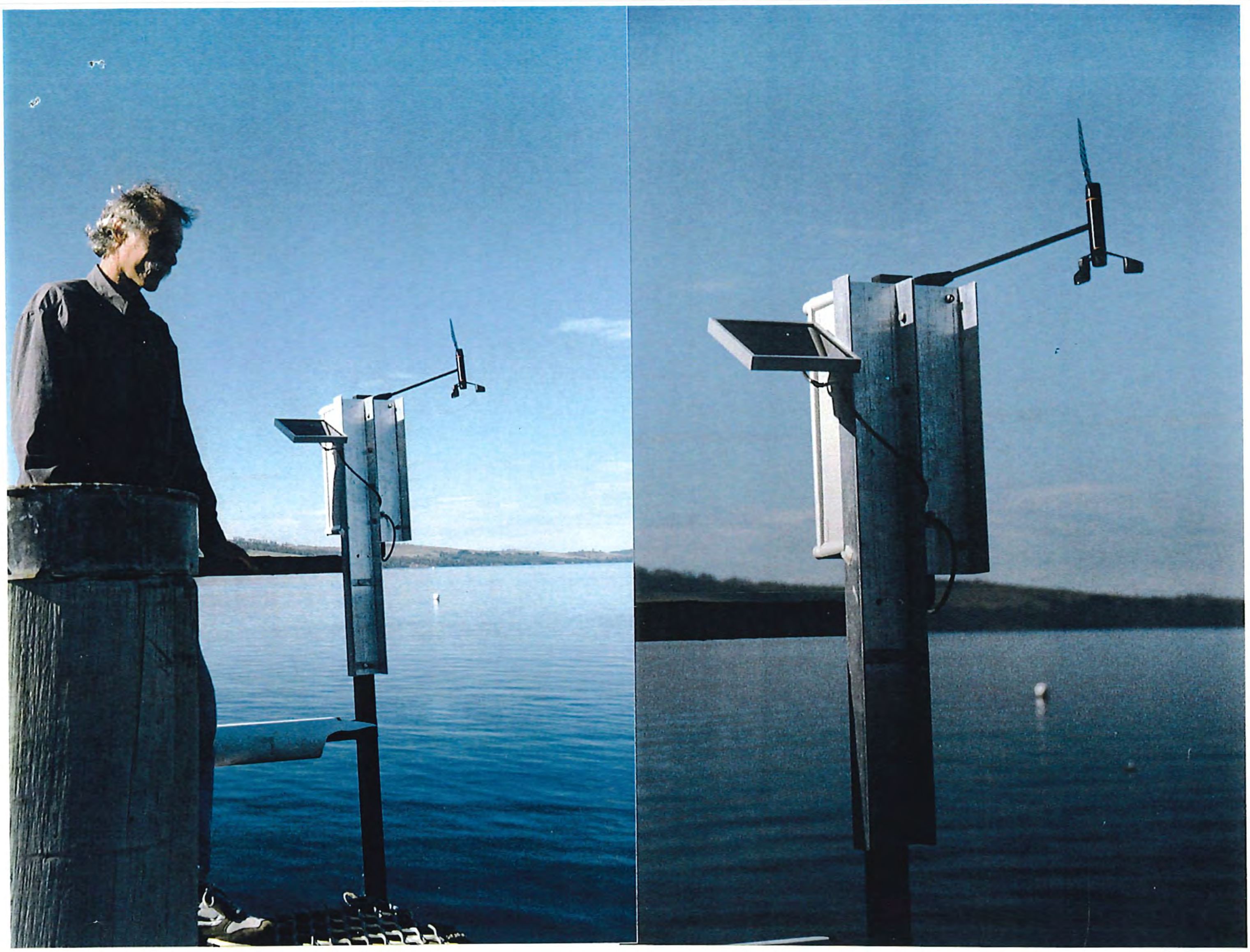


Fig.4b. Performance of the optical system (as % transmission) in the range of 0 to 8 µg chlorophyll a / L using an algal culture of *Tetraselmis suecica* , but added on top of a background of tannin-stained water.





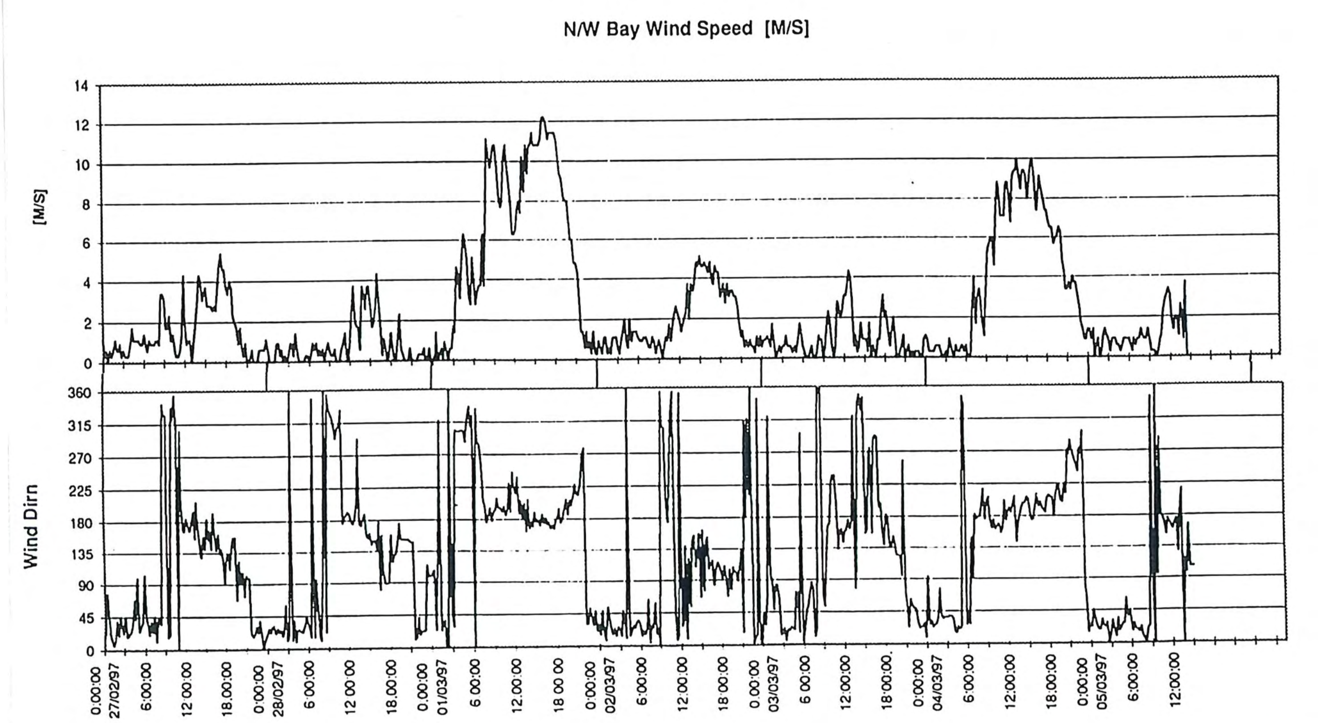


Fig.5. Prototype of data acquisition system, first tested to log wind speed and direction at a Tasmanian fish farm site. Note anemometer and solar panel as auxilliary power supply.

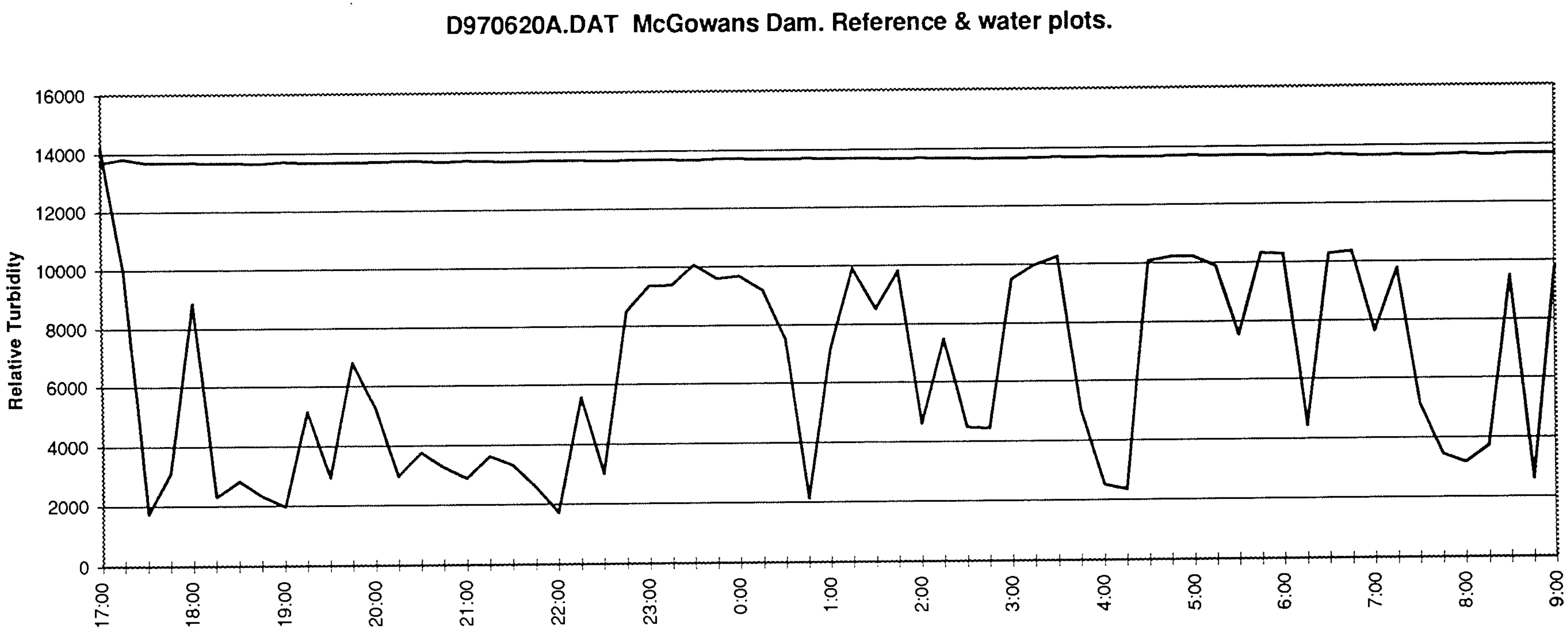


Fig.6. Performance of the monitoring buoy over a diurnal cycle in shallow McGowans Dam. The upper graph is the reference beam while the lower plot is the output from the main light beam. The dips in the lower graph are the result extinction of the light beam by floating weeds and resuspended sediment. The real turbidity signal for this water body is represented by the envelope of maximum readings.