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A CURRENT METER AND A LEVELLER FOR INTERTIDAL SURVEYING

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ABSTRACT

A simple and dependable current meter that can be produced in as many units as required, and a fluid-based leveller for rapid work in awkward places, are described. The current meter works by interrupting a beam of light thus inducing signals in a photodiode. The signals are then recorded on shore. The leveller consists of clear plastic tubing, a reference reservoir and reel, and an adjustable measuring staff. Both instruments can be quickly and inexpensively constructed from ordinary materials. Several applications are described for each instrument.

INTRODUCTION

THERE is a need for inexpensive and therefore expendable current meters, simple enough to make in quantity so that several can be used together in near-shore ecological work. Such meters could be risked during storms, and near rocks and weeds. There is also a need for meters allowing continuous monitoring so that readings can be correlated with other events, such as water levels, wave action, and the oxygen consumption of biota *in situ*. For these reasons I designed and tested the current meter described here, as part of a continuing survey of the ecology of *Clava squamata* (Müller), a naked hydroid (Aldrich *et al.*, 1980).

There is also a need for a simple and rapid method of establishing precise levels on shores. A very small change in level is often correlated with abrupt changes in biota, as witness the marked stratification of lichens, the upper range of algae, etc. Levelling must often be done "around corners" or behind rocks, where line-of-sight methods will not work without great inconvenience. Rain and fog make these methods even more difficult, and they are not convenient for use in rock pools or on rock faces. The leveller described here was improved from a suggestion by Dr F. Jeal, and this instrument has also been used for surveying the distribution of *Clava squamata*.*

MATERIALS AND METHODS

Current Meter

The current meter (Fig. 1, *W*) consists of a plastic propeller (from a child's windmill), (A) affixed to a brass wood screw which drives a plastic gear (C). This gear is glued to a split plastic pipe (occulting rotor, B). As this rotor is turned by the propeller, it occludes a light beam twice in each revolution. This beam is produced by the lamp (K_1, *X*), (an ordinary small 12 volt automobile lamp) and illuminates the photodiode (E_1) that is sealed into the pivot tube (E) with epoxy cement. The pivot tube is made of rigid metal (brass or galvanized iron), the lamp tube (K) is copper, the body (I) and the buoyant top (M) are wooden. The fin (J) and pivot guides (G and H) are aluminium, but brass or copper could be used for all metal parts to avoid electrolysis. The upper pivot guide (G) also forms the gear case to

*See also Baker & Crothers (1987) Ed.

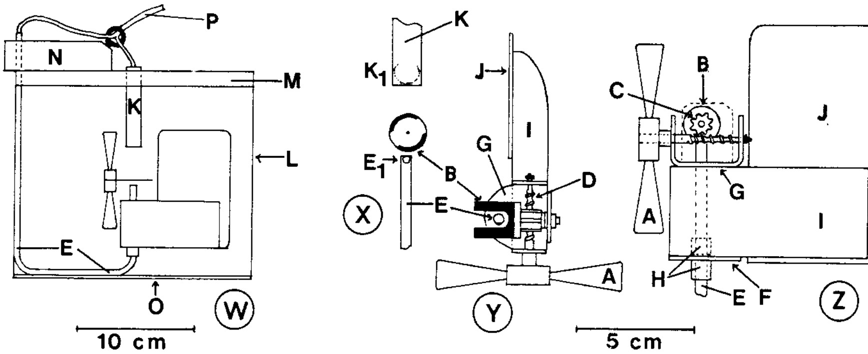

FIG. 1.
Current meter. *W*, side view; *X*, detail of light path; *Y*, plan view of moving parts; *Z*, side view of moving parts. A, propeller; B, occulting rotor; C, pinion; D, worm gear; E, pivot tube; E_1, photodiode; F, lower pivot guide; G, upper pivot guide and gear case; H, collars; I, body; J, fin; K, lamp tube; K_1, lamp; L, wire mesh (1.5 cm) cage; M, buoyant top; N, mounting block; O, brace; P, wires.

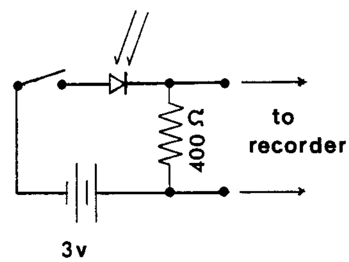

FIG. 2.
Circuit diagram for the photodiode. See text for explanation.

hold the brass screw and plastic gear (C). The entire assembly is encased in galvanized wire mesh (meshes approximately 2 cm square), with a bottom of similar material (not shown) to keep weeds away from the moving parts. The assembly can swing freely around the vertical pivot. The photodiode is a standard part (BPX 65, part no. 304–346, RS Components Ltd, P.O. Box 427, 13–17 Epworth Street, London EC2P 2HA, England) and is on a separate circuit from the lamps (Fig. 2). A "Linseis" Model LM 300, portable 12 volt DC two-channel chart recorder was used to record the pulses from the meters. This recorder is sensitive to voltage so the resistor (Fig. 2) was used to short circuit the current and provide a recordable voltage drop. It is convenient to use a recorder because sudden changes in current speed can be detected, but a much cheaper recording device is an electromagnetic pulse counter (part no. 259–741, RS Components Ltd). These might have to be used with a transistor circuit to handle the greater power required. A junction box was used to switch between the lamps and photodiodes in the four current meters used here.

The meters cost between about £5 and £7 each, but in use require long lengths of cable—although cheap two-stranded flex will do.

Leveller

The fluid leveller (Fig. 3) consists of a reel (*W*) holding 60 meters of 10 mm clear plastic tubing (7 mm inside diameter) (E). The inner end of the tube (E_1) is connected to the reservoir (D) within the drum (A) of the reel. The aluminium rotor from the spin dryer of a discarded washing machine was used here. The plywood flange (B) holds the tubing in

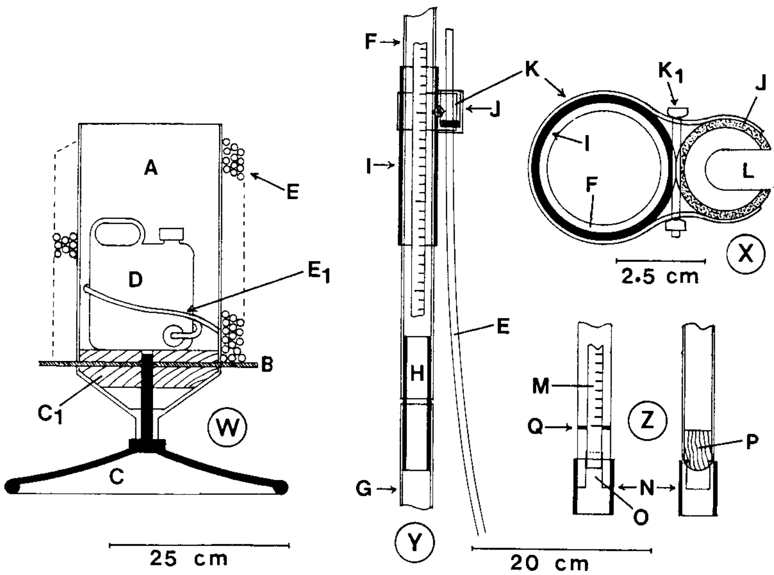

FIG. 3.
Water leveller. *W*, reel and reservoir assembly; *X*, section of slide and tube holder; *Y*, levelling staff; *Z*, feet of staff. A, drum; B, flange; C, stand; C_1, brace; D, reservoir; E, tube; E_1, slack tube; F, upper portion of the staff; G, lower portion; H, connecting piece; I, slide; J, tube holder; K, clamp; L, slot for tube; M, measuring tape; N, protecting cap; O, slot for tape; P, guide; Q, datum mark.

place. A wooden brace (C_1) steadies the inner end of the pivot shaft on the stand (C, an old steering wheel). The free end of the tubing is led to the staff (*Y*), formed from two pieces of rigid PVC pipe (F,G) that can be separated at the connecting piece (H). The slide (I) holds the end of the tubing (E) in (J). The tubing can be slipped in and out of the holder (J) through the slot (L,*X*), and a rubber ring on the tube (see *Y*) keeps it from slipping down or out. The slide can be raised or lowered as required to keep the end of the tubing above the fluid level in the reservoir.

The measuring tape (M,*Z*) was made from two tailor's plastic measuring tapes joined together into a continuous loop with a length of dressmaker's elastic ribbon, to keep the loop taut on the staff. The staff is tall enough to measure 2.5 m changes in level. The ends are slotted (O) to hold the tape in position, and the rounded guides (P) facilitate its being slid around the staff as required with the scale on the front and the elastic tape on the back of the staff. The cap (N) protects the bottom of the staff and the datum mark (Q), 10 cm above the bottom is used for measuring from the substrate up. The measuring tape is passed over the slide (I).

The total cost was about £30—of which the tubing was by far the most expensive item.

OPERATION

Current Meter

Four current meters were built and tested for a further study of the ecology of the naked hydroid *Clava squamata* (Müller) (see Aldrich *et al.*, 1980), the present work is still in progress. In one set of experiments, the four meters were tied to rocks and the algal substrate for *Clava*, the large phaeophyte, *Ascophyllum nodosum* (L.) (see Fig. 4, D and C).

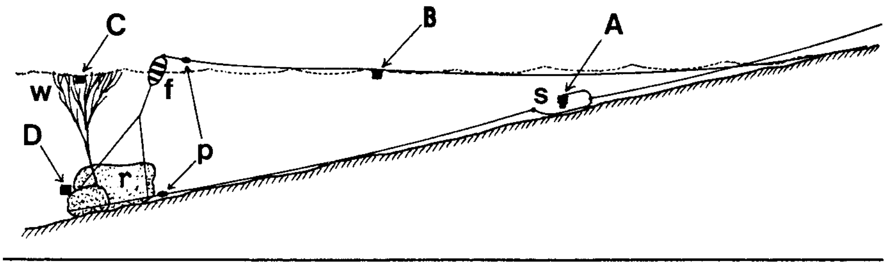

FIG. 4.
Deployment of current meters. A, hanging current meter with added weight; s, sledge; B, floating current meter; f, float; p, pulleys; C, current meter in *Ascophyllum nodosum* (w); D, current meter tied to rock (r).

Two cables were led from each meter, one for the lamp and one from the photodiode. It was found in practice that wire splices had to be well coated with epoxy cement, otherwise the sea water destroyed the connections within a few hours, due to electrolysis. The meters were emplaced during low tide and recordings were made at intervals throughout the tidal cycle. The length of cable used is limited only by the number of people available to carry it around the shore. In another set of measurements, a path was cleared through the stones on the beach and a pulley (p) was attached to a rock (r) at the lowest water level. An endless rope was connected to the sledge (s) (the sledge was made from a single length of 10 mm iron bar). A current meter with a weight beneath it (A) was hung from the upper portion of the sledge. The sledge and attached meter were then drawn across the tidal current flowing parallel to the shore, giving a transect of current speeds just over the bottom. Another meter (B) was similarly drawn across the surface of the current using a pulley connected to a float (f). Fortunately, the current meters float.

Since there is an alternating flow at 90° to the shore in strong waves, this component of the current might be measured by placing some current meters with the axis of the propeller fixed in this direction—such meters could be made without a vane and pivot. Other fixed meters could be placed with their axes in line with the shore, thus recording both the wave-induced long-shore current (Pethick, 1984) and the normal tidal current.

The only problems encountered were with the underwater electrical connections. These could be entirely avoided by having long continuous wires from each meter. The lamps were sealed into their holders with grease, a temporary measure that worked without problems. Sealing with waterproof cement would be better. The mechanical parts gave no trouble at all. There is virtually no friction between the brass screw and the nylon gear. The propellors turned freely in the wind when emersed. This gearing is necessary to reduce the rate of pulses to what can be followed by the chart recorder. Any convenient propellors can be used, ones with greater surface area than shown would be better for very slow currents; as built, currents slower than 0.3 kmh^{-1} would not operate the meters.

The meters were individually calibrated by placing them in the tidal current and taking readings at different speeds, determined by timing the progress of boards and fruit over a measured distance. A better mode of calibration would be to tow the meters behind a boat at measured speeds to avoid the naturally uneven flow of streams.

As built, these meters are not intended for long periods of continuous use. They are suited to be used in larger numbers than could be afforded with commercial meters, as when surveying several portions of a shore simultaneously. The basic design could be modified for longer use by employing a hall-effect transistor (sensitive to magnetic fields) and a rotating magnet, instead of a lamp. Such a modification would require much less electrical current, but would involve more complicated circuits because the signals would have to be amplified.

Leveller

The reservoir and tubing were filled with ordinary tap water, but automobile antifreeze could be added to both improve visibility and prevent freezing. With the 60 m of water-filled tubing coiled on the reel, the assembly is quite heavy, and I provided a carrying handle (not shown). Once the tubing is reeled out the empty reel can easily be moved during the course of the survey.

In order to establish the upper levels of *Ascophyllum nodosum* on the shore, the reel was placed in a convenient position high enough to keep the water level in the tube at a readable point on the staff. It is not necessary to have the reservoir exactly level. The tubing was then reeled out completely with the free end in the slide high enough on the staff to prevent the water from spilling out. The staff was then placed near the reel for the first point to be levelled; a long narrow board was used as a "foot" to average the height of irregular ground surfaces. The cap was loosened on the reservoir to allow free equilibrium of air pressure, and water allowed to reach a stable level. There will be some surging back and forth after the tubing is moved. Once the water level had stabilised, the measuring tape was slid to bring a convenient reading opposite the level in the tubing. After levelling the first point and noting the reading, the staff was carried, and the tubing dragged, to the next point. The new reading was noted without moving the tape, the slide can be moved at will without affecting the readings. After the limit of the length of the tubing was reached (the reading at this last point was noted as usual), the reservoir and reel were carried to a convenient point near the staff (which was not moved). After moving, the reservoir will almost certainly be at a different level from the original one and it is very inconvenient to try to place it exactly as before. One has simply to let the water level stabilise as usual, then to slide the measuring tape to bring the last reading (before moving the reel) opposite the level. The original level will thus be preserved. E.g., if the tape was set at 0.50 m at the first point near the reel, successive levels might be at say, 0.45 m, 0.55 m, 0.47 m, with the final point before moving the reel at 0.52 m. After moving the reel this level might be changed to say, 0.67 m; one simply resets the tape to read 0.52 m as before and the levelling can proceed on the same basis as the original. One has to reset the tape only after moving the reel. We noted our readings as + or − so many centimeters from the original level.

One can level down the shore starting from the top, when the limit is reached by the height of the staff. We used the full height but it is difficult to read levels 2.5 m above ground level. One can reset the tape after moving the reel as before. When measuring the heights of flat surfaces, it may be more convenient to turn the tape so that it reads from bottom to top, the 10 cm mark can then be set on the datum mark (Q, *Z*, Fig. 3) and the true distance below the water level can be read off directly. When levelling the position of biota on the sides of rocks etc, the tape can be used in either orientation, setting 0.00 either at the object of interest, or at the water level, whichever is the most convenient. With several people to carry the tubing around obstacles, one can level along the shore very quickly. Of course the tubing does not have to be 60 m long, shorter lengths and smaller reels can be made for use by a single operator. Providing that the tube is kept free of bubbles, the accuracy will be as good as a "precise level" used in engineering works, say 5 mm vertical error in 100 m of horizontal measurement, and more accurate than ordinary "double" levelling sufficient for most building construction (1–2 cm/100 m), (R. C. Cox, civil engineer, personal communication). This degree of accuracy is far greater than that required by any conceivable ecological survey, and the versatility of the instrument allows it to be used where line-of-sight instruments would fail; e.g., around "corners", into caves, during rain and fog. In the configuration shown, only one operator is required once the tubing has been reeled out, unlike the simple "U" tube without a reel and without a staff with an adjustable scale (Slingsby and Cook, 1986).

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REFERENCES

ALDRICH, J. C., CROWE, W., FITZGERALD, M., MURPHY, M., MCMANUS, C., MAGENNIS, B. and MURPHY, D. (1980). Analysis of environmental gradients and patchiness in the distribution of the epiphytic marine hydroid *Clava squamata*. *Marine Ecology Progress Series*, **2**: 293–301.

BAKER, J. M. and CROTHERS, J. H. (1987). Intertidal Rock in *Biological Surveys of Coasts and Estuaries*. Ed. J. M. Baker and W. J. Wolff, Cambridge.

PETHICK, J. (1984). *An introduction to coastal geomorphology*. Edward Arnold, London. pp. 260.

SLINGSBY, D. and COOK, C. (1986). *Practical ecology*. Macmillan, Basingstoke. pp. 213.