Wetlands Ecology and Management **11**: 195–198, 2003.

An inexpensive instrument for sediment erosion-accumulation rate measurement in intertidal environments

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Received 11 April 2002; accepted in revised form 3 June 2002

Key words: Instruments, Sediment-erosion rate, Wetlands

Abstract

A low-cost instrument to determine elevation changes in intertidal environments is presented. The instrument consists of two small PVC pipes driven into the soil and a ruler attached to a bar sustained by two rods that are inserted into the pipes during the measurement. This method cost only a fraction of similar ones described in the literature. Furthermore, because large numbers can be deployed in an area, statistically significant sedimentation-erosion rates can be obtained for places where spatial variances are very large.

Introduction

Determination of erosion-sedimentation rates in sedimentary environments is a crucial issue requiring precision in the vertical scale and adequate areal distribution of data points in relation to the scale of the study region. Intertidal environments, specially the meso and microtidal ones, normally have large extensions subjected to a variety of dynamic, biological, chemical and sedimentological conditions. Rates of erosion-accumulation may vary significantly in short distances; therefore, point measurements with low areal density may lead to large errors in estimation of the regional changes.

Since the onset of wetland studies, one of the most important issues has been the determination of changes suffered by the wetland surface produced by current and wave activity both during fair weather and under storms, sediment trapping by plants and animals, bioturbation, mean sea level variations, sediment compaction and wetland subsidence, among others. Many methods have been devised to measure the temporal and spatial variation in sediment erosion-accumulation rates in order to define a sediment balance for the whole wetland under study. These methods could be classified as tracers, instrumental and surveying techniques.

Most tracers are related to radioisotopes both naturally occurring in the environment and introduced. One of the most common techniques is the determination of sediment deposition rates using the changes in ^{210}Pb or ^{137}Cs activity along a shallow core (Delaune et al. 1989; Stam 1999). However, others consider defining marker horizons using either artificial (Letzsch and Frey 1980) or uncommon materials for the area (Kanus and Gent 1987) specifically set up below sediment surface. The former method allows for long term (10–150 yrs range) rates but has little capability to define changes in the short range (weeks to 2 yrs) and to associate them with dynamic processes. The latter also require coring of the sediment to check for the underlying marked layer thus disturbing the natural evolution of the site. Stoddart et al. (1989) spread a layer of beach sand over the marsh to define a marker horizon whereas Chmura et al. (2001) did the same with clay-size feldspar. All these methods assume that net accumulation occurs on the wetland, if net erosion is present, the marker horizon (specially in the later example) could disappear.

Although surveying has become faster and more accurate with the development of laser-based systems, these equipments are expensive and seldom used repeatedly in short sampling intervals. Optical theodolites have good accuracy but the time required to survey a large area may be less than that allowed by land exposure specially in macrotidal environments.

Other rather expensive methods are continuously developed. For instance, Long (personal comm., 1989) built a gamma probe that measured changes in the sediment density profile from a depth of 5 cm with a sampling rate of 2 s. Outputs could be calibrated to obtain changes in sediment elevation. Recently an electronic system (PEEP) based on photoelectric determinations of the surface level has been offered commercially. Both systems require extra data loggers which must be stored in water-tight containers. Although their accuracy, precision and sampling rate are very important improvements, leaving them unattended for long periods of time may be risky. Also, due to their high cost, only very few of them could be deployed simultaneously in the same area.

Other authors have developed systems to measure sedimentation-erosion rates by means of stakes, rods and plates. Stakes and rods have been used extensively (i.e., Pestrong (1965), Reed (1989), Daborn et al. (1991)). The general idea is to set up a stake in the sediment as reference and define the changes in elevation from this reference. Several modifications were made as the stakes themselves introduce a marked erosion by interaction with waves and currents. One such modification was the bridge system: two vertical rods at a certain distance apart connected by a horizontal rod or bridge from the middle point of which the measurement is made.

The Sedimentation-Erosion Table (SET) originally designed by Schoot and de Jong (1988) and further developed by Boumans and Day (1993) is a very interesting method that diverges from the previous one. It is based on a nine-point grid within a small area attached to a single arm connected to a vertical pipe, which is introduced into another pipe permanently installed in the sediment. Since the arm can rotate, it can obtain measurements in a circle around the central pipe. Although the SET is quite accurate, construction and implementation costs for low budget projects become prohibitive, specially if the study covers a wide area with large point density.

Considering the need for our studies of an instrument that is quite inexpensive and can be employed in large quantities at low costs with high precision and durability we introduce here a new design for the bridge method that fulfill all those criteria.

Bridge method

The standard Bridge Method consists of two rods introduced into the sediment, at a certain distance from each other, and a bar or bridge connecting them at a certain height above the surface. Employing the bar as reference level and assuming that both rods are stable in the vertical as well as in the horizontal position, measurements of surface elevation are made with a ruler. As far as we know there are no standardized criteria for the size of the rods nor for the distance above the surface for the location of the bridge. Nor there is consistent information about the type of material from which the instrument should be made. For instance, Daborn et al. (1991) employed wood stakes 1 m apart and the bridge was a wood table located 20 cm above the surface but, in many cases, the rods are made of iron. After several experiences, in which the cost of each station and durability only allow to have few stations, we redesigned the system with a format that allows a much better performance. After several tests we reached the design shown in Figure 1. One-meter apart, we drive into the sediment 20 cm long, PVC pipes (1.9 cm diameter, 1 mm wall-thickness) at about 15 cm deep. The bottom end is capped and sealed to prevent both water and sediment from entering the pipe. The upper, exposed end is machined to allow for a screw cap which is carefully taken out before each measurement and recapped at the end. The bridge is portable and fitted to the rods at the time of the measurements. In this case, the bar was a flat, iron plate 2 mm thick with a slot on each end designed to fit the rods. In the middle of the bar we adapted a hydraulic-lab limnimeter including the measurement portion that allows determinations to 0.1 mm. A two-way level was used to insure perfect vertical alignment of the ruler. Two 60-cm iron rods (1.27 cm diameter) machined at the upper end attached by a nut to a fix point on the bar are used. The rods are inserted into the pipes and by means of the two-way level, the pipes and the rods are checked for horizontality.

Measurements are obtained by lowering the limnimeter ruler until the tip barely touches the soil. The system has two screws that allow for large and small movements. Thus, allowing the tip to approach the soil very slowly in order to avoid sediment disturbance. Readings are obtained at the marker on the bar with a 0.1-mm precision. An experienced operator can set up the system and gather a reading in less than 4 minutes.

The cost of one set of pipes fully prepared for

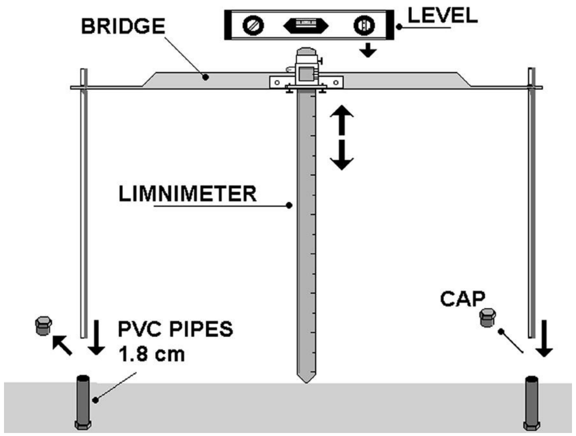

Figure 1. Schematics of the new bridge system introduced in the present paper.

installation costs $ 2. The construction of the bar, at $40 with the level included, is the most expensive item. In our case, the limnimeter ruler was an instrument salvaged from the Hydraulic Laboratory of the Universidad Nacional del Sur so it did not have any cost. However, in previous experiences we used a meter- long stainless steel ruler. On the bar, a screw driven into a metal plate was employed to fix the ruler for the reading.

Discussion and conclusions

At a salt marsh-tidal flat complex in the Bahía Blanca Estuary we installed 15 pairs of pipes which have been fully in operation for over two years now. Along this period, a total of 5 pipes was lost (and replaced) due to heavy erosion of the sediment where they were located or because of the bioturbation of crabs making their holes beside or beneath the pipe. There is no evidence that the pipes were disturbed by the flow or ''accidentally'' misplaced by some fisherman passing by.

Time and spatial variability of sediment changes in any intertidal environment are normally stated but seldom expressed quantitatively. To provide such information, a high-density network of sensors must be set up and regular control of their behavior would require some expeditious and reliable operation. Expensive instrumentation may sacrifice areal distribution to accuracy and reliability. The researcher is then forced to assign his/her results to a large portion of the study area assuming that his/her measured changes are representative of it. However, in the relatively short period we have being measuring an area of about 3 km^2 of the Bahía Blanca Estuary salt marsh, we found a large spatial and temporal variability in the sediment dynamics. As an example, we show the results of only 4 sensors located within a radius of 100 m (Figure 2) for almost two years starting in May 2000.

For instance, during the one-year period (November 2000 (280) – October 2001(320)), sensors E1, E5 and E6 showed a marked accumulation (lower values) while E7 indicated erosion (higher values). E1 is one of the stations where a crab drilled a hole under one of the pipes, so, as it could not longer be used at that position it was moved a short distance away but with a new designation. Another indication of the spatial variability is the accumulation event which occurred on Julian day 689 present in all sensors but with varying intensity.

In conclusion, the new design has allowed us to continue with our measurements which had been interrupted because of the loss of rods. It has also provided a longer record than before and, due to its low cost, a much larger surface coverage with quite accurate determinations of elevation changes in relation with various geomorphological features and plant distributions that were not possible previously. This also provides statistically significant sedimentation-

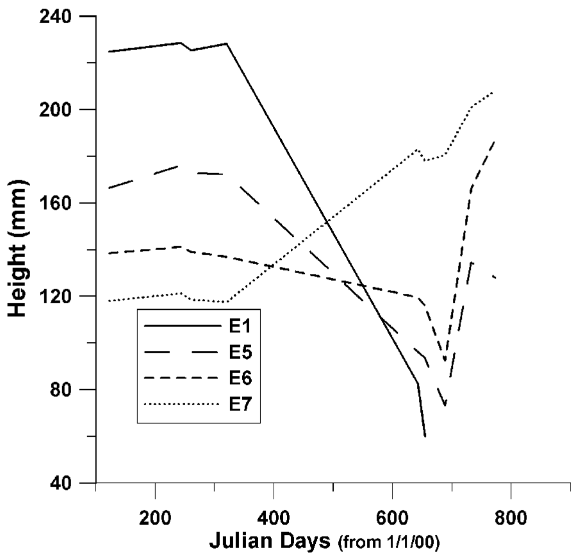

Figure 2. Time series for 4 example stations from the Bahía Blanca Estuary. They were selected to show the high spatial variability in elevation changes within a small area of the salt marsh. The time axis corresponds to Julian Days starting on January 1, 2000 and covering up to April 11, 2002. Larger values indicate erosion and lesser ones accumulation.

erosion rates in places where spatial variances are very large. Because of the fast reading rate, one operator on foot can cover the15 stations distributed over an area of 3 km^2 in less than 2 hours. After the first year test period, we added another 15 sets to cover a larger area of the wetland under study and plan to add another 15 sets during 2002.

Acknowledgements

Research dealing to the present paper was supported by grants from Fundación Antorchas, CONICET and Universidad Nacional del Sur. The authors wish to thank the personnel of the Laboratorio de Geología Marina of IADO (Mr Miguel Colombani and Mr Hugo Pellegrini) for helping in the construction of the system, Dr Daniel E. Pérez for providing the limnimeter and Lic Walter D. Melo for drawing the figures.

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