A non-motorized dye ejector for visualization of flow \textit{in situ} and its use with coral reef crinoids *

R. S. Colman 1 **, H. C. Crenshaw 2 **, D. L. Meyer 3 and J. R. Strickler 4 **

1 54 Coleman Drive; Melbourne, Victoria 7890, Australia
2 Department of Zoology, Duke University; Durham, North Carolina 27706, USA
3 Department of Geology, University of Cincinnati; Cincinnati, Ohio 45221, USA
4 Department of Biosciences, University of Southern California; Los Angeles, California 90089-0371, USA

Abstract

We describe a portable, non-motorized device for delivering a tracer dye into seawater under field conditions. Dye is ejected at a constant flow rate over a period of tens of minutes. The ejector works in a wide range of ambient pressures without external energy requirements. The flow rate is adjusted simply by varying the length of the delivery tube. The dye streams permitted observations of the upcurrent and downcurrent flow regimes for a filter-feeding crinoid (Comanthus bennetti) living at a depth of 8 m on a coral reef. The results indicate that the crinoid may enhance the rate of particle capture by changing the scale of turbulence in the water passing through the mesh of the filtration fan.

Introduction

Crinoid echinoderms are passive suspension-feeders depending on ambient current to bring them food particles. Thus, crinoid microhabitat distribution and feeding posture appear intimately related to the speed and periodicity of water movements (Meyer, 1982). The relations between small-scale water movements and crinoid distribution and abundance have been especially studied for coral reef environments of the tropical Western Atlantic and Western Pacific (Meyer, 1973; Meyer and Macurda, 1980). To examine these relationships more closely and to test hypotheses about specific adaptations to flow regimes, detailed studies of small-scale flow patterns around crinoids under natural conditions on the reef are desirable.

Vogel (1981) has reviewed ways for visualizing water flow past benthic organisms; a semiquantitative, but very revealing method is to release dye (often from a motor-driven device) upstream from an organism. To study flow through crinoids living on coral reefs, we developed a non-motorized pump that is simple, reliable, inexpensive and easy to operate. In the present study, our purposes are to describe this device and to illustrate its use for study of crinoids \textit{in situ}.

Materials and methods

The dye releasing device (Fig. 1) includes Chamber 1 (72 ml) holding the dye solution and Chamber 2 (485 ml), which can be evacuated and sealed. One wall of Chamber 2 is a piston head driven by the ambient water pressure. Incompressibility of the dye fluid in Chamber 1 prevents activation of the pump until the needle valve is opened. After the valve is opened the ambient pressure pushes the piston head into Chamber 2 and forces the piston shaft into Chamber 1, thus pumping the dye solution out via the needle valve. During dye release, the rise in pressure in Chamber 2 is negligible because the piston sweep is small compared to the total volume of Chamber 2; therefore, the flow rates remain constant over the period of dye release. The dye ejector can be used at depths shallower than 3 m with Chamber 2 evacuated. At depths greater than 3 m, the ejector can be used without evacuation; however, to minimize back-pressure on Chamber 2, the evacuation is recommended if possible.

We used our dye ejector to visualize flow through an individual crinoid (Comanthus bennetti) living at a depth of 8 m at John Brewer Reef (18°38'S; 147°3'E), Great Barrier Reef, Australia. The crinoid was perched on the downstream end of a small coral head about 1.2 m above the bottom and exhibited a normal feeding posture (the filtration fan). During our observations (mid-afternoon on 4 July 1983), the current was running unidirectionally and
relatively steadily at about 10 cm s⁻¹. The dye ejector was adjusted to release a stream of fluorescein in seawater at a rate of 3 ml min⁻¹ from an ejection point 4 cm upstream from the crinoid. The course of the dye was photographed from a vantage point perpendicular to the axis of flow; at 30 s intervals, 20 photographs were made with the crinoid in place and 10 photographs were made after the crinoid had been removed from its perch.

Results and discussion

The flow rate from the ejector (Fig. 1) is continuous, constant and highly repeatable. The rate can be regulated by the length and internal diameter of the delivery tube (Fig. 2). Smaller diameters and longer lengths increase the friction between the inner wall of the tubing and the fluid, thus decreasing the dye flow. For example, for tubing with an inner diameter of 0.4 mm, a tubing length of 10 cm results in a flow rate of 8 ml min⁻¹ at a depth of 10 m. The easiest method for adjustment of the flow rate is to deploy the ejector with an overlong segment of tubing and then to cut off segments until the desired rate is achieved. The device can deliver dye at a constant rate over a period of tens of minutes while the path of the released dye is recorded photographically. The rate of dye release into the ambient current regime must be neither too high nor too low. If the rate is too high, the dye stream is too wide for accurate resolution of flow patterns. If the rate is too low, the stream becomes too fine (or even discontinuous) and falls below the resolution of underwater photography.

The use of the dye ejector is illustrated for a crinoid (Comanthus bennetti) perched on a coral head (Fig. 3). Because the water flowed for about 1 m over the rough surface of the coral head, turbulence was induced in the overlying seawater on a scale corresponding to the scale of