Barnacle Plate Sediment Production by Sheepshead, the Indian River, Florida

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Abstract

Living barnacles eaten by sheepshead fishes results in the production of broken barnacle plate sediment. The yearly rate of production of broken barnacle plates is 4.9 kg m^{-2} and varies seasonally, with the largest mean flux in summer (22.5 g m^{-2} day^{-1}) and the least in winter (1.9 g m^{-2} day^{-1}). The mean grain size mode of broken barnacle plates is positively correlated with the flux of broken barnacle plates. Experiments with exclusion and inclusion cages support the postulation that increases in flux and size of broken barnacle plates are caused by the feeding activity of larger sheepshead.

Introduction

Fishes are an important contributor to fragmentation of carbonate skeletons, although little is known about the particles produced [1]. One well-known example is grazing by parrot fish in reefs [2]. In coastal marine and estuarine environments, the sheepshead *Archosargus probatocephalus* produces new carbonate sediment by feeding on barnacles.

A barnacle community [3] lives on the underside of floating docks in the Indian River Lagoon at the Harbor Branch Foundation (27°32′N, 80°21′W). Our observations indicated that this site would be useful for measurements of the flux of barnacle fecal pellets [4] and smashed barnacle plates [5]. The purpose of this study is to show by means of an uncaged particle trap that sheepshead contribute a large amount of broken barnacle plates to the sediment, and with inclusion/exclusion cages having sides of different mesh size, that the flux and size of the broken barnacle plates are related to the size of the sheepshead.

Methods

Sediment traps were made from welded steel frames, and plastic film was used to cover the floor of both caged and uncaged traps. Galvanized poultry netting or nylon fish netting (2.5- and 7.1-cm mesh) formed the sides of the caged traps. The 2 × 2.2 m uncaged trap was suspended 1 m below the barnacle community by small-diameter nylon lines at each corner. When the cage was used as an enclosure, one adult sheepshead (about 600 g; 25-cm Standard Length [S.L.]; three different fish were used, one at a time) placed in the cage could feed on a 4 m^2 area of the barnacle community overhead. As an exclosure, the cage prevented fish and other organisms larger than the mesh size from reaching the barnacles. Particles which settled onto the plastic sheet floor were swept into a bucket by a SCUBA diver. These particle traps were not expected to capture mud-sized particles quantitatively. Grain size analysis was done by sieving at one-half Phi intervals [6], and size frequency curves were computer generated. Linear regression and Student's *t*-test [7] were used in our analyses of results. Seventeen experiments with uncaged traps encompassing 386 days were grouped into quarterly periods representing the seasons. Two exclusion cages were deployed in eight experiments from early June to mid-November for a total of 133 days. One inclusion cage was deployed in five experiments for a total of 46 days during the period early June to mid-September.

Results

Four types of particles were recovered from the uncaged and caged traps: quartz sand, broken barnacle plates, clumps of unbroken barnacles (>16 mm), and barnacle fecal pellets. The latter two are not the result of fish activities and therefore are not considered further. Quartz sand together with broken barnacle plates accounted for 83%–96% of the total weight of particles recovered from each trap deployment. Inspection by low-power microscope showed that barnacles fractured across the plates, not along sutured plate edges.

Particle Flux

The seasonal variation in flux of broken barnacle plates for the uncaged trap was 1.9–22.5 g m^{-2} day^{-1} (Fig. 1). Placing barriers (nets) between the barnacle community and the fish caused a decrease in flux of broken barnacle plates. Summer-fall data from the uncaged trap are comparable to the exclusion cages (Fig. 1). With increasingly stringent barriers (no net in the uncaged trap, 7.1-cm net, then 2.5-cm net), the broken barnacle plate flux decreased from 18.6–22.5 to 5.6 to 0.6 g m^{-2} day^{-1}, respectively. Alimentary tracts from sacrificed sheepshead contained some barnacle shell fragments, so that measurements of broken barnacle plate flux directly beneath the feeding site yielded minimal determinations.

For the five inclusion cage experiments (with 2.5-cm mesh), the mean flux of broken barnacle plates produced by one sheepshead plus those smaller fish able to penetrate the net was 4.3 ± 4.4 (range = 0.3–9.7) g m^{-2} day^{-1}.

Quartz sand was deposited in the uncaged particle traps because of the bottom-feeding activity of mullet [5]. The flux of quartz sand varied seasonally; $\overline{X}$ = 0.5 ± 0.06, 0.8 ± 0.4, 2.2 ± 1.4, and 2.4 ± 1.1 g m^{-2} day^{-1} for winter, spring, summer, and fall, respectively. Traces of quartz sand were recovered from the cage experiments, but only the exclusion cage with 7.1-cm net had measurable amounts, $\overline{X}$ = 0.3 ± 0.3 (0.1–0.7) g m^{-2} day^{-1} (Fig. 2).

Particle Size

Size-frequency curves and statistical data for individual samples from the uncaged experiments, selected to represent each season, show a coarse mode of broken barnacle plates ($\overline{X}$ = 2.7–4.0 mm) and a finer mode of quartz sand (0.2 mm, Fig. 2). The mean grain size mode of broken barnacle plates was smallest in the winter, 3.0 mm, and largest in the summer, 3.8 mm. Grain size modes of broken barnacle plates were positively correlated with the flux of broken barnacle plates (r = 0.75; $P < 0.001$). The mean grain size mode for quartz sand did not change.

Size-frequency distributions for the caged and uncaged sediments were similar, except that sediment from cages (11 out of 13) did not contain the 0.2-mm quartz mode and the barnacle plate size modes were smaller. For exclusion cages, the mean grain size mode of broken barnacle plates was 2.83 ± 0.0 mm for the 7.1-cm net, and the mode decreased with the 2.5-cm net to 2.7 ± 0.37 mm (2.00–2.83). Student's t-test [7] showed that this difference in mean mode size was significant ($P < 0.05$). The inclusion cage with 2.5-cm net siding gave a mean grain size mode of 2.50 ± 0.45 mm (2.00–2.83) for broken barnacle plates.

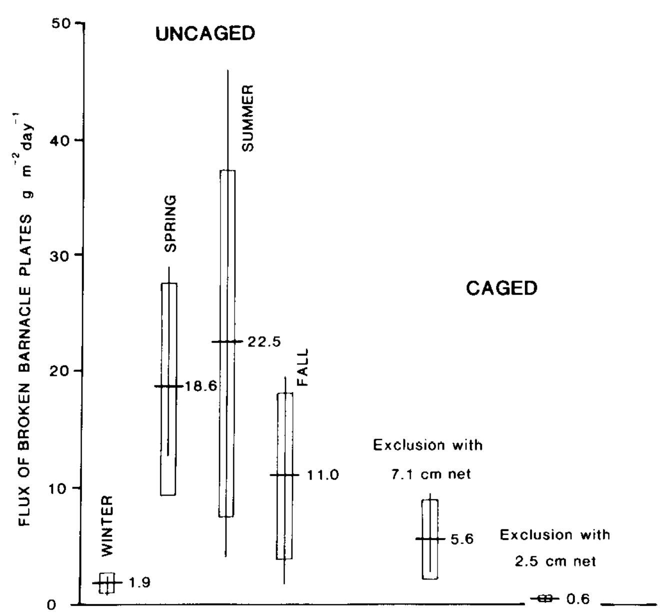

Figure 1. Broken barnacle plate flux from caged and uncaged sediment traps suspended beneath a living barnacle community. Horizontal line and numbers, mean values; boxes, ±1 SD; vertical lines, total ranges.

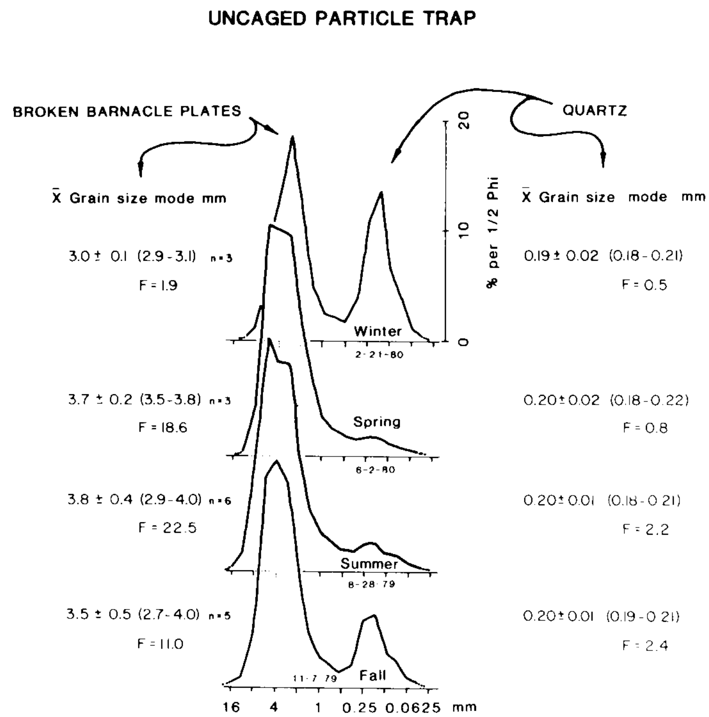

Figure 2. Partial grain size distribution (coarser and finer fractions not shown), mean grain size modes, and mean fluxes for broken barnacle plates and quartz sand recovered from uncaged sediment traps. Mean values, ±1 SD, (with ranges given in parentheses); n, number of measurements; F, mean particle flux in grams per square meter per day.

Discussion

We have shown that, as access to the living barnacle community became less stringent (2.5-cm net, 7.1-cm net on exclusion cages, and no net on the uncaged trap), the flux and mean grain size mode of broken barnacle plates increased. We postulate that this increased flux and size are due to the feeding activity of successively larger sheepshead, and not due (a) to increased size of barnacles through growth, or (b) to feeding by increased numbers of small fish. In the following two paragraphs, we discuss (a) and (b).

Barnacle Growth

Diving observations showed that large barnacles were always present and that at no time during the year of our experiments were barnacles absent from the dock. It has been shown by others [8] that *Balanus eburneus*, the dominant barnacle species, settles in every month of the year, although most abundantly in October-November and April. Thus, small barnacles are readily available, and growth is presumed to replace those barnacles eaten by sheepshead and other predators.

Small Fish

Quite small sheepshead (15-mm S.L.) have jaws and teeth characteristic of the adult [9], but they probably do not feed on barnacles. As our observations did not suggest otherwise, we presumed that the number of small fish (those able to pass through a 2.5-cm net) was similar for both caged and uncaged experiments. If this presumption is correct, then the increased flux and grain size mode for uncaged experiments (18.6–22.5 g m^{-2} day^{-1}; 3.7–3.8 mm) as compared to an exclusion cage with a 2.5-cm net (0.6 g m^{-2} day^{-1}; 2.17 mm) cannot be the result of small fish. With all other variables unchanged, and assuming the same population of small fish, placing one young adult sheepshead (25-cm S.L.) inside one cage caused an increase in the mean flux of broken barnacle plates to 4.3 g m^{-2} day^{-1} with a mean grain size mode of 2.5 mm. These data support our postulation that larger fish produced more broken barnacle plates of larger size than did small fish.

The annual flux of broken barnacle plates produced by sheepshead is 4.9 kg m^{-2}; for comparison, a Caribbean parrot fish population in Pico Feo Reef produced 0.49 kg m^{-2} $year^{-1}$ [2], with the latter composed mostly of coral reef carbonate-skeleton fragments, not barnacles.

Acknowledgments

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