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Recolonization of gravel habitats on Georges Bank (northwest Atlantic)

Jeremy S. Collie [a,*], Jerome M. Hermsen [a,1], Page C. Valentine [b]

[a] University of Rhode Island, Graduate School of Oceanography, Narragansett, RI 02882, USA
[b] United States Geological Survey, Woods Hole, MA 02543, USA

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ABSTRACT

Gravel habitats on continental shelves around the world support productive fisheries but are also vulnerable to disturbance from bottom fishing. We conducted a 2-year *in situ* experiment to measure the rate of colonization of a gravel habitat on northern Georges Bank in an area closed to fishing (Closed Area II) since December 1994. Three large (0.25 m^2) sediment trays containing defaunated pebble gravel were deployed at a study site (47 m water depth) in July 1997 and recovered in June 1999. The undersides of the tray lids positioned 56 cm above the trays served as settlement panels over the same time period. We observed rapid colonization of the gravel substrate (56 species) and the settlement panels (35 species), indicating that colonization of gravel in this region is not limited by the supply of colonists. The species composition of the taxa found in the trays was broadly similar to that we collected over a 10-year period (1994–2004) in dredge samples from gravel sediments at the same site.

The increase in abundance of animals in the gravel colonization trays was rapid and reached a level in 2 years that took 4.5 years to achieve in the surrounding gravel sediments once fishing had stopped, based on data from dredge sampling at this site. The increase in biomass of animals found in the sediment trays paralleled the trend of biomass increase observed in dredge samples over the same period (1997–1999) but was lower in value. These data suggest that after rapid initial increase in abundance of organisms, succession proceeded by increasing individual body size.

A comparison of settlement panel and tray faunas revealed that the mean biomass of structure-forming epifauna (sponges, bryozoans, anemones, hydroids, colonial tube worms) on the panels was 8 times that found on the trays. Structure-forming taxa constituted 29% of the mean biomass of the panel fauna but only 5.5% of the tray fauna. By contrast, the mean biomass of scavengers (crabs, echinoderms, nudibranchs, gastropods) in the trays was 32 times that on the panels. Colonization of the tray gravel was more rapid for free-living species (many of which are prey for fish) than for structure-forming epifauna, though colonists of the latter species were present. The reduced success of structure-forming species in colonizing the tray gravel possibly is related to factors such as intermittent burial of the gravel by migrating sand and low survival of new recruits due to the presence of high numbers of scavengers on the gravel. These two factors might explain, to varying degree, the slow recolonization of gravel habitats by structure-forming species in Closed Area II of the northern part of Georges Bank.

1. Introduction

Continental shelves support high levels of biological production, including the bulk of world fisheries. These important ecosystems are subject to natural and human disturbances. Natural disturbance to continental shelf habitats and communities is caused chiefly by tidal currents and storm-induced wave action, which attenuates below 60 m water depth on Georges Bank, our study area (Twitchell et al., 1987). Human disturbances include bottom fishing, hydrocarbon exploration and production, and other infrastructure activities. Mobile bottom-fishing gear is widely used on continental shelves around the world (Kaiser et al., 2002); the spatial distribution of bottom fishing is patchy, but where it occurs, it is considered the most pervasive threat to marine biodiversity (NRC, 1995). To regulate and mitigate human activities on continental shelves requires that we can (1) distinguish human from natural disturbance, (2) understand how human disturbance affects ecosystem function, and (3) measure the recovery rates of continental shelf communities. Depending on the substrate, recovery rates can range from one year to more than a decade (Collie et al., 2000a), but there have been few direct measurements.

* Corresponding author. Tel.: +401 874 6859; fax: +401 874 6240.
E-mail addresses: jcollie@gso.uri.edu (J.S. Collie), Jerome.Hermsen@noaa.gov (J.M. Hermsen), pvalentine@usgs.gov (P.C. Valentine).
[1] Present address: National Marine Fisheries Service, Northeast Regional Office, Gloucester, MA 01930, USA.

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Georges Bank is a shallow submarine plateau off the east coast of North America with an area of approximately 43,000 km^2 within the 200-m isobath (Fig. 1). It has been an important fishing ground since the 18th century (Backus and Bourne, 1987). A gravel lag deposit is present on the northern edge of the bank, covering an area of approximately 3000 km^2 (Valentine and Lough, 1991). In this area, strong semi-diurnal currents have winnowed the seabed sediments, leaving a veneer of gravel pavement overlying sand. The gravel is ecologically important because it is substrate for the attachment of juvenile sea scallops (*Placopecten magellanicus*) and also for attachment of colonial epifauna, including hydroids, bryozoans, and tube worms (Collie et al., 1997). This biologically rich habitat provides an abundant food source for demersal fish and is especially important as a nursery ground for juvenile cod and haddock (Lough et al., 1989).

Disturbance to the gravel pavement from mobile fishing gear, especially scallop dredges, is apparent in side-scan sonar images (Valentine and Lough, 1991). In December 1994, a large area of Georges Bank in US waters abutting the US/Canada boundary was closed to bottom fishing to reduce fishing mortality on the principal groundfish species (Fig. 1). Since that time, we have conducted studies of the benthic fauna in Closed Area II, in adjacent areas of gravel open to fishing, and in fished and unfished gravel habitats on the Canadian part of the bank. Spatial comparisons between heavily fished and lightly fished areas have indicated significant differences in abundance, biomass, and species composition of the benthic communities (Collie et al., 1997).

The closed area, in offering protection from bottom fishing disturbance, has provided a rare opportunity to measure the long-term recovery of benthic communities on gravel habitats (Collie et al., 2005). To supplement our dredge sampling of the gravel inside and outside of Closed Area II, we conducted a 2-year recolonization experiment with gravel-filled trays and polycarbonate settlement panels from July 1997 to June 1999. The objective of this experiment was to measure the rate of colonization on substrates we could collect relatively intact from the seabed for complete enumeration. The purpose of this report is to analyze the colonization of sediment trays and panels as measured by the abundance and biomass of species, and to compare these results with similar data we have collected over a 10-year period (1994–2004) based on dredge sampling at the same and adjacent sites on the gravel habitat.

2. Methods

Six sediment aggregating modules (SAM) were designed and constructed at the Equipment Development Laboratory of the Graduate School of Oceanography (Fig. 2). The design was patterned after "New Free Vehicles" intended for deployment in the deep sea (Snelgrove et al., 1995). Tested in laboratory flume studies, the low-profile, sloping base of these vehicles was found to minimally disturb the boundary layer flow at horizontal current velocities comparable to the deep sea (10–15 cm s^{-1}). Each SAM has a poured concrete base (weight 300 kg in water) to anchor the tray to the sea floor. The base is a spherical section with a bottom diameter of 142 cm and height of 25 cm, designed to allow a smooth flow of water over the gravel in the tray. A depression was molded into the top of the base to accommodate the stainless-steel tray (inner dimensions $50 \times 50 \times 11$ cm; surface area 0.25 m^2). The SAM bases have a larger slope angle than the "New Free Vehicles" and bottom-current velocities are higher on Georges Bank ($\sim$50 cm s^{-1}) than the horizontal velocities used in the flume tank experiments (Snelgrove et al., 1995). Therefore we expected the SAM tray bases to reduce, but not eliminate, flow artifacts on the sediment trays.

Four galvanized steel posts supported a superstructure consisting of a tray lid, coiled lines, and deployment bail (Fig. 2). The lid was a polycarbonate square (56 cm × 56 cm; 0.31 m^2) reinforced with aluminum plate and attached to an aluminum guide bar fitted through a slot in the steel superstructure. A 40-cm

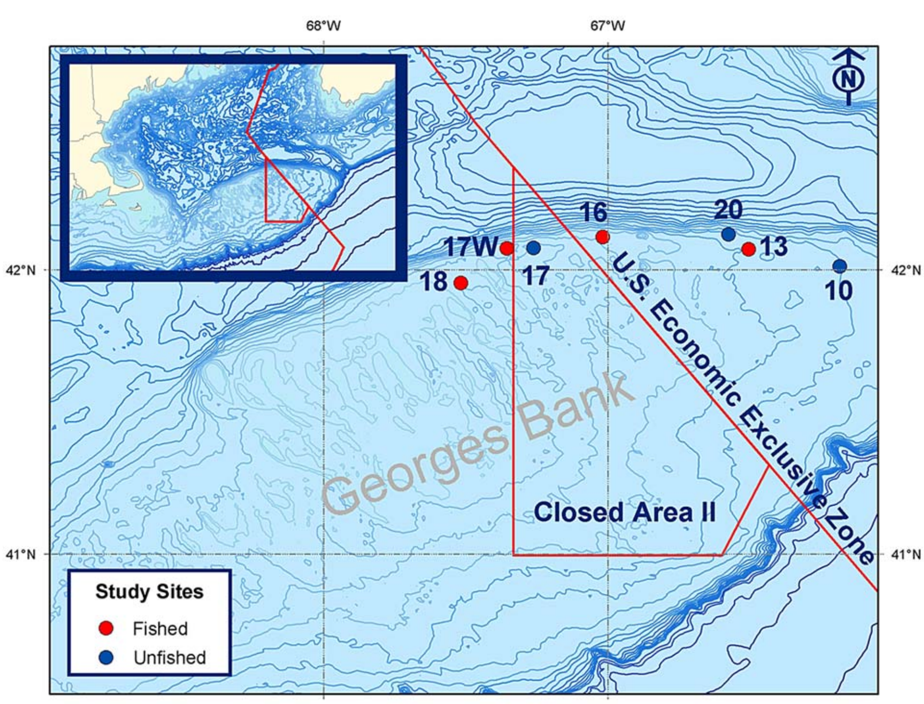

Fig. 1. Map of Georges Bank showing the location of the area closed to fishing in December 1994 (Closed Area II) and the fished and unfished gravel habitat study sites surveyed between 1994 and 2004. The sediment recolonization (SAM) trays and settlement panels were deployed at Sites 17 and 20 (modified from Asch and Collie, 2005).