Do deep-sea scavengers use plant material and algae as a food resource?

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Deep-sea fish depends directly or indirectly on food produced in the upper layer of the oceans. It is well known that food dumps can occur in the deep-sea after the spring or autumn bloom of algae, forming a green carpet on the sea floor. This food carpet attracts benthic invertebrates, especially large sea cucumbers. Our baited time-lapse cameras at the sea floor showed for the first time in a number of video clips, that deep-sea grenadiers, the most abundant demersal fish in the deep ocean, rapidly respond to and feed vigorously on large plant food falls mimicked by spinach. Similar behaviour was demonstrated in reaction to simulated dumps of plant debris (phytodetritus) at the seafloor. This 'vegetarian behaviour' highlights the variability in the scavenging nature of deep-sea fish.

Fig. 1. Preparing the spinach bait at the foot of the ALBEX lander (Autonomous Lander for Benthic EXperiments). Right panel is after a 5 hours deployment.

Deep-sea communities living at and near the sea floor in the deep ocean primarily rely on food sources produced at other places. This is often in the form of remains of algae and zooplankton which live in the upper 200 m of the oceans and sink to the sea floor after dying. Benthic invertebrates such as sea cucumbers are the primary consumers of this food source. Deep-sea grenadiers are the most abundant bottom-living fish in the deep ocean; they are generally considered to be the top predators/scavengers in deep-sea communities. Previous baited camera experiments with bottom landers and stable isotope analyses have demonstrated that carcasses from animals living in surface waters are also an important component in their diets. Some grenadier stomachs even contained vegetable material dumped from ships, e.g. onion peels, oranges, and algae. These latter observations led us to the question: is plant material also an attractive food source for deep-sea fish?

In October 2008 we simulated a plant food fall using spinach blocks fitted at a benthic lander equipped with a baited time-lapse camera on the Atlantic Iberian margin at 3000 m depth (Figs. 1 and 2). Deep-sea grenadiers and cusk-eels were rapidly attracted by the bait and fed vigorously on it (Fig. 3). The majority of the bait was consumed within a half hour. These observations indicate that (1) plant

Fig. 2. Recovery of the ALBEX lander with the spinach experiment.

Fig. 3. Behaviour of deep-sea grenadiers and a cusk-eel at the spinach bait at 3000 m on the Atlantic Iberian margin. (A) Attraction to and investigation of spinach bait, (B) 'feeding frenzy', fishes vigorously attacking bait, (C) spinach spilling out of stocking after attack, (D) consumption of spinach by grenadier.

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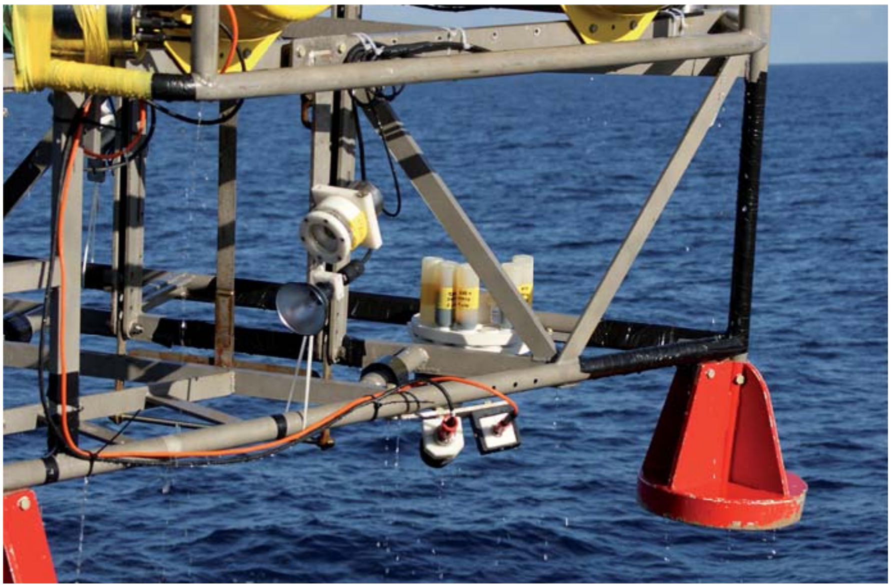

Fig. 4. Detail of the ALBEX lander with the phytodetritus experiment. The carousel with algae pots to mimic a phytodetritus dump and the video cameras with lamps are visible.

material can produce an odor plume similar to that of animal carrion and attract deep-sea fish, and (2) deep-sea fish readily eat plant material. Since higher plant remains are scarce in the deep-sea, these results led us to ask if remains of marine algae material, *i.e.*, phytodetritus, might also be a food source for deep-sea fish. In October 2009 we simulated a phytodetritus dump at the seafloor in two contrasting environments: (1) the NE Atlantic where carpets of phytodetritus have been previously observed and (2) the nutrient-poor oligotrophic western Mediterranean, where the deposition of phytodetritus at the seafloor is a rare occurrence. We recorded the response of the scavenging fauna to phytodetritus released from an in situ benthic lander equipped with baited time-lapse cameras (Fig. 4). In the Atlantic Iberian margin at 3000 m, grenadiers and cusk-eels were again attracted by our vegetarian dish (Fig. 5A-C). The phytodetrital patch was significantly diminished within 2 hours. Abundance estimates calculated from first arrival times of grenadiers at the lander corresponded well with abundance estimates from video-transects, indicating that fish were indeed attracted by the scent of the algal bait. In the western Mediterranean, however, only a single grenadier was observed investigating the phytodetrital patch but the fish showed no real interest in the bait (Fig. 5D). Abundance estimates from first arrival times at the bait were lower than estimates obtained from video-transects and trawl catches. This suggests that the Mediterranean fish were not readily attracted to this food source. The phytodetrital patch was significantly diminished after 6.5 hours mainly by invertebrate activity (Fig. 5E).

Stable isotope values of the fish at both study sites did not demonstrate a strong trophic link to phytodetritus, whereas their fatty acid profiles indicated a strong link between their lipid pool and algae, which may be attributed to trophic transfer. This study suggests that deep-sea fish, such as grenadiers on the Atlantic Iberian margin, is attracted to phytodetritus in areas where this reaches the sea-floor regularly. The study represents to our knowledge the first *in situ* documentation of deep-sea fish ingesting plant material and phytodetritus and highlights the variability in the scavenging nature of deep-sea fish. In the future, we will try to quantify the exact contribution of this vegetarian food source to the diet of grenadiers. A BBC news video clip of our spinach experiment can be viewed via www.nioz.nl/media.

Fig. 5A-C. Behaviour of grenadier fishes at the phytodetritus patch at 3000 m on the Atlantic Iberian margin. (A) Attraction to and investigation of the phytodetritus, (B) investigation and ingestion of phytodetritus, (C) the diminished phytodetritus patch after a few hours.

Fig. 5D-E. Behaviour of a grenadier fish (D) and a *Chaceon* crab (E) at the phytodetritus patch at 3000 m in the Mediterranean.