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Some Observations of Fish Orientation to Current Direction and Effects on Predator-prey Interactions*

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Abstract

Direct underwater observations of demersal fish orientation and behavior in currents were made during a series of manned submersible dives on Georges Bank and in adjacent canyons. Fish in currents of significant velocity oriented at angles which allowed detection and interception of macroplanktonic prey which drifted downcurrent. When feeding was observed, the fish assumed an upcurrent orientation to consume prey. The observed interactions indicate that the prey field of individual predators is only in an upcurrent direction from the position of the predator during periods of high current velocity. Because the distribution of macroplanktonic prey is dynamic on both spatial and temporal scales, the composition and density of the prey to individual fish varies spatially and temporally. These types of predator-prey interactions do not fit present models of prey selectivity. The use of direct underwater observation techniques will allow high-resolution studies to further elucidate these types of interactions.

Introduction

Studies on the prey of commercially-important fishes are common in the scientific literature because food intake ultimately controls productivity (e.g. Powles, 1958; Steele, 1963; Wigley and Theroux, 1965; Daan, 1973; Langton and Bowman, 1980). Other studies not only describe prey species but also relate the predator's selectivity of a prey item to its availability in the environment (Montgomery, 1980; Kohler and Ney, 1982; Laur and Ebeling, 1983). A problem inherent in this approach is the inability to ascertain the predator's foraging tactics which influence its prey field and selection of specific prey items.

Currents have been shown to affect fishes at a variety of spatial and temporal scales (Auster, 1984, 1985). The size distribution of several fish species over specific substrates has been shown to be effected by cyclic changes in the speed of currents. Behavior and foraging tactics also change in relation to changes in current speed. These changes in distribution and behavior affect the predator's prey field and selection of specific prey items. In this paper, observations of the effects that currents have on the orientation of several demersal fish species to prey are described, the limits to interactions caused by this phenomenon are discussed, and the problems associated with defining predator-prey relationships and the utility of direct underwater observations to help in the better definition of these relationships are noted.

Materials and Methods

Direct underwater observations of demersal fish orientation and behavior were made opportunistically by biologist-divers from the four-man (two scientists) submersible *Johnson-Sea-Link II* (Harbor Branch Foundation, Fort Pierce, Florida, USA). Twelve dives were made along the southern slope of Georges Bank (76–92 m), in Lydonia Canyon (140–220 m), Oceanographer Canyon (180–275 m), Gilbert Canyon (580–610 m), Veatch Canyon (140–190 m), and at a deep slope station (460–610 m) during 3–11 July 1984 (Fig. 1). All dives were made during daylight hours and the transects at each station covered approximately 1,100 m.

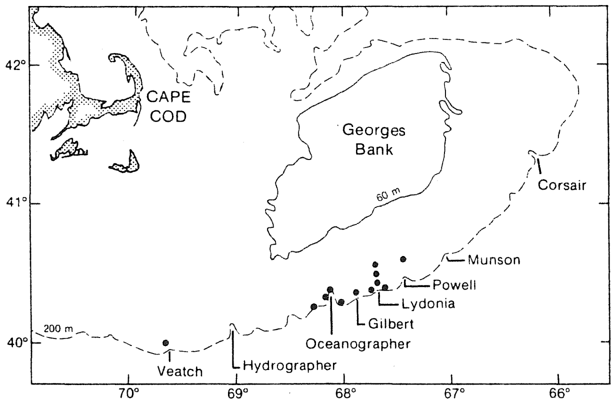

Fig. 1. Location of submersible dive stations on the southern slope of Georges Bank.

The observations included orientation of fish to current direction, estimated current speed, and fish behavior in relation to currents and prey species. The behaviors of various species were documented with a 3/4-inch video-tape system and external color video-camera with zoom capabilities on a pan/tilt mechanism.

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Observations

Ocean pout (*Macrozoarces americanus*)

Ocean pout were observed in an erect posture on the bottom, with the tail curved toward the anterior part of the body. The ventral side of the head was not in contact with the substrate. Twenty-eight individuals were observed at current speeds of 0.10 to 0.75 knots (1 knot = 31 m/min). Twenty-four of these (86%) were oriented within 90° of the direction of the oncoming current, with 18 individuals (64%) oriented within 45° of the oncoming current. Only four fish were oriented in a downcurrent direction where the speeds were approximately 0.1–0.2 knots. Unidentified prey items drifting downcurrent toward the predators were consumed by several individuals which were oriented in an upcurrent direction. Prey items were not pursued in a downcurrent direction.

Hakes (*Urophycis* sp.)

Adult red hake (*U. chuss*), white hake (*U. tenuis*) and long-finned hake (*U. chesteri*) oriented to significant current speeds (velocities which limit maneuverability or success in capturing prey) while swimming or resting on the bottom. Large hakes (⩾60 cm TL) swam in near-random directions at low current speeds (<0.25 knots), and all size-classes swam in random directions in low current areas of boulder fields. Long-finned hake were observed feeding in high current areas on euphausiids (*Meganyctiphanes norvegica*) which drifted toward individual fish. These fish were either oriented in the upcurrent direction or turned upcurrent just before consuming the prey. Euphausiids were not pursued in the downcurrent direction.

Goosefish (*Lophius americanus*)

Goosefish were observed on the bottom or in individually-formed depressions of the substrate. In high current areas, they were generally oriented within 90° C of the upcurrent direction. At low current velocities (<0.25 knots), the largest fish (⩾90 cm TL) oriented in near-random directions. No feeding was observed.

Silver hake (*Merluccius bilinearis*)

Individuals, approximately 45 cm TL, performed longer swimming forays from a starting point during periods of low current speed than during periods of high current speed. At high current speeds (0.75–1.0 knots), fish were observed on the substrate and sometimes moved upcurrent in short hops of about one to five body lengths. No sustained swimming or feeding was observed.

Discussion

The foregoing observations indicate that current speed is a factor which affects the orientation, search area and planktonic prey field of individual fish. Prey items are selected from an upcurrent potential prey field, and those which have moved downcurrent of the predator are not part of the potential prey field at significant current velocities. Figure 2 is a conceptual representation of the situation near or on bottom and demonstrates the ephemeral nature of the planktonic prey field on a short temporal scale (minutes to hours). This type of interaction only occurs in areas of significant current flow. Although the predators are able to maneuver in all directions in areas of low current velocity, they may orient in an upcurrent direction in order to maximize the potential of encountering, identifying and capturing the oncoming prey.

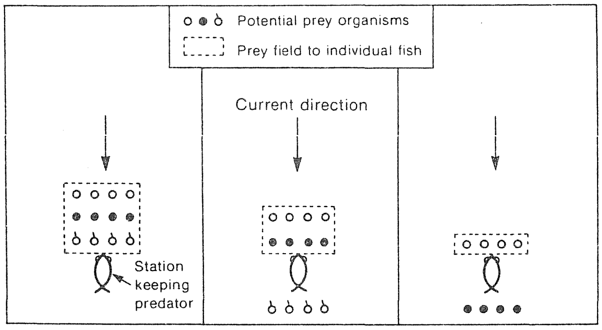

Fig. 2. Conceptual representation of the movement of different types of macrozooplankton through the prey field of a station-keeping predator on a short time-scale. (Organisms outside the prey field are not part of the food items available for selection.)

The prey field of these demersal planktivorous fishes varies greatly on short spatial scales. Although little is known about the small-scale horizontal variability in the distribution of macroplanktonic prey organisms, existing information indicates that their distributions can be highly aggregated over short distances. Colton *et al.* (1980), from hourly sampling over a period of 4 days, showed that densities of larval herring on Georges Bank were in the range of 10.3–290.4 per 100 m^3. Observations on the near-bottom horizontal distribution of mysids in Cape Cod Bay showed that densities varied widely on a scale of meters (Stewart *et al.*, 1985). Therefore, the density of planktonic prey organisms that are available to individual predators is dynamic both spatially and temporally.

Station-keeping by predators for foraging on planktonic prey, as decribed in this paper, has been previously observed for planktivorous tropical reef fish (Hobson and Chess, 1978), a temperate kelp-bed fish (Hobson and Chess, 1976), and salmonids (Dunbrack and Dill, 1984). This type of foraging in areas exposed to currents is beneficial because less energy is expended in searching a specific volume of water for prey. However, current velocities beyond some maximum level reduce the optimality of this strategy because greater energy is expended in station-keeping.

Predator-prey interactions have been viewed as relatively static events on short-time scales. Samples of the composition of fish diets and the surrounding fauna are utilized to determine indexes of selectivity for predators (Allen, 1941; Ivlev, 1961; Jacobs, 1974). These techniques have the implicit assumption that all potential prey in the environment are available to all predators. However, the planktonic prey field of individual predators in current-dominated environments is dynamic (in the order of minutes to hours), and the obsevations presented in this paper indicate that the way of viewing predator-prey interactions should be changed to higher-resolution temporal and spatial scales.

The use of direct underwater observation techniques (e.g. SCUBA, manned submersibles, remotely-operated vehicles, and remote camera systems) is essential for elucidating and quantifying predator-prey relationships on the scale at which they occur. In the light of past and present descriptive studies (Auster, 1984, 1985), future research should entail (a) time-lapse studies on current-exposed surfaces to discern functional species and/or size-class feeding groups at different current velocities over the entire tidal range, (b) flume studies to discern the effects of orientation and current velocity on prey-capture success and reaction distance, and (c) continued qualitative field observations to discern more subtle effects of current-induced phenomena on predator-prey interactions.

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