COLOR PATTERNS OF PILOTFISH (*NAUCRATES DUCTOR*) AND THEIR POSSIBLE SIGNIFICANCE.—Two color patterns and the behavior of pilotfish (*Naucrates ductor*) were observed near the equator in the central Pacific from underwater windows of a drifting raft (Gooding, 1965; Gooding and Magnuson, 1967). Pilotfish, associated with whitetip sharks (*Carcharhinus longimanus*), were observed from 11 to 13 March 1964. From one to seven pilotfish 8–20 cm long and from one to four remora (*Remora remora*) were associated with each shark.

Typical coloration of pilotfish includes about eight black vertical bars (including those on the head and the caudal fin) against a light silvery background (Fig. 1). Further description and a good figure are presented by Marshall (1965).

A transient coloration of pilotfish, previously unreported in the literature, was also observed from the raft. The characteristic black vertical bars faded and disappeared, leaving the fish with a silvery-white appearance with some bluish color on the dorsum. This bluish color, when observed closely, consisted of about three broad patches in tandem across the dorsum (Fig. 2). Borders between the bluish and whitish areas were not sharply defined. The lower half of the fish's body remained whitish.

This transient coloration was recorded during 16 observations of sharks and their associated pilotfish. It occurred only when the pilotfish from more than one shark intermingled. One pilotfish while chasing another lost its bars and exhibited the transient coloration during the chase. The more intense the chase, the more dramatic the color change seemed to be. When chasing activities stopped, the typical barred coloration returned. This sequence was observed many times. Usually the pursuing fish was larger than the pilot fish being chased. If the smaller fish were chased the chased fish did not lose its barred coloration. If two fish were similar in length, the bluish-white coloration appeared in both fish, but less intensely in the chased fish. The smaller fish was sometimes driven as far as 5 m from its shark. Several times a pilotfish also chased a remora. Transient coloration did not appear when the pilotfish ate pieces of fish we tossed into the water nor when they chased natural foods.

These interactions occurred between pilotfish from the same shark or from different sharks. They did not occur, however, when only one shark was present, even though a number of pilotfish accompanied the shark. Nor did they always occur when several sharks were present. Pilotfish always separated and stopped chasing each other when two sharks swam away from each other. Usually the pilotfish remained with their original shark, but since the pilotfish could not be identified with certainty some permanent interchange of fish could have taken place. Identification of pilotfish was based largely on size.

Transient coloration appeared to be part of an aggressive threat display in defense of the shark as a moving territory. The expectation would be that these interactions would drive the smaller pilotfish from a shark, thus reducing intraspecific competi-

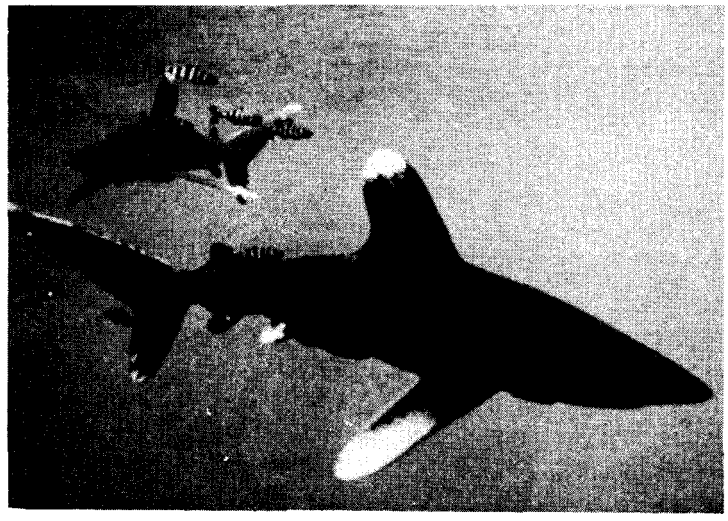

Fig. 1. Whitetip sharks (*Carcharhinus longimanus*) with pilotfish (*Naucrates ductor*) photographed from a drifting raft in the central Pacific Ocean.

tion for the larger dominant pilotfish. Aggression should be more successful in driving off the smaller fish if an alternative shark were available for the subordinates. Ineffectiveness of aggression in the absence of an alternative residence might explain the absence of aggression when only one shark was present.

Since pilotfish apparently defend the shark as a moving territory, they would be expected to obtain some benefit from the association. The most significant benefit may be protection from predation. Once, pilotfish pursued by a dolphin (*Coryphaena hippurus*) were observed to flee to the raft and then to the shark. For the following 30 min their attraction to the shark appeared greater than usual. Protection from predation was the most obvious benefit that a variety of fishes obtained by associating with a drifting raft (Gooding and Magnuson, 1967). Fishes at the raft often avoided predators by swimming close under the raft when predators approached. Once a golden jack (*Caranx kalla*) left the raft in the company of a shark without being attacked by dolphins which had previously chased the jack to the raft.

Other potential advantages of an association with sharks are 1) the shark is used as a substrate for depositing eggs, 2) pilotfish feed on the ectoparasites of the shark, and 3) pilotfish depend on the fragments of the fish being eaten by the shark or the feces of the shark. But Whitley (1951) pointed out that data to support these ideas are largely nonexistent or even contradictory. Pilotfish in the boundary layer around a swimming shark should also obtain an advantage of traveling with little expenditure of energy (Shuleikin, 1958). We did not observe pilotfish spawning, nor eating the numerous ectoparasites present on the sharks. When food was tossed to the sharks, pilotfish ate fragments broken by the feeding of the shark. Yet pilotfish did not depend upon fragments as they also foraged independently on small fishes and zooplankton. One pilotfish swam for 3 min on its side immediately adjacent to the upper surface of the shark's pectoral

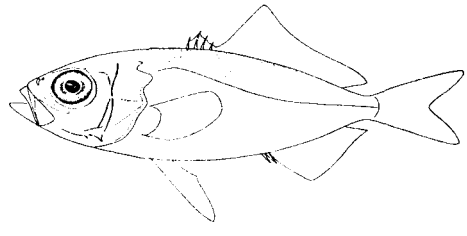

Fig. 2. A diagrammatic sketch of the transient coloration of pilotfish.

fin, with little caudal movement evident. These aspects of the association would appear less important than predator avoidance.

The barred coloration may be important to predator avoidance because it has some features of an aposematic display. Cott (1957) summarized features of an aposematic display—the pattern of coloration is usually bold and consists of vivid tones such as black, white, or shades of red. The animal is highly conspicuous in nature. Some feature of an aposematic animal or its immediate environment is potentially dangerous or noxious to a predator—for example, the smell of a skunk. The pilotfish has the conspicuous coloration. They were readily visible to us and could be identified as pilotfish near the maximum range of visibility. The shark provides the potential danger. Pilotfish, observed from the raft, were not always adjacent to the shark as usually pictured, but wandered out to the limits of visibility, apparently on feeding forays. When a predator encounters the conspicuous markings of the pilotfish in the monotonous epipelagic environment, the stimulus could signal the presence of a shark nearby and thus reduce the likelihood that feeding behavior would be released in the predator.

Some other fishes that associate with animals potentially dangerous to predators are also conspicuously marked and may be aposematic animals. Amphiprionids or anemone fishes have vivid white and orange or white and brown vertical bands and live in close association with anemones. Juvenile omaka (*Caranx mate*) have dark vertical bars and live in association with jellyfish (Gosline and Brock, 1960). A number of other examples can be found among fishes.

These observations suggest that the transient coloration of pilotfish is part of an agonistic display and that the typical coloration of pilotfish may be aposematic. A more definite conclusion, especially in regard to the typical coloration, will have to await additional and more critical observations.

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