ARTICLES

They found enough tuna to support commercial fishing. The plane was more effective than vessel in search for tuna schools.

AN AIRCRAFT AND VESSEL SURVEY OF SURFACE TUNA SCHOOLS IN THE LESSER ANTILLES

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Scientists of BCF's Tropical Atlantic Biological Laboratory studied the distribution of surface tuna schools in the waters adjacent to the Lesser Antilles Islands in February-April 1966. It was part of the laboratory's investigation of the biology and ecology of tunas in the tropical Atlantic Ocean.

Observations of the location, size, and species composition of the schools were made from BCF's research vessels "Undaunted" and "Geronimo"--and from an aircraft piloted by a professional tuna spotter. An important part of the study was to determine whether the ability to locate tuna schools could be increased by using a plane along with a research vessel. In this report, we compare the results obtained from the ship and the plane and discuss the efficiency of a survey in which both participate.

Aerial scouting for pelagic fish is used in many parts of the world (Iversen, 1963; Marty, 1965). Land-based aircraft are employed by the U. S. commercial tuna seining fleet to scout for tuna schools and give detailed directions for setting purse seines (Broadhead and Marshall, 1961; Broadhead, 1962). Float planes and helicopters also have been used. Some vessel operators believe that assistance from aircraft is well worth the cost.

The ocean bordering the Antillean region, from Puerto Rico to Trinidad, was surveyed for surface tuna schools from the Undaunted between Feb. 26 and March 18, 1966 (figs. 1 and 2). Oceanographic data were collected at least three times each day. The vessel traveled about 80-90 nautical

Fig. 1 - BCF's Undaunted. (Photo by Jossi, TABL.)

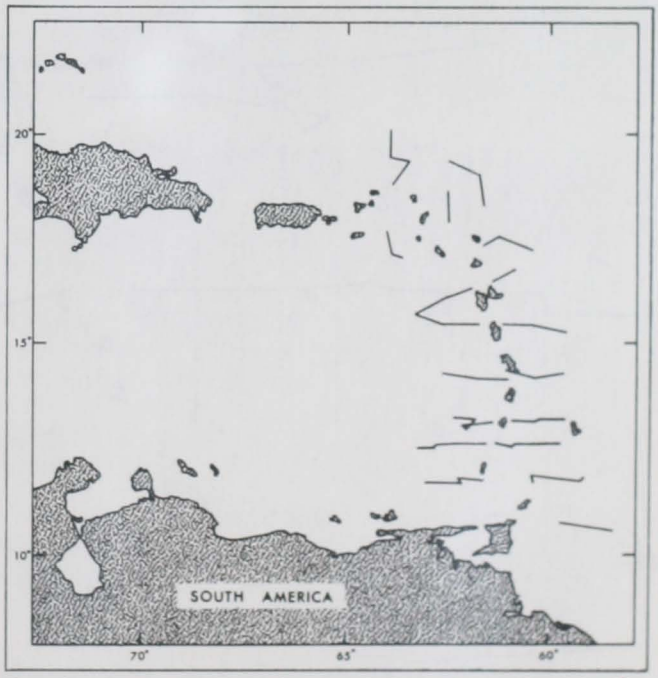

Fig. 2 - Lesser Antilles, showing daily cruise tracks of the Undaunted, February 26-March 18, 1966.

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miles each day along a straight transect line. Individual transect lines, representing successive days' surveys, were spaced at 45-60-mile intervals. The St. Vincent-Grenada portion of the area was again surveyed from the Undaunted March 26 to April 1, and from the Geronimo, April 2 to 14. During these two periods, the transect lines were spaced at 15- to 20-mile intervals.

Fig. 3 - Cessna-180 used during tuna survey.

A Cessna-180 aircraft was operated along with the Undaunted from February 26 to March 28 (fig. 3.). The plane was flown in a pattern used for search and rescue work (U. S. Coast Guard, 1963) (fig. 4). While the vessel sailed a straight track, the plane flew along a parallel track pattern perpendicular to the vessel's. The lengths of the plane's transect lines were adjusted so that the plane crossed above the vessel at approximately $\frac{1}{2}$-hour intervals. At average speeds of 10 knots for the vessel and 97 knots for the plane, it proved practical to fly 15 minutes (24.2 nautical miles) along the long leg of the flight pattern and 3.5 minutes (5.7 nautical

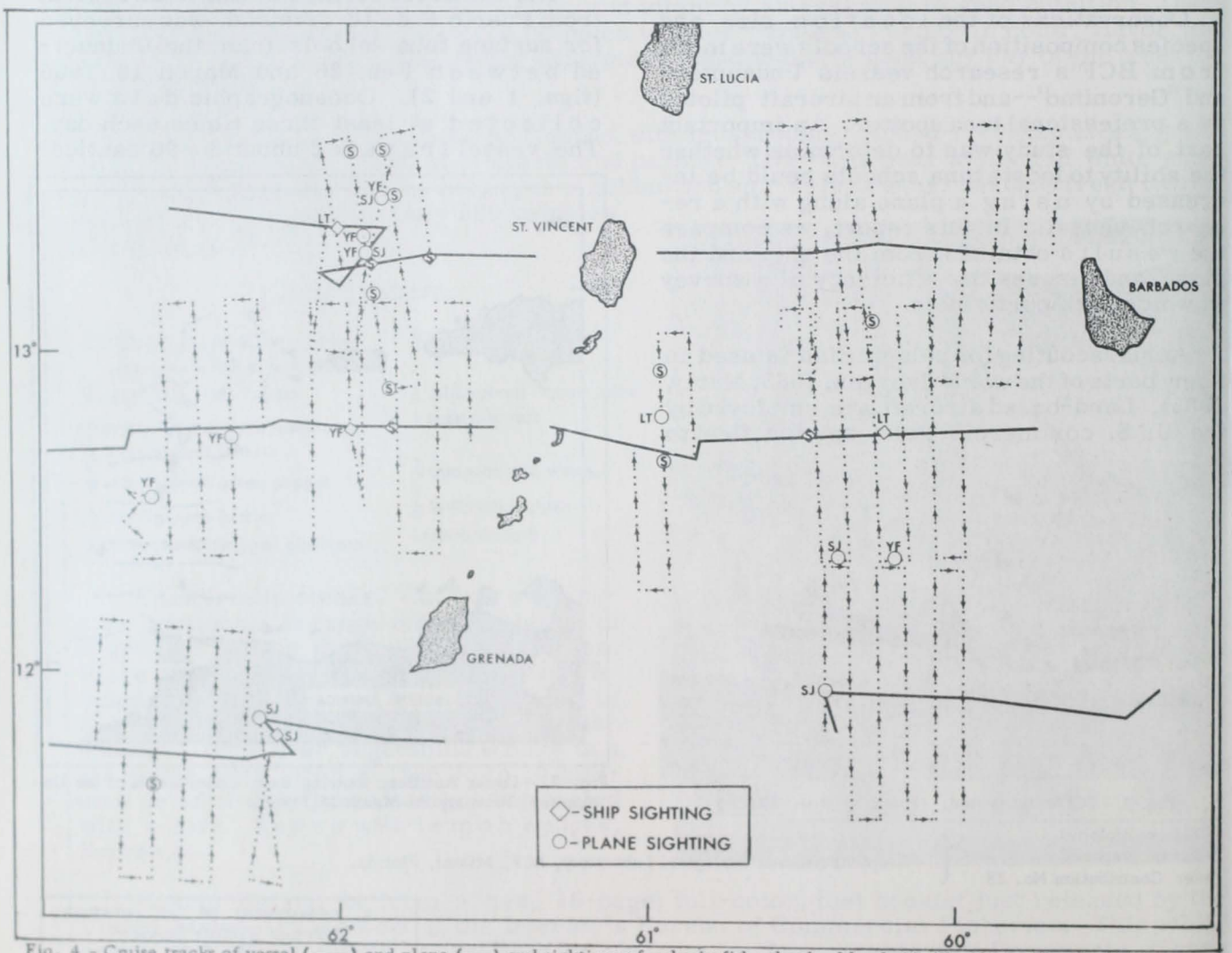

Fig. 4 - Cruise tracks of vessel (——) and plane (---) and sightings of pelagic fish schools, March 11-17, 1966. The 6 solid lines represent daily vessel tracks. YF, yellowfin school; SJ, skipjack school; LT, little tuna school; S, unidentified sighting.

miles) along the short leg. The plane usually flew at 1,500 feet.

DISTRIBUTION OF FISH AND BIRDS

No schools of tuna or other pelagic fishes were sighted from the ship or plane in 11 days of scouting (February 26-27, March 1-2, 4-10) from Puerto Rico to St. Lucia. Trolling yielded 5 little tuna (Euthynnus alleteratus) and one yellowfin tuna (Thunnus albacares); evidently, they were isolated individuals, not part of schools. Chumming and additional trolling failed to produce increased catches.

Larger numbers of fish were observed off the southern Lesser Antilles from St. Lucia to Trinidad. Ship and plane personnel sighted tuna and other pelagic fishes 27 times in 6 days of scouting (March 11-13, 15-17) (fig. 5). Yellowfin tuna or skipjack tuna (Katsuwonus pelamis) or both, were seen 20 times; unidentified species of tuna or billfishes were seen 7 times.

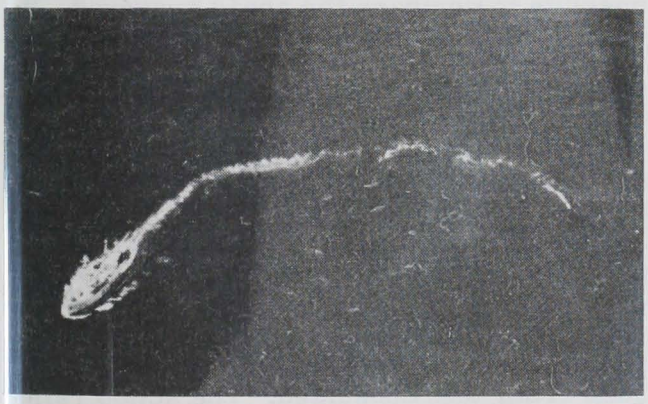

Fig. 5 - Photograph of mixed yellowfin and skipjack tuna school, estimated size 20 tons, and the Undaunted photographed from 1,300 feet altitude, March 15, 1966.

Sightings indicated a greater abundance of tunas on the west side of the southern Lesser Antilles than on the east side. Fourteen tuna schools were recorded on the west side of St. Vincent and Grenada on March 11, 15, and 16, compared with six on the east side on March 12, 13, and 17 (fig. 4). Both yellowfin and skipjack tuna schools were seen in each area. Four sightings of unidentified pelagic fishes were made on the west side and three on the east side of the islands.

Later, west of St. Vincent and Grenada, 52 tuna schools were seen in 18 days (March 26-28; March 31-April 14). Skipjack tuna were most abundant in schools estimated at 15 to several hundred tons each. Yellowfin tuna were in schools estimated at 15 to 50 tons per school. Some schools contained a mixture of yellowfin and skipjack tunas. Size of skipjack ranged from 4 to 35 pounds and yellowfin 33 to 154 pounds. Identifications were made either from captured fish or from observations at close range (from the vessel) and through binoculars (from vessel and plane). The tonnage estimates, made by experienced tuna fishermen aboard the research vessel, were corroborated by the spotter pilot. The resource appeared sufficiently large to support commercial fishing. Several fish schools behaved in a manner that would make them potentially available to commercial fishing by either live-bait or purse-seine methods. Fishing from the research vessels was by the live-bait method.

Sooty terns (Sterna fuscata) were seen frequently; frigate birds (Fregata magnificens), boobies (Sula spp.), noddy terns (Anous spp.), and tropic birds (Phaethon spp.) also were present. The terns, frigate birds, and boobies often were associated with tuna schools. Sightings of birds and tunas were more numerous on the west than on the east side of St. Vincent and Grenada. During March 11-17, 33 flocks of more than 10 birds each were seen on the west side of the islands, compared to 17 flocks on the east side.

The greater abundance of tunas and birds west of the Lesser Antilles was associated with differences in the biological and physical features of the ocean environment (table).

Physical and Biological Features of the Oceanic Environment on the East and West Sides of the Southern Lesser Antilles Islands, March and April 1966

Feature	West of Islands	East of Islands
Number of tuna schools observed	14 (3 days)	6 (3 days)
Number of bird flocks[1/] observed	33 (3 days)	17 (3 days)
Depth of mixed layer (meters)	40-100	70-150
Average rate of C-14 uptake (g. C/m.^{2}/day)	0.048 (4 stations)	0.025 (3 stations)
Average zooplankton displacement volume (ml./1,000 m.^{3})	177 (14 stations)	72 (4 stations)

1/More than 10 birds.

The mixed surface layer was shallower on the west side of the island chain than on the east. Primary productivity, measured as the rate of uptake of carbon isotope C-14, was nearly twice as much on the west as it was on the east side; the average displacement volume of zooplankton was about $2\frac{1}{2}$ times higher.

EFFICIENCY OF SEARCH

The distance at which tuna schools or birds associated with tuna schools can be detected visually varies widely. Behavior of the animals, weather conditions, and the observer's experience are critical factors. Under ideal weather conditions, an experienced observer aboard a vessel may detect a school of tuna "breezing" at the surface up to 3 miles away. A bird flock may be seen from 5 miles away.

Visibility of surface-schooling fish is better from a plane than from a ship because the observer is higher; under ideal conditions, fish schools may be seen 5 to 8 miles away. From a plane birds can be seen up to about 1 mile; birds are difficult to see because their dark dorsal surfaces blend with the color of the sea. Birds seen from a vessel are more visible because they are silhouetted against the sky. Unfavorable weather and sea conditions affect visibility from both surface and air, but certain spotting difficulties are less troublesome to spotters in a plane. For instance, from an aircraft fish schools and surface ripples ("wind spots") are easier to tell apart than they are from a vessel.

The areas searched by the plane and ship were compared by assuming an effective visibility limit for each. For ease in computation, this limit was assumed to be that distance beyond which the number of targets detected was equal to the number missed within the limit (U. S. Coast Guard, 1963). In this survey, weather conditions and the state of the sea surface limited visibility to less than maximum distances. The sea was usually choppy (sea state 3-5) and whitecaps were numerous. The visibility limit of fish schools from the ship was approximately 1 mile and of bird flocks approximately 4 miles. From the plane, the scouting distance for fish and bird flocks was estimated conservatively at 1 mile, primarily because of the sea state. All flying was below the elevation of the lowest clouds.

Plane and ship tracks crossed at intervals of about $33\frac{1}{2}$ minutes; in that time, the ship traveled 5.7 miles and the plane 54.1 miles. Under the above assumptions for visibility, the maximum areas effectively searched for fish in each interval were 11.3 square miles (vessel) and 108.2 square miles (plane). The maximum areas searched for birds were 45.4 square miles (vessel) and 108.2 square miles (plane). These values indicate that the plane should have encountered, on the average, about 9.6 times more fish schools and about 2.4 times more bird flocks than the Undaunted. The ship's personnel often located fish schools by first locating bird flocks and then approaching the flocks to determine whether fish schools were present. Under this searching technique, the plane would be expected to encounter only 2.4 times as many schools as the vessel.

The sightings of fish schools from the plane and the vessel were compared for the area from St. Lucia south to Trinidad in March 11-17. In March 26-28, when the plane scouted randomly for fish schools, it was not possible to compare the areas surveyed. In 6 days (March 11-13, 15-17), 8 vessel sightings of pelagic fishes and 19 plane sightings were recorded. In the same period, 24 bird flocks of more than 10 birds and 22 smaller flocks were seen from the Undaunted. Twenty-six bird flocks of more than 10 birds and 49 smaller flocks were sighted from the plane.

The survey indicated that the plane was more effective than the vessel in searching for surface tuna schools. The numbers of fish schools and bird flocks seen from the plane were 1 to $2\frac{1}{2}$ times greater than those seen from the Undaunted. The actual ratio of small flocks of birds seen from the plane, compared to those sighted from the vessel (2:2), was close to the expected ratio (2:4). The ratio for fish schools seen (2:4) was less than the expected ratio (9:6). Much of the time, however, vessel personnel depended on flock sightings to indicate the location of schools of fish under the hovering birds. The ratio for large flocks of birds seen (1:1) suggests that these flocks were visible from the vessel for a greater distance than assumed in the theoretical calculations.

Use of the plane broadened the geographical area that could be searched within a given period. Its use increased the likelihood of sighting concentrations of fish, since tuna schools (and bird flocks) often are aggregated in certain oceanic areas because of favorable environmental conditons.

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SPACECRAFT SURVEYS AID OCEANOGRAPHIC STUDIES

An intensive study of GEMINI photographs taken over a number of oceanic and coastal areas has revealed that they are of significant value to ocean scientists. A scientist of the U. S. Naval Oceanographic Office, Suitland, Md., stated in a recent paper that large-scale oceanographic features observed in outer-space color prints may aid scientists in correcting charts, tracking river effluent, and detecting shoal areas.

Among other possible applications for spacecraft in oceanography are ice surveillance, sea state measurements, and mapping of currents. Radar, infrared, and passive microwave devices would be used in such work.

The scientist said that a few years ago the words "spacecraft" and "oceanography" were incompatible. Today, however, the combination of outer space and inner depths is no longer considered a fantasy. The Naval Oceanographic Office has been working on such a program since October 1965.

A summary shows that oceanographers may have both scientific and economic reasons for turning to spacecraft. Earth-orbiting satellites provide a means of constantly surveying remote areas such as the Arctic, Antarctic and South Pacific. More frequent coverage of the world's oceans could also be obtained and a new global perspective provided. These factors would lead to a better understanding of oceanic phenomena.

The scientist pointed out that two-thirds of a satellite's orbiting time is spent over the ocean. Aircraft flying across large water masses have already proven that valuable scientific data can be gathered remotely.