**Abstract.**—Aerial surveys were conducted daily from 19 May to 9 June 1995 to document the apparent abundance and migration behavior of giant bluefin tuna, *Thunnus thynnus*, over the Great Bahama Bank region of the Straits of Florida. Our objectives were to conduct an aerial assessment of giant bluefin tuna in this region and to compare our results with previous aerial surveys conducted in the 1950's and 1970's. Two professional bluefin spotter pilots flew 70-nmi transect surveys along "Tuna Alley" as well as surveys into adjacent areas in search of bluefin tuna. The present study area was broader than that surveyed in the 1970's, which consisted of repeated flight tracks, each 1 nmi, across Tuna Alley at a point just south of South Cat Cay. Spotter aircraft carried a data acquisition system consisting of a global positioning system (GPS), a laptop computer, and a 35-mm camera to photograph schools. A total of 839 giant bluefin tuna were documented, within range of totals counted in the 1974–76 surveys (368–3,125 bluefin tuna). Single fish and loosely aggregated schools of up to 100 fish were seen travelling steadily north along the western flank of the Great Bahama Bank. They did not engage in feeding, smashing, or cartwheeling behaviors that are exhibited in New England waters. All bluefin tuna appeared to be "large giants," weighing an estimated 227 kg and over. There is little information documenting the origins and previous locations of giant bluefin tuna travelling along the Great Bahama Bank; therefore the use of direct counts of bluefin tuna in this region as an index of spawning biomass would require further documentation.

Manuscript accepted 27 September 1996.
Fishery Bulletin 95:300–310 (1997).

# Aerial survey of giant bluefin tuna, *Thunnus thynnus*, in the Great Bahama Bank, Straits of Florida, 1995

**Molly Lutcavage***
**Scott Kraus**
Edgerton Research Laboratory
New England Aquarium, Central Wharf, Boston, Massachusetts 02110
*E-mail address: mlutcavg@neaq.org.

**Wayne Hoggard**
Southeast Fisheries Science Center
National Marine Fisheries Service, NOAA
3209 Frederic Street, Pascagoula, Mississippi 39568

In the 1950's, and later in 1974–76, the U.S. National Marine Fisheries Service conducted aerial surveys for bluefin tuna, *Thunnus thynnus*, migrating along the Great Bahama Bank region (Rivas, 1954, 1978). It is generally believed that large bluefin tuna travel along the Straits of Florida from late April through mid-June on their way to feeding grounds at higher latitudes where they are usually resident from June through October. The bluefin tuna found on the Great Bahama Bank are giants (over 185 cm/107 kg) and are believed to have recently spawned in the Gulf of Mexico or in the Straits of Florida (Rivas, 1978; Mather et al., 1995). Sport fishermen since the 1930's and researchers alike believe that these fish are members of the seasonal assemblage occurring off New England and maritime Canada (Farrington, 1939; Rivas, 1954; Mather et al., 1995). Fish tagged and released on the Great Bahama Bank have been recovered primarily in the northeastern U.S., Canadian, and Norwegian waters.

Recreational fishermen and researchers have identified a narrow region of the Great Bahama Bank off South Cat Cay as Tuna Alley (Fig. 1) because travelling schools seem to concentrate in this region and are easily visible by air (Rivas, 1954, 1978; Anonymous[1]). In three surveys conducted from May through June 1974–76, survey aircraft flew a 1-mi long transect across Tuna Alley, at 25°31'N and 79°18'W, for about 60 minutes (Rivas, 1978). Flights were conducted on days when weather was suitable for flying for a total transect effort ranging from 38 to 52 hours per survey period (Rivas, 1978). The number of bluefin tuna encountered was multiplied by the number of minutes in a day to derive a daily abundance estimate. This estimate was then multiplied by the assumed 50-d migration interval to derive an estimate of spawning population size. Over the three-year survey period this estimate ranged from 9,630 to 99,360 fish. Rivas (1978) linked the presence and apparent abundance of bluefin tuna in the area with environmental factors, such as increased wind speed and (less strongly) with

[1] Anonymous. 1975. A study of the application of remote sensing techniques for detection and enumeration of giant bluefin tuna. Southeast Fish. Sci. Center, Natl. Mar. Fish. Serv., NOAA, Miami FL. Contribution rep. 437, 48 p.

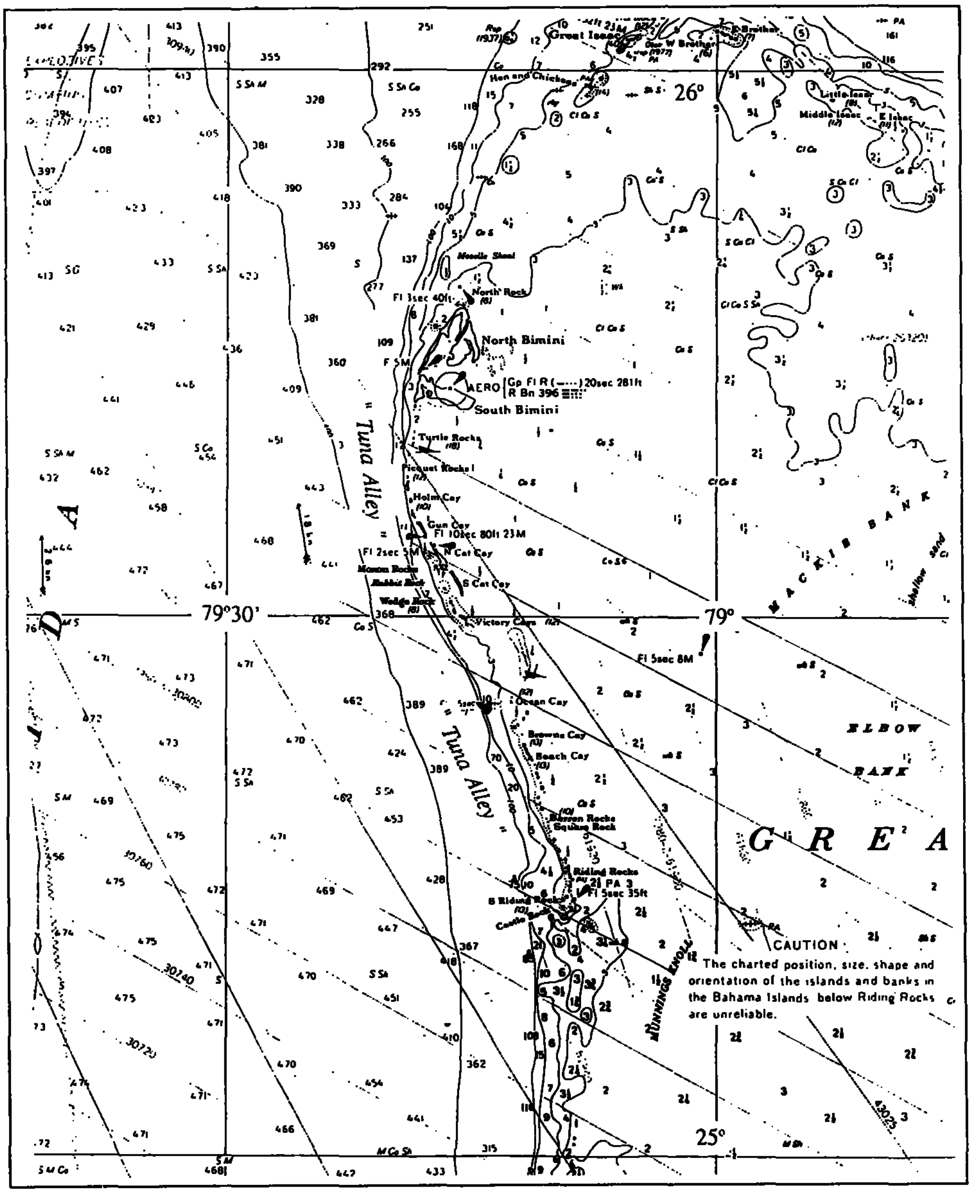


**Figure 1**

View of the study region showing the location of "Tuna Alley" along the western margin of the Great Bahama Bank, Straits of Florida.

wind direction, lunar phase, and tide. He tentatively concluded that the difference in magnitude of the annual population estimates might be attributed to differences in wind speed across Tuna Alley and, consequently, to changes in the visibility of bluefin tuna to aircraft and fishing vessels.

The decline of North Atlantic bluefin tuna stocks since the 1970's has heightened efforts to obtain more accurate indices of abundance, particularly for spawning biomass. Despite documented changes in bluefin tuna stocks and commercial fishing practices, there have been no aerial surveys or direct assessments of giant bluefin tuna transiting the Great Bahama Bank for over 20 years. From 19 May to 9 June 1995, we conducted an aerial survey of giant bluefin tuna transiting the Great Bahama Bank region in the general vicinity of the Bimini islands and sand cays. Our objectives were to document their apparent abundance and behavior and to compare the results of the present study with those obtained in previous aerial surveys conducted by the National Marine Fisheries Service.

## Methods

Bluefin tuna were sighted and counted by two tuna spotter pilots each having over 20 years of experience in the commercial bluefin tuna, yellowfin, and tropical tunas purse-seine fisheries. It is standard practice for spotters to identify species and to estimate average size, weight, and total tonnage before a set is made. The two spotter pilots, having participated in the 1994 New England bluefin tuna aerial survey (Lutcavage and Kraus, 1995), flew a single-engine aircraft (Supercub, tailnumber 344Z, and Cessna 172, tailnumber 270Q) that had viewing access from both sides. Flights originated from Executive Airport, Fort Lauderdale, FL, and required approximately a 40–55 min transit to reach the Great Bahama Bank area near Bimini. The two pilots began spotting fish when they reached the Florida Straits. The survey was targeted to occur between 11:00–13:00 h, similar to the time of day covered by the 1974–76 surveys. The data acquisition system (Tunalog, Cascadia Research, Inc.) consisted of a global positioning system (GPS), a laptop computer with mouse (for event marking), and a 35-mm camera, identical to that used in the New England bluefin tuna spotter survey (Lutcavage and Kraus, 1995), to photograph schools. Position was automatically logged every 15 seconds, and daily flight tracts were reconstructed and bluefin tuna positions plotted with OPCPLOT, version 7.0.

Each day the transect aircraft (Supercub 344Z, except on 28 May) surveyed a zigzag transect line of approximately 70 nmi in length along Tuna Alley, beginning at a southernmost point near 24°45'N and following a zigzag pattern north to approximately 25°48'N. The starting point was set far enough south to incorporate the southernmost limit of the presumed migration route on the Great Bahama Bank where bluefin tuna are visible from the air (Rivas, 1954; Mather et al., 1995). On the first survey day (19 May) the transect aircraft 344Z carried an observer (Hoggard) to establish and verify survey protocol. The starting point of the transect was staggered slightly so that daily transects were not identical. Surveys were conducted at an altitude of 750–1,000 feet and at a true airspeed of 80 knots. The transect legs forming the zigzag were flown to points approximately 3 nmi west of Tuna Alley and were bounded on the east by the shallows of the Great Bahama Bank. The transect was repeated unless rain squalls and strong winds greatly reduced visibility. The spotter conducting the transect noted any bluefin tuna encountered during transit to the starting point.

The "discovery" aircraft Cessna 270Q did not fly dedicated transects, (except on 28 May). Its mission was to search Tuna Alley and adjacent areas between N. Bimini and Orange Cay in order to identify the general limits of bluefin tuna travel patterns, and to locate, photograph, and observe the behavior of any bluefin tuna encountered. The spotter was free to determine his own search patterns and carried an observer on six survey days. There were two aircraft present in the study area on 14 out of 17 survey days. Pilots remained in radio contact with one another, except for the period of time when the Supercub 344Z was conducting the transect. At the beginning of each survey and at the end of each transect leg pilots recorded their estimation of wind strength and direction, visibility, cloud cover, and water color. During surveys they were instructed to mark the location of all sighted bluefin tuna with the mouse event marker and to document them with photographs when possible. Radio contact with local sport fishing boats targeting bluefin tuna allowed the spotters and observer to collect general information on sea surface temperature, sizes of landed fish, and additional sightings.

## Results

Spotters flew a total of 11,910 nmi (158 hr, including time in transit), encountering bluefin tuna on 10 out of 17 survey days. Approximately 7,126 nmi (115 h) were flown over the Great Bahama Bank. Of these, 1,502 nmi were trackline distance (usually 2 transects/day). Spotters documented 53 bluefin tuna schools overall and estimated a total count of 839 fish (Table 1). No bluefin tuna were sighted on any transits over the Florida Straits; turtles, sharks, delphinids, and flying fish, however, were sighted on numerous occasions. Most bluefin tuna sightings occurred north of 24°30'N, and within the presumed migratory route identified by Rivas (1954) and Mather et al. (1995). Other sightings on or adjacent to the Great Bahama Bank near Tuna Alley included loggerhead sea turtles (*Caretta caretta*), unidentified dolphins, tiger (*Galeocerdo cuvier*) and other sharks, a single sperm whale (*Physeter macrocephalus*), schools of skipjack tuna (*Katsuwonus pelamis*), Bermuda chub (*Kyphosus sectatrix*), permit (*Trachinotus falcatus*), and other unidentified fish.

Sightings ranged from individual bluefin tuna to loosely aggregated schools from 20 to 100 individuals, all judged by spotters to be large giants (> 226 kg, or about 196 cm), similar in size to giants landed

**Table 1**

Giant bluefin tuna aerial survey, 19 May–9 June 1995, over the Great Bahama Bank. Sea water temperatures provided by charter boats. Wind speed and direction estimated by pilots based on sea state.

| Sea water temp (°C) | Date | Total no. of bluefin | Total no. of sightings | Winds (knots) North end | Winds (knots) South end |
|---|---|---|---|---|---|
| | 19 May | 0 | 0 | S 15–20 | |
| | 21 May | 0 | 0 | SSW 10–15 | |
| | 22 May | 0 | 0 | WNW <10 | WNW 10–15 |
| | 23 May | 0 | 0 | WNW 8 | |
| 26.4 | 25 May | 0 | 0 | ENE 10–15 | |
| | 26 May | 0 | 0 | CALM | |
| 26.7 | 28 May | 8 | 1 | ENE 8 | SSE 10–12 |
| 28.6 | 29 May | 8 | 2 | E 15 | E 12–15 |
| 29.2 | 30 May | 45 | 4 | CALM | ESE 8–10 |
| 28.9 | 31 May | 75 | 9 | CALM | SE <10 |
| 28.9 | 1 June | 181 | 3 | E 10–12 | ESE 15–20 |
| | 2 June | 125 | 9 | ESE 20 | SE 20–30 |
| 29 | 3 June | 149 | 10 | SSE 20 | ESE 25–30 (squalls) |
| 27.9 | 4 June | 186 | 8 | ESE 12–15 | S/E 25+ (squalls) |
| 28.5 | 7 June | 59 | 5 | WSW 15 | W 5–8 |
| 29 | 8 June | 1 | 1 | NNW 8–10 | WSW 8 (squalls) |
| | 9 June | 1 | 1 | CALM | |
| | Totals | 839 | 53 | | |

by anglers (Beare[2]). Bluefin tuna were first observed in Tuna Alley on 24 May from a sport fishing boat but were not observed from the air until 28 May. Sightings peaked in the first week of June (Table 1) and declined gradually to the last survey day (9 June) when only one giant was seen. According to interviews conducted with charter boat captains, aerial sightings were consistent with the timing and general location of bluefin tuna sightings by recreational vessels. However, aerial sightings were more extensive and covered a much broader area than that covered by charter boats, which tended to limit their fishing on Tuna Alley to a strip of approximately 12 nmi between Bimini and Victory Cay. The last bluefin tuna was sighted in Tuna Alley on 11 June, and all fishing ended by 12 June. Surface seawater temperatures taken by charter boats during the survey ranged from 26 to 29°C, and the prevailing winds were primarily from the E/SE sectors (Table 1).

A general account of sightings per unit of effort (SPUE) and search mileage is given in Table 2. Daily transects were conducted by the Supercub 344Z on all but one survey day (28 May), and the 4 June transect was abandoned because of squalls at the starting point (Table 3). Three out of 53 sightings (with counts of 100, 6, and 1 bluefin tuna, respectively) occurred on transect.

[2] Beare, Captain D. 1995. 2462 Lighthouse Point, FL 33064. Personal. commun.

Although our analyses of environmental conditions occurring during the survey are limited, some general conclusions can be drawn. Tropical storm Allison in the Gulf of Mexico generated strong winds and squalls that affected the survey region beginning on 1 June. General SPUE was highest from 1 to 4 June, associated with strongest winds, although fish were also seen on completely calm days with light and variable winds. Peak sightings occurred in the six days following the new moon on May 29. Although the majority of search effort occurred between 11:00 and 13:00 h, the largest school of an estimated 100 bluefin tuna was sighted on 1 June at 09:53 h. On this day pilots had an early start because wind conditions (ESE 15–20 kn) were expected to be especially suitable for the appearance of bluefin tuna. According to interviews with charterboat captains, a total of no more than 10–20 bluefin tuna were sighted over the survey period on Tuna Alley by recreational vessels before survey aircraft had arrived in the morning at the study site.

## Discussion

The total number of bluefin tuna seen in the 1995 survey (839) was generally within the range of bluefin tuna counted in the 1974–76 surveys (368–3,125). Upon examination of school positions for possible re-

**Table 2**

A summary of sightings of giant bluefin tuna during an aerial survey, 19 May–9 June 1995 over the Great Bahama Bank.

| Aircraft | T/D | Date | Start time | Total time (h) | Est. time on Banks | Total nmi | Nmi. on banks | Number of sights | No. of bluefin | Sight. per 100 nmi | Bluefin per 100 nmi |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 344Z | T* | 19 May | 9:14:0 | 4.9 | 3.4 | 340 | 230 | 0 | 0 | 0.00 | 0.00 |
| 344Z | T | 21 May | 9:15: 0 | 3.7 | 2.2 | 249 | 139 | 0 | 0 | 0.00 | 0.0 |
| 270Q | D | 22 May | 9:48: 0 | 6.2 | 4.7 | 441 | 331 | 0 | 0 | 0.00 | 0.0 |
| 344Z | T | 22 May | 9:47:15 | 5.9 | 4.4 | 388 | 278 | 0 | 0 | 0.00 | 0.0 |
| 270Q | D* | 23 May | 9:17:25 | 6.6 | 5.1 | 424 | 314 | 0 | 0 | 0.00 | 0.0 |
| 344Z | T | 23 May | 9:18:15 | 6.5 | 5.0 | 440 | 330 | 0 | 0 | 0.00 | 0.0 |
| 270Q | D | 25 May | 9:52:15 | 6.1 | 4.6 | 438 | 328 | 0 | 0 | 0.00 | 0.0 |
| 344Z | T | 25 May | 9:42:30 | 6.4 | 4.9 | 406 | 296 | 0 | 0 | 0.00 | 0.0 |
| 270Q | D | 26 May | 9:23:15 | 3.6 | 2.1 | 268 | 158 | 0 | 0 | 0.00 | 0.0 |
| 344Z | T* | 26 May | 9:23:45 | 3.6 | 2.1 | 244 | 134 | 0 | 0 | 0.00 | 0.0 |
| 270Q | T | 28 May | 9:46: 0 | 7.5 | 6.0 | 540 | 430 | 1 | 8 | 0.23 | 1.9 |
| 344Z | T | 29 May | 9: 9:15 | 5.9 | 4.4 | 383 | 273 | 2 | 9 | 0.73 | 3.3 |
| 270Q | D | 30 May | 9:21:45 | 5.7 | 4.2 | 364 | 254 | 3 | 37 | 1.18 | 14.6 |
| 344Z | T | 30 May | 9:20: 0 | 5.7 | 4.2 | 372 | 262 | 1 | 8 | 0.38 | 3.1 |
| 270Q | D | 31 May | 9:23:15 | 5.6 | 4.1 | 345 | 235 | 3 | 30 | 1.27 | 12.7 |
| 344Z | T* | 31 May | 9:17:15 | 5.7 | 4.2 | 374 | 264 | 6 | 45 | 2.27 | 17.0 |
| 270Q | D | 1 June | 7:13: 0 | 5.9 | 4.4 | 348 | 238 | 2 | 81 | 0.84 | 34.1 |
| 344Z | T | 1 June | 7:13:30 | 6.0 | 4.5 | 399 | 289 | 1 | 100 | 0.35 | 34.7 |
| 270Q | D | 2 June | 8:51:15 | 5.5 | 4.0 | 316 | 206 | 6 | 93 | 2.91 | 45.2 |
| 344Z | T | 2 June | 8:44:30 | 5.6 | 4.1 | 341 | 231 | 3 | 32 | 1.30 | 13.8 |
| 270Q | D | 3 June | 9:11:30 | 5.1 | 3.6 | 297 | 187 | 4 | 84 | 2.14 | 44.9 |
| 344Z | T | 3 June | 9: 5:15 | 5.2 | 3.7 | 298 | 188 | 6 | 65 | 3.19 | 34.6 |
| 270Q | D* | 4 June | 9:54:15 | 3.2 | 1.7 | 206 | 96 | 4 | 90 | 4.18 | 94.0 |
| 344Z | T** | 4 June | 9:53:15 | 3.2 | 1.7 | 188 | 78 | 4 | 96 | 5.10 | 122.4 |
| 270Q | D* | 7 June | 9: 8:15 | 6.5 | 5.0 | 464 | 354 | 2 | 29 | 0.57 | 8.2 |
| 344Z | T | 7 June | 9: 2:15 | 7.1 | 5.6 | 445 | 335 | 3 | 30 | 0.90 | 9.0 |
| 270Q | D* | 8 June | 9:34:30 | 5.9 | 4.4 | 425 | 315 | 1 | 1 | 0.32 | 0.3 |
| 344Z | T | 8 June | 9:38:15 | 5.8 | 4.3 | 384 | 274 | 0 | 0 | 0.00 | 0.0 |
| 270Q | D | 9 June | 9:54:15 | 4.0 | 2.5 | 268 | 158 | 1 | 1 | 0.63 | 0.6 |
| 344Z | T | 9 June | 9:54:15 | 4.2 | 2.6 | 262 | 152 | 0 | 0 | 0.00 | 0.0 |
| | | | Totals | 162.9 | 117.9 | 10,656 | 7,356 | 53 | 839 | | |

Abbreviations: nmi=nautical miles; T=transect aircraft; D=discovery aircraft; *=Observer present. Great Bahama Bank mileage was estimated as total flight miles minus 110 (distance over land/Straits of Florida). Estimated time on Bank is total time minus 1.5 h. Transect aircraft mileage includes survey miles spent off transect. **=Transect abandoned due to squalls.

dundant counts, a school of 100 fish recorded by Supercub 344Z and one of 80 fish recorded by Cessna 270Q (Table 4) were judged to be the same, giving an adjusted estimated total count of 759 bluefin tuna. Bluefin tuna were most abundant adjacent to the region west of and between South Bimini and Castle Rock, with sighting concentrations near Victory and Gun Cays (Fig. 2A) similar to distributions described in the past by anglers (Farrington, 1939) and noted by Rivas (1954; 1978).

The Cessna 270Q's search area included broad search tracks extending to North Rock and west of Tuna Alley (Fig. 2B), but no bluefin tuna were sighted in these areas. In comparison with the 1970's surveys, the two survey aircraft produced a 2–3 fold increase in effort hours but had only 33–45% of the number of observation days in comparison with the 1974–76 surveys, which began almost three weeks earlier and ran 7–11 days later in June (Table 5). In the 1974 and 1975 surveys, no bluefin tuna were observed after 11 June and 2 June, respectively. Although it is possible that bluefin tuna entered the region without being detected by recreational vessels, nevertheless, according to aerial and charter boat sightings, the 1995 migration period of about 20 days was considerably shorter than the presumed 50 day migration period noted in the 1950's and the 1970's (Rivas, 1978). Although SPUE values are not strictly comparable in the present and 1974–76 surveys because of differences in survey protocols and platforms (Table 5), there are resemblances in the general appearance and behavior of giant bluefin tuna.

In the present survey the majority of bluefin tuna (50 out of 53 sightings) were documented off transect; therefore the longitudinal transect along the Great

**Table 3**

Transect of the giant bluefin tuna aerial survey, 19 May–9 June 1995 over Great Bahama Bank.

| Date | Start time | End time | Trackline nmi | Sighting | Bluefin tuna | Sightings per 100 nmi | Bluefin tuna per 100 nmi |
|---|---|---|---|---|---|---|---|
| 19 May | 10:51:0 | 11:50:0[3] | | 0 | 0 | 0 | 0 |
| 19 May | 12:35:0 | 13:15:0[3] | | 0 | 0 | 0 | 0 |
| 21 May[1] | 11:07:30 | 12:09:15 | 72 | 0 | 0 | 0 | 0 |
| 22 May | 11:28:0 | 12:42:45 | 80 | 0 | 0 | 0 | 0 |
| 22 May | 13:33:0 | 14:50:45 | 75 | 0 | 0 | 0 | 0 |
| 23 May | 10:57:15 | 12:11:0 | 77 | 0 | 0 | 0 | 0 |
| 25 May | 11:44:0 | 12:46:0 | 71 | 0 | 0 | 0 | 0 |
| 25 May | 13:40:15 | 14:43:15 | 70 | 0 | 0 | 0 | 0 |
| 26 May | 11:06:30 | 12:05:45 | 71 | 0 | 0 | 0 | 0 |
| 28 May | 11:46:45 | 12:47:29 | 80 | 0 | 0 | 0 | 0 |
| 29 May | 11:06:45 | 12:15:14 | 74 | 1 | 1 | 1.3 | 1 |
| 29 May | 13:04:29 | 04:15:00 | 74 | 1 | 1 | 1.3 | 1 |
| 30 May | 11:06:30 | 12:11:15 | 71 | 0 | 0 | 0 | 0 |
| 30 May | 13:05:0 | 14:10:30 | 71 | 0 | 0 | 0 | 0 |
| 31 May | 11:11:30 | 12:10:45 | 69 | 1 | 1 | 1.46 | 1 |
| 31 May | 13:07:15 | 14:07:15 | 69 | 0 | 0 | 0 | 0 |
| 1 June | 09:06:15 | 10:06:0 | 68 | 1 | 100 | 1.47 | 147 |
| 1 June | 10:59:45 | 11:58:15 | 66 | 0 | 0 | 0 | 0 |
| 2 June | 11:13:0 | 12:08:30 | 68 | 0 | 0 | 0 | 0 |
| 3 June | 11:24:45 | 12:22:45 | 69 | 0 | 0 | 0 | 0 |
| 4 June[2] | | | | | | | |
| 7 June | 11:28:50 | 12:52:45 | 95 | 0 | 0 | 0 | 0 |
| 7 June | 13:19:15 | 13:46:15 | 28 | 1 | 6 | 3.54 | 21 |
| 8 June | 11:25:0 | 12:31:0 | 70 | 0 | 0 | 0 | 0 |
| 8 June | 13:25:0 | 14:40:30 | 78 | 0 | 0 | 0 | 0 |
| 9 June | 11:45:0 | 13:09:15 | 84 | 0 | 0 | 0 | 0 |
| | | Totals | 1,650 | 5 | 109 | | |

[1] Trackline altered to avoid local storm squalls.
[2] Transect abandoned because of squalls. All transects, except that flown on 28 May, were conducted by Supercub 344Z.
[3] We experienced GPS problems on 19 May 1995; therefore times were estimated, not actual.

Bahama Bank and Tuna Alley may be less effective than other survey methods. On days when fish were present on the banks, general sightings per search mile (i.e. schools or bluefin tuna per nmi of spotter pilot search effort) were within the same order of magnitude for the Cessna 270Q and the Supercub 344Z (which spent nearly half its search time off transect).

In general, the schooling behavior of bluefin tuna travelling adjacent to the Great Bahama Bank differed substantially from what we have observed in the Gulf of Maine aerial surveys (Lutcavage and Kraus, 1995). On the Great Bahama Bank, giant bluefin tuna were much less tightly aggregated and did not exhibit cartwheeling and milling formations or smashing behaviors that indicate feeding, although they are said to "smash" on rare occasion farther offshore (Mather et al., 1995). In contrast with prolonged surface "shows" and the appearance of densely packed schools in New England, the Great Bahama Bank schools spent very little time at the surface, making it difficult for pilots to photograph the school in entirety. As in previous surveys, schools were most readily detected and successfully photographed while swimming over white sand in shallow water. Photographs of schools in the deeper blue water usually depicted only a few fish visible at the surface. Because of the lack of color contrast between the tuna and the water and because of their deeper position in the water column, these schools were more difficult to detect and photograph, but experienced spotters use several cues including color contrast and surface disturbance to identify bluefin tuna.

Singles and loosely aggregated groups swam steadily north at an estimated speed of 6–8 knots, similar to speeds reported by Mather et al. (1995), with the exception of one school, which we followed for 36 minutes in the air (Fig. 3). As two fishing boats approached from opposite sides, the school of ten fish changed spatial conformation several times, turned west, and disappeared into deeper water.

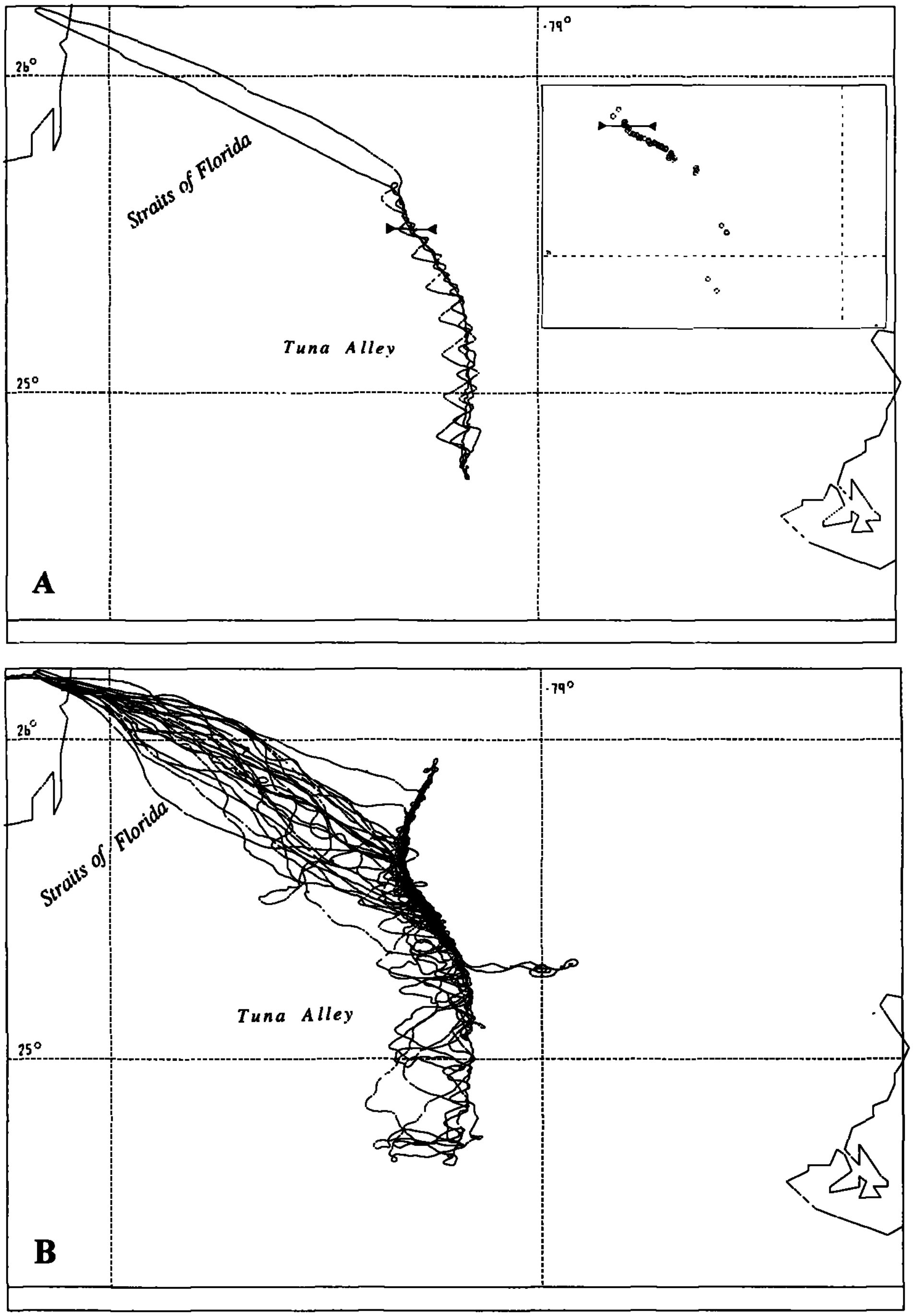


**Figure 2**

(**A**) Example of aircraft transit (Supercub 344Z, 25 May 1995) showing tracks across the Straits of Florida and two zigzag transects along Tuna Alley. Inset depicts the location of giant bluefin tuna sightings. For reference, arrows denote the location of the 1 mi flight tract conducted in the 1974–76 surveys (Rivas, 1978) (**B**) Combined search tracks of the discovery aircraft, Cessna 270Q.

In general, spotters estimated that all the bluefin tuna they had encountered were large giants ranging from 227 kg to over 295 kg (approximate length: 225–250 cm straight fork length [SFL]). Three fish landed by anglers during the survey period ranged from 264 to 280 cm SFL (250–317 kg), equivalent to

**Table 4**

Giant bluefin tuna aerial survey, 19 May–9 June 1995, over the Great Bahama Bank. Sighting positions.

| Aircraft | Date | Time | Latitude | Longitude | Count |
|---|---|---|---|---|---|
| 270Q | 28 May | 16:10:30 | N25:24.60 | W079:14.93 | 8 |
| 344Z | 29 May | 10:50:42 | N25:03.50 | W079:09.68 | 8 |
| 344Z | 29 May | 11:16:24 | N24:52.97 | W079:10.30 | 1 |
| 344Z | 30 May | 12:28:0 | N25:24.73 | W079:14.15 | 8 |
| 270Q | 30 May | 11:17:20 | N25:25.47 | W079:14.42 | 15 |
| 270Q | 30 May | 12:32:19 | N25:26.04 | W079:14.45 | 10 |
| 270Q | 30 May | 12:39:48 | N25:25.87 | W079:14.43 | 12 |
| 270Q | 31 May | 11:10:1 | N25:36.93 | W079:18.94 | 10 |
| 344Z | 31 May | 12:47:27 | N25:05.97 | W079:09.72 | 1 |
| 344Z | 31 May | 10:52:30 | N25:05.76 | W079:09.71 | 8 |
| 270Q | 31 May | 13:7:15 | N25:27.35 | W079:15.17 | 10 |
| 344Z | 31 May | 10:28:42 | N25:29.94 | W079:17.04 | 7 |
| 270Q | 31 May | 10:35:13 | N25:33.75 | W079:18.40 | 10 |
| 344Z | 31 May | 10:17:24 | N25:34.92 | W079:19.50 | 25 |
| 344Z | 31 May | 11:20:0 | N24:54.18 | W079:11.33 | 1 |
| 270Q | 1 June | 08:30:29 | N25:32.09 | W079:18.06 | 1 |
| 344Z | 1 June | 09:52:42 | N25:28.17 | W079:15.65 | 100 |
| 270Q | 1 June | 09:53:40 | N25:28.53 | W079:15.94 | 80 |
| 270Q | 2 June | 10:34:41 | N25:29.17 | W079:16.36 | 7 |
| 270Q | 2 June | 12:39:10 | N25:30.49 | W079:17.37 | 7 |
| 270Q | 2 June | 12:2:38 | N25:29.70 | W079:17.02 | 27 |
| 270Q | 2 June | 11:14:47 | N25:29.63 | W079:16.73 | 17 |
| 270Q | 2 June | 13:5:52 | N25:32.93 | W079:18.48 | 27 |
| 344Z | 2 June | 12:23:29 | N25:32.52 | W079:18.22 | 12 |
| 270Q | 2 June | 12:15:29 | N25:28.30 | W079:16.24 | 8 |
| 344Z | 2 June | 13:14:06 | N25:31.65 | W79:18.18 | 10 |
| 344Z | 2 June | 10:26:12 | N25:28.10 | W079:15.54 | 10 |
| 344Z | 3 June | 12:33:00 | N25:34.15 | W079:19.16 | 12 |
| 344Z | 3 June | 12:56:00 | N25:22.33 | W079:12.31 | 14 |
| 344Z | 3 June | 12:43:15 | N25:29.69 | W079:17.21 | 3 |
| 344Z | 3 June | 10:54:59 | N25:07.61 | W079:10.14 | 6 |
| 344Z | 3 June | 11:15:47 | N24:51.24 | W079:10.59 | 5 |
| 344Z | 3 June | 10:37:44 | N25:20.97 | W079:12.35 | 25 |
| 270Q | 3 June | 12:55:51 | N25:30.92 | W079:17.93 | 5 |
| 270Q | 3 June | 12:26:57 | N25:30.55 | W079:17.38 | 35 |
| 270Q | 3 June | 11:59:11 | N25:24.77 | W079:14.62 | 17 |
| 270Q | 3 June | 13:10:5 | N25:25.24 | W079:14.60 | 27 |
| 344Z | 4 June | 12:09:59 | N25:30.59 | W079:17.58 | 15 |
| 270Q | 4 June | 12:1:59 | N25:28.80 | W079:16.36 | 35 |
| 270Q | 4 June | 11:35:26 | N25:27.84 | W079:15.54 | 13 |
| 270Q | 4 June | 11:24:0 | N25:29.77 | W079:17.07 | 35 |
| 344Z | 4 June | 11:18:0 | N25:27.88 | W079:15.51 | 25 |
| 344Z | 4 June | 11:14:45 | N25:28.34 | W079:16.13 | 30 |
| 270Q | 4 June | 12:7:30 | N25:27.25 | W079:14.91 | 7 |
| 344Z | 4 June | 11:48:28 | N25:27.53 | W079:15.31 | 26 |
| 270Q | 7 June | 11:2:6 | N25:28.58 | W079:15.90 | 25 |
| 270Q | 7 June | 14:10:22 | N25:30.77 | W079:17.70 | 4 |
| 344Z | 7 June | 14:40:00 | N25:27.00 | W079:14.92 | 12 |
| 344Z | 7 June | 11:08:30 | N25:28.97 | W079:16.35 | 12 |
| 344Z | 7 June | 13:28:29 | N25:24.24 | W079:14.37 | 6 |
| 270Q | 8 June | 14:40:00 | N25:27.82 | W079:15.29 | 1 |
| 270Q | 9 June | 12:08:14 | N25:08.88 | W079:11.53 | 1 |

the highest range of values given in the length histogram of fish captured previously in the Bahamas from 1939 to 1966 (Mather et al., 1995). Rivas (1976) noted that the mean length of Bahama bluefin tuna increased by 20–25 cm over a 20-yr period dating back to the 1950's. Bluefin tuna documented in New England aerial surveys spanned a much broader range of size classes and include small medium (145–178 cm SFL, 61<107 kg), large medium (178–196 cm, 107<141 kg), and a broader range within the giant bluefin tuna size class (>196 cm, >141 kg).

As in previous Bahamas surveys, the majority of sightings occurred under conditions of strong winds, but 121 out of 839 (759 adjusted total) bluefin tuna were sighted under calm or variable wind conditions. Experienced tuna guides emphasized that bluefin tuna do not appear on the Bank until winds are of sufficient strength from the southern sector or when

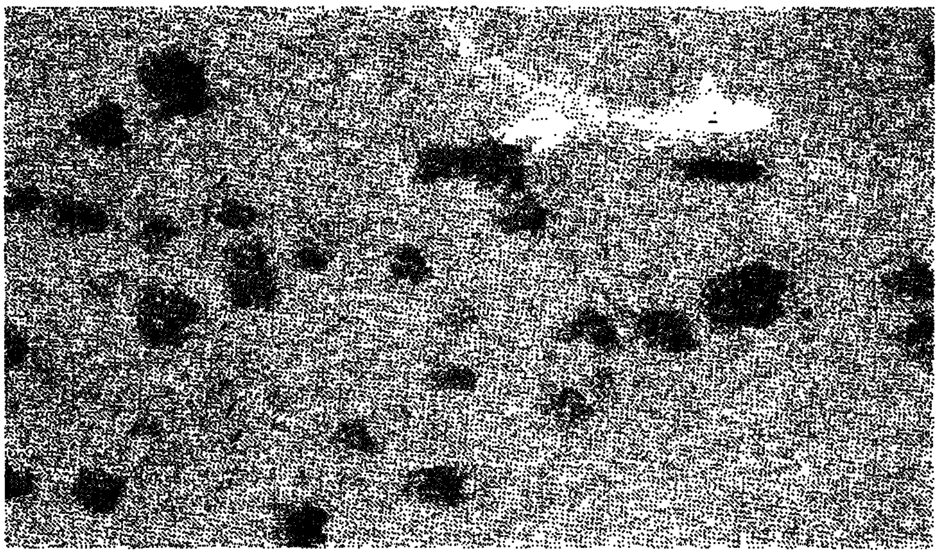

**Figure 3**

A school of ten giant bluefin tuna photographed on the Great Bahama Bank (N25:27.35, W79:15.17) on 31 May 1995 from discovery aircraft Cessna 270Q. The school was arrayed in "soldier formation" as swimmers from the boat approached.

**Table 5**

Comparison of giant bluefin tuna aerial surveys conducted in the Straits of Florida and the Great Bahama Bank region.

| | 1974[1] | 1975[1] | 1976[1] | 1995 |
|---|---|---|---|---|
| Survey dates | 9 May–16 June | 1 May–16 June | 2 May–20 June | 19 May–9 June |
| Survey type | 1-mi transect across Tuna Alley | 1-mi transect across Tuna Alley | 1-mi transect across Tuna Alley | 70-nmi transect and discovery flts. |
| Aircraft used | not given | not given | not given | 2, single engine |
| Time of day (h) | 11:00–13:00 | 12:00–14:00 | 09:30–14:00 | 11:00–13:00 |
| Total observation days | 37 | 46 | 42 | 17 |
| Total survey hours | 37.7 | 48.6 | 51.6 | 117.9 |
| Date of first sighting | 9 May | 1 May | 6 May | 28 May |
| Date of last sighting | 11 June | 2 June | 15 June | 9 June |
| Total bluefin | 3,125 | 368 | 1,120 | 839 |

[1] 1974–76 surveys are taken from Rivas, 1978.

the Gulf Stream's edge intercepts the Bank (or both), producing stronger northerly flow. Previous reports have also noted the bluefin tuna's apparent avoidance of the "dirty water" tidal flow from the Bank, which varied a good deal over the survey period. However, on at least two occasions we observed bluefin tuna in turbid water. In the present study, the period of highest sightings occurred in the six days following the new moon. Although aerial sightings were not given in relation to lunar phase for the 1974–76 surveys, this period coincided with the lowest catch per boat day for 11 Cat Cay bluefin tuna tournaments from 1941 to 1960 (Rivas, 1978).

It is possible that the apparent relation of strong winds with appearance of bluefin tuna on Tuna Alley may be driven by oceanographic conditions occurring in adjacent staging areas. In general, flow over the Great Bahama Bank in the Bimini area is weak and driven by wind and tide (Lee[3]). Although the Bank constitutes a topographic wall, it is not associated with strong upwelling. Much stronger flow and upwelling occurs where the Loop Current leaving the Gulf of Mexico impinges on the north coast of Cuba. The dynamics of eddy systems near Cay Sal Bank and northern Cuba could conceivably influence travel routes of bluefin tuna, a concept that is reinforced by the reports of giant bluefin tuna on Cay Sal Bank and the Old Bahama Channel by anglers and fish spotters (Rivas, 1954; 1978; Mather et al., 1995), and one that would explain the large variability in numbers of bluefin tuna sighted on Tuna Alley from year to year (e.g. an order of magnitude difference in sightings between 1974 and 1975 (Rivas, 1978).

During the survey, surface sea water temperatures in the Straits of Florida and adjacent to the Great Bahamas Bank, obtained from advanced high-resolution radiometer (AVHRR) satellite imagery, ranged from 26° to 30°C, nearly 10°C higher than the mean sea surface temperature associated with bluefin tuna schools in the New England region (Lutcavage et al.[4]). However, our opportunity to examine additional environmental conditions that might have influenced bluefin tuna occurrence on the Great Bahama Bank region in 1995 was limited. Sea surface temperatures across the Straits of Florida are somewhat uniform in the late spring and summer, and to our knowledge there were no current meters or buoy data reflecting the precise boundary of the Gulf Stream edge. This information, along with tide and wind stress records, might have provided a more specific relation between environmental conditions and the appearance of bluefin tuna on the Great Bahama Bank.

There are numerous reports of giant bluefin tuna in other areas of the Bahamas and Straits of Florida beyond Tuna Alley, particularly to the east and northeast off Walkers Cay, the Abacos, and also in deep water regions west and southwest of the Great Bahama Banks and off Cuba (Rivas, 1978; Mather et al., 1995; Murray[5]). Recent longline captures also corroborate the presence of bluefin tuna in the eastern areas, well before and concurrent with the assumed migration period of fish that transit Tuna Alley (Turner[6]). In addition, giant bluefin tuna were landed in the first week of June in the Gulf of Maine, nearly coincident with our first sightings on the Great Bahama Bank. At present there is little information that would identify whether fish travelling in this region are members of the same assemblage, and further, whether they had recently exited the Gulf of Mexico, or had travelled from areas to the south and east, or from the Windward Passage, as suggested by Mather et al. (1995).

Mather et al. (1995) reported that the Great Bahama Bank migration area continues along the western edge of the Little Bahama Bank, and they sighted giant bluefin tuna travelling north between the Great and Little Bahama Banks in May–June 1968. It is clear that without complementary oceanographic surveys, the sporadic appearance and diffuse aggregation behavior of giant bluefin tuna on the Great Bahama Bank present serious problems for direct aerial assessment in this region. Although fish can be seen and enumerated under suitable conditions during daylight hours, there is no way of determining how many fish transit the Straits of Florida in deeper water, or determining their presence and abundance in other regions of the Bahama islands. Lacking this information, the use of direct counts of bluefin tuna in this region as an index of spawning biomass seems unwarranted. Alternatively, aerial surveys on the Great Bahama Bank, in conjunction with direct sampling of landings, may provide an index of regional abundance and information on the size classes and reproductive status of bluefin tuna transiting the area. In the future, examination of oceanographic conditions occurring in the Loop

[3] Lee, T. 1995. Rosenstiel School of Marine and Atmospheric Science, Univ. Miami, Miami, FL. Personal commun.

[4] Lutcavage, M., J. Goldstein, and S. Kraus. 1996. Sustaining tuna fisheries—issues and answers. Proceedings of the 47th tuna conference; Lake Arrowhead, CA, 20–23 May 1996.

[5] Murray, Captain E. 1996. 8101 Nashua Dr., Palm Beach Gardens, FL 33418. Personal commun.

[6] Turner, S. 1995. Southeast Fish. Sci. Center, Natl. Mar. Fish. Serv, NOAA, Miami, FL. Unpubl. data.

Current, Cay Sal Bank, and north Cuban coast might provide information that could be used to forecast the appearance and relative abundance of bluefin tuna across the western Bahama Banks and the Straits of Florida. A direct hydroacoustic count of all bluefin tuna transiting the Straits of Florida would provide additional information on the numbers of bluefin tuna exiting the Gulf of Mexico, and possibly, regions of the Caribbean.

## Acknowledgments

Spotter pilots George Purmont (Little Compton, RI) and Dave Thompson (Chatsworth, NJ) provided their considerable skills and aircraft for this survey. We thank Gerry Scott, Steve Turner, and Rosemary Sullivant for logistical support, Dennis Lee for bluefin tuna longline capture locations, and Captains Edward Murray, Danny Beare, and Richard Wright for helpful discussions on the Bahamas bluefin tuna sport fishery.

## Literature cited

**Farrington, S. K., Jr.**
**1939.** Atlantic game fishing. Garden City Publ. Co., Inc. NewYork, NY, 298 p.

**Lutcavage, M., and S. Kraus.**
**1995.** The feasibility of direct photographic assessment of giant bluefin tuna in New England waters. Fish. Bull. 93(3):495–503.

**Mather, F. J., III, J. M. Mason Jr., and A. C. Jones.**
**1995.** Historical document: life history and fisheries of Atlantic bluefin tuna. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-370, 165 p.

**Rivas, L. R.**
**1954.** Preliminary report on the spawning of the western North Atlantic bluefin tuna (*Thunnus thynnus*) in the Straits of Florida. Bull. Mar. Sci. 4:302–321.

**1976.** Variation in sex ratio, size differences between sexes, and change in size and age composition in Western North Atlantic giant bluefin tuna (*Thunnus thynnus*). International Commission for the Conservation of Atlantic Tunas, Madrid, Collective Volume of Scientific Papers 5(2):297–301.

**1978.** Aerial surveys leading to 1974–1976 estimates of the numbers of spawning giant bluefin tuna (*Thunnus thynnus*) migrating past the western Bahamas. Int. Comm. Conserv. Atl. Tunas Coll. Vol. Sci., paper 7, p. 301–312.