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SYNOPSIS OF BIOLOGICAL DATA ON BLUEFIN TUNA Thunnus thynnus (Linnaeus) 1758 (ATLANTIC AND MEDITERRANEAN)

Exposé synoptique sur la biologie du thon rouge Thunnus thynnus (Linnaeus) 1758 (Atlantique et Méditerranée)

Sinopsis sobre la biología del atún rojo Thunnus thynnus (Linnaeus) 1758 (Atlántico y Mediterráneo)

Prepared by
K. TIEWS
Institut fur Kusten- und Binnenfischerei der
Bundesforschungsanstalt fur Fischerei
Hamburg, Federal Republic of Germany

FISHERIES DIVISION, BIOLOGY BRANCH
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1 IDENTITY

1.1 Taxonomy

1.1.1 Definition

Phylum VERTEBRATA
- Subphylum Craniata
  - Superclass Gnathostomata
    - Series Pisces
      - Class Osteichthyes
        - Subclass Teleostei
          - Order Percomorphida
            - Suborder Scombroidea
              - Family Scombridae
                - Subfamily Scombrinae
                  - Gennus *Thunnus* South, 1845
                    - Species *Thunnus thynnus* (Linnaeus) 1758

The Atlantic bluefin tuna, *Thunnus thynnus* (Linnaeus) 1758, is a pelagic marine schooling fish inhabiting temperate and tropical waters of the Atlantic and adjacent seas. It may reach a weight of 1, 000 lb or more.

According to Mather III (1959), the bluefin can be distinguished from *T. alalunga*, *T. atlanticus*, *T. obesus* and *T. albacares* by means of the length of the pectoral fin, which is less than 4/5 of the head length and usually not reaching the second dorsal fin or beyond, and by means of the lower gill rakers on the first arch (24-28 in *T. thynnus*, 15-23 in the other species).

The question as to whether or not the eastern Atlantic and western Atlantic forms of the bluefin are distinct has been the subject of considerable speculation. In 1875 the western Atlantic form was differentiated by Storer under the name *Thunnus secundodorsalis* on the basis of the position of the anal fin and the length of the pectoral. Jordan and Evermann (1926) retained Storer's classification but were doubtful if the two fish were indeed separate species. Russel (1934) pointed out that the two fish were most likely the same species but were sufficiently separated geographically to show distinct variations in some characters. Godsil and Holmberg (1950) concluded that specimens of *T. thynnus* from the eastern and western Atlantic appeared to be identical in most characters, but recommended that they be further studied.

Ginsburg (1953), on the other hand, thought the two fish diverged in respect to a number of characters and designated the western Atlantic bluefin as a distinct species, *Thunnus secundodorsalis* (Storer 1867). Some of the differences which Ginsburg (1953) found are non-existent, if tunas of equal size are compared. Frades' (1931) measurements of eastern Atlantic bluefin, which Ginsburg used for his comparison, were collected from larger fish than the bluefin which Ginsburg examined from the western North Atlantic. Using data from various sources it can be shown (Table I) that there is no obvious difference in body depth and head length in tunas of 110-130 cm. Also, in smaller tunas real differences are unlikely (Table II).

Table I
Comparison of biometric indices of bluefin tuna of 110 - 130 cm

Indices	Western Atlantic (Godsil and Holmberg 1950) (quoted by Ginsburg, 1953)	Mediterranean Tunis Heldt (1927) G_1	Eastern Atlantic Mediterranean Sicily Aricò and Genovese (1953) G_1	Mediterranean Sicily Genovese (1956) $G_1 + G_2$
	-	M= 3. 558	M= 3. 786	M= 3. 349
Body depth	3. 51 -3. 96	LC. 3. 358-3. 758	3. 576-3. 995	3. 254-3. 444
	-	3. 566	3. 471	3. 451
Head	3. 40 -3. 52	3. 512-3. 620	3. 392-3. 550	3. 414-3. 484
	-	5. 440	5. 571	5. 46
Pectoral Fin	4. 61 -5. 08	5. 26 -5. 62	5. 282-5. 861	5. 362-5. 558

Table II
Comparison of biometric indices of bluefin tuna of less than 110 cm

Indices	Western Atlantic Ginsburg (1953) (65-70 cm)	Eastern Atlantic Genovese (1956) Go
	M= 3.68	M= 3.10
Body depth	3.53 - 4.00	2.932 - 3.268
	3.26	3.403
Head	3.19 - 3.34	3.336 - 3.464
	4.97	5.48
Pectoral fin	4.68 - 5.32	5.245 - 5.715

Also the difference in the number of pectoral fin rays, as quoted by Ginsburg (1953), is possibly non-existent, since Crane (1936) found similar numbers for western Atlantic tunas as for those from the eastern North Atlantic. The difference in the length of pectoral fins between western and eastern North Atlantic tunas is of similar magnitude as that existing between tunas of the Mediterranean and of the eastern North Atlantic (see section 1.3).

Rivas (1954d) is of the opinion that the bluefin tuna of both sides of the North Atlantic belong to the same species but may represent separate and distinct breeding populations at the racial or subspecific level. This belief is based on the discovery of spawning activity in the western North Atlantic bluefin in the Straits of Florida in May and June, during which time the European bluefin is spawning in the central Mediterranean, about 4,000 miles distant.

Although there may be very little mixing of eastern and western populations, we believe that evidence indicates that there is only one species of bluefin tuna in the North Atlantic. Further research is needed, however, to recheck the statement of Smith (1950) that Thunnus thynnus (L.) of South African waters has only "26-31 slender gill rakers". If those figures should be correct, they are evidence that he describes another species of Thunnus. According to Mather III (1960) there are three species of Thunnus which have total gill raker counts between 25 and 33, i.e. T. albacares, T. alalunga and T. obesus while T. thynnus has 34-42 gill rakers.

1.1.2 Description

- Morphology

The body of T. thynnus is fusiform, compressed, and especially robust in front (Fig. 1) (Ehrenbaum 1936). Caudal peduncle greatly depressed, slender, with a wide keel on each side. Head large, broadly convex above, well compressed. Snout conic, slightly or not wider than long. Eye about first third in head, rounded. Adipose eyelid marginal. Mouth curved slightly, large; jaws about even. Maxillary reaches opposite hind pupil edge. Teeth simple, conic, small, uniserial in jaws. Minute vomerine and palatine teeth. Front nostril a simple pore at about last third in snout, hind one a short vertical slit close before eye. Interorbital wide, convex. Gill rakers 9 to 16 + 22 to 28 slender, nearly equal to eye. Entire trunk scaly, below and posteriorly; scales are minute. Pectoral region with corselet; scales a little larger above pectoral base, very narrowly exposed. Corselet extends little beyond pectoral tip. Soft dorsal and anal largely covered with minute scales, also bases of caudal and pectoral. Caudal base with a short small keel above and another below caudal peduncle keel. Lateral line of minute scales, slopes rather irregularly down to caudal peduncle. Spinous dorsal inserted midway between snout tip and soft dorsal origin, or about opposite pectoral region or little before, interspace before soft dorsal very short. Soft dorsal inserted nearer spinous dorsal origin than caudal base. Anal inserted just behind base of soft

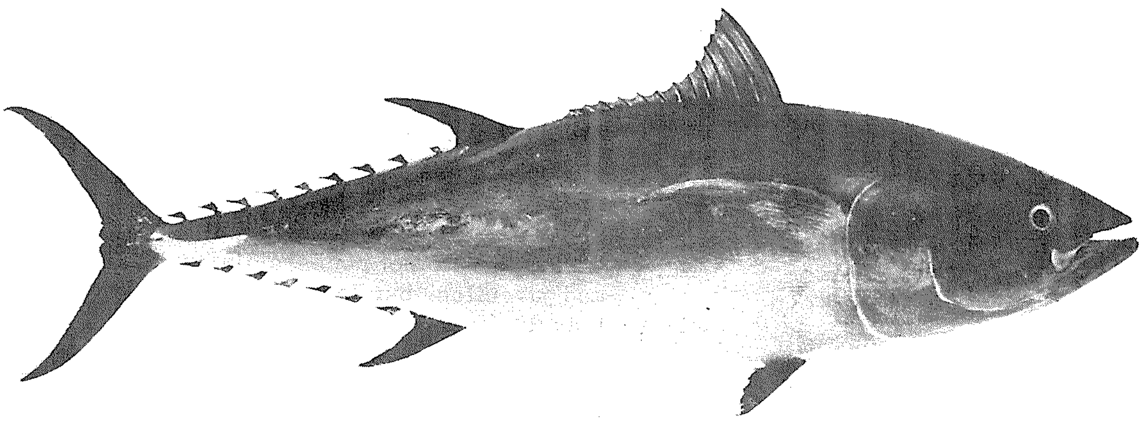


Fig. 1 Bluefin tuna (Thunnus thynnus L.) (Ehrenbaum 1936)

dorsal, similar. Finlets alike, first increase, then decrease in size behind. Caudal deeply lunate, even pointed lobes. Pectoral moderate, pointed, inserted about level with eye. Ventral inserted opposite pectoral origin.

- Anatomy

One of the most complete studies on the comparative anatomy of bluefin is that of Godsil and Holmberg (1950). They describe in great detail the visceral organs, and the circulatory and skeletal systems, and point out how they differ in the bluefin from other closely related tunas. In their examination of bluefin caught near Provincetown, Mass., they found considerable variations in body structure and their arrangement. They obtained the same vertebral count for all fish examined except for one California bluefin. The counts may be summarized as follows :

Number of vertebrae	- 39 omitting the hypural
First haemal arch	- 10th vertebra (on the 11th in one California bluefin)
First elongate haemal spine	- 19th vertebra
Number of precaudal vertebrae	- 18
Number of caudal vertebrae	- 21

The majority of specimens examined contained a large, conspicuous air bladder that covered the full width and almost the entire length of the body cavity. Serventy (1956) found that the air bladder was only fully developed in large, mature fish. It increased in size in relation to the body cavity during growth but was very irregular in shape in the intermediate stages.

Watson (1962), basing her key to the species of Thunnus on skeletal and visceral anatomy, gives the following description of T. thynnus: "Alisphenoid extending ventrally more than halfway into interorbital opening; gill rakers exceed other 5 species (of Thunnus)-Atlantic, 9-15+24-29; Pacific, 10-15+21-25; air bladder rounder anteriorly, devoid of dorsal pouch". According to the same author, T. thynnus has together with T. alalunga and T. obesus the following group characteristics:

1. One or more inferior foramen in caudal vertebrae, which are small or inconspicuous in lateral view;

2. Posterior hemal zygapophysis on precaudal vertebrae, bearing hemal arches, are short, not produced;

3. Liver - ventral surface striated by surface vessels; dorsal surface emitting 3 or more vascular plexuses; 3 lobes subequal or middle slightly larger, ventrally each lobe distinctly separated from adjoining lobe by cleft. These characters do not necessarily apply to larvae and juveniles, but do apply to specimens longer than 20 cm in fork length.

Krummholz (1959) provides some interesting information on the percentage of total body weight in bluefin made up by different body organs. He reported that, for each sex, the gonads contributed more to the total body weight than any other single organ. These were followed in decreasing order by the stomach, caecal mass, liver, heart, intestine and gall bladder. The entire gut, consisting of the stomach, caecal mass and intestine, made up 1.50 percent of the total body weight, and all viscera combined, 3.57 percent. The bluefin had the relatively smallest visceral mass (excluding the gonads) of 11 species of fish examined. On the other hand, it had the largest heart, in proportion to its body size, of any of the 11 species.

Another interesting comparison by Krummholz showed that the digestive tract of the white marlin and the sailfish weigh relatively twice as much as that of the bluefin tuna, whereas that of the blue marlin is relatively more than 75 percent heavier. These differences most likely indicate significant differences in diet.

The pineal apparatus of fishes was first described for the bluefin tuna but was subsequently found to recur in all species of Thunnus and in certain related genera (Breder and Rasquin 1947; Rivas 1953). It consists of a median, translucent, oval "window" in the skin at the interorbital region, leading to the brain and transmitting light by means of a tube through a foramen in the skull. The discovery of this structure is considered as a clue to the possible effect of light as a factor in the movement and behavior of tunas.

- Color

Members of the genus Thunnus are all dusky dorsally and silvery white ventrally, without darker spots, longitudinal lines, or vermiculations on their ventral, lateral, and dorsal surfaces (Mather III 1959). The dark dorsal area terminates abruptly above the mid-lateral area, and there is frequently a narrow irregular zone of irridescent blue between it and the lighter neutral area. Young individuals, particularly, may display a whitish pattern of vertical bars or rows of spots on their lateral and ventral surfaces.

Ehrenbaum (1936) describes the color of T. thynnus as dark blue on its dorsal surface and grey with numerous and dense silver spots on its sides. The caudal fin is brown to bluish, the second dorsal reddish yellow, and the finlets are yellow with black edging.

Crane (1936) states the color to be blackish-bronze on the dorsal surface as far down as the dorsal margin of the eye or slightly lower, with a longitudinal strip of bluish bronze running the entire length of body and extending as low as the level of the lower margin of the pectoral fin base; rest of body silver. These colors change and fade rapidly after death and exposure to air.

According to Ehrenbaum (1924), Sanzo found great differences in coloration of the back of bluefins, varying from dark black to light blue. He believed that the black tuna had recently come up from great depths while the light colored fish had been in the upper layer for sufficient time to adapt to the light conditions there.

Arena (1959a) observed that many bluefin tunas caught in trap nets near Ligny, Sicily, had two distinct white spots of triangular shape near their second dorsal fin. Fish with this characteristic coloration were commonly called "fish with glasses". After death these spots faded quickly. He observed other tunas of very intensive dark color on their dorsal side, and he also surmised that these emerged from great depths.

1.2 Nomenclature

1.2.1 Valid scientific name

Thunnus thynnus (Linnaeus, 1758)

1.2.2 Synonyms

Rosa (1950) provides the following list of synonyms:

"Scomber thynnus Linnaeus, 1758 (original description)
Thunnus thynnus Jordan and Evermann, 1896
Thunnus (T.) thynnus Fraser-Brunner, 1950
Albacora thynnus Dressler and Fesler, 1889
Orcynus thynnus Jordan and Gilbert, 1882
Scomber pinnulis Artedi, 1738
Thunnus coretta Jordan and Evermann, 1926
Thunnus saliens (?) Jordan and Evermann, 1926
Thunnus subulatus Jordan and Evermann, 1926
Thunnus vulgaris South, 1845
Thynnus coretta Cuvier and Valenciennes, 1831
Thynnus mediterraneus Risso, 1826
Thynnus thynnus Cuvier, 1817
Thynnus vulgaris Cuvier and Valenciennes, 1831"

Sintesis and Bellón (1954) provide additional synonyms:

"Thynnus brachypterus Rosenhauer, 1856
Thynnus alalonga Machado, 1857
Orcynus thynnus Lütken, 1880
Zunnos Aristóteles
Orcynos Oppianos
Melandrys Ateneo".

1.2.3 Standard common names, vernacular names

See Table III.

Table III
Common and vernacular names (Rosa, 1950, and others)

Country	Standard Common Name	Vernacular Name(s)
Algeria		Tonno, Atun
Belgium	Thon rouge	Thon, Tonyn (Flemish)
British Guiana	Tunny	Bluefin tuna
Canada	Bluefin tuna	Tuna, Horse mackerel, Thon (French)
Canary Is.	Ravil	Peje de Ley, Atún, Patudo, Tuna
Chile	Atún grande de Juan Fernandez	Atún de aleta azul
China 1/	Heiyu	
Cuba	Atún	
Cyprus Is.	Minery	
Denmark	Tunfisk	
Dominican Republic	Atún	
Finland	Tonnikala	
France	Thon rouge	Thon, Thon commun, Toun, Thoun, Tonnu, Atuna, Atunchikia, Bonita, Peche - oblanka
French-speaking West Africa	Thon rouge	Walas (Ouolof dialect, Senegal)
Germany	Roter Thun	Thunfisch, Gemeiner Thun, Grosser Thun.
Greece	Tonnos	Thunnos, Thounina, Stereomi, Orkinos, Maiatico (young)
Hawaiian Is.	Bluefin tuna	Great albacore, Short-finned tuna, Common tuna, Leaping tuna, Tuna, Great tuna, Horse mackerel, Ahi (Hawaiian)
Ireland	Tunny	Tuinnin (Galway locality), Tuinnin (Kerry locality)
Italy	Tonno	Tono, Ton, Tunnu, Tuno, Tunne, Tonina, Tunisca, Turina, Tonnocolo, Barilaro, Pompilo, Pompin, Trampeto, Trompin, Trompilo, Thoun, Toun, Tunno, Trompeto, Tonnina, Tuna, Tun, Tunina, Tonnino, Tonnachello and Scampirro (young)
Japan 2/	Kuromagura	Kuroshibi, Maguro, Omaguro; young: Meji, Yokowa, Kakinotane
Madeira Is.	Atum Rabilho	Rabilho

1/ Verbal information from Mr. C. Chuang-ti, Taiwan.
2/ Sintesis and Bellón (1954)

Malta Is.	Tonn	Tunna, Tton -tuno, Ton (young), Tunai (adult), Tunnaj (juvenile)
Martinique Is.	Thon gros	
Mexico	Atún de aleta azul	Atún
Morocco	Thon rouge, Atún	Thon, Atunete, Atuarro
Netherlands	Tonijn	Tonyn
Norway	Makrellstoerje	Tunfisk
Poland	Túnczyk	
Portugal 3/	Atum	Atuarro, Albacora, Cachorreta, Atum de recuado, Atum de direito, Atum de revês
Puerto Rico	Atún	
Rio de Oro	Albacora	
Romania	Ton	
Spain	Atún rojo	Atún, Cunnarroyá, Cimarroyá, Atuná, Cunnarrón, Cimmarrón, Tonyina, Toñina, Tuñina, Atuarro, Tunyina, Albacora, Cachorreta, Arroaz
Morocco (former Spanish Morocco)	Atún	Atunete, Atuarro
Sweden	Tonfisk	Makrilstörje
Tunisia		Tonno, Thoun, Atun
Turkey	Cremisi Ballkys	
Union of South Africa	Tunny	Bluefin tunny, Tuna, Bluefin tuna, Blouvintonyn (Afrikaans)
United Kingdom	Tunny	Common tunny
United States	Bluefin tuna	Tuna, Horse mackerel, Great albacore, Leaping tuna, Giant tuna, Great tuna
U.S.S.R.	Tunéz	
Venezuela	Atún	Albacora, Tuna
Yugoslavia	Trup	Tuna, Tun, Tunina, Tunj, Trup crveni, Tunjevina, Ili, Mladi, Sarban, Sarabanĉic

3/ Atum - Specimens longer than 1.9 meters or weighing more than 100 kilos
Atuarro - Specimens 1.4 to 1.9 meters long or weighing 50 to 100 kilos
Albacora - Specimens 1.1 to 1.4 meters long or weighing 25 to 50 kilos
Cachorreta - Specimens less than 1.1 meters long or weighing less than 25 kilos
"Atum de recuado", "Atum de direito" and "Atum de reves" are names given to the fish during their different migratory movements.

1.3 General variability

1.3.1 Subspecific fragmentation (races, varieties, hybrids)

- Meristic counts

As shown in Table IV, there is a striking difference between the counts of pectoral rays as given by Ginsburg (1953) and by Crane (1936). These counts should be repeated on larger samples using the same method of counting.

Counts of dorsal and ventral finlets of various authors for various regions are given in Table V. Although the counts of different regions show slight differences, i.e. Mediterranean tunas seem to have higher numbers of finlets than the others, one has to be cautious when interpreting these differences. Ginsburg (1953) states that with growth the last dorsal and anal ray, which is partly detached, becomes altogether separated from the rest of the fin and turns into a finlet. As a result, large specimens may average fewer rays and a greater number of finlets. Mather III (1959) recognized this problem and recommended that the number of dorsal finlets be added to the number of second dorsal rays, and the number of anal finlets to the number of anal rays in comparing tunas.

However, the difference noted between the numbers of finlets of Mediterranean tuna (x_1 = 9.72; x_2 = 8.81) and of eastern North Atlantic tuna (Portuguese coast, south Spanish coast and North Sea (x_1 = 8.99; x_2 = 8.07) cannot be explained by respective differences in the size of the fish because the Atlantic tunas with the lower number of finlets were generally much larger than those investigated in the Mediterranean. For example, the tunas studied by Nédélec (1954) were 208-260 cm long, whereas those examined by Genovese (1956) were mostly smaller than 160 cm. Yet, the higher counts were made by Genovese (1956). On the other hand, the lower counts of the sample investigated by Navaz (1950), if compared with that of Nédélec (1954) may be related to the smaller size of the tunas examined.

Since finlet counts are easy to obtain and may permit the distinction of populations or subpopulations more attention should be paid to them. In compiling and analyzing the count data, however, the size of the tunas should be considered.

Gill raker counts of various authors are given according to regions in Table VI. As in the number of finlets, no significant difference between tunas of the eastern and western North Atlantic can be concluded from these data. The difference of the grand averages of total gill rakers counts is only 0.13 between the two regions.

The widest difference was found for the lower gill rakers and was between Tiews' (1957a) counts of 22-28 for the eastern Atlantic and the counts of 24-28 by observers in the western Atlantic. This difference may have been due to the method used for separating the lower from the upper gill rakers, however, because in the total number the American counts have a similar variation as the European counts.

In Table VII we give the frequency of combinations of numbers of gill rakers on the lower and upper limbs of the first gill arch of 232 bluefin tunas from the North Sea. The data show evidence of some asymmetry between the left and right sides.

Godsil and Holmberg (1950) and Mather III (1959) believe that California bluefin differ significantly in gill raker count from those of the Atlantic (Table VI).

Even wider differences are found between the Atlantic and the Australian southern bluefin tuna, Thunnus thynnus maccoyii (C.), for which Serventy (1956) has reported gill raker counts (Table VI). The Japanese bluefin tuna, Thunnus thynnus orientalis (Temminck and Schlegel 1842), is reported to have a similar number of gill rakers (12-13/24-26 = 36-39) as the Atlantic bluefin (Serventy 1956).

- Varieties

Various authors have followed the example of Heldt (1927) and have taken series of biometric measurements in order to investigate whether or not differences exist in the body proportions of tunas caught in different regions, and if such differences permit the distinction of tuna stocks. Nearly all of these studies concern

Table IV
Meristic counts of Thunnus thynnus (L.) 1/

Organs	Eastern Atlantic				Eastern and Western Atlantic Fowler (1936)	Western Atlantic		
	Frade (1931)	Ehrenbaum (1936)	Frade and Vilela (1960)	Smith (1950) (South Africa) 2/		Crane (1936)	Ginsburg (1953)	Rivas (1955)
1 st Dorsal fin rays	10-14	13-14	10-15	XII-XV	XII to XV- I or II	XIV	13-14	13-14
2 nd Dorsal fin rays	12-14	14-15	1/11-16	12-14	12-14	1, 11	14-16	13-15
Dorsal finlets	8-10	9-10	8-10	8-10	8-10	9-11	8-9	8-10
2 nd Dorsal fin rays + finlets	21-24	-	-	-	-	-	23-24	21-24
Anal fin rays	12-14	14	2/10-14	I-III, 11-12	II-III, 11-12	1, 10-11	13-15	13-15
Anal finlets	7-10	8-9	5-10	7-9	7-9	8-10	8	8-9
Anal fin rays + finlets	19-23	22-23	-	-	-	-	21-23	21-23
Pectoral fin rays	32-34	31-33	30-34	-	-	1, 31-33	33-38	-
Ventral fin rays	6	1+5	1/5	-	-	-	-	-
Vertebrae	-	18+21	-	-	-	-	-	-

1/ Counts of finlets and gill rakers are given in Tables V and VI.

2/ In view of the very low gill-raker counts (26-31) reported by Smith, the identification of species is doubted (see under 1.1.2).

Table V
Comparison of finlet counts of bluefin tuna according to regions and observers

	Dorsal finlets					
	8	9	10	11	Σ	$\bar{x}_1$
Mediterranean						
Heldt (1927)	1	7	77	7	92	9.98
Aricò and Genovese (1953)	-	26	68	1	95	9.74
Genovese (1956)	3	78	111	5	197	9.60
	4	111	256	13	384	9.72
Eastern Atlantic						
Frade (1931)	5	75	20	-	100	9.15
Navaz (1950)	5	83	12	-	100	9.07
Nédélec (1954)	3	51	33	-	87	9.34
Rodriguez-Roda (1957)	67	223	10	-	300	8.81
	80	432	75	-	587	8.99
Western Atlantic						
Ginsburg (1953)	6	5	-		11	8.45
Rivas (1955)	3	28	4	-	35	9.03
	9	33	4	-	46	8.89

	Anal finlets							
	5	6	7	8	9	10	Σ	$\bar{x}_2$
Mediterranean								
Heldt (1927)			-	5	81	3	89	8.98
Aricò and Genovese (1953)			1	25	67	2	95	8.74
Genovese (1956)			1	46	147	3	197	8.77
			2	76	295	8	381	8.81
Eastern Atlantic								
Frade (1931)	-	-	4	64	30	2	100	8.30
Navaz (1950)			1	62	35	2	100	8.38
Nédélec (1954)	-	-	-	40	47	-	87	8.54
Rodriguez-Roda (1957)	1	3	68	224	4	-	300	7.76
	1	3	73	390	116	4	587	8.07
Western Atlantic								
Ginsburg (1953)				11	-		11	8.00
Rivas (1955)				29	6		35	8.17
				40	6		46	8.13

Table VI
Frequencies of gill-raker counts for bluefin tuna
listed according to regions and observers

	Western Atlantic						Eastern Atlantic						Eastern Pacific	Western Pacific
	Upper gill-raker counts:													
	J. C.	L. R. R.	F.J.M.	R.H.G.	J. G.	Total	C.R.R.	F.J.M.	K. T.	W. K.	R. R.	Total	G.& H.	D. L. S.
9	-	-	1	-	-	1	-	-	-	-	-	-	-	10
10	-	1	1	1	-	3	1	-	-	-	1	2	1	65
11	1	2	1	3	-	7	-	-	2	-	-	2	1	154
12	6	10	26	8	-	50	4	-	21	9	1	35	14	73
13	25	16	70	19	-	130	1	2	111	53	6	173	8	9
14	8	5	33	9	-	55	1	2	87	34	9	133	1	-
15	-	1	4	2	-	7	-	-	10	4	-	14	1	-
16	-	-	-	-	-	-	-	-	1	-	-	1	-	-
n	40	35	136	42	-	253	7	4	232	100	17	360	26	311
$\bar{x}$	13, 00	12, 71	13, 04	12, 90	-	12, 97	12, 14	13, 50	13, 37	13, 33	13, 29	13, 33	12, 38	11, 02
	Lower gill-raker counts:													
21	-	-	-	-	-	-	-	-	-	-	-	-	2	24
22	-	-	-	-	-	-	-	-	1	-	-	1	3	113
23	-	-	-	-	-	-	-	-	6	-	-	6	11	125
24	5	1	14	6	-	26	-	2	33	5	3	43	9	41
25	14	9	44	11	-	78	1	2	80	42	6	131	1	7
26	14	15	49	20	-	98	3	-	83	35	7	128	-	-
27	7	7	25	4	-	43	3	-	28	16	1	48	-	-
28	-	3	4	1	-	8	-	-	1	2	-	3	-	1
n	40	35	136	42	-	253	7	4	232	100	17	360	26	311
$\bar{x}$	25, 58	26, 06	25. 71	25. 60	-	25. 72	26. 29	24. 50	25. 41	25. 68	25. 35	25. 49	23. 15	22. 68
	Total gill-raker counts:													
31	-	-	-	-	-	-	-	-	-	-	-	-	-	9
32	-	-	-	-	-	-	-	-	-	-	-	-	2	56
33	-	-	-	-	-	-	-	-	-	-	-	-	1	81
34	-	-	1	1	-	2	-	-	-	-	-	-	1	83
35	-	1	1	-	-	2	-	-	3	-	1	4	10	52
36	3	1	3	4	-	11	1	-	4	2	1	8	5	23
37	4	6	18	3	-	31	-	2	30	8	2	42	6	6
38	10	4	33	7	-	54	2	-	53	25	4	84	-	-
39	15	13	41	13	5	87	2	2	69	33	1	107	2	-
40	6	7	18	6	4	41	1	-	48	17	7	73	-	1
41	2	2	16	3	2	25	1	-	20	11	1	33	-	-
42	-	-	3	1	-	4	-	-	4	3	-	7	-	-
43	-	1	-	-	-	1	-	-	1	1	-	2	-	-
n	40	35	134	38	11	258	7	4	232	100	17	360	27	311
$\bar{x}$	38. 58	38. 77	38. 49	38. 61	39. 73	38. 77	38. 71	38. 00	38. 86	39. 05	38. 65	38. 90	35. 59	33. 68

Sources:
- J. C. — Jocelyn Crane (1936)
- L. R. R. — L. R. Rivas (1955)
- F. J. M. — F. J. Mather III (1959)
- R. H. G. — F. J. Mather III (1959) counts by Dr. R. H. Gibbs, Jr., et al.
- J. G. — J. Ginsburg (1953)
- C. R. R. — C. R. Robins (1957)
- K. T. — K. Tiews (1957a)
- W. K. — W. Kourist (North Sea, 1959, unpublished, Institut für Küsten- und Binnenfischerei)
- R. R. — Rodriguez-Roda (1960) (Barbate, south Atlantic coast of Spain)
- G. & H. — Godsil and Holmberg (1950) (California)
- D. L. S. — D. L. Serventy (1956) (Australia)

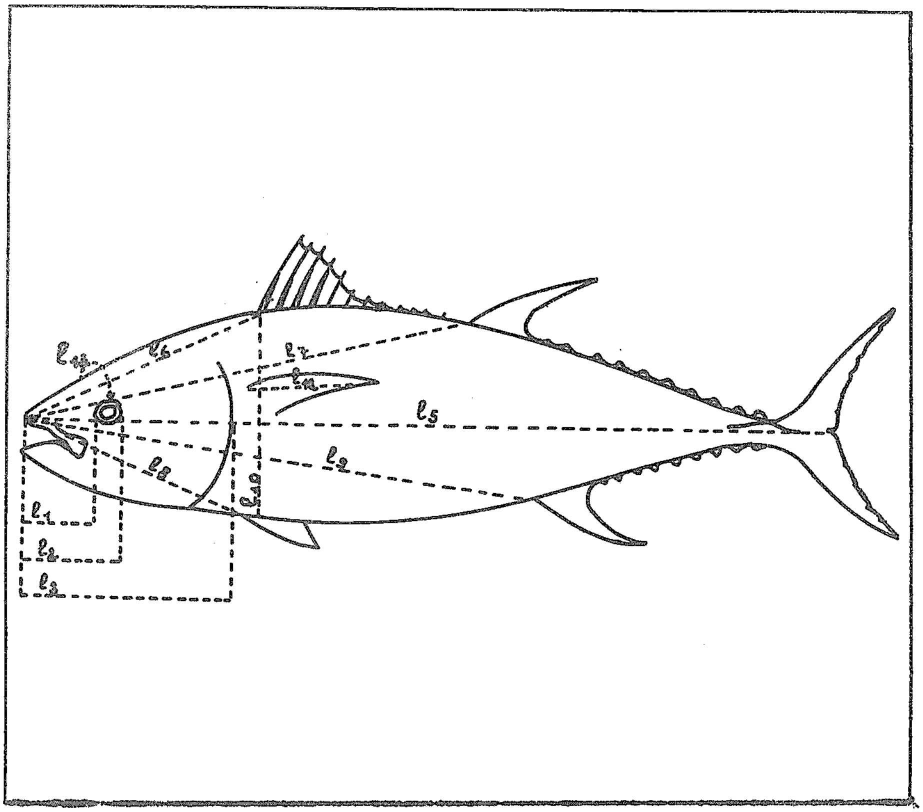


Fig. 2 Measurements taken on the bluefin. The following indices have been used by the various authors:

$$(Hi) = \frac{l_5}{l_{10}} ; \quad Ti \frac{l_5}{l_3} ; \quad Oi_1 = \frac{2l_3}{l_1+l_2} ; \quad Oi_2 = \frac{l_3}{l_2-l_1} ;$$

$$Oi_3 = \frac{l_3}{l_{13}} ; \quad Pi = \frac{l_5}{l_{12}} ; \quad \frac{Pi}{Ti} = \frac{l_3}{l_{12}} ; \quad Di = \frac{l_5}{l_6} ;$$

$$D'i = \frac{l_5}{l_7} ; \quad Vi = \frac{l_5}{l_8} ; \quad Ai = \frac{l_5}{l_9} .$$

(Aricò and Genovese 1953)

Table VII
Frequency of combinations of gill rakers on the lower and upper limb of first gill arch in 232 bluefin tunas from the North Sea (Tiews 1957a)

Combination No.	cerato-hypobr. limb No.		epibr. limb No.		Sum. No.	left side %	right side %
1	25	+	13	=	38	18. 1	16. 9
2	26	+	13	=	39	16. 0	16. 5
3	26	+	14	=	40	15. 4	14. 2
4	25	+	14	=	39	10. 7	12. 4
5	24	+	13	=	37	7. 8	7. 8
6	27	+	14	=	41	5. 6	6. 9
7	25	+	12	=	37	3. 9	5. 2
8	27	+	13	=	40	3. 8	5. 5
9	24	+	12	=	36	3. 6	0. 9
10	24	+	14	=	38	3. 0	3. 8
11	26	+	12	=	38	3. 0	2. 2
12	23	+	13	=	36	2. 2	0. 9
13	26	+	15	=	41	1. 3	1. 3
14	27	+	15	=	42	1. 3	1. 7
15	25	+	11	=	36	0. 9	0. 0
16	25	+	15	=	40	0. 9	0. 9
17	27	+	12	=	39	0. 9	0. 4
18	22	+	13	=	35	0. 4	0. 0
19	23	+	12	=	35	0. 4	0. 4
20	27	+	11	=	38	0. 4	0. 0
21	28	+	13	=	41	0. 4	0. 4
22	24	+	11	=	35	0. 0	0. 9
23	24	+	15	=	39	0. 0	0. 4
24	27	+	16	=	43	0. 0	0. 4

the European side of the Atlantic. A comparison of biometric indices, as defined in Fig. 2, is given in Table VIII. Since these indices all change with length, only tunas of equal length can be compared. Since Nédélec (1954) and Russel (1934) obtained their measurements on North Sea tunas above 208 cm, the table is restricted to size groups of 200 cm and larger, except in the case of Genovese (1956) whose data include tuna 160 cm and larger.

It might be worth mentioning that these researchers worked independently and none was familiar with the work of all the others.

The results of these studies may be summarized as follows. Frade (1931) concluded that there were significant differences between the tuna which he examined on the Portuguese coast and those which Heldt (1927) measured in Tunis. Aricò and Genovese (1956) stated that the tunas of the Tyrhennian Sea differed by so many characters from those of Algarve, Tunis and the North Sea as to constitute separate races. Genovese (1956) believed that bluefin taken in the Channel of Messina were of the same genetic make-up as those from the north eastern coast of Sicily. According to Nédélec (1954), the tunas of the eastern North Atlantic are distinct from those of the Mediterranean in having a greater head length, a longer pectoral fin, a shorter distance from the snout to the insertion point of the first dorsal fin, the ventral fins inserted more to the rear, and fewer finlets.

A critical examination of the data, however, shows that only differences in the head length, pectoral fin length and number of finlets support

Table VIII

Comparison of biometric indices for bluefin tuna, above 200 cm in fork length, caught in the North Sea, near Algarve, and in the Mediterranean

Indices	North Sea Nédélec (1954)	North Sea Russel (1934)	Algarve (Portugal) Frade G_4 (1931)	Mediterranean Tunis Heldt G_4 (1927)	Mediterranean Sicily Aricò and Genovese G_4 (1953)	Mediterranean Sicily Genovese G_{3+4} (1956) (above 160 cm)
Oi_1	M= 2.46 -	M= 2.42 LC=2.385- 2.455	M= 2.406 2.381- 2.430	M= 2.433 2.410- 2.456	M= 2.393 2.360- 2.426	M = 2.404 1/ 2.382- 2.426
Oi_2	11.28 -	11.42 11.079-11.762	9.726 9.231-10.221	10.98 10.42 -11.54	10.517 9.927-11.107	9.32 8.539-10.101
Oi_3	1.96 1.927- 1.993	- -	- -	1.82 -	1.843 1.803- 1.882	2.003 1.944- 2.062
Ti	3.71 3.654- 3.766	3.74 3.681- 3.799	3.713 3.658- 3.768	3.87 3.81 - 3.93	3.82 3.762- 3.881	3.650 3.575- 3.725
Pi	5.58 5.360- 5.800	5.57 -	5.590 5.410- 5.770	5.99 5.67 - 6.31	6.22 5.944- 6.497	5.82 5.595- 6.045
Pi/Ti	1.51	- -	1.491 1.466- 1.516	1.516 1.476- 1.556	1.612 1.582- 1.644	1.557 1.531- 1.583
(Hi)	3.91	- -	4.410 4.335- 4.485	3.81 3.635- 3.985	4.410 3.925- 4.247	3.693 3.473- 3.907
Di	3.65 3.587- 3.713	3.62 3.558- 3.682	3.555 3.510- 3.600	3.518 3.458- 3.578	3.638 3.553- 3.723	3.492 3.430- 3.549
Di	1.95 1.924- 1.976	1.93 1.909- 1.951	(1.886) 1.871- 1.901	1.887 1.858- 1.916	1.932 1.902- 1.916	1.893 1.860- 1.926
Vi	3.15 3.064- 3.236	3.17 3.096- 3.244	3.197 3.137- 3.257	3.397 3.329- 3.465	3.178 3.057- 3.300	2.800 2.674- 2.926
Ai	1.65 -	1.64 1.632- 1.668	1.660 1.648- 1.672	1.657 1.634- 1.680	1.650 1.616- 1.683	1.589 1.557- 1.615

1/ Refers to all tunas of size group G_0 - G_4

the case for the existence of two separate stocks of bluefin tuna on the European side of the Atlantic. The insertion of the dorsal and ventral fins are at equal lengths from the snout in both groups. The latest tagging experiments, discussed under section 3. 5. 1, have demonstrated that tunas frequently travel thousands of miles in short periods of time. It is the author's belief, therefore, that the conclusions stated above will not stand under critical inspection and that further studies will prove the existence of a single bluefin population in the eastern North Atlantic.

It is recommended that, in the future, special attention be given to the more promising characters of head length, pectoral fin length and number of finlets. The past measurements by Europeans have been made not in straight lines but along the curved surface of the body. I have found weights of 235 cm bluefin tuna caught in the North Sea in September 1955 to range between 155 kg and 335 kg (Tiews 1957a), in the ratio of 1:2. 16. The heavier tuna would appear to have a relatively shorter head and pectoral fin than the lighter fish if measurements were taken along the body surface. We recommend, therefore, that measurements be made only along straight lines, as practised by Marr and Schaefer (1949).

1. 3. 2 Genetic data (chromosome number, protein specificity)

Very few studies have been conducted on the genetics of bluefin. Costa (1959) found that the atrial heart tissues of T. thynnus were very rich in lipoids active in the Wassermann reaction. Rivas (1954b) reported that blood samples had been collected for a study of proteins and amino-acids and were being investigated at the Rutgers University Serological Laboratory.

Frade and Vilela (1960) found deformations of the skull consisting of a lateral external groove on both sides and abnormalities of internal organs (especially the swim bladder) in 14 of 1, 000 bluefin tuna investigated on the Portuguese coast. Frade (1930b) believes that these abnormalities could be hereditary and proposes to use them in racial studies.

2 DISTRIBUTION

2.1 Delimitation of the total area of distribution and ecological characterization of this area

Rosa (1950) gives the following geographical distribution for the bluefin tuna:

North Atlantic Ocean	Found at times on the northern coast of U.S.S.R. on the coast of Murmansk, coast of Norway and Lofoten Is., Iceland, Kattegat and Skagerrak Straits, coast of Denmark, United Kingdom and Ireland. Found frequently on the coast of France in the Bay of Biscay, coasts of Spain, Portugal, Azores, Madeira, Canary and Cape Verde Is., Spanish Morocco, French Morocco, Spanish Sahara, French West Africa, Gambia, Portuguese Guinea, Sierra Leone, Liberia; Canada along Labrador, Newfoundland, New Brunswick and Nova Scotia; coast of the United States from Maine to Florida, Bermuda Is., Caribbean Sea; coast of Cuba, Puerto Rico, Tobago and Trinidad Is., Venezuela and British Guiana.
Mediterranean Sea	Coast of Gibraltar, Spain and Balearic Is., France, Corsica Is., Italy, Sicily and Sardinia Is., Malta Is., Yugoslavia, Greece, Cyprus Is., Turkey, Syria, Lebanon, Egypt, Libya (Tripolitania and Cyrenaica Tunisia, Algeria, Spanish Morocco.
Black Sea	Coast of Bulgaria, Romania, U.S.S.R. on the coast of Crimea, Turkey, Sea of Marmara, Straits of Bosporus and Dardanelles.

In the opinion of the author, the record of occurrence of T. thynnus L. near Cape Verde Is. and southerly in the tropical zone of the West African coast still needs further confirmation. Also the identity of bluefin tuna on the coast of the Republic of South Africa should be rechecked, since the gill-raker counts as quoted by Smith (1950) do not correspond with those generally known from T. thynnus L., but rather indicate the identity of another tuna species (see section 1.1.2). In view of this uncertainty, the record of T. thynnus in Angola, given by Vilela and Monteiro (1959), should also be rechecked.

It can be stated that T. thynnus L. occurs from 20° - 70° N on the eastern side and from about 10° - 50° (or 60°) N on the western side of the North Atlantic. This area covers the subtropic and temperate sections of the North Atlantic. The bluefin, therefore, has the most northerly distribution of any of the tunas. Distribution to the northward is restricted to the summer months and to areas with water temperatures above 10-12°C (Fig. 3).

At the southern limits of its distribution the bluefin encounters surface temperatures which are around 25°C (in the Mediterranean) on the eastern side and up to 27°C (in the Caribbean Sea) on the western side of the North Atlantic. When the tunas are in these areas they are mostly subsurface, probably in search of cooler water.

Sella (1931) reports that a temperature of 14°C may cause the bluefin to become dormant. Small tunas appear to be less sensitive to lower temperatures than large ones, as indicated by the smaller average size of tunas caught during the winter.

According to Sella (1931), during its feeding period the bluefin shows little sensitivity to salinity differences. During its migration the fish passes temporarily through the Bay of Buccari with salinity of 31-32°/oo and can be found in water of 38°/oo on the coast of Cyrenaica as well as in the Bosporus with 18-20°/oo salinity. However, the bluefin seems to avoid waters with a salinity as high as 39°/oo, as can be found in some southern regions of the Mediterranean.

There is reason to believe that, in the western Atlantic, bluefin tuna are associated with the Gulf Stream and are likely to be found

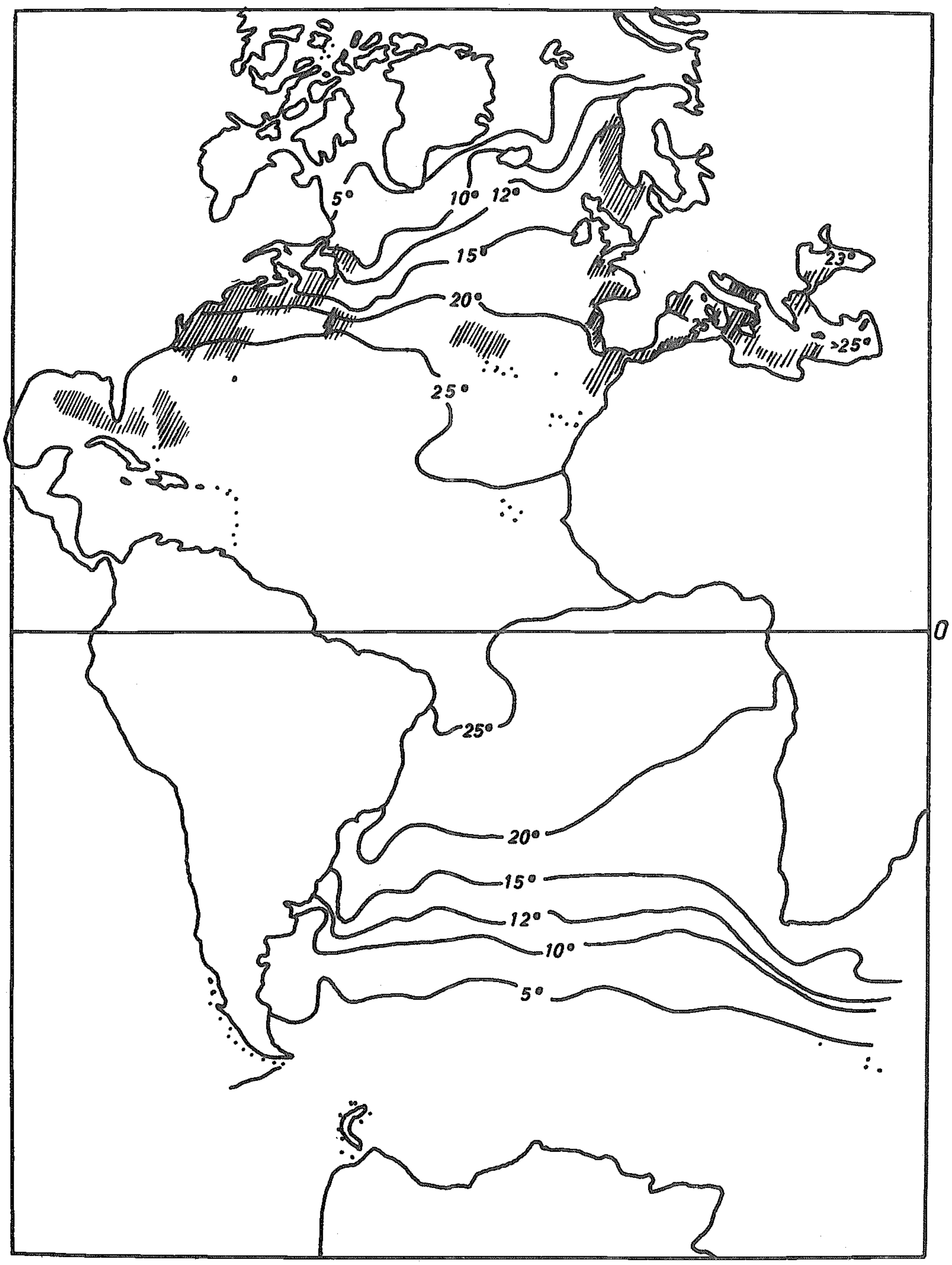


Fig. 3 Chart showing summerly (April to October) distribution areas of Thunnus thynnus (arts hatching) in the Atlantic according to various authors (based on catch localities reported). Isotherms are given for the month of August according to Schott (1944).

within the boundaries of that current (Anonymous 1952). This statement is also true for the northerly distribution of bluefin on the European side of the Atlantic.

It can be generally said that bluefin tuna occur during their reproductive period in subtropical areas that have relatively low productivity, but during their feeding period they occur in large schools in areas that are known to be of very high productivity and which can offer them sufficient quantities of prey fish for food. This is true for both sides of the Atlantic.

Although such rich areas are usually on the Continental Shelf, bluefin tuna may leave their feeding grounds and travel thousands of miles across the great depths of the Atlantic, as recent tagging experiments have shown (see section 3.5.1).

Controversial views have been expressed on the vertical distribution of tunas. Pavesi (1889) was of the opinion that the tuna lived during the winter in the great depths of the abyssal, but came to the surface in the spring to spawn. Roule (1924) and other authors have stated that the tuna is a bathy-pelagic fish, spending its life near the surface and in the upper water layers, varying with the distribution of food fish. In the northern portion of its range, the bluefin is usually found above or near the thermocline, and only occasionally goes below (Tiews 1957a) (see section 5.2.3).

2.2 Differential distribution

2.2.1 Areas occupied by eggs, larvae and other junior stages: annual variations in these patterns, and seasonal variations for stages persisting over two or more seasons

There are few records in the literature of such distributions. Much work needs to be done to better our knowledge of these early stages in the life history of the bluefin tuna.

- Eggs

Sanzo (1932) found eggs in the Straits of Messina from May to July 1925-1927 (quoted by Rivas 1954a). Lozano Cabo (1958) states that eggs of bluefin have been collected near the Dardanelles and on the coast of Algeria. Arena (1959a) reported the occurrence of great quantities of eggs between the Eolian Is., and Akyüz and Artüz (1957) reported that eggs of tuna were found in the Black Sea from July to September by Vodianitzkii and Kazanova (1954).

Rivas (1954b) collected numerous bluefin eggs during May and June in plankton tows in the Straits of Florida, along the eastern edge of the Florida Current, from Cuba to, and including, the western edge of the Bahama Banks.

- Larval stages

Ehrenbaum (1924) gives the following list of

Sr. No.	Date	Locality	Length of line, m	Number of larvae	Length of larvae, mm
144	July 24,1910	Southern part of Jonic Sea	25	1	7.3
160	August 1,1910	E. of Is. Rhodos	25	1	4.7
161	August 2,1910	W. of Is. Rhodos	25	1	7.1
187	August 18,1910	Jonic Sea E. of Cape Spartivento	1000	1	9.3
189	August 19,1910	S. of Cape Spartivento	25	1	6.8
192	August 20,1910	near Messina	600	2	6.8;9.4
196	August 22,1910	40 miles S. of Capri	25	1	8.4
199	August 28,1910	E. of Sardinia	300	1	9.2
215	August 31,1910	NW of Is. Pityusen	25	1	8.0
438	November 17,1911	Middle Atlantic	56	2	6.8;7.0
529	August 5,1912	NE of Malta	57	1	7.8

localities where he collected larvae that he provisionally identified as T. thynnus.

The record of two larvae from the middle Atlantic in November 1911 deserves special mention. Unfortunately Ehrenbaum does not give the exact position. All the other larvae were found in the Mediterranean Sea.

Sanzo (1932) described larvae of T. thynnus between 34 and 90 mm which were caught in the Straits of Messina and near Palermo (quoted by Thiel 1938).

Dieuzeide (1951) recorded the catch of four larvae between 4 and 8 mm along the coast of Algeria between Alger and La Calle in July 1950. Two of the larvae were caught 40 miles off-shore, the other two 54 miles off-shore. They were taken on the surface during the night between the hours of 2330 and 0600.

Akyüz and Artüz (1957) state that both eggs and larvae of tuna were found in the Black Sea during July-September by Vodianitzkii and Kazanova (1954)

Rivas (1954b) reported that larvae in various stages of development were caught during May and June by plankton tows in the Straits of Florida along the eastern edge of the Florida Current, from Cuba to, and including, the western edge of the Bahama Banks.

- Young fish

Records on the occurrence of young tuna between 1 and 5 kg in great quantities near Ceuta and Cape Tres Forcas from May to autumn are given by de Buen (1925).

Dieuzeide and Roland (1955) describe post-larval stages between 211 and 464 mm (fork length) (135 - 1845 g) which were caught on the coast of Algeria near Philippeville and Castiglione. They record also that in October 1948, in November 1949 and in October 1952, tuna of 800 - 2000 g and 40-50 cm were caught in this same locality in considerable quantities.

Scaccini (1959) found large schools of ten to several hundred young tuna less than two years old (70-80 cm, 10-12 kg) in the Adriatic and Tyrrhenian Seas. During the summer he observed tuna as small as 8 to 12 cm, weight 40 to 100 g in the Adriatic Sea. In April to June these had grown to 60-70 cm (4 - 5 kg) and were found also in the Tyrrhenian Sea.

Morović (1961) mentions that young tuna, mostly between 65 and 85 cm (3.4 - 10.0 kg) are caught with purse seines in the Adriatic Sea between Pula, Zirje and Jabuka, where the water depth is 100 - 200 m.

Young bluefin tuna between 4 and 70 kg have been found around Sardinia (Scaccini 1961b).

Young tuna from 0.5 - 9 cm occur in the surface waters of the Straits of Messina and on the coast of the Gulf of Gaeta (north of the Gulf of Naples) (Scaccini 1961a). The smallest size groups can be caught by means of artificial lights in late June and early July. Stages up to 9 cm are present during the months of August to October. Lo Bianco (1909) reported the occurrence of young tuna of 11 - 18 mm in July and of 25 - 32 m in August-October in the Gulf of Naples.

Young tunas between 4 and 7 kg (60 cm) have been caught during October and November on the northern coast of the Mediterranean in the Bay of d'Aigues-Mortes (Büser-Lahaye and Doumenge 1954).

The bluefin tuna catch of the Bay of Biscay consists of rather young fish which measure, according to Castagné, Fauvel and Le Gall (1949), between 70 and 125 cm, weighing between 4.5 and 24 kg, and 2 to 4 years of age.

Young bluefin weighing as little as half a pound (about 10 in, 25 cm) have been found in the Straits of Florida along the eastern edge of the Florida Current, from Cuba to, and including, the western edge of the Bahama Banks, from about the middle of July on (Rivas 1954b).

Mather III (1962b) states that little is known of the distribution of very small (less than 2.5 kg) bluefin tuna. Considering the enormous numbers of these fish which must exist, only few are taken.

He believes they occur occasionally in large numbers on the south east coast of Florida and in coastal waters extending from Cape Hatteras northward to about 41°N. From August to October they are also in the northern Gulf of Mexico and near Cape Cod.

- Areas occupied by adult stages; seasonal and annual variations of these

Iyigüngör (1957) states that adult bluefins can be captured throughout the year in the Bosporus and Marmara Sea. This is also true of the Straits of Messina. According to Vilela (1960) bluefin tuna arrive during the first days in May or sometimes even in April on the Portuguese south coast near Algarve and disappear from there at the end of August. In the North Sea the tuna occurs from July to October or November. The tuna arrives first on the Norwegian coast and three to four weeks later in the middle parts of the North Sea, south of the Fladen Ground area. There are fluctuations from year to year in respect to the time of arrival of the tunas amounting to three to four weeks earlier or later (Meyer-Waarden and Tiews 1959; Hamre 1958). The strength of the run into the North Sea also fluctuates greatly from year to year, depending on several factors (Meyer-Waarden and Tiews 1959; Hamre 1959; Rodewald 1960 and others).

In the western Atlantic, the tuna are known to occur along the western Bahamas during May and June and in northern waters, up to Nova Scotia and Newfoundland. During July through October, numerous new records have been obtained whereby the known range of the fish may be now extended to the north (Caribbean) coast of South America (Rivas 1954b). The records indicate that they occupy the southern part of their range during the winter and the northern part during the summer, thereby suggesting a rather wide seasonal migration in a north-south direction. Occurrences of the bluefin in its summering area are erratic and unpredictable, depending on the availability of food and probably also on other factors which are not yet known. Shifts in the localities of concentrations of bluefin sometimes occur from year to year and sometimes after periods of two or three years or longer (Mather III 1962b).

From early 1957 through the spring of 1960 the U.S. Bureau of Commercial Fisheries conducted eight cruises with the research vessel Delaware for the purpose of investigating the stocks of tuna present in the off-shore waters of the Northwest Atlantic; 111 stations were occupied utilizing longline gear (Anonymous 1961). Table IX shows the catches of *T. thynnus* made on these eight cruises in relation to area and time of year.

Table IX
Bluefin catch in off-shore waters of the Northwest Atlantic by the vessel Delaware using longline gear (Anonymous 1961)

Period	Locality	Number of bluefin caught	Total weight lb	Number of baskets
March-April 1957	29-39°N 59-74°W	16	3, 755	474
June-July 1957	37-40°N 66-73°W	83	28, 655	892
Sept. -Oct. 1957	29-42°N 64-77°W	2	650	1, 255
April-May 1958	38-42°N 51-61°W	194	31, 053	642
July-Aug. 1958	32-41°N 64-73°W	5	980	1, 097
Jan. -Feb. 1959	36-40°N 66-72°W	88	18, 025	514
May 1959	38-39°N 68-69°W	450	69, 000	380
April-May 1960	35-41°N 62-74°W	29	4, 940	420

Table X
Bluefin catch in the gulf of Mexico and the Caribbean Sea by the vessel Oregon using longline gear (Wathne 1959)

Date	Locality	Number of bluefin caught	Total weight lb	Number of hooks
May 25,1954	22°33'N-97°04'W	1	105	236
July 15, "	28°38'N-88°06'W	1	1, 112	326
March 9,1955	28°10'N-87°51'W	1	300	426
April 12, "	20°02'N-81°50'W	1	600	450
April 23, "	19°55'N-74°10'W	8	4, 610	430
April 24, "	19°45'N-74°45'W	8	4, 110	430
April 25, "	19°30'N-67°50'W	3	-	410
April 28, "	20°50'N-86°10'W	1	-	390
Jan. 31, 1956	27°35'N-87°37'W	1	853	510
March 24, "	27°13'N-89°35'W	6	2, 330	500
March 25, "	25°40'N-91°03'W	3	2, 865	500
March 26, "	24°48'N-91°40'W	1	-	500

Wathne (1959) reported the catch (Table X) of 35 bluefin tuna in the Gulf of Mexico and the Caribbean Sea, made by the U.S. Bureau of Commercial Fisheries vessel Oregon.

The results of these cruises and other available information (Bigelow and Shroeder 1953; Mather III 1960 1962b) indicate that, from July through October, the season of maximum water temperature in the inshore waters of the western North Atlantic, the bluefin are apparently almost all on or near the Continental Shelf between Cape Hatteras and Newfoundland, including the outer shoals and banks. Longline fishing in this period indicated the almost complete absence of the species from the deep oceanic waters.

The first bluefin to arrive in northern waters usually are large individuals, taken late in May or in the first half of June off Cape Cod or Gloucester. Next are the small specimens which may appear anywhere from the Chesapeake Capes to Cape Cod from mid-June to early July. The medium-sized fishes usually are the last, sometimes occurring off eastern Long Island in July, but rarely arriving in numbers off Cape Cod, where they are more frequently found, before August, or in Nova Scotia before September. T. thynnus of this size also are usually the last to leave the northern areas, having been recorded in Cape Cod Bay in November and off Nova Scotia in October, after the larger and smaller fish have departed.

During the late autumn, T. thynnus moves from its summer feeding grounds to its wintering areas, which are much more extensive. During November 1960, a dense concentration of bluefin tuna was found by longline fishing along the 1, 000 fathom curve off southern New England, Long Island, and New Jersey (Mather and Bartlett, in press). Most of the fish taken were of medium size, but a few were smaller.

The distribution of bluefin tuna in the western North Atlantic, in the period of minimum water temperatures (January-April), has also been determined mainly by longline fishing. The area occupied by the species in this season is vast and its limits have not been completely defined. Size segregation is more distinct in this season than in the summer. Although large individuals may be found over practically all of the wintering area, the medium-sized and small ones (with the exception of juveniles weighing less than 2. 5 kg) have rarely been taken south of 36°N in offshore waters or south of Cape Hatteras along the coast.

There is little knowledge of the distribution of small bluefin tuna in winter. The few longline catches recorded have been in the vicinity of the Gulf Stream between 66°W and 72°W. Trolling catches are limited to a few in the Cape Hatteras area.

The run of giant bluefin along the edge of the shelf off Cat Cay and Bimini in the northwestern Bahamas from early May until mid-June is the most dramatic evidence of the general spring migration of the species. Great numbers of these fish regularly appear in schools just below the surface when a southerly wind is blowing, travelling northward at speeds estimated to average 3.5 knots (Rivas 1955). The oceanic longline catches for May and June suggest that most of these large individuals remain east of the Gulf Stream until they are well beyond Cape Hatteras.

Medium-sized T. thynnus have been taken in good numbers over a wide area between 37°N, 58°W, and the edge of the Continental Shelf. Catch rates for these fish outside the 1,000-fathom curve have been higher in spring than in any other period. This was especially true during the Delaware cruise 59-6 in May 1959, when the rates for six stations just north of the Gulf Stream in the vicinity of 38°30'N, 68°30'W averaged 15.6 fish per 100 hooks. These results suggest a schooling up of medium-sized bluefin tuna on the northern edge of the Gulf Stream prior to their inshore movement, corresponding to the concentration along the 1,000- fathom curve north to northwest of this area in November prior to their offshore movement. Many of the bluefin caught from the Delaware in May were tagged, and one was recaptured in Cape Cod Bay in August 1959 (Mather 1960).

2.3 Behavioristic and ecological determinants of the general limits of distribution and of the variations of these limits and of differential distribution

In general, it seems that the summer distribution of the bluefin depends chiefly on two factors: the abundance of forage fish and the surface temperature of the water. Surface temperature seems to be of prime importance, as the tuna will be found only in areas with rich forage concentrations when the surface temperature is above a certain minimum (about 12°C). Rich food concentrations in areas having surface temperatures below 12°C seem to be inaccessible for the fish.

It is the surface temperature that is important rather than the temperature at which the forage fish lives. Tiews (1957a) observed that bluefin tuna in the North Sea fed on herrings living close to the bottom where temperatures were commonly found to be 6-8°C. The surface temperature was about 10°C higher.

Lühmann (1959) tried to explain the differences observed in the first appearance of the tuna on the German fishing grounds (North Sea) by investigating surface temperatures in waters north of Scotland during the month of August in the years 1955-1958. He suggested that in warm summers, when the 12°C isotherm is situated farther north than in cool summers, the immigration of tuna takes place earlier than during cool summers. When the water temperature decreases in autumn below 12-14°C, the tuna return to more southerly latitudes. It seems to be characteristic that the minimum temperature restricting their northerly distribution corresponds with the winter temperature of the Mediterranean Sea, being 12-14°C. It is, therefore, unlikely that the fish can winter-over in areas with temperatures below this range.

At present we have no knowledge of the winter distribution of bluefin in the eastern North Atlantic. It is thought that the fish spends the winter in waters off the west coast of North Africa with temperatures between 15 and 20°C. However, the tuna does not necessarily need to go so far south since it could find water temperatures of 12-14°C off the coast of Portugal at a latitude of about 40°B (Fig. 4).

Several other correlations between temperature and occurrence of tuna have been noted. According to Sara (1960) temperatures of 16°C to 18°C (preferably 17°C), at depth of 25 m, are the most favorable for the occurrence of tuna in the madrage of Magazzinazzi. It is very likely that also in this case temperature is the limiting factor. As expected, the bluefin is only found in the Black Sea when the surface temperature is above 12-14°C, and it leaves the Black Sea when the temperature goes below this point.

Bluefin tuna can be caught throughout the year in the Marmara Sea and the Bosporus, although they are not far distant from the Black Sea (Akyüz and Artüz 1957). This is because their temperature does not drop below the critical limit of about 12°C, while in the Black Sea winter temperatures may reach as low as 6-7°C.

In the western North Atlantic the winter distribution of the bluefin also appears to be regu-

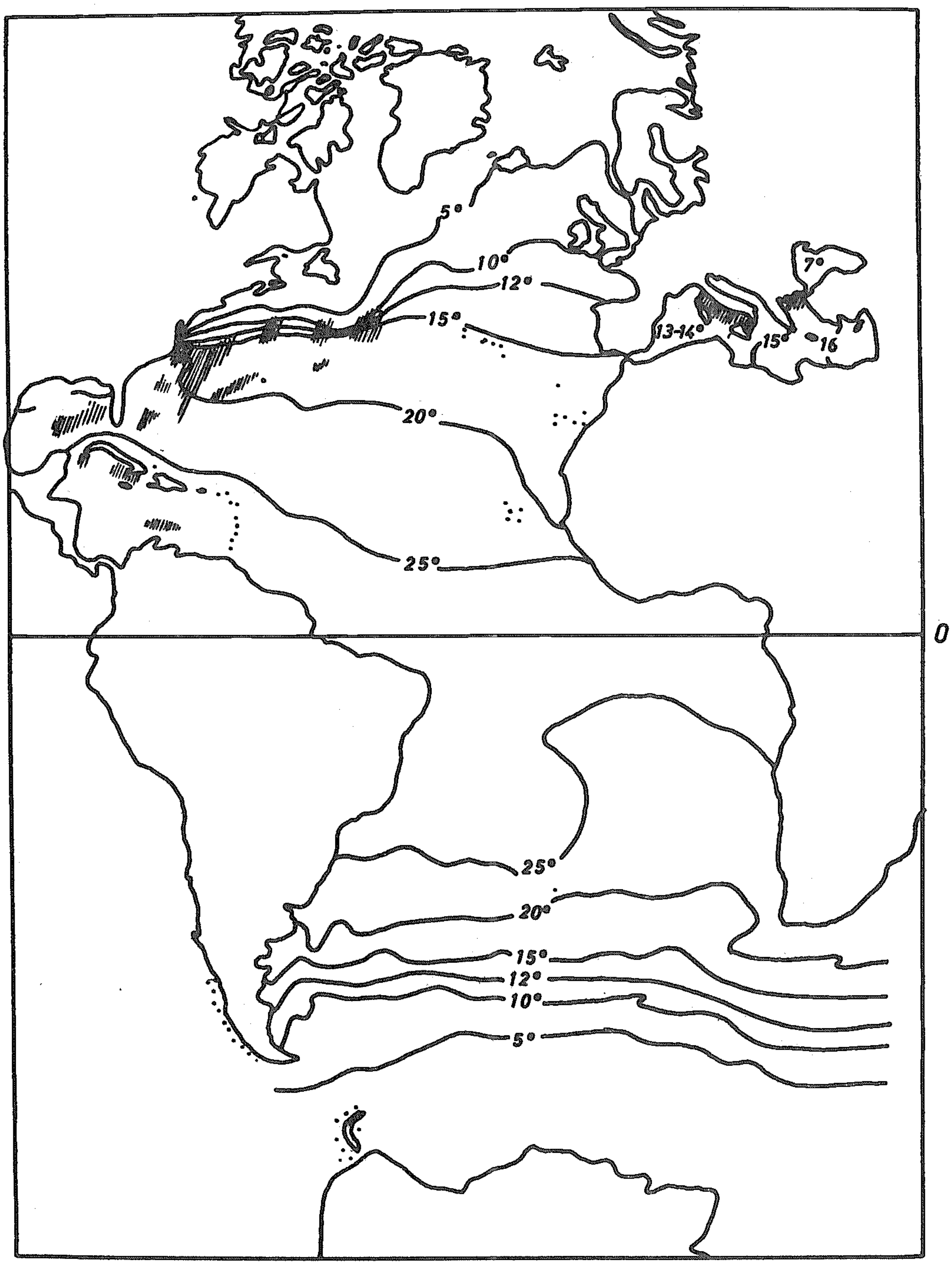


Fig. 4 Chart showing winterly (November to March) distribution areas of Thunnus thynnus (arts hatching) in the Atlantic according to various authors (based on catch localities reported). Isotherms are given for the month of February according to Schott (1944).

lated by the 12°C isotherm, as indicated by the seasonal distribution charts of Mather III (1962b).

As stated earlier (section 2.1) salinity seems to be of little importance as a determinant of the distribution of bluefin. The tuna regularly enters the Black Sea having a salinity of 18-20°/oo.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.1.1 Sexuality (hermaphroditism, heterosexuality, intersexuality)

The bluefin tuna is heterosexual. No externally observable characters are known to distinguish males and females. According to Frade and Vilela (1960), in young fish the distinction of sexes is not possible even if internally inspected. In such specimens histological examination is necessary.

3.1.2 Maturity (age and size)

Sella (1929) stated that in the Mediterranean Sea, the bluefin reaches maturity in its third year of life having a length of 97.5 cm and a weight of 15 kg. Le Gall (1954) reported that maturity is reached at a length between 95 and 105 cm corresponding to weights of 12 - 17 kg. With rapid growth this size can be reached in two years, or under unfavourable conditions in four years.

On the Portuguese coast, fish between 65 and 70 cm, judged to be two years old, were found to be immature. Fish measuring 1 m were mature, and some had even spawned. Frade and Vilela (1960) tentatively concluded that the bluefin reaches maturity at a length of 80-90 cm and at an age of about two years.

3.1.3 Mating (monogamous, polygamous, promiscuous)

The bluefin is polygamous.

T. thynnus (Linnaeus) when impounded in trap nets is said to have performed as follows (Sella 1911). One individual, probably the male, was noted to pass with a rapid twist under another, probably the female, rubbing venters with it. Heldt (1932) reported a word-of-mouth account which he is disposed to accept as follows. Two tunny would rise from deeper water to a depth of four or five fathoms and roll around touching their ventral surfaces together. At this moment the eggs and milt would be released. Then the fish would descend again and the whole act was seen to be repeated several times.

Although these data are much too fragmentary to be used as a basis of definite conclusion, the evidence would tend to indicate individual pairing, while nothing in it would tend to support the idea of communal reproductive act, so often casually attributed to schooling oceanic fishes (Breder 1951).

3.1.4 Fertilization (internal, external)

External. It is likely that the eggs are fertilized while they float in the surface layer after spawning.

3.1.5 Fecundity

There is only one reference known to the author. Frade (1950) determined the ovary weight (7.8 kg) of a tuna having a total weight of 160 kg. The ripe eggs, already filling the oviduct, were separated from each other and counted. They numbered 1,200 eggs per g; the total number was calculated to be 9,360,000 eggs. The age of this tuna is estimated to have been ten years.

3.1.6 Spawning

- Spawning seasons (beginning, end, peak)

The known European bluefin spawning grounds comprise mainly the central Mediterranean (Roule 1924), and the breeding season extends from late April through about the middle of July (Roule 1924; Heldt 1926; Sanzo 1929). The ripening of the gonads begins about late April and early May in various parts of the Mediterranean (Roule 1924). At this time, the fish school in great numbers and form shoals composed sometimes of several thousand individuals which then travel to the spawning grounds where they arrive during the last two weeks in May. Sexual maturation is then completed and the actual spawning takes place during the months of June and early July.

Fernando de Buen, quoted by Heldt (1926) offers the following frequency distribution of gonad development for bluefin tuna from the southwestern coast of Spain for the year 1923.

		Males percent	Females percent
May	Not yet ripe	100	100
June	Not yet ripe	32	67
	In full maturity	60	30
	Spent	8	3
July	Not yet ripe	1	26
	In full maturity	33	12
	Spent	66	62
August	Spent	100	100

The above frequency indicates that spawning takes place during June and July in southwestern Spain and confirms Roule's observations for the Mediterranean. The occurrence of eggs in the Straits of Messina as determined by daily plankton tows conducted during the months of May, June and July of the years 1925, 1926, and 1927 (Sanzo 1932), also indicates that spawning takes place from late May through the middle of July (Rivas 1954a).

Dieuzeide (1951) states that the occurrence of larvae shows that the bluefin of the western Mediterranean spawns during the first days of July.

Vilela (1960), investigating the spawning of tuna on the Portuguese coast, confirmed the results of Frade and Manaças (1933) and Frade (1935 1937) and comes to a similar conclusion: that spawning starts in the second half of June and extends over a period of 7 - 8 weeks. Males ripen earlier than females.

Arena (1959a) found the first ripe ovaries in tuna caught in Sicilian madragues from May 22 to June 22.

Bullis and Mather III (1956) found on April 12 1955 in the northern Caribbean a male of 245 cm with ripe testes weighing 26 lb. On April 24 and 25 they found two more males that were running ripe. Most of the giant bluefins taken off Bimini and Cat Cay in May and June probably had spawned somewhat earlier, possibly in April or early May, and not far south of these places, judging by the condition of their gonads.

Rivas (1954a) reports that spawning in the Bimini area probably does not begin until early May (Fig. 5). The almost sudden disappearance of the fish towards the middle of June and their reappearance in northern waters in late June and early July, would seem to indicate that the spawning season does not extend much beyond the middle of June, as also indicated by the rate of growth of the young.

- Number of spawnings per year, frequency

There is no indication that the bluefin spawns more than once a year. However, several authors (Sanzo 1910; Frade and Manaças 1933; Vilela 1960; Rivas 1954) state that the fish spawns fractionally.

Frade and Manaças (1933) found ova in various stages of development and suggested that spawning occurs in several batches with a maximum in mid-June.

Rivas (1954a) found the ovaries of all but one of 25 females examined in 1952 to be recently spent. The ovaries of the single fish were partly spent but still contained a number of eggs visible to the naked eye in the follicles and lumina.

- Induction of spawning, artificial fertilization

As to environmental factors affecting spawning of the European bluefin, Roule (1924) states that the breeding fish seek the warmer and most saline waters. The surface temperatures of the spawning grounds range from 19° to 21.6°C (average about 20°C) in the central Mediterranean (Roule 1924), and from 24.9° to 29.5°C, in the Straits of Florida, from Havana to Bimini (Rivas 1954a).

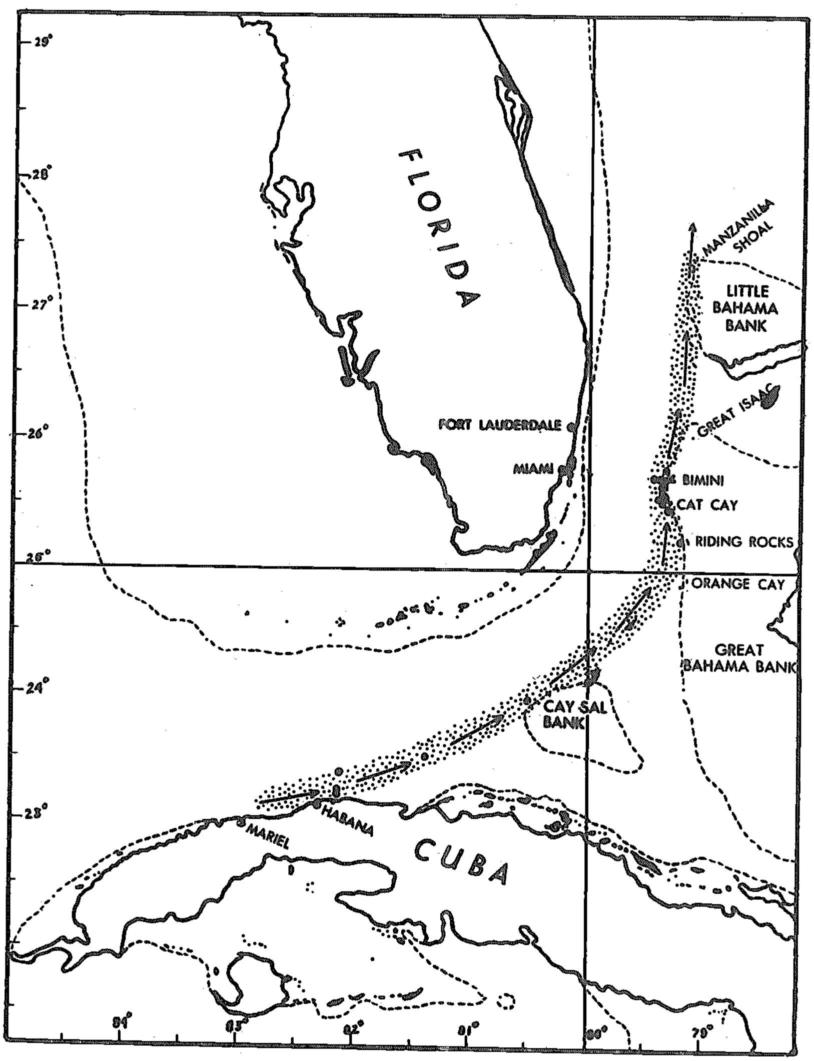


Fig. 5 Chart of the Straits of Florida (modified after U. S. Navy Hydrographic Office No. 1411) showing presumed migratory route (arrows) and spawning area (stippled) of western north Atlantic bluefin tuna (Thunnus thynnus). Black dots indicate egg and larval fish collecting stations. (Rivas 1954a).

Sella (1931) finds that the large bluefin of the Mediterranean reach spawning condition at a surface salinity of 37.2 to 37.8°/oo and at a surface temperature of 18° to 22°C. After spawning the fish lose their preference for this salinity range and are then found also in more saline water of 38°/oo. The smaller tuna are less sensitive to salinity and temperature and have been found to spawn in water having more than 38°/oo (38.2 - 38.5°/oo) and a relative high temperature of 23-25°C. The absolute temperature is not alone important but also the pattern of the temperature development. Spawning usually occurs at the time of the maximal increase in temperature.

3.1.7 Spawning grounds

Heldt (1932) presents evidence that spawning may take place either in shallow or deep water but close to the surface at depths of about 8-10 m.

Dieuzeide (1951) states that the occurrence of larvae demonstrates that spawning in the western parts of the Mediterranean takes place at 40-60 miles from the coast of Algeria. Sanzo (1910) collected eggs of the bluefin in Sicilian madragues (quoted by Ehrenbaum 1936), and Rivas (1954a) found them close to shore off Bimini.

Scaccini (1959) believes that the Mediterranean bluefin has different spawning grounds, one being located between Sardinia, Sicily and Tunisia, another being likely in the Ionic Sea.

Spawning grounds in the Straits of Messina have been detected by means of egg catches (Sanzo 1932).

Ferreira (1932) concluded that spawning of bluefin takes place in waters near the Azores.

In the western North Atlantic some spawning occurs in the Straits of Florida along the eastern edge of the Florida Current from Cuba to, and including, the western edge of the Bahama Banks during May and June (Rivas 1954b). Numerous large, adult, male and female individuals examined were all found to be in a ripe or recently spent condition. Plankton tows conducted in the area produced numerous eggs and larvae in various stages of development and juveniles were obtained from the stomach of predaceous fishes, especially dolphin (Coryphaena).

Active spawning also takes place during May in the area from Riding Rocks to Bimini along the western edge of the great Bahama Bank (Rivas 1954a).

3.1.8. Egg: structure, size, hatching type, parasites and predators

The ripe ovarian eggs of the Bahama bluefin are spherical, translucent, possess a very thin, smooth membrane and measure 0.7 to 1.1 mm in diameter with a mode of 0.9 mm (Rivas 1954a). The fertilized egg of the Mediterranean bluefin tuna is also spherical, smooth, and measures 1.0 to 1.12 mm in diameter, with a single, rather large oil globule of about 0.27 mm (Sanzo 1932). As the embryo develops, the oil globule appears surrounded by micromelanophores and keeps a position more or less equidistant from the head and tail of the embryo. In more advanced stages, from about 22 hours before hatching, the embryo is also covered with micromelanophores (Sanzo 1932).

The difference in size between the European and the western Atlantic bluefin eggs may be explained on the basis of the difference in water temperature at which the eggs are matured and spawned, the temperature being 6° to 8°C higher in the western Atlantic (Rivas 1954a).

3.2 Larval history

3.2.1 Account of embryonic and juvenile life (prelarva, larva, postlarva, juvenile)

The larva of Thunnus is characterized mainly by the preopercular spinescence, the dense, black pigmentation of the high, anterior dorsal fin and the number of vertebrae (39) (Rivas 1951). Although the larval stages of Thunnus can be distinguished from those of other genera of scombrids, the various species within the genus are very difficult to separate.

Sanzo (1932) found that the bluefin larva measures at the time of hatching between 2.84 and 3.04 mm, averaging 2.96 mm.

The freshly hatched larva has the following characteristics (Sanzo 1932): the head is still unseparated from the vitellin sack; eyes without pigment and mouth not yet opened. The vitellin sack is egg shaped and only little differentiated. The fins start to develop. The pigmentation consists of black and yellow elements. The yellow pigments immediately disappear if placed in formalin.

The larva differentiates quickly. After 12 hours the larva has reached a length of 3.56 mm. The yolk sac has shrunk, the head has separated from it and the eyes are considerably enlarged. A few hours later, in the second half of the first day of life, the larva has obtained a length of 3.80 mm. The mouth is opened and the intestinal tract is considerably enlarged. The eyes show first pigmentation. The anal opening has shifted to the front. The yellow and black pigmentation, deposited mainly along the disposition of the dorsal fin, has decreased. The number of segments remain unchanged at 39. Sanzo was not able to keep the larvae alive for more than six days after they had completely consumed their yolk sac.

Ehrenbaum (1924) provisionally identified 13 larvae, between 4.7 and 9.4 mm in length, to be T. thynnus. He gives the following description for the largest specimen (Fig. 6):

Larva of 9.4 mm: Vertebrae 18+21 = 39; short and thickset body; large head; strong dentition on jaws and praeoperculum; 1st dorsal fin early and strongly developed with dark pigment; anal fin at great distance from anus. The 1st dorsal fin is less high than in T. germo and does not reach to the front of the 2nd dorsal fin, if folded downward. Only 12 fin rays are recognizable, but the space between the 12th ray and the 1st ray of the second is large enough for the development of two more rays. In the 2nd dorsal and in the anal fin 12 + VIII rays can be counted, of which the last VIII are the forerunners of the finlets. Although the caudal fin of this larva was damaged, its hind edge was found to be indented. The ventral fins are rather large and reach the anus. Eighteen strong teeth could be counted on each of the jaws and three on each side of the palate. The narines are still confluent. Spines on preoperculum are strongly developed. The middle spine is the longest and reaches sack of viscera. On each side of this spine there is one middle long spine and next to these two in upper direction and two to three below, decreasing in length. Otocyst is covered by a threefold denticulated comb. The sack of viscera is short and thickset. The dorsal swim bladder is small. Viscera are richly pigmented. Also parts of the head rich on pigment which is lacking on hind parts of the body.

Dieuzeide (1951) found four larvae off the coast of Algeria in July 1950 which he considered in agreement with Ehrenbaum (1924) to be from T. thynnus (L.).

According to Padoa (1933), Sanzo (1910) has described a postlarval bluefin tuna of 34 mm which looked much like an adult fish. The dorsal fins were very high. The second dorsal fin had 14 fin rays, the pectoral fin 32, the ventral fin six rays and the caudal fin was found to be forked. Scales were found to be absent on the body, but were present in the orbital region.

Morović (1961) examined a large number of juvenile bluefin measuring between 63 and 96 cm caught in the Adriatic Sea that had predominantly eight dorsal finlets and either seven or eight anal finlets.

Dieuzéide and Roland (1955) described 31 juvenile bluefin tuna which were found on the Algerian coast and measured 172 to 500 mm. These fish had either eight or nine dorsal finlets and the majority had eight anal finlets.

The smaller finlet count obtained by Morović (1961) is probably related to the fact that the fish he examined were smaller. As was mentioned earlier (section 1.3.1), there is evidence that the number of finlets increases with length of fish.

- Feeding

Oren, Ben-Tuvia and Gottlieb (1959) investigated the food of 31 bluefin between 45 and 53 cm, i.e. in the first year of life, in the eastern Mediterranean and reported that: 30% of the food was decapods and Euphausiacea, 28% amphipods, 20% fish, 18% cephalopods, 2% stomatopods, 1% heteropods and 1% tunicates. The authors concluded that young T. thynnus,

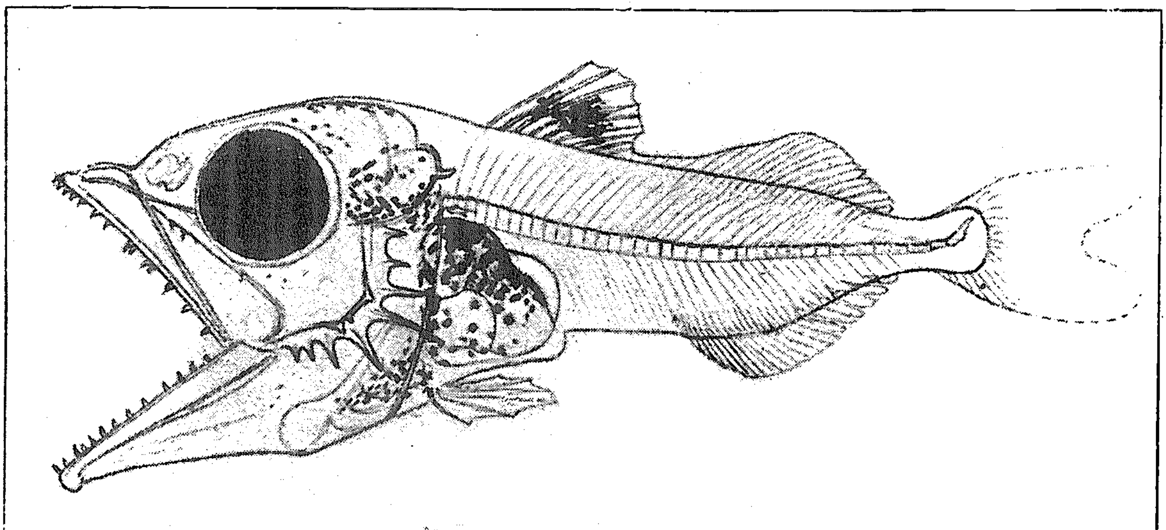


Fig. 6 Larva of Thunnus thynnus L. (?) Messina (St. 192) August 20, 1910. 9.4 mm in length (Ehrenbaum 1924).

Euthynnus alleteratus and Germo alalunga in the first year of life have similar feeding habits. The food fish of the young tuna were larvae and relatively young fish of clupeids, such as Sardina pilchardus and Engraulis encrasicholus.

- Periods of : development and survival

Ehrenbaum (1924) reports that Sanzó was able to observe the embryonal development of bluefin eggs. The larvae hatched at a length of 2.3 mm from eggs which were kept for two days. The distance from point of head to anus measured 1 mm.

- Parental care

No information is available, but the existence of any form of parental care is very unlikely.

- Parasites and predators

Parasitic infection of fry has not been reported. It is likely that restricted power of locomotion makes larval stages an easy prey for predators.

Rivas (1954c) found a juvenile tuna of 45 mm (fork length) in the stomach of a dolphin (Coryphyena hippurus) captured off the coast of Miami, Florida, in June 1953.

3.3 Adult history

3.3.1 Longevity

The age of the oldest fish found during age determination studies on bluefin tuna was estimated to be 14 years by Sella (1929) for the Mediterranean, by Mather III and Schuck (1960) for the western Atlantic, and by Tiews (1960a) for the North Sea; while Hamre (1958) found 13 years to be the oldest age for fish in samples of bluefin from the Norwegian coast. Frade (1950) determined that a 263 cm bluefin from the Atlantic was 16 years old (quoted by Frade and Vilela 1960).

It is likely that extremely large bluefin may reach a maximum age of 17 to 18 years. Age determinations on giant tuna are needed.

3.3.2 Hardiness

The bluefin exhibits during feeding periods a remarkable power of adapting to a great variety of hydrographical and biotic conditions. During the reproductive period, however, the fish develops a high degree of sensitivity towards his environment with respect to salinity and temperature.

It is said that the fish is extremely hardy and can withstand severe injuries. It has been observed that bluefin severely injured by means of boat hooks and with deep wounds on their back, continued to follow ships for hours. Sometimes great scars related to such injuries can be seen on tuna in the landings of German fishermen.

It also seems that the fish can go hungry for weeks, as indicated in the case of the tuna which were tagged on the American coast, crossed the Atlantic and were recaptured 112 days later in a very lean condition on the Norwegian coast.

There seems to be no preference for any specific food item which might tend to limit their distribution. On the contrary, almost all kinds of accessible food have been found in the bluefin's stomach.

3.3.3 Competitors

All species of fish utilizing the same food resources as the bluefin could be considered its competitors. However, this species experiences no serious competition for if one feeding resource should become exhausted, the bluefin can search for another food supply quicker than most of its competitors.

3.3.4 Predators

According to Frade and Vilela (1960) the bluefin has numerous predators, changing with the different stages of the tuna's development. The following toothed whales are predators of adult tuna: Orca gladiator, Phocaena communis and Globicephalus melas. The swordfish Xiphias gladius is also a predator. Orca gladiator (roaz de bandeira) is supposed to be the main predator of the bluefin on the Mediterranean coast of Spain (Priol 1944).

Fereirra (1932) found Phocaena communis and Globicephalus melas to be among the worst predators of the bluefin tuna in the waters around the Azores.

Sintesis and Bellón (1954) include also the sharks Carcharinus lamia and Carcharodon rondeleti in the list of predators, as well as Grampus griseus. According to this author, Globicephalus melas is especially predacious on tuna.

These predators injure or kill the tuna and also frighten them so that they may disappear for long periods from the fishing grounds. If the enemies of the tuna enter the madragues, it is necessary to get rid of them as soon as possible. They are caught by means of hooks which are baited with tuna meat, or they are harpooned.

The small tuna have numerous enemies, among which the adults of their own species or of other tuna species may be predominant.

3.3.5 Parasites and diseases

Table XI gives a list of parasites found in bluefin tuna. Ten of the 13 species of parasites listed were found by Tiews (1957a, 1960b) in North Sea tuna. According to Frade and Vilela (1960), Nunes-Ruivo has found five species of parasites in fish of the Portuguese coast, from which Pseudocycnus appendiculatus Heller is likely misidentified and identical with the newly described Pseudocycnus thynni Brandes, 1955.

Tiews (1957a) studied the abundance and the rate of infection of some of the gill parasites, hoping that by quantitative analysis of these parasites he might learn something of the relationship between the tuna stocks of different areas. However, in view of the great variations he found between the samples, the methodological difficulties in counting, and the obviously cosmopolitan character of the tuna parasites, he concluded that there was little chance to reach any conclusive answer by such a method.

According to unpublished observations of the author, Hexacotyle thynni may also damage the gills, but since the infestation of any one gill has not been found to be larger than 26 specimens no very serious damage can be anticipated.

Lüling (1953) observed that Ëlythrophora brachyptera caused considerable damage to the gill tissues of bluefin caught in the North Sea. He often found parasites crowded close together covering several cm^2 of the gills.

Dollfus (1955) observed the occurrence of Kudoa in the muscle of tuna caught on the Atlantic coast of Morocco. He believes that the Myxosporidae is likely identical with K. clupeidae which Balozet (1930) studied on Pomatomus (= Temnodon) of the coast of Morocco.

3.3.6 Greatest size

Crane (1936) reported that the largest tuna caught by harpoon in the Gulf of Portland weighed 1,600 lb (730 kg) according to newspaper accounts. In the catch statistics discussed by her the largest tuna weighed 976 lb (445 kg).

Sella (1932) stated that the Mediterranean tuna reaches 400 kg, the west Atlantic tuna 700kg.

The author found that the largest tuna caught by the German fishermen from 1951 to 1961, by hook and line in the North Sea was 280 cm (fork length) gutted weight was 416 kg.

According to tables given by Akyüz and Artüz (1957), the largest tuna landed in Istanbul measured 330 cm and the heaviest was 420 kg.

Meyer-Waarden (1959), who obtained the length composition of 2,148 tuna caught in a madrague of Larache (Morocco) in June 1956, found the largest tuna to be 320 cm in total length which corresponds to a fork length of about 3.0 m.

3.4 Nutrition and growth

3.4.1 Feeding (time, place, manner, season)

Rivas (1954b) observed that the reduction or cessation of feeding in the breeding individuals studied in the Bahamas (May-June), as indicated by the stomach contents, was confirmed by the lean condition of the body as compared with non-breeding, robust individuals examined later in the season (August-October) in northern waters, and known to be actively engaged in feeding.

According to Sara (1960), Roule (1924) sugges-

Table XI

List of parasites found in Thunnus thynnus L.[1/]

Name of parasites	Organs in which parasites were found
Copepoda parasitica:	
1. Elythrophora brachyptera Gerstaecker, 1853 (= Caligus alalonga Kroyer)	gill lamelli, pseudo branchial (I, II)
2. Pseudocycnus thynnus Brandes, 1955[2/]	between gill lamelli (I)
3. Cecrops latreillei Leach	gills (II)
4. Brachiella thynni Cuv.	fins (Nunes-Ruivo)(II); gills (Schäperclaus, 1954)
5. Caligus coryphaenae Steenstrup & Lütken	caudal fin (I)
6. Penella filosa (Linnaeus, 1758)	skin, near pectoral fin; muscle (I, II)
7. Penella orthagorisci (Wright, 1870)	skin, near pectoral fin (I)
Monogene trematodes:	
8. Hexacotyle thynni (Delaroche, 1811) v. Nordmann, 1840	gill lamelli of 1st gill arch (I)
9. Tristoma onchidiocotyle Setti, 1899	copulae, connecting gill arches of both body sides (I)
Digene trematodes:	
10. Didymocystis wedli Ariola, 1902	encysted in small capsules of each 2 individuals on gill lamelli (I)
11. Hirudinella clavata (Menzies, 1791)	intestines (I)
Nematodes:	
12. Contracaecum (Thynnascaris) legendrei (Dollfus, 1933)	intestines (I)
Myxosporidae	
13. Kudoa clupeidae (C. W. Hahn)	muscle (III)

1/ Sources: (I) Tiews (1957a, 1960b); (II) Nunes-Ruivo, as quoted by Frade and Vilela (1960); (III) Dollfus (1955).

2/ The record of P. appendicularis Heller (II) is likely identical with this species.

ted that full gonads may press on the digestive organs and disturb the normal digestion.

German fishermen using hook and line made the observation that tuna take the bait or fodder from early in the morning at sunrise to about 11 a.m.

Gregory (in Serventy 1941) reporting on the early summer occurrence of the Australian southern bluefin tuna in Albany harbor, stated that "it seems to be definitely established that the tuna never feed in the harbour; their stomachs are invariably empty".

3.4.2 Food (type, volume)

Bigelow and Welsh (1925) stated that the principal food of bluefin consists of menhaden, mackerel and herring, with occasional dogfish, squid and the smaller schooling fishes.

Crane (1936) found the following food in 34 stomachs of bluefin from the Gulf of Maine.

Five of the 34 stomachs were completely empty. Almost all of the food was in an advanced state of digestion.

The stomach contents of seven bluefin tuna taken near Bimini, Bahamas, in May 1956, consisted of 560 young-of-the-year procupine fish, 90 salps, the axial skeletons of 5 small, eel-like fish, 4 portunid crabs, the beak of 1 octopus, and a plant leaf. The gonads of all specimens of tuna appeared to be near spawning condition (Krummhölz 1959).

Morovic (1960) studied the stomach content of 1,343 small bluefin tuna caught on the Yugoslavian coast; 1,051 (78%) of the tuna had empty stomachs. The author attributed this high rate of empty stomachs to a rapid rate of digestion.

Akyüz and Artüz (1957) found that tuna feed on pelagic fish, such as bonito, mackerel and horse-mackerel during their stay in the Marmara Sea in winter months.

Thiel (1938) stated that the food of bluefin in the North Sea consisted of herring and other clupeid fish, mackerel, garfish (Belone belone) and occasionally of spiny dogfish (Squalus acanthias) and squid.

Postel (1955) believed that the occurrence of bluefins is closely related to the occurrence of

Food	No. of stomachs in which it occurred
Merluccius bilinearis (from 1 to 38 fish in a single stomach, each measuring from 8 to 13 in in length. In most of the tunas the food consisted entirely of this species)	26
Seaweed (in stomachs containing little other food; only one or two fronds were found in each stomach)	4
Squids (one or two in a stomach, alone or with shrimps)	3
Meganyctiphanes norvegica (numerous; all adults)	2
Clupeid, 215 mm	1
Clupeids, different from above; three, ca. 75 mm	1
Sebastes marinus; four, 53 to 117 mm	1
Tylosaurus marinus; one, 135 mm	1

small crustaceans, i. e. Meganyctiphanes norvegica, Euphausia kronii, Brachycelus crusculum, Euthemisto bispinosa etc. Sella, de Buen and Frade and Vilela (1960) have often found large quantities of crustaceans (decapods, isopods and schyzopods), as food of the bluefin. On the south coast of Iberia the swimming crab (Polybius henslowi) is abundantly found in the stomach of the bluefin. Other food items are heteropods, pyrosomes, salps and copepods.

3.4.3 Relative and absolute growth patterns and rates

Age determinations on bluefins have been conducted by various authors. Sella (1929), Hamre (1958), Vilela (1960), Rodriguez-Roda (1960), Mather III and Schuck (1960) used ring formations on vertebrae; Westman and Gilbert (1941), Westman and Neville (1942) and Mather III and Schuck (1960) used scales. A third method of estimating age and growth by following the seasonal progression of dominant size groups has been applied to the bluefin by Westman and Gilbert (1941), Westman and Neville (1942), Rivas (1954a), Tiews (1957a), Hamre (1958), Lühmann (1959), Mather III and Schuck (1960). Other authors, as Doumenge (1954), Doumenge and Lahaye (1958), determined the age composition of catches by means of length frequencies and growth curves given by other authors. Tiews (1960a) separated the different age groups of tuna in German North Sea tuna catches by means of the allometric growth of the eye-diameter.

Scales of tuna can be read for age only in fish of less then seven years. Scales of older fish are too thick and are unreadable, whereas vertebrae can be used for age determinations in fish of all year classes (Westman and Gilbert 1941).

The results of age determinations by various investigators as given in Fig. 7, show remarkable agreement. All authors later than Sella (1929) confirm generally his observation made on 1, 500 fish of the Italian coast. Figures given by Rodriguez-Roda (1960) show the greatest deviation.

Mather III and Schuck (1960) provide information on the actual growth of bluefin as derived from tagging experiments. One fish, tagged off Cape Cod, Mass., July 27 1954, was recaptured by French fishermen in the Bay of Biscay August 16 1959. When tagged, the fish measured 72.5 cm, and its weight when recaptured was reported as approximately 65-70 kg (143 - 154 lb equivalent to about 150 - 154 cm). These sizes are near the lower limits for ages two and seven, respectively. Another bluefin was tagged August 11 1957, off Chatham, Mass., and when tagged was estimated as 75 lb (about 114 cm), and it weighed 130 lb (about 150 cm) when recaptured. These lengths are in good agreement with those shown in Fig. 7 for ages four and six respectively.

Rodriguez-Roda (1960) derived the equation $L = 17.86 + 6.9862 \cdot R$ for the relationship between the fork length (L in cm) of tuna and the radius (R in mm) of the 4th or 5th precaudal vertebra. For the back calculation of length corresponding to each ring, he found $1 = 17.86 + \frac{v}{V}(L-17.86)$, wherein V is the radius of the whole vertebra, v the radius of each ring, L the fork length of the fish and 1 the fork length of the fish at the age which corresponds to the respective ring. A simpler expression for this would be $1 = 17.86 + 6.9862 \cdot v$, wherein 1 = fork length and v = radius of ring for which 1 shall be determined.

Tiews (1960a) devised a new method for separating year classes of large tuna by means of eye diameters, based on the assumption that the size of the eye diameter is related not only to the length of fish but also to its age.

Changes in body proportions during growth have been described by the following authors: Heldt (1927), Frade (1931), Aricò and Genovese (1953) and Genovese (1956), and can be summarized as follows :

1) Body depth decreases relatively with fork length. The decrease is linear to length. This is also true for the head length and the distance from tip of snout to the insertion point of the ventral fins.

2) Eye diameter decreases relatively with head length, but with increasing length at a decreasing rate.

3) Distance of eye from snout, measured along the body surface, increases relatively with head length, but with increasing length at a decreasing rate.

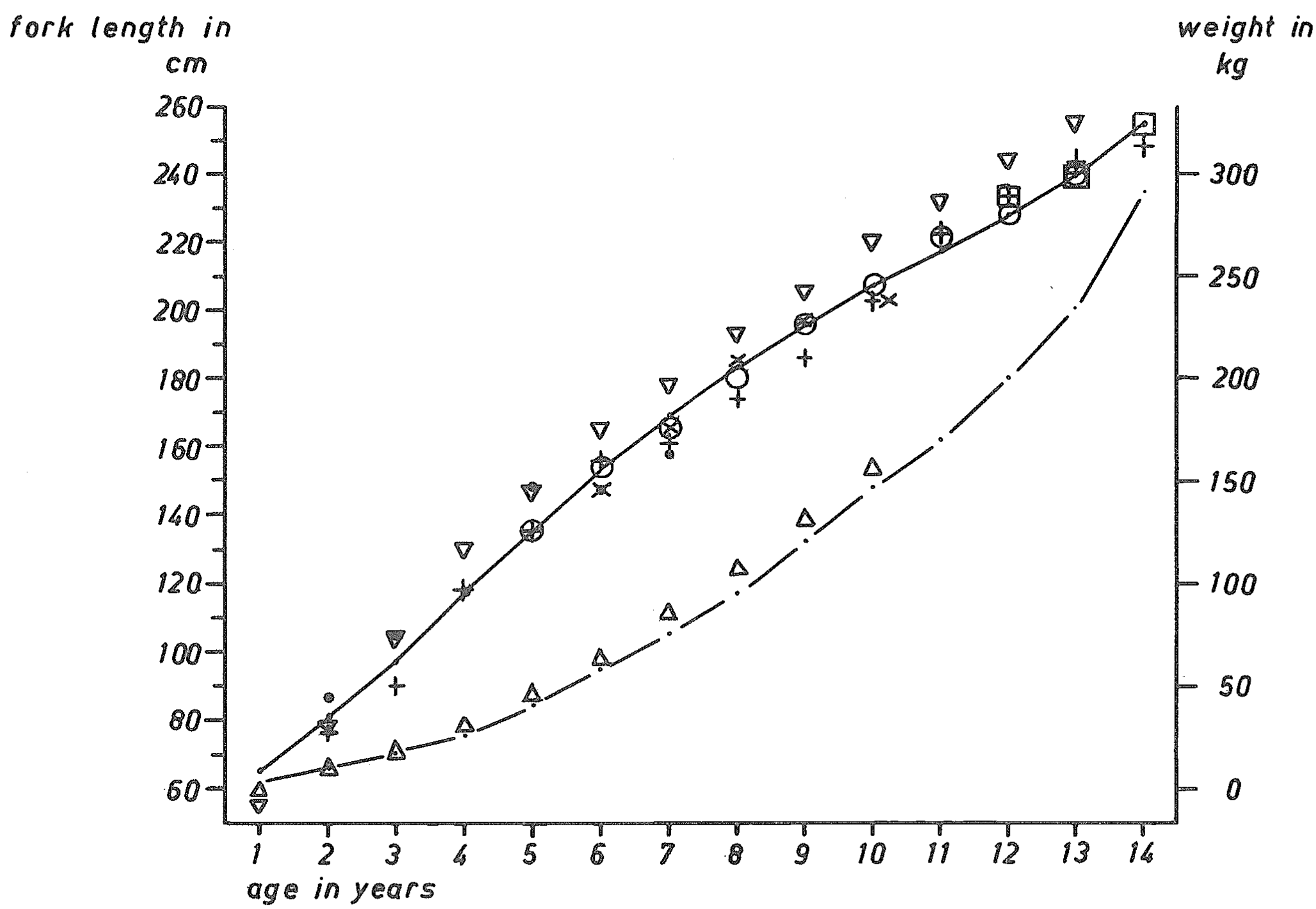
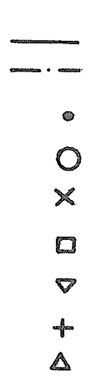


Fig. 7 Growth curve as given by various authors.



length given by Sella (1929)
weight given by Sella (1929)
length given by Westman and Gilbert (1941)
length given by Hamre (1960)
length given by Vilela and coll. (1960)
length given by Tiews (1960a)
length given by Rodriguez-Roda (1960)
length given by Mather III and Schuck (1960)
weight given by Mather III and Schuck (1960)

4) Length of pectoral fins decreases relatively with fork length, but with increasing length at a decreasing rate. This is also true for the distance from tip of snout to the insertion point of the anal fin.

5) Distance from tip of snout to the insertion points of the first and second dorsal fin decreases relatively with fork length, but in specimens above 200 cm at a lesser rate than in those between 100 and 200 cm.

Rivas (1955) reported that the western Atlantic bluefin increases in weight about 7.5 percent during its sojourn on feeding grounds off New England for a period of about a month while moving from the Cape Cod area to Wedgeport. A similar monthly increase has been observed while the tunas are feeding off Wedgeport during July and September.

Bahr (1952), investigating North Sea tuna stock, found an average increase of 70 kg in the weight of the giant tuna during their 2-1/2 month stay in the North Sea. Tiews (1957a) calculated that tuna of 215 to 240 cm fork length increased their weight during their 2-3 months' stay in the North Sea by 11.0 kg in 1954 and 17.4 kg in 1955, which is equivalent to about 34% and 54% respectively of their yearly increase of weight.

Lühmann (1959) estimated the total weight increase during the stay of tuna in the North Sea to be between 25 and 39 kg for age groups VIII to XIV.

3.4.4 Relation of growth to feeding, to other activities, and to environmental factors

Very little detailed information of this kind is available. In general, Mather III and Schuck (1960) describe the differences between summer and winter growth (see section 3.4.3). Various authors have found differences in the feeding habits of tuna or of feeding conditions during the course of the season or between seasons (Bahr 1952; Tiews 1957a, 1960a, 1961, 1962; Luhmann 1959) which may result, in one way or another, in growth differences. It may be also assumed that unfavorable environmental factors, especially water temperature, may prevent the tuna from reaching the rich northern feeding grounds and may thus lead to a decrease in their annual growth.

3.5 Behavior

3.5.1 Migration and local movements

Tuna are fishes of the open sea roaming far and wide in search of food. From the time of Aristotle the migrations of these fish have been a subject of interest and speculation. Modern methods of research have done much to describe the movements of the tuna but much still remains to be determined.

A general picture of the movements of these fish in the eastern Atlantic has been provided by Norman and Fraser (1948). In April, May and June the fishes congregate for spawning, such gatherings taking place in the area between Sicily, Sardinia and Tunis, in the Atlantic just outside the Straits of Gibraltar, and probably in other places where conditions are suitable for the development of the eggs. Spawning is at once followed by a feeding migration, the spent and hungry fishes, which have not taken food for some time, dispersing in all directions, intent upon nothing but obtaining nourishment. In European waters there is a definite northerly movement during the summer months, and tuna are only to be found in such places as the North Sea and the Norwegian coast from July to about October.

They appear at the mouth of the English Channel at the end of June, then move rapidly up the west coast of Ireland and around the north of Scotland, where they appear to split up into two main groups (Fig. 8), one of which makes for the coast of Norway and the other moves southwards into the North Sea, going to about the coast of Yorkshire. The approach of winter, with the consequent fall in the temperature of the sea, brings a reverse migration.

Most authors are in agreement that the bluefin tuna enters and leaves the North Sea from the north rather than through the English Channel, but definite proof is still lacking.

Hamre (1961) has studied in considerable detail the migrations of tuna on the Norwegian coast. On the basis of catch statistics and age

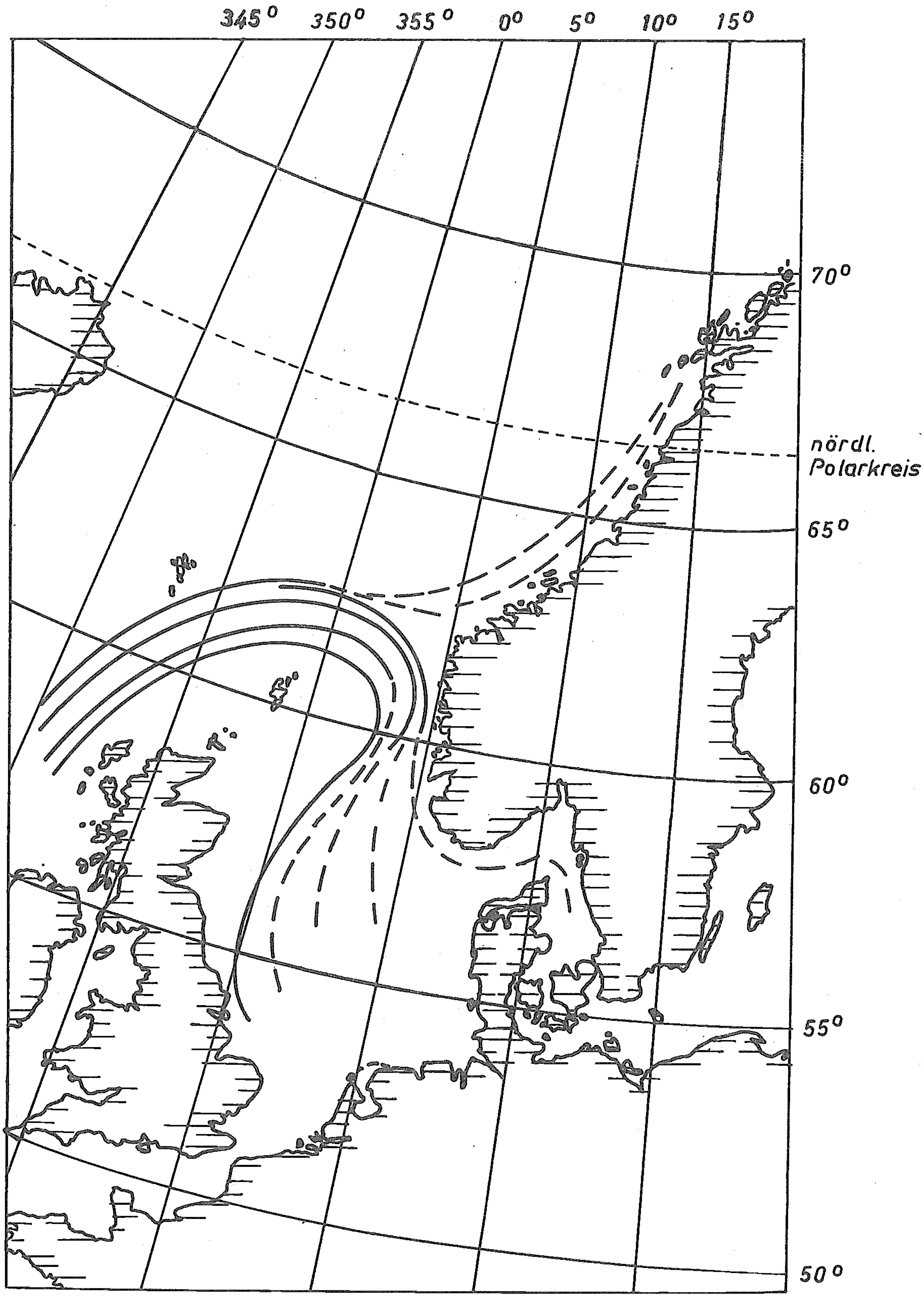


Fig. 8 Presumed migratory route of bluefin tuna in the North Sea and on the Norwegian coast according to various authors.

determinations the tuna stock can be separated into different contingents according to size and age of fish and time and place of occurrence. The tuna caught in the northern district of the coast are the oldest fish and arrive in July at the beginning of the season. The south district is visited by a middle age group that also arrive early and by small, young fish that arrive some weeks later. Assuming that these different groups belong to the same contingent, the tuna must change its migration pattern with increasing age.

Rivas (1953, 1955) described the presumed migratory route of the giant bluefin in the western North Atlantic (Fig. 9). The evidence indicates that the large fish occurring in the Straits of Florida in the late spring migrate to the north and constitute part of the population occurring off Cape Cod and Nova Scotia during the summer and early autumn. During their migration the fish are thought to be closely associated with the Gulf Stream and to travel at a rate of about 15 miles a day. No giant bluefin tuna have ever been captured or seen, however, between the Straits of Florida and northern waters, but this may be due to lack of exploration or they may be travelling very deep. Since the fish are absent from one place when present in the other, and since there are no morphological dissimilarities between fish from the two areas, it is assumed that there is just the one population - definite proof depends on tagging information.

The first scientist to study the possible interchange of tuna between the Mediterranean and the Atlantic and between the eastern and western Atlantic was Sella (1929). He also did the first tuna tagging and studied the origin of hooks that he found attached to tuna. Although his tagging was unsuccessful, from the distribution of hooks he assembled considerable information on the movements of the fish along the European coast.

The first successful tuna tagging was done by Westman and Neville (1942) on the American coast near Long Island. Of 23 fish tagged two were recovered after two months near the place of tagging. In the following years many types of tags were tried on various tuna species by American scientists.

The first successful tagging in Europe was performed from the Norwegian Institute of Marine Research. Since 1958, 202 tuna have been tagged, from which, according to Hamre (1961) 20 returns were reported prior to October 1961. Tag recoveries along the Norwegian coast have confirmed Hamre's theory that migration habits of the tuna change with age.

According to Vilela and Monteiro (1961) one tuna that was tagged near Cadiz, and recaught in the Gulf of Lyon, provides the first direct tagging result demonstrating an interchange between the tuna populations of the Atlantic and the Mediterranean.

Although it was anticipated by Sella (1931), the first transatlantic migration of tuna was demonstrated through the tagging program of the Woods Hole Oceanographic Institution, U.S.A. About 1,172 bluefin tuna have been marked since April 1954, 34 of them in the Bahamas area in 1961 (Mather III 1962b). Two small tuna, tagged on the coast of Martha's Vineyard, Mass., in July 1954, were recaught five years later in the Bay of Biscay by French fishermen.

Mather III (1962c) reported on two further transatlantic recaptures. Two tuna, tagged on the 1st and 10th of June 1961 near the Bahamas, were recaught on the 28th of September and 6th of October on the Norwegian coast northwest of Bergen. Both fish, within 118 days, had travelled more than 4,000 miles, corresponding to an average daily migration of about 34 miles or 63 km.

3.5.2 Schooling

Scaccini (1959) observed that juvenile tuna of 70-80 cm, weighing 10-12 kg, occurred in schools of ten to several hundred. This observation is contrary to that of Roule (1924) who reported that tuna are dispersed when juvenile and first join in schools after spawning.

In general, the very young fish search for warmer and less saline water than do larger juvenile fish. The author believes that density of the water, i.e. the combined factors of temperature and salinity, is responsible for the segregation of age groups of tuna. Their distribution is also determined, however, by the occurrence of their food.

Crane (1936) reported that bluefin of approxi-

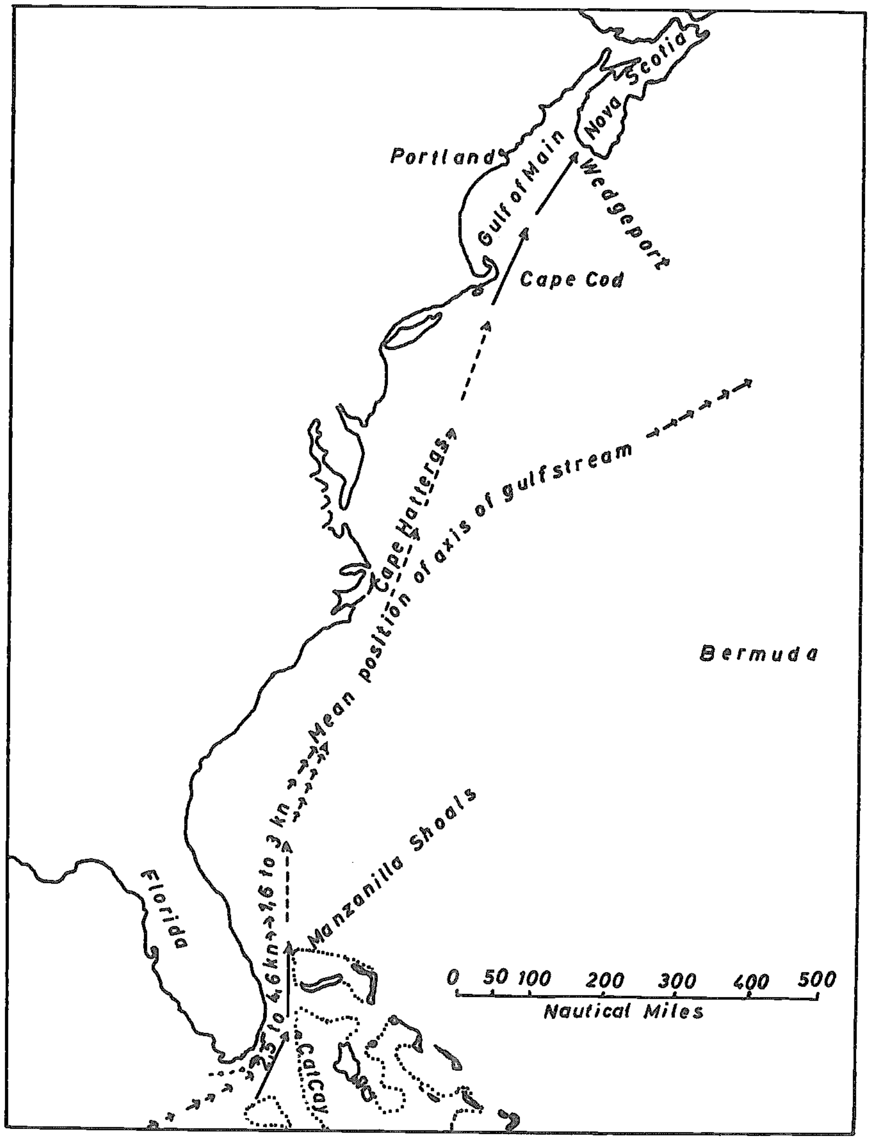


Fig. 9 East coast of North America from the Straits of Florida to Nova Scotia, showing the presumed migratory route (arrows) of giant tuna (Thunnus thynnus). Data on Gulf Stream from U.S. Navy Hydrographic chart No. 1411. (Rivas 1955).

mately the same size formed small schools of which up to 20 or more might be visible at the surface at once, leaping or swimming slowly along with the tips of their fins breaking water. Small and large fish were never seen in the same school. As a rule, the smaller the fish, the more individuals in the school, while the largest fish often seemed to be solitary.

Scaccini found tuna schooling according to size, but schools having fish of different size were living close together.

Arena (1959a) observed also in the madragues of Portugal that tuna of equal size school together and swim between 5 and 10 m in the so-called death chambers of the set net. Small tuna of only 60 kg swim deeper.

Mather III (1962b) also states that tunas tend to school according to size, but in schools of mixed sizes the larger fish are frequently below the smaller ones.

Tunas of different species but similar sizes may school together. Mather III (1962b) observes that in northern waters skipjack, Katsuwonus pelamis, are sometimes taken in the same schools as small bluefin, Thunnus thynnus, while in southern waters, they are often found schooling with T. atlanticus. Bullis and Mather (1956) report that longline catches indicate that T. obesus may school with T. albacares of the same size.

There is a tendency for the number of tuna in schools to vary inversely with the size of the individuals. The schools of large bluefin tuna observed off the Bahamas usually number from 6 to 20 fish each, although they sometimes include 50 to more than 100 (Mather III 1962b). The composition of schools of large T. thynnus off New England seems to be similar, according to Mather, except that smaller individuals may be mixed with the larger ones. Schools of medium-sized bluefin may number 1, 000 or more fish, while schools of smaller individuals may include several thousand. Schools of medium-sized and small bluefin often consist of many layers of fish and may extend over a much greater area than is indicated at the surface.

Rivas (1955) was able to observe schools of bluefin tuna over long periods of time in the Straits of Florida and calculated their speed of movement to range from three to five knots, with an average of 3. 5 knots.

Rivas (1954b) mentions that schools running close to shore in the Bahamas show erratic movements, whereas those running well offshore in deep water were much more regular in their movements. Underwater hydrophones lowered into the middle of bluefin schools revealed no evidence of sound production by these fish.

Murray (1955) reported some very interesting information on the size of the bluefin schools off the Massachusetts coast. Purse seine nets on two "small scattered schools" yielded 2 tons and 10 tons. A successful set on a "breezing" school yielded 20 tons. On one occasion an estimated 1, 000 tons of tuna were sighted in several closely associated schools. Attempts to divide the fish into smaller groups that could be handled in the purse seine, by steaming through the middle of the schools, were unsuccessful. Tuna close to shore were generally found in small schools, milling and moving erratically and presenting difficult targets for purse seining. Two sets in an inshore area yielded a total catch of 12. 5 tons, with an average fish weight of 25 lb.

3. 5. 3 Reproductive habits

(See sections 3. 1. 1, 3. 1. 3, 3. 1. 4, 3. 1. 6 and 3. 1. 7).

- Physiology

The tunnies, and perhaps a few of their relatives, are unique among fishes in possessing a body temperature which is three degrees or more above that of the surrounding water - that is to say, they are warm-blooded fishes. This peculiarity is perhaps associated with their tremendous muscular activity (Norman and Fraser 1948).

Sintesis and Bellón (1954) reported that the blood temperature could be even 5 - 8°C higher and Ehrenbaum (1936) even 10°C higher than the surrounding water temperature. Also these authors relate this phenomena to the great muscular power of the fish.

Tiews and Mines (unpublished data) have studied the change of temperature with time in the heart and liver after the death of giant bluefin tuna (219-266 cm), caught by hook and line in the North Sea. They found that the heart temperature at the time of death averaged 4.2°C (range 1.2° - 9.1°C) above the water temperature (16.2°C). After 45 min the heart temperature reached its maximum and had increased by an additional 2.4°C. The liver temperature was found to be higher than that of the heart. It averaged 12.6°C (range 10.9 - 13.7°C) above the water temperature at the time of death. After one hour a maximum temperature was reached and determined to have increased by another 2.1°C on the average.

Kühl (1958) studied the distribution of fat in North Sea tuna between 228 and 257 cm in length. He found that the fat content in the fish varied greatly in the various portions of the body and ranged between 3.5 and 47.0%. It was greatest in the connective tissues beneath the skin of the ventral portion of the tail and in the dorsal parts. The fat content was smallest in the muscle tissues. With increasing body weight the fat content gradually increases from the body surface towards the central part of the body.

Frade (1947) found that the liver has its maximum fat content at the peak of the gonad development. The liver weight may then amount to 6.6% of the head weight of the fish. At the end of spawning season, the fat content of the liver may equal only 3.7% of the head weight. It is likely that during spawning, when the fish is feeding little or not at all, it is utilizing fat stored in its liver.

4 POPULATION (STOCK)

4.1 Structure

4.1.1 Sex ratio

Vilela and Monteiro (1961) summarize their investigations on the sex ratio of bluefin tuna caught on the Portuguese coast as follows:

Years	Males N	Males %	Females N	Females %	Total N	Total %
1958	78	36.4	136	63.6	214	100.0
1959	116	37.1	197	62.9	313	100.0
1960	106	40.8	154	59.2	260	100.0
1961	110	34.0	214	66.0	324	100.0
Total	410	36.9	701	63.1	1,111	100.0

The females were more abundant than males in all four years.

As demonstrated by Vilela (1960), there is obviously no difference in sex ratio between fish going or coming from the spawning grounds: (See below).

These results are very similar to those of Frade (1950) who found in 1933 and 1934 that from a total of 8,988 tuna 5,125 (57.1 percent) were female (quoted by Frade and Vilela 1960).

Rodriguez-Roda (1960b) found that 64.5 percent of 607 tunas caught during the years 1956-1958 off the south Atlantic coast of Spain (Barbate) were females.

Also Rivas (1954a) investigating the sex ratio of tunas between 200 and 255 cm in waters off the Bahama Bank found females dominating:

Years	Total number examined	Number and percent Males	Females
1952	35	10(29%)	25(71%)
1953	31	8(26%)	23(74%)
1954	29	11(38%)	18(62%)
	95	29(31%)	66(69%)

Bullis and Mather III (1956), in examining 13 bluefin from the north Caribbean Sea, found that 10 were females and 3 were males. Crane (1936) states that the 30 tuna which she studied from Portland, Maine, were all males having empty gonads.

4.1.2 and 4.1.3 Age and size composition

Observations on the age and size composition of bluefin tuna populations are relatively few.

The German Institute for Coastal and Freshwater Fisheries has systematically studied the size composition of North Sea tuna since 1951. The results of these investigations were published by Bahr (1952), Tiews (1957a 1960a 1961), Lühmann (1959) and Meyer-Waarden (1958). The results showed that only old tuna of not less than about nine or ten years were caught during this period in the middle parts of the North Sea by German fishermen.

		1958 N	1958 %	1959 N	1959 %	1960 N	1960 %
Going to the spawning grounds May and June	Males	52	36.9	66	36.7	55	44.4
	Females	89	63.1	114	63.3	69	55.6
Coming from the spawning grounds July and August	Males	26	35.6	50	37.6	51	37.5
	Females	47	64.4	83	62.4	85	62.5

Tiews (1960a) gives the age composition of tuna caught by German fishermen in 1959 as follows :

Age groups	Year classes	Number	Percent	Average length cm
XII	1947	1, 110	29. 0	234. 830±0. 335
XIII	1946	2, 327	61. 0	240. 725±0. 240
XIV	1945	381	10. 0	247. 531±0. 635
Total	1945-1947	3, 818	100. 0	239. 930±0. 161

Since 1954, Hamre (1959 1960 etc.) has investigated the age-size composition of Norwegian tuna catches, which are made by purse seine, and has found that the age composition differs as to regions. The youngest tuna were 5 years old (see section 3. 5. 1); the numbers decreased rapidly at ages greater than 13 years.

Castagné, Fauvel and Le Gall (1949) gave the following length frequency distribution of 133 bluefin caught in June and July 1949 off the coast of St. Jean de Luz:

Total length in cm :	70	75	80	85	90	95
%	4. 5	14. 3	4. 5	3. 7	14. 4	18. 0

Total length in cm :	100	105	110	115	120	125
%	7. 5	4. 5	15. 1	9. 0	2. 3	2. 2

These tuna weighed between 4. 5 and 24 kg and were 2 - 4 years old.

Vilela et al (1960) gave the length distribution of tuna caught in the madragues of the south Portuguese coast to range between 110 and 250 cm, with modes at 150 and 170 cm.

Vilela and Monteiro (1961) report an essentially different size composition for catches made by hook and line in November 1960 off the coast of Sesimbra, Portugal. These fish ranged from 41. 5 to 86. 5 cm with a single mode at 68 cm. Rodriguez-Roda (1960b), investigating the size composition of bluefin tuna caught off the south Atlantic coast of Spain (Barbate) during the years 1956-1958, found a similar size composition as that reported by Vilela et al (1960) for Portuguese madrague catches. In a sample of 607 bluefin the size ranged from 110 to 259 cm, with a single mode at the 190-199 class interval.

Buser-Lahaye and Doumenge (1954) and Doumenge and Buser-Lahaye (1958) studied the age composition of tuna caught in the Bay of d'Aigues in 1953 and 1954. The catch was composed of year classes 1 - 4 with year class 3 as the most abundant one.

Meyer-Waarden (1959) studied the length composition of 2, 148 tuna caught in the madragues of Larache (Morocco) and found a range of 42. 5 to 322. 5 cm and a prominent mode at about 200 cm.

Akyüz and Artüz (1957) determined the size composition of Turkish tuna catch in 1955 and 1956 to range from 120 to 330 cm with the modes varying considerably with the year.

The age composition of tuna catch in Cape Cod Bay and off Nova Scotia for the years 1948 to 1951 is reported by Mather III and Schuck (1960) for an arbitrarily selected size range (70 to 270 lbs) to illustrate year class sizes.

4. 2 Size and density

Information on the size and density of the population is not yet available. Estimates of these parameters are extremely difficult to derive because of the migratory habit of the bluefin and the lack of any uniform fishing gear.

4. 3 Natality and recruitment

No information is available (see section 3. 1. 5).

4. 4 Mortality, morbidity

4. 4. 1 Rates of mortality

There is evidence from tagging that the fishing mortality of the eastern North Atlantic tuna stock is rather high. About 10% of the tagged Norwegian fish were recaught within one year, i. e. 20 fish from a total of 202 tagged fish (Hamre 1961) (see also section 3. 5. 1).

4. 4. 2 Factors or conditions affecting mortality

See sections 3. 3. 4, 3. 3. 5 and 5.

5 EXPLOITATION

5.1 Fishing equipment

5.1.1 Fishing gear

- Set nets or trap nets

The set net fishery of Europe has existed for many years. The net is known as the "madrague" or "thonnaire" in France, "tonnara" in Italy, "almadraba" in Spain, "armação" in Portugal and as "dalyan" in Turkey. It consists of a system of walls of netting, anchored to the bottom of the sea, sometimes miles in length, and so arranged as to intercept the migrating shoals of fish. It is divided into a number of compartments communicating with one another, into which the fish are guided. All of these lead into a final compartment, the "death chamber", the floor of which is formed of further netting. Here the fish are imprisoned until removed by the fishermen. (Fig. 10).

Iyigüngör (1957) gives the following measurements for a madrague near Salistra: 113 fathoms long, 33 fathoms broad, 9 fathoms deep; and for a madrague near Kartal: 112 fathoms long, 33 fathoms broad and 22 fathoms deep. Twenty to 25 men are needed to manage the gear. The season for madragues in Turkish waters is from April to the end of August, and the catch per madrague is only 100 to 150 fish.

The madragues are usually placed not deeper than 40 to 50 m. In some areas, as for example in Cadiz, the madragues can catch tunas from both directions going to and coming from the spawning grounds. A good madrague can catch up to 14,000 large tuna per season.

On the Yugoslavian and Greek coast a simple net wall is set in order to close small bays when tuna have entered. On the signal of a watchman the net is closed by pulling the open end ashore. The fish are finally caught by means of special beach seines.

- Hook and line

The catching of tuna by means of hooks baited with fish, maize or merely with a tuft of feathers is common in the Mediterranean.

In the Straits of Messina, in the day fishery, 3 to 4 cm hooks are used baited with dead or live fish. The fishing lines are cast from drifting boats to a depth of about 15 m in an area in which "camiu" or chumming has been practised (Genovese 1959b). The hooks used by the night fishery range from 5 to 9 cm in length. In this instance, the hooks are baited with dead fish and the fishing is done by surface trolling or from drifting boats with the hooks dropped down to 50 - 80 m. This fishery has not changed very much with the course of time.

Iyigüngör (1957) reports that tuna are caught by hook and line in Turkish waters from November to April. Bonito, mackerel and other fish are used as bait. The fishery is performed from small boats, 4 - 4.5 m in length, frequently powered with out-board motors. Two men constitute the crew. The best fishing is supposed to be between 9 and 10 a.m.

The Danish, German and Swedish fishermen fish for tuna exclusively with hook and line. Since 1960 most of the German fishermen use ordinary Japanese longline hooks. The Japanese hooks are reported to give more bites because they can be better hidden in the bait fish, and they become more deeply imbedded in the mouth of biting tuna so that fewer tuna are lost from the lines. The hook is placed at the desired depth, usually 20 - 25 m, by means of a small glass or rubber ball to which the respective length of line is fastened and which drifts free from the boat. Five to six hooks are usually fished by one boat. Fresh herring, mackerel or whiting are used as bait. Since 1961, chumming has become a common practice. The lines are set only after the tuna have been seen with echorecorders.

A few years ago German fishermen caught most of their tuna on the surface using bamboo poles. Since 1955, however, the fish have seldom occurred on the surface.

Electric tuna lines were developed by Kreutzer (1950 1951) in cooperation with the Institute for Coastal and Freshwater Fisheries. (Meyer-Waarden 1951). (Fig. 11).

Murray (1954) reports that fishermen on the west side of the Atlantic have used hand lines made of 48 lb halibut line or 3-strand manila,

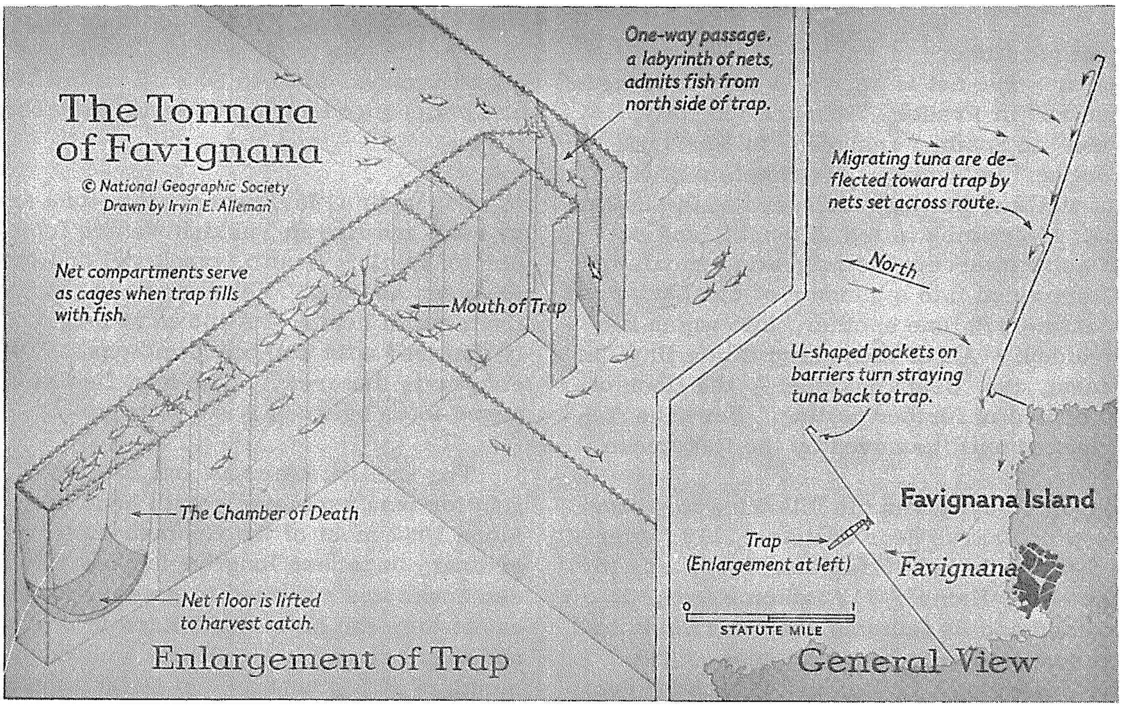


Fig. 10. Sicilian madrague

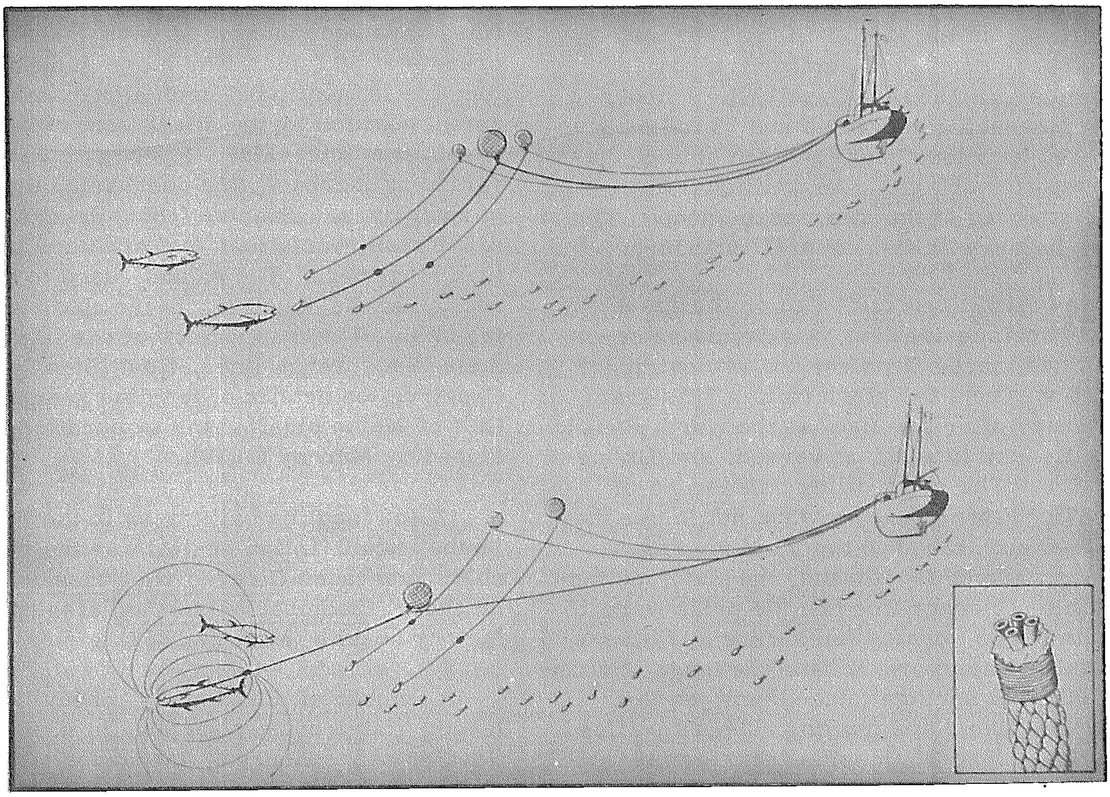


Fig. 11. Method of electrical hook and line fishing in the North Sea (Meyer-Waarden, 1959)

to catch tuna near the surface and at depths of several fathoms.

- Surface trolling

Since 1960, in the Bay of Biscay, French fishermen have conducted surface trolling for tuna (Pommereau 1955). Usually 5 - 6 hooks and lines measuring between 3 and 35 fathoms are attached on a long beam on each side of the boat, now power driven. An additional three lines are attached at the stern of the boat. The hooks are baited with fish or artificial lures.

Murray (1952) experimented on the American coast with surface-trolling gear involving seven trolling lines, three from each of two outrigger poles and one from the stern rail. This gear was patterned after that used in the North Pacific albacore fishery (Powell, Alverson, and Livingstone 1952). The two trolling poles were of Douglas fir, 35 ft in length; when not in use they were raised and lashed to the main rigging. Troll lines were of 261-thread, hardlaid, cotton-seine twine. Inboard lines on the poles were 15 fathoms in length, center lines were 20 fathoms, and the outer lines were 22 fathoms long. Paired galvanized steel springs (placed between the poles and the lines) and trolling rubbers (spliced into the lines about 10 fathoms from the poles) served as shock absorbers. Several types of trolling jigs were used throughout the season, including white, yellow, and red double-hook "bone" jigs, black wooden jigs, green and red plastic squids, and lead jigs with red and white feathers (Murray 1953).

- Live bait fishery

In 1947, the French fishermen copied the methods of the California live bait fishery and were quite successful. Sardines, caught by means of purse seines, are used as live bait.

This fishing method was developed because the tuna will pursue the live sardines, which try to flee into the shadow of the boat, and are then hooked when taking the bait. During the fishing, water is sprayed around the stern of the boat in order to further excite the tuna and prevent it from recognising the hook and leader. A crew of 10 to 19 men is usually needed for live bait fishing.

- Longline fishing

Longline fishing for bluefin has been successfully introduced on the west side of the Atlantic by the U.S.A. Modified Japanese tuna longlines have been used which are designed to operate at 50 fathoms or more in depth. The longline is suspended in an approximate horizontal position by the attachment of floats at one-basket intervals. Fishing depths may be varied by increasing or decreasing the length of float lines. Shapiro (1950) describes some of the many variations that are used in rigging tuna longlines. The basket, used to hold one section of the longline, is the customary fishing unit. The components of one basket include main line, branch lines, float lines, and float. Construction details of longline gear used in the Gulf of Maine bluefin tuna explorations is described by Murray (1953).

Of the longline baits tried in the Gulf of Maine, squid (Loligo pealei) was the most acceptable; menhaden (Brevoortia tyrannus) and mackerel (Scomber scombrus) also gave satisfactory results (Murray 1953).

A number of small boats, about 40 ft in length, fish longlines for bluefin in waters off Nova Scotia. Herring, menhaden, mackerel, whiting and butterfish are used as bait. Catch records for these small craft are not readily available but are estimated to exceed 30 tons per boat for the 3-month fishing season. In these waters shark damage is not a problem (Murray 1953, 1954). (Fig. 12).

Arena (1959b) tried Japanese longlining in the Tyrrhenian Sea but failed, most likely because of the high water transparency which necessitates the use of gear finer than the robust Japanese gear. His experiments with artificial lures, such as squids, and with illuminated lures had only modest results.

- Purse seines

Purse seines are used for catching bluefin on both sides of the Atlantic and also in the Mediterranean, and probably are the most efficient and productive gear currently employed for capturing large quantities of pelagic fishes. Murray (1952) has provided a description of the

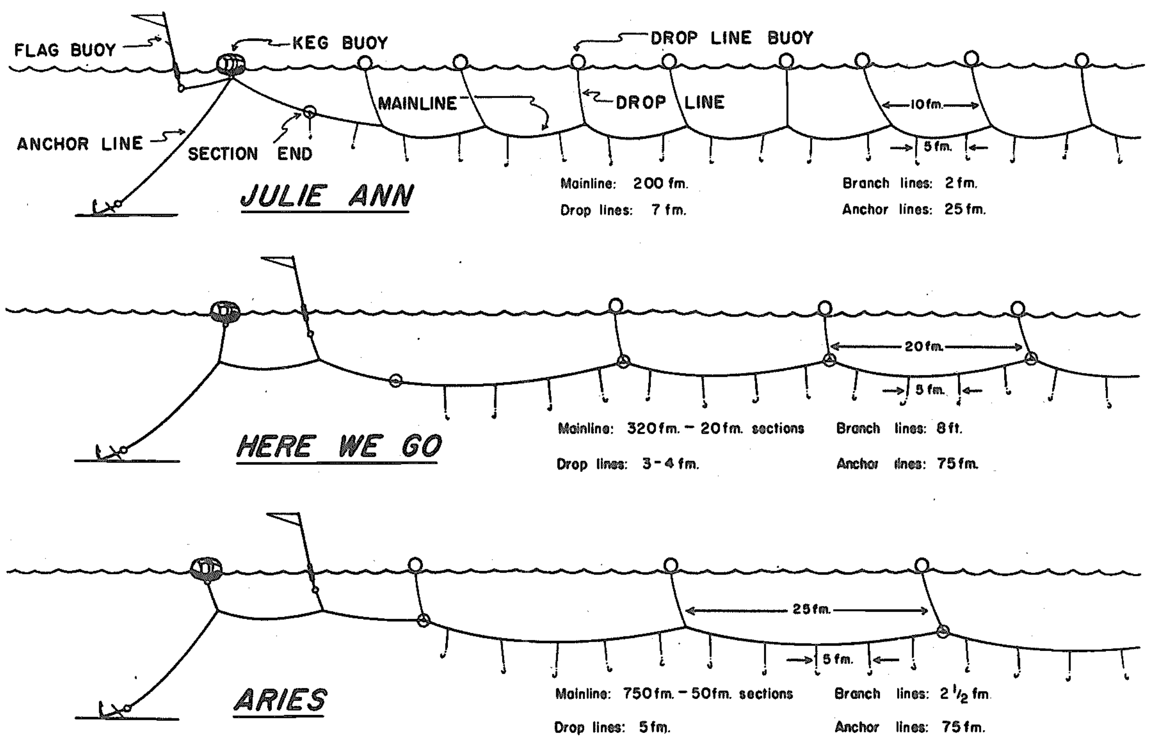


Fig. 12. Diagram of long-line gear used by three Gloucester boats fishing for bluefin tuna on Stellwagen Bank. (Not drawn to scale). (Wilson, 1960)

purse seines used in New England waters. The dimensions of the seines vary with the size of tuna to be captured and the size of the vessel employed.

In Norway the purse seine is the sole gear now being used for catching bluefin tuna. Hamre (1960) reported that the successful results obtained with the purse seine in the late 1940's caused a rapid expansion of the Norwegian tuna fishery. Thus in the years 1946-1950 the yearly mean catch of tuna in Norway was 1, 016 tons, whereas the yearly mean in 1951-1955 increased to 8, 908 tons. (Fig. 13).

Domančić (1954) described unsuccessful attempts to fish for bluefin with a purse seine on the coast of Tunisia. He recommends that the tuna be chummed from a by-boat during the encircling procedure, in order to keep the school of fish together.

Scaccini and Biancalana (1959) reported that bluefin tuna of 4 - 30 kg were caught from March to November 1950 in Italian waters by means of a purse seine being operated on an experimental basis. Because of the occurrence of large numbers of small tuna they recommend purse seine fishing in Italian waters. According to Iyigüngör (1957), Turkish fishermen have experimented with primitive purse seines, following the example of Italian and Yugoslavian fishermen.

- Gill nets

In Italy, according to Scaccini and Biancalana (1959), gill nets having mesh sizes of 14-16 cm (stretched mesh) are used for catching bluefin tuna. They are about 100 m long and are either used as set nets or as drift nets.

Murray (1953) tested the fishing possibilities of gill nets for bluefin tuna in the Gulf of Maine using linen and nylon drift gill nets of four mesh sizes. No tuna were captured.

- Trammel nets

Trammel nets were also tested by Murray (1953) but without success.

- Harpooning

Sund (1938) stated that in 1924 in Bergen, Krohnstad developed a hand harpoon rifle using a small 40 cm harpoon that was used by some fishermen with considerable success. German fishermen have used these harpoon rifles to catch bluefin tunas in the North Sea (Fick 1937). The end of the harpoon line was attached to a rubber ball which was released from the boat when the tuna was hit. The tuna soon tired and could be easily brought aboard. This fishery was not continued by German fishermen after the second World War.

As described by Crane (1936), harpooning was at one time a common fishing method for tuna in the western North Atlantic. The fishing launches, 20 to 35 ft in length, were each rigged with a platform or "pulpit" in the bow, and from here the harpooner made his strike.

5.1.2 Fishing boats

Various types of boats are used for tuna fishing most of which were not especially designed for this purpose. In the Norwegian tuna purse seine fishery normal herring purse seine boats are being used. Danish, German and Swedish fishermen use 20-24 m fishing cutters which were built for and are also being used for trawl fisheries. Special large wooden boats having no engines are used for the madrague fishery, forming part of the madrague and also housing the numerous crew members. In the Mediterranean, small fishing boats, some of which are not even motorized, are used for hook and line fishing.

The only fisheries for which special boats have been designed are the French live bait and trolling fisheries. According to Pommereau (1955) the average modern French tuna clipper measures 24-25 m, width 6.5 - 5.7, tonnage 150-180 BRT, speed 10.5 knots, main engine 350 hp. The live bait tank has a capacity of 30-40 tons of water; 10 - 15 tons of live sardines can be stored. Refrigeration units are aboard, also radiotelephony. A catch of 125-225 tons can be kept for two months. During the winter, these boats are used for stern trawling and have a radius of action of 6, 000 miles. (Fig. 14).

Murray (1955) gives the following measurements for the purse seine boat Western Pride which was a Pacific Coast seiner used for

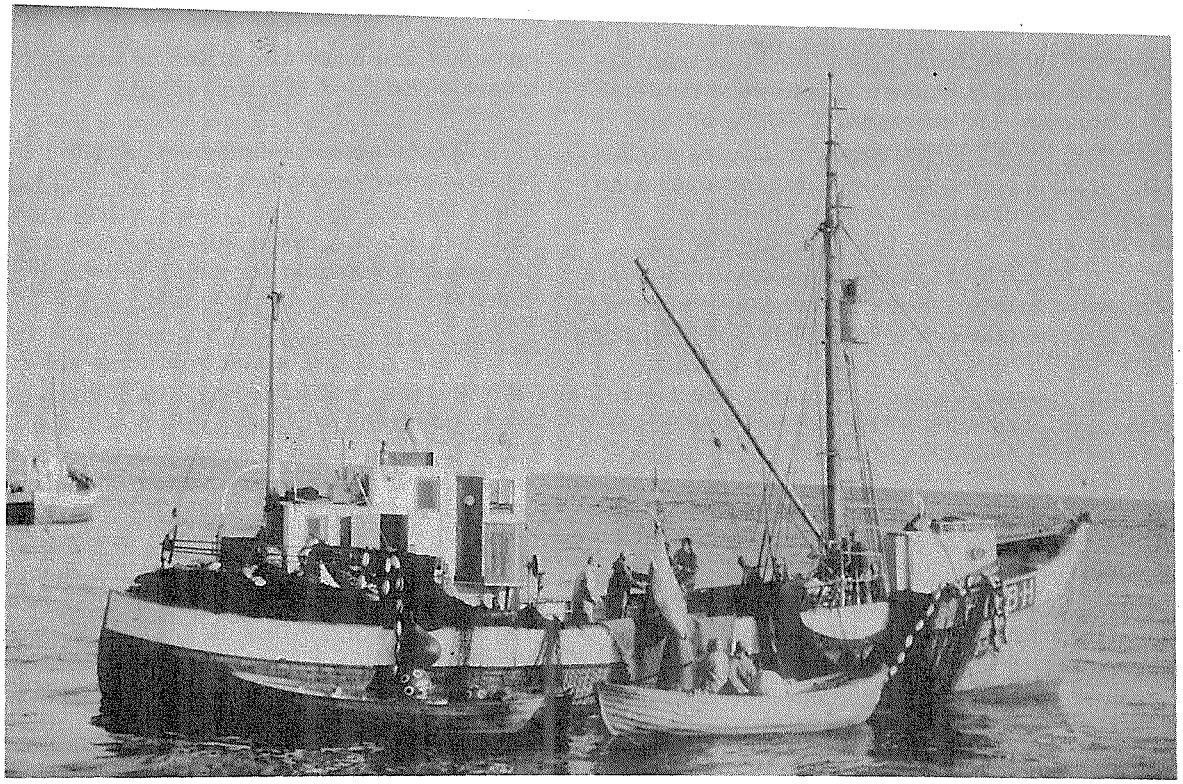


Fig. 13. Norwegian purse seine party (Foto: Tiews, 1960 c)

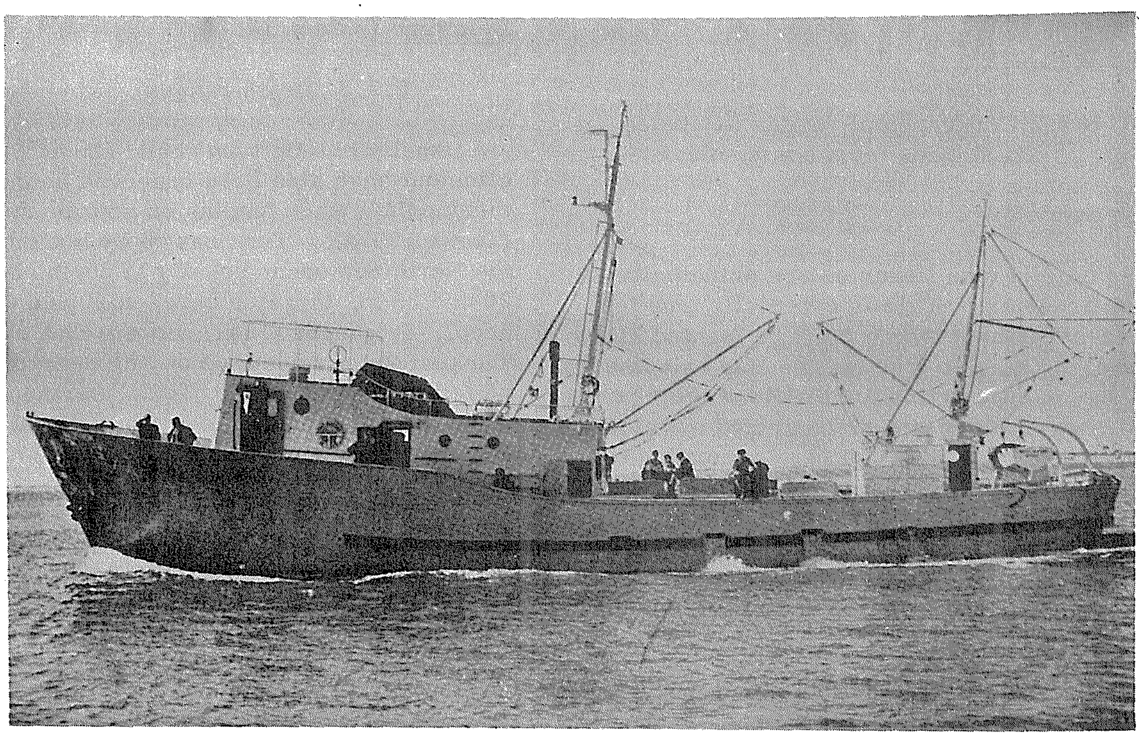


Fig. 14. Modern French tuna clipper as used for live bait fishing. (Pommereau, 1955)

exploratory fishing surveys on the American Atlantic coast: length 71.8 ft; beam 20.4 ft; depth 10.6 ft; tonnage 118 gross tons. The vessel was powered by a 200-horsepower Diesel engine equipped with a power take-off unit for operation of the purse-seine winch located on deck aft of the deckhouse. Natural ice was carried for preserving the fish catch, with an auxiliary refrigeration unit to maintain fish-hold temperatures at approximately 25°F. Fish-hold capacity was rated at 95 tons. A heavy, flat-bottom seine skiff, measuring 26 ft in length and 15 ft in width, equipped with a 100-horsepower gasoline engine was used to assist in fishing operations.

The introduction in recent years of light nylon nets and the power block has revolutionized the American west coast tuna industry. The majority of the former live-bait vessels have now converted to the purse seine method of fishing. Since they obtain larger catches with shorter runs from port, their efficiency has been greatly improved.

5.2 Fishing areas

5.2.1 General geographic distribution

See section 2.2

5.2.2 Geographical ranges (latitudes, distances from coast, etc.)

See section 2.2

The bluefin tuna fisheries are principally coastal fisheries. This is especially true for the trap-net fishery which must be located close to shore. It is also true for the live bait fishery in the Bay of Biscay and for the Norwegian purse seine fishery, which are also carried out closely adjoining the coast. In Norway, according to verbal information obtained by Hamre, the best fishing zone for tuna is about four to eight miles off the coast, although the total fishing area extends up to 50 nautical miles off-shore. The Mediterranean hook and line fishery also takes place near the coast.

German fishermen, using hook and line, fish in the middle parts of the North Sea exceptionally far from the coast. Their favorite fishing grounds are 50 to 100 miles or more off the coast of England (Tiews 1957a).

The American small-boat longline fishery which has developed recently on Stellwagen Bank (Mass.Bay) is an inshore fishery being carried out only about 20 miles off-shore. Also purse-seine fishing for tunas in this area is done rather close to the coast.

Murray (1952) stated that huge schools of bluefin tuna, estimated at 2 to 200 tons each, were observed within 60 miles of Cape Cod. This is well within the operational range of small local fishing craft which are easily adaptable to longlining.

Crane (1936) observed that the tuna usually remain outside of Casco Bay in an area extending 12 and more miles off the shore at water depths of at least 40-45 fathoms. However, they also occasionally occur in shallower water.

Favorable possibilities for the development of an off-shore tuna longline fishery in oceanic regions off New England at certain seasons were recently found by the U.S. Bureau of Commercial Fisheries Exploratory fishing vessel Delaware (Wilson 1960).

5.2.3 Depth ranges

Usually bluefin tuna occur above the thermocline but have also been observed below the thermocline when feeding on bottom living fish (Tiews 1957a). Tuna caught by hook and line in the North Sea occur usually at depths between 20 and 35 m, in water between 50 and 200 m deep. Iyigüngör (1957) reports that tuna in Turkish waters occur at depths between 14 and 25 fathoms (25-45 m). The fishermen ordinarily place their hooks at a depth of 18 fathoms (32 m).

Murray (1953) found that the relatively shallow layer of warm water (17-30 m) prevailing in the Gulf of Maine presumably keeps the tuna fairly close to the surface. This is in agreement to the findings made on the Norwegian coast (Hamre 1961). The purse seining only takes place after tuna have been observed at the surface.

Arena (1959a) states that the bluefin occurs at depths of 10-15 m in the madragues.

According to Crane (1936) the tuna stays usually at a depth of 40-45 fathoms off the Maine coast and is found only occasionally in shallower water.

In the clear waters of the Gulf Stream off Havana, Cuba, large individuals of bluefin tuna are captured by longline at depths between 100 and 200 m (Rivas 1953).

In the western North Atlantic T. thynnus, except for very small individuals, appears to live at depths of from 15 to 100 fathoms in the winter. In the spring large individuals appear in schools travelling near the surface off the northwestern Bahamas, and many schools may be found feeding or travelling on the surface in the area from Cape Hatteras to Newfoundland in the summer, but there is evidence that they also feed on the bottom in the latter period (Mather III 1962b).

According to data on illumination obtained from Sverdrup, Johnson and Fleming (1946), the range of light intensity (70 to 450 foot-candles) to which tunas seem to react corresponds at noon, in the summer, to depths of about 90 to 140 m in clearest ocean water, and 45 to 75 m in average ocean water. It is interesting to note that according to Kishinouye (1923), the Pacific species of Thunnus are mostly found in depths between 20 and 100 m and seldom or never in depths of more than 130 m. In the clear waters of the Gulf Stream off Havana, Cuba, large individuals of bluefin tuna are captured by the longline, swordfish and marlin fishermen, nearly always in depths between 100 and 200 m (Rivas 1953). The approximate coincidence of these figures suggests an interesting line for future studies.

5.3 Fishing seasons

5.3.1 General pattern of fishing season

The tuna going to and coming from their spawning grounds are caught by means of madragues during the period from the end of April to about August. In certain localities the madrague fishing season is shorter starting in May and terminating in July. From late September to March an autumn-winter fishery with hook and line on various sizes of tuna takes place in most parts of the Mediterranean and adjacent waters.

The older tuna, spawning prior to the younger fish, occur on their northern feeding grounds as early as July or even at the end of June. This is true for both sides of the Atlantic. They usually disappear from these grounds early in October.

5.3.2 Duration of fishing season

While in some parts of the Mediterranean the bluefin tuna can be caught throughout the year, the fishing season in northern waters is limited to rather short periods seldom extending over more than three months. The season for single age groups is even still shorter, lasting often only two to three weeks on the Norwegian coast according to Hamre (1960). Since the fish migrate so rapidly and the fishermen cannot follow the fish, the fishery is confined to limited areas and times.

The longest fishing seasons, practically extending over the whole year, occur in Sicilian and Turkish waters (Arena 1959a; Iyigüngör 1957).

5.3.3 Dates of beginning, peak and end of season

Iyigüngör (1957) states that three seasons can be distinguished in the Bosporus and Marmara Sea tuna fishery:

1) November to the end of January,

2) March to April for hook and line fishery,

3) April to August for madrague fishing.

According to Akyüz and Artüz (1957) the Turkish bluefin tuna fishing season has two peaks, one in March and one in July-August.

Vilela (1960) has observed that the tuna begin to appear in Algarve (south coast of Portugal) in the first days of May or even at the end of April, and disappear at the end of August. During the fishing season there are two maxima in the catches separated by an interval of about seven weeks. The first maximum is the period in which the tuna comes for spawning, from 27/28 May to 23/24 June, the second in the returning period, 8/9 July to 4/5 August.

On the Portuguese west coast the catch of small tuna usually starts in September-October (Vilela and Monteiro 1961). In some years the fishing season is limited to one month only, as in 1960, when the catch started and was terminated in November; 82% of the total catch obtained (5, 500 tuna, each averaging 6. 3 kg) was taken from 28 to 30 November.

According to figures published by Hamre (1960,1961) the catch season on the Norwegian coast starts during 28-30 July and terminates 10-14 weeks later. The peak of the season varies from year to year depending chiefly on the strength of runs of tuna of the various age groups.

In the northern districts of Norway the peak of the season is not later than August, while the main catch in the southern districts has been obtained in some years during September, in others also in August.

The German fishing season usually starts at the beginning or middle of August, and terminates at the beginning or middle of October. The peak of the season is usually in September but in some years occurs in August (Tiews 1957b).

In Portland, Maine, the fishing season starts at the end of June, having its peak in July to August and the tuna disappear altogether in October. The season corresponds to the herring and mackerel fishing season (Crane 1936).

5. 3. 4 Variations in time or duration of fishing season

Information concerning the variation in time or duration of the fishing season is presently known only from the Norwegian and German tuna fisheries. It is the aim of the Scombriform Fish Committee of the International Council for Exploration of the Sea to uniformly organize the collection of data in this respect. In 1961, J. Hamre and the author were appointed by the Committee as members of a working group to promote this program.

Meyer-Waarden and Tiews (1959) found a relationship between the Norwegian and German catches of tuna of corresponding age groups. In years with early immigration of large tunas to Norwegian waters in July and early emigration during the end of July or the beginning of August, the arrival of tunas in the North Sea can be expected to be also early during the beginning of August. Since the season in the North Sea is restricted to the period from August to October, a one month delay in the appearance of tuna means a considerable loss of catch, influencing the success of the whole season.

A favorable catch on the German fishing grounds does not necessarily correspond with a favorable catch in Norwegian waters.

There is a fair chance, however, to predict the probable success of the German North Sea tuna season by the end of July or beginning of August depending on the catch of the Norwegian fishery in July (Meyer-Waarden and Tiews 1959).

5. 3. 5 Factors affecting fishing season

- Hydrographic and climatological factors

Hamre (1961) described how, in 1959, a sudden change of hydrographic conditions on the Norwegian coast influenced the tuna fishing. The fish arrived in a period in which hydrographic conditions were unusually good for the purse-seine tuna fishery, the yield being relatively high in relation to the abundance of fish. A light wind from the south and high air temperature had established a thin layer of warm water from the surface to about 15 m depth on the fishing grounds. Great quantities of food organisms were present on which the tuna were feeding. Two weeks later the wind changed to the north. The surface water was transported from the coast, probably together with the food organisms upon which the tuna were feeding. Observations of tuna up to 50 nautical miles offshore were reported by passing vessels. The purse-seiners, however, do not operate so far from the coast, and consequently the yield of the fishery in the area concerned became extremely low during the period when the best fishery was expected.

Rodewald (1960) found that the German catches of giant tuna in the North Sea seem to depend on the anomalies of the atmospheric circulation which exist along the migration route of the tuna from June to August or September. In the years with good catches, the June distribution of pressure resulted in southerly winds which may have positively influenced the migrations of tuna to the North Sea. Associated with the favorable wind were higher surface temperatures along the migration route. Lühmann (1959) is of the opinion that surface temperatures along the migration route of the tuna may greatly influence the time of their arrival in the North Sea.

Arena (1959a) when investigating the influence of different factors on the catch of a tuna trap near Trapani on the west coast of Sicily, found that southwest currents of 0.49 m/sec. corresponded with bad catches, while northeast currents of 0.73 m/sec. were associated with good catches. Best catches were made at surface temperatures of 20°C, at an air pressure of 750 mm and with southeast winds. This is in agreement with the observations of Lozano Cabo (1957,1958). He found that the best tuna catches of the madragues of Morocco and Spain were obtained at surface temperatures between 19.25 and 20.5°C, while below 18°C no catch was made. Catches also declined at surface temperatures above 20.5°C.

In general, for madrague tuna fishing to be successful on the south Atlantic coast of Spain and on the Atlantic coast of Morocco, surface temperatures between 18 and 21.5°C are necessary. If the temperature is higher, the tuna go in search of cooler temperatures in the deeper waters and disappear from the area in which the madragues are erected.

There is a rather close relationship between the temperature of the water layer at 25 and 30 m depth and the occurrence and catch of tuna at the Castellamare del Golfe (Sara 1960). A temperature around 17°C, at a depth of 25 m is the most favorable for the occurrence of tuna in the madrague.

Arena (1959a) and Lozano Cabo (1957,1958) found no correlation between the tides and catches. Water transparency, however, was correlated with the size of catch in the madragues. Best catches were made at a visibility depth of 15-16 m. Catches were poorer at a visibility above or below this depth.

On the contrary, Sara (1960) found no relation between the occurrence of tunas and the transparency of the water determined by a Secchi disc. He also found no relation between tuna occurrence and salinity, phosphate, nitrate, pH and oxygen values.

- Other factors

The success of a fishing season depends furthermore on recruitment, which may fluctuate greatly according to Hamre (1960,1961), Tiews (1957a) and Meyer-Waarden and Tiews (1959). The German fishery, depending on a few age groups and a dominant year class, is especially affected by these fluctuations.

It seems apparent that the recruit year classes occur at different ages in the North Sea. While the dominant age group of the 1952 recruits was about 9 years old, that in 1957-1958 was about 12 years old. This indicates that the different year classes do not follow the same migration routes.

5.4 Fishing operations and results

5.4.1 Effort and intensity

According to Scaccini and Biancalana (1959), during the periods 1900 to 1907 and from 1950 to 1957, approximately 48 madragues and 45 small madragúes were operated in Italian waters. According to Lozano Cabo (1958), six madragues were recently operated on the Atlantic coast of Spanish Morocco.

Pommereau (1955) states there are about 50 modern tuna clippers engaged in bait fishing in France.

The number of Norwegian tuna purse seiners has decreased in number in recent years. The fleet is estimated to comprise about 50-60 boats at present.

Tiews (1957b) and Lühmann (1959) report that 40-60 high sea cutters from Germany participate in tuna hooking in the North Sea, having carried out a total of 67 - 173 fishing trips per season during the years from 1954-1958. However, only 10 to 20 of these fishermen do intensive tuna fishing, making 4-6 fishing trips per season. The others are occasionally employed and make only 1-2 trips.

5.4.2 Selectivity

Doumenge (1954) and Doumenge and Lahaye (1958) compared the tuna catches made by purse seines, drift nets and hook and line in the Bay of d'Aigues (French coast of the Mediterranean) and found no particular selectivity by the different kinds of gear.

Although the size of hooks used by German fishermen has been continuously decreased, no change in catch has been revealed related to this factor. Small Japanese hooks are more effective than the larger Norwegian Mustad hooks, both catching fish of the same size composition. These results apply to giant tuna only, however, it is likely that tuna under a certain size cannot be caught with hooks as large as those being used by the German fishermen.

There is a biological selectivity in the gear since tuna in spawning condition have ceased feeding and cannot be caught by hook and line. Tuna in this condition are caught, however, by madragues. Feeding tuna are successfully caught by the various hooking methods and by purse seining, as well as madragues.

5.4.3 Catches

The compilation of bluefin tuna catches, as given in Table XII, is based on the FAO Yearbook of Fishery Statistics. However, in the case of Portugal, the figures given by Vilela and Cadima (1961) and Vilela and Monteiro (1961) have been used since the FAO data include also the catch of bonito.

In the years 1954 to 1959, the total catch of Atlantic bluefin tuna ranged from 27,000 tons (1959) to 45,000 tons (1955).

Very few catch-per-unit-of-effort data are available. Tiews (1957b) and Lühmann (1959) found the following fluctuations in the catch per unit effort of the German tuna fishery, expressed in catch per 12-14 days' tuna trip:

1952	1953	1954	1955	1956	1957	1958	
2.6	5.4	6.1	6.9	5.2	7.3	4.9	tons[1/] per trip
298	307	648	1,068	555	1,286	380	tons[1/] of total landings.

5.4.4 Past and present factors affecting operations and results

If the occurrence of tuna in the North Sea is under a certain density, German fishermen shift from tuna fishing to herring fishing. The size of the catch influences the price and the price affects the quantities landed. In recent years a considerable part of the German and Norwegian tuna catches have been exported because of local market conditions.

Lozano Cabo (1958) was of the opinion that prior to 1955 too many madragues were employed on the Atlantic coast of Morocco so that fishing operations were unprofitable. A reduction from 6 to 3 madragues since 1955 has greatly improved the economy of the operation.

A considerable decline in the Italian catch per unit effort has been observed by Scaccini and Biancalana (1959). Approximately 48 madragues caught an average of 5,613 tons of tuna per season during the period 1900 to 1907. From 1950 to 1957, only 1,832 tons per year were caught by 45 madragues.

Unfavorable weather affects purse-seine operations but has little or no effect on the German method of hook and line fishing from large cutters.

1/ Gutted tuna, with head and gills left intact.

Table XII
Catch of Atlantic bluefin tuna
by country, in 1, 000 metric tons (FAO 1959)

	1954	1955	1956	1957	1958	1959
Africa						
Angola (bluefin and albacore)	3.4	4.2	4.0	3.6	3.5	1.5
Morocco	2.3	4.8	3.6	4.5	10.5	5.0
Tunisia	1.7	2.2	1.5	1.7	1.3	...
America, North						
Canada (Atlantic)	0.1	0.1	0.2	0.1	0.1	0.1
U.S.A. (Atlantic)	0.7	0.4	0.2	0.5	1.1	1.2
Asia						
Turkey	...	...	...	0.8	0.4	0.5
Europe						
Denmark	0.9	1.1	0.5	0.6	0.2	0.8
France (incl. Algeria)	4.2	3.9	2.2	6.1	2.0	6.5
Germany, Fed. Rep. of	0.6	1.0	0.6	1.3	0.4	1.0
Greece (bluefin tuna and frigate mackerel	0.6	1.2	0.9	0.5	0.7	0.7
Italy	...	...	...	...	3.0	2.1
Malta and Gozo (bluefin tuna and albac.)	0.1	0.1	0.1	0.1	0.1	0.1
Norway	9.5	10.4	4.1	5.0	3.0	2.5
Portugal 1/	1.2	1.2	2.3	0.8	0.7	0.9
Spain	11.3	14.1	12.5	14.8	13.8	4.2
Sweden	0.1	0.1	∅	0.1	∅	...
Yugoslavia	0.7	0.4	0.3	0.4	0.4	0.2
	37.4	45.2	33.0	40.9	41.2	27.3

1/ Catches made by madragues (Vilela and Cadima 1961). Apart from these there are catches made by live-bait fishing on the west coast off Sesimbra which amounted in 1960 to 32.4 tons.

Table XIII
Comparison of catches made in madragues of Morocco, the South Atlantic coast of Spain (Lozano Cabo 1958) and of Portugal (Vilela and Cadima 1961) in number of bluefin tuna caught

Year	Morocco	South Atlantic coast of Spain	Portugal
1927	7,297	-	-
1928	7,218	-	-
1929	8,959	73,137	-
1930	9,539	106,002	-
1931	6,368	88,126	15,973
1932	4,755	54,459	15,671
1933	12,236	50,985	16,274
1934	6,287	37,117	8,815
1935	12,769	25,723	9,026
1936	3,214	47,198	22,667
1937	11,056	83,892	41,075
1938	-	59,356	14,118
1939	3,407	50,430	9,271
1940	14,636	42,057	10,006
1941	15,353	30,763	13,104
1942	9,963	35,730	12,293
1943	16,589	76,236	32,403
1944	6,459	61,685	18,821
1945	12,356	46,406	17,331
1946	9,590	62,932	29,318
1947	22,480	62,786	22,580
1948	17,493	45,234	19,717
1949	17,675	82,393	20,115
1950	21,604	56,773	16,879
1951	14,132	32,069	17,549
1952	11,180	54,191	21,481
1953	13,369	63,197	24,934
1954	9,428	50,960	12,031
1955	-	58,114	10,270
1956	-	62,539	19,260
1957	-	58,515	7,434
1958	-	-	5,753
1959	-	-	15,844

Table XIV
Italian tuna catches made by madragues and by pelagic fisheries from 1951 - 1956, in metric tons (Scaccini and Biancalana 1959)

	1951	1952	1953	1954	1955	1956	Average yields
Madragues	2, 075	1, 046	2, 011	1, 890	1, 609	1, 559	1, 698
Pelagic fisheries	675	722	476	592	555	351	562
Total	2, 750	1, 768	2, 487	2, 482	2, 164	1, 910	2, 260

5. 5 Fisheries management and regulations

There are no regulations on the tuna fisheries at present.

Nearly all countries concerned with bluefin tuna fishing carry out research programs of various scope. Research is mainly directed to improve fishing techniques and to explore new fishing possibilities for local fisheries. Much effort is also being made to study the various phases of life history of the fish and to assess the landings. Unfortunately this latter research is restricted to a few countries only. Several tagging programs have been launched.