BIGEYE TUNA (*THUNNUS OBESUS*) AND THE TUNA FISHERIES OF FRENCH POLYNESIA

by

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1. INTRODUCTION

French Polynesia has a wide Exclusive Economic Zone (EEZ), established in October 1979, stretching over 4.8 million km² in the South Pacific, in which most species of tropical tunas and tuna-like species are fished, at the surface or in subsurface waters. The main commercial species are:

- Yellowfin tuna (*Thunnus albacares*), caught at the surface and in subsurface waters;
- Bigeye tuna (*Thunnus obesus*), caught only in subsurface waters;
- Albacore tuna (*Thunnus alalunga*), caught only in subsurface waters;
- Blue marlin (*Makaira mazara*), caught at the surface and in subsurface waters;
- Skipjack tuna (*Katsuwonus pelamis*), caught only at the surface;
- Wahoo (*Acanthocybium solandri*), caught only at the surface.

Other istiophorids (*Tetrapturus audax*, *T. angustirostris*, and *Istiophorus platypterus*) are also caught at the surface and in subsurface waters. Swordfish (*Xiphias gladius*) is present, but uncommon. Minor tunas such as black skipjack (*Euthynnus affinis*) and dogtooth tuna (*Gymnosarda unicolor*) are present, but not actively sought.

There is a long tradition of coastal tuna fishing in French Polynesia. Historically, fishermen in canoes have fished for deep-swimming tunas, using handlines made of vegetable fibers, hooks made of wood and mother-of-pearl, and chunks of fish or live fish for bait. Sinking the line was achieved with a stone, around which the line was initially coiled. The fish, caught in precise fishing spots known as "tuna holes," were mainly yellowfin and *mana* (*Prometichthys prometheus*). This "stone fishery," which uses small boats with outboard engines, locally called *poti marara*, and modern lines and hooks, which generally operate close to fish-aggregating devices (FADs) moored in the vicinity of the larger islands (Moarii and Leproux, 1996), but tuna holes are sometimes fished as well. The catch still consists of yellowfin, but albacore is now important because the handlines are operating deeper than in the past (Abbes *et al.*, 1994). Very few bigeye are caught by this fishery.

Alongside this modernized traditional fishery, a fishery targeting skipjack, using locally-built Chriscraft called *bonitiers*, has developed since World War II, with much success (Brun and Klawe, 1968). The catches of the bonitiers catches consist mainly of skipjack, but include lesser quantities of small yellowfin and dolphinfish (*Coryphaena hippurus*). The fishing method used is a jigline rigged with a barbless hook tied on a traditional lure made of mother-of-pearl. This fishery was the most important supplier of tuna for the local market for several decades, but since 1990 the development of monofilament longlining has caused it to decline. Recently the number of active *bonitiers* has stabilized because prices of fresh skipjack have increased, and the fishery now seems economically viable.

The use of monofilament longlines stems from a fishery which originated in Hawaii. The gear consists of a main line made of synthetic fiber, 3 to 4 mm in diameter and up to more than 40 nautical miles long, on which

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branch lines and hooks are attached with a "snap." Setting the line begins just before dawn, and retrieving is done in the evening. French Polynesian longliners are of various sizes, with the largest over 25 m. Such large vessels can set 1,500 to 2,000 hooks per day, and can stay at sea for several weeks. This fishery started in 1990 and developed rapidly, favored by strong demand in local fresh-fish market. The fleet is now quite large, and stabilized at 60 longliners in 1996. The species caught vary according to fishing grounds, seasons, and the depth at which the hooks are set. The main targets are yellowfin, albacore, bigeye and billfishes. Very recently, experimental fishing for swordfish at night, setting the longline close to the surface, was successful.

Since the Japanese began expanding their traditional longline fishery in the 1950s, Asian-flag longliners have operated in the South Pacific, targeting yellowfin, albacore and bigeye. Recently, bigeye tuna has been actively sought by "super freezer" longliners which supply the high-priced *sashimi* market in Japan. In the French Polynesian EEZ these long-range longliners, mainly Japanese and Korean, operate under license. Taiwanese vessels have not been allowed to fish since 1980, and since 1992 the Japanese fleet has not applied for licenses, so now only Korean longliners operate.

The purpose of this paper is to summarize the data, statistics, and biological information collected on these various fisheries inside and around the French Polynesian EEZ, with emphasis on bigeye tuna. The prospects of developing a French Polynesian longline fishery targeting bigeye in the northern part of the EEZ are discussed.

2. CATCHES

Table 1 presents the best estimates of the French Polynesian tuna catches for 1954-1995, obtained from various sources. It is not complete, particularly for the earlier years, as fishermen operating in coastal waters are not required to report their catches. The quantities of skipjack and small yellowfin sold at the Papeete Market are a good estimator of the total catches by *bonitiers* in French Polynesia, as shown by the data provided by a surey made in 1976-1978 and 1980-1992. Catches by *poti marara* are recorded only by some fishermen's unions. Extrapolation to the whole of French Polynesia yields estimates ranging from 200 to 500 MT per year of tunas and other large pelagic fish, mainly albacore, yellowfin and dolphinfish.

The catches of French Polynesian longliners include several species of tunas, billfish and some other species of minor importance. Sharks are generally discarded at sea, with some exceptions for mako shark (*Isurus oxyrinchus*). Catches increased steadily with of the entry of new vessels. The greatest annual catch was 2,650 MT in 1994, and preliminary estimates for 1996 are over 3,000 MT. The goal is to reach a steady production of 11,000 MT per year in the future. The bulk of the catch is sold fresh or frozen on the French Polynesian market, with some exports to Japan, Hawaii, and France. It is hoped that such exports can be increased in the future.

Reporting catches has been a condition for licensing for foreign longliners since 1980; figures for earlier years are estimates. Currently the quota is negotiated with Korea, as Japan has not sought access to the EEZ since 1992. Catches by foreign longliners are estimated to have reached 7,000-8,000 MT per year in the past; current catches are moderate.

3. DISTRIBUTION OF EFFORT, CPUE AND ABUNDANCE INDICES

3.1. French Polynesian vessels under French flag

There are no reliable statistics of effort by coastal craft, because of the multiplicity of landing points and the absence of legal obligations. A partial survey of some landing points has provided some sparse data, which will be improved. Surveys were conducted in some years, but these are difficult to maintain for financial reasons.

Fishery statistics for the French Polynesian longline fleet are not yet complete. These should be stratified by size of vessel and areas fished to compute effective effort. However, data on overall nominal effort are available, computed on the basis of the quantities of frozen bait imported and converted to number of hooks (one herring = one hook), as follows:

Year	Number of longliners	Number of hooks (millions)
1990	2	0.07
1991	8	0.65
1192	25	0.95
1993	50	3.65
1994	66	5.00
1995	65	5.90

3.2. Foreign flags

Fishery statistics for licensed longliners operating in the French Polynesian EEZ are heterogeneous. They include:

(i) Since 1980, Fishing Announcements, transmitted by radio to the French authorities on a weekly basis, expressed in day's fishing and weight of fish caught, by species. The geographical positions reported cover several days, and therefore are not very precise.

(ii) Since 1984, daily records in fishing logbooks, including precise data on geographical positions and catches, in numbers and weights of fish, by species, and effort, in numbers of hooks. These data should be sent by mail by the boat-owner's company, but only a fraction is received (Josse, 1992; Thiriez, 1995).

Fishery statistics for longliners operating outside the EEZ are available on a 5°x5° square basis, as follows:

- Taiwan: 1967-1992, by month;
- Korea: 1975-1987, by month, and 1988-1992, by quarter;
- Japan: 1962-1981, by month.

4. SPATIAL DISTRIBUTION OF CPUE IN THE EEZ

Using a combination of the detailed statistics available from foreign longliners, averaged over the 1984-1992 period, it has been possible to make maps of the catches per unit of effort (CPUEs), in kilograms of tuna per 100 hooks (Chabannes *et al*, 1993). Maps of such CPUEs for albacore are presented in Figure 1, and in Figure 2 for bigeye, and yellowfin. Albacore is the most abundant tuna south of 11°S; bigeye and yellowfin are more abundant north of that latitude, but clearly bigeye is found further offshore than yellowfin, which is concentrated around the islands in the north, and also in the central EEZ.

A map of the CPUE of bigeye caught by the French Polynesian longliners (Figure 3) shows that this fleet is fishing the same areas, but with less success. One possible reason is the fact that fishing trips in the northern part of the EEZ are not easy, even for the relatively-large French Polynesian longliners, since there is no suitable harbor for unloading in the Marquesas Islands.

5. SPECIFIC INFORMATION ON BIGEYE

5.1. Quality of the fishery statistics

Figure 4, provided by Dr. A. Fonteneau, shows clearly a continuity of the concentration of bigeye tuna caught in the northern part of the EEZ with the major fishing concentration of bigeye in the South Pacific, centered at roughly 10°S and 130°W. Bigeye caught on this particular fishing ground, which are called *seiki* by the Japanese fishermen, are considered to be of prime quality for *sashimi*, (Ashenden and Kitson, 1987). Consequently, fishing effort is believed to be high in this area. It is important for French Polynesia to have access to accurate fishery statistics in waters adjacent to its EEZ, as the fisheries are sharing a common resource. The quality of such statistics can be assessed as follows:

5.1.1. Foreign flags

In the EEZ itself, fishery statistics for the foreign longliners operating on bigeye concentrations in the north are apparently correct, and there is no reason to suspect misreporting of species, as higher prices are received for bigeye. However, as explained above, such statistics are not fully reported in logbooks on a daily basis by all the longliners operating in the EEZ, so there is a problem of rate of coverage, which could be estimated by comparing radio reports to the available logbooks. Such work was done for the period up to 1992 by Chabannes *et al.* (1993), but must be updated for recent years.

Outside the EEZ, where there is no legal obligation to report, only 5°x5 ° data are available, but not for all years and countries. Access to more precise data, if available, on a 1°x1°-month basis, for instance, would be very useful for two purposes:

(i) Studying in detail the apparent movements of tuna, as reflected by catches, to try to estimate the degree of interaction between fisheries inside and outside the EEZ;

(ii) Exploring the relationship between the fisheries and broad climatic events, such as El Niño-Southern Oscillation, inside and outside the EEZ.

Size frequencies of tuna caught by foreign longliners fishing in French Polynesia are not reported. Size frequencies seem to be recorded on Japanese longliners operating outside the EEZ. It is not clear if longliners operating inside the EEZs of various nations collect size frequencies which pertain to those nations individually.

5.1.2. French Polynesian longliners

The catches of bigeye seem to be correctly reported by large longliners, the only ones able to fish in the Marquesas Islands area, in the northern part of the EEZ. Such vessels unload their catches only at the Papeete Central Auction Market, where the tunas are correctly sorted by species. Minor confusion with yellowfin could exist for small longliners operating around the Society Islands, and particularly Tahiti, at the center of the EEZ, but apparently bigeye is rare in this area.

Size frequencies of bigeye tunas landed at Papeete are recorded by EVAAM (Etablissement pour la Valorisation des Activités Aquacoles et Maritimes). Figures 5a and 5b show size frequencies for 1995 and 1996. These should be raised to the total catch in the near future.

As a partial conclusion, there is a good potential for improving the precision of bigeye fisheries statistics in the EEZ. A combination of data, *e.g.* substitution of size frequencies among fleets by area, could be used for filling the gaps in a common data base.

5.2. Biology and ecology

The data on these topics are collected mainly by experimental fishing, using a longline rigged with depth recorders and hook timers (Josse *et al.*, 1995), conducted by the ORSTOM oceanographic vessel *Alis* within the general framework of program ECOTAP, extending from 1995 to 1997. Various physical oceanographic measurements are collected. Micronectonic pelagic trawl hauls are made regularly on planktonic layers detected with echosounders. The pelagic trawl opening is 15 m high, with 5-mm mesh in the codend, and the net is rigged with a trawl instrumentation system. The available results are as follows.

5.2.1. Environmental conditions

High availability of bigeye in the northern part of the EEZ seems to be linked to the abundance of forage associated with equatorial upwelling. Hydrological conditions are characterized by a sea-surface temperature ranging from 26° to 28°C, a marked thermocline at 100-150 m, and low levels of dissolved oxygen in deeper water, with values decreasing in the thermocline and as low as, or less than, 1 ml/l below the thermocline. Misselis (1996), using cladistic methods, showed two particular seasonal bodies of water, characteristic of bigeye (Figures 6 and 7).

5.2.2. Biology and ecology

Size frequencies of individual bigeye, by sex, caught during 1993 and 1995-1996 are shown in Figure 8. Similar quantities of large males and females can be seen, indicating a similar growth pattern for both sexes, which is not the case for yellowfin and albacore. This observation is not incompatible with the slight dimorphism in growth for very large bigeye shown by Shomura and Kaela (1963). Otoliths are collected from each fish. Determination of the age of the fish, using daily growth increments, has been undertaken by the South Pacific Commission.

The depths at which the tuna bite on the baited hooks have been computed with a new method of modelling the curve formed by a basket of 25 hooks on the monofilament main line between two buoys (Wendling, 1995). Using time-depth recorders (TDRs) at the middle of the basket permits adjustment of the curve, as done previously by Boggs (1992), who used a simple catenary curve. From these data the range of swimming depths of feeding tunas and associated species, summarized in Figure 9, are computed. For bigeye, observed values range from 120 m (26.5°C) to 450 m (9°C), with a mean value of 275 m (15.5°C). These values agree with those reported by Boggs. This indicates a deep feeding habitat for bigeye, shared with some sharks, swordfish, *opah* (*Lampris regius*), and pomfret (*Taractes longipinnis*). Such a habitat agrees with the hypothesis of Suda *et al.* (1969), and with the behavioral thermoregulation shown by Holland *et al.* (1992).

Feeding is studied in two ways:

(i) Observation of daily feeding patterns, using hook timers on the branch lines (Boggs, 1992);

(ii) Identification of stomach contents, compared with micronectonic catches caught by pelagic trawls in the vicinity of the longline set. Also, a continuous recording by echo-integration of the planctonic layers is made during longlining operations. From these, trophic indices will be computed and compared with tuna distribution.

Reproduction is studied by systematic recording of sexual state and weighing the gonads. A gonadosomatic index (GSI) is computed as:

$$GSI = (\text{Gonad weight} \times 10^4) / (\text{Fork length}^3),$$

after Miyabe (1994). Gonad weight is in grams, and fork length in centimeters.

Values for bigeye are displayed in Figure 10. It can be seen that the GSI of females over 100 cm (23 kg) is sometimes 3 or more, which is the generally accepted value for the GSI which indicates sexual maturity of tunas. Consequently, the Marquesas Islands area could be a spawning ground for bigeye. It is likely that the spawning area extends to the main fishing concentrations north and east of the Marquesas Islands (Figure 4).

An unexpected occurrence of young bigeye was observed north of the Marquesas Islands near 5°S, 140°W in January 1996, when 77 young bigeye associated with 7 young yellowfin were caught by trolling near a moored TOGA (Tropical Ocean and Global Atmosphere) weather buoy. Unfortunately, there were no conventional tags aboard the vessel, but one fish was tagged with a sonic tag and then tracked. The size frequencies of these fish are shown in Figure 11. A particular feature of all these fish is the unusual size of the swimming bladder, which was fully functional in fish over 40 cm long (Figure 12). This feature, which has not been reported in other areas where young bigeye occur, such as the eastern tropical Atlantic, could be interpreted as an unusual early development of an organ which improves the ability of the fish for diving and chasing in deeper waters, the only apparent source of food in this pelagic ecosystem. A similar feature has been suggested by Pereira (1995 and 1998) for young Atlantic bigeye in the area of the Azores Islands.

6. CONCLUSION

Clearly, a concentration of deep-swimming bigeye exists in the northern part of the French Polynesian EEZ. This concentration is continuous with the important international longline fishing ground east-northeast of the Marquesas Islands. It is a considerable shared resource, currently exploited mainly by the international fleet. The geographical situation of the Marquesas Islands, the land closest to this concentration, is *a priori* very convenient for establishing a flow of *sashimi*-grade tuna toward markets where it is in demand. Such an activity is profitably established in islands of the western central Pacific (Hanmet and Pintz, 1996). Unfortunately, there is currently no good harbor in the Marquesas Islands, and the main airstrip would have to be enlarged for wide-bodied aircraft. However, the government of French Polynesia is aware of this potential.

At the scientific level, it is expected that the ECOTAP program will provide information on the biology, ecology and environmental characteristics of tunas in the EEZ, and that this can be used for optimizing the new French Polynesian fishery. After 1998, studies in tuna fisheries biology will be carried out by EVAAM.

In regard to stock assessment, particularly for bigeye tuna, which seems to be heavily exploited, it is acknowledged that the ranges of most stocks of tunas probably extend over wide areas of the Pacific Ocean. Consequently, collaboration at international level is necessary. Such cooperation is already under way, and scientists from the South Pacific Commission and French Polynesia will work with a future international commission for the conservation of Pacific tunas.

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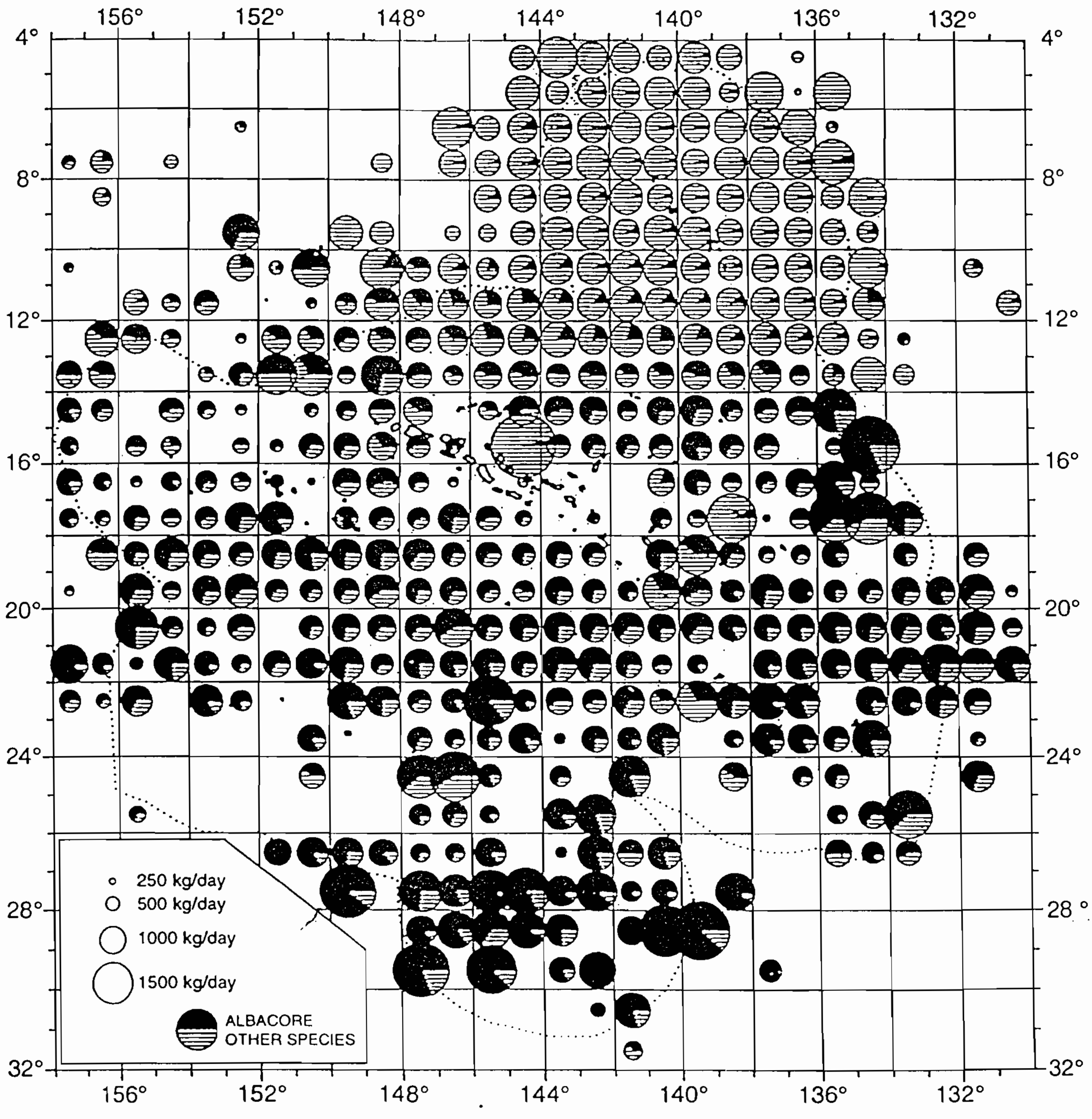

FIGURE 1: Ratios, for Korean longliners, of the CPUEs (kg/day) of albacore to those of all species combined in the EEZ of French Polynesia, computed from the average annual values for 1984-1992.

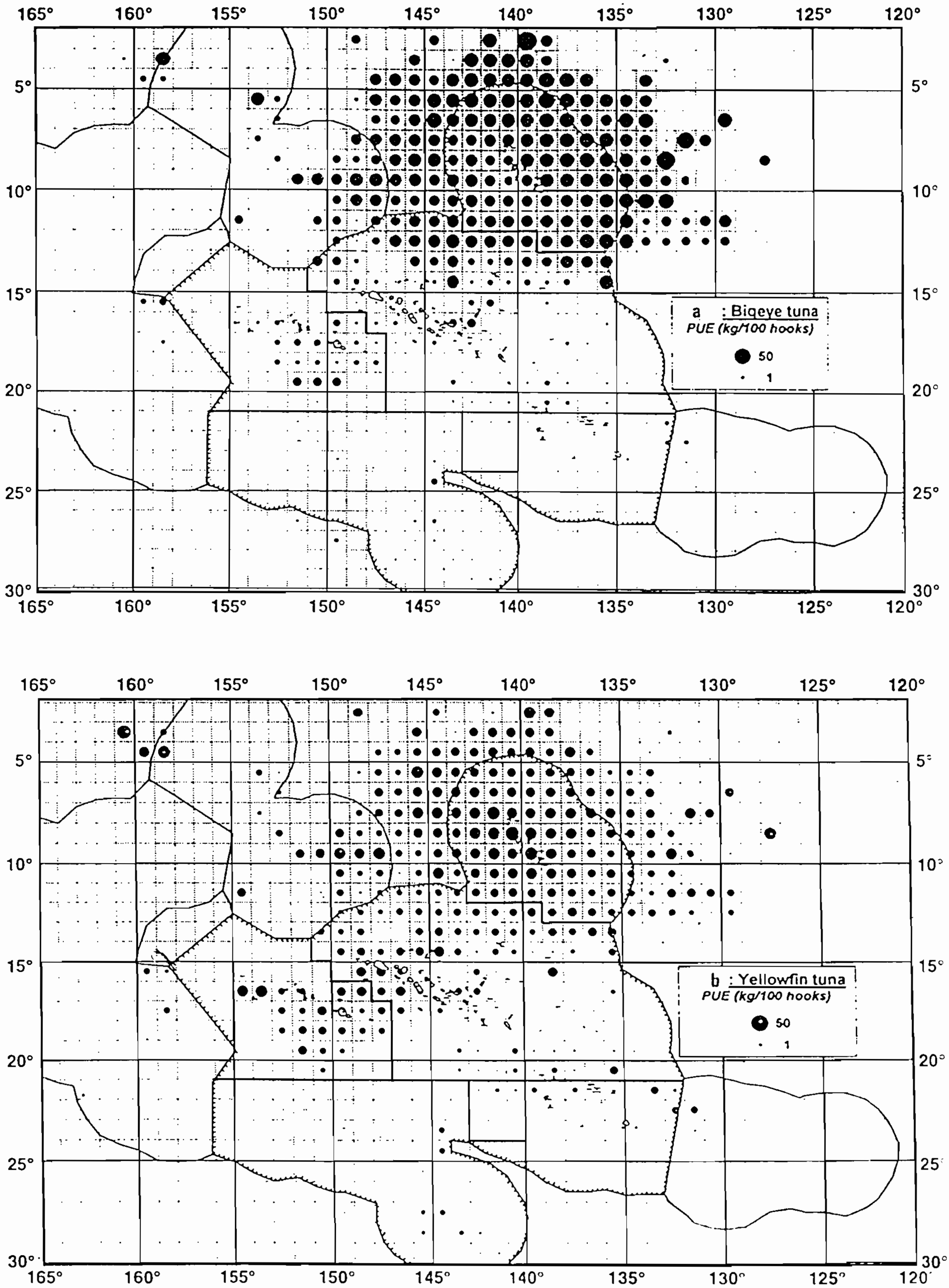

FIGURE 2: Geographical distributions of CPUEs (kg/100 hooks) of bigeye (upper panel) and yellowfin (lower panel) tuna in the EEZ of French Polynesia, computed from the average annual values for Japanese and Korean longliners during 1984-1992.

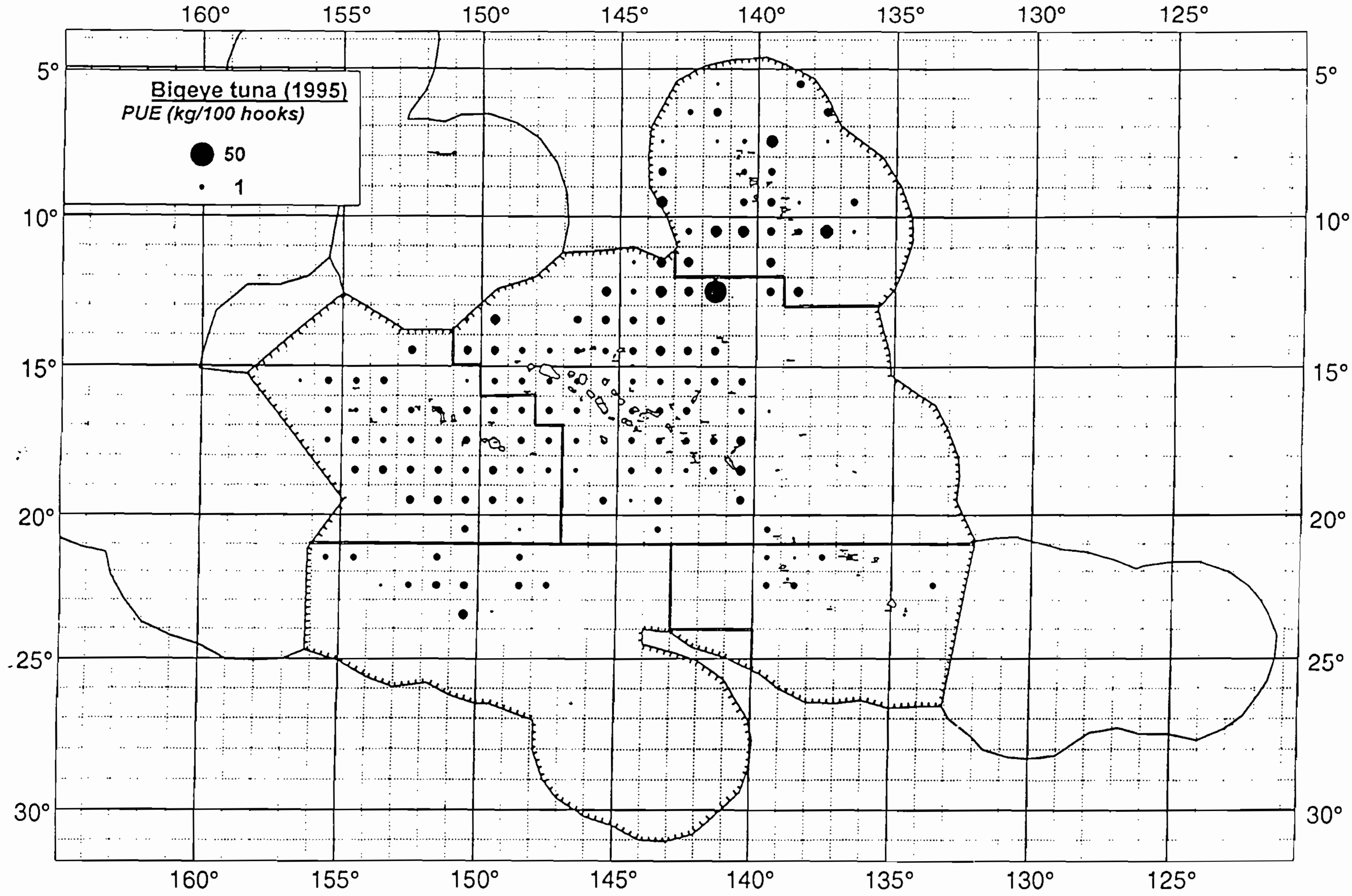

FIGURE 3: Geographical distribution of CPUEs of bigeye tuna for French Polynesian longliners during 1995.

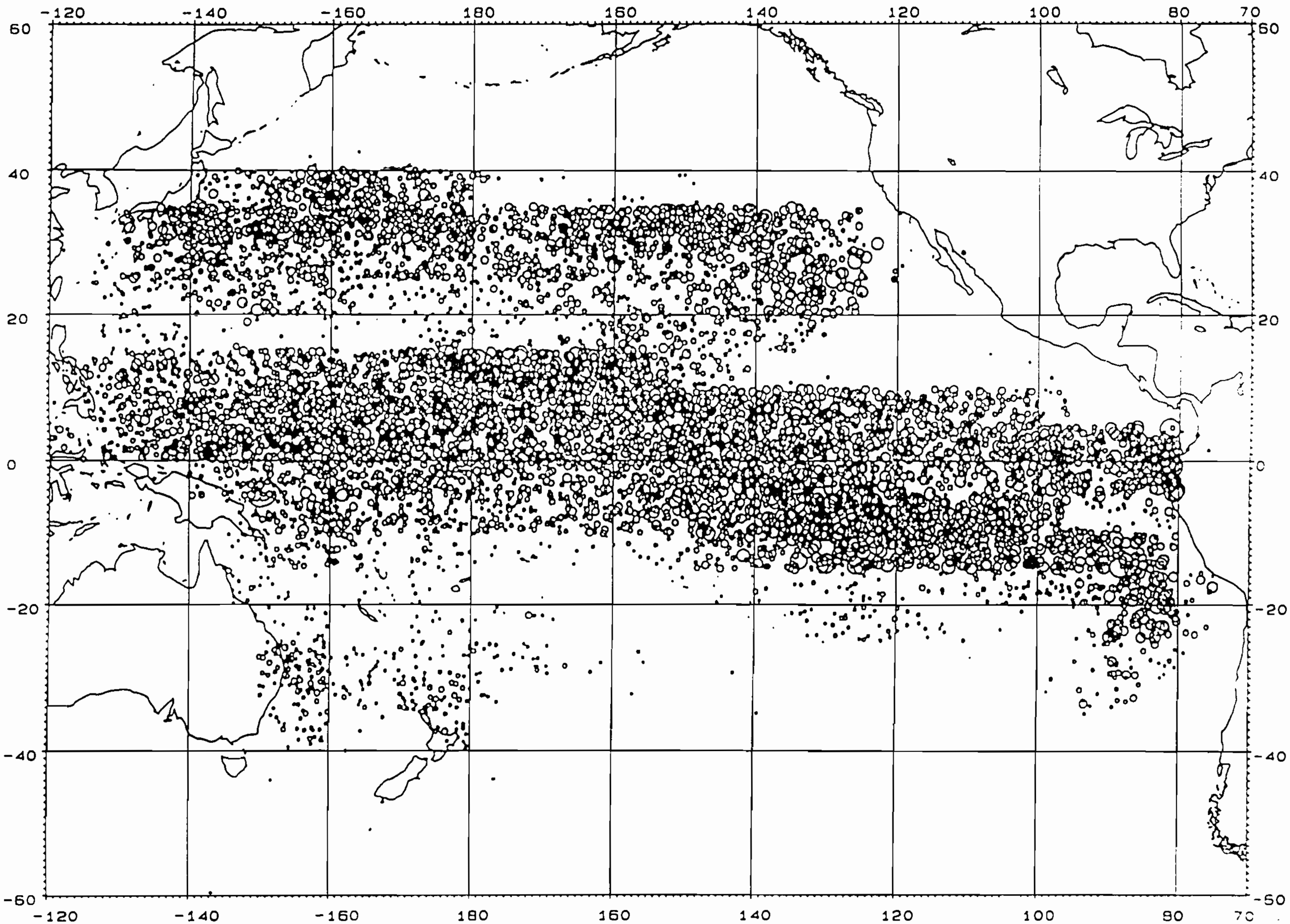

FIGURE 4: Geographical distribution of the total catches of bigeye tuna by all longline fleets in the Pacific Ocean, 1952-1993. Each circle represents a monthly catch, randomly distributed within the reported 5° square. Source: A. Fonteneau, World Tuna Data Base (TUCAW).

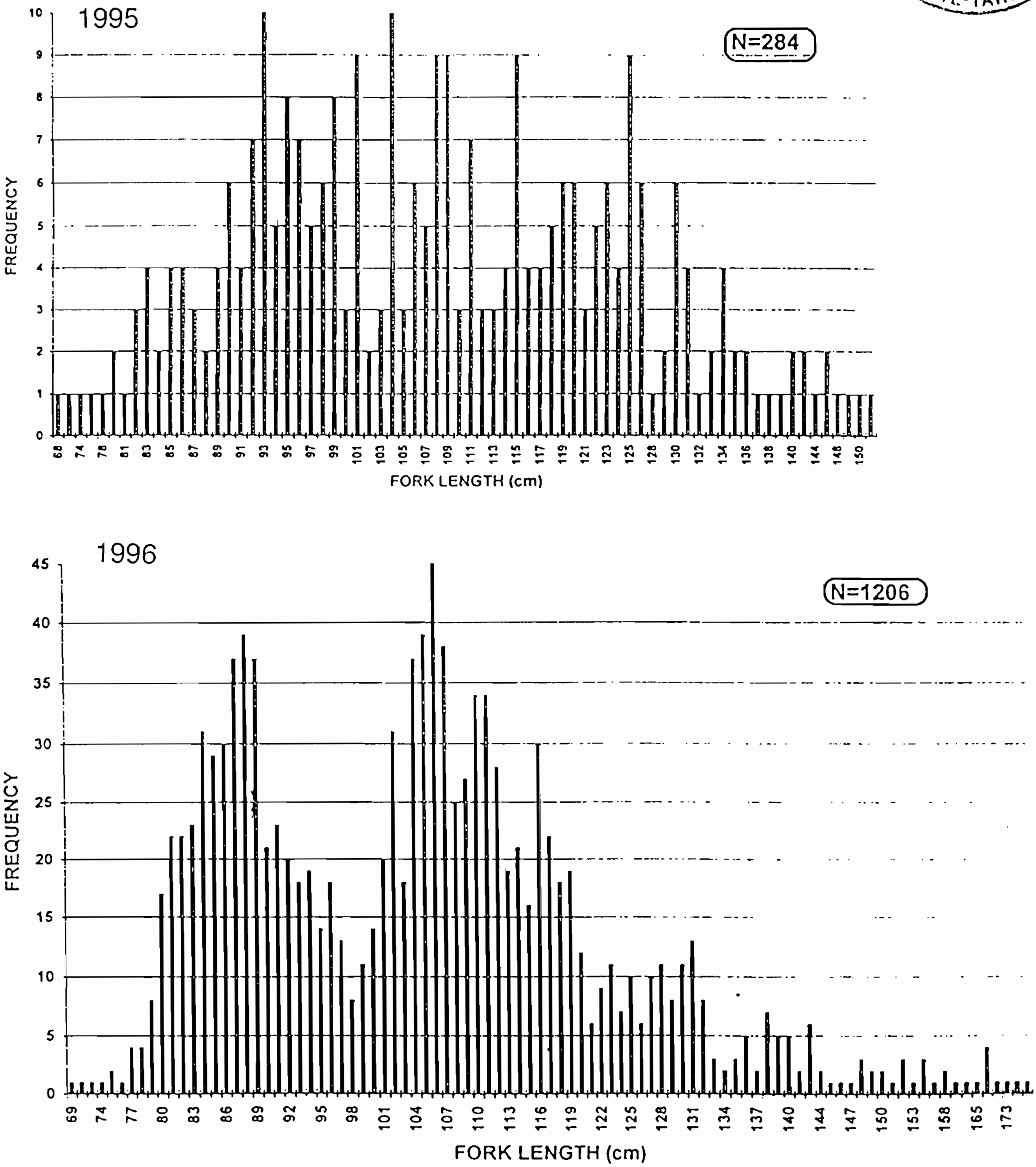

FIGURE 5: Length frequencies of bigeye caught by French Polynesian longliners and landed at the Papeete auction market during 1995 (upper panel) and January-September 1996 (lower panel).

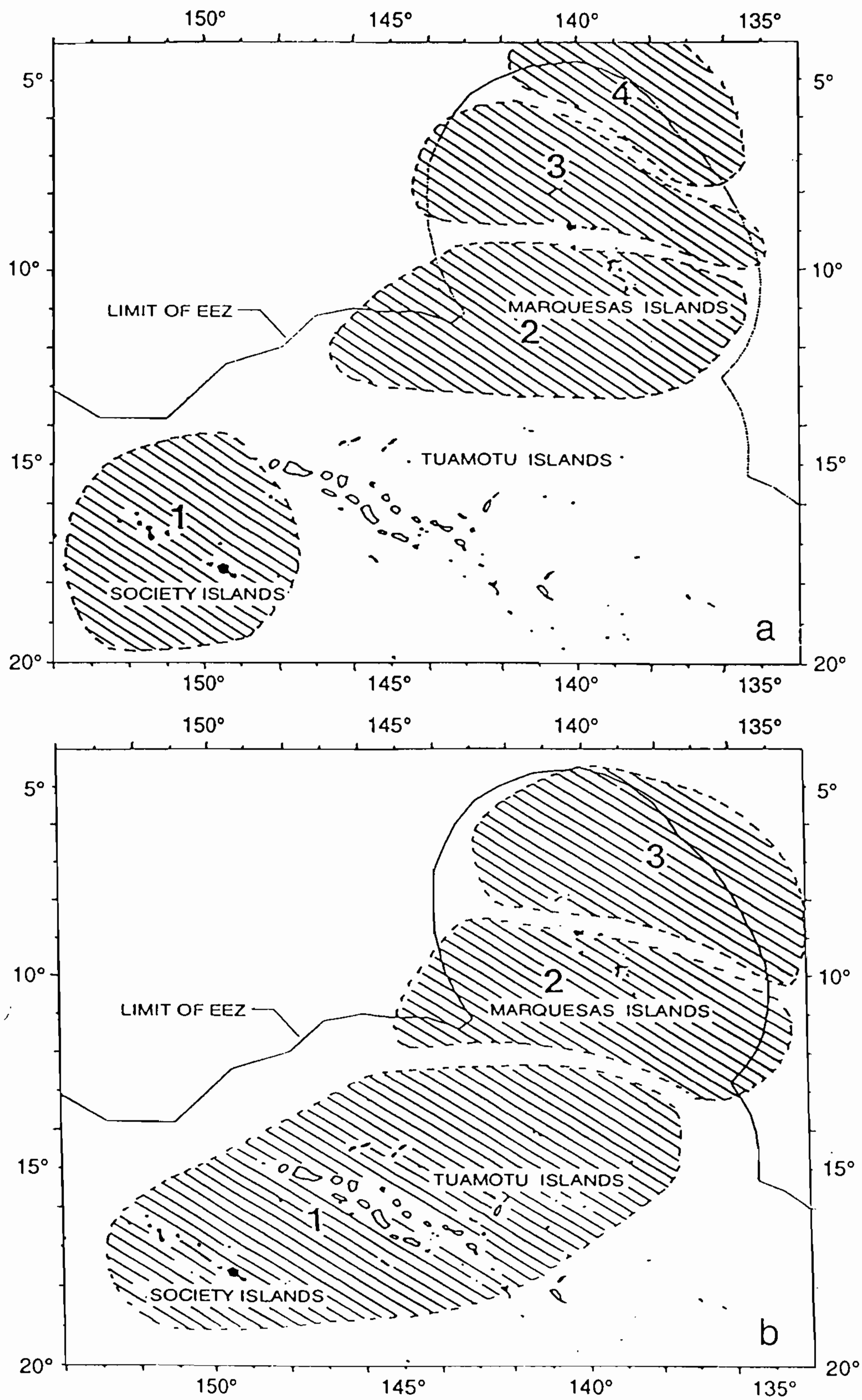

FIGURE 6: Characteristics of the habitat of deep-swimming tuna in the northern part of the EEZ of French Polynesia during the austral winter (upper panel) and the austral summer lower panel). The four bodies of water were separated by cladistic methods. Bigeye tuna is associated with bodies 3 and 4.

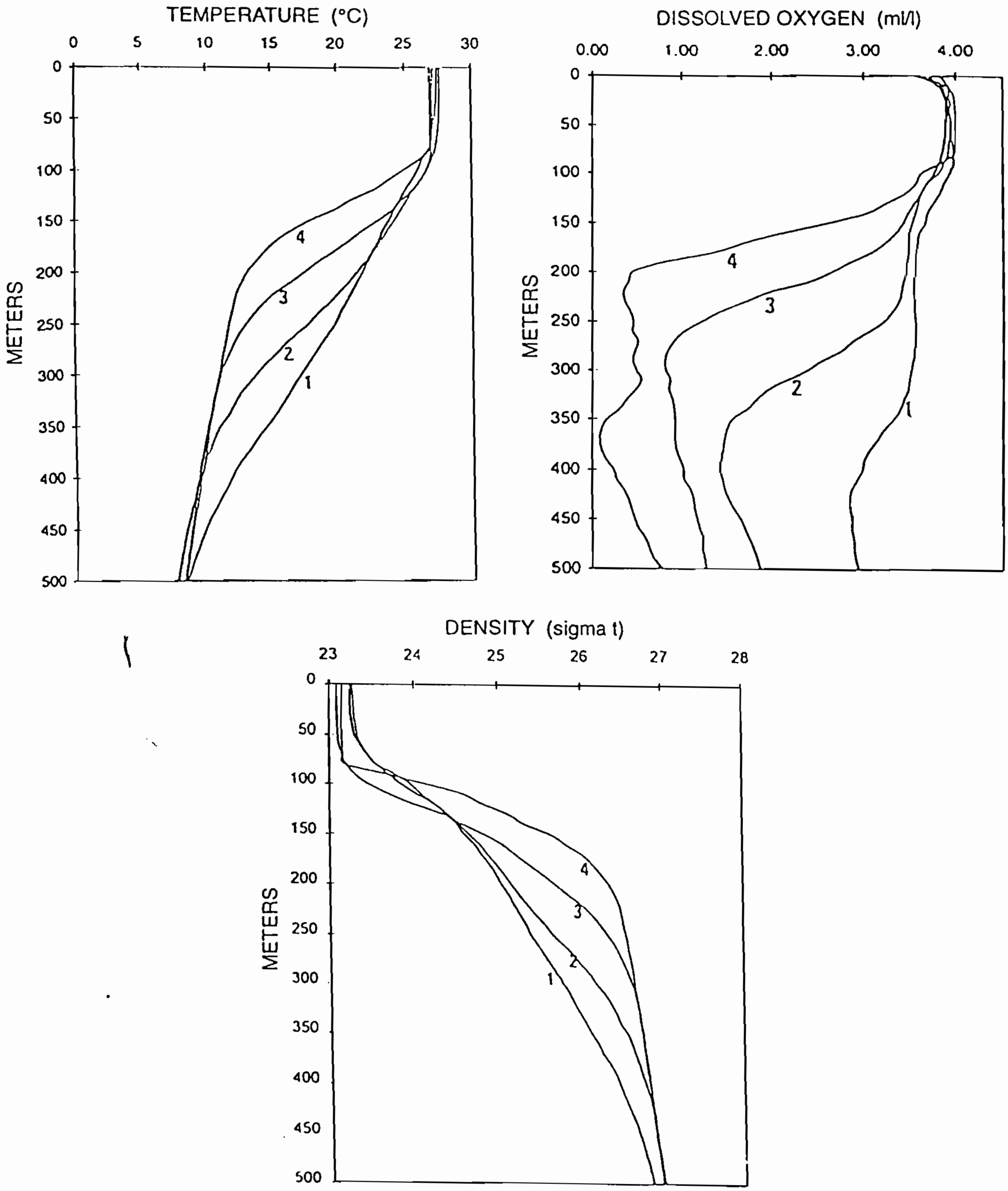

FIGURE 7: Profiles of temperature, dissolved oxygen, and density for the four bodies of water shown in Figure 6.

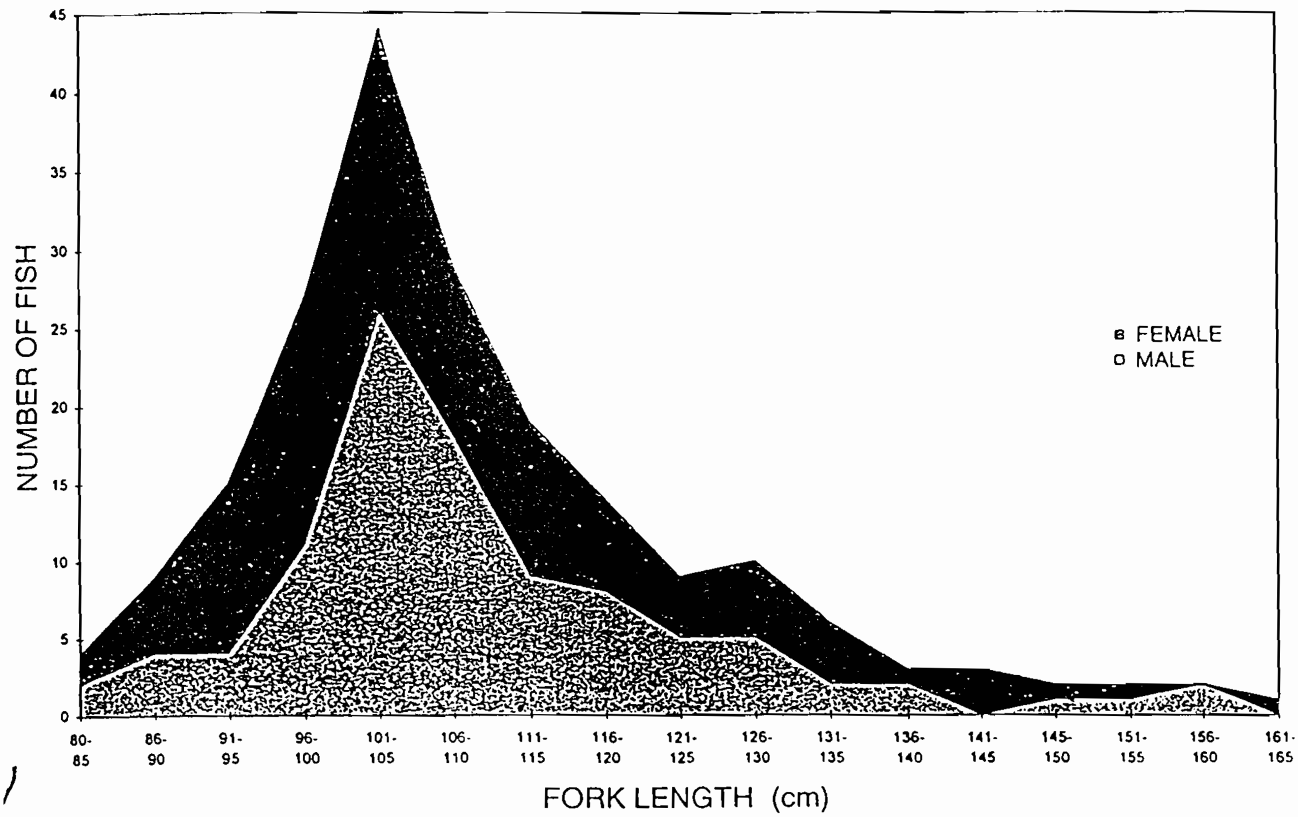

FIGURE 8: Length frequencies, by sex, of bigeye tuna caught by the N.O. *Ali* during 1993 and 1995-1996.

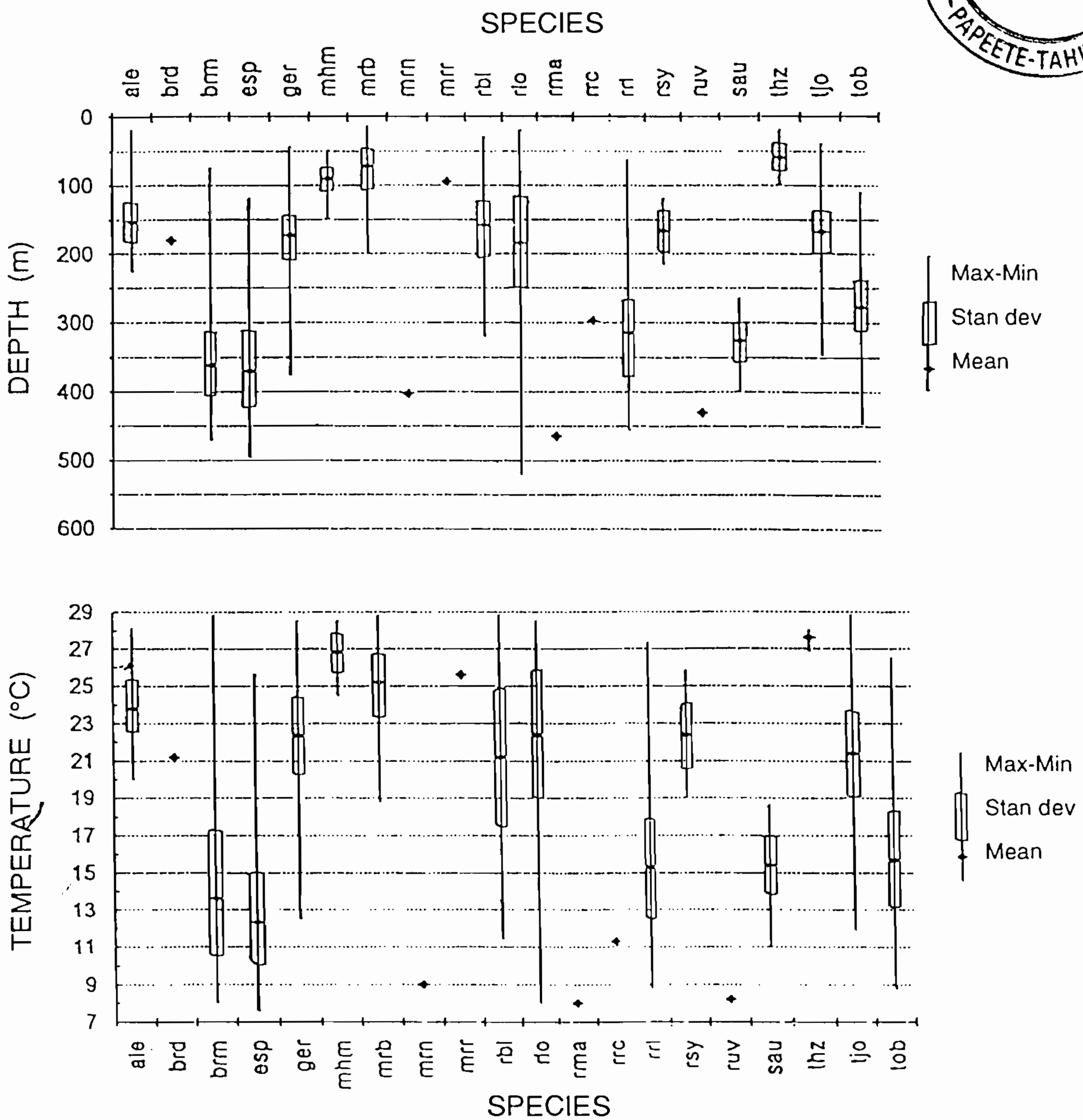

FIGURE 9: Ranges of depth and temperature for various tunas and associated species caught by the N.O. *Alis* in the EEZ of French Polynesia during 1993. The species are indicated by the letters on the far right, as follows: ale: *Alapisaurus ferox*; brd: barracuda; brm: *Taractes longipinnis*; esp: swordfish; ger: albacore; mhm: dolphinfish; mrb: blue marlin; mrn: black marlin; mrr: striped marlin; rbl: *Prionace glauca*; rlo: *Carcharinus longimanus*; rma: hammerhead shark; rrc: *Alopias superciliosus*; rrl: *Alopias* sp; rsy: *Carcharhinus falciformis*; ruv: *Ruvettus pretiosus*; sau: *Lampris opah*; thz: wahoo; tjo: yellowfin tuna; tob: bigeye tuna.

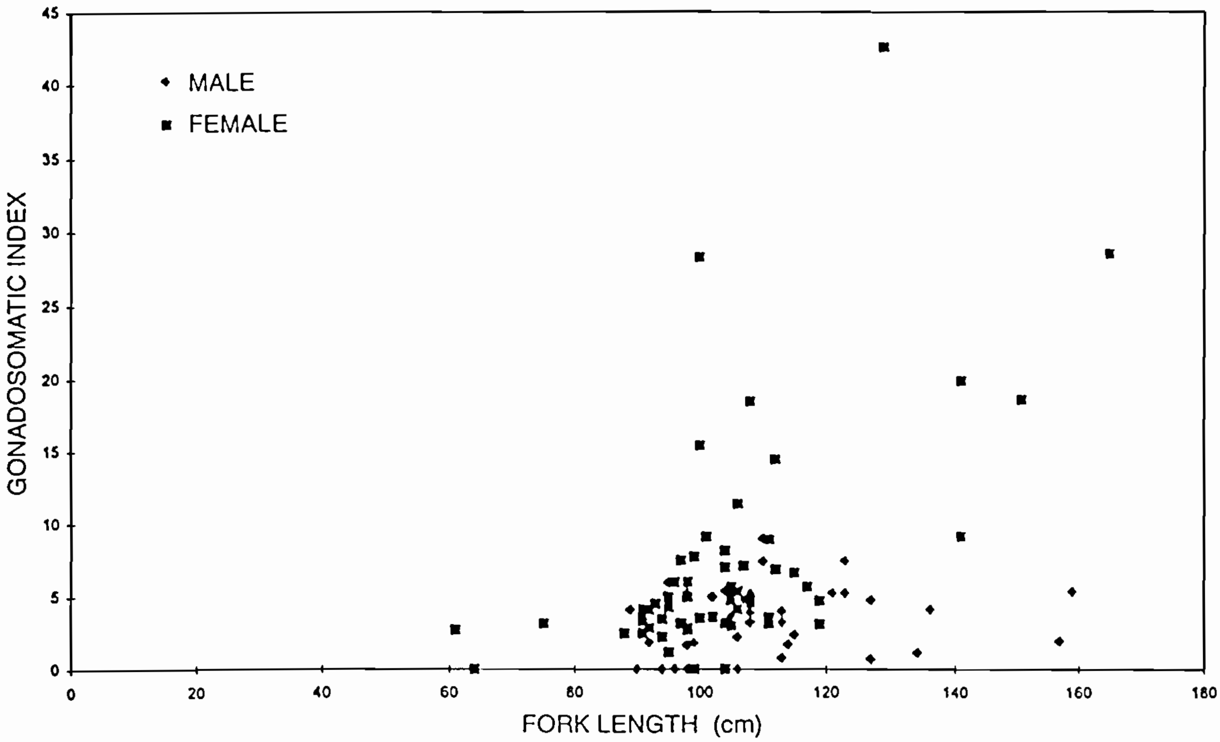

FIGURE 10: Gonadosomatic indices of male and female bigeye caught by the N.O. *Alis* during 1993 and 1995-1996.

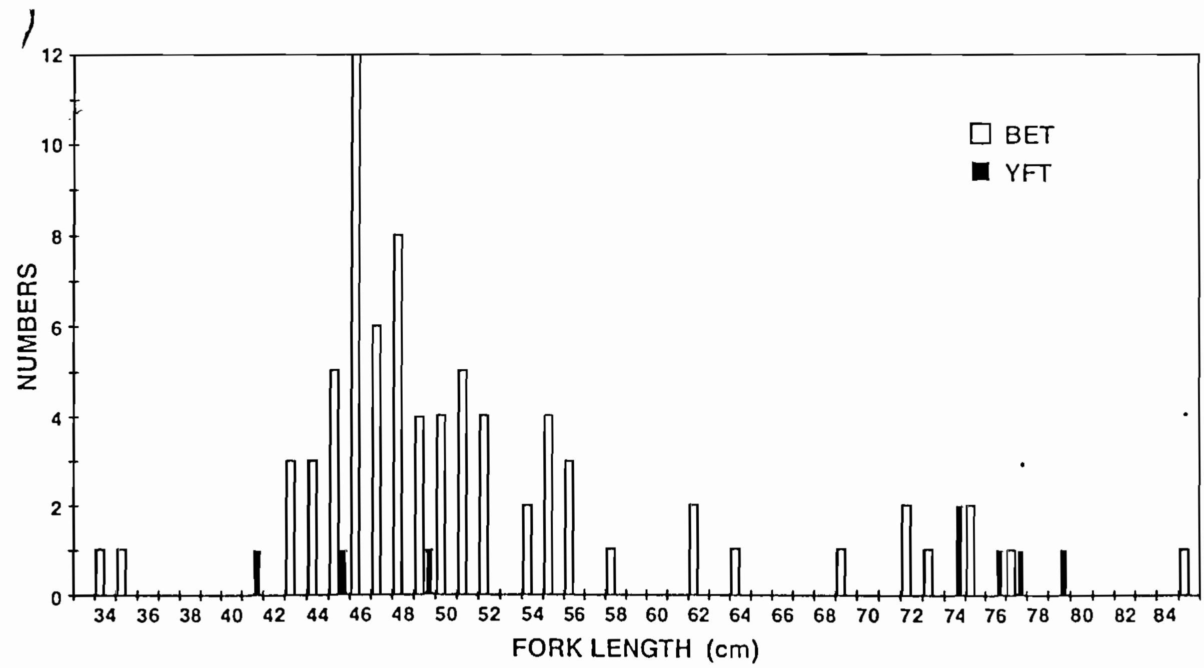

FIGURE 11: Length frequencies of juvenile bigeye and yellowfin tuna caught by trolling near 5°S-140°W during January 1996.

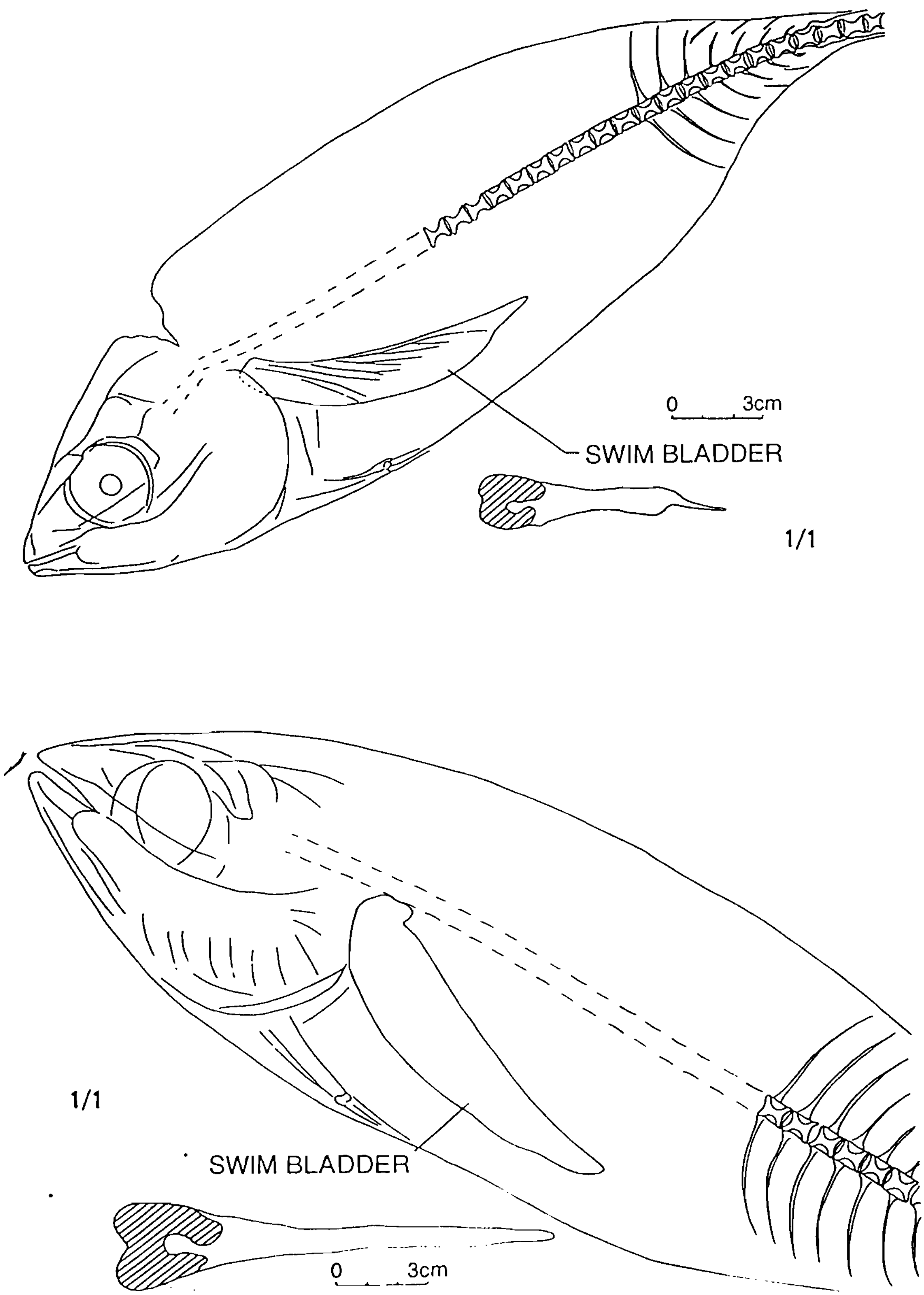

FIGURE 12: Drawings, from radiographs, of two young bigeye tuna caught by trolling, showing the unusual sizes of their functional swim bladders. Upper views of dissected and dried bladders are added. The upper fish is 43 cm FL, with a swim bladder volume of 55 cm^3; and the view shows a fully-developed swimming bladder. The lower fish is 34 cm FL, with a swim bladder volume of 25 cm^3. The upper view shows the "tail" of the swim bladder, which is not fully developed.

TABLE 1: Historical series of tuna catches, in metric tons, in the EEZ of French Polynesia. Catches by *poti marara* coastal craft, estimated at 200-500 MT per year, are not included. The values in parentheses are catches of bigeye tuna. J: Japan ; K: Korea, T: Taiwan. The 1996 values are for January-November only.

Year	Sales of skipjack and small tuna at Papeete market	Landings of skipjack and small tuna; all of French Polynesia	Catches of bigeye by French Polynesian longliners	Catches of bigeye by foreign longliners	Countries under license and reporting
1954	358				
1955	339				
1956	410				
1957	296				
1958	259				
1959	343				
1960	380				
1961	395				
1962	566				
1963	625				
1964	490				
1965	558				
1966	789				
1967	639				
1968	710				
1969	804				
1970	712				
1971	484				
1972	569			4023 (902)	J, T
1973	563			5659 (1110)	J, T
1974	535			5266 (1684)	J, T
1975	652			7044 (3330)	J, K, T
1976	658-844	1521-1902		7264 (2943)	J, K, T
1977	670-870	1774-2218			
1978	984-1230	2649-3313			
1979	805			1945 (819)	J
1980	992	1312		2944 (1618)	J
1981	1035	1468		4726 (1254)	J, K
1982	1067	1557		2631 (663)	J, K
1983	903	1491		1423 (291)	K
1984	1300	2344		2018 (822)	J, K
1985	903	1623		4774 (1931)	J, K
1986	981	1356		4293 (1967)	J, K
1987	907	1536		4467 (2184)	J, K
1988	750	1314		5187 (2790)	J, K
1989	986	1370		2901 1004)	J, K
1990	786	1400	55 (4)	4232 (1825)	J, K
1991	769	1472	250 (35)	5541 (3213)	J, K
1992	574	1406	820 (57)	2305 (1110)	K
1993	425		2400 (163)	1395 (750)	K
1994	479		2653 (165)	2130 (1231)	K
1995	343		2455 (182)	2023 (1321)	K
1996				3032 (1842)	K

Sources: Bard (1974); Bessineton (1976); Josse *et al.*, Rapport ECOTAPP (1995); EVAAM, Direction des Affaires Maritimes, Chabannes *et al.* (1993).

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Bigeye tuna (Thunnus obesus) and tuna fisheries of French Polynesia.

In : Deriso R.B. (ed.), Bayliff W.H. (ed.), Webb (N.J.). World meeting on bigeye tuna. La Jolla : IATTC, (9), 171-189.

(Special Report - IATTC ; 9). World Meeting on Bigeye Tuna, 1., Papeete (PYF), 1993/07.

ISSN 0749-8187