# ATLANTIC BLUEFIN TUNA: 100 CENTURIES OF FLUCTUATING FISHERIES

Alain Fonteneau[1]

*SUMMARY*

*This document reviews the major changes observed in several bluefin fisheries that have been identified in various areas of the Atlantic Ocean and Mediterranean Sea during the last 10,000 years. This study first briefly reviews the multiple fisheries that have already been active in prehistoric and historical times and at the beginning of 20th century, during which major industrial fishing activities have been permanently developed on bluefin, especially in the Mediterranean Sea. The analysis of the fishing activities during the last 50 years is mainly focused on the catch and effort data of Japanese longliners because this fleet has been heavily targeting bluefin and providing the best and longest statistical series available, and these data cover a wide geographic area. This historical analysis of bluefin fisheries shows the large-scale yearly migrations of bluefin tunas between their spawning and feeding zones. It also shows that bluefin tuna have been historically fished in a very wide range of ecosystems thus showing great variability in the targeted time and area strata. The paper describes and discusses this major variability of the bluefin fishing strata that remains widely unexplained. Further data mining and ad hoc research should allow to better explain this major variability of the bluefin fisheries that has been playing an indirect but probably significant role in past and present stock assessments of both western and eastern Atlantic stocks.*

*RÉSUMÉ*

*Cet article fait un bilan des principaux changements observés dans les diverses pêcheries de thon rouge identifiées dans l'Atlantique et la Méditerranée durant les 10000 dernières années. Ce bilan débute par un bref examen des pêcheries de thon rouge historiques qui ont été actives dans les époques préhistoriques et historiques jusqu'au début du 20ième siècle, des périodes pendant lesquelles des industries thonières majeures ont été développées sur le thon rouge dans divers pays, en particulier en Méditerranée. L'analyse des pêcheries de thon rouge actives durant les 50 dernières années est concentrée sur l'analyse des données de la flottille de palangriers japonais, du fait que cette flottille est l'une des plus importantes à cibler le thon rouge, la seule à disposer d'excellentes données statistiques durant un demi siècle et ceci en exploitant une vaste zone de pêche. Cette analyse historique montre bien les grandes migrations du thon rouge entre ses zones de ponte et trophiques. Elle met aussi en évidence le fait que le thon rouge a durant cette période été péché dans une vaste gamme d'écosystèmes, de multiples modifications ayant été observées durant cette période dans les strates où le thon rouge était exploité. L'article discute aussi cette majeure variabilité des strates où le thon rouge a été historiquement exploité. L'article conclue qu'une recherche accrue de données historiques de pêche associée à une recherche biologique accrue serait nécessaire pour mieux comprendre cette grande variabilité historique des pêcheries de thon rouge. La conclusion est que ces changements majeurs dans les strates exploitées ont pu jouer un rôle indirect majeur dans les évaluations passées et actuelles des stocks de thon rouge de l'Atlantique Est et Ouest.*

*RESUMEN*

*Este documento revisa los principales cambios observados en las diversas pesquerías de atún rojo que se han identificado en varias zonas del Atlántico y Mediterráneo durante los últimos 10.000 años. Este estudio revisa brevemente en primer lugar las múltiples pesquerías que han estado activas en tiempos históricos y prehistóricos y a principios del siglo XX, durante el cual se han desarrollado permanentemente las principales actividades pesqueras industriales dirigidas al atún rojo, especialmente en el Mediterráneo. El análisis de las actividades pesqueras durante los últimos 50 años se centra especialmente en los datos de captura y esfuerzo de los palangreros japoneses porque esta flota se ha estado dirigiendo en gran medida*

[1] Fonteneau Alain, IRD scientist, CRH, BP 171, Sète, France. E Mail : Fonteneau@IRD.fr

*al atún rojo y facilitando la mejor y más larga serie estadística disponible, con datos que cubren una amplia zona geográfica. Este análisis histórico de las pesquerías de atún rojo muestra las migraciones anuales a gran escala de los atunes rojos entre sus zonas de desove y sus zonas tróficas. Muestra también que los atunes rojos se han pescado históricamente en un abanico muy amplio de ecosistemas y que muestran una gran variabilidad en los estratos espaciales y temporales objetivo. El documento describe y debate esta gran variabilidad de los estratos de pesca del atún rojo que sigue sin explicación. Una mayor minería de datos e investigación ad hoc permitirían explicar mejor esta variabilidad de las pesquerías de atún rojo que ha estado desempeñando un papel indirecto pero probablemente significativo en las pasadas y presentes evaluaciones de los stocks tanto del Atlántico occidental como del Atlántico oriental.*

*KEYWORDS*

*Bluefin, fisheries, variability, Brazil, North Sea, Mediterranean Sea*

## 1. Introduction

The main goal of this paper is to make a global overview and discussion of the multiple changes observed in the various tuna fisheries that have been catching bluefin tuna during the recent 100 centuries, i.e. since the end of the last glaciations. Such a review has been already done by various scientists at various scales, for instance by Mather et al 1995, Doumenge 1998, Pusineri *et al.* 2002 and MAc Kensie 2007, but the analysis of historical changes in the bluefin fisheries remains of great scientific interest.

The Atlantic bluefin tuna fisheries have been, by far, the most active fisheries targeting a tuna species during millenniums. Among the other tuna species, bluefin tuna is probably the best prototype of a highly migratory species doing extensive yearly migrations between its spawning and feeding zones, mainly in temperate waters, but also in equatorial warm waters, and being fished during these various periods of its life cycle. This historical overview of the bluefin fisheries will be stratified into three major periods:

1) After the end of the last glaciations to the Middle Ages: 8000 BC-1300 AD.

2) 1300-1900: Six centuries of major bluefin fisheries, using coastal beach nets and traps targeting potential spawners, during, before and after their migration to their spawning zones, mainly in the Mediterranean Sea and in the Eastern Atlantic.

3) 20th century to now: a wide diversity of multiple and fluctuating fisheries and fishing gears that have been targeting bluefin in a wide rage of fishing areas between 25°South and 65°North on both sides of the Atlantic Ocean.

The final goal of this paper will be to discuss this observed major variability in the bluefin fishing zones and seasons, in relation with the environment and the increasing fishing mortality suffered by the bluefin population and by their favourite preys, also often overfished.

## 2. A brief review of historical bluefin fisheries

### *2.1 The early centuries of active bluefin fishing: 8000 BC-1300 AD*

Bluefin tuna have been permanently exploited, especially in the Mediterranean Sea but also in the North Sea during thousands of years, for instance in various islands of the Egean Sea (Desse an Desse Berset 1994). Doumenge 1998 made a very good synthesis of these very active historical bluefin fisheries implanted in the Mediterranean Sea (Volos, Saliagos) and in the Atlantic, close to the Gibraltar straights.

It can also be noted that bluefin tuna was also common in the Black Sea during ancient Greek times and found in Pantikapei (currently - Kerch).

Furthermore, various archaeological excavations in Denmark and Sweden have also shown that bluefin has been also fished the North Sea and the Baltic as well, several centuries before Christ (MacKenzie, this Symposium).

All these traditional fisheries were highly localized in peculiar coastal fishing spots where bluefin was highly vulnerable in relation with its feeding concentrations or its spawning migrations (already well described by various authors).

### *2.2 The 1300-1900 period: multiple beach seine and anchored trap fisheries*

The birth of large scale fisheries targeting bluefin in various areas of the Mediterranean Sea took place about 7 centuries ago, mainly in Italy and later in Spain, mainly using large beach seines that were still predominantly used in the Mediterranean Sea until the early 17th century. The development of the present traps, seasonally using a network of fixed anchored nets, was observed west & East of Gibraltar in several spots of the Mediterranean Sea (**Figure 1**).

The paradox is that the historical catch and effort data of these Mediterranean historical traps show a good quality, at least much better than the present ICCAT Mediterranean statistics, they are still available today and they have been widely used and analyzed, among others, by Ravier and Fromentin 2001 and by Fromentin 2008. This highly valuable historical data base shows that hundreds of traps were then active in and around the Mediterranean Sea, and that they have permanently been targeting spawning bluefin during centuries. These traps were also fully integrated to a large scale vertical fishing industry, linked to the construction and maintenance of the traps, and to the transformation and transport industry, targeting its consumers in many European countries (Doumenge 1998).

The analysis of these data by Fromentin & Ravier have shown the existence of long term cycles of biomass, and driven by the environmental variability and probably quite independently of the exploitation rates of the stock. It can now be firmly concluded that the Mediterranean Sea has been, during most years and during millenia, a major spawning zone for Atlantic bluefin tunas.

It should also be noticed that juvenile bluefin have been also targeted in the Bay of Biscay, mainly by Spanish fishermen, during their summer feeding migrations, since the 17th century, but mainly since the nineteenth century by troll and more recently by pole and line vessels using live bait.

## 3. 20$^{th}$ century: A wide diversity of multiple fishing gears targeting bluefin in many areas

### *3.1 Overview of catch trends by bluefin fisheries*

**Figure 2** shows an estimated trend of bluefin catches by gear in the Atlantic during the 20$^{th}$ century. This figure shows the low negative impact of the world war 1 and 2 on the bluefin fisheries and the quite high level of bluefin catches by traps during the first half of the century in a range that can be estimated between 10 and 20,000 tons yearly and with an average catch of 15,000 t during the 1900-1949 period (always large fish). This figure also shows the major decline of the trap fisheries during the second half of the century and the major increase of total catches, reaching an average level of 30,000 tons during the second half of the twentieth century, primarily due to purse seiner catches, but also to increasing longline catches since 1960. All these fisheries have been fairly well documented in a wide range of ICCAT scientific documents. This chapter 3 will be focusing on a brief review of the changes observed in some selected fisheries of peculiar interest, while the following chapter 4 will analyse the changes observed in the Japanese bluefin fishery by longliners.

### *3.2 1900-1970: North Sea bluefin fisheries*

Harpoons (manual and using a gun), and hand lines have been used by Norwegian artisanal fishermen in the fjords to catch bluefin (and probably also before the 20$^{th}$ century). Active purse seine fisheries were developed by Norway starting since 1930, but with quite low total yearly catches, mainly because of the very small boats and nets used in these early years, when large biomass of bluefin where often observed and reported by scientists as well as by fishermen (well before and during this early period). The major development of Norwegian purse seiners fishery targeting bluefin was only after WWII, but it appears that bluefin was sometimes very abundant well before. For example 2,000 tons of small bluefin were caught in Goteborg bay, Sweden, by sardine vessels and hand lines during a single month in August 1942.

Major fisheries developed in the North Sea (sensu largo) mainly off Norway (Hamre *et al.* 1968, Tangen *et al.*, Nottestadt et al this conference) and also in Germany, Denmark and Sweden during the period 1930-1960 (**Figure 3**), targeting large or very large bluefin, should also be kept in mind (MacKenzie 2007). The increasing

sizes of bluefin caught in the North Sea (Fromentin, this Symposium) indicate that there was no significant recruitment in the North Sea fishery since the late fifties and sixties, leading to the collapse of the fisheries during the sixties. The end of the North Sea bluefin fishery is not fully understood (Tiews 1978), but it is not due to the overfishing of the bluefin stock, but probably to environmental causes and changes in the bluefin migration patterns (Fromentin this symposium). This recent major change in the geographical distribution of the bluefin population remains widely questionable, and it is not understood why the adult bluefin did not came back during recent years in the North Sea, when they are quite abundant off Island and Faeroe Islands, and when herring stocks are now abundant in the North Sea.

### *3.3 Mediterranean Sea and Gibraltar area:*

Record high catches have been more or less permanently observed during the 20$^{th}$ century in this area, by a wide diversity of fisheries and gears, but predominantly by traps until the middle of the 20$^{th}$ century. It is also quite clear that there have been major changes observed in the Mediterranean fishing zones, but unfortunately the very poor quality of the present ICCAT catch and effort data does not allow to show and to analyse these changes. It would, for instance, appear that there was a major spawning zone off the Baleares Islands during the 1990s, when this fished stratum is now more or less vanished (possibly in relation with an overfished and now vanished sub population?).

More recently, very high bluefin catches were noticed off Turkey and Libya, but these geographical changes cannot be evaluated quantitatively as the 1° squares catches have not been declared to the ICCAT for most of the fleets fishing in these areas. Major catch declines have been observed during recent years for most Mediterranean traps, a decline probably indicative of the presently low adult biomass.

It should also be noticed that among the countries targeting bluefin near the entrance of Mediterranean Sea, Morocco has been always a major bluefin fishing country, permanently active in the Atlantic, Gibraltar and the Mediterranean Sea, taking note that this country has also been facing a period of major decline of its bluefin fisheries, at the end of the 1960s and 1970s (**Figure 4**).

### *3.4 Black Sea*

Bluefin has been fished in the Black Sea since ancient times, and also during the first half of the last century and until the 1960s. The species was often recorded in small schools off the northern coast of the Black Sea in late summer and during the autumn (without target fishery). Bluefin used to migrate in the autumn to the mouth of the Kerch Strait (narrow strait between Azov and the Black Sea) to forage on the Azov population of anchovy (*Engraulis encrasicholus*), which migrate for wintering to the Black Sea (Romanov Pers. Com.). It was reported (anecdotical records) that bluefin damaged anchovy purse seines breaking net wall during their movement in and out of the purse seine. Bluefin were also often recorded as by-catch in the traps along southern Crimea. Starting from the early 1970s, bluefin becomes very rare on the north coast of the Black Sea: the last bluefin reported in the Black Sea was caught in 1975 (trap by-catch). Nowadays: bluefin vanished from the Black Sea, probably in relation with the severe overfishing and decline in the quality of its ecosystem (most top predators having also vanished from this semi closed sea).

It can also be noticed that the world record of the largest bluefin ever caught has been observed in the Black Sea, 787 kg.

### *3.5 Bluefin sport fisheries*

There is a long history of various bluefin sport fisheries targeting bluefin in various areas of the Atlantic Ocean. Bluefin sport fisheries have been active since 1850 on the eastern coast of United States, and small bluefin were commonly caught recreationally in this area since the mid 1850s. The first bluefin giants, that were common during these years, were caught only in the early years of the 20$^{th}$ century, and only following the development of suitable fishing tackle and the improvements in fishing vessels. A major bluefin tournament, the Sharpe cup, has been targeting giant bluefin in Nova Scotia since 1930. A bluefin world record has been observed in this Nova Scotia sport fishery: 1496 pounds in 1979. The US sport fishery has been very active until 2003, but since 2004, it has been noticed that the U.S. bluefin catches/CPUEs of large bluefin by rod and reel are very low, probably due to a local effect, while simultaneously in Canada, the Gulf of St Lawrence bluefin catches/CPUEs are high.

Various sport fisheries targeting bluefin can also be noticed in various areas, in England, in Denmark, France (northern Brittany, see Fonteneau and Le Person, this document), etc, but unfortunately the activities of most of these sport fisheries are still poorly documented and never reported to the ICCAT. These data would clearly be of great scientific interest to follow the spatio-temporal changes of the bluefin distribution, and an increased effort should be developed by ICCAT to recover these valuable historical data.

## 4. 1956-2006: half a century of Japanese longline fisheries

### *4.1 Overview*

Japanese longliners have been the major fleet permanently catching large quantities of bluefin in the Atlantic and in the Mediterranean Sea since the early sixties. As a consequence, the percentage of bluefin caught by Japanese longliners against total bluefin catches by longliners has been always very high: 70% of the total bluefin catches by longliners during the 1950-2005 period were caught by Japanese vessels (**Figure 5**). Furthermore, as this major Japanese fleet has always been providing the ICCAT with quite good catch and effort statistics, at least much better than all other bluefin fisheries, these detailed catch and effort data offer a highly valuable potential for a scientific analysis of changes in the bluefin population. The overview of the bluefin catches and CPUEs by Japanese longliners during the period 1956-2006 will be discussed in the following paragraphs.

Yearly and monthly bluefin catches by area by the Japanese longliners since 1960 have been synthesized and shown by **Figures 6** and **7**:

– **Figure 6** shows the yearly and average monthly catches observed in 6 selected areas of major interest for bluefin: Mediterranean Sea, Gulf of Mexico, USA East Coast, Azores Iceland and Brazil.

– **Figure 7** shows the monthly catches taken each year by Japanese longliners in the same six fishing areas during the same period 1960-2006. This figure is of key interest to show the major historical changes observed in the bluefin time and area fishing strata of Japanese longliners.

### *4.2 Period 1956-1966*

The first Japanese longliners arrived in the Equatorial Atlantic in 1956 and they concentrated their fishing activities targeting yellowfin in the Equatorial areas between 10°N and 10°S (**Figure 8**). During their 3 first years of activities, there was no report of significant bluefin catches by the fleet (only 743 individuals reported during these three first years), keeping in mind that during the same period, there were already various bluefin fisheries already active in the Northern Atlantic (Morocco, North Sea, and USA) and in the Mediterranean Sea (**Figure 9**).

On the opposite, during subsequent years 1959-1966 and in the same equatorial fishing zone, very high catches and very high CPUEs of bluefin were seasonally noticed for the Japanese fishery (before the implementation of deep freezing, when bluefin was sold at canneries at a low value per kilo). Surprisingly, these first large bluefin catches were taken only in the equatorial areas off Brazil and in warm surface waters (in a range between 24° and 28°C). Bluefin were not « the » target species in this equatorial fishery, then dominated by yellowfin, but it was often seasonally the dominant species (**Figure 10**), thus also probably often « a » real target of Japanese longliners, despite the low relative value of the species. This was for instance probably the case in April 1964 when approximately 2,700 tons of bluefin were caught during one month, i.e. 60% of the total tuna catches taken in this area.

The following period 1964-1966 has been, for the Japanese longliners, their period of highest bluefin catches, an average of 14000 t. being taken each year during this period, and possibly much more[2]. This Brazilian equatorial fishery was a highly seasonal one, taking place each year in March and April, and later in September and October, i.e. before and after the typical Bluefin spawning season in the Mediterranean Sea and in the Gulf of Mexico (**Figure 11**) (Takeuchi *et al*., this symposium). Bluefin sizes caught were quite different in the North Sea and Brazil areas, smaller fishes being taken off Brazil at an average weight of about 180 kg (based on the small

[2] It appears that the Japanese bluefin catches off Brazil may have been possibly widely underestimated. This conclusion can easily be reached: if the total number of bluefin reported to the ICCAT as being caught in the Brazil area is correct – a total of 157.000 fish caught during the 1958-1966 period, and if the average weight of 180 kg estimated from Japanese size sampling is correct, then these historical bluefin catches taken by Japan off Brazil could have been underestimated by a factor of nearly 2.

size sampling done by Japan, Takeuchi *et al.* 1999), while a majority of North Sea bluefin during this period had an average weigh well over 200 kg.

The equatorial status of these bluefin catches still remains very strange, as bluefin have never been significantly caught in such warm waters after this fishing event (although large numbers of longliners have been since permanently fishing in this area). The origin and status of these fishes remain widely uncertain: the rather limited Japanese sampling tend to indicate that these bluefin were not in spawning condition (Takeuchi *et al.* 1999), and the analysis of monthly CPUEs by area tend to suggest that these fishes were then doing a southward migration (south of 15°S) during the Northern winter. As large fleets of longliners have been permanently fishing in the same area, but without bluefin catches, it can be concluded that the major bluefin concentrations then observed off Brazil are now vanished ones.

In the same geographical area, it should also be noted and kept in mind, that during the 1964-1967 period, large catches of bluefin have been also taken off Florida and Bahamas in May and June, typically the bluefin spawning season observed in the Gulf of Mexico and in the Mediterranean Sea, taking note that these bluefin were highly concentrated in a small time and area strata. Unfortunately, the biological condition of these bluefin remains poorly understood, and this stratum is not considered as being a known spawning stratum, although such hypothesis has recently been envisaged by Lutcavage *et al.* 1999 based on the results obtained by pop up tagging.

A final comment on the yearly bluefin catches observed during this early period is that a cascading decline of yearly catches has been observed between the Nordic, Brazilian and Bahamas fisheries, a decline leading to the very low level of catches later observed in these 3 fisheries (**Figure 12**).

### *4.3 Period 1967-1974*

Very low yearly catches of bluefin were caught by Japanese longliners during this period, only 1300 t. /year. This period took place just before the implementation of ultra freezing and its subsequent sashimi boom, thus probably in relation with a low targeting of the species. It was also the period of lowest bluefin total catches in the entire Atlantic, with an average yearly total catch of only 16,000 tons (period 1968-1973), probably due to a combination of low abundance and still a low commercial value in Japan.

### *4.4 Period 1975-1993*

The first years of this period, 1975-1980, took place during the fast development of deep freezing on board the Japanese fleet, and when bluefin had been increasingly targeted by longliners (and other gears), because of its increasing value on the sashimi market. Quite large catches of bluefin were then been caught in the Gulf of Mexico during this 1975-1981 period, when after the implementation of low bluefin quotas in the western Atlantic in 1981, the Japanese longliners moved to new fishing zones in the northern Atlantic South of 45°N, between the eastern coast of the United States and Morocco. This period of still moderate yearly catches was a transition period for Japan, and producing an average catch of 3,000 tons of bluefin each year.

### *4.5 Period 1994-2006*

The most recent period, 1994-2006, has been showing moderately increasing yearly catches of bluefin, with an average level of 3,600 t taken each year by Japanese longliners, and the time and area patterns developed by the fishery have been remarkably stable during the entire period. **Figure 7** shows a major targeting of northern feeding concentrations North of 50°N and reaching 65°N, between August and November. Minor bluefin catches have been also observed each year in the central eastern Atlantic (March to May or June) and in the Mediterranean Sea (in May), these fisheries targeting pre spawning bluefin.

### *4.6 An average overview of 50 years of Japanese longliners bluefin fishing*

A global summary of fishing activities exerted by Japanese longliners during this half century of bluefin fishing can be given by a map showing the best monthly CPUE ever observed in each 5° squares and month for this fleet during the 50 years period (**Figure 13**). Such a map is showing all the areas where bluefin had sometimes during the period a high local monthly abundance. A corresponding figure, **Figure 14**, shows the average of the 3 best monthly bluefin CPUEs by 5° squares observed for the Japanese fleet during the same period, a figure showing that if the highest bluefin CPUEs have been observed during the early period (before 1980), these best CPUEs have been quite stable during the entire period.

A similar historical overview of Japanese bluefin activities is also given by the map showing the average bluefin catches by 5° squares during the entire period and also showing the Longhurst (2007) ecological provinces **(Figure 15)**. The geographical distribution of these bluefin fishing zones is quite wide and scattered in various ecosystems, and surprisingly without any dominant fishing zone, as each of the main fishing areas has been dominant and predominantly fished only during a limited fraction of the entire 50 years period. As a consequence, bluefin caught by Japanese longliners during the period have been taken in a wide range of sea surface temperatures (**Figure 16**) ranging between 3° and 28°C.

### 4.7 Conclusion on Japanese longline fisheries and bluefin

Japanese longliners have always been and by far the main LL fleet targeting bluefin in the Atlantic and they are clearly of major interest in order to study the rather unique biological and fishery patterns that are typical of bluefin tuna. These 50 years of Japanese catch and effort data are clearly of major interest to study and to better understand the dynamics of bluefin in its environment in the Atlantic. Many of these changes in the bluefin fishing strata remain widely unexplained and further investigations should be developed by SCRS in order to at least understand their mechanisms.

## 5. Bluefin: historical lessons from biology and fisheries

Bluefin tuna in the Atlantic has been the tuna species showing the greatest flexibility, and permanently changing its areas of concentration and its apparent migration routes. Bluefin tuna is also and by far, among all other tuna species, the species having shown the best thermoregulation and being taken in the widest range of SST: from sub Arctic to equatorial waters (**Figure 15**). This species is also showing a wide variability of its vulnerability to fisheries:

– Bluefin stocks are highly vulnerable to a wide range of fisheries especially before, during & after their spawning seasons, as bluefin tunas have been always showing a strict homing towards its spawning “hot spots” that are taking place in well known and very small time & area strata (Cury 1994). There is probably no choice for bluefin but to show such a strict homing behaviour, and spawning in its very small birth strata, but this fundamental evolutionary characteristic is increasingly dangerous in the world of modern fisheries. These spawning strata are also possibly showing some year to year variability, for instance due to environment (Mediterranean Sea) and/or to overfishing (end of spawning in the Baleares Islands area?), and also a possible subsequent genetic erosion of its sub-populations.

– Bluefin stocks are also highly vulnerable during their feeding concentrations that appear to be highly variable over time: vanishing feeding concentration off Brazil, off Norway, in the Black Sea, off Trebeurden (sport fishery) and recently along the U.S. coast. However some of these feeding concentrations, for instance of juvenile bluefin in the Bay of Biscay, seem to be relatively stable, at least at the limited time scale of the available data.

– On the contrary, it should also be noted that outside of these feeding and spawning hot spots, the vulnerability of the bluefin population to the fisheries is probably quite low, due to the wide habitat of the species (geographically and vertically) and to its quite low overall biomass.

Bluefin historical fisheries have been permanently showing quite unique large scale variability, at both local and global scales, but surprisingly this major geographical variability of bluefin fisheries and stocks remains most often poorly explained. Part of this variability can probably be explained by environmental fluctuations and by subsequent long term biomass cycles that have been well demonstrated by Fromentin and Ravier. There is no doubt that the environmental variability widely conditions (1) the bluefin spawning strata, (2) their feeding strata, and (3) the overall levels of bluefin biomass. However, it appears that many of the observed changes in bluefin fisheries and fishing zones remain difficult to fully explain: North Sea, Brazil, Bermuda, more recently vanishing bluefin on the U.S. coast and in the Baleares fishing grounds, and others. The increasing effects of bluefin overfishing and of subsequently declining stock biomass sometimes offer logical and clear potential explanations. However, the local declines of the bluefin favourite preys may also partly explain some local declines in the US coast, in Norway, in the Trebeurden Bay, etc. In various cases, such as the collapse of the Brazilian and of the North Sea fisheries, our understanding of these major changes remains widely limited and questionable.

## 6. Conclusion

The Atlantic bluefin probably offers the best example of “highly migratory species” exploiting a very wide range of temperate & equatorial ecosystems. Surprisingly, when the observed time and space variability of the bluefin biomass is clearly a major one, it remains still poorly understood by scientists. As a consequence of this lack of understanding, it remains impossible to model its fine scale and global stock dynamics, due to its great & widely unexplained variability. This is no doubt that an improved understanding of the observed major changes in the distribution patterns of bluefin would significantly improve the assessment of its population (Brill and Lutcavage 2001).

However these major scientific uncertainties concerning bluefin could be partly solved in the future if a major research effort could be conducted by ICCAT scientists in four fields:

– Very good Task II statistics should be obtained on all fleets, so as to obtain all the legal ICCAT basic catch and effort and sizes statistics for bluefin (that are presently missing for most bluefin fisheries). A fishing fleet that is not providing 100% of this legal TASK II data to the ICCAT should not be allowed to fish bluefin!

– An improved biological research should be urgently conducted on spawning and feeding bluefin tunas: their feeding, behavior and migration routes as a function of the environment, as well as upon spawning potential as a function of age. This basic biological research remains very weak and widely insufficient for such a complex species.

– An intensive wide scale tagging program be conducted on bluefin: tagging all sizes and in all the main fishing zones, using dart tags, archival and pop up tags, and more importantly ensuring that all major fisheries are reporting well their recoveries of tagged tunas (if necessary with observers on board fishing vessels and at the farms).

– A major Atlantic wide research should also be conducted on increased data analysis, based on a improved data mining of historical data, and analyzing all the existing bluefin fishery and tagging data in depth, and also fully taking into account the environmental variability and the variability of preys available to bluefin.

Such a major research effort should widely help to better understand the historical variability of the bluefin fisheries and to obtain a fully comprehensive and realistic modelling and stock assessment of the Atlantic bluefin population.

## References

Brill, R.W., Lutcavage, M.E. 2001. Understanding environmental influences on movements and depth distributions of tunas and billfishes can significantly improve population assessments. *American Fisheries Society Symposium* 25, 179-198.

Cury, P. 1994. Obstinate nature: An ecology of individuals. Thoughts on reproductive behaviour and biodiversity. Canadian Journal of Fisheries and Aquatic Science 51, 1664-1673.

Desse, J., Desse-Berset, N. 1994. Stratégies de pêche au 8ème millénaire : les poissons de Cap Andreas Kastros (Chypre). In: Fouilles récentes à Khirokitia (eds. A. Le Brun), Editions Recherche sur Civilisations, Paris, pp. 335-360.

Doumenge, F. 1998. L'histoire des pêches thonières. Collect. Vol. Sci. Pap. ICCAT 50, 753-803.

Fromentin, J.M. 2008. Back to the future: Investigating historical data from Atlantic bluefin tuna fisheries. This Symposium

Fromentin, J.M. 2008. Lessons from the past: investigating historical data from bluefin tuna fisheries. Fish and Fisheries, 2008, 10, 1-20.

Hamre, J., Lozano, F., Rodriguez-Roda, J., Tiews, K. (1968) Report from the bluefin tuna working group. Conseil Permanent international pour l'Exploration de la Mer, Copenhagen, Statistical Newsletters No. 38, 27p.

Longhurst, A. 2007. Ecological Geography of the Sea. Academic Press, 560 p.

Lutcavage, M., Brill, R.W., Skomal, G.B., Chase, B.C., Howey, P.W. 1999. Results of pop-up satellite tagging of spawning size class fish in the Gulf of Maine: do North Atlantic bluefin tuna spawn in the mid-Atlantic? Canadian Journal of Fisheries and Aquatic Science 56, 173-177.

Mather, F.J., Mason Jr, J.M., Jones, A. 1995. Historical document: life history and fisheries of Atlantic bluefin tuna. NOAA Technical Memorandum NMFS-SEFSC-370, Miami, 165 pp.

MacKensie, B.R., Myers, R. 2007. The development of the northern European fishery for north Atlantic bluefin tuna Thunnus thynnus during 1900-1950. Fisheries Research, 87, 229-239.

Nøttestad L., Tangen, Ø., Sundby, S. 2008. Possible mechanisms and explanations for the drastic decline and disappearance of Atlantic bluefin tuna in the Norwegian fisheries since the early 1960s: What went wrong and what can we do? This Symposium.

Pusineri, C., Ravier, C., Fromentin, J.-M. 2002. Retrospective analysis of the bluefin tuna Nordic fisheries data. Collect. Vol. Sci. Pap. ICCAT 54(2): 517-526.

Ravier, C., Fromentin, J.-M. 2001. Long-term fluctuations in the eastern Atlantic and Mediterranean bluefin tuna population. ICES Journal of Marine Science 58, 1299-1317.

Takeuchi, T., Suda, A., Suzuki, Z. 1999. Review of information on large bluefin tuna caught by the Japanese longline fishery off Brazil from the late 1950s to the early 1960s. Collect. Vol. Sci. Pap. ICCAT, 49(2): 416-428.

Takeuchi, T., Oshima, K., Suzuki, Z. 2008. Inference on nature of Atlantic bluefin tuna off Brazil caught by the Japanese longline fishery around the early 1960s. This Symposium.

Tangen, Ø. 2008 The Norwegian fishery on Atlantic bluefin tuna 1920-1985, This Symposium.

Tiews, K. 1978. On the disappearance of bluefin tuna in the North Sea and its ecological implications for herring and mackerel. Rapport et Procès-verbaux des Réunions du Conseil international de l'Exploration de la Mer 172, 301-309.

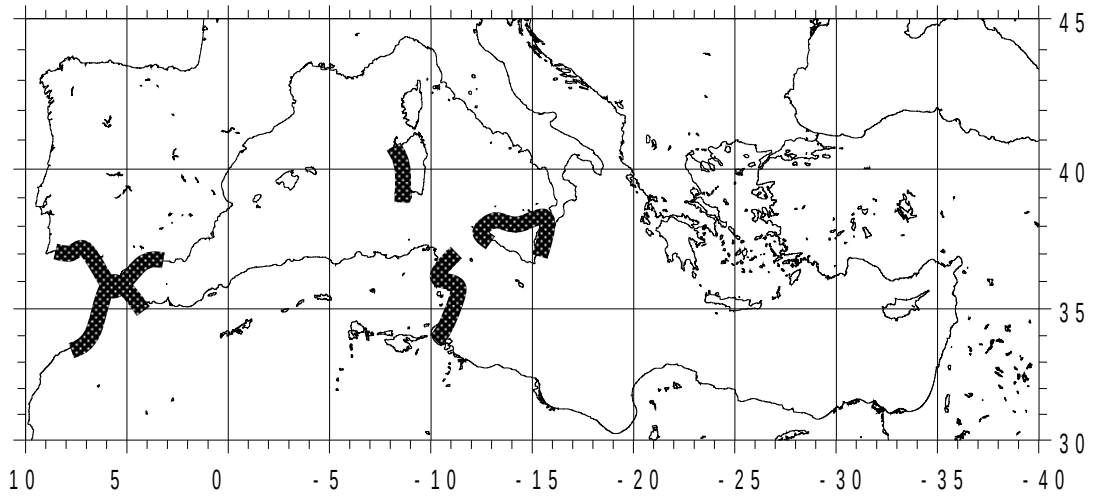


**Figure1.** Main areas where bluefin traps have been active in the Mediterranean Sea and in the Atlantic close to the Strait of Gibraltar.

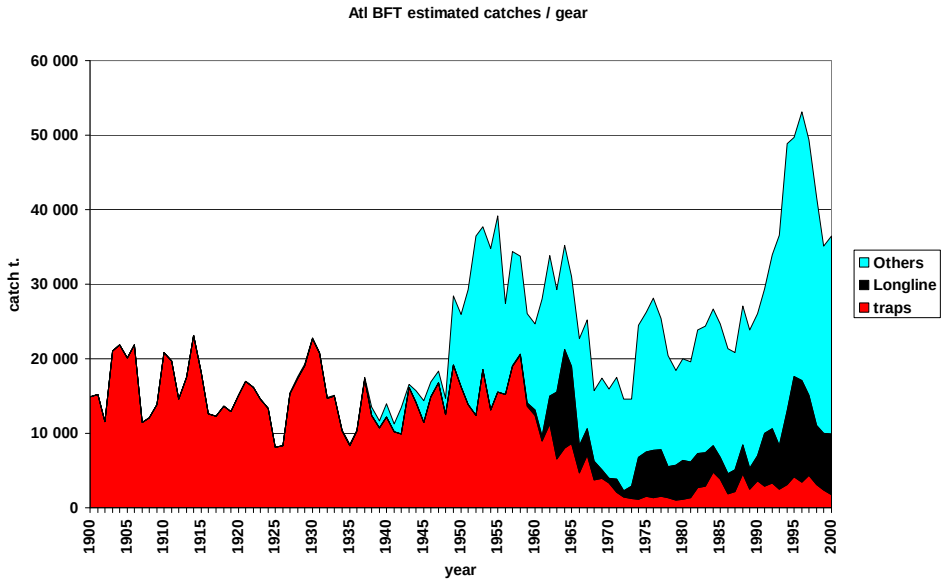


**Figure 2.** Bluefin catches by gear during the 20th century (catches during the 1900-1949 period have been estimated from Fromentin 2008; data after 1950 are taken from ICCAT).

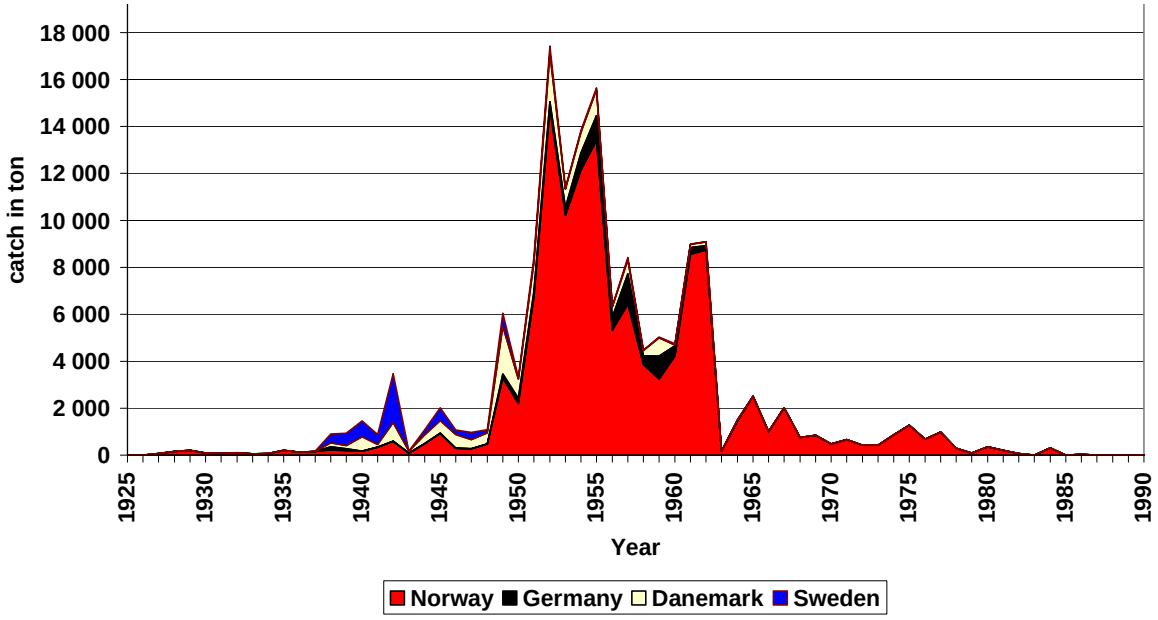


**Figure 3.** Bluefin catches taken in the North Sea by country during the 1930-1990 period.

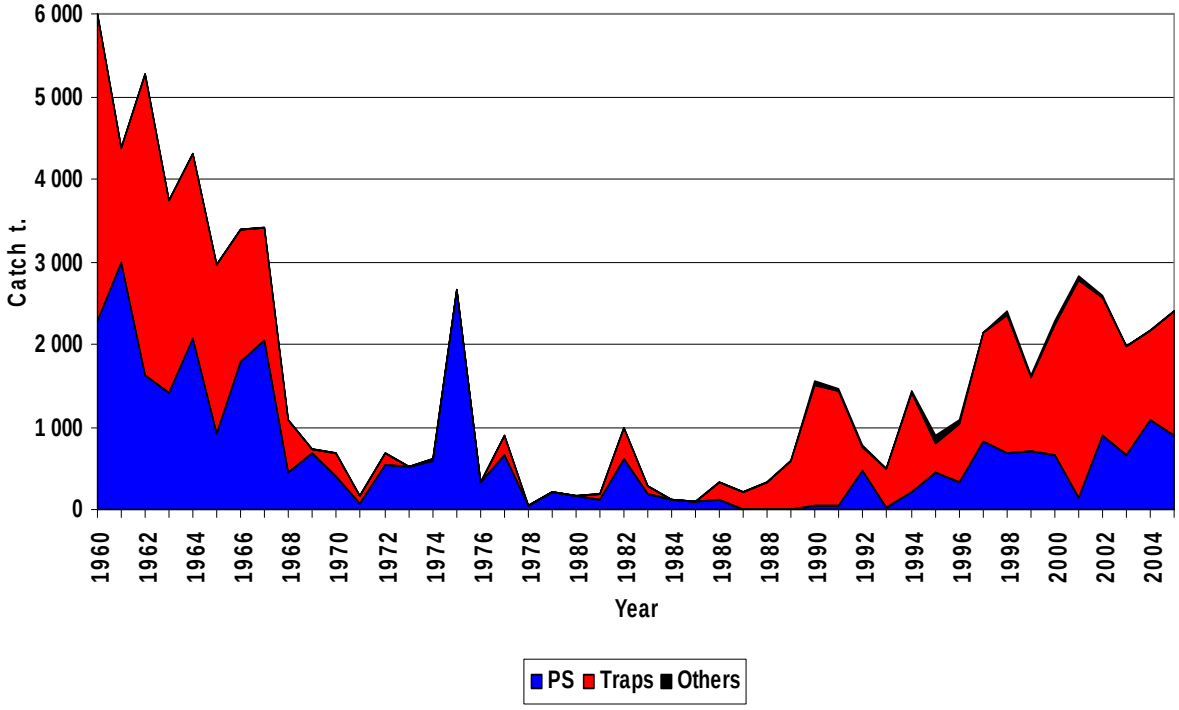


**Figure 4.** Bluefin catches reported by Morocco and its coastal fisheries active in the Mediterranean Sea and the Atlantic during the 1960-2006 period.

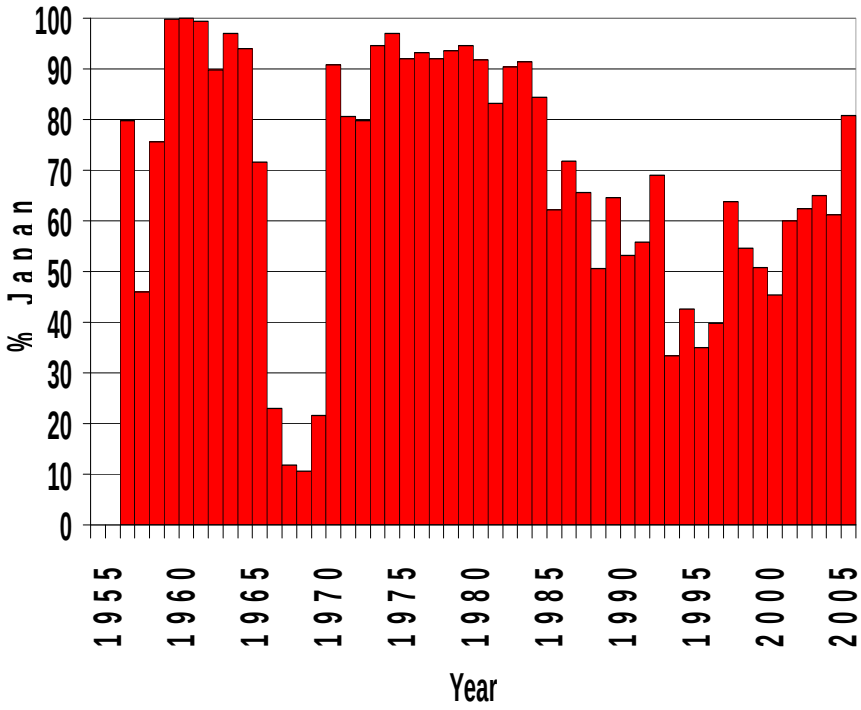


**Figure 5.** Percentage of bluefin caught by Japanese longliners against total bluefin catches by longliners.

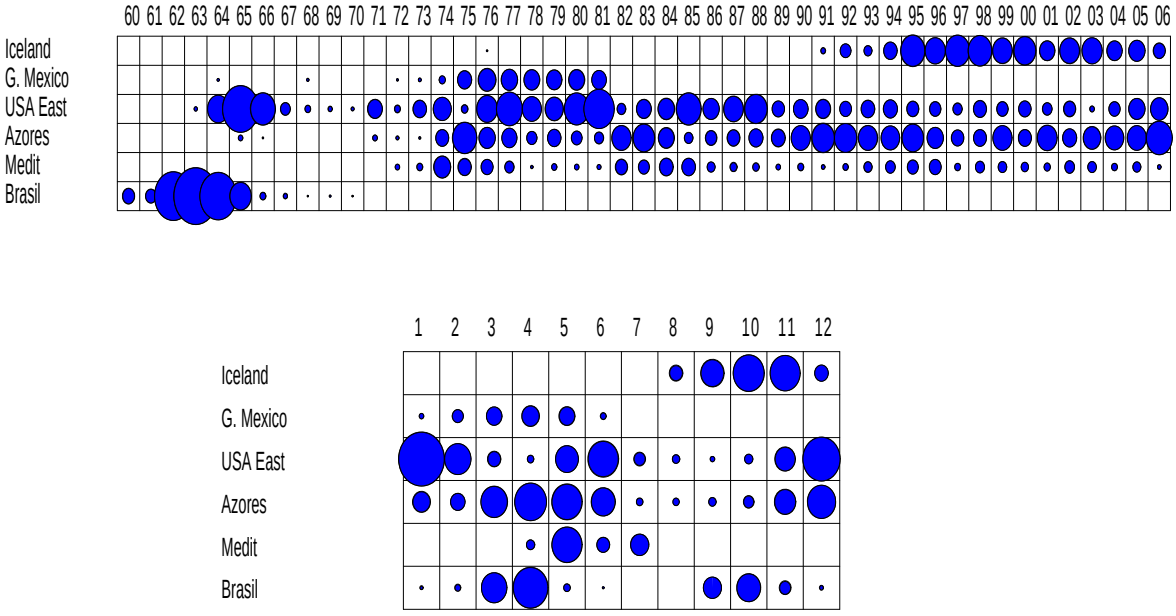


**Figure 6.** Yearly and average monthly catches of bluefin observed in the 6 major fishing zones exploited by Japanese longliners (shown by figure 6) during the 1960-2006 period.

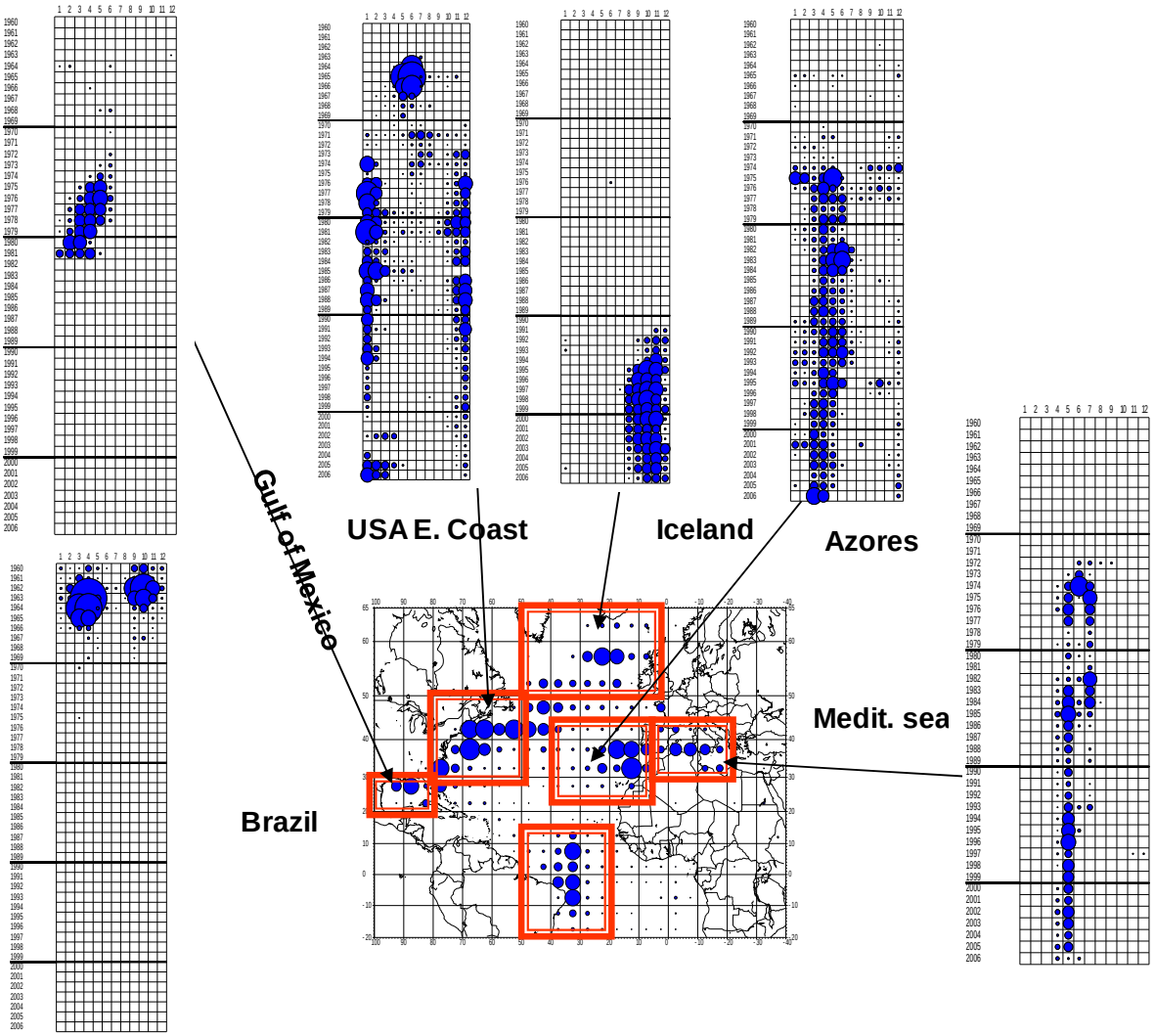


**Figure 7.** Average bluefin tuna catches by Japanese longliners (1960-2006) and monthly bluefin catches by area taken each year by the same fleet in the 6 selected areas shown in the central panel.

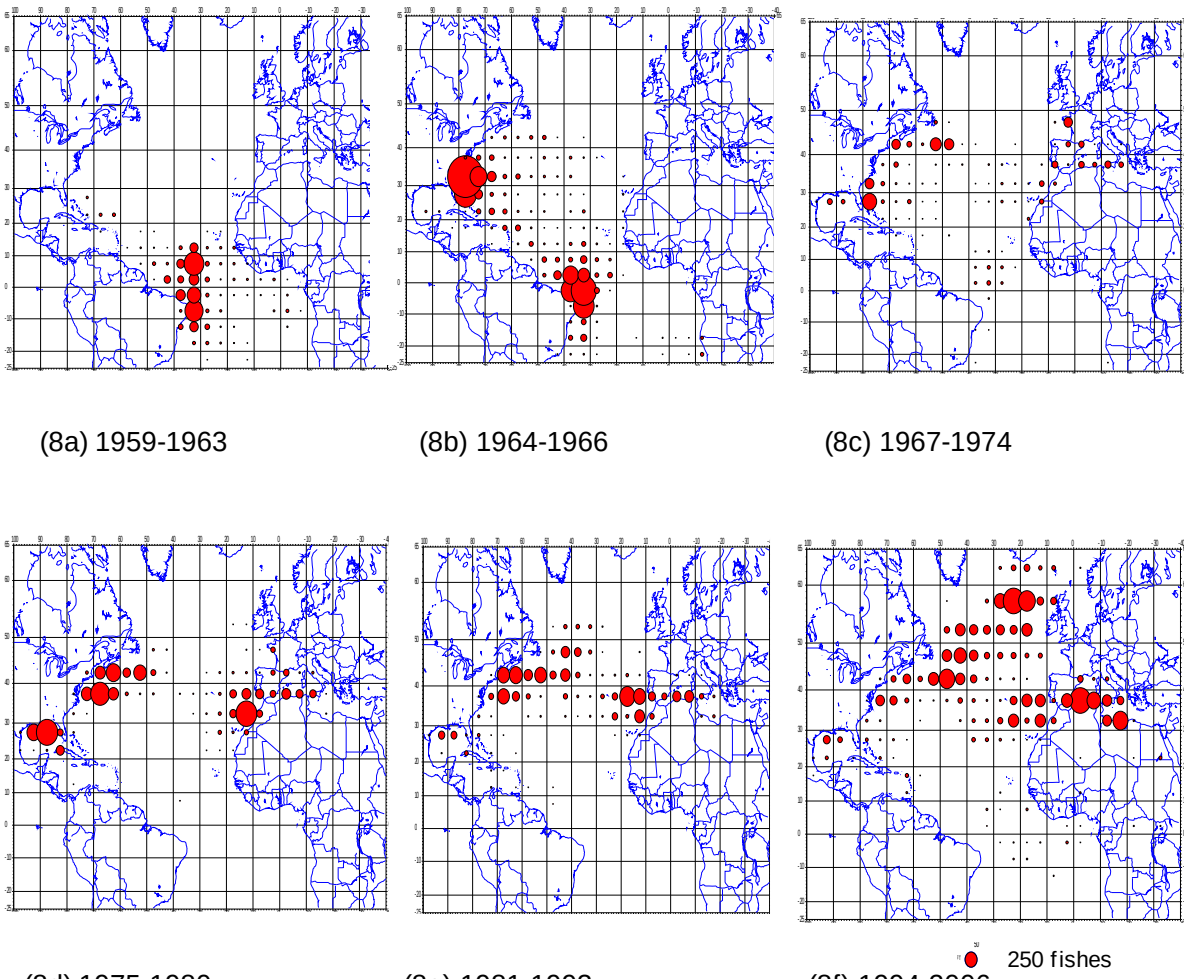


**Figure 8.** Maps showing the average bluefin catches by Japanese longliners during 6 selected periods: (a) 1959-1963, (b) 1964-1966, (c) 1967-1974, (d) 1975-1980, (e) 1981-1993 and (f) 1994-2006.

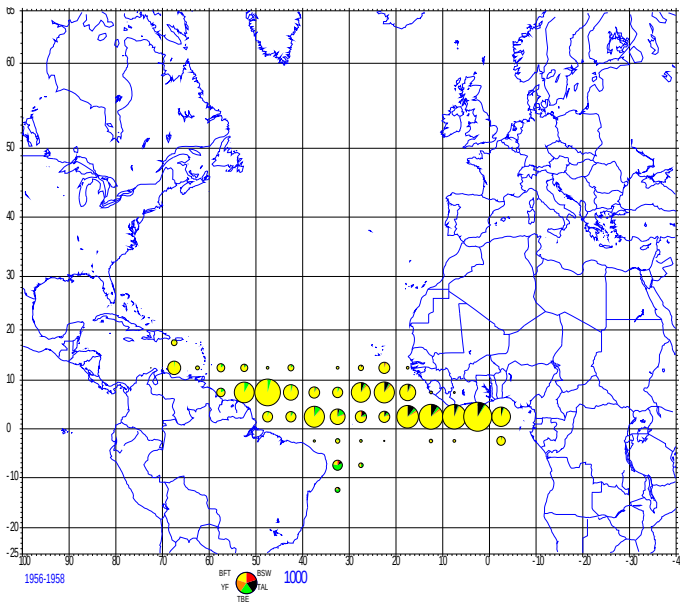


**Figure 9.** Average catches by species, by 5° square, of Japanese longliners during the first years of this fishery, period 1956-1958 (a purely equatorial fishery and without bluefin catches).

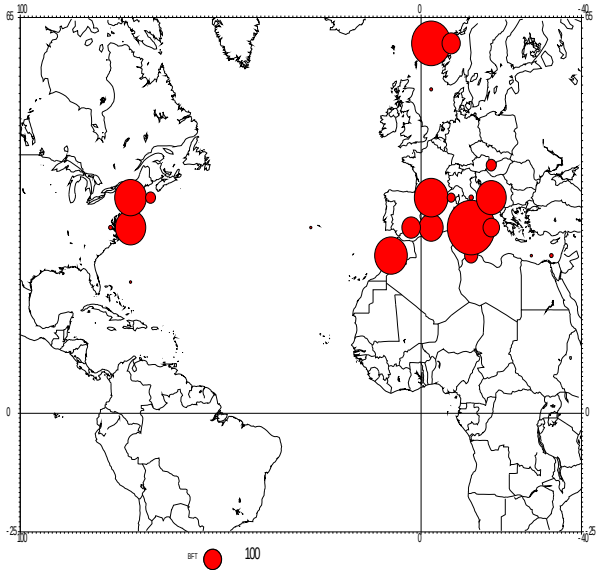


**Figure 10.** Map qualitatively showing the geographical distribution of various major bluefin fisheries active during the 1956-1958 period.

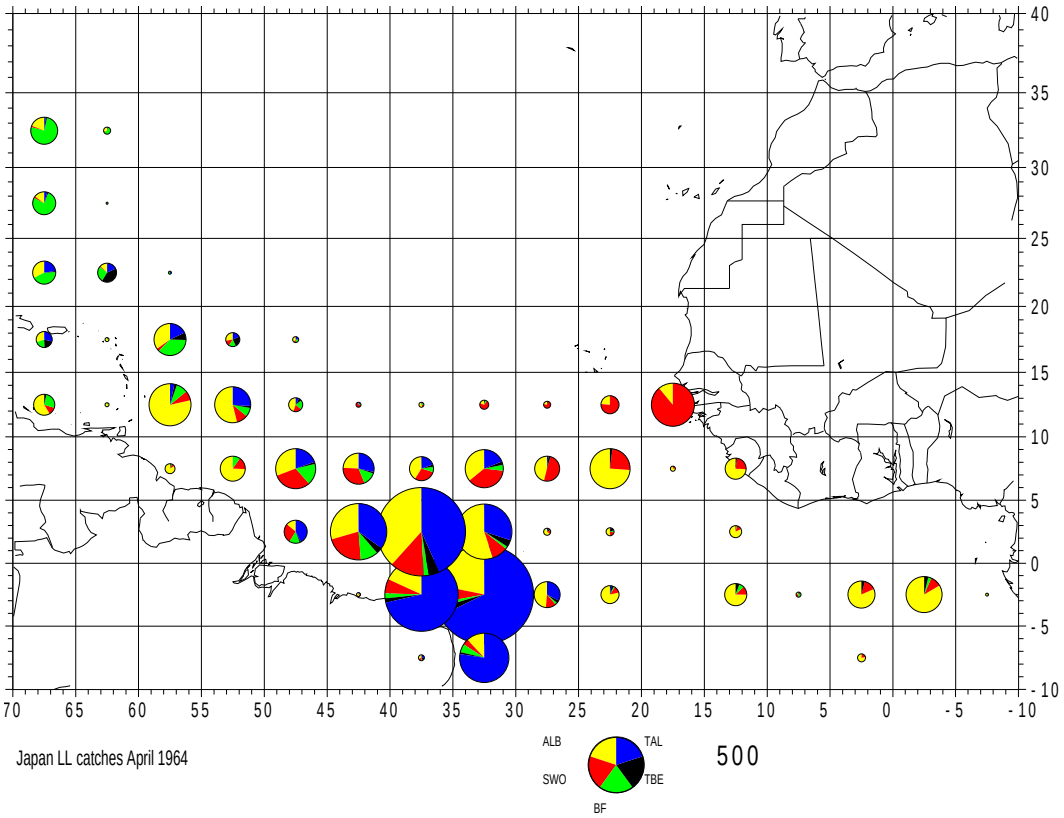


**Figure 11.** Catches by species taken by 5° squares Japanese longliners during the month of April 1964, about 2700 tons of bluefin caught in only 1 month in equatorial waters off Brazil, and corresponding to about 60% of the total catches taken by the fleet during this month in the core fishing area (5°N-10°S, 30 to 40°W).

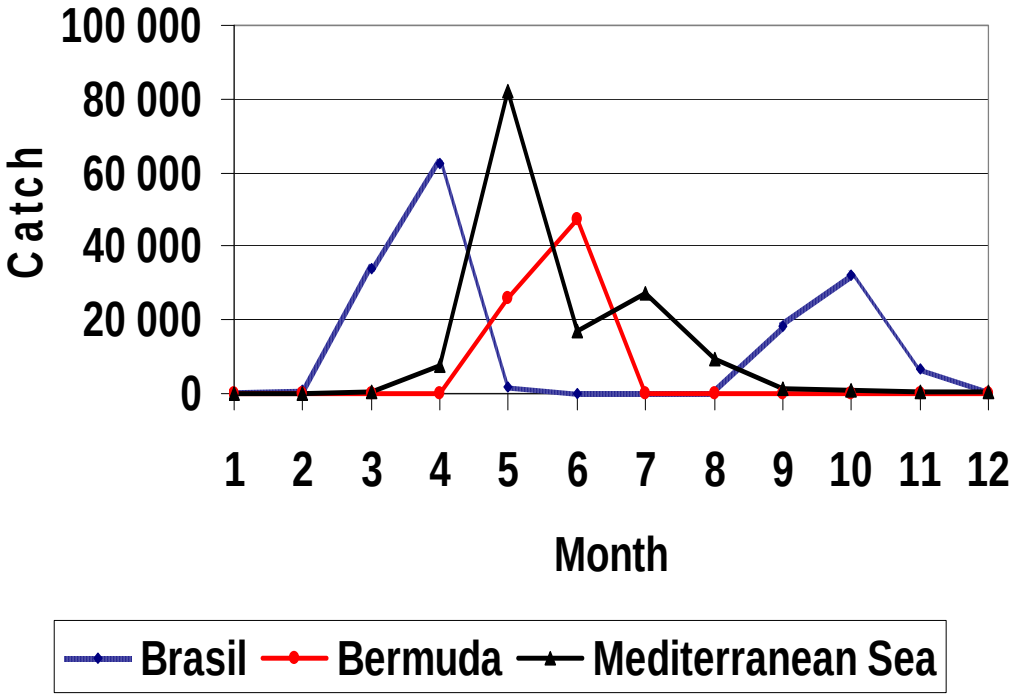


**Figure 12.** Average monthly catches of bluefin in three selected areas: off Brazil, off Bermuda islands (during the early 60ies) and in the Mediterranean Sea (average period 1972-2006).

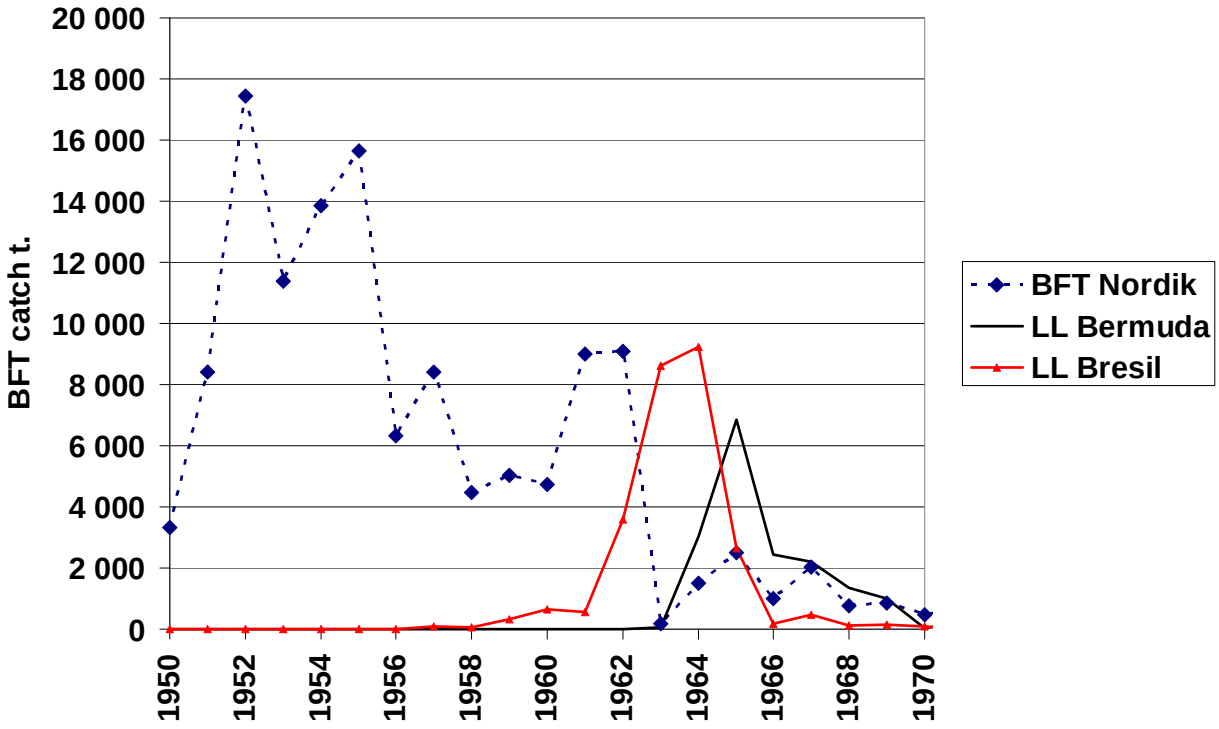


**Figure 13.** Yearly catches of large bluefin caught by North Sea purse seine fisheries, and by longliners off Brazil and the Bahama Islands.

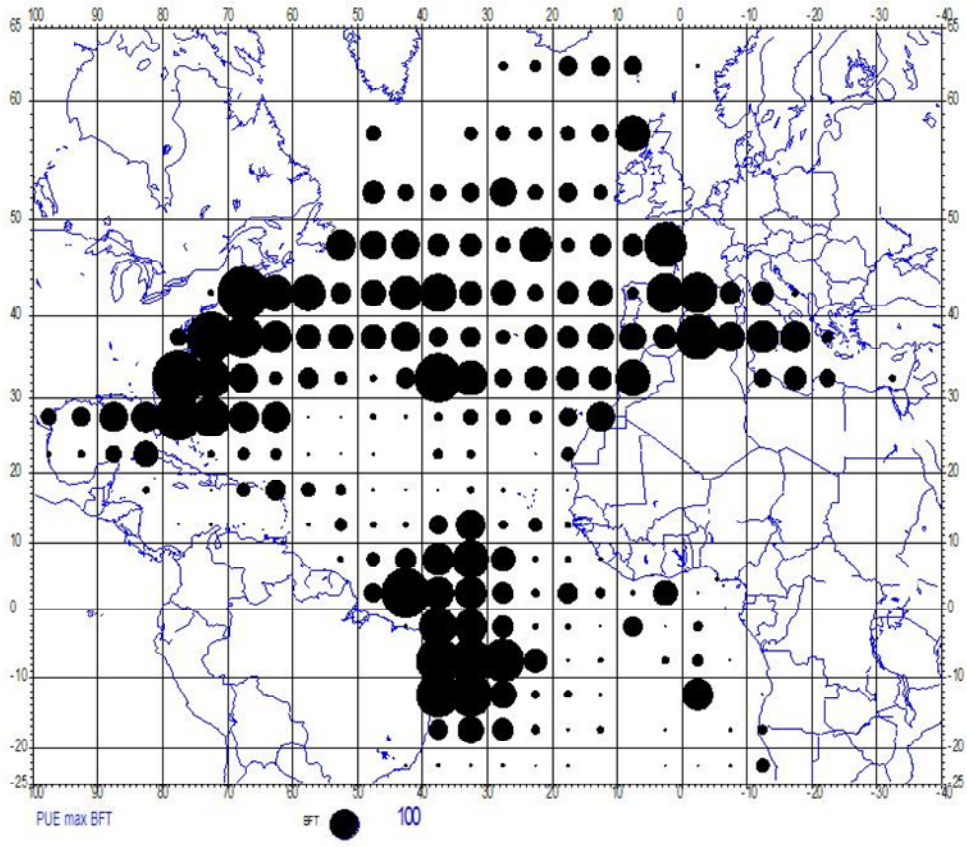


**Figure 14.** Map showing the average best monthly CPUE ever observed in each 5° squares and month for Japanese longliners during the 1956-2005 period.

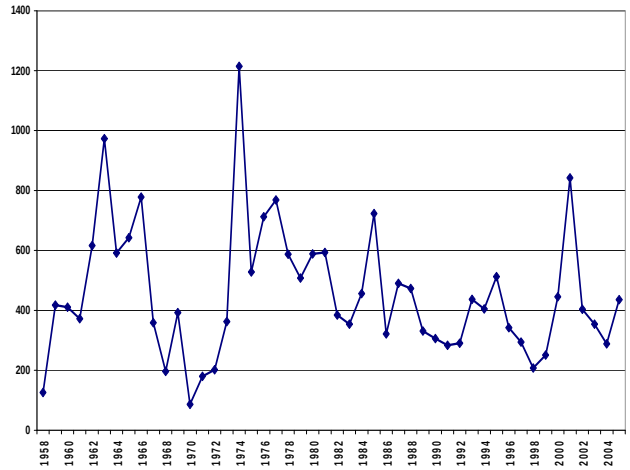

**Figure 15.** Average yearly bluefin nominal CPUEs of Japanese longliners in the monthly 5° squares where/when the bluefin CPUEs was at its highest level.

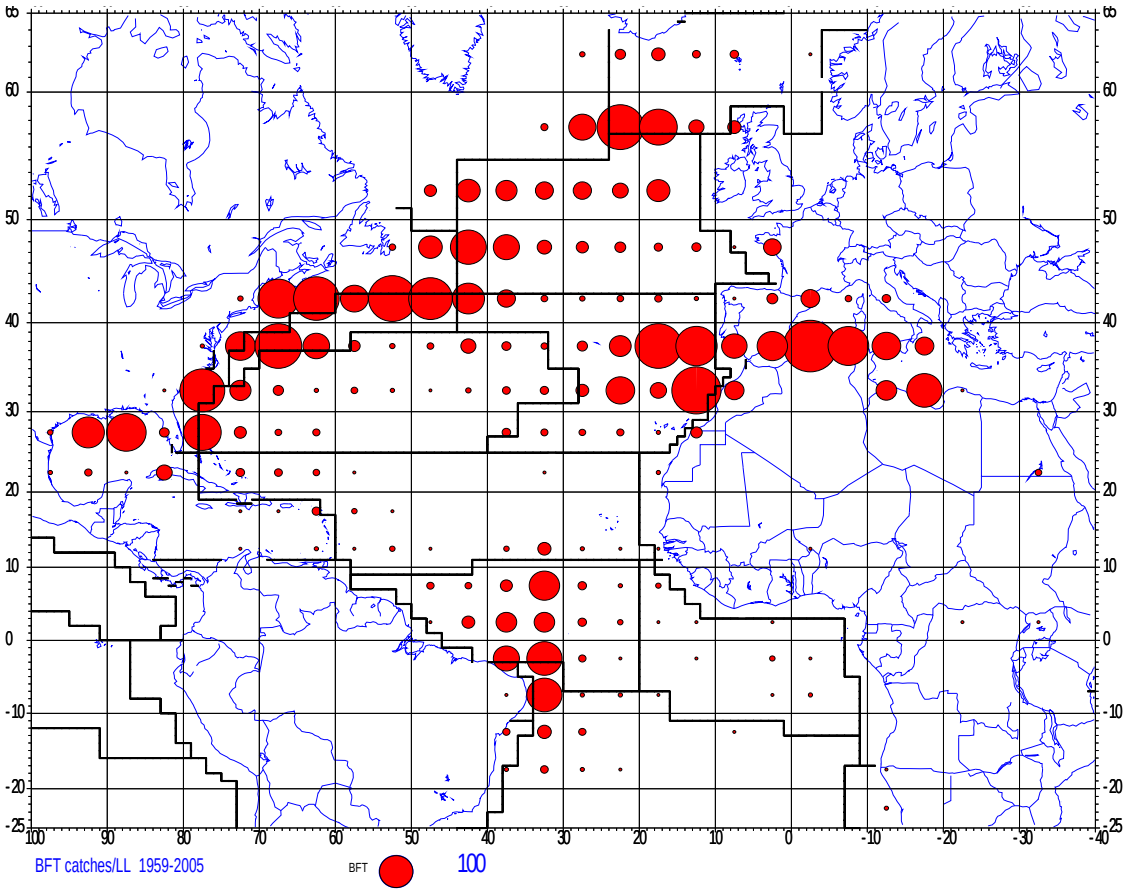


**Figure 16.** Map showing the average bluefin catches of Japanese longliners during the 1956-2005 period and the Longhurst 1998 areas.

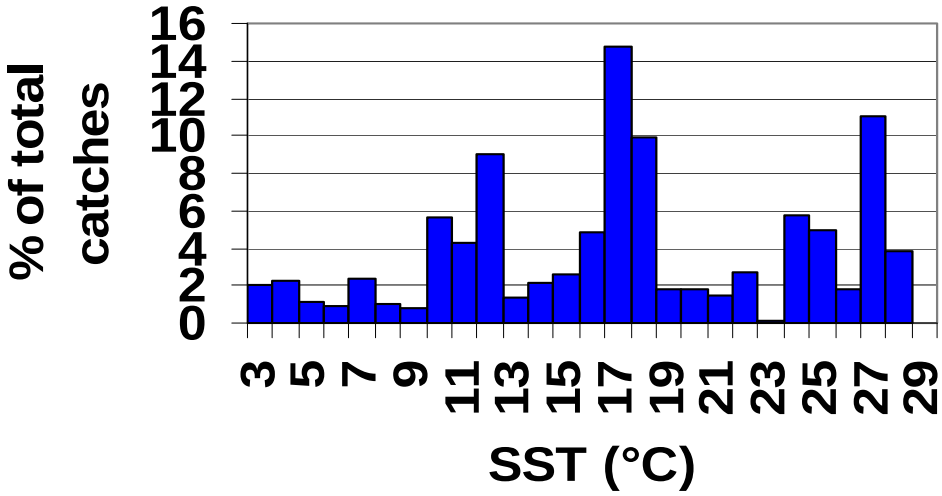


**Figure 17.** Bluefin catches taken by Japanese longliners during the 1956-2006 period as a function of the average statistical quarterly sea surface temperature observed (from Levitu 1998 atlas) in each 5° and quarter fishing strata.