

## MOVEMENT OF ATLANTIC BLUEFIN TUNA TOWARD THE STRAIT OF GIBRALTAR INFERRED FROM JAPANESE LONGLINE DATA

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### SUMMARY

*This paper attempts to infer movement of large adult Atlantic bluefin tuna (ABFT) toward the Strait of Gibraltar for spawning in the Mediterranean Sea using Japanese longline data. Monthly distribution of Atlantic bluefin tuna caught by the Japanese longline fishery indicates counter clockwise movement of Atlantic bluefin tuna. Information on pop-up satellite tags reported by Block et al (2005) was compared with the inferred migratory pattern by the Japanese longline data. There was fairly good agreement in suggesting the counter clockwise movement of the large adult Atlantic bluefin tuna, although the two sets of information seem to suggest difference in the migratory pattern, if any, around the Strait of Gibraltar. Two hypotheses could be proposed for migration around the Strait of Gibraltar: (1) Most of the large adult Atlantic bluefin tuna come to the Strait of Gibraltar area from the south along the Mauritanian and Moroccan coast with some migration from the north along the Iberian Peninsula; and (2) Most of the large adult Atlantic bluefin tuna come to the Strait of Gibraltar area from the north along the Iberian Peninsula although some significant portion migrates from the south along the Moroccan coast. As trap and longline CPUE for large adult Atlantic bluefin tuna, with a fairly good consistent trend, continuously provide vitally important information for population studies, including stock assessment, monitoring and comparing the information of these two distinctively different fisheries are important key elements for management of Atlantic bluefin tuna.*

### RÉSUMÉ

*La présente étude vise à déduire le passage des spécimens de thons rouges de l'Atlantique (ABFT) adultes de grande taille par le détroit de Gibraltar pour aller se reproduire en Méditerranée en utilisant les données des palangriers japonais. La distribution mensuelle du thon rouge de l'Atlantique capturé dans la pêcherie palangrière japonaise indique que les thons rouges suivent un mouvement dans le sens inverse des aiguilles d'une montre. Les informations des marques pop-up reliées par satellite déclarées par Block et al (2005) ont été comparées avec le schéma migratoire déduit sur la base des données palangrières japonaises. Le postulat selon lequel les thons rouges de l'Atlantique adultes de grande taille suivent un mouvement dans le sens inverse des aiguilles d'une montre fait largement l'unanimité, bien que les deux jeux de donnée semblent suggérer des différences du schéma migratoire, le cas échéant, dans les environs du détroit de Gibraltar. Deux hypothèses peuvent être avancées en ce qui concerne la migration dans les environs du détroit de Gibraltar : (1) La plupart des thons rouges de l'Atlantique adultes de grande taille rejoignent le détroit de Gibraltar depuis le Sud le long des côtes de Mauritanie et du Maroc et une partie de la migration est réalisée depuis le Nord le long de la péninsule ibérique ; et (2) la plupart des thons rouges de l'Atlantique adultes de grande taille rejoignent le détroit de Gibraltar par le Nord le long de la péninsule ibérique même si une partie significative migre depuis le Sud le long de la côte marocaine. Étant donné que la CPUE de la madrague et de la palangre des thons rouges de l'Atlantique adultes de grande taille, présentant une tendance relativement uniforme, fournit de manière continue des informations d'une importance cruciale pour les études de population, notamment les évaluations de stock, le suivi et la comparaison des informations de ces deux pêcheries très différentes sont des éléments fondamentaux pour la gestion du thon rouge de l'Atlantique.*

### RESUMEN

*Este documento trata de deducir los movimientos del atún rojo del Atlántico adulto grande (ABFT) hacia el Estrecho de Gibraltar para desovar en el Mediterráneo utilizando los datos del palangre japonés. La distribución mensual del atún rojo del Atlántico capturado por la pesquería de palangre japonesa indica un movimiento contrario a las agujas del reloj del atún*

*rojo del Atlántico. La información de marcas pop-up por satélite comunicada por Block et al. (2005) se comparó con el patrón migratorio deducido a partir de los datos del palangre japonés. Ambos documentos estaban de acuerdo al sugerir el movimiento contrario a las agujas del reloj del atún rojo del Atlántico, aunque los dos conjuntos de información parecían sugerir diferencias en el patrón migratorio, si lo había, cerca del Estrecho de Gibraltar. Se pudieron proponer dos hipótesis para la migración cercana al Estrecho de Gibraltar: (1) La mayoría de los atunes rojos grandes adultos llega a la zona del Estrecho de Gibraltar desde el Sur, a lo largo de la costa de Mauritania y Marruecos, con algunas migraciones procedentes del Norte, a lo largo de la Península Ibérica, y (2) la mayoría de los atunes rojos grandes adultos llega a la zona del Estrecho de Gibraltar desde el Norte, a lo largo de la Península Ibérica, aunque una parte importante viene desde el Sur, por la costa de Marruecos. Dado que la CPUE del palangre y las almadrabas para el atún rojo grande adulto, con una tendencia bastante coherente, proporciona continuamente información de gran importancia para los estudios de población, lo que incluye las evaluaciones de stock, hacer un seguimiento y comparar la información de estas dos pesquerías diferentes y separadas son importantes elementos clave en la ordenación del atún rojo del Atlántico.*

#### KEYWORDS

*Trap, longline, CPUE, Strait of Gibraltar, migration, PSAT*

## 1. Introduction

Abundance indices derived from traps located in the Strait of Gibraltar are important to monitor the abundance of large adult bluefin tuna and have been used in the stock assessment models for Atlantic bluefin tuna. There are two abundance indices for large adults of east stock along with indices from Japanese longline fishery. Catch information of tuna trap nets around the Strait of Gibraltar must provide reliable abundance indices for large adults of the eastern stock because they are neatly located in the bottle neck area where the large adults have to pass through to spawn in the Mediterranean Sea.

While information from the traps on apparent abundance of large sized spawning stock has important value, abundance indices derived from the traps may not necessarily cover the stock trend of the entire population of large adults and may be influenced by the availability of the stock to this gear as the tuna traps are located very close to the shore. On the other hand, the Japanese longline fishery target bluefin tuna in vast oceanic waters as well as areas close to the trap nets. Therefore, it is worth investigating how large adult bluefin tuna migrate to the Gibraltar areas from oceanic habitat areas such as waters off the UK, Ireland and Iceland where Japanese longline operates for large adult bluefin.

As the two indices for large spawning bluefin tuna, i.e., trap and Japanese longline, are calculated during the time of the tunas entering the Mediterranean Sea through the Strait of Gibraltar, this paper infers plausible migratory routes of large adult bluefin tuna towards the Strait of Gibraltar using Japanese longline data. Implications of the inferred migratory pattern on the interpretation of abundance indices of the trap and the longline fisheries are contemplated.

## 2. Materials and methods

Nominal catch rates (number of bluefin per 1,000 hooks) of the Japanese longline fishery by 1 degree squares, months and years were calculated for the eastern North Atlantic. Migratory patterns of large adult bluefin tuna were inferred from the monthly distribution of CPUE. Archival tagging results of a large adult bluefin tuna reported by Block et al (2005) were compared with the monthly longline CPUE maps.

### 3. Results

#### 3.1 Japanese longline data

**Figure 1**, exemplified by year 2008, shows a typical pattern of monthly succession of Japanese longline catch rate in recent years. The year 2008 was chosen as an example presentation because this year has relatively wider time and area coverage of the Japanese longline operations than other years. It is noted that the monthly pattern of CPUE distribution is fairly consistent among the years checked for the period from 1994 and 2009.

Assuming this succession of monthly change of the catch rates roughly represents migratory pattern of the large adult bluefin tuna, it could be summarized as follows:

*From January to May:* A high CPUE area is located in the south of Greenland, around 40°W and 40-45°N in January. By March, high CPUE areas moved to a south eastern direction from January and are located 20-35°W and 30°N with another small spot close to the Moroccan coast along 30°N. By May, the high CPUE areas moved further east and northward along the Moroccan coast, some entered the western Mediterranean.

*From June to December:* There are no operations for June and July in the areas north of 20°N. The high CPUE area appears in August south of Iceland and west of Ireland around 50°N and 15-20°W. By October, the high CPUE area moved northwest and located in water 55-60°N and 15-30°W. By December, the high CPUE area moved south west in waters 45-50°N and 25-45°W. There are no catches of bluefin tuna in the tropical areas south of 20°N where the longline fished for bigeye for the entire period analyzed. The southernmost longitude where bluefin were caught during the entire period analyzed was around 27°N between the Madeira Islands and the African coast, for several years, all in April.

As there were no longline operations along the Iberian Peninsula during the recent period, it is not possible to make the inference on the movement of large adult bluefin tuna around this area. However, longline operations near the Iberian coast occurred in an older time around the mid-1970s. Therefore, monthly distributions of longline CPUE from March to June in 1974 were produced (**Figure 2**). The year 1974 has the largest observation in the area although the observation is still low compared to the Moroccan side. It seems that the monthly distribution maps tend to indicate the fish come from the south.

#### 3.2 PSAT tracking

Information taken from paper by Block et al (2005) is **Figure 3** of their document. This figure shows the track record of a bluefin tuna (191cm FL when released off the U.S. coast in 1999) that had been monitored for 4.5 years. Since this fish entered the Mediterranean Sea during the spawning season in three consecutive years from 2001 to 2003, it is considered to be bluefin tuna that originated in the Mediterranean Sea. Relevant panels of **Figure 3** in the original paper (**c**, **d**, and **e**), from which the timing of bluefin tuna approaching toward the Strait of Gibraltar can be inferred. Panel **c** completed a counter clockwise movement with heavily compressed in east-west direction. Panels **d** and **e** when they are connected complete a counter clockwise movement. As for direction of movement toward the Strait of Gibraltar just before passing through the Strait, Panels **c** and **d** seem to show the fish coming from the north along the coast of Portugal and Spain while Panel **e** seems to show the fish coming from the south along the coast of Mauritania and Morocco. It is noted that the southern-most position before entering the Mediterranean Sea is in the south of the Strait of Gibraltar for those three years. In addition to this fish, one additional track record of fish that had been tracked 4 years and entered the Mediterranean Sea was provided in the supplementary information of Block et al (2005). This fish showed approaching the Strait of Gibraltar from the north along the Iberian Peninsula for all 4 years. The tracking result of the two fish indicates, except for one year, that those fish entered the Mediterranean Sea from the north along coast of the Iberian Peninsula.

Since the tracking results previously shown were based only on two individuals, it is not clear that the migratory pattern shown by these two fish is representative of the whole stock. In this regard, comparison with **Figure 4** of Block et al (2005) that plotted all PSAT tracking by seasons would be more appropriate to infer if the migratory pattern of the whole stock coming toward the Strait of Gibraltar shows northern or

southern routes. Unfortunately, no clear pattern of migratory route, whether the fish come from north or south, can be inferred due to widespread overlapping distribution of plots.

## 4. Discussion

### *4.1 Limitations those two kinds of information*

There are uncertainties to infer movements of bluefin tuna for both monthly CPUE maps of the Japanese longline statistics and PSAT tracking results. As for the Japanese longline data, it is not certain whether or not the change in the high CPUE area in the longline fishing ground reflects movement of bluefin, although it is certain that Japanese longline targets and follows bluefin tuna consistently after the early-1970s. In addition, the time and area coverage of the Japanese longline operations has become limited, especially the operations in waters off Portugal and Spain are lacking. Therefore, the data give little information as to whether or not the fish approaching the Strait of Gibraltar also come from the north along the Iberian Peninsula although there are fragmental data along the Iberian coast in the mid-1970s that suggest the fish come mostly from the south.

On the other hand, PSAT information this paper used is based on the monitoring of the two individual fish. Therefore, it is not certain whether this fish represents the pattern of movement of the entire eastern stock. If all PSAT track points were plotted, only blurred pictures that give little information on a smaller scale migratory pass. In addition, all PSAT fish by Block et al (2005) were tagged in the eastern coast of North America. It is unfortunate that the number of archival tags released from the Mediterranean Sea is very small as those fish might show a different migratory pattern from those released from the western Atlantic.

### *4.2 Comparison of migratory pattern inferred from Japanese longline data and PSAT tagging*

Taking into account the limitations that the two sets of information have, a comparison of the movement pattern was made. Both sets of information showed characteristic counter clockwise movement consistent with monthly processions each other. For the longline data, the movement pattern is shown schematically in the December panel of **Figure 1** with red and blue curves, while the PSAT plots for the east and west Atlantic origin groups tend to show a similar counter clockwise movement (**Figure 4**). Note that the western side of the curves in the December panel of **Figure 1** is not connected since it is obvious that fish pass through the 45°W line and migrate to U.S. and Canadian waters. However, both set of information can not tell whether or not there is a consistent pattern of fish movement approaching the Strait of Gibraltar either from south or north. On the other hand, longline data show that there is a substantial influx of large bluefin tuna coming from south along the coast of Mauritania and Morocco, while the PSAT information based on two individual fish indicates the fish coming from the north along the Iberian coast.

### *4.3 Size of fish*

The size of bluefin tuna taken by Japanese longline around the Strait of Gibraltar (area 30-40°N and 20°W to the Strait of Gibraltar) is shown in **Figure 5**. The majority of the fish range from 200 to 250 cm in fork length. The size of bluefin taken by Japanese longline is more similar to that by Moroccan traps (Idrissi and Abid, 2009) as most of the sampling was made off the Moroccan coast. It is known for the Moroccan trap that large fish come earlier, then smaller fish follow (Idrissi and Abid, 2010), but there was no indication of such phenomenon in the Japanese fishery operating in oceanic waters off Morocco although the number of measurements is small and incomplete among the months.

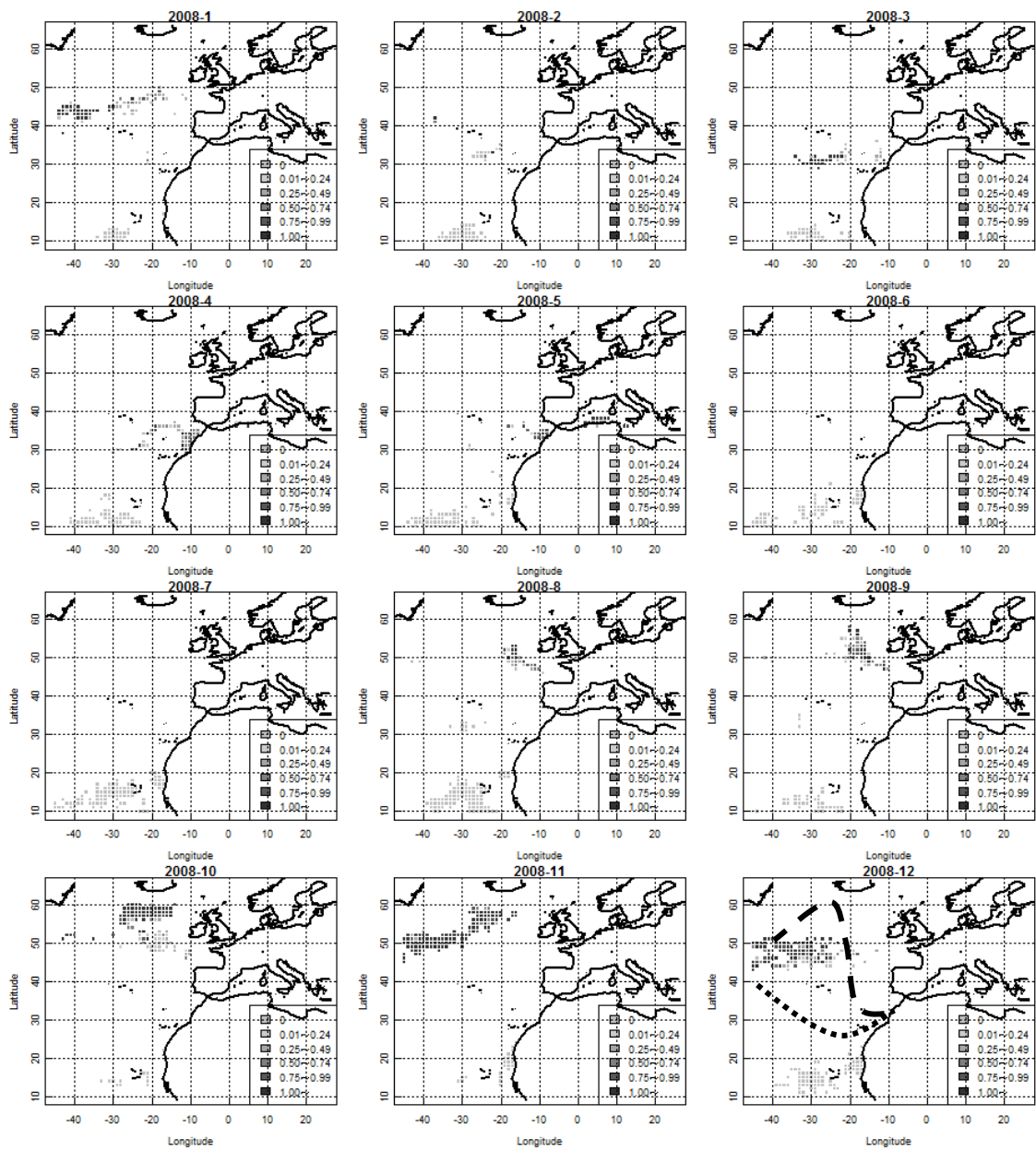
### *4.4 Implications of inferred migratory pattern toward the Strait of Gibraltar on interpretation of abundance indices of trap and Japanese longline indices*

Based on a comparison of two sets of data, Japanese longline CPUE distribution and PSAT tracking, two migratory routes could be hypothesized for large adult Atlantic bluefin tuna approaching the Strait of Gibraltar: (1) Most of bluefin tuna approaching toward the Strait of Gibraltar come from the south along the Mauritanian and Moroccan coast forming a part of a counter clockwise movement with some fish coming from the north along the Iberian coast; (2) Most of the fish migrate from the north along the Iberian coast toward the Strait of Gibraltar with some significant portion migrating to the south along the Moroccan coast.

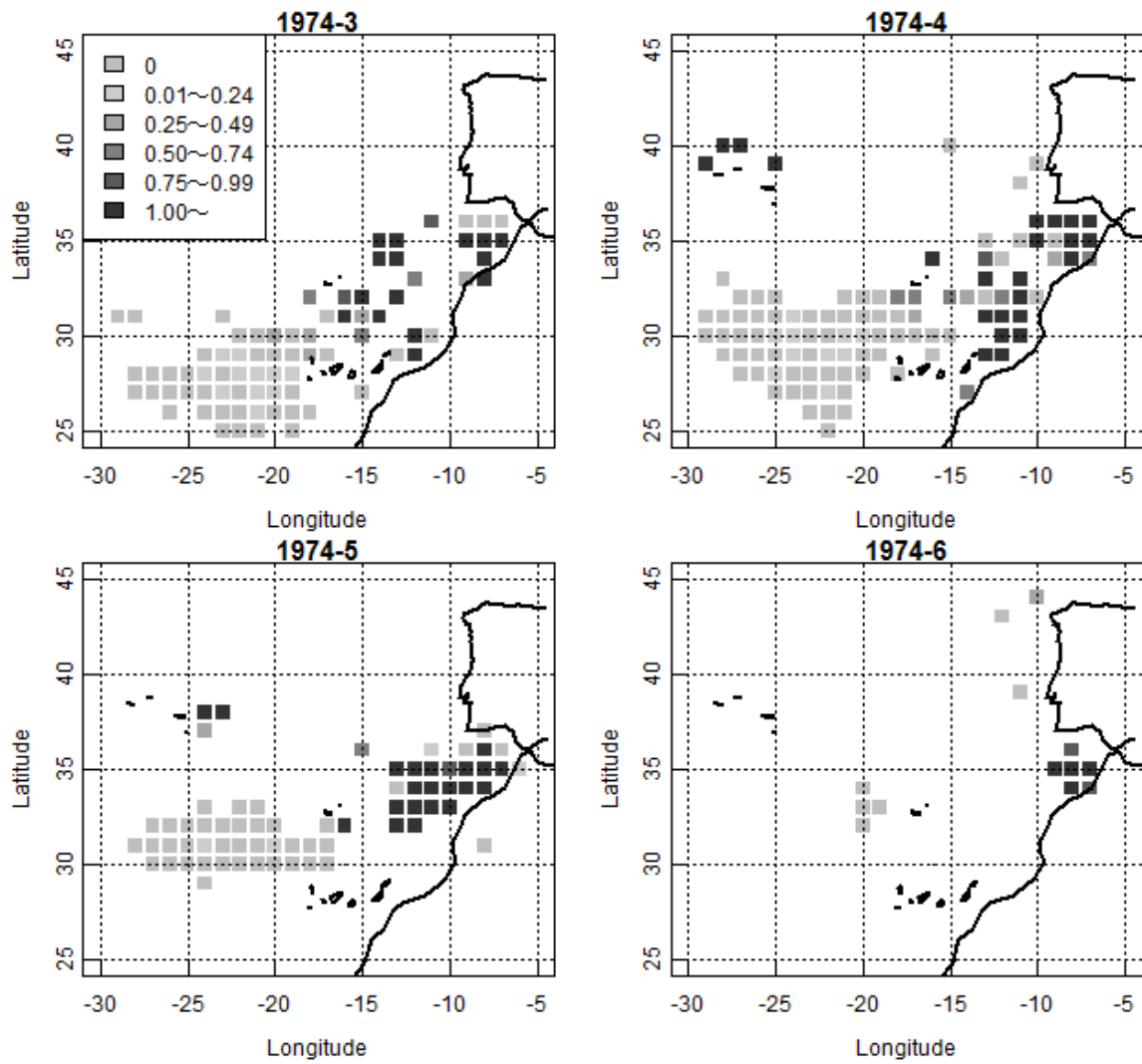
There are similarities between the Moroccan and Spanish traps in CPUE trend (ICCAT, 2011, BFTE-Figure 2). A close relationship was observed with the bluefin tuna caught by the Japanese longline and Moroccan traps in seasonality, size of fish taken although Japanese longline operates in an extensive offshore area off Moroccan traps operate. There is concern about the accuracy of the CPUE trend provided from Japanese longline due to smaller time area coverage in recent years. The concern would be raised also to the trap indices because of their limited time and areal coverage although they are located in good locations where spawning bluefin tuna concentrated. However, it is encouraging that the Japanese longline in the area of the Strait of Gibraltar and the trap fishery in the coast of Iberian Peninsula show roughly the similar trend in CPUE (ICCAT, 2011, BFTE-Figure 2). Therefore, it is concluded that monitoring the apparent abundance indices from the coastal trap fishery and from the offshore longline fishery are important for better understanding of the population dynamics of Atlantic bluefin tuna.

## References

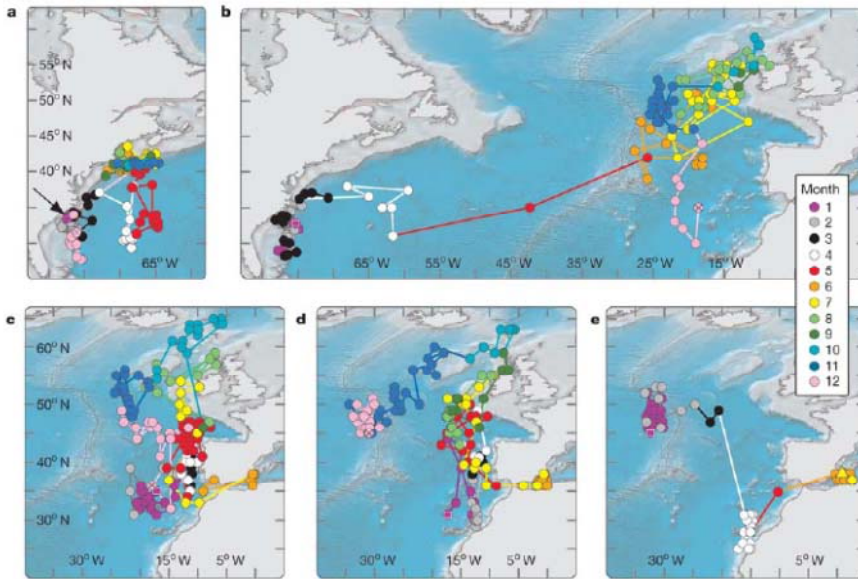
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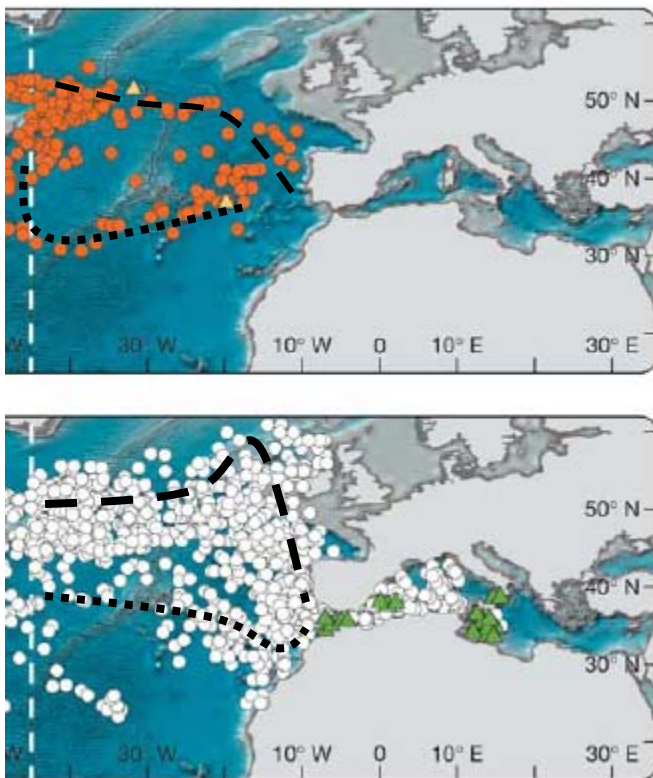
**Figure 1.** Monthly distribution of CPUE for bluefin tuna caught by Japanese longline for 2008 (Schematic migratory pattern was superimposed on December map, dotted line from January to June, broken line from July to December)



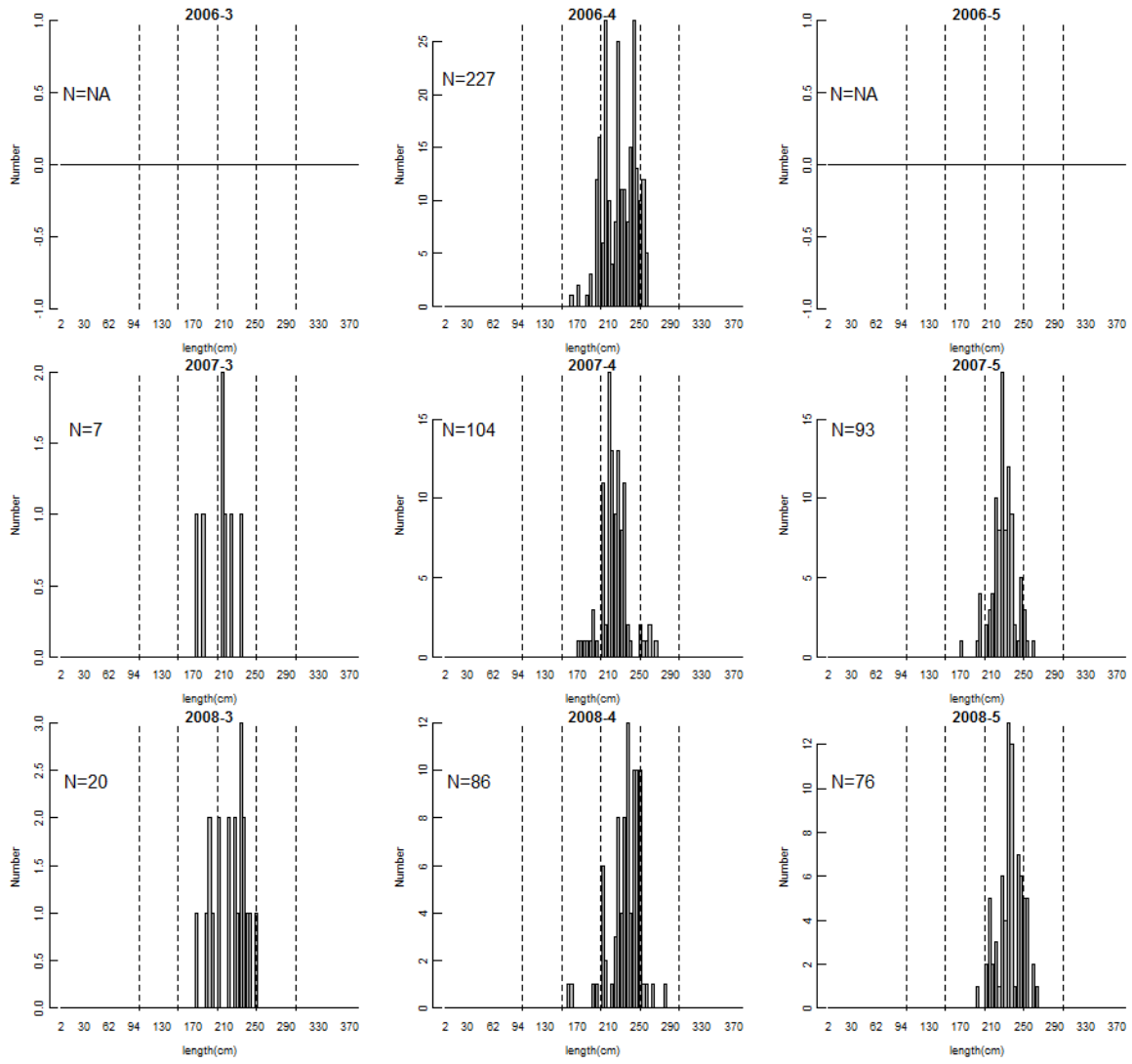
**Figure 2.** Monthly distribution of Japanese longline CPUE from March to June of 1974.



**Figure 3.** PSAT tracking records cited from Figure 3 of Block et al (2005).



**Figure 4.** Plots of PSAT results excerpted from **Figure 1** of Block et al (2005). Dotted and broken curves overlaid are the incoming and outgoing routes of large adult bluefin to and from the Mediterranean Sea inferred from Japanese longline data.



**Figure 5.** Length composition of bluefin tuna caught by Japanese longline in waters off the Strait of Gibraltar for 2006-2008 from March to May.