Chapter 7
Research Related to Bluefin Tuna Fishing in the Bay of Biscay

Abstract This chapter reviews the research made on bluefin tuna in the Bay of Biscay fishery from a historical point of view. The subjects dealt with range from geographical origin, migrations from this area, conventional and electronic tagging, growth, and a compendium of studies on this fishery, are discussed. The ICCAT official statistics corresponding to landings, biological samplings (before and after the implementation of the PARP), the demographic structure of catches, and the abundance index of juvenile fishes are also considered.

7.1 Historical Antecedents

The first reference concerning the biology of Cantabrian Sea ABFT came from the French scientist (Heldt 1943), who deduced the migrations of the species from the Cantabrian Sea to the Mediterranean by examining hooks found in ABFT (fishes found in the fisheries of Sardinia, Sicily and Tunisia).

The first studies on ABFT biology and fishing in the Cantabrian Sea were made by the Spanish scientist Navaz (1950), who presented landing statistics for this species and described ABFT seasonality in the area, revealing that 90% of catches are taken between May and August. He also made a biometric study of specimens landed in the port of San Sebastian (Spain). His French contemporary Le Gall (1950, 1951) presented statistical data and biological samplings of French ABFT catches near the coast of Saint Jean de Luz (France), describing the seasonality of the fishery and the presence of some specimens in their period of sexual maturity, detailing the dynamic of the different tunas in the Bay of Biscay according to their weight composition. De la Tourrase (1951) carried out a large study describing ABFT fishing in the Cantabrian Sea as well as the introduction of the bait boat fishing system, with which very high fishing yields were obtained. Similarly, Creac’h (1952) studied the yield and economics of ABFT fishing in the Cantabrian Sea, providing data on the dynamics of the different groups depending on length and time of appearance in the fishing area between April and December. According to this author the number of vessels targeting tuna (ABFT and albacore tuna) in the port of Saint Jean de Luz was 85. In Pommereau (1955) the evolution of ABFT fishing on the Basque coast...
from ancient times up until the introduction of bait boat in 1948 is examined, placing emphasis on the great increase in catches that it brought with it. He also presented tuna landing statistics in Saint Jean de Luz between 1948–1954, emphasizing the maximum of 3600 t of ABFT and 1060 t of albacore tuna in 1951 and describing the characteristics of the 75 tuna fishing boats of the port.

In 1961 within the International Council for the Exploration of the Sea (ICES), the Bluefin Tuna Working Group (BFTWG) was founded, whose main mission was to compile ABFT catches within the area of that organization in order to study the relationships among the catches of the different sub-areas and the time when the tunas reached the fisheries. The scientists Hamre (Norway) and Tiews (West Germany) were elected as the first members of this group and scientists from other countries involved in ABFT fisheries were later incorporated, Aloncle and Maurin from France, and Lozano and Rodríguez-Roda from Spain. Prior to 1972, the year in which the ongoing collection of information on the ABFT fishery in the Cantabrian Sea began, the group had published five reports. In none of them had the information concerning Spanish catches in the Cantabrian Sea yet appeared, the report corresponding to the period 1973–1975 being the one containing the first Spanish data (Aloncle et al. 1977). The last report of the BFTWG was published in 1981 (Aloncle et al. 1981). At the beginning of the 1980s the BFTWG was disbanded due to the activity developing in the field of research and fisheries statistics of tunas pursued by ICCAT from the beginning of the 1970s.

From 1972, Bard et al. (1973) began observing the French and Spanish ABFT fisheries in the Bay of Biscay and soon afterwards Cort and Cendrero (1975), Cort (1976) initiated the information and sampling network that the Spanish Institute of Oceanography (IEO) still maintains. At the end of the 1980s the scientists of the Basque organization AZTI-Tecnalia joined the investigation of tuna.

### 7.2 Birth and Geographical Origin of Bluefin Tuna in the Bay of Biscay

In a recent study by Fraile et al. (2014) using proportions of carbon and oxygen isotopes ($^{13}$C and $^{18}$O) in ABFT from the Bay of Biscay collected between 2009 and 2011, the overall contribution of ABFT from the western part of the Atlantic to the Bay of Biscay fishery was found to be <1% in those years, though in certain years this percentage can increase to 2.7%, which suggests that the fishery is almost exclusively made up of fishes born in the spawning area of the Mediterranean. In order to carry out the study the values obtained were compared with reference samples of ABFT, one from the Mediterranean and another from the Gulf of Mexico. This study confirms that in certain years there is a presence of fishes from the western Atlantic in the Bay of Biscay, just as had previously been determined by tagging (Mather III et al. 1967; Cort 1990).
Based on data from logbooks of the 1980s and publications of the time, Cort and Rey (1984) presented maps relating ABFT juvenile migrations from wintering areas and vice versa with water surface temperature. Following the same methodology, Cort (1990, 2009) applied it to the Bay of Biscay fishery. In this way, during the intermediate phase of the boreal spring from May, the 17–20 °C isotherms move northwards leading the ABFT to emigrate towards more northern areas of the ocean. Once they reach the Bay of Biscay the shoals remain in the southeastern part where the waters of the eastern edge are warmer than in the rest (García-Soto 2006). It is precisely in the oceanic part of this area that they group throughout the summer. The displacement of the isotherms southwards in October marks the start of the return of the tunas to their wintering areas. That is to say that the migration of the shoals of juvenile ABFT from wintering areas to the Bay of Biscay and vice versa is associated with the latitudinal displacement of the surface isotherms. Nevertheless, Arregui et al. (2018) show that this association is not entirely accurate, as some juveniles carrying electronic tags have occupied winter habitats in which water temperatures can reach 10 °C, something that was also described in Cort et al. (2014).

7.3 Migrations in and from the Bay of Biscay

The arrival of juvenile shoals in the Bay of Biscay usually takes place at the end of the boreal spring (May–June), mainly from the west of the Iberian Peninsula, in some cases around the cold waters of the Portuguese continental shelf (Gil 2006) and in others from the northwest and mid-Atlantic or from the vicinity of the Bay of Biscay (Goñi et al. 2010; Arregui et al. 2018), their final destination being the bottom of the Bay where they find an abundance of food (Ortiz de Zárate and Cort 1986; Logan et al. 2010a, b). In the interior of the Bay the tunas form large shoals of juvenile fishes of the same age (Cort 1990) and search for food continually. These shoals act differently depending on the nature and behaviour of their preys. Their formations and the effects they bring about on the sea surface give away their presence, which provides fishermen with the opportunity to make catches.

The small spawners (up to 2.2 m) arrive in mid-July and by the end of August they can hardly be found in this area (Cort 1976; Cort and Rodríguez-Marín 2009), although in recent years they are frequent in autumn (October). The recovery of a juvenile ABFT tagged in the Bay of Biscay (1990) and recovered in the North Sea (60° N/8° W) eight years later (Cort unpublished) as well as the presence of these fishes to the south of 62° N, caught by Norwegian vessels in August (Hamre and Tiews 1963; Tangen 2009) are evidence of the short seasonality of this group in the Bay of Biscay.
7.4 Bluefin Tuna Migrations to and from the Bay of Biscay. Conventional Tagging

Cort et al. (2010) describe the different types of tags used in ABFT tagging, and establish as conventional tags those that are made up of small plastic tubes (2 mm width and 12 cm length) with a little harpoon on the end, which are inserted in the dorsal part of the fish by means of a steel applicator.

Following a description of the juvenile ABFT of the Atlantic coasts of Morocco made by Furnestin and Dardignac (1962), in the 1970s French scientists tagged ABFT juveniles in that area, some of which were recovered in the Bay of Biscay in the following and successive years (Aloncle 1973; Lamboeuf 1975; Brêthes 1978, 1979). It was the first time ABFT tagged in other areas of the eastern stock had been recovered in the Bay of Biscay. Years later, and as a result of tagging by Spanish scientists on Spanish Mediterranean coasts, some of those fishes were also recovered in the Bay of Biscay (Cort 1990), which shows the interchange of ABFT of the same stock among different areas.

French scientists had tagged 34 ABFT in the westernmost part of the Cantabrian Sea during the albacore tuna tagging surveys between 1967 and 1972, of which two were recovered in the western Atlantic (Aloncle 1973). This demonstrated that juvenile ABFT make transatlantic migrations from East to West, something that had already been shown in the other direction, from West to East, by Mather III et al. (1967). The surveys targeting ABFT organized by the IEO began in 1978 and continued until 1991. A total of 5,653 ABFT were tagged, mainly juveniles, of which 360 (6.4%) were recovered in the following years: 329 (91.4%) turned up in the Bay of Biscay again; 16 (4.4%) were recovered in the Atlantic fisheries of the U.S.A. (Table 7.1); 7 (1.9%) in the Mediterranean, and 8 (2.2%) in diverse eastern Atlantic fisheries. The ABFT that were recovered in the fisheries of the eastern Atlantic and Mediterranean were adults and some of them, which had spent up to 9 years at liberty, had increased in weight by up to 250 kg (Cort 2006).

The surveys were carried out on board commercial fishing vessels using troll in the first years and later, from 1979, on bait boat vessels. The tagging system was always the same: the fishes were taken to the tagging cradles, where they were measured and tagged with conventional tags. Once tagged, they were freed in an operation that lasted a few seconds.

The results of these experiments show that most of the juveniles tagged in the Bay of Biscay, and while they are still juveniles, return in later years which has been shown clearly by Arregui et al. (2018), who refer to their “strong fidelity to the area”. Having reached sexual maturity, fishes tagged in the Bay of Biscay have been recovered in areas in which spawners are common, as shown in Fig. 7.1. This demonstrates the connection of ABFT with other fisheries of the eastern and western stocks (Cort 1990, 2006). With the exception of the recoveries that took place in the year following tagging, above all those recovered in the Gulf of Lion a year afterwards, we know nothing of their movements during the years they were at
### Table 7.1 Count of bluefin tunas making transatlantic migrations, tagged in *IEO* surveys in the Bay of Biscay (1978–1990)

| Tagging | Tag number | Date (month, day, year) | Latitude | Longitude | FL (cm) | Age (years) | Date (month, day, year) | Latitude | Longitude | FL (cm) | RW (kg) |
|---------|------------|--------------------------|----------|-----------|---------|-------------|--------------------------|----------|-----------|---------|--------|
| R 3874  | 08-20-1978 | 43.50 N                  | 2.35 W   | 78        | 2       | 01-02-1980  | 42.18 N                  | 60.45 W  | —         | 12     |        |
| R 7336  | 09-13-1979 | 44.20 N                  | 2.40 W   | 103       | 3       | 08-25-1980  | 43.00 N                  | 69.00 W  | 114       | 27     |        |
| R 7388  | 09-13-1979 | 44.20 N                  | 2.40 W   | 85        | 2       | 12-15-1985  | 41.02 N                  | 51.01 W  | 202       | 150    |        |
| R 9706  | 08-17-1980 | 43.40 N                  | 3.15 W   | 60        | 1       | 08-13-1982  | 40.36 N                  | 72.03 W  | 112       | —      |        |
| R 9757  | 08-17-1980 | 43.40 N                  | 3.15 W   | 84        | 2       | 09-05-1981  | 39.40 N                  | 72.40 W  | 93        | 14     |        |
| S 2469  | 08-04-1980 | 43.55 N                  | 3.03 W   | 80        | 2       | 08-10-1981  | 39.40 N                  | 72.40 W  | 99        | —      |        |
| S 5898  | 08-13-1982 | 44.30 N                  | 2.25 W   | 60        | 1       | 09-07-1983  | 39.40 N                  | 72.30 W  | 94        | 18     |        |
| AT 3547 | 08-09-1985 | 43.30 N                  | 1.48 W   | 80        | 2       | 08-25-1988  | 45.00 N                  | 66.00 W  | —         | —      |        |
| AT 3869 | 09-30-1986 | 43.43 N                  | 2.55 W   | 64        | 1       | 06-25-1988  | 38.50 N                  | 73.58 W  | 114       | 32     |        |
| EM 7172 | 10-05-1986 | 43.57 N                  | 2.27 W   | 66        | 1       | 08-15-1989  | 39.44 N                  | 73.20 W  | 130       | —      |        |
| EM 7218 | 10-05-1986 | 43.57 N                  | 2.27 W   | 67        | 1       | 09-03-1987  | 40.04 N                  | 73.40 W  | 105       | 19     |        |
| EM 7486 | 10-07-1986 | 43.55 N                  | 2.31 W   | 64        | 1       | 08-13-1988  | 39.20 N                  | 73.45 W  | 100       | 18     |        |
| EM 8479 | 08-03-1988 | 44.18 N                  | 2.24 W   | 60        | 1       | 10-15-1989  | 38.00 N                  | 75.00 W  | 90        | —      |        |
| YF 915  | 08-25-1990 | 44.00 N                  | 3.37 W   | 64        | 1       | 09-29-1991  | 40.33 N                  | 71.28 W  | 92        | 16     |        |
| YF 985  | 08-25-1990 | 44.00 N                  | 3.37 W   | 65        | 1       | 08-28-1991  | 40.45 N                  | 71.52 W  | 91        | 16     |        |
| YF 6153 | 08-20-1990 | 43.13 N                  | 3.21 W   | 63        | 1       | 07-10-1993  | 36.45 N                  | 75.10 W  | 125       | 35     |        |
Fig. 7.1 Some of the long migrations of young bluefin tunas tagged in IEO surveys in the Bay of Biscay (1978–1990) (The numbers in the circles indicate years at liberty. A reference is included to the 17 specimens that emigrated to the coasts of the U.S.A.). Taken from Cort (2006)

It is particularly interesting to note that migrations are made by juveniles to the western Atlantic from the Bay of Biscay fishery.

Nowadays, with electronic tags that tell us practically everything about the movements of the fish and its environment, conventional tagging has lost its importance. Even so, other conventional tagging surveys have been conducted, such as those of 2005 and 2007, organized by AZTI-Tecnalia and the IEO, in which 2,141 were tagged (Rodríguez-Marín et al. 2008a). Later, AZTI-Tecnalia tagged 7,698 bluefin tunas in a survey organized by ICCAT-GBYP between 2012 and 2015. The results of these surveys (Tensek et al. 2018) confirm those from surveys carried out in the past. Overall, the Bay of Biscay is the area in which most eastern stock bluefin tunas have been tagged.

In addition to the information obtained from the recovered fishes regarding migrations, many of them have been used to carry out growth analysis, all of which comes thanks to the fact that they were measured when tagged and the fishermen who recovered them facilitated data on their sizes, though this does not always happen.
7.5 Electronic Tagging

The first electronic tagging experiments on bluefin tuna in the Bay of Biscay were conducted by AZTI-Tecnalia from 2005 to 2009, when 136 archival tags and 29 pop-up tags were placed ($Lh = 60–107$ cm) (Arrizabalaga et al. 2008; Goñi et al. 2010; Arregui et al. 2018). In 2009 the University of Cádiz and IEO tagged a further 101 ($Lh = 60–85$ cm) (Medina et al. 2011).

Arregui et al. (2018) show that five of the internal tags were recovered, four in the following 1–5 years in the Atlantic and one 7 years later. This latter tag had only recorded the data of three years and when the fish was recovered it was in the adult phase in the Mediterranean. The year in which it passed through the Strait of Gibraltar for the first time could not be known (Arregui, pers. comm.). The results also show that the juvenile wintering areas are found between the Bay of Biscay, Cape San Vicente and the Azores. Similarly, the western Atlantic is a wintering area (Cort et al. 2014; Arregui et al. 2018).

The recovery rate of internal electronic tags has fallen considerably with respect to that of conventional tags since these activities coincided with the start of PRPA, which has led to a considerable fall in fishing activity in this area. ICCAT-GBYP has subsequently organized diverse electronic tagging surveys, one of them in the Bay of Biscay. Tensek et al. (2017) cite and reveal the results of these activities.

7.6 Age and Growth of Bluefin Tuna in the Bay of Biscay.

Age-Length Key and Length-Weight Relationship

The first scientists to publish ABFT growth studies in the Bay of Biscay were Compeán-Jiménez and Bard (1983). They are credited with the use of fin rays for ageing, a technique that had not previously been used for this kind of study in ABFT. The methodology represented a large step forward from the one in use up until then (otolith age-reading), given that the fish does not get damaged and so samples are obtained at no cost since the sale of the fish is not affected. Some years later, using the same methodology, Cort (1990) specified some aspects regarding observable bands in the samples and presented an integral growth equation through a combination of data from the Bay of Biscay (fishes up to 200 cm) and samples from the traps fishery of the Bay of Cadiz (192 fin rays from fishes up to 3 m caught in June, 1984). Age groups of juveniles and small adults (ages 1–8 years) of the Bay of Biscay and adults of 6 to 19 years from the Bay of Cadiz were combined. The full equation that resulted, using the classical model of Von Bertalanffy (1938) was:

$$L_t = 318.85 \left[1 - e^{-0.093(t+0.97)}\right]$$
where: $L_t$ = fish length; $L_\infty$ = asymptotic value of the growth curve, supposedly very close to $L_{\text{max}}$ (maximum population length); $k$ = growth rate (annual); $t$ = time (age, generally in years); $t_0$ = theoretical instant when $L_t = 0$.

This equation was adopted by the ABFT assessment group in 1991 and remains a reference today. It is still in use by this group for eastern stock assessments. For its validation Cort et al. (2014) used different methodologies, one of which was to superimpose the age readings of 578 ABFT caught in the Bay of Biscay and Mediterranean Sea onto the growth curve, as well as 131 data obtained from recaptured ABFT, fundamentally from the Bay of Biscay. The result of the analysis indicated a good fit of the data to the model.

On the left of Fig. 7.2 the growth curve of the eastern stock is shown (solid line) on which readings/age of fin rays (blue points) and growth data from tagging-recovery (red points, eastern Atlantic; green points, western Atlantic) have been superimposed. On the right are the corresponding residuals.

The only way to evaluate the predictive power of the curve is by observing a posteriori and analyzing the residuals. The analysis of these indicates that there are no systematic errors in the model as it presents a symmetrical distribution of the data on both sides of the x-axis. The values of the analysis are given in Cort et al. (2014).

A few years after spine reading for age determination began, the first age-length key (ALK) for the Bay of Biscay fishery was established (Rey and Cort 1984; Cort 1990).

The Bay of Biscay fishery is made up of juveniles aged 1–4 (5–30 kg) and of small spawners of 5 to >10 years (40–150 kg). Usually, the juveniles remain accessible to fishing from June until October–November and small spawners mainly in July and August (Cort and Nøttestad 2007; Cort and Rodríguez-Marín 2009).

The analytical expression relating length and weight is: $P = b \, L^k$, in which:

- $P$ = weight of the individual (kg)
- $L$ = length of the individual (cm)
- $b$ and $k$ = constants.
Table 7.2 from Cort (1990) shows the length-weight relationships for the seasons in which there is a greater presence of specimens: summer and boreal autumn (June–October).

In relation to larger fishes passing through the Cantabrian Sea and Bay of Biscay, the length-weight relationship in summer reflects the fact that these fishes are still in a state of reduced fattening condition.

### 7.7 A Fin Ray Sample that Confirms the Nature of Visible Rings

Based on a sample of 1,536 spines collected between 1980 and 1986, Cort (1990) describes the different visible rings in fin ray cross-sections as follows:

- **The hyaline rings** are “winter” rings and are formed between autumn and boreal spring (November/April–May).
- **The single hyaline rings** may be thin or thick. If they are thin it indicates that there was considerable slowing in growth and if they are thick it means that there was more growth but with food with little protein.
- **In the double hyaline rings** the first ring is formed at the start of autumn and the second at the end of winter-spring.
- **The opaque band** (active growth) represents the growth that takes place between June–November, when food is very rich in proteins.
- **The tracking of the opaque band** between June and November (marginal growth) shows the exponential growth that stops in the winter months.
- **At the beginning of the fishing season** (June) the recently formed winter ring is at the edge of the fin ray; there is hardly any opaque band. At the end of the fishing season (October–November) the ring is distant from the edge and the opaque band is very broad.

Despite the above, the fin ray samples vary considerably, and in addition to single rings (thin and thick) and double rings, there are triple rings and false ones; singles and doubles appearing even in the same sample.

Twenty-four years after making this description, the nature of the different observable parts in the cross-sections was confirmed in a fin ray recovered from an ABFT tagged with an internal electronic tag, from which all movements of the fish are known over the two years that the migration lasted between the fish being caught,
tagged and freed in the Bay of Biscay (18 August, 2007) and recovered in the same area two years later (2 August, 2009).

If it is difficult to recover an internal electronic tag, it is even more so and obtain the fin ray from the same fish as in this case. It is exceptional and unprecedented. The interpretation of the visible bands in the ray cross-section together with the movement of the fish (Fig. 7.3) revealed the “winter” nature of the hyaline bands described by Cort (1990), and it was also possible to confirm that the double rings (in the sample studied) were formed during the transatlantic migrations, westwards and eastwards, of the fish during the second winter after having been freed. The article that contains this information was published in *Reviews in Fisheries Science & Aquaculture* in August 2014 (Cort et al. 2014).

The interpretation of this sample, which must be made together with Figs. 7.3 and 7.4, is the following:

The movements of the fish over two years are represented on the dark-colored graph in the interior of the fin ray cross-section (Fig. 7.3) and are interpreted using the data from the two axes. Thus, for example, 14-Nov-07 indicates that the fish was still in the Bay of Biscay (longitude 2° W) after having been tagged on 18 August; on 22-Feb-08 it was wintering in the middle of the Atlantic Ocean (25° W); and on
01-Jun-08 it had returned to the Bay of Biscay where it would remain until November 2008 (2°–8° W). On 18-Dec-08 it was wintering in the western Atlantic at longitude 45° W; on 28-Mar-09 it reached 55° W off the coasts of the U.S.A. and Canada; and finally, a very swift migration saw it return to the Bay of Biscay (06-Jul-09) where it was recovered in August 2009. According to Arregui et al. (2018), this fish crossed the Atlantic in 22 days.

Figure 7.4 shows the temperature in which the fish moved while it was at liberty. In the Bay of Biscay the water temperature went from 22 °C in August 2007 to 14 °C in December 2007, when it migrated to the mid-Atlantic. Between January and April 2008 it moved in more temperate waters (17 °C). During this time the winter ring formed as represented in Fig. 7.3 with a red circle Ring, age 2 (Ø 3.5 mm) and a small white arrow that points towards the ring; represented as a HYALINE RING FORMATION (AGE 2) in Fig. 7.4.

From this moment the letters A, B and C are added to both Figs. 7.3 and 7.4, in which the visible structures in the spine are shown. In this way, A represents the stay of the fish in the Bay of Biscay during the summer of 2008, which is when the opaque band forms in the spine (Fig. 7.3). The water temperature is similar to that of the previous summer-autumn. Area B is the second winter in which the fish migrates across the Atlantic (to 55° W) between December 2008 and May 2009. In both figures the different phases of its long stay in the northwest Atlantic are represented by the letters B1, Bp and B2, which is when the pair of hyaline bands forms. The values of water temperature in these dates are completely different to those of the previous winter since the fish enters and leaves the Gulf Stream (Arregui, pers. comm.; Cort et al. 2014), and hence the abrupt falls and rises in values, which vary between 10 and 17.5 °C. Lastly, area C is the marginal growth increment of the spine, the active growth of the fish when it has returned to the Bay of Biscay shortly before being recovered in August 2009.
It must be pointed out that although the latitude is not represented on the graph, the fish moved between 35° and 50° North (Arregui et al. 2018).

7.8 Other Studies on Bluefin Tuna

In the Bay of Biscay studies have also been carried out on feeding (Ortiz de Zárate and Cort 1986; Logan et al. 2010a, b), feeding patterns (Cort and Rey 1979), microelements in otoliths (Rooker et al. 2014; Fraile et al. 2014), parasites (Cort 1990; Rodríguez-Marin et al. 2008b), reproduction (Cort et al. 1976), biometry (Cort 1990), comparative morphology (Addis et al. 2014), behaviour in feeding and regarding predators (Cort 1990), age composition of shoals (Cort 1990), presence of large specimens (Cort 1980, 1981); population dynamics (Bard and Cort 1979, 1980; Cort 1990), and the description of fishing systems (Merino 1997). Similarly, in the context of the biological and genetic sampling and analyses by the program ICCAT-GBYP, the Bay of Biscay has been an important sampling area (Di Natale et al. 2018).

7.9 Official Bluefin Tuna Catches in the Eastern Atlantic (ICCAT, 1950–2016)

The Fig. 7.5 is an advance of the results of the analysis made in the last section of the present article determining the main reasons behind the events described below.

On one hand, ABFT juvenile catches taken in the Bay of Biscay between 1950 and 2016 and those of Morocco (Atlantic part) between 1958 and 2004 are shown (in grey). On the other, the catches of spawners in the Atlantic area mainly caught by the traps in the Strait of Gibraltar, by Asian longliners, basically Japanese, and in the northern European fisheries mostly by Norwegian purse seiners, are represented (in black). The data are taken from the official statistics of ICCAT (ICCAT Database 2017) that appear in ICCAT (2017).

There are four distinct stages:

1950–1963: This period saw a spectacular increase in catches of spawners as a result of the introduction of ABFT fishing in the north of Europe, mainly of purse seine in Norway (Hamre 1960). At the same time the juvenile bait boat fisheries developed in the Bay of Biscay and purse seine in Morocco (Atlantic area). While higher catches were obtained in these latter fisheries, those of spawners fell drastically within a few years.

1963–1975: The fall of the spawner fisheries led to the practical disappearance of the traps in the Strait of Gibraltar and the start of the collapse of fisheries in the north of Europe, which came a few years later (Tiews 1978). Meanwhile, the juvenile fisheries remained stable.
1975–2008: The spawner fisheries of the Strait of Gibraltar recovered a little, though never to the levels of the 1950s, as a result of the installation of a few traps in the area of the Strait of Gibraltar (Cort et al. 2012), but those of northern Europe collapsed at the beginning of the 1980s. The juvenile fisheries (mainly in the Bay of Biscay) continued to operate without changes. In 2008 the PRPA of ICCAT (2008) was implemented.

2008–the present: with the PRPA fully enforced it is difficult to make any conjectures since catches only reflect what is taken in each fishery in accordance with the fishing quotas assigned. While the spawner fisheries, basically traps and longline continue and grow, the juvenile fisheries are in a drastic decline as fishermen do better economically by selling their quotas.

### 7.10 Historical Series of Catches in the Bay of Biscay

The ABFT fishery of the Bay of Biscay has traditionally been one of the most important of the eastern stock. As the fleets of both France and Spain have caught ABFT in this area any study must consider the contributions of both countries. In Cort and Bard (1980) this fishery is described within the framework of the SCRS.

The first historical series of ABFT catches in the Bay of Biscay (Spain + France) between 1950 and 1986 was published by the IEO in 1990 (Cort 1990). Figure 7.6
Fig. 7.6 Historical series of bluefin tuna catches (metric tons) in the Bay of Biscay (Spain+France), 1950–2016

presents this series projected onwards to the present thanks to a review of catches made by the IEO and AZTI (supported by ICCAT-GBYP), which ended with joint publications presented to the SCRS (Cort et al. 2015).

In the series there is a first phase (1950s) with France taking the maximum catches and dominating the fishery. Over time, its importance fell and at the end of the last century there were practically no French bait boat vessels left, the fleet having reconverted to pelagic pair trawl gear. The increase that began to appear in the 1990s was due to the expansion in fishing effort by Spain as a result of improved technologies, which were becoming more advanced every year.

In the initial phase of the fishery the mean catches of France and Spain were 2,200 and 2,100 t/year respectively, whereas towards the end of the 20th century between 1990 and 2000 an average of 3,100 t/year were caught in Spain and 560 t/year in France, confirming the decline of the French bluefin tuna fishery in the Bay of Biscay. The fall in the end phase of the series was due to the implementation of the PRPA from 2008, which assigned a quota of less than 1000 t/year to this fishery, which has not even been reached in several cases because it was sold to other fisheries, such as the traps and purse seiners.

Spanish catches by port are detailed in Cort et al. (2015), who point out that 97.1% of the Spanish bluefin tuna catches of the Bay of Biscay come from Basque ports, making up 85,613 t of the total of 88,170 t. The rest correspond to other regions such as Cantabria, Asturias and Galicia. It also states that vessels targeting this species caught 81.8%, while the remaining 18.2% corresponded to by-catches taken by other fleets, mainly those targeting Thunnus alalunga.

This historical series is evidently highly stable. Although there are fluctuations, the fall that took place in the middle of the 2000s was indeed drastic, just when the PRPA of ICCAT was implemented. Moreover, it must be remembered that this
series is very affected in the last years by a new strategy from northern Spain, which consists of selling quotas to other fisheries, such as the Mediterranean traps and purse seine fisheries, which is cited in the paper of Tensek et al. (2018).

### 7.11 Biological Sampling. Demographic Structure of Catches

In the Bay of Biscay fishery ABFT length samplings have been made regularly since 1972. Though it was French scientists who began this work (Bard et al. 1973), samplings have since been made in Spain, mainly in the port of Fuenterrabía (Hondarribia). The measurement taken is zoological length (from the snout to the outer part of the tail fin, FL), and distributions at age are drawn up using the length by applying age-length keys, the age of the fish being determined by reading fin rays. This practice is fundamental to assessments of the population since they require analytical models, which depend upon the demographic structure of catches.

Since 1950 when the French scientist J. Le Gall published the distribution of ABFT lengths in the Bay of Biscay in ICES (Le Gall 1950, 1951) we have known that this fishery has been mainly made up of juvenile fishes. In his articles this author also referred to the seasonality of spawners (>40 kg), which pass through this area between July, August and mid-September (Table 7.3).

From this sampling came the information that, of a catch of 3,759 t, 70% were juveniles aged 1–4 years. This fact has been confirmed by Bard et al. (1973), Cort (1990), and Cort and Abaunza (2015).

Figures 7.7, 7.8 and 7.9 are length samplings made before the implementation of the PARP.

In these three cases we see that of a very high total catch (between 172,000 and 353,000 fishes/year) almost all of the fishes caught (98.9%) were juveniles (<5 years). This was at a time when there were not many spawners in the Atlantic and small-sized fishes commanded a high price due to the French market.

**Table 7.3** Samplings carried out in St-Jean-de-Luz (France) between 13 April and 23 October 1951. (Adapted from Le Gall 1951)

| Year 1951 | April | May  | June | July | August | September | October |
|-----------|-------|------|------|------|--------|-----------|--------|
| Catch (t) | 12    | 258  | 665  | 652  | 838    | 867       | 467    |
| Fork length (cm) | 65–78 | 65–70 | 70–92 | >120 | 120–145 | 120–145 | 76–78 |
| Round weight (kg) | 4.1–8.7 | 4.6–8.7 | 7–17 | 23–41 | 29–70 | 29–70 | 7–9 |
| Age       | 1–2   | 1–2  | 2–3  | 3–5  | 4–6    | 4–8       | 1–2    |
Since the implementation of the PARP (2008) this fishery has undergone considerable changes:

- The minimum length has been raised to 8 kg, which means that fishes aged one year and some of age two are no longer caught.
- The reduced quotas assigned in recent years (2012–2015) have led to their sale to other spawner fisheries, traps and purse seine.
7.11 Biological Sampling. Demographic Structure of Catches

| Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----|---|---|---|---|---|---|---|---|
| %   | 13.5 | 61.5 | 18.9 | 5.2 | 0.8 | 0.1 | 0.002 | 0 |

**Fig. 7.9** Length frequencies and corresponding ages, year 1993 (before the implementation of the PARP) Bay of Biscay $N =$ number of fish caught ($Fl =$ Fork length)

| Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----|---|---|---|---|---|---|---|---|
| %   | 0 | 27.0 | 38.2 | 21.0 | 8.0 | 5.3 | 0.2 | 0.2 |

**Fig. 7.10** Length frequencies and corresponding ages, year 2009 (after the implementation of the PARP) Bay of Biscay $N =$ number of fish caught ($Fl =$ Fork length)

- In the first year of fishing (2016) after selling the quota, the fleet has targeted large-sized fishes, which fetch a better price.

These facts can be observed in the following two examples (Figs. 7.10 and 7.11) together with the total number of fishes caught, which is actually very small in comparison with previous decades.
While in 2009 (Fig. 7.10) juveniles aged 2–4 (86.2%) were still being caught, the presence of spawners in the catch was clear (Cort and Martínez 2010). In 2016, following four years in which the quota was being sold off, fishing switched to large-sized fishes as this was more profitable. By that year the juvenile catch (2–4 years) had fallen to 29.9%.

**Table 7.4** Demographic structure of bluefin tuna catches in the Bay of Biscay (1949–2010)

| Age | Mean weight (kg) | Num. Fish | Catch (kg) | % fish | % weight |
|-----|------------------|-----------|------------|--------|---------|
| 1   | 5                | 4,774,272 | 23,871,360 | 37.3   | 15.3    |
| 2   | 11               | 5,459,690 | 60,056,590 | 42.7   | 38.6    |
| 3   | 20               | 1,744,950 | 34,899,000 | 13.6   | 22.4    |
| 4   | 37               | 524,681   | 19,413,197 | 4.1    | 12.5    |
| 5   | 53               | 179,399   | 9,508,147  | 1.4    | 6.1     |
| 6   | 66               | 63,311    | 4,178,526  | 0.5    | 2.7     |
| 7   | 80               | 28,954    | 2,316,320  | 0.2    | 1.5     |
| 8   | 106              | 14,463    | 1,533,078  | 0.1    | 1.0     |
| Total |          |           | **12,789,720** | **155,776,218** | 100 | 100 |
| Actual catch | | | **155,301,000** |
| Residual (%) | | | **0.3** |
Ten years on from the first implementation of the PRPA, Fig. 7.11 shows the cohorts the measure was aimed to preserve in grey. The presence of 9 year old fishes is noteworthy, as this age corresponds exactly to the ABFT born in the year the PRPA was adopted (2007). Moreover, unlike previous decades the presence of large fishes is highly significant, something which ties in with the latest reports of the assessment group, in which a great increase was reported in the biomass of the spawning stock (ICCAT 2012, 2014, 2017).

Based on an analysis of the periods 1966–1986 (Cort 1990) and 1966–1996 (Cort and Ortiz de Zárate 1997), Table 7.4 presents a summary of catches converted to ages of the Bay of Biscay fishery extended to 62 years (1949–2010).

The results confirm something of great importance, which is that 97.5% of the catch (in number of fishes) of this fishery is made up of juveniles (<5 years, Fig. 7.12),

Fig. 7.12 Juvenile specimens (2–3 years; 8–15 kg) caught in the Bay of Biscay (1980s). (Documentary archive, IEO)
and it can be confirmed that the exercise was performed correctly since the total catch deriving from the mean weight at age applied to each age is only 0.3% above the real catch in this period (155,301 t). The results of this review were presented to the SCRS in 2016 (Cort 2017).

7.12 Fishing Effort and Abundance Index

The fishing effort of the tuna fleet is monitored by local observers in the largest ports of the north of Spain, both those where only ABFT is landed (Fuenterrabía) and those where landings also include albacore tuna (Guetaria, Ondárroa, Bermeo and Santoña). It is also monitored by the log books kept by some fishing vessels. The unit of fishing effort was *Days at sea*.

Following recommendations made by the SCRS in the 1980s, the Bay of Biscay fishery has been used in assessments as an indicator of the abundance of Atlantic eastern juveniles, and so since then a nominal abundance index has been used for age groups 2 and 3 (fishes of 7–30 kg), i.e. an indicator that included catches of this age group and the days at sea used to catch them (Cort 1995; Ortiz de Zárate and Rodríguez-Cabello 2000). But following the recommendations of the scientific committee this index was standardised because the committee considered that other factors, such as age, the year and month of the catch, the crew number or the number of live bait tanks should be considered in the analysis in order to develop the index more precisely (Rodríguez-Marín et al. 2003; Santiago et al. 2012). As this is a very well defined fishery both in space and time there were no significant variations in results with respect to the nominal index. Age groups 2 and 3 (15–25 kg) were selected for the standardized index.

![Abundance index (expressed in fishes/days at sea) of bluefin tuna juveniles (ages 2–3) in the Bay of Biscay](image)

Fig. 7.13 Abundance index (expressed in fishes/days at sea) of bluefin tuna juveniles (ages 2–3) in the Bay of Biscay
For better interpretation, Fig. 7.13 combines the results of the nominal and the standardised indices. The abundance index (expressed in fishes/days at sea) of juvenile bluefin tuna in the Bay of Biscay remains stable throughout the series studied, though there are evident fluctuations and maximums that may be a reflection of years of good recruitments. The fall in recent years was caused by changes in fishing strategy since the implementation of the PRPA in 2008.

The lack of reliability of this index since the PRPA was introduced has made it necessary to seek new ways of obtaining information on the abundance of juveniles in this fishery. To this end, in recent years AZTI has been developing an index based on acoustics obtained in annual surveys (Goñi et al. 2017). In a few years the series may have become large enough to use in assessments.

As we have seen, the ABFT fishery of the Bay of Biscay plays a very important role in the general context of research into the species. In this area field research, samplings and statistical monitoring of the fishery have been carried out for decades and have contributed greatly to our knowledge of the species and improvements in the quality of assessments. All of this work means that the basic tasks of advising administrators, the fishing sector and society as a whole can be performed more effectively.

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