Chapter 8
A Publication that Sheds Light on the Disappearance of the Eastern Atlantic Bluefin Tuna Spawner in the 1960s

Based on an article recently published, the influence the massive catch of juvenile fishes on the eastern Atlantic spawning stock (Bay of Biscay and Morocco) between 1949 and 2006 is described, the event which probably led to the decline of the traps of the Strait of Gibraltar and the collapse of the northern European fisheries from the 1960s. The results of the population analysis carried out reveal that during the period from 1949 to 1962, according to the most optimistic scenario, the quantity of fishes reaching the spawning phase would not surpass 16%; during the period 1970–2006, this figure would rise to 41%; and in the present due to the prohibition of catching juveniles in most of the fisheries as a result of the PRPA, all of the mortality in the juvenile phase is due to natural causes.

Up until now we have seen the contribution of the ABFT Bay of Biscay fishery to the eastern stock from 1949 to the present highlighting that there is a before and an after of the PRPA. We shall proceed to look at how this fishery has influenced the remaining eastern Atlantic fisheries.

Among the most relevant events of the last decades, in the introduction we cited the overfishing of the 1960s, which brought with it the downfall of the Atlantic traps and the collapse of the northern European fisheries, among them the Norwegian purse seine fishery. These facts have been the subject of numerous studies and publications (Tiews 1978; Fromentin 2002, 2009; Ravier and Fromentin 2001; Nøttestad and Graham 2004; MacKenzie and Myers 2007; Fromentin and Restrepo 2009; Fromentin et al. 2014; Fromentin and Lopuszanski 2013; Bennema 2018), the organization of an ad hoc symposium in 2008 (ICCAT 2009), and diverse hypotheses relating the event to environmental factors and changes in ABFT migratory patterns. Nevertheless, no conclusion was reached that could explain the true reasons behind the "1963 enigma", so-called because it was from that year that the fall of spawner fisheries took place. In a recent publication Faillettaz et al. (2019) attribute these facts to climate variability.

To provide another response, in 2015 the article "*The fall of the tuna traps and the collapse of the Atlantic bluefin tuna, Thunnus thynnus (L.), fisheries of northern Europe from the 1960s*" was published in *Reviews in Fisheries Science & Aquaculture* by Cort and Abaunza (2015). The study contains an extensive review of the catch data of the adult and juvenile Atlantic fisheries between 1914 and 2010 as well as a

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review of studies on the biology and fishing of the species with the aim of studying the consequences of juvenile mortality on the adult population of the eastern Atlantic. The article describes how the ABFT juvenile fisheries (<40 kg, <5 years of age) began to proliferate in the eastern Atlantic at the end of the 1940s, the Bay of Biscay being the first place it did so (with the bait boat fishery) and later, in the middle of the 1950s the Atlantic coasts of Morocco (with purse seine). In both cases these were artisanal fisheries, though this did not make it any less significant as we shall now see. In the western Atlantic ABFT juveniles also began to appear in the purse seine catch from the 1960s, however there is ample scientific information available to dismiss any relation between this circumstance and the events that took place in the eastern Atlantic.

According to this study, the author's working hypothesis was to find out if the level of juvenile catches in the Northeast Atlantic in the period 1949–1962 can plausibly explain the disappearance of adult ABFT from the fisheries in northern Europe and the decrease in the yields of the traps of the Strait of Gibraltar and the adult fishery in the Bay of Biscay. The method of analysis was to use a simple deterministic model of cohort analysis in equilibrium based on the principle of parsimony or Occam's razor (Shiflet and Shiflet 2006). Taking into account the available data and the proposed objective, this simple model can provide a useful answer to the hypothesis presented while deliberately disregarding other factors and approaches that would complicate the model without contributing significant improvements to the main results.

To perform the simulation, the classical equations applied in cohort analysis and catch curve analysis were used (Pitcher and Hart 1982; Hilborn and Walters 1992). Only having catch data and an estimate of natural mortality, the model serves to estimate fishing mortality and abundance at age in the stock (Pitcher and Hart 1982). The three main assumptions of the model were: (a) the population has a constant recruitment at age 1 in each of the periods analyzed: 1949–1962, 1970–2006 and 2009 (a necessary condition for the analysis of cohorts in equilibrium); (b) natural mortality is constant = 0.14; (c) migratory movements were not considered in relation to the western stock of ABFT.

In the data specifications, the authors took into account the ICCAT publications regarding the assessment of the ABFT stock (ICCAT 2014b). Following the concept of equilibrium, they considered a constant recruitment in each period of time (although the cohorts of 1974 and 1994 did not fit well with the mean value of the second period). In this way, the decrease in the abundance of the population reflects the decrease in each of the cohorts (Haddon 2011). The following equation was used to calculate fishing mortality at age i (F_i), with an initial population at age $i = 1$, natural mortality of M, and catch at age $i = C_i$ (the catch data are known up to 4 years old):

$$C_i = N_i \frac{F_i}{F_i + M}\left[1 - e^{-(Fi+M)}\right]$$

The software used to solve the equation in F_i was the program Matlab©R2010a.

Table 8.1 Bluefin tuna juveniles (ages 1–4) caught (number of fish) in the fisheries of the Bay of Biscay and Morocco (Atlantic) between 1949–2009. Taken from Cort and Abaunza (2015) (Courtesy of *Taylor and Francis Group*)

Period 1949–1962/Age	Catch (fish)	Period 1970–2006/Age	Catch (fish)	Current period (2009)/Age	Catch (fish)
1	306,982	1	178,662	1	0
2	128,672	2	74,895	2	21,523
3	42,947	3	24,870	3	16,760
4	12,824	4	7,432	4	4,982
Total	491,426	Total	285,859	Total	43,265

The number of fish present in a population will depend upon the initial number of the population and of those that die. In this way, once F_i was obtained, to get the abundance of that age in the following year, the authors applied the survival equation:

$$N_{i+1} = N_i e^{-(Fi+M)}$$

Thus, the different F at ages 1, 2, 3 and 4 were calculated in the three periods considered (1949–1962, 1970–2006 and 2009) as well as the corresponding survivors in the following year (N_2, N_3, N_4 and N_5). The abundance at age 1 = N_1 comes from the initial starting assumption for recruitment in each period.

The study contains 8 basic criteria, of which we will cite the most significant for the purposes of understanding the results of the analysis: According to the information coming from the ABFT assessments (ICCAT 2012, 2014), the abundance and potential of this resource in the Mediterranean Sea is much higher than in the Eastern Atlantic. It is logical to think that the number of recruits that leave the Mediterranean Sea for the Atlantic Ocean is less than those remaining in the Mediterranean Sea. Under this assumption, the authors selected three scenarios for the percentage of ABFT recruits that migrate from the Mediterranean to the Atlantic: 20, 30 and 40%. The population values of the initial abundance in the Eastern Atlantic will correspond to each of the percentages.

In Table 8.1 the values used for the analysis during the three periods described are shown. In the most recent period (2009), the effects of ICCAT's recovery plan were already noticeable, as most of the juvenile catch had disappeared.

The study continues with the description of the catch statistics (in weight and in numbers) of ABFT in the eastern Atlantic, (Bay of Biscay and the Atlantic coast of Morocco, fundamentally) for the three periods considered: 1949–1962, 1970–2006 and 2009. In the first period the catch was 83,448 t in weight and 6,879,967 fishes in number (491,426 fishes caught/year). In the second period the catch was 101,800 t, corresponding 10,576,771 fishes (285,589 fishes caught/year) and for the third period the catch was 728.8 t, equivalent to a total of 43,265 fish caught/year.

In Table 8.2 the results of the simulation analyses are shown. Logically, it can be observed how the initial population is a factor of great influence in the estimations of the fishing mortality at age and of the survivors at age assuming, as has previously been stated, that M is constant.

In this study for the period 1949–1962, a recruitment of 2,000,000 ABFT of 1 year of age to the eastern stock is established. Considering the three scenarios of emigration of juveniles from the Mediterranean to the Atlantic of 20, 30 and 40%, it is observed that:

- In the first scenario (20%; 400,000 emigrants), the total mortality exceeds the number of fish recruited, so this result is not possible.
- In the cases of 30 and 40% of emigrants, fishing mortality far exceeds natural mortality in all ages except in age 4 of the 40% emigration rate scenario. The consequence of this total mortality is a survival curve with a very pronounced decrease, showing very low survival rates of 3% and 16% at the end of the four years considered in the second and third scenarios respectively (see Table 8.2; Fig. 8.1).

The recruitment to age 1 in the eastern stock of ABFT for the period 1970–2006 was assumed at 3,000,000 fish. Considering again the three scenarios of juvenile emigration (20, 30 and 40%), this study showed that:

- *F* at ages 1 and 2 is still higher than natural mortality, especially in the 20 and 30% emigration scenarios, although less pronounced than in the 1949–1962 period. In the same way, the resulting total mortality generates survival curves with less pronounced decreases than in the previous case, resulting in survival rates at the end of the four years of 26 and 41% (Table 8.2, Fig. 8.1).

For the third period (year 2009), the estimated recruitment of ABFT to age 1 is around 4,000,000 fish. The analysis of the three emigration scenarios of juveniles from the Mediterranean to the Atlantic of 20, 30 and 40% shows that:

- The population dynamics of ABFT in the Northeast Atlantic for the juvenile age groups is determined by the natural mortality rate, since fishing mortality is practically nil. As a result, the survival curves show much gentler decreases and significantly higher survival rates at the end of the four years (53 and 55%) than in the previous periods (Table 8.2, Fig. 8.1).

Based on the results presented above, the study concludes that the high values of fishing mortality in the juvenile ages of ABFT (well above natural mortality) during the period 1949–1962 and also in ages 1 and 2 during the period 1970–2006 demonstrate the great importance of fishing activity on a juvenile population for the future of sustained spawner fisheries in the eastern Atlantic.

It should be mentioned that by applying the natural mortality values of the last review carried out by the ABFT assessment group (ICCAT 2017), which point to values much higher than those used in the present study, the result of the analysis would have been much more pessimistic.

Table 8.2 Result of the analysis of the juvenile population. The recruitment values were taken from the analysis by the bluefin tuna assessment group of the SCRS (ICCAT, 2014) F = fishing mortality; Z (total mortality) = $F + N$ (natural mortality). Taken from Cort and Abaunza (2015) (Courtesy of *Taylor and Francis Group*)

Period	Scenario 1	20% outgoing	Final population	Mortality Z (%)	Survival (%)	F_1	F_2	F_3	F_4
	Recruitment	Initial population							
1949–1962	2,000,000	400,000	0	100	0	1.7	–	–	–
1970–2006	3,000,000	600,000	154,070	74	26	0.40	0.30	0.10	0.04
2009	4,000,000	800,000	423,609	47	53	0.0	0.03	0.03	0.01
Period	Scenario 2	30% outgoing	Final population	Mortality Z (%)	Survival (%)	F_1	F_2	F_3	F_4
	Recruitment	Initial population							
1949–1962	2,000,000	600,000	16,231	97	3	0.80	0.90	0.80	0.60
1970–2006	3,000,000	900,000	325,166	64	36	0.20	0.10	0.06	0.02
2009	4,000,000	1,200,000	652,088	46	54	0.0	0.02	0.02	0.01
Period	Scenario 3	40% outgoing	Final population	Mortality Z (%)	Survival (%)	F_1	F_2	F_3	F_4
	Recruitment	Initial population							
1949–1962	2,000,000	800,000	129,620	84	16	0.50	0.40	0.20	0.10
1970–2006	3,000,000	1,200,000	496,415	59	41	0.20	0.10	0.04	0.01
2009	4,000,000	1,600,000	880,570	45	55	0.0	0.02	0.02	0.01

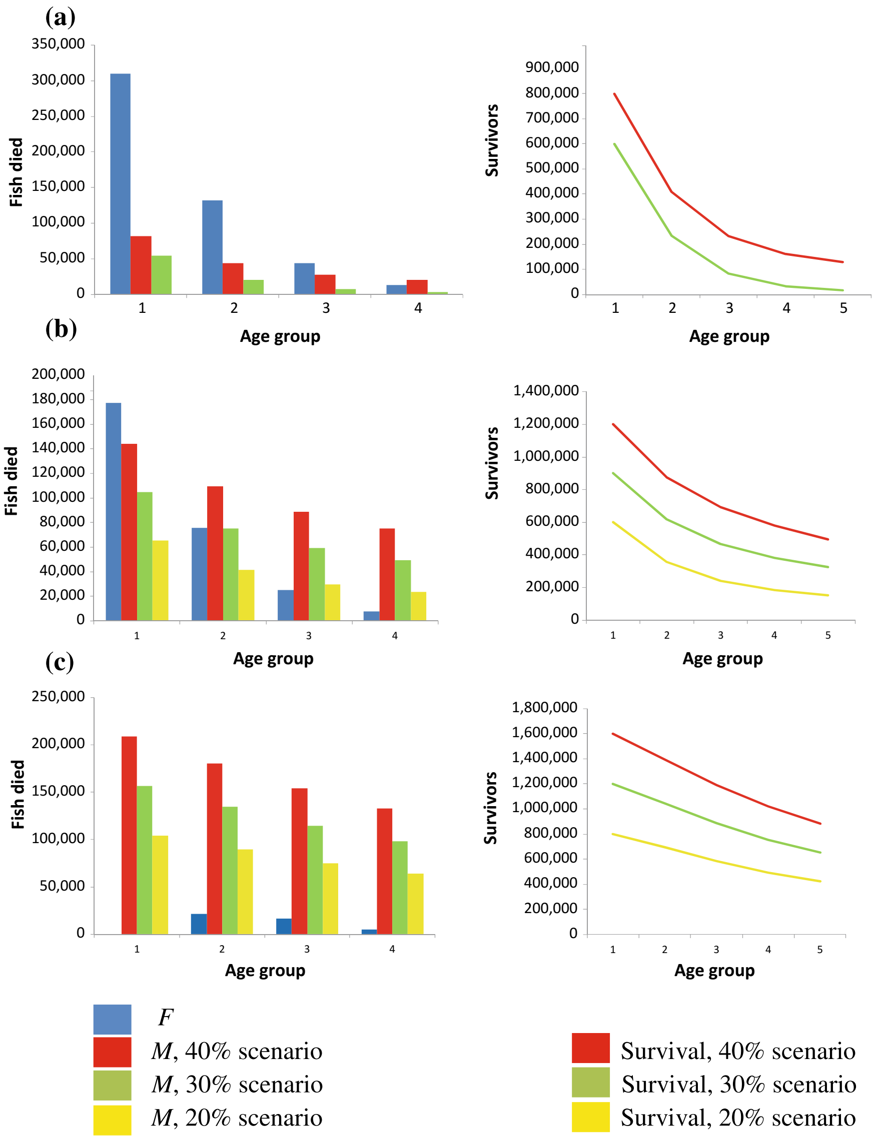

Fig. 8.1 Left column: comparison of the number of fishes/age (ages 1 to 4) dying due to fishing mortality (F) and due to natural mortality (M) in each of the scenarios and in each of the periods. Right column: survival curves/age in each of the scenarios and in each of the periods. Above (**a**): period 1949–1962; Central (**b**): period 1970–2006; Below (**c**): present period: 2009. (Adapted from Cort and Abaunza 2015)

From the results of the analysis, the survival of juveniles in the 1949–1962 period, after having passed through the juvenile fisheries (Morocco and Bay of Biscay) for 4 years and a mean of 491,426 fishes/year having been caught, in the most optimistic scenario the quantity of fishes reaching the spawning phase would not surpass 16% (Table 8.1). In the intermediate period (1970–2006), now with a mean catch of less than the previous period (285,859 fishes/year), this figure would rise to 41%; and now in the present, with the practical disappearance of the juvenile fisheries, all the mortality in the juvenile phase is due to natural causes.

The Fig. 8.2 represents graphically the conclusion of the study according to which it is demonstrated that the juveniles represented by the circle in the figure above it should have been the future spawners of the other two figures. Special attention should be paid to the quantities caught that appear on the y-axis of the three figures.

The article verifies that the assessments of the resources of the eastern stock carried out by the ABFT assessment group of the SCRS do not detect these facts since they consider the stock as a unit (eastern Atlantic + Mediterranean) and because, moreover, the database of the juvenile catches used in the last assessment in 2014, for the period 1949–1962, is highly underestimated providing, as it does, a picture of the situation that is far from the reality. Specifically, according to this assessment, between 1950 and 1962 1,860,000 ABFT of 1–4 years were caught (ICCAT 2014), when in reality the figure was 6,559,000. The incorporation of these latter catches in the model in the following assessment (in 2017) would have greatly changed the results during the initial phase of the fishery giving a more realistic view than that offered by the results of 2014 in addition to bringing a vision of how the state of the fishery was at the beginning of the intensive exploitation in the 1950s (Fig. 8.3; ICCAT 2014). But something unexpected happened in 2017. All references to these facts were eliminated by removing from the model all the data from between 1950 and 1967 (ICCAT 2017). Why were these data deleted? It had been determined that little information (biological sampling) was available covering that period, which meant that substitutions would have had to be made of data in great quantities, something which, although true, is commonly done in the SCRS assessment groups. The authors consider that the deletion of these data from the reports of the group meant the loss of an important part of the history of the eastern Atlantic bluefin tuna fisheries, as well as the loss of hugely valuable information from the golden age of the spawner fisheries of northern Europe and the traps of the Strait of Gibraltar. Moreover, it meant the loss of the data relating to the overfishing of juveniles that affected the spawner fisheries for years afterwards.

We can conclude this section by stating that the origin of the crisis of the ABFT Atlantic spawner fisheries in the 1960s (traps, Strait of Gibraltar and northern Europe) was possibly the result of the intensive fishing of spawners for a period of 5–10 years and of juveniles in the Bay of Biscay (from 1949) and in waters of Morocco (from 1958). The crisis arose when ICCAT had not yet been founded, so nobody can be blamed for what happened. But the fact that international organizations responsible for defending the preservation of fishing resources now exist does not guarantee the fulfillment of the preservation policies that they themselves determine. It is the political will of the states forming part of these organizations that will ultimately lead

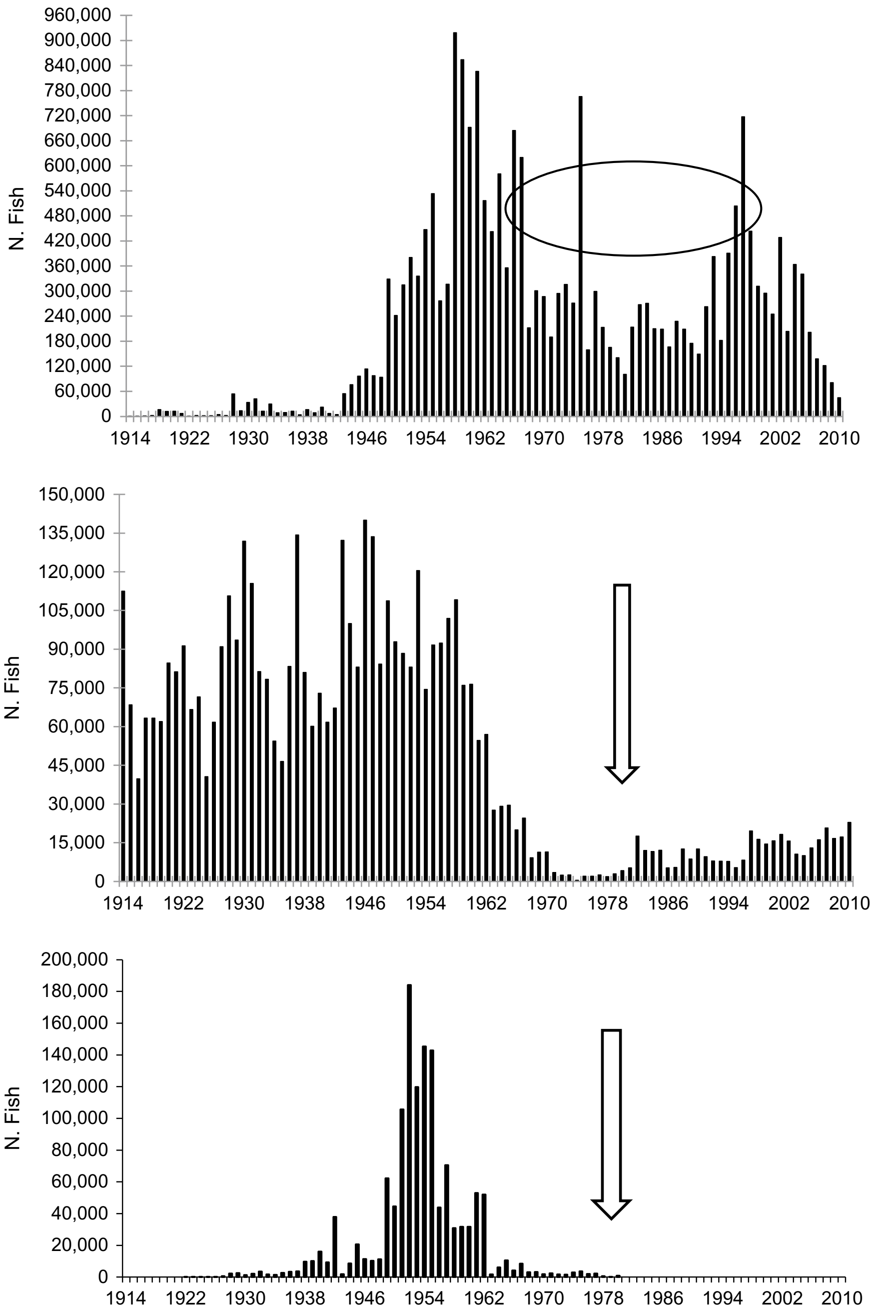

Fig. 8.2 *Above*: juvenile bluefin tuna catches in the fisheries of the Atlantic part of the eastern stock (Morocco and Bay of Biscay). *Central*: bluefin tuna spawner catches in the Atlantic traps of the Strait of Gibraltar (Spain, Morocco and Portugal). *Lower*: bluefin tuna spawner catches in the northern European fisheries

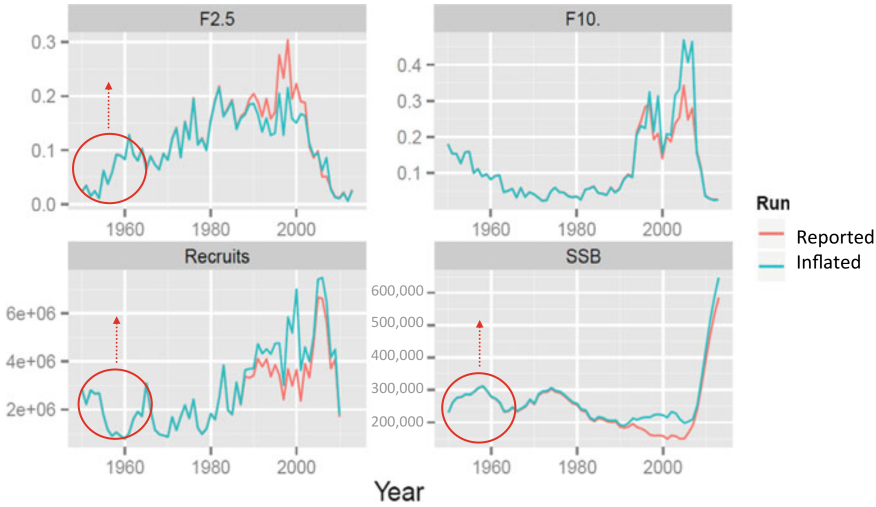

Fig. 8.3 Estimates of fishing mortality (of ages 2 to 5 and 10+) in the upper part; biomass of the spawning stock (in t) and recruitment (in number of fishes) in the lower part according to the population analysis made in 2014. *Red line*: declared catch. *Blue line*: inflated catch. (Courtesy of ICCAT). The red circles/arrows represent the increase expected following application of the analysis of the data supplied by Cort and Abaunza (2015)

to these measures being correctly implemented. ABFT is a clear example of the failure to enforce the measures adopted for its conservation even decades after ICCAT was established (WWF 2008). Nevertheless, under the pressure of environmental NGOs from the 1990s and the requests of Sweden in 1993 (Safina 1993) and Monaco in 2009 (Fromentin et al. 2014) to include bluefin tuna in Appendix 1 of the *Convention of International Trade in Endangered Species of Wild Fauna and Flora* (*CITES*), the situation has been turned around completely such that now, under the monitoring of ICCAT's Pluriannual Recovery Plan (PARP) whose implementation began in 2008, the resources of this species are apparently in much better shape (ICCAT 2017).

There have been many theories to explain what happened to the bluefin tuna spawner population from 1960 and what it was that made this species disappear from the fisheries of northern Europe. In general, it had been put down to environmental factors, the scarcity of prey (herring and mackerel) or to changes in the migratory behaviour of bluefin tuna (ICCAT 2009). Nevertheless, until now nobody had demonstrated the effects of the expansion of the juvenile fisheries in the eastern Atlantic region (Bay of Biscay and Morocco).

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