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Analysis of the daily catch and effort data of the bluefin Algarve trap fishery during the years 1898-1900.

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Summary

This paper is based on the recently recovered daily catch and effort data of the Algarve traps during the 1898-1900 period. The 18 traps that were then active in the Algarve South of Portugal were targeting the 2 migrations of BFT, toward and from the Mediterranean Sea. Their bluefin catches was significant, corresponding to average yearly catches of 61.000 bluefin, i.e. approximately 7900 t. Migration dates and durations in and out the Med are estimated based on the daily CPUEs of the traps. Migration patterns have been very stable during the 3 years. The entry migration took place during 42 days, and during 53 days for their return. Daily catches are showing large waves of tunas during the 2 migratory phases. It can be hypothesised that each of these tuna waves are spending about 52 days in the Med, and that each of these tuna groups are stable groups of schools that are consistent between their arriving and returning migrations. Migration trajectories along the Algarve coasts can be estimated from the daily CPUEs of the various traps and they appear to be variable between the various phases of the entry and returning migrations. The daily data by trap show that most traps catch entering BFT, but at quite low CPUE, when only few traps are efficient to catch the returning bluefin, but with much larger CPUEs. The analysis of catch and CPUEs during the entry and returning phase allows to conclude that the catchability and fishing mortality of the bluefin stock in the Algarve trap fishery was much larger during the return phase. Additional daily data from other traps, historical and contemporary, should be collected and analyzed in order to provide more comprehensive results on migration, stock structure and exploitation rate of the stock.

Résumé

Cet article est base sur les données de prises et d'effort des madragues du Portugal en 1898-1900 qui ont été récemment récupérées. Les 18 madragues qui étaient alors actives sur la cote de l'Algarve, au sud du Portugal, ciblaient les 2 migrations du thon rouge vers et en provenance de la Mer Méditerranée. Les prises annuelles de cette pêcherie étaient significatives atteignant en moyenne 61000 individus et environ 7900 tonnes. Les dates et les durées des migrations vers ou depuis la Mer Méditerranée sont estimées en se basant sur les prises et les PUE des madragues. Les migrations ont été très stables durant les 3 années observées. La migration entrant en Méditerranée a lieu durant 42 jours et celle de retour durant 53 jours. Les prises journalières montrent des fortes vagues de thons durant les 2 phases. On peut admettre l'hypothèse que les thons passent environ 52 jours dans la Mer Méditerranée, et que chacune de ces vagues de biomasses seraient des groupes de thons stables durant les migrations d'entrée et de sortie. Les trajets migratoires des thons le long des cotes de l'Algarve sont estimés à partir des CPUEs . Les routes migratoires des thons sont différentes en entrée et en sortie. Les données montrent aussi que si toutes les madragues capturent des thons en entrée, parfois avec des faibles PUE, alors que seules quelques madragues capturent efficacement les thons en migration de retour. L'analyse des prises et des PUE journalières des diverses madragues durant les 2 phases de la migration montrent que la capturabilité du stock et la mortalité par pêche du stock sont beaucoup plus fortes durant la migration de retour. Il est recommandé que ce type de données journalières soient collectées et analysées pour d'autres madragues, historiquement et actuellement, ceci afin de fournir des résultats plus compréhensifs sur les migrations, la structure du stock et ses taux d'exploitation.

1- Introduction

Various studies on bluefin tunas based on the analysis of historical trap data have been published in the scientific literature and they have been providing highly valuable results on the interannual variability of the Eastern Atlantic bluefin tuna stock. Because of the large number of coastal traps[1] that have been active in various fishing zones, in the Mediterranean Sea and in its immediate proximity, the analysis of these trap fishery data, can be of great scientific interest to study this valuable resource that has been actively exploited during millenniums. Most of the present analysis of these historical trap data, for instance by Neuparth 1925, Fromentin and Ravier 2001 or Powers and Fromentin 2005, have been done at a global scale of the yearly catches taken by each of the traps for which these data were available.

However, detailed statistics of daily catch and effort statistics have been also collected on most bluefin Mediterranean traps, but these detailed data have very seldom analysed by scientists. These detailed daily data can be of great interest to study the detailed pattern of the bluefin migrations as well as to better estimate the yearly abundance of bluefin tuna that have been entering or going out each year from the Mediterranean Sea. Ideally these daily data should be associated with environmental data, as the meteorogical conditions, sea surface temperature or turbidity of the water may condition the daily catches of the traps (ref…). The most interesting results expected from the analysis of daily data can be obtained on traps that are targeting the two migration flows of bluefin, when they are entering and when they are going out from the Mediterranean Sea, as their analysis may provide valuable information on the migratory routes, and on the migration periods and duration, and indirectly on their peaks of spawning in the Mediterranean Sea. Among the traps of great potential interest, many of the historical traps active in the Algarve coast south of Portugal (analyzed by Neuparth 1925) have been targeting for centuries these 2 migration phases of bluefin, targeting arriving and returning bluefin. The activity of Portuguese traps has been identified since 1368, and it appears that these traps have been functionning since their early days with anchored nets, i.e. as the real Sicilian traps (and not as the beach seines used in Spain until the nineteen century). These early Portuguese traps were then owned by the kings of Portugal, and in 1433 their property was given by King Don Duarte to Prince Henrique. It can be noticed that the large funds and huge benefits offered by these traps have been a major source of funding for all Portuguese marine exploration and conquests developed by Portugal during the 15th century.

The daily data of the 18 Algarve traps have been collected and the 1898 data have been already well analysed by Don Carlos de Bragança, King of Portugal in his book (Bragança de 1899), but these valuable detailed data were not computerized and not available to ICCAT scientists.

As the ICCAT GBYP has been promoting and active data mining of historical trap data, all the 1898 daily catch and effort data used then by the king of Portugal were identified and recovered in the Vasco da Gama Lisbon aquarium. Additional daily catch and effort data of the same traps were also identified and recovered for two additional years, 1899 and 1900 in the archives of king Don Carlos stored in the same library of the Vasco de Gamma aquarium. All these daily data of the 1898-1900 period are now available in the ICCAT GBYP data base.

The goal of this paper is to analyse these daily catch & effort data of the Portuguese traps during these 3 years, to examine the potential scientific input of this detailed historical data set in the today context of the bluefin stock assessment done by ICCAT

[1] about 250 traps active during some periods,

scientists and to recommend additional data mining and investigations following these results.

2- Material and methods

Don Carlos de Bragança was a king actively involved in a multiple range of terrestrial and marine scientific investigations that were often conducted in close cooperation with the Prince of Monaco. Don Carlos was convinced[2] that the detailed fishery data of Portuguese traps would be of great scientific interest to learn more on bluefin tuna resource migrating towards their Mediterranean spawning zones, and later moving back to the Northern Atlantic. Subsequently, the administrator of each of the Portuguese traps had to fill during 3 years, 1898 to 1900, monthly detailed "log books", indicating the fishing mode of the trap (targeting bluefin moving in or out), the fishing days without catches, and the daily catches by species during all days with a fishing operation. The present data mining has shown that these original daily data of the 18 active traps then active in Portugal were stored in the Vasco de Gamma Aquarium in Lisbon[3], were they have been recovered and computerized thanks to the ICCAT GBYP data mining program and with the kind assistance of the Vasco de Gamma librarian. The exact geographical positions of each trap are fixed and well known see figure 1, their positions being given in table 1 (from west to east).

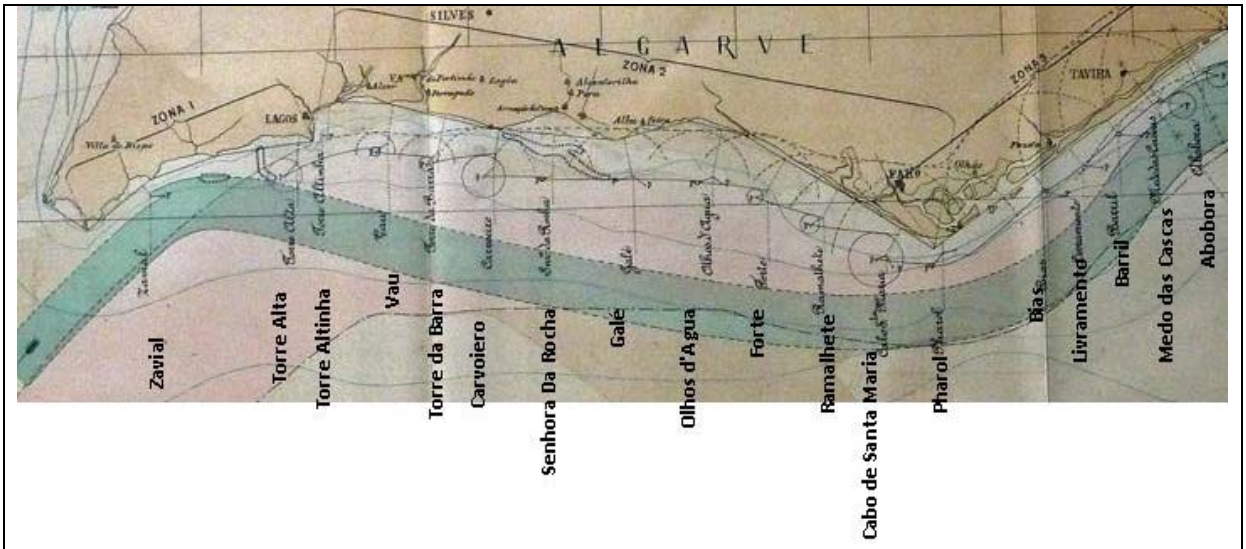

Figure 1: Position and names of the 18 Portuguese traps active during the 1898-1900 period and analysed in the present study (Modified from Don Carlos 1898)

[2] Well before the ICCAT and its so called TASK2 requesting detailed catch and effort statistics to all its member countries.

[3] This Vasco de Gamma aquarium being created by the same king Don Carlos in 1895.

Trap	Lat. N	mn	Lon W	mn
Zavial	36	58	8	52
Torre Alta	37	0	8	43
Torre Altinha	37	2	8	39
Vau	37	1	8	36
Torre da Barra	37	0	8	30
Carvoiero	36	59	8	26
Senhora Da Rocha	36	59	8	22
Galé	36	59	8	20
Olhos d'Agua	36	59	8	13
Forte	36	58	8	8
Ramalhete	36	56	8	2
Cabo de Santa Maria	36	52	7	57
Pharol	36	52	7	51
Bias	36	56	7	45
Livramento	36	59	7	38
Barril	37	1	7	36
Medo das Cascas	37	3	7	34
Abobora	37	4	7	31

Table 1: Names and positions of the Portuguese traps active during the 1898-1900 period.

It should be kept in mind that there is a distance of only 73 nautical miles between the most eastern of the traps (Abobora) and the most western one (Zavial): then the distance between these Algarve traps is quite limited (the average distance between traps being only of 4.3 miles) and this is a very short distance for fast swimming fishes, such as adult bluefin tunas.

It would appear that these historical Algarve traps were also catching various by-catch species, such as swordfish and sharks, but these quantities were not registered in the log books submitted by Don Carlos, and this lost information has not been computerized.

In these daily catch log books available, all the bluefin catches are classified in 3 categories: the 2 main ones being the bluefin tunas identified by fishermen as tunas migrating towards or from the Med, and a very small third group of bluefin tuna, called "*recuados*" i.e. tunas that are moving backwards, and that are estimated by King Don Carlos as being resident of Algarve waters (doing random movements in the area, but not migrating). All these log books sheets have been sent to the laboratory of King Don Carlos in Lisbon, and they are still available today for consultations. These data are nearly covering all the fishing activities of Portuguese traps, taking note that some monthly data sheets are missing in 1899 for 3 of the traps. In these log books, all the bluefin catches have been identified in numbers of tunas, and never in weight, and classified in 2 well identified categories: large and medium bluefin (identified in the log books as "atuns"and as "atuarros". The log books also contain the catches in numbers of smaller tunas classified in 2 categories called "albacora" (Portuguese name of *Thunnus alalunga*) and "cachorretas". It would seem that these 2 groups would also correspond to small bluefin, but possibly mixed with other tuna species (with albacore for the 1st group and with small tunas with the second one). These 2 groups described by De Bragança 1898[4] are quite ambiguous and of minor importance, and they have not been thoroughly analyzed in the present work.

[4] Extracts from the Work by De Braganza 1898 on the species caught by traps:
« Portugal fishermen classify BFT catches under the generic term of « tunas », but using various peculiar names, corresponding to sizes caught. Based on the work by other authors and on my personal investigation, there is no doubt that the term « atum » corresponds to large BFT, when « atuarro » corresponds to BFT at sizes under the average. The portuguese term « albacora » corresponds to albacore (Thunnus alalunga), a species taken at sizes

Unfortunately, there are no indication available on the exact sizes or length of these bluefin caught in each of these categories. Indirect estimates of the average weights of these 2 categories of bluefin have been obtained by Pereira 2011 and these average weights are consistent with those given by Vilela and Cadima 1959: 150 kg for “atuns”, 70 kg for “atuarros” and 40kg for “albacore”, allowing estimating the daily total catches of bluefin in weight. The numbers of other species, such as small tunas and other species mixed, caught daily by each trap are also available in these log books. The available log books also indicate if the trap was active each day, and as the daily catches of bluefin, classified in 3 size categories, are known each day, also indicating if the effort was targeting the inward or the outward migration, during the 2 entire fishing seasons, daily CPUE have been calculated for each trap.

Many comments are also done by the managers of the traps on many of the fishing sheets, or on additional sheets, but they have not been captured in the ICCAT data base nor used in the present analysis because of their heterogeneity. Most of these comments were about the bad weather, too rough seas, too dark waters, or too strong winds, all these parameters explaining the low levels of bluefin catches. Other comments are also dealing with the behaviour of bluefin tunas, these fishes being too deep and never eating during their migration towards the Mediterranean Sea, or upon their great voracity when they are migrating back from tne Med.

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The goal of this paper will be to analyse the daily catches and CPUE of these 18 Algarve traps during the entire fishing seasons of the 3 years 1898-1900 and to built hypothesis on bluefin exploitation and migration schemes observed during this historical period. This “zoom analysis” of the trap data will be done in conjunction with the analysis of the yearly catches of the same traps during the period 1852-1970, another data set collected by J.G. Pereira under the same ICCAT GBYP data mining program. This larger scale data set from Pereira would tend to show based on the yearly catches of 2 of the best Algarve traps that are available (figure 2), that the 1898-1900 period was for these 2 traps a period of intermediate catches: much lower catches than in the 1870-1885 period, but much higher catches than in subsequent years.

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well under the aberage sizes of BFT. It appears that small BFT at sizes of albacore are often misclassified in the statistics by fishermen as being albacore. I have also noted that the portuguese term « bonito » describing a small tuna, can also be used by fishermen for very small BFT, as well as the term « cachorreta ».
Albacore tuna (Orcynus alalunga, Linné) is frequent along our coasts,..”

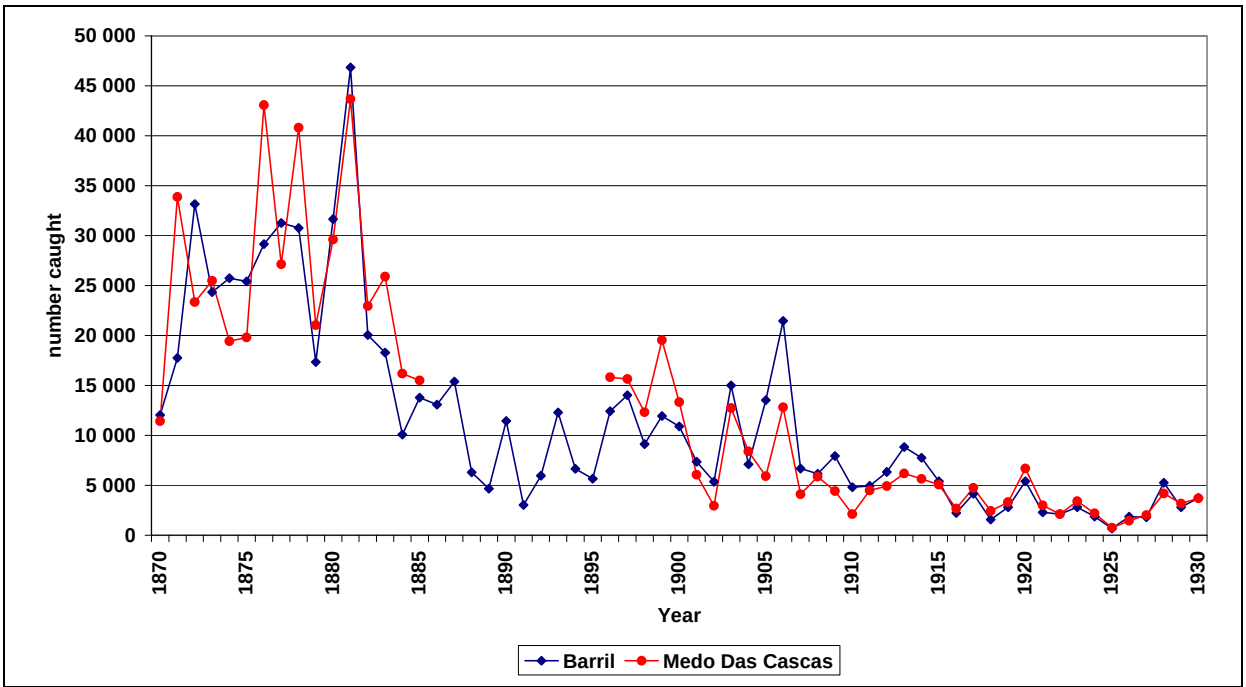

Figure 2: Yearly catches of bluefin of large and medium bluefin (in numbers) caught by 2 of the most productive Algarve traps, Barril and Medo das Cascas, during the 1870-1930 period (both located in eastern Algarve, see figure 1).

3- Data analysis

3-1- Total fishing efforts targeting In&Out bluefin

The total daily efforts exerted by the 18 Algarve traps are identified in the log books, and as a function of the bluefin targeted by the configuration of the anchored nets of each trap: either fishing effort targeting bluefin migrating towards the Mediterranean Sea during the April to June period, or fishing effort targeting bluefin migrating from the Mediterranean Sea after spawning, sometimes at the end of June, and each year in July and August.

Total average daily fishing efforts exerted by the trap fishery targeting the in & out bluefin migrations are shown by figure 3.

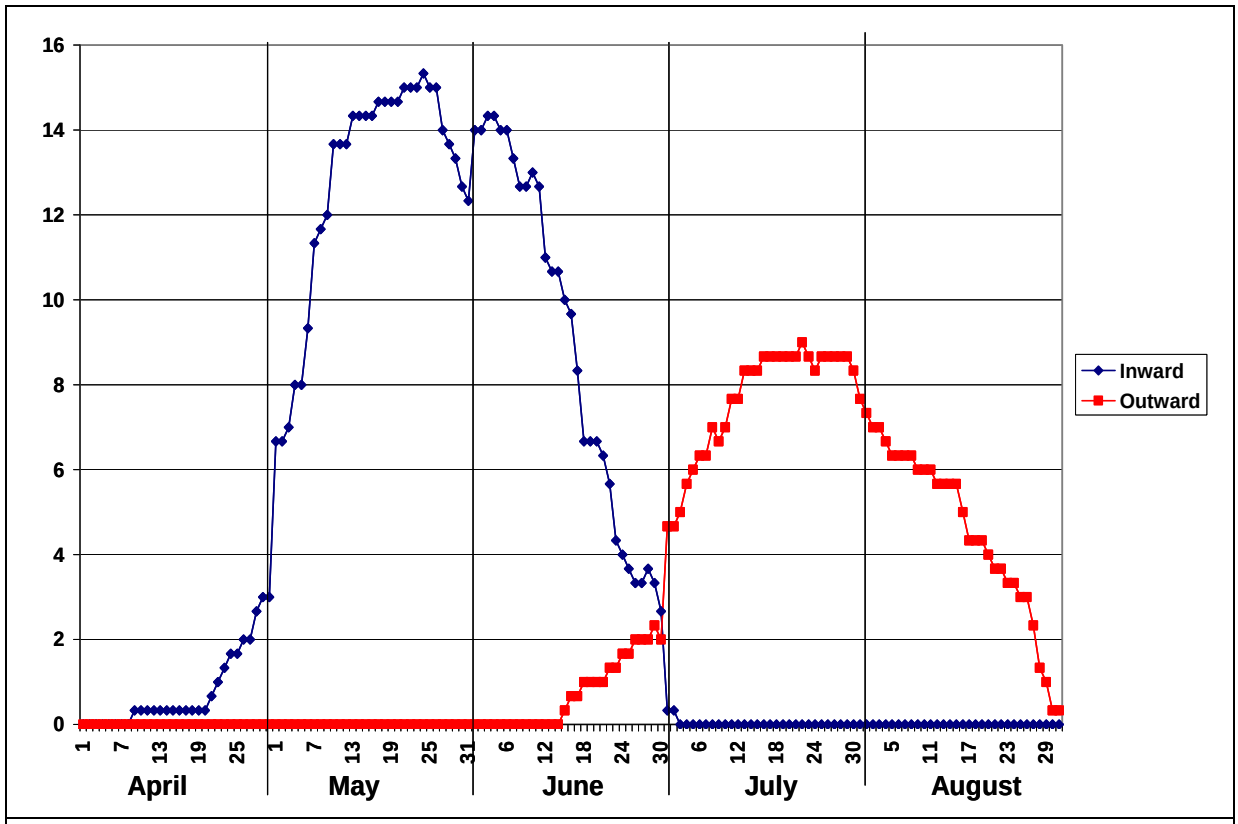

Figure 3: Average daily efforts exerted by the Algarve traps during the period 1898-1900 on bluefin migrating towards (inwards) and from the Mediterranean Sea (outward).

Daily fishing efforts are slowly growing during the second half of April, reaching a maximum during the period between the 2nd week of May and mid June. Fishing efforts targeting the outgoing migration are starting during the second half of June, showing during 2 weeks an overlap with fishing efforts that are still targeting the inward migration. Efforts targeting the outward migration are showing a maximum during the second half of July, and they are steadily declining until the end of August. Figure 4 shows the interannual variability of this average fishing pattern, showing that fishing efforts are showing similar seasonal patterns and levels during the 3 years under study.

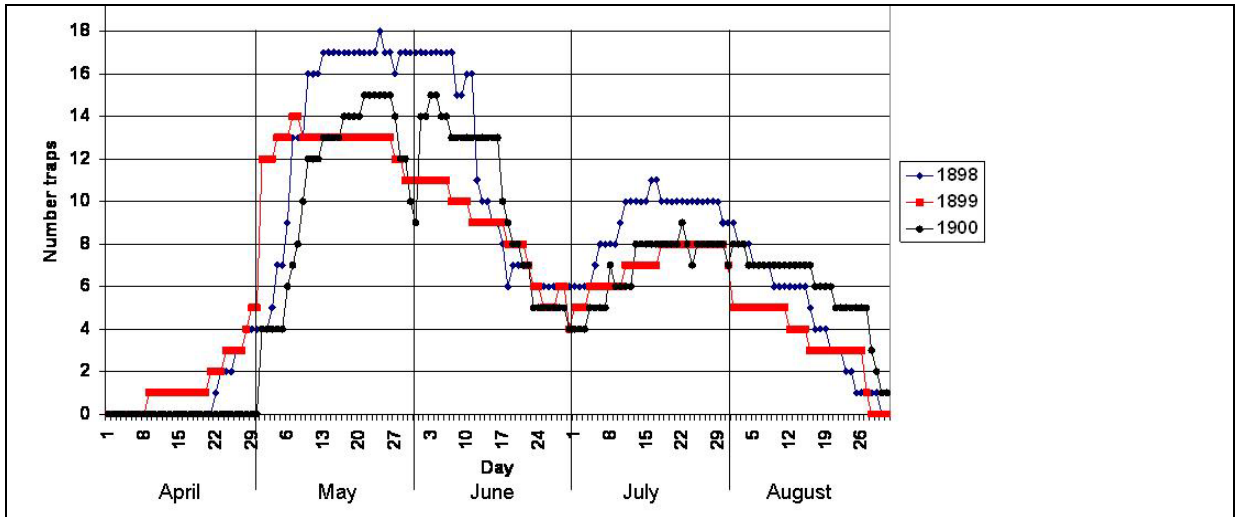

Figure 4: Daily efforts exerted by the Algarve traps during the 3 years 1898, 1899 and 1900.

3-2- Total catches by species

Total yearly catches (obtained and available on a daily basis for each trap) are shown by table 2.

Year		in	out	Res	Total number	Total weight
1898	Small BFT	3 161	314	1 036	4 511	180
1898	Medium BFT	4 709	3 145	649	8 503	595
1898	Large BFT	28 577	26 255	2 669	57 501	8 625
Total 1898		**36 447**	**29 714**	**4 354**	**70 515**	**9 401**
1899	Small BFT	639	1 405	200	2 244	90
1899	Medium BFT	3 703	6 145	393	10 241	717
1899	Large BFT	13 872	23 378	2 335	39 585	5 938
Total 1899		**18 214**	**30 928**	**2 928**	**52 070**	**6 744**
1900	Small BFT	1 285	2 402	416	4 103	164
1900	Medium BFT	2 763	10 681	119	13 563	949
1900	Large BFT	9 408	32 763	359	42 530	6 380
Total 1900		**13 456**	**45 846**	**894**	**60 196**	**7 493**

Table 2: Total yearly catches by species, in numbers of fishes and estimated weights, recorded in the presently recovered daily log books

Bluefin was by far during this period the main species caught: a yearly average catch of 60900 individuals, a majority of them being of large bluefin, 76 % of number caught and 89 % of a total average catch in weight estimated at about 7880 tons yearly (table 3). These yearly catches show little variability between years: a minimum of 52070 individuals in 1899 (an underestimated number, due to the lack of some log books some month for some of the major traps) and a maximum of 70515 fishes in 1898.

Catches of small tunas species identified in the log books are at a very low level estimated at levels lower than 10 tons yearly, and they may include an unknown proportion of very small bluefin.

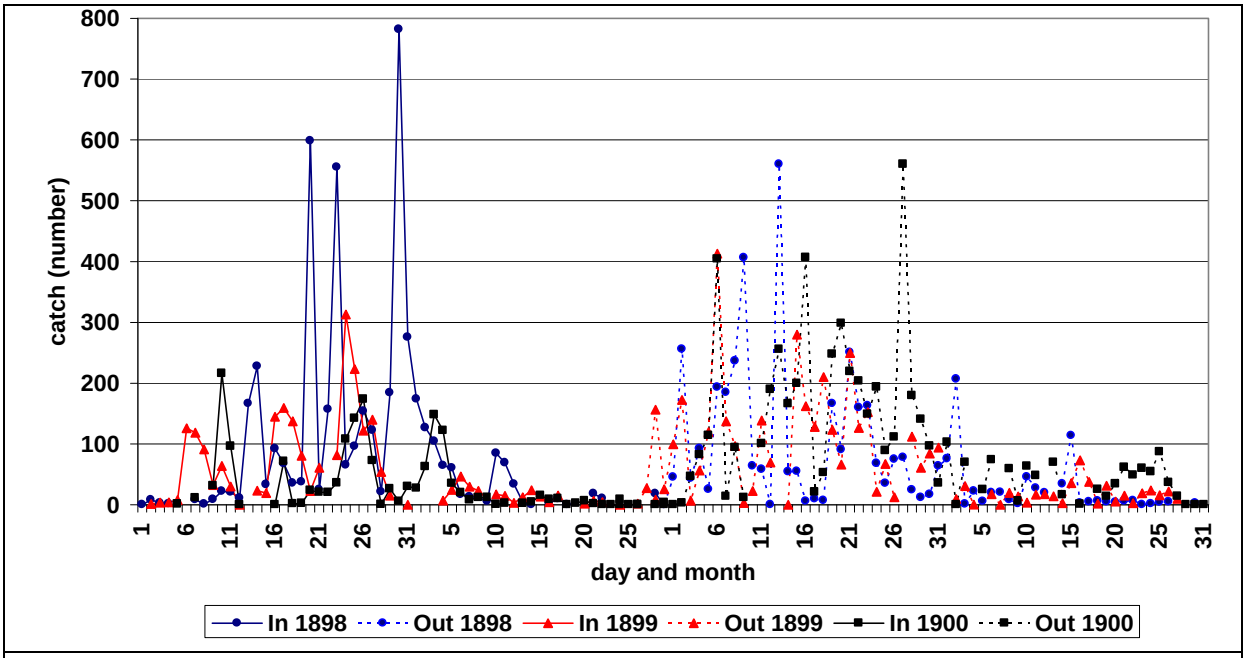

Figure 5: Total daily catches of bluefin (large and medium) in estimated weight (tons) taken by the 18 Algarve traps during the 3 years 1898-1900, fishes migrating towards of back from the Mediterranean Sea being distinguished based on the operating mode of the traps.

The following table 3 summarizes the average yearly catches by bluefin size categories, in numbers and in estimated weights, taken by the Algarve fishery and available on a daily basis in the recovered log books during the 1898-1900 period.

Table 3: period 1898-1900, catches of bluefin by size categories identified in the log books

Size	Total number	Total weight
Small bluefin	3 619	145
Medium bluefin	10 769	754
Large bluefin	46 539	6 981
Total	60 927	7 879

3-3- Daily catches of large and of medium size bluefin

The average daily catches of large and small bluefin (average weight estimated by Pereira at 150 & 70 kg) are shown by figure 6.

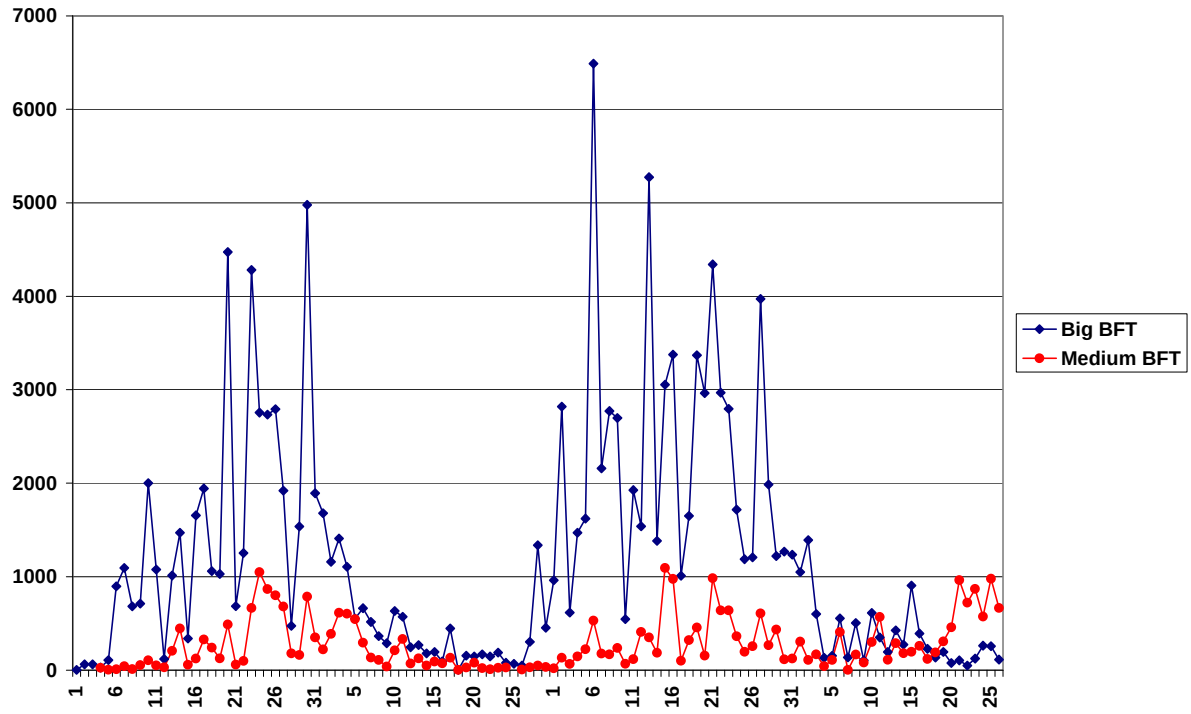

Figure 6: Average daily catches of large and of medium bluefin by the Algarve traps during the 1898-1900 period

This figure 6 shows that the daily levels and trends of the 2 main size categories of bluefin, large and medium, are quite different: most often much larger catches of large bluefin, less variability of medium size bluefin catches, these catches being relatively important in August (and even larger than for large bluefin at the end of august).

3-4- Two fishing seasons targeting inward and outward bluefin migrations

Daily total catches of the 3 migrating groups of bluefin taken, migrating to & from the Med and Algarve resident, by the Algarve traps are shown figure 7.

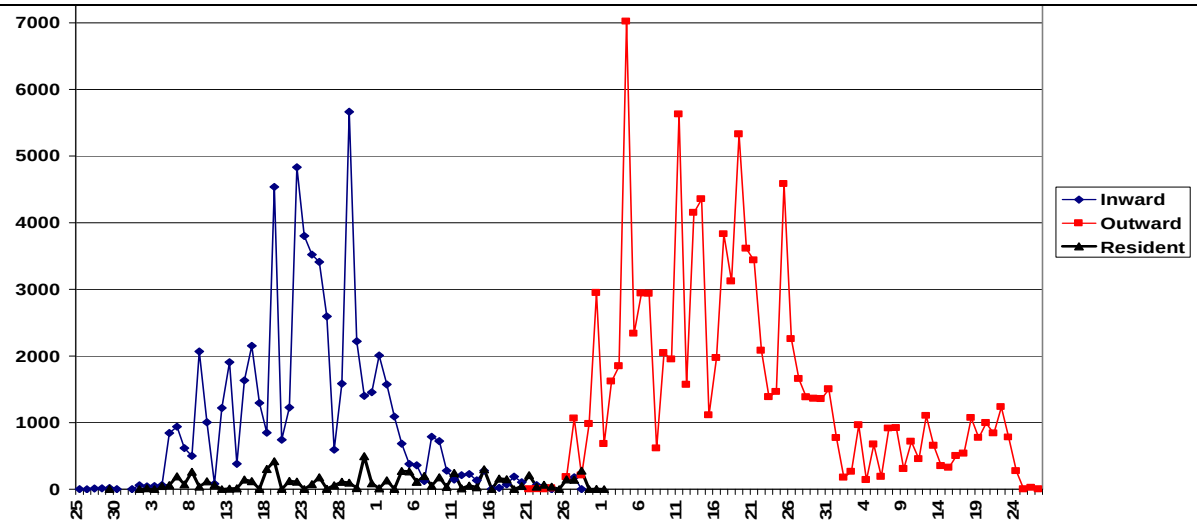

Figure 7: Average daily catches taken on the 3 groups of bluefin during the 1898-1900 period: catches of bluefin migrating towards the Mediterranean Sea (blue), of bluefin migrating back from the Med (red), or of bluefin classified in the log books as “atuarros” being resident on the Algarve coast.

The average daily CPUEs of the active Algarve traps has been calculated as the total bluefin catches of each day divided by the number of traps active each day during the 3 years 1898-1900. This pattern of average daily bluefin CPUEs is shown by figure 8.

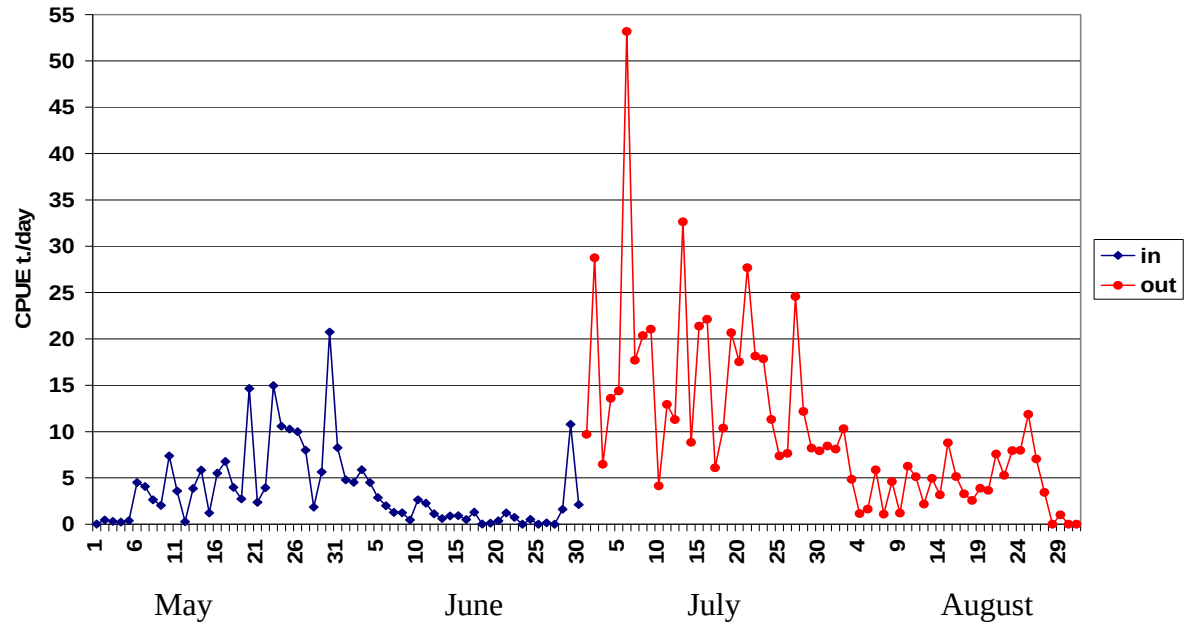

Figure 8: Average daily CPUE of bluefin in the Algarve trap fishery during the period 1898-1900 on bluefin migrating towards the Med ("in") and from the Med ("out").

The total catches of large bluefin observed each year and during the average period are given in the following table 4.

Table 4: Total caches of large and medium bluefin taken by the Algarve fishery on the arrival and returning migration of bluefin, yearly and on the average.

		Large bluefin				Medium bluefin		
	1898	1899	1900	**Average**	1898	1899	1900	**Average**
Total In	30 656	16 079	9 682	**18 806**	5 324	4 094	2 841	**4 088**
Total Out	26 845	23 506	32 848	**27 733**	3 179	6 147	10 706	**6 677**
Total	**57 501**	**39 585**	**42 530**	**46 539**	**8 503**	**10 241**	**13 547**	**10 765**
Ratio of BFT catches Inward/total in %	53	41	23	**40**	63	40	21	**38**

3-5- Between traps geographical heterogeneity of bluefin catches

Daily catches of large and medium bluefin observed during the 3 years under study are show figure 9 (May and June, inward migration) and figure 10 (July and August, outward migration).

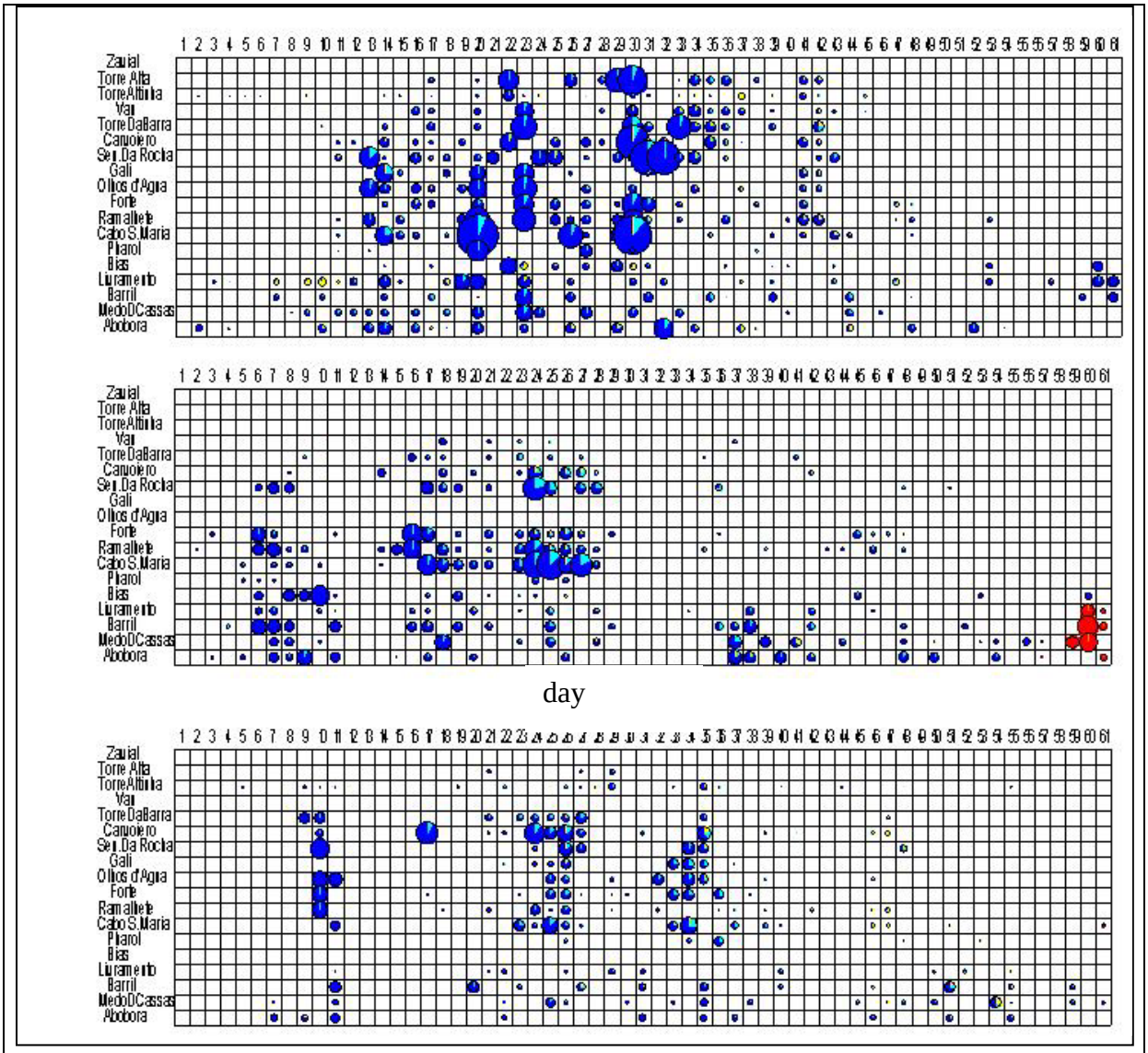

Figure 9: Daily catches of small and medium bluefin taken during May (days 1 to 31) and June (days 31-61) by each of the Algarve traps during the year 1898 (upper panel), 1899 (central panel) and 1900 (lower panel). Inward migration in blue (large bluefin dark blue & medium bluefin light blue), outward migration in red (dark red: large bluefin, orange: medium bluefin)

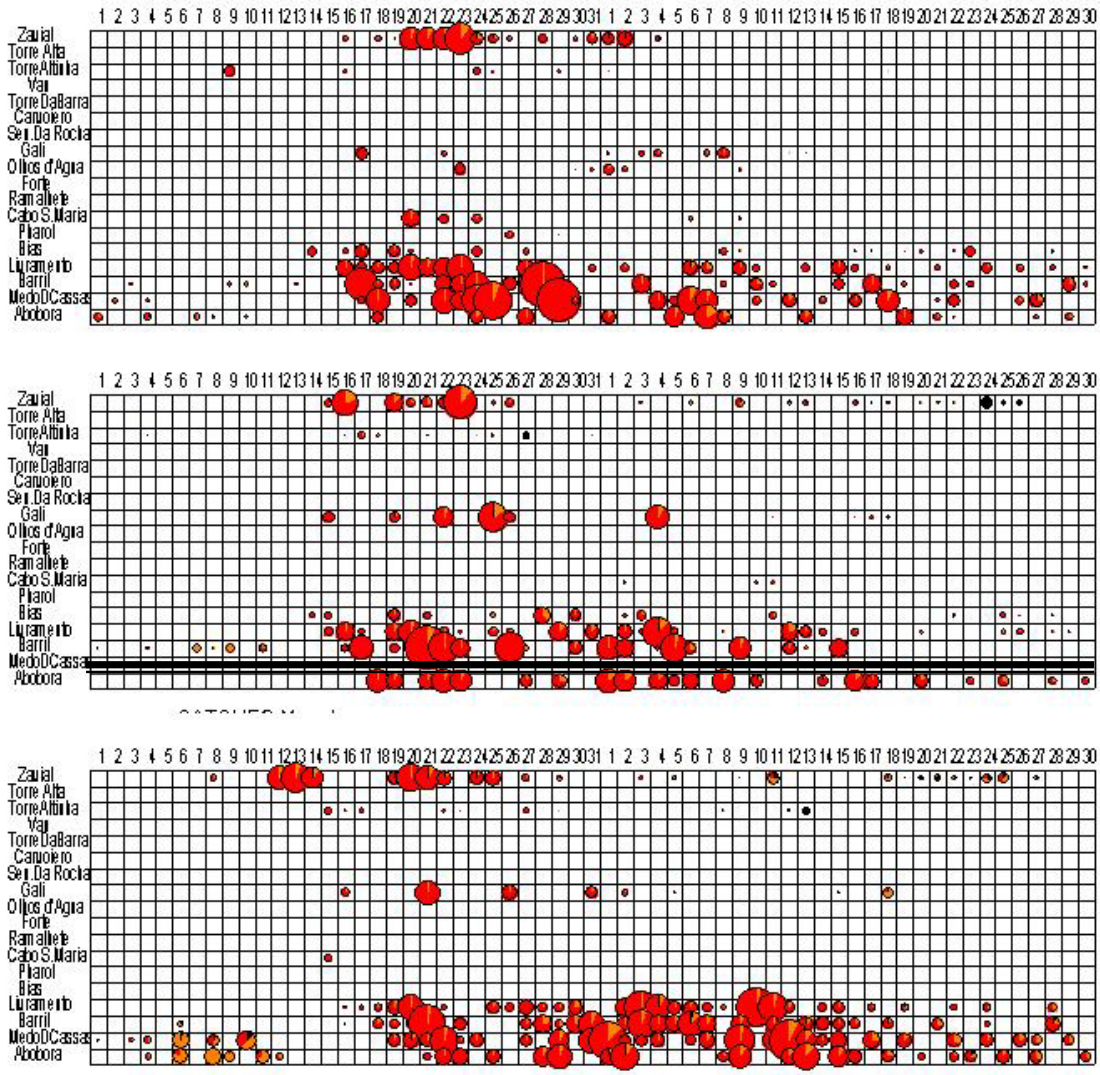

Figure 10: Daily catches of small and medium bluefin taken during July and August by each of the Algarve traps during the year 1898 (upper panel), 1899 (central panel) and 1900 (lower panel). In dark red: large bluefin and orange: medium bluefin. Data from the Medo Das Cascas missing in 1899.

The corresponding fishing maps showing the average monthly catches of bluefin by each of the trap are shown by figure 11.

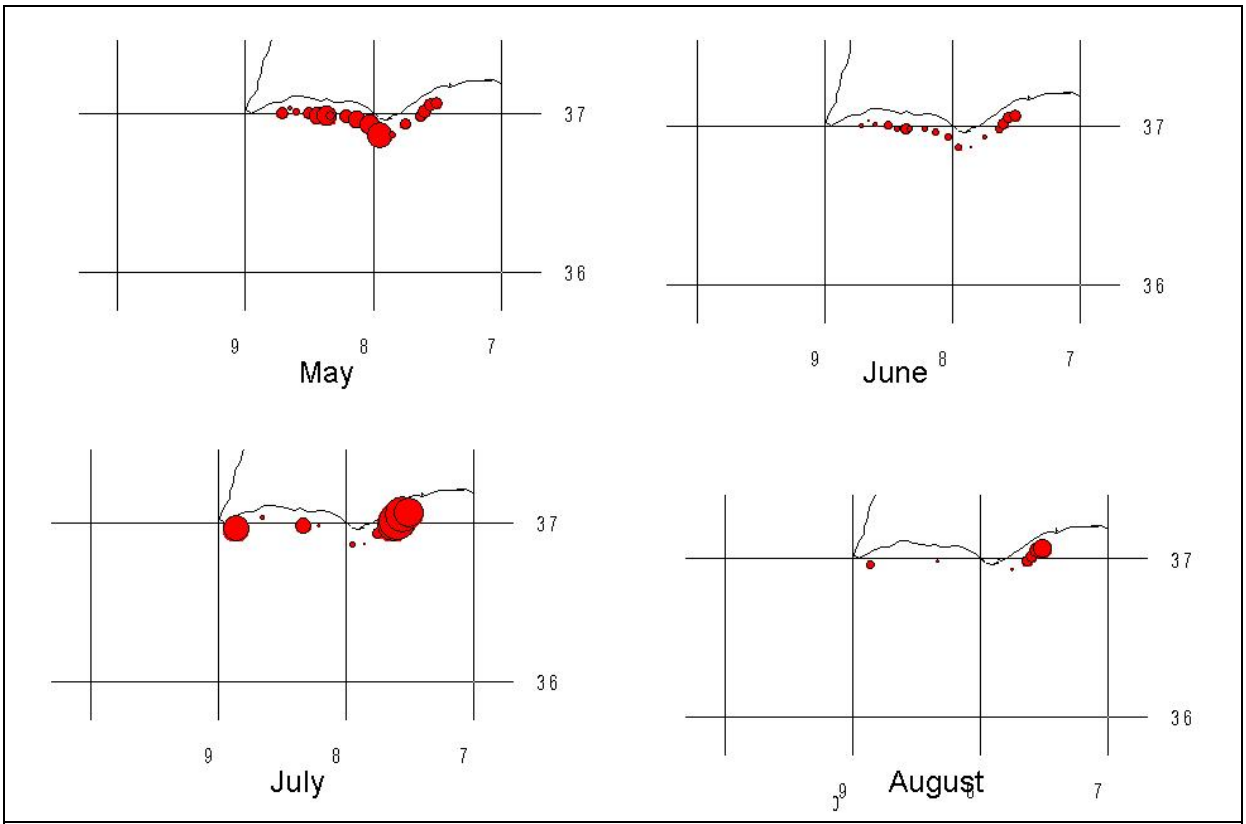

Figure 11: Average monthly catches of bluefin in weight by the 18 Algarve traps during the period 1898-1900.

3-6- Sequences of daily catches

Figure 12 is showing the daily total catches of bluefin (in estimated weight) taken each year by the combined Algarve trap fishery. This figure shows that successive periods of very large catches are observed each year during the 2 fishing seasons.

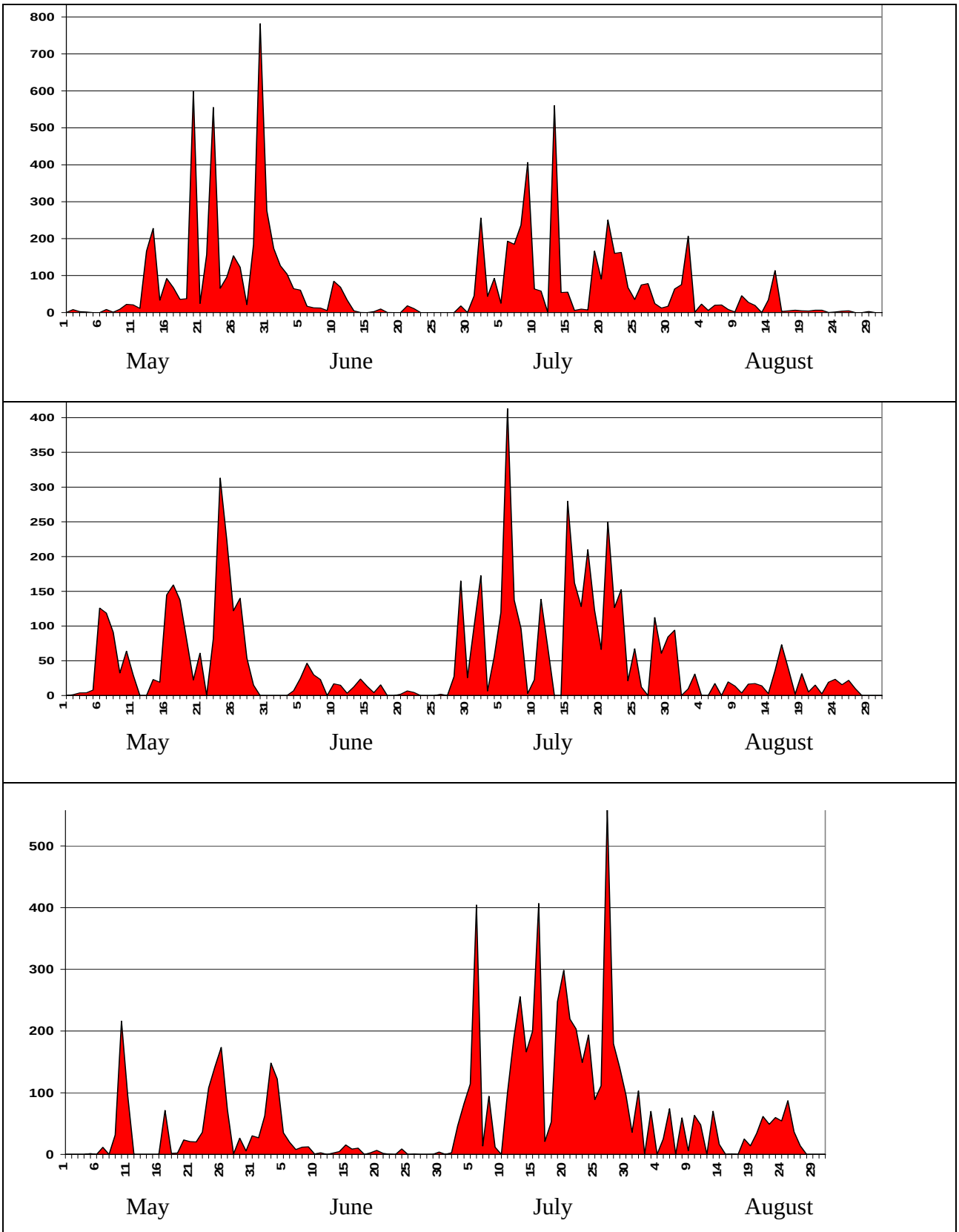

Figure 12: Daily total catches of medium and large bluefin (estimated in tons) caught by the combined Algarve fishery in 1898 (upper panel), in 1899 (mid panel) and in 1900 (lower panel)

3-7- Dates and durations of the fishing seasons:

Migration patterns (inward or outward) and the exact dates of these migrations can be estimated based on the observed daily catches of bluefin taken by the combined traps. This calculation has been done independently on the dominant and more homogeneous group of large bluefin and on bluefin classified as small bluefin (an average weight estimated at 70 kg). The same calculation has been done for each year, and for the average period 1898-1900.

In each case, the 3 steps of each migratory phase have been measured in the following way:

1) 1st day of significant migration (beginning of the migration) reached when 1% of the catches have been reached (during the entering or the outgoing migrations)
2) Modal day of the migration reached when 50% of the catches in numbers have been reached
3) Last day of significant migration (end of the migration) reached when 99% of the catches in numbers have been reached

These results are shown on figure 13.

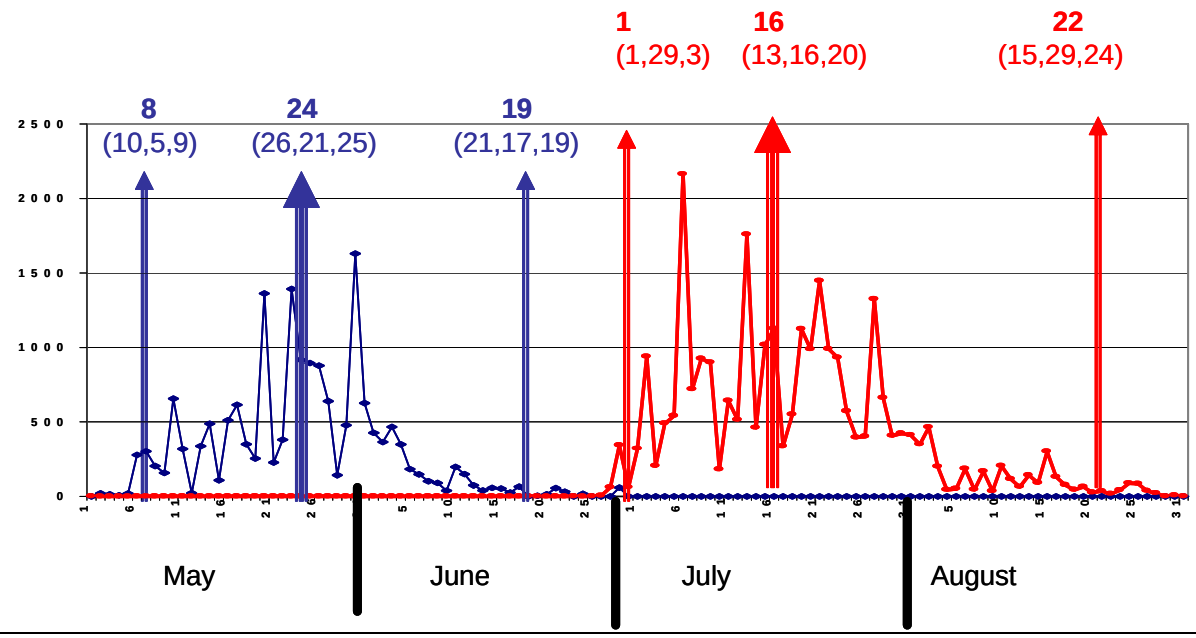

Figure 13: Average daily catches of large bluefin during the 1898-1900 period, and corresponding dates of inward and of outward migrations: beginning dates (1% of numbers caught, mid dates (50% of catches) and final dates (99% of numbers). The numbers in the upper line indicate the average dates, and numbers in the lower line indicate the dates observed in 1898, 1899 and 1900)

This figure 13 shows that the observed pattern of daily catches in the Algarve trap fishery during the 1898-1900 period was very stable in term of initial and final dates of migrations, and also its duration, & for both the arrival and return runs:

- An average initial date of arriving migration starting on May 8th and a finishing date on June 19th., and then an average duration of 42 days of these arrival runs,
- An average initial date of return migration starting on July 1st a finishing date on August 22th, and then an average duration of 53 days for these return runs,
- an average duration of 53 days between the modal dates of arrival and return dates, corresponding to the average duration of bluefin spawning migration between the Algarve coast and the Mediterranean spawning zones.

It should be noted that there was very limited variability observed between the 3 years studied concerning the arrival and departure dates and in the durations observe (this variability being shown by figure 13)

Figure 14 shows the same information but for medium size bluefin and for each of the years, 1898, 1899 and 1900, this figure showing that similar patterns and levels of catches have been observed during these 3 years, these catches being much lower than catches of large bluefin (shown by figure 5), but not at the end of August, when they tend to be larger.

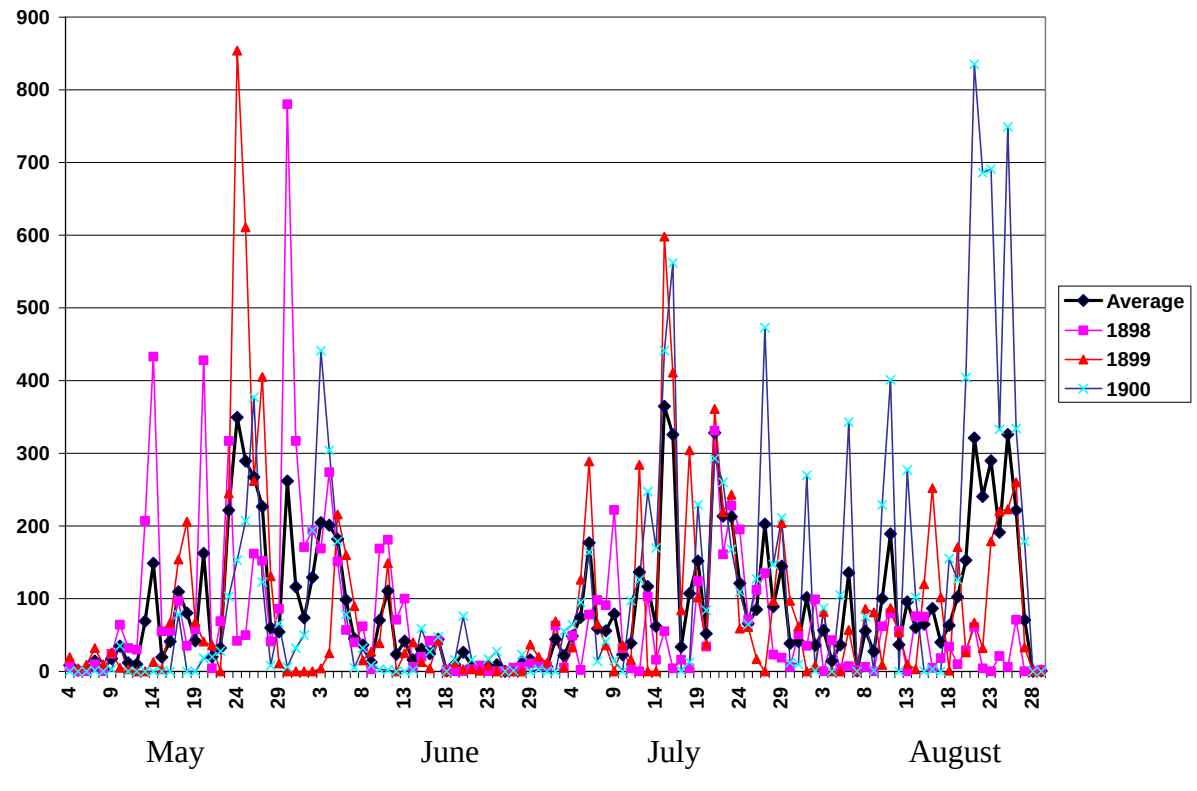

Figure 14: Daily catches of small bluefin by the Algarve traps in 1898, 1899, 1900 and the average of these 3 years

3-8- Catches of small bluefin registered as "albacore" (average weight estimated at 40kg)

Low but systematic catches of these small bluefin identified as "albacora" were taken by the Algarve traps during historical times, as shown by the yearly catches recovered by Pereira 2011 (figure 15).

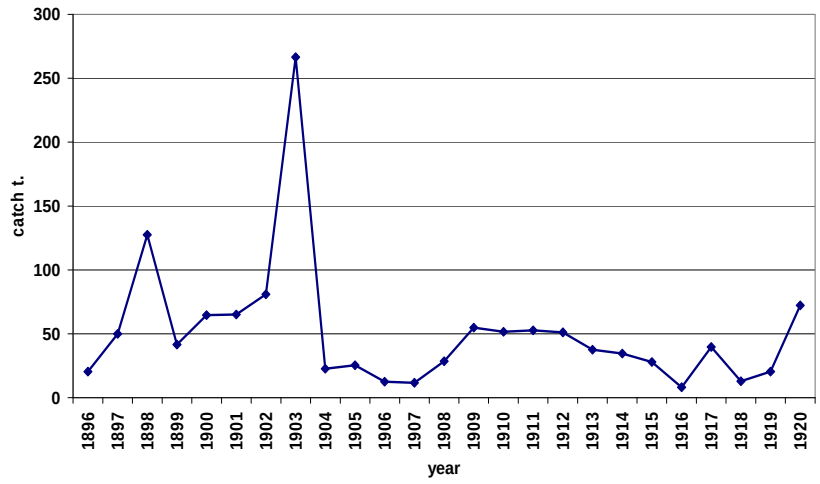

Figure 15: Yearly catches of albacore, i.e. small bluefin, taken by the Algarve traps (Pereira data set)

The analysis of the 1898-1900 data also shows that these catches are observed more or less continuously during the inward and outward migrations of bluefin (see figure 16), but showing lower levels of daily catches during the period July-August, during the outward migration of bluefin. The tuna waves that are commonly observed for bluefin are not seen for these small bluefin, the daily catches of this category showing day to day variability but without clear modes (figure 16).

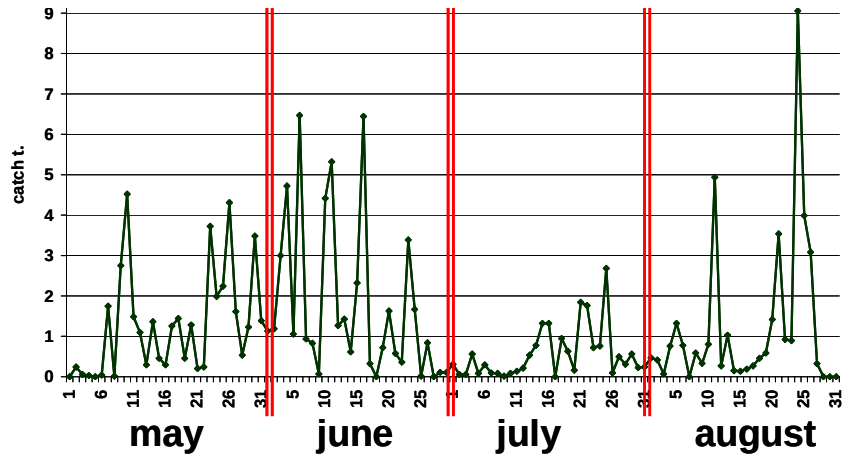

Figure 16: Average daily catches of small bluefin, recorded as "albacora" taken by the Algarve trap fishery during the 1898-1900 period.

4- Discussion

4-1- bluefin migrations and Algarve trap fisheries

The annual migration of animals corresponds to massive movements of large fraction of the population that are fast moving, in large groups and at given dates, towards a given

geographical spot. This migration does not stop until these migrants have reached their target. In case of spawning migrations, this target should be reached at the given period that is suitable for reproduction and for the development of larvae (for instance during given days or weeks) (definition modified from Dingle 1996).

This strict definition of migration has been very seldom identified for tunas: when they have been classified as highly migratory species by the law of the sea, they seldom show the typical migratory behaviour of this definition, that have been observed for a wide range of animals such as birds, turtles, butterflies and various species of fishes.

However, the present daily fishery data of the Algarve traps offer a strong confirmation/proof that North Atlantic bluefin are showing this typical and clear migratory behaviour: large fraction of the population following each year and at a given exact date and following the same migratory pathway, and probably targeting the same spawning strata.

The historical knowledge of trap fishermen and the work by scientists, among others by Rodriguez Roda 1964, allows to firmly concluding that migrating bluefin caught by traps during their arrival run in May and June are fished in prematuration or maturation status. On the opposite, all bluefin taken during the return run in July and August are in post spawning condition and typically showing flaccid small gonads. These biological information are fully consistent with seasonal migrations of adult bluefin towards or from their spawning zones, probably located in the Mediterranean Sea, East of Gibraltar straight. The opposite and rather strange hypothesis developed by De Buen 1931 that all bluefin caught by Portuguese and Spanish traps west of Gibraltar were not migrating towards the Mediterranean Sea but towards another spawning strata in the Eastern Atlantic (Bay of Biscaye or Canary Islands) has not been kept.

Consistent migrations have been observed in the Algarve traps during each of the 3 years, 1898, 1899 and 1900, the observed pattern of daily catches observed in the Algarve trap fishery during the 1898-1900 period being very stable in term of its initial and final dates, and also its duration, & for both the arrival and return runs (cf parag. 3-7). The duration of 53 days between peak catches of the 2 migratory phases would correspond to the average duration of a spawning migration of bluefin between the Algarve coast and the Mediterranean spawning zones.

This stability of the migration dates is really remarkable, keeping in mind that these bluefin are probably moving from or towards remote areas: their travelling agenda has been well kept in their memories and genes, as they reach in due time their Mediterranean spawning zones in order to ensure the conservation of the population. These bluefin migrations observed in the Algarve traps typically belongs to the category of an “obstinate homing behaviour” shown by adult bluefin when targeting the area where they are born some years before (Cury and Fonteneau 1998). Such obstinate behaviour appears to be a biological necessity for the bluefin population: a relatively small population (under 1 million tons of adults) that is scattered in very wide feeding zones covering more than 10 million km2, at northern and equatorial latitudes, and then a deep need in order to ensure the success of reproduction, to concentrate the adult in well defined time and area strata. And then a need for adult bluefin to remember their time and area birth strata, and to be able to come back to this strata in due time.

The Algarve trap data would tend to fully confirm the efficiency and stability of this homing behaviour!

4-2- Local environment and daily CPUEs

The available data set does not include the local environmental data (wind, waves, current, water temperature and transparency, etc) that could explain the variability of daily catches. There is no doubt that these environmental conditions should influence the daily

catch rates, conditioning the movements of tunas and their entry in the trap, and conditioning the manoeuvres and fishing efficiency of the trap. However, King Don Carlos in his study of the 1898 data, reached the conclusion that local meteorological factors did not played a significant role in the arrival of tunas in the traps. He concluded that unknown oceanic parameters were the main factors conditioning the local abundance of tuna caught by the traps.

It could also be concluded, based on the present analysis, that if local conditions may increase or decrease the catchability of given traps during short periods of time, the global flow of arrival and departure of bluefin, as well as monthly total catches, are probably conditioned much more by the global context of large scale migrations between its quite remote feeding and spawning zones, and by the biomass of the adult stock (a parameter than was necessarily quite stable during our 3 years period).

4-3- Spawning dates inferred from the Algarve trap fisheries?

Dates of dominant spawning by the large adult bluefin fished by the Algarve trap can be estimated based on their arrival and return dates in the Algarve traps. The daily patterns of catches and CPUEs in this fishery shows that very low level are observed between the end of the 1st week of June and the last days of June, a period during which most bluefin tuna are in the Mediterranean sea: this period was probably their main spawning season. The central date, or main date for this spawning, can also be estimated as the central date between the date of 50% arrivals and of 50% returns. This average date was observed on June 19th, and with little variability between years: June 21st in 1898, June 16th in 1899 and June 21st in 1900. This date of bluefin potential peak spawning in the Mediterranean Sea estimated from Algarve traps would be consistent with most past and present knowledge on bluefin spawning, for instance with the conclusion by Mather 1995 that large bluefin mainly spawn during the 2nd half of June.

The same method was also used to estimate the potential spawning dates of medium size bluefin: as the average date of the 50% arrivals is estimated on May 27th and the 50% return date on July 26th, the average peak of the spawning season of small bluefin would be estimated on the 27th of June. This later date (8 days later) would be consistent with the conclusion by F. Mather 1995 that small bluefin would spawn later than big bluefin. This late spawning of small bluefin is also well supported by the late return of medium size bluefin observed in late August.

4-4- In&Out CPUEs and catchability of the Eastern Atlantic and Mediterranean stock?

The analysis of daily CPUEs has been showing that each year the CPUEs were much higher during the return migration after spawning (figure 17).

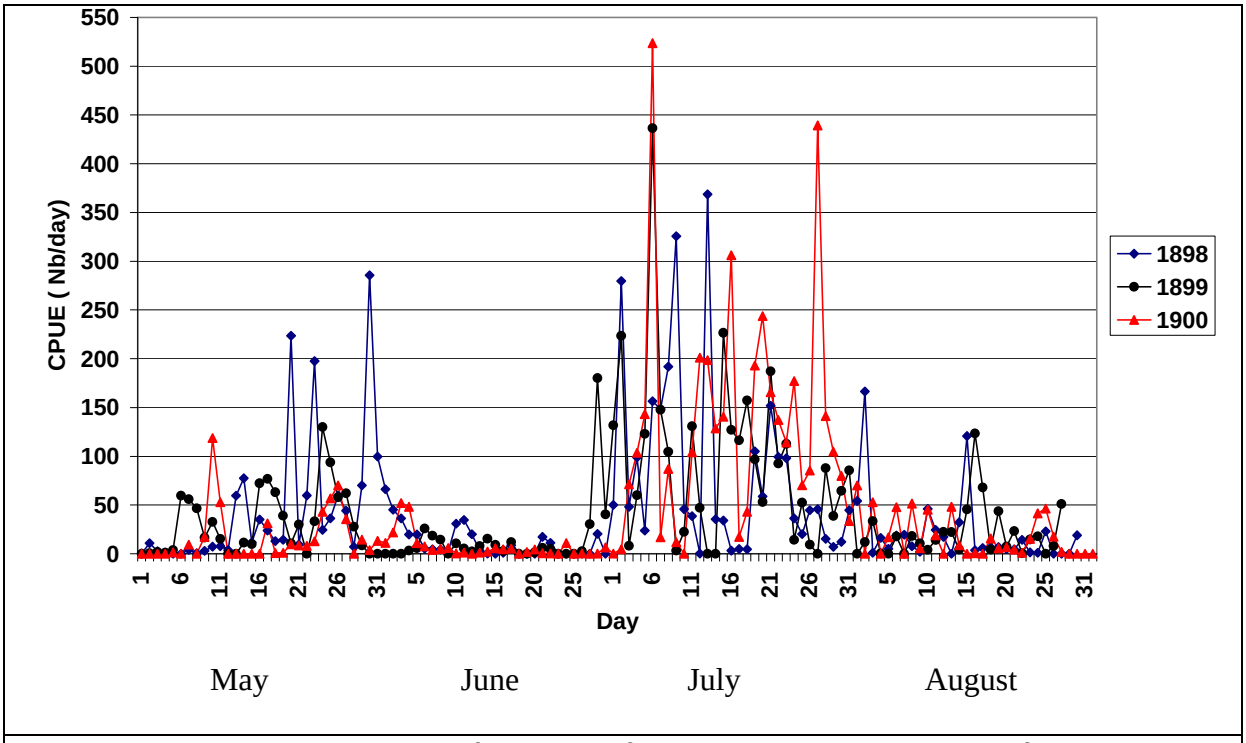

Figure 17: Average daily CPUE of large bluefin taken by the Algarve trap fishery in 1898, 1899 and 1900 (number of fishes caught/number of active traps)

In the logical hypothesis that the same stock was exploited by the Algarve trap fishery during the May to August period, it would mean that the cachability of the bluefin stock in the Algarve fishery would be much higher during the returning phase. As the total biomass of the stock has been probably be decreasing between May and August by the significant catches taken by other traps on the same stock (inter alia in Spain and Italy), this increase of catchability would probably be greater than the increased in CPUEs, and as a function of stock exploitation rates.

Subsequently, the fishing mortality exerted on the stock during the return migration would tend to be higher than the fishing mortality exerted on the stock during the migration towards the Med, even keeping in mind that few of the traps are efficient and active to target bluefin returning from the Med.

Furthermore, this conclusion can easily be reached based on the ratio of the numbers of bluefin caught during the 2 migrations (cf table 4). As the total numbers caught on the returning fishes are similar (1898) or much larger (1899 and 1900), with an average of 60 % of large bluefin caught during the return migration and 62% of medium size bluefin. It would imply that fishing mortality exerted on the returning bluefin is larger, and possibly much larger if the exploitation rate is high in the Med.

4-5- Algarve resident vs migratory bluefin?

The log books of all the traps are taking note that a small but consistent proportion of bluefin that are resident on the Algarve coast are taken by the traps, often large bluefin, and especially during the migration towards the Med (see figure 7). This point has seldom been noted by scientists but seems to be a realistic observation that should be further studied.

4-6- Corridas of bluefin : are they consistent stable "microcohorts" of bluefin doing In&Out migration

The Analysis of daily catches has been showing that both the entering and the returning bluefin catches are highly heterogeneous: showing alternate periods of very large catches, and period of low catches (cf figure 12). These tuna waves, called "corridas" by the trap fishermen, have been extensively studied by Don Carlos 1898, his work making an extensive study of the 1898 data.

Don Carlos reached the hypothetical conclusion that each of these waves of bluefin[5] that are migrating towards the Med, 5 of them being identified in 1898, are formed by the same groups of tunas that are also observed in the migration of bluefin outgoing from the Med. He also estimated that the duration between the entry and the output of these tuna waves was nearly identical for each of these 5 tuna waves, each of these groups being absent during about 52 days.

In the absence of tagging data, this hypothesis remains difficult to validate, but it may well be a realistic one. This duration close to 52 days is also very close to the average duration between the modal date of entry and the modal date of come back estimated at 53 days during the 1898-1900 period (figure 13). There is also some rationality to hypothesize that the first and last groups of tuna entering into the Med, would be the first and last to come back from the Med.

This stability of various tuna groups during nearly 2 months and during a spawning trip in the Mediterranean Sea, each of them with a large biomass that could probably be measured in 10th of thousand tons, would be extremely interesting for scientists. Such behavioural hypothesis should be better envisaged and studied by ICCAT scientists as it could easily have consequences on the stock and sub population structure, and on the catchability of the stock.

4-7- Geographical simultaneity of tuna waves: high correlation of high daily catches between traps

It can be noted that the waves of tunas caught during entering migration tend to appear simultaneously in most traps (see figures 9 and 10). On the opposite, returning bluefin is caught by few of the traps, east and west of Algarve, but also simultaneously. This apparent synchrony of the catches is probably in relation with the small distances between traps, a total distance of only 73 miles between the most remote traps, and by the fast potential speed of migrating large bluefin.

4-8- What Migratory routes of In&Out bluefin along the Algarve coast?

As the exact position and depth of each trap are well known, the observed catches of bluefin tuna by the active traps during each given day indicate the exact position of migration and distance from the shore of the migrating tunas. Furthermore, the comparison of the daily catches by each trap during successive days allow to measure the changes in migrating biomass, or/and their distance from the coastline as a function of the period.

Figure 17 and 18 show examples of bluefin catches of each trap grouped by periods of 3 days, and during the 2 main periods of the inward and outgoing migrations, during 1898 (figure 17) and 1898 (figure 18).

[5] These corridas, or waves of migrating tunas, could be designated as « micrococohorts »

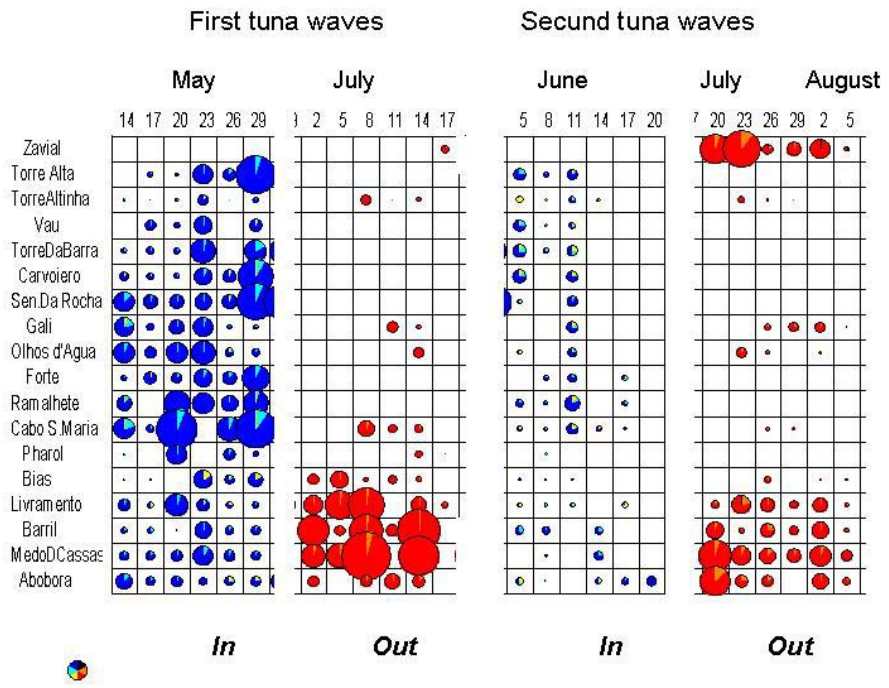

Figure 18: Year 1898, catches by trap by 3 days periods, during the 1st and 2nd periods of 18 days with large catches of migrating tunas. Pies in blue, catches of bluefin tuna migrating towards the Mediterranean Sea, pies in red bluefin returning from the Med. between July 1st and August 6th.

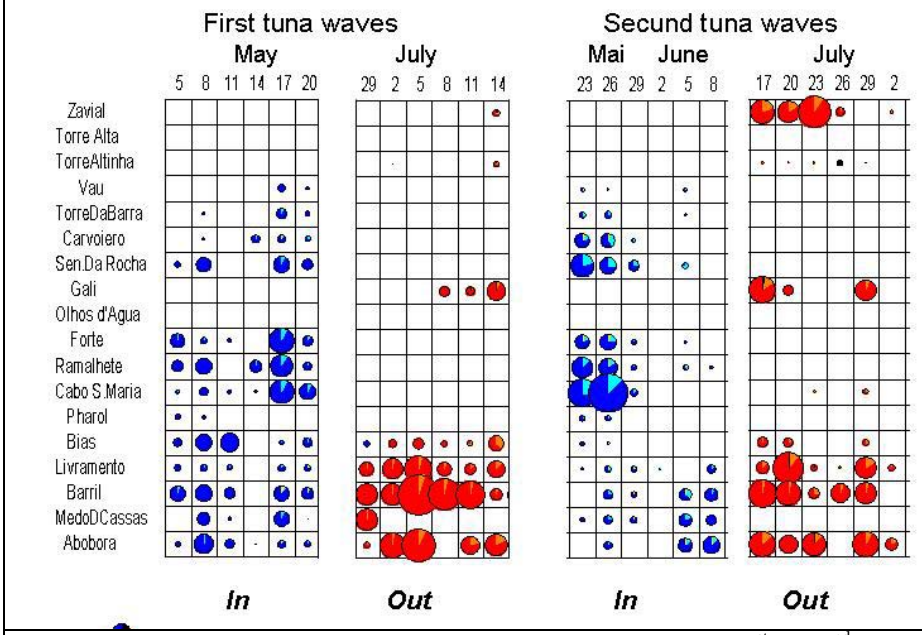

Figure 19: Year 1899, catches by trap by 3 days periods, during the 1st and 2nd periods of 18 days with large catches of migrating tunas: pies in blue, catches of bluefin tuna migrating towards the Mediterranean Sea between May 4th & June 9th, pies in red bluefin returning from the Med. between June 29th and August 3rd (data from Medo Das Cascas trap missing in July and August)

These daily catches by each trap allows to rebuild hypothesis on the trajectories of migrating fishes and on their distance to the coast line where the traps are located, a. method widely used by Don Carlos de Bragança in his analysis of the 1898 data. As an example figure 20, redrawn from his 1898 paper, shows the hypothetical movement pattern estimated for the 2nd wave of bluefin in 1898 (figure 18 on the right showing the catches used to build this hypothesis).

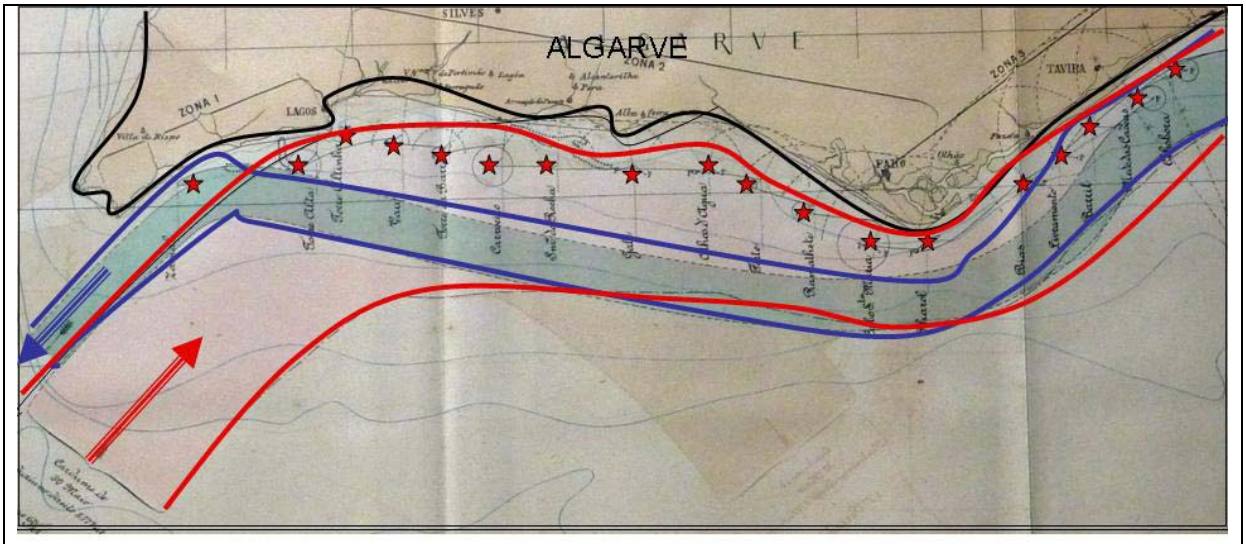

Figure 20: Estimated trajectories (position and extent as a function of traps and coast line) of given waves of bluefin migrating towards and from the Med, a figure based on the 2nd wave of bluefin in 1898 (derived from Don Carlos 1898 map)

These migration routes of bluefin in relation to the coastline and to the position of anchored traps are fundamental, as they condition the CPUEs of the traps: a migration route remote from the coastline or schools that are too scattered will decrease the CPUE for a given biomass of migrating tunas. The details of these between year's fluctuations of the distance and scattering are probably conditioned by several factors: environmental ones (current, transparency, waves), pollution, noise, etc…

However, the present data would tend to indicate that the observed migration patterns are very strong and well imprinted in the ADN of these bluefin tunas, and possibly showing various sub populations of bluefin, each one showing some peculiarities in its migrating trajectories.

4-9- Distances and travelling times & speed between Algarve, feeding & spawning zones

The daily catch statistics in Algarve are providing strong evidence that significant biomass of bluefin is migrating in the area at given dates. It is then interesting to compare these Algarve time and area strata to other bluefin time and area strata corresponding to spawning and feeding concentrations, and to evaluate the duration between these strata and the minimal speed required to migrate between these spots.

As an example a quick calculation, table 5, has been done for the following strata in the Med and in the North Atlantic.

Table 4: Distance and travelling duration between Algarve and 4 major fishing strata observed during recent years

Type of strata		Date concerned	Distance Naut Miles	time travelled days	Average speed knots
Spawning	Algarve<-> Baleares & return	mid June	850	59	0,6
Spawning	Algarve<-> Sicily & return	mid June	1350	59	1,0
Feeding	Algarve > W Scotland	September	1200	60	0,8
Feeding	Algarve->Norway 1 way	mid July	1700	20	3,5

The estimated speed needed to do this spawning and feeding migrations that are typical of bluefin appears to be reasonable ones, or even quite slow for adult bluefin. The only case of sustained high speed being the historical migration between Algarve and Norway at about 3.5 knots, knowing that the first outward migration of bluefin were observed in the Algarve traps during the 1st days of July, when the large scale arrival of these large bluefin tunas in Norway (period 1930-1970) was observed during the 3rd week of July (Norwegian weekly statistics, recently recovered ICCAT data base).

4-10- Interest to recover simultaneous daily data from other traps?

The analysis of 3 years of these localized historical daily data offers an interesting understanding of the bluefin tuna migration pattern. As there were many traps still active in this area during this period, it would be very interesting to recover similar daily data from as many traps as possible during the end of the 19th century, and to analyze all these trap data in conjunction. Such integrated analysis should help to rebuild the "pieces of the bluefin migratory puzzle" around the Med, allowing to better understand the bluefin migration pattern and its between years variability during this historical period.

A successful recovery and analysis of these daily trap catch and effort data, historical and recent ones, should also be of great interest to estimate better the relative proportion of bluefin that are resident in the Med and of bluefin that are permanently migrating In&Out the Med, spending only about 50 days each year in the Mediterranean Sea.

The ICCAT data mining program ran under the GBYP project would be the ideal tool to search if some of these detailed data are sleeping in libraries and if they could be recovered and analyzed under the ICCAT framework.

4-11- Atlantic bluefin: 1900 vs 2010?

There would also be a great scientific interest to recover daily data of traps, inside or outside the Mediterranean Sea, that are still active at the end of the 20th and beginning of the 21st centuries, to analyze them in details, and to compare the bluefin CPUEs, seasonality and movement patterns apparent in the today data in comparison of the 1900 Algarve data set: one century after. This comparison should of course include the recent daily catch and effort data of bluefin tunas caught by the Algarve that are still active today. These combined detailed data should help to better identify the changes in the bluefin adult population, its behaviour and level of apparent abundance, in the context that the bluefin stock was probably in good shape in 1900, when it is severely overfished today.

5- Conclusion

This first analysis of the 1898-1900 catch and effort data of the historical trap fishery in Algarve, Portugal, are clearly of great scientific interest, as the bluefin stock was still (probably) moderately exploited and when the Algarve coast was still a virgin ecosystem, without noise and pollution introduced by massive urbanism, tourism, pollution and marine noise.

This data set if of peculiar interest because of the fixed positions of the traps, with perfectly well identified positions, and because of the nearly exhaustive catch and effort daily information obtained of this fishery during a period of 3 years, allowing to analyze the between years variability of the data, at least to some extent. This first overview of this data set has been already providing a large amount of firm results and allowing building various hypothesis. It would now be of great scientific interest to recover and to analyze in conjunction with the 1900 Algarve data, the same type of daily catch & effort data by size on other traps, simultaneously and during recent years.

These results should be of great interest to allow the SCRS scientists to build more realistic stock assessment models that would be taking into account the migration of bluefin, a fundamental parameter that has not yet been introduced in the ICCAT stock assessment models.

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