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A review on the Atlantic Bluefin Tuna

# Introduction

Tuna is one of the oceanic top predators and plays a significant role in the marine ecosystems comprising nearly 20% of the value of capture fisheries. The main commercial species of tuna are the Atlantic bluefin, southern bluefin, albacore, bigeye, yellowfin and skipjack [[1](#_ENREF_1)]. These species are the predators of the pelagic ecosystem and are highly migratory with their distribution covering most of the tropical and temperate areas around the globe.

The Atlantic Bluefin tuna (hereafter referred to as BFT) is the largest species of tuna and one of the most highly priced fish species in the world. Bluefin fishing in the Mediterranean Sea has been a common practice for millennia and it takes advantage of the reproductive migration of the species from the foraging grounds in the Atlantic to the spawning areas in spring [[2](#_ENREF_2)]. The development of deep freezing storage and enhanced farming techniques have been lucrative for fisheries and resulted in a significant increase in catches leading to an overexploitation of the eastern bluefin tuna stock [[3](#_ENREF_3)]. Furthermore, Studies show that sustainable fishing practices are not merely related to the management of the effort intensity, rather the life history traits of the exploited species are also important. Factors such as late age-at-maturity, low rate of population increase, large size, and slow growth could make the species more vulnerable to over-exploitation and increase the rate of decline. Contrasting the two groups of temporate and tropical tuna, the tropical tunas exhibit rapid growth, early maturity, continuous spawning, short life span, limited maximum size and distribution restricted to warm waters. The eastern Bluefin tuna however, belongs to the temperate tuna group which is characterised by relatively slower growth compared to other tuna and tuna like species, later maturity(c. 4 years) shorter spawning season (c. 2 months), longer life span (>20 yrs) and large size (>3 meters) [[4](#_ENREF_4)]. Therefore, the over-exploitation of the bluefin tuna may affect the decline of this species more severely, compared to other tuna species such as skipjack which does not have the same biological traits of Bluefin [[5](#_ENREF_5)]. In this study, we focus on the status of the bluefin tuna over a 22 years time period (1995-2017) and analyse issues related to its exploitation, and management based on the analysis of the bluefin catch in the three regions of Mediterranean, West Atlantic and East Atlantic ocean. In section 1, an overview of the BFT is presented. In Section 2, the current management structure of the Atlantic BFT is explained followed by the analysis of the catch data for the period between (1995-2017), followed by an optimisation model in Section 3. Finally, Section 4 presents the discussions and conclusions of the study.

# Overview of BFT, catches and management

## Habitat

Tunas migrate long distances during their life cycle and amongst their major habitats are the Atlantic, Indian and Pacific oceans. The biotic and abiotic environmental parameters, as well as oxygen and temperature and water salinity affect the spatial distribution and abundance of this species [[6](#_ENREF_6)]. Furthermore, the distribution of prey is one of the main drivers in the distribution of bluefin tuna, for example in the study by [[7](#_ENREF_7)], the abundance of Bluefin tuna in the Gulf of Main in the Northwest Atlantic region was examined and the result suggest that it was strongly correlated with the Herring density in the region. The Bay of Biscay is an important Atlantic Bluefin Tuna bait boat fishery mainly comprised of juveniles (i.e. age 1-3, 55-110 cm straight fork length). The interannual consistency of this fishery and the targeting of early life stages, makes the Bay of Biscay assemblage a key component of the Eastern stock assessment [[8](#_ENREF_8)] . In a recent study by [[9](#_ENREF_9)], 136 internal archival tags and 29 pop-up satellite archival tags were used to track juvenile Atlantic Bluefin tuna in the Bay of Biscay. The results show a significant geographic dispersion from autumn to spring with high habitat concentration in the Bay of Biscay during summer, when bluefin tuna inhabits in the mixed layer. A high percentage of the individuals which left the Bay of Biscay towards the end of the year, returned the next year, suggesting a strong fidelity to the Bay of Biscay. 33% of the records during the overwintering period revealed residency in the Bay of Biscay and surrounding areas. Half of the fish overwinter in the mid Atlantic, near the Madeira Islands. The finding in [[9](#_ENREF_9)], challenge previous assumptions regarding the seasonality and annual movements of Bluefin Tuna from Bay of Biscay, while demonstrating extensive spatio-temporal dispersion. Satellite taggings and genetic tests show that Eastern and Western populations mix during migrations and the migration patterns also differs depending on the age and size of tuna and fluctuations in oceanographic conditions . The population of East Atlantic tuna is substantially larger than west and therefore the catch quota is higher (29000 tonnes for the Eastern Atlantic and the Mediterranean). The east side however faces problems such as rampant illegal fishing, over capacity and catches significantly higher than the quota.

The effect and importance of water salinity is yet unclear in the literature, since in some studies it is suggested that it is not important in influencing oceanic distribution [[10](#_ENREF_10)]while others have found it to be important [[1](#_ENREF_1), [11](#_ENREF_11)] . Based on the GAMS result in [[6](#_ENREF_6)], the importance of water salinity has been supported and it shows variable response curves for all the species considered in their study. Trophic resources play a major role in the spatial distribution of tunas, and lower salinity could indicate favourable trophic areas induced by fluvial water supplies [[12](#_ENREF_12)].

## Bluefin Tuna catch (1995-2017)

In this section the amount of catch (Tonnes) is reported for the period between (1995-2017) for three regions of Mediterranean Sea, East and west Atlantic. Although the Mediterranean is part of the East Atlantic , its catch data has been analysed separately.

The catch data has been retrieved from the ICCAT database [[17](#_ENREF_17)]. There are 8 main gear types in this analysis namely the Baitboat(bb), HL(Handline), Longline(LL), Purse Seine(PS), RR(Rod-and-reel), Trap (TP), Troll (TR) and Other. The fishing gears are different interms of their structure, method of operation, standards of catch procedure and material used and continually change and adapt as the understanding on the species behaviour increases. In the remainder of this section, each of the three regions are reported separately following a comparison between the three regions.

### Mediterranean Sea

The countries included in the Mediterranean region are European Union (Spain, France, Italy, Greece, Croatia, Cyprus, Malta, Portugal, Serbia& Montenegro), Egypt, Albania, Morraco, Tunisie, Turkey, China PR, China Taipei, Japan, Korean Republic, Israel, Libya, Panama, Algeria, Syria. Furthermore, the two entities of Not elsewhere Included (NEI), which refers to catch statistics that cannot be linked directly to a state or fishing entity, and ICCAT have also been counted as countries in this analysis.

Figure 1 shows the yearly total catch per gear type in the region, and it can be viewed that the purse seine gear type with 84% of the total catch dominates all the other gear types in terms of the catch volume. Purse Seine is commonly used for pelagic fish in coastal waters where the bottom and surface serve as natural dams to prevent fish from leaving the area enclosed by the net. Seines could make short sea trips(<24hrs) and are able to catch a high volume in each trip [[18](#_ENREF_18)] [[19](#_ENREF_19)]. The Mediterranean fishing fleet have grown exponentially partly due to the EU subsidies driving mechanisation via purse seine capture techniques and ranching. One of the problems caused by this, is the overcapacity of the tuna fleets which is a contributing factor to over-exploitation. A higher volume of catch is needed for the tuna fleets to stay economically viable and the allocated quotas to the CPS are less than the level required to sustain a profitable fleet, leading to speculation of unregulated fishing activities in some of CPCs [[14](#_ENREF_14)].

Figure 1: Catch per geartype-Mediterranean

Figure 2 illustrates that 2007 was the peak year in terms of total catch with 52558.84 tonnes and the lowest amount of catch is in 2011 of 5789.82 tonnes. However, an uprising trend of catch can be seen post 2011.

Figure 2: Yearly total catch-Mediterranean

The total catch per country for the period of 1995-2017 is shown in Figure 3. The figure shows that the highest volume of catch belongs to the EU group with a total catch of 293,842 tonnes Followed by the NEI. The country with the lowest amount of catch is Serbia and ICCAT. The high level of NEI may be partly explained by the illegal and unreported catch within the region. In a 2011 report by ICCAT, the illegal catches were estimated to be up to 107% above the allowable Total Allowable Catch (TAC) in 2007, and in a study by Gagern et al. [[20](#_ENREF_20)] , significant levels of excess catch in the Eastern Atlantic and Mediterranean is reported such that between 2008-2011, the catch exceeded the TAC by 57%.

Figure 3: Total catch by country-Mediterranean

### East Atlantic

The countries in the East Atlantic region are EU (Spain, France, Ireland, Netherland, Portugal, UK), China, Taipei, Denmark, Faroe Islands, Guinea Ecuatorial, Iceland, Japan, Korean republic, Moroc, Norway, Panama, Senegal, Seychell, Sierra Leone, Iccat and NEI.

Based on the Gear Type, the trap method, dominates the other methods with 35% of the total catch while the RR method is the least used method in the East Atlantic. Traditional traps are an ecologically compatible fishing technology and have provided sustainable BFT fishery for over 2000 years. Furthermore, the traps should be used as BFT sentinel gear and as a source of significant ecological information [[21](#_ENREF_21)].

Figure 4: Catch per geartype-East Atlantic

The yearly catch shows a different pattern to that of the Mediterranean region. The year 1997 had the highest volume in terms of total catch with 16304 tonnes, and year 2012 is the year with the least amount of catch with 3834 tonnes. Similar to the Mediterannean region, the catch volume shows an increasing trend post 2012.

Figure 5: Yearly total catch-East Atlantic

In terms of the total catch by country, EU, Japan and Morocco fleets dominate the East Atlantic region and the lowest amount of catch belongs to Equatorial Guinea. Also, the amount of NEI reported in the region is negligible.

Figure 6: Total catch per country East Atlantic

### West Atlantic

The West Atlantic region is comprised of countries including USA, Mexico, Canada, Japan, Brazil, China Taipei, Cuba, France(St Pierre et Miquelon), Korea, Panama, Sta Lucia, UK(Bermuda and Turks and Caico). In 1998, the scientific committee of ICCAT announced the annual west Atlantic catch of 2500 tonnes is not sustainable and in order to restore the population to 1970s levels a near zero quota should be implemented. In a 2008 study, the collapse of the Western Atlantic Bluefin Tuna stock has been highlighted and the danger of extinction has been reported. Poor management and over fishing of the species are accounted as the main reasons of this collapse [[22](#_ENREF_22)]. The study also suggests that the allowed Western area quota from year 2002 is 2700 Tonnes. The figures in the yearly chart (Figure 8) show that the quota measure has been effective and that the yearly catch since 2003 has not exceeded the recommended amount. Whether this is due to complying with the quota or due to reduced stock of fish is not in the scope of this study, however figures suggest that since 2013 the total yearly catch has increased which may signal partial stock recovery.

In terms of the gear type, the RR method is the most common method in the West Atlantic region with 52% of the total catch. The proportion of fish caught by rod and reel is remarkable given that fish is caught one at a time in contrast to other methods such as purse seine, in which large nets allow for a much larger capture. The prevalence of small scale fishing such as RR, may also be explained due to lower catch volumes and quotas in West Atlantic which would not economically justify the use of large scale vessels.

Figure 7: Catch per gear type- West Atlantic

The yearly total catch data shows that 2002 was the peak year in terms of the total catch while 2013 was the year with the lowest catch volume.

Figure 8: Total yearly catch-West Atlantic

The region is dominated by the USA fleet while the UK Turks and Caico Island has the least amount of catch.

Figure 9: Total catch by country- West Atlantic

## Management

Bluefin tuna is managed by the international commission for the conservation of Atlantic Tunas (ICCAT) that manages the species in two stocks of western and eastern with the boundary set in 45° W meridian. However the Biomass in the Eastern part is much larger compared to the western region [[13](#_ENREF_13)]The ICCAT, was established in 1966 in Rio de Janeiro in response to the International concern over the sustainability of tuna population and is comprised of 53 contracting party countries (CPC) around the world as in 2019. Amongst the most important responsibilities of ICCAT is the agreement on annual quota allocation to each member based on a body of scientific and management data on trade and fishing activities. These quotas are agreed based on i)historical and present fishing practices ii)status of the fish stock, including distribution and biology iii)relative commercial dependence on stocks by local coastal communities iv)past record of compliance with and contribution to ICCAT measures [[14](#_ENREF_14)].

In a 2006 ICCAT report [[15](#_ENREF_15)], the overfishing and overexploitation of the stocks indicated substantial risk of population collapse, however, in 2014, the urgent management actions significantly improved the status of the population. The stock assessment has been improved by using outstanding technological development of electronic tags capable of providing insight into the habitat preference, migration patterns, stock structure and reproductive behaviour of the BFT.

It should be noted that although ICCAT is the main regulator of the Tuna sector, individual CPCs have also taken measures against the over exploitation of BFT. Given that the Atlantic BFT is recognised as an endangered species by the International Union for conservation for nature (IUCN) Red List as this stock remains overfished, in the European marine area, the management of the Eastern Atlantic stock is essential to the future of the species.

For example, as an ICCAT member, the United Kingdom has prohibited the catch or target of the Bluefin Tuna in its waters for commercial and recreational vessels and there are no specific quota to catch Bluefin tuna since it is a prohibited species for UK registered commercial fishing vessels. If the species is caught as a by-catch it must be returned to the sea, alive and unharmed to the greatest extent possible. If the fish is dead then it should be landed and may be donated for scientific research, and it may not be sold [[16](#_ENREF_16)].

# Economic analysis

To verify if the data for the three regions under consideration in this study contain statistically significant trend, the T-test and the Mann-Whitney tests are conducted. In the first step, In order to understand the distribution of the total catch data, the Anderson-Darling, Ryan-Joiner and Kolmogorov-Smirnov tests are conducted and the results are reported in Table 1.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Normality test | Ryan-Joiner | Kolmogorov-Smirnov | Anderson-Darling | Mean | STDev |
| Region | P-value | RJ | P-value | KS | P-value | AD |
| MED | <0.010 | 0.929 | <0.010 | 0.232 | <0.005 | 1.605 | 27,489 | 15,533 |
| ATE | >0.1 | 0.971 | >0.15 | 0.102 | 0.416 | 0.361 | 8,017 | 3,182 |
| ATW | >0.1 | 0.965 | 0.039 | 0.189 | 0.078 | 0.65 | 2,156 | 470 |
| N=23 |

Table 1: Normality test



Figure 10: Probability Plot of total catch Med



Figure 11:Probability Plot of total catch ATE



Figure 12:Probability Plot of total catch ATW

Based on the P-values of the normality tests, it can be concluded that the catch data for the West Atlantic and East Atlantic have a normal distribution(in at least two methods) whereas the total catch in the Mediterranean region has a non-normal distribution (P-values<0.05).

For comparison of the total catch in ATE and ATW, the two sample T test is used which shows P-Value<0.0001 meaning that there is statistically significant difference between the total catch in ATW and ATE region. For comparing the Mediterranean region with the other two regions (East and West Atlantic), the Mann-Whiteney test is used and the reported P-values is <0.00001 for all groups.

These results show that there is statistically significant difference between the total catch volume in these three regions, with the Mediterranean having the highest volume followed by the East Atlantic and West Atlantic region respectively.

Based on the ICCAT data presented in the previous section, an NPV analysis and projection for the East Atlantic and Mediterranean region is presented in this section following the example of [[23](#_ENREF_23)] . For each gear type , we will firstly define the parameters used in the model as below:

Revenue

Catch

Cost

Profit

NPV

An optimization model is developed which selects the combination of gear types for maximising the total NPV. The NPV assessment of the East Atlantic is based on the historical data from ICCAT. A binary linear programming model is developed in which the total NPV is maximised such that the decision variable if the geartype is selected and otherwise.

Such that:

where is the biomass available, and is the level of quota allocated to the region in year t , and are the coefficients of the cost and price respectively.

Global optimal solutions were found in both scenarios. Moratorium intervals are introduced in the model to allow for further stock recovery. Three discount rates are considered in each scenario(0.04,0.08,0.1) and Tables 2, 3 NPVs are estimated for each gear type. The five main geartypes of PS, BB, LL ,TP and remainder are considered as (.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Period(P\*8%) | Ideal gear types | r | NPVT (mill $) | moratorium period |
| 1995-2060 | Purse seine, trap | 0.1 | 1716 | 15 years |
| 1995-2060 | Purse seine, trap | 0.08 | 2302 | 15 years |
| 1995-2060 | Purse seine, trap | 0.04 | 6401 | 15 years |

Table : NPV 1995-2060

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Period(P\*8%) | Ideal gear types | r | NPVT (mill $) | moratorium period |
| 1995-2100 | Purse seine, trap | 0.1 | 1978 | 25 years |
| 1995-2100 | Purse seine, trap | 0.08 | 3433 | 25 years |
| 1995-2100 | Purse seine, trap | 0.04 | 33625 | 25 years |

Table :NPV 1995-2100

In the first scenario, the base year for the optimisation is 1995 and the Last year is 2060. In the second scenario, the base year is 1995 and the last year is 2100. It can be viewed from the results that in the first scenario, and assuming a 15 years moratorium period, geartypes purseseine, trap and baitboat are selected. In the second scenario, and assuming a moratorium period of 25 years, also purse seine and trap are selected. Under the current assumptions, the Longline, remainder and bait boat method were not selected in any scenario. For LL and remainder this could be due to the fact that both methods has a much higher number of effort days leading to higher cost, furthermore baitboat has much lower catch capacity and therefore lack economy of scale compared with other method.

These results also confirm the results earlier found in Bjornal and Brasao[[23](#_ENREF_23)] which shows that in the longer term, the trap method will continue to be the most sustainable method and that the baitboat geartype will eventually be shut down due to its low profitability and catch volume. Furtheremore, the purse seine method which has the highest catch volume, will stay as one of the governing methods eartype in the region also shown in the previous sections.

# Discussion and conclusions

This study highlights the trends in total catch for the Atlantic Bluefin tuna in the period between 1995- 2017 and presents an optimisation model for the short term and long term NPV assessment of the East Atlantic Bluefin Tuna. Following an increased international pressure and the danger of collapse of the Bluefin Tuna, in 2007, the ICCAT initiated implementing management measures to reduce the risks. Since 2007, the allowable quotas for East Atlantic have been cut significantly from 36000 tonnes in 2006, to less than 13000 tonnes in 2011. Additionally, the improved surveillance and the bluefin catch documentation scheme was put in place to mitigate illegal catches and track BFT along the entire supply chain [[20](#_ENREF_20)]. Analysing the figures in the period between 1995-2017 shows that in all three regions the total catch has decreased since 2011, signalling the positive and effective impact of the sustainability measures taken by the ICCAT.

Based on the ICCAT report in 2018, in the East Atlantic region, the recovery plan will be replaced by a management plan for the Eastern stock as the current status of stock no longer appears to require the emergency measures [[24](#_ENREF_24)]. In 2017, The East Atlantic had a total catch of 23847 Tonnes and based on the guideline generated by ICCAT, the TAC for East Atlantic in 2018, 2019 and 2020 is 28200, 32240, 36000 tonnes respectively, showing an increasing confidence and hence the projected TAC seem to be reasonable and achievable.

For the West Atlantic region, in 2017, the ICCAT’s scientific committee on research and statistics conducted a stock assessment and concluded that the biomass of the western stock has been increasing since about 2004, following two decades of stability and has reached 69% of the 1974 biomass level. For the West Atlantic region, the annual total allowable catch, inclusive of dead discards is 2350 tonnes for 2018, 2019 and 2020 [[25](#_ENREF_25)]. Furthermore, in order to avoid the increasing fishing mortality of BFT, CPCs shall prohibit any transfer of fishing effort from the West Atlantic to East and vice versa.

The NPV assessment for the East Atlantic and Mediterranean region for the short term and long term period, which considers moratorium periods of 15 years and 25 years respectively, shows that the trap and purse seine methods are selected as ideal gear types in terms of maximising the total NPV sustainably.

In terms of the geartype, in the Mediterranean region the purse seine method, is the governing method, while the trap method has the highest catch volume in East Atlantic. In the West Atlantic, the highest volume of catch is by the RR method which is a small scale approach. The result of our statistical analysis shows that the total volume of catch is higher in the Mediterranean region compared to the other two regions and therefore even though the amount of catch has decreased in the recent years, precautionary measures are suggested for this region to ensure the recovery of the stocks and avoid over-exploitations. Furthermore, the amount of NEI catch is higher in the Mediterranean compared to the other two regions which calls for more strict regulation on illegal activities and reporting within that area.

The Atlantic BFT is a precious marine resource from which many local industries benefit. The future research avenues could focus on the sustainable management measures to protect this species and ensure the economic continuity of this sector.

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# Appendix:

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year  | BB | HL | LL | Other | PS | RR | TP | TR | Yearly Total catches |
| 1995 | 206 | 2745.751 | 1791.9752 | 504.099 | 23799 | 816 | 941.96 | 17.421 | 30822.20615 |
| 1996 | 5 | 1828 | 9855.584 | 338.42 | 26021 | 321.277 | 950.61 | 78.992 | 39398.88299 |
| 1997 | 4 | 2071 | 7313.224 | 275 | 24278.99999 | 31.444 | 612.9 | 7.103 | 34593.67102 |
| 1998 | 11 | 1061.00001 | 4117.072 | 273 | 31792.12702 | 31.444 | 852 | 10.645 | 38148.288 |
| 1999 | 4 | 1284.38583 | 3338.265 | 218 | 33798.496 | 248.13318 | 852 | 9.912 | 39753.19201 |
| 2000 | 37.802 | 1541.76504 | 3423.923 | 725.94601 | 33237.382 | 230.77693 | 739.003 | 2.168 | 39938.76598 |
| 2001 | 28.1 | 890.41406 | 4144.09 | 348.688 | 33043.168 | 276.91996 | 1177.272 | 4.997 | 39913.64903 |
| 2002 | 0.9 | 1157.9042 | 3234.105 | 322.9 | 34043.948 | 361.77081 | 515.279 | 16.659 | 39653.46601 |
| 2003 | 8.7 | 1110.98866 | 3483.8033 | 178.06584 | 37290.74168 | 293.35486 | 220.646 | 19.441 | 42605.74136 |
| 2004 | 16.89 | 1039.8373 | 3035.615 | 186 | 37869.342 | 285.5827 | 154.223 | 10.38 | 42597.87 |
| 2005 | 4.74 | 335.66982 | 3426.815 | 165.65 | 36638.955 | 283.79316 | 111.842 | 9.044 | 40976.50899 |
| 2006 |  | 337.08995 | 3407.5795 | 75 | 38362.80268 | 157.25086 | 125.315 | 6.34 | 42471.378 |
| 2007 |  | 74.503 | 3269.14 | 85 | 48994.28702 | 42.86208 | 93.054 | 0 | 52558.8461 |
| 2008 |  | 132.47302 | 2372.4315 | 0 | 13540.29013 | 16.583 | 151.562 | 0 | 16213.33966 |
| 2009 | 38.14 | 101.42823 | 1344.0362 | 0 | 11447.60899 | 58.2058 | 143.9405 | 0 | 13133.35975 |
| 2010 | 1 | 260.0408 | 1242.1029 | 1.1686 | 4985.56019 | 188.06576 | 280.8347 | 0 | 6958.77299 |
| 2011 |  | 276.37543 | 961.81902 | 0.79162 | 4306.07363 | 80.0222 | 164.7472 | 0 | 5789.8291 |
| 2012 | 1.86232 | 194.22068 | 586.53275 | 1.1929 | 6183.06638 | 7.565 | 125.2239 | 0 | 7099.66393 |
| 2013 | 2.00388 | 230.1534 | 604.92084 | 2.371 | 7991.78073 | 9.709 | 222.0025 | 17.389 | 9080.33035 |
| 2014 | 9 | 278.0707 | 588.34165 | 1.4795 | 8195.00947 | 11.09436 | 231.7608 | 27.9416 | 9342.69808 |
| 2015 | 25.366 | 347.84794 | 784.33573 | 0.887 | 9994.21897 | 12.80328 | 192.0167 | 1.852 | 11359.3276 |
| 2016 |  | 281.57065 | 1523.1621 | 5.16962 | 11319.00114 | 1.724 | 0 | 31.50439 | 13162.13189 |
| 2017 | 50.4772 | 596.60238 | 1183.7804 | 89.54516 | 14470.33311 | 17.33912 | 271.507 | 0 | 16679.58434 |
| Total  | 454.98 | 18,177.09 | 65,032.65 | 3,798.37 | 531,603.19 | 3,783.72 | 9,129.70 | 271.79 | 632,251.50 |

Table 4: Mediterranean\_ICCAT\_1995\_2017

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | bb | HL | LL | other | PS | RR | TP | TR | Yearly Total catch-ATE |
| 1995 |  3,093.26  |  -  |  4,521.67  |  555.00  |  458.10  |  75.00  |  1,152.00  |  -  |  9,855.03  |
| 1996 |  5,368.88  |  -  |  4,212.00  |  273.15  |  323.00  |  -  |  1,921.00  |  -  |  12,098.03  |
| 1997 |  7,214.59  |  162.00  |  4,057.40  |  60.34  |  828.00  |  -  |  3,982.00  |  -  |  16,304.33  |
| 1998 |  3,139.33  |  324.00  |  3,789.00  |  387.00  |  700.00  |  -  |  3,586.39  |  -  |  11,925.71  |
| 1999 |  1,553.53  |  324.00  |  3,569.97  |  404.13  |  726.10  |  -  |  3,959.77  |  -  |  10,537.50  |
| 2000 |  2,032.44  |  324.00  |  3,735.69  |  507.16  |  661.20  |  -  |  2,996.42  |  2.00  |  10,258.91  |
| 2001 |  2,426.24  |  61.20  |  3,303.14  |  557.67  |  152.80  |  -  |  3,585.30  |  -  |  10,086.35  |
| 2002 |  2,634.62  |  62.50  |  2,896.42  |  631.00  |  886.70  |  -  |  3,235.30  |  -  |  10,346.53  |
| 2003 |  1,409.41  |  109.04  |  2,748.41  |  521.37  |  490.01  |  -  |  2,116.02  |  -  |  7,394.26  |
| 2004 |  1,901.73  |  87.23  |  2,063.90  |  290.48  |  1,078.00  |  2.00  |  1,978.09  |  -  |  7,401.43  |
| 2005 |  2,282.29  |  11.31  |  2,700.45  |  423.85  |  1,197.32  |  -  |  2,407.90  |  -  |  9,023.12  |
| 2006 |  1,262.57  |  4.24  |  2,033.02  |  831.25  |  407.91  |  95.15  |  2,894.75  |  -  |  7,528.89  |
| 2007 |  2,435.77  |  10.41  |  1,704.88  |  501.38  |  -  |  0.63  |  3,787.92  |  0.16  |  8,441.15  |
| 2008 |  2,393.39  |  6.28  |  2,491.22  |  181.02  |  -  |  5.45  |  3,165.65  |  -  |  8,243.00  |
| 2009 |  1,259.57  |  1.98  |  1,951.15  |  296.77  |  1.72  |  8.93  |  3,164.36  |  -  |  6,684.48  |
| 2010 |  724.53  |  20.94  |  1,193.51  |  123.85  |  0.63  |  22.98  |  2,292.47  |  -  |  4,378.90  |
| 2011 |  635.91  |  18.94  |  1,124.75  |  34.87  |  0.33  |  32.19  |  2,136.83  |  -  |  3,983.83  |
| 2012 |  282.88  |  25.34  |  1,138.82  |  48.39  |  -  |  27.22  |  2,311.36  |  -  |  3,834.01  |
| 2013 |  243.02  |  20.69  |  1,167.45  |  137.35  |  1.46  |  25.70  |  2,563.64  |  3.12  |  4,162.43  |
| 2014 |  94.58  |  16.33  |  1,194.02  |  145.55  |  -  |  26.44  |  2,375.93  |  64.69  |  3,917.54  |
| 2015 |  171.68  |  60.35  |  1,466.53  |  191.06  |  -  |  43.90  |  2,905.31  |  2.30  |  4,841.12  |
| 2016 |  1,085.29  |  34.87  |  1,828.85  |  252.57  |  41.74  |  -  |  2,715.92  |  8.71  |  5,967.93  |
| 2017 |  1,194.58  |  100.92  |  2,168.14  |  293.81  |  48.69  |  -  |  3,362.45  |  -  |  7,168.58  |
| Total | 44840.0949 | 1786.561 | 57060.3821 | 7649.01124 | 8003.71901 | 365.583 | 64596.77 | 80.9655 | 184383.09 |

Table 5: ATE\_Catchdata

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Year | HL | LL | other | PS | RR | TP | Total catch-ATW |
| 1995 | 75.00003 | 628.95003 | 384 | 249 | 1039 | 72 | 2447.95 |
| 1996 | 35.99998 | 711.60002 | 433 | 245 | 996 | 90 | 2511.6 |
| 1997 | 16.99997 | 537.00003 | 293 | 250 | 1178.3 | 59 | 2334.3 |
| 1998 | 28.99999 | 887.00002 | 342 | 249 | 1082 | 68 | 2657 |
| 1999 | 15.00003 | 1075.48298 | 278.981 | 248 | 1109.792 | 44.493 | 2771.749 |
| 2000 | 3.20001 | 1079.534 | 283.378 | 275.2 | 1117.467 | 16.052 | 2774.831 |
| 2001 | 9.00001 | 714.749 | 201.295 | 195.9 | 1647.669 | 15.786 | 2784.399 |
| 2002 | 4.49001 | 940.03798 | 107.044 | 207.74 | 2031.123 | 28.129 | 3318.564 |
| 2003 | 0 | 418.10299 | 139.349 | 265.42 | 1398.514 | 83.99 | 2305.376 |
| 2004 | 1.48502 | 824.81002 | 97.125 | 31.786 | 1137.304 | 32.028 | 2124.538 |
| 2005 | 2.282 | 556.18701 | 89.067 | 178.283 | 922.206 | 8.434 | 1756.459 |
| 2006 | 0.309 | 714.42298 | 85.287 | 3.594 | 1004.825 | 2.998 | 1811.436 |
| 2007 | 0 | 520.08715 | 63.05299 | 27.948 | 1022.884 | 3.591 | 1637.563 |
| 2008 | 0.5552 | 764.86026 | 77.92622 | 0 | 1133.363 | 23.005 | 1999.71 |
| 2009 |  | 573.46815 | 120.6684 | 11.43974 | 1250.489 | 23.463 | 1979.528 |
| 2010 | 2.67668 | 703.07713 | 106.6837 | 0 | 1006.198 | 38.787 | 1857.423 |
| 2011 | 0.866 | 945.43509 | 131.114 | 0 | 886.7376 | 42.605 | 2006.758 |
| 2012 | 1.313 | 701.71299 | 117.262 | 1.678 | 915.385 | 16.575 | 1753.926 |
| 2013 | 0 | 614.86493 | 121.331 | 42.54103 | 690.8103 | 11.372 | 1480.919 |
| 2014 | 0 | 636.27041 | 119.0653 | 41.84 | 809.6829 | 19.544 | 1626.403 |
| 2015 | 1.736 | 572.08996 | 138.8339 | 38.84898 | 1083.596 | 6.4728 | 1841.577 |
| 2016 | 14.23204 | 591.22183 | 95.87119 | 0 | 1190.021 | 9.5176 | 1900.863 |
| 2017 | 5.04301 | 615.12254 | 123.6575 | 0 | 1138.769 | 12.62723 | 1895.219 |
|  | 219.18798 | 16326.0875 | 3948.992 | 2563.219 | 25792.14 | 728.4696 | 49578.09 |

Table 6:ATW\_Catchdata