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# A Review of the Atlantic Bluefin Tuna (Thunnus Thynnus) Fishery Between 1995 and 2017

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***Abstract***

*This paper is a review of the capture fishery of the Atlantic bluefin tuna between 1995 and 2017. It considers the exploitation of the fish, catching activity within the fishery over this time period alongside the management efforts to protect stocks. Catch data over the period was analysed and an optimisation model produced to select the most sustainable gear type. Trap and Purse seine methods of catching Atlantic bluefin tuna were selected as the optimal for sustainability. The study also highlighted the higher level of catch not assigned to a specific country or fishing entity within the Mediterranean region, a potential sign of illegal, unreported and unregulated (IUU) fishing activity. The Atlantic bluefin tuna is a precious marine resource from which many local industries benefit. The research undertaken suggests that regulators should focus on encouraging Trap and Purse Seine gear types, focus on reducing IUU in the Mediterranean and continue with the current quota system that has sustained yields since 2011 in the Western Atlantic region and grown them in the Eastern Atlantic and Mediterranean regions in order to promote sustainable management, protect this species and ensure the economic continuity of this sector.*

**Keywords:** Renewable Energy, Built Environment, Sustainable Development.

## Introduction

Tuna are one of the top oceanic predators and play a significant role in marine ecosystems while comprising nearly 20% of the value of capture fisheries. The main commercial species of tuna are the Atlantic bluefin (Thunnus thynnus), southern bluefin (Thunnus maccoyii), albacore (Thunnus alalonga), bigeye (Thunnus obesus), yellowfin (Thunnus albacares) and skipjack (Katsuwonus pelamis) [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 (Thunnus thynnus), also known as northern bluefin tuna, giant bluefin tuna and tunny (hereafter referred to as BFT) is the largest species of tuna and one of the most highly priced fish species in the world. BFT fishing in the Mediterranean Sea has been a common practice for millennia and takes advantage of the reproductive migration of the species from the foraging grounds in the Atlantic to the spawning areas in spring [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 over-exploitation of the eastern BFT stock [3]. Furthermore, studies show that sustainable fishing practices are not merely related to the management of the effort intensity but that 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 temperate 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 BFT however, belongs to the temperate tuna group which is characterised by relatively slower growth compared to other tuna and tuna like species with later maturity (c.4 years), shorter spawning season (c.2 months), longer life span (>20 yrs) and large size (>3 meters) [4]. Therefore, the over-exploitation of BFT 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 as BFT [5]. In this study, we focus on the status of BFT over a 22 year 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 (Med), West Atlantic (ATW) and East Atlantic (ATE) ocean. The Atlantic bluefin tuna is a precious marine resource from which many local industries benefit with this paper exploring and understanding the mechanics of the exploitation of the species in order to contribute to the sustainable management of the fishery. In section 1, an overview of the BFT is presented. In Section 2, the current management structure of the BFT fishery is explained followed by 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**

Tuna migrate long distances during their life cycle with their major habitats in 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 these species [6]. Furthermore, the distribution of prey is one of the main drivers in the distribution of BFT. For example in the study by [7], the abundance of Bluefin tuna in the Gulf of Maine in the Northwest Atlantic region was examined and the results suggested that it was strongly correlated with the herring density in the region. The Bay of Biscay is an important BFT 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] . In a recent study by [9], 136 internal archival tags and 29 pop-up satellite archival tags were used to track juvenile BFT 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 BFT inhabit 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], challenges previous assumptions regarding the seasonality and annual movements of BFT from the Bay of Biscay, while demonstrating extensive spatio-temporal dispersion. Satellite tagging and genetic tests show that Eastern and Western populations mix during migrations and the migration patterns also differ 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 (29,000 tonnes for the Eastern Atlantic and the Mediterranean). The eastern 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] while others have found it to be important [1, 11]. Based on the GAMS result in [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 tuna, and lower salinity could indicate favourable trophic areas induced by fluvial water supplies [12].

**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 at the 45° W meridian. However the biomass in the Eastern region is much larger than the Western region [13] ICCAT, was established in 1966 in Rio de Janeiro in response to international concern over the sustainability of tuna populations and is comprised of 53 contracting party countries (CPC) around the world as of 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, and iv) past record of compliance with and contribution to ICCAT measures [14].

In a 2006 ICCAT report [15], the overfishing and overexploitation of the stocks indicated substantial risk of population collapse, however, in 2014, urgent management actions significantly improved the status of the population. The stock assessment has been improved by 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 BFT is recognised as an endangered species by the International Union for the Conservation of 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.

**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]. There are 8 main gear types in this analysis namely the Bait boat (bb), Handline (HL), Longline (LL), Purse seine (PS), Rod-and-reel (RR), Trap (TP), Troll (TR) and Other. The fishing gears are different in terms of their structure, method of operation, standards of catch procedure and material used and continually change and adapt as the understanding of the species behaviour increases. In the remainder of this section, each of the three regions are reported separately.

**Mediterranean Sea**

The countries included in the Mediterranean region catch statistics are the European Union (EU) (Spain, France, Italy, Greece, Croatia, Cyprus, Malta, Portugal, Serbia & Montenegro), Egypt, Albania, Morocco, Tunisia, 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 can make short sea trips (<24hrs) and are able to catch a high volume in each trip [18] [19]. The Mediterranean fishing fleet has 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 CPCs are less than the level required to sustain a profitable fleet, leading to speculation of unregulated fishing activities in some of CPCs [14].

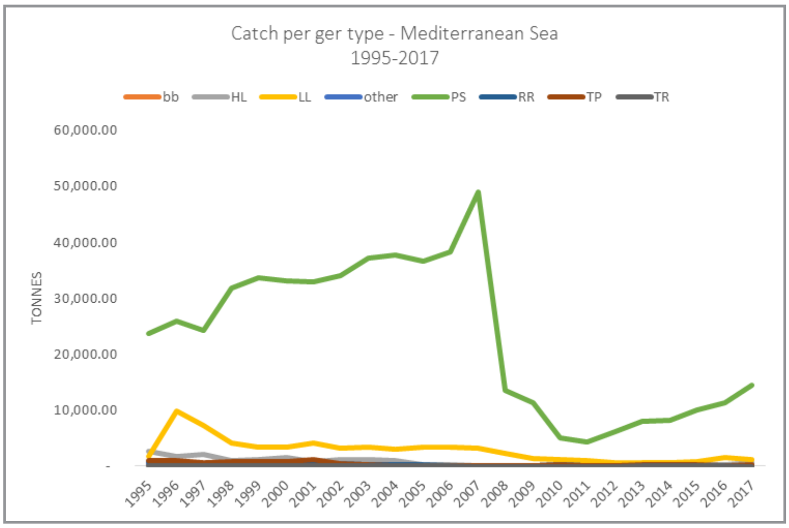


**Figure 1:** Catch per geartype-Mediterranean

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, a rising trend of catch can be seen post 2011.

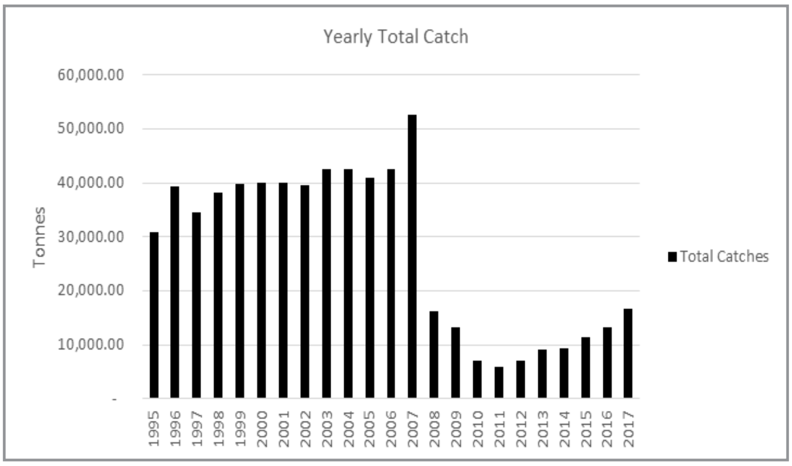


**Figure 2:** Yearly total catch-Mediterranean

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 European Union 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] , 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%.

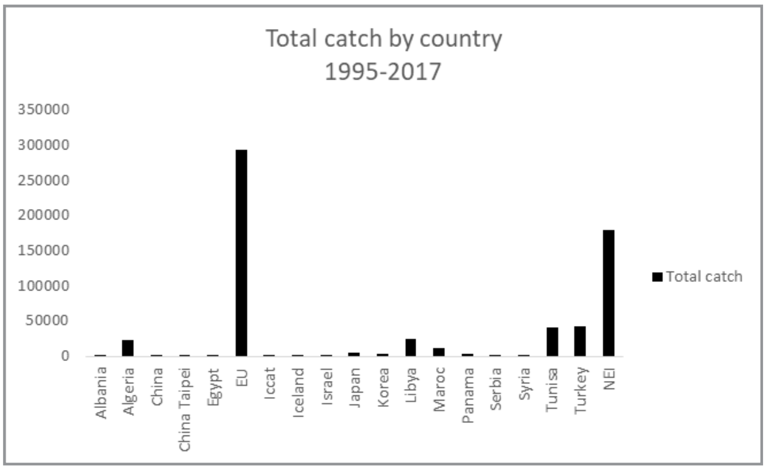


**Figure 3:** Total catch by country-Mediterranean

**East Atlantic**

The countries catching BFT in the East Atlantic region are EU (Spain, France, Ireland, Netherland, Portugal, UK), China, Taipei, Denmark, Faroe Islands, Equatorial Guinea, Iceland, Japan, Korean republic, Morocco, Norway, Panama, Senegal, Seychelles, Sierra Leone, ICCAT and NEI.

The Trap (TP) method dominates gear types used with 35% of the total catch while Rod-and-reel (RR) is the least used method in the East Atlantic. Traditional traps are an ecologically compatible fishing technology and have provided a sustainable BFT fishery for over 2000 years. Furthermore, the traps can be used as BFT sentinel gear and as a source of significant ecological information [21].

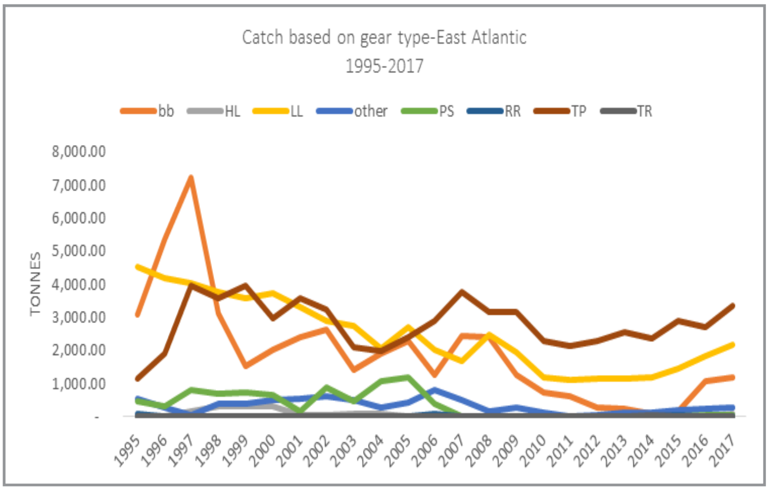


**Figure 4:** Catch per gear type-East Atlantic

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 Mediterranean region, the catch volume shows an increasing trend post 2012.

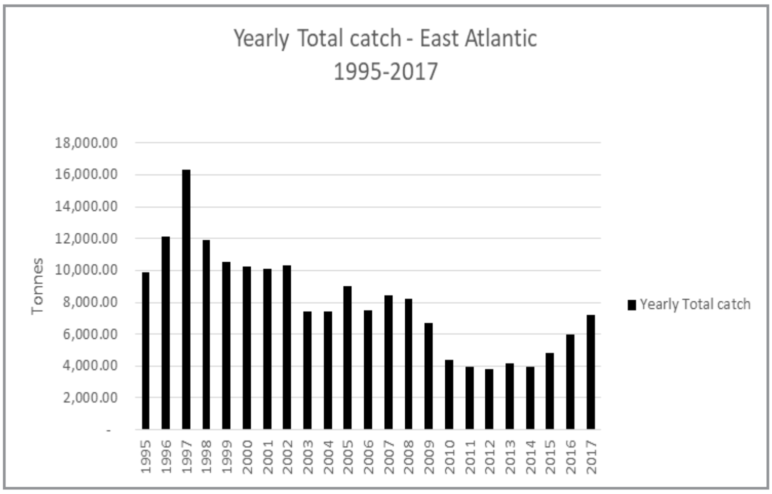


**Figure 5:** Yearly total catch - East Atlantic

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

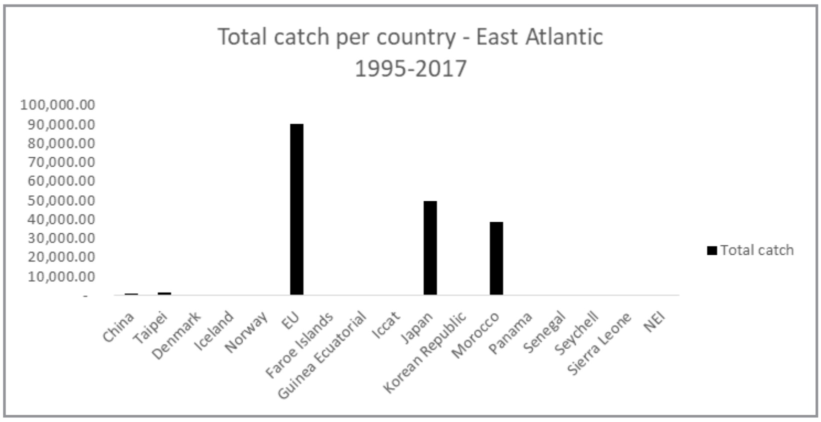


**Figure 6:** Total catch per country - East Atlantic

**West Atlantic**

The West Atlantic region's catch is comprised of countries including the USA, Mexico, Canada, Japan, Brazil, China Taipei, Cuba, France (St Pierre et Miquelon), Korea, Panama, St. Lucia, UK (Bermuda and Turks and Caicos). 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 BFT stock has been highlighted and the danger of extinction has been reported. Poor management and over fishing of the species the main reasons of this collapse [22]. The study also states 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 the fish are 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.

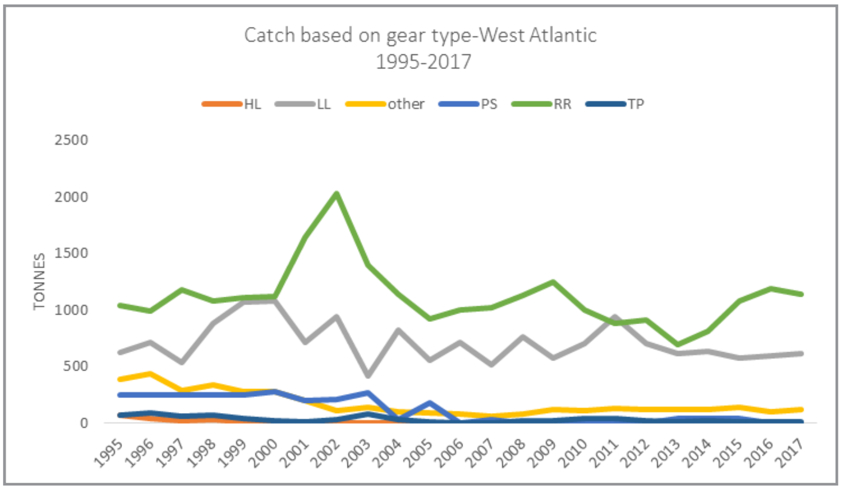


**Figure 7:** Catch per gear type- West Atlantic

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.

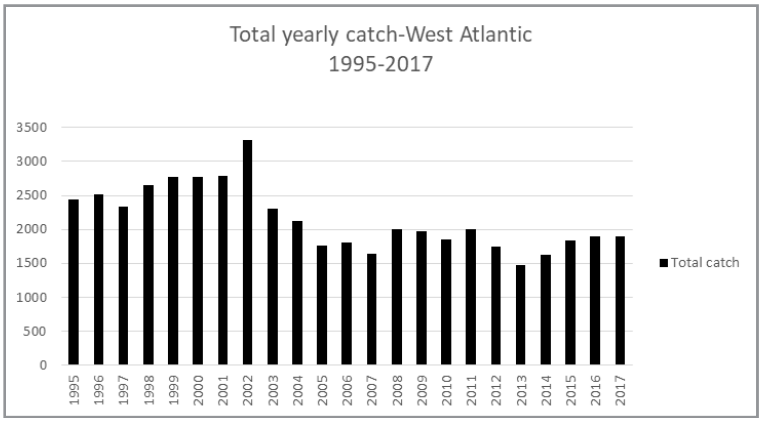


**Figure 8:** Total yearly catch-West Atlantic

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

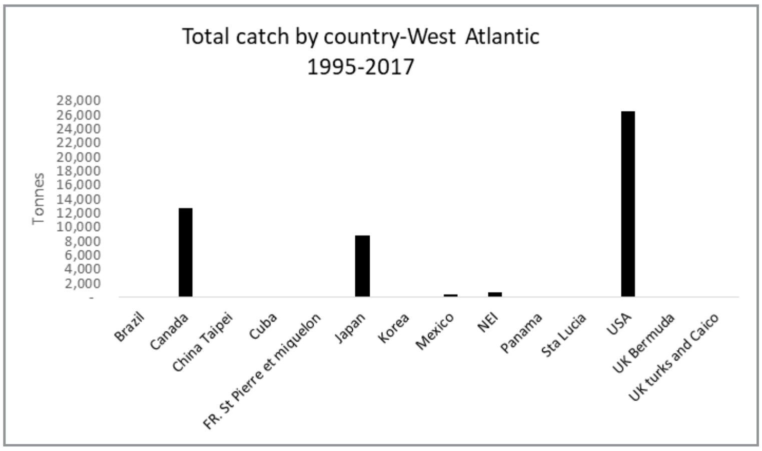


**Figure 9:** Total catch by country- West Atlantic

**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.

**Table 1:** Normality test

| 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 |

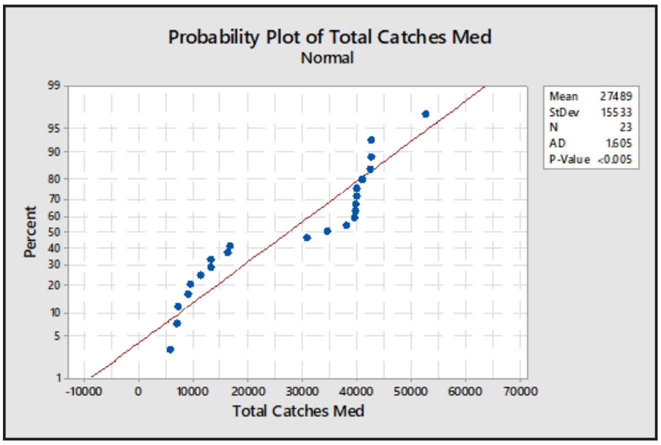


**Figure 10:** Probability Plot of total catch Med

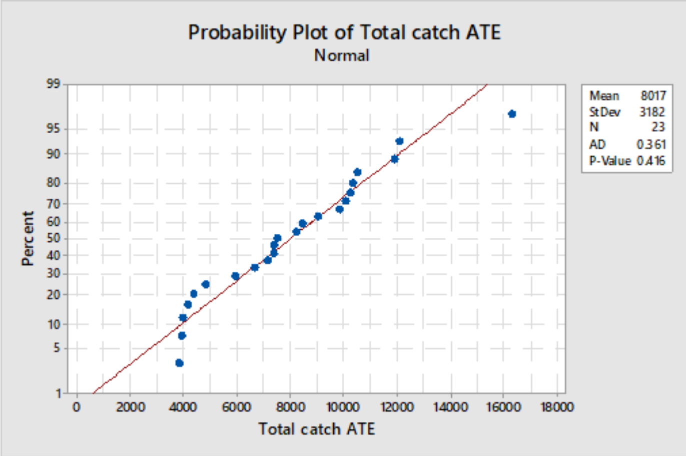


**Figure 11:** Probability Plot of total catch ATE

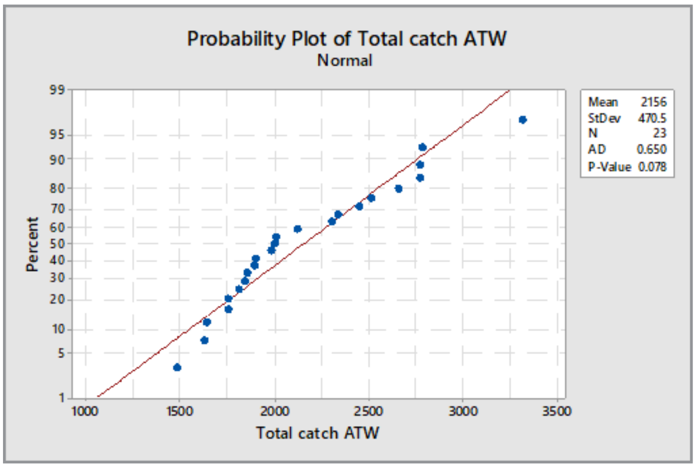


**Figure 12:** Probability Plot of total catch ATW

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-Whitney 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] . For each gear type (i=1,..,n), we will firstly define the parameters used in the model as below:

Revenue $$Rev_{t,i} = (1-\gamma)p_{i,t}Ca_{t,i}$$

Catch $$Ca_{t,i} = q_i E_{t,i} B_t^{a_i}$$

Cost $$Co_{t,i} = c_i E_{t,i}$$

Profit $$\pi_{t,i} = Rev_{t,i} - Co_{t,i}$$

NPV $$\sum_{i=1}^{n} \left(\frac{1}{1+r}\right)^t \pi_{t,i}$$

An optimisation model was 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 $x_i = 1$ if the gear type is selected and $x_i = 0$ otherwise.

$$\max z = \sum_{i=1}^{n} NPVT \quad i = 1, \ldots, n$$

Such that:

$$\sum_{i=1}^{n} B_{i,t} \geq Ca_{i,t} \quad (t = 1, \ldots, T \quad i = 1, \ldots, n)$$

$$\sum_{i=1}^{n} Ca_{i,t} \leq Q_{i,t} \quad (t = 1, \ldots, T \quad i = 1, \ldots, n)$$

$$c_{i,t} = \varphi c_{i-1,t-1}$$

$$P_{i,t} = \varphi' P_{i-1,t-1}$$

where $B$ is the biomass available, and $Q$ is the level of quota allocated to the region in year t , $\varphi$ and $\varphi'$ 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 gear types of PS, BB, LL, TP and Remainder (all other gear types) are considered as ($i = 1,..,5$).

**Table 2:** NPV 1995-2060

| 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 3:** NPV 1995-2100

| 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 |

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, gear types Purse seine, Trap and Bait boat 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 methods were not selected in any scenario. For LL and remainder this could be due to the fact that both methods have a much higher number of effort days leading to higher cost, furthermore Bait boat has much lower catch capacity and therefore lack economy of scale compared with other method.

These results also confirm the results earlier found in Bjorndal and Brasao [23] which shows that in the longer term, the Trap method will continue to be the most sustainable method and that the Bait boat gear type will eventually be shut down due to its low profitability and catch volume. Furthermore, the Purse seine method which has the highest catch volume, will stay as one of the main methods of gear type in the region.

## Discussion and Conclusions

This study highlights the trends in total catch for the Atlantic bluefin tuna (Thunnus thynnus) 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 increased international pressure and the danger of collapse of the bluefin tuna, in 2007, ICCAT initiated implementation of management measures to reduce the risks. Since 2007, the quotas for the East Atlantic have been cut significantly from 36,000 tonnes in 2006, to less than 13,000 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]. 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 the stock suggests that there no longer appears to be a requirement for emergency measures [24]. In 2017, The East Atlantic had a total catch of 23,847 Tonnes and based on the guideline generated by ICCAT, the TAC for East Atlantic in 2018, 2019 and 2020 is 28,200, 32,240 and 36,000 tonnes respectively, showing an increasing confidence with the projected TAC seeming reasonable and achievable.

For the West Atlantic region, in 2017, 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]. Furthermore, in order to avoid increasing the 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, 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 gear type, in the Mediterranean region the Purse seine method, is the governing method, while the Trap method has the highest catch volume in the East Atlantic. In the West Atlantic, the highest volume of catch is by the Rod-and-reel 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 bluefin tuna 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:**

**Table 4:** Mediterranean_ICCAT_1995_2017

| 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 5:** ATE_Catchdata

| 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 6:** ATW_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 |