ALTERNATIVE CATCH ESTIMATES FROM MARKET AND THIRD PARTY DATA

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SUMMARY

Three new datasets holding bluefin tuna catch data not currently used to produce catch estimates that go into the stock assessment were analysed to assess the level of fish removals they support. The analysis addressed issues such as duplication and incomplete records and explored the impact of assumptions used and associated uncertainty. The results produced catches that were lower than those in official statistics (Task I data) but very close to them for the recent years. The analysis identified key gaps and assumptions that affect the robustness of the findings and highlighted the value of using different sources to estimate total catches.

RÉSUMÉ

Trois nouveaux jeux de données contenant des données de capture de thon rouge actuellement non utilisés pour produire des estimations de capture dans l'évaluation des stocks ont été analysés afin d'évaluer le niveau de capture de poisson qu'ils représentent. L'analyse portait sur des questions telles que la duplication et les enregistrements incomplets et a exploré l'impact des hypothèses utilisées et l'incertitude associée. Les résultats ont produit des captures inférieures à celles des statistiques officielles (données de la tâche I), mais à un niveau très proche de celles-ci au cours des dernières années. L'analyse a identifié des lacunes et des postulats clés qui ont une incidence sur la solidité des résultats et a mis en évidence la valeur de l'utilisation de différentes sources pour estimer les captures totales.

RESUMEN

Se analizaron tres nuevos conjuntos de datos que contenían datos de captura de atún rojo que actualmente no se usan para producir estimaciones de captura incluidas en la evaluación de stock con el fin de evaluar el nivel de extracciones de peces que representan. En el análisis se abordaron cuestiones como los registros incompletos o duplicaciones y se exploró el impacto de los supuesto utilizados y la incertidumbre asociada. Los resultados produjeron capturas inferiores a las de las estadísticas oficiales (datos de Tarea I), pero con niveles muy cercanos en años recientes. En el análisis se identificaron lagunas clave y supuestos que afectan a la robustez de los hallazgos y resaltan el valor de utilizar diferentes fuentes para estimar las capturas totales.

KEYWORDS

bluefin tuna, data collections, trade, catch statistics

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1. Introduction

One of the aims of the ICCAT Atlantic-Wide Research Programme on Bluefin Tuna (ICCAT GBYP) is to use datasets not currently incorporated in the ICCAT database to support BFT stock assessment work.

Three new datasets holding data on BFT catches were donated to the GBYP recently; the data were acquired from different sources including Japanese auction market records, fishing and/or ranching operators records, ICCAT Bi-annual Statistical Reports, CoC Reports and the BCD database. (Gagern *et al.* 2013). These new datasets are not currently used to calculate catch statistics for stock assessment so, they are an alternative source of catch estimates.

Alternative approaches to calculate total BFT catches or account for misreporting in management advice have been considered in the past in response to concerns about the representativeness / completeness of official catch statistics (e.g. Metian *et al.* 2014; Fromentin *et al*. 2014; Gagern *et al*. 2013). These studies pointed to discrepancies between the official catch data used for the stock assessments and the number of BFT fish that have actually been caught. Earlier analysis undertaken using the 3 datasets used here also seemed to support that conclusion (Bregazzi 2013).

This paper presents the results of analysis of the 3 datasets and provides estimates of total catches (removals) of Atlantic bluefin tuna for the stocks and period covered by the data.

2. Material

2.1 Catch datasets

Three datasets with data on BFT catches that have not been used before to inform the official catch statistics were used in the analyses. The datasets were acquired from three different sources that can broadly described as:

Form 1: This form provides data on auctioned BFT from all major Japanese auction markets. The main features of the information in this file are:

- Covers years from 2000 – 2012.
- It was based on daily auction market reports;
- Covers BFT from the Eastern stock only;
- Covers fish auctioned fresh;
- Covers both wild and farmed fish;
- Covers fish that have been exported from the EU. This means that fish from the Eastern stock caught by the EU fleet which were exported to a third country (e.g. USA) before sent to Japan will not be part of this dataset;
- A number of assumptions have been used to assign fish to geographical area, gears, and catch years;
- This dataset does not include data from the Japanese longline fleet fishing in the NE Atlantic and the Mediterranean;
- BFT sold frozen will not be included in this dataset

Form 2: Data on BFT production obtained from some fishing and/or ranching operators records, vessels logbooks, and sampling programmes. Features of this file include:

- Covers years from 1995 to 2008.
- Covers both wild and ranched fish;
- Covers Live, Fresh and Frozen products

Form 3: Data on BFT production from ICCAT Bi-annual Statistical Reports, CoC Reports and BCD Database. Features of this file include:

- Covers years from 2004-2014.
- Covers Live, Fresh and Frozen products;
- Covers both wild and ranged fish;
- BCD data were extracted in January and March 2014

2.1 *Other information*

In addition to the 3 datasets, the analyses also made use of additional information including:

- Standard ICCAT conversion factors for different presentation types;
- ICCAT conversion factors for weight of fattened fish; and
- Standard ICCAT bluefin tuna length-weight relationship.

The analysis used the latest version of the 3 Forms after all assumptions described in Bregazzi (2015) have been applied (e.g. assumptions used to allocate catches to different geographical areas and farmed fish to different catch years).

3. Methodology

3.1 Development of a database

The first part of the work focused on developing a single database using the 3 datasets that would meet the needs of the analyses planned. The datasets were also tested for consistency to ensure that the information is recorded according to official (ICCAT) formatting. Discrepancies from the standard presentation of data were rectified before the records were included in the database.

The 3 datasets were then imported to the working structure adopted for the analysis; a data frame consisting of six elements (**Table 1**) was created to allow matching and comparison of all records. This frame includes all possible combinations to allow identification of where records match across the frame from all data sources.

Four main gear types were used in the data frame (longline, purse seine, trap and unclassified) with the other gear types having very limited or no bluefin tuna catch to compare, and these have been subsumed into the "UNCL" category for this analysis. Only the years 2001 – 2012 have been used in the full data frame for comparison between data sources. For these years two BFT related data sources were available in addition to the Task I catch data.

Using the working structure, a number of checks were run to test the completeness of the datasets. The tests considered possible gaps and inconsistencies including:

- Entries with number of fish but not weight and vice versa;
- Entries missing key frame data;
- Departure from expected values e.g. outliers in average weight estimates or several entries with the same BCD;
- Entries for which average weight could not be calculated;
- Inconsistencies in dates (e.g. harvest date for the fish was after the date it was put on the market (i.e. harvested in 2001 but on sale during 2000) or where the auction date was long after the fish have been harvested e.g. auctioned in August 2002 after being harvested in 2000).
- Entries for which the presentation type was missing
- Data duplication both across the 3 Forms and within data held in each Form

For each of the checks, we kept records of the entries that have been flagged. For example, the missing weight query has identified 55,576 individual fish reported on the Japanese market (Form 1 dataset) that do not have a weight record in kg although a fish was reported. In these cases a decision has to be made to determine if we can replace missing weights with estimates based on average weights (based on source, year etc.).

3.2 Estimation of total catches

During the development of the final database, records with incomplete or wrong data or not fitting the specifications of the analysis were excluded or flagged for further analysis to fill the gaps if that was deemed possible. Records that were flagged for further analysis included those missing catch weight or fish numbers; although it was not possible to fill the gaps for missing fish numbers, the analysis calculated missing weight records using average weight values where appropriate. The missing values have been generated based on averages of weight by year, flag, gear type, and product shape.

The incomplete/unfit category included records that provided product in belly meat, weight estimates that were above certain boundaries, or catches recorded against more than one nation. From those, only the latter, was maintained for our analysis but that means that catch estimates cannot be calculated per nation since catches form Joint Fishing operations (JFO) recorded against more than one nations could not be split. For this reason the analysis provided catch estimates per year and not per nation.

Records of secondary products such as belly meat were excluded from the calculations to reduce the risk of double counting of fish where multiple presentation forms are available in the market. Only records showing primary products i.e. the majority of a fish carcass e.g. dressed ("DR") or gilled and gutted ("GG") were used for the analysis.

Once relevant data were excluded or updated to fill gaps, analysis was run to convert all entries into round weight; that included either conversion from the type of presentation reported to round weight or a two-step conversion to also allow for the effects of fattening to be reversed. The conversion factors used for the calculations are shown in **Table 2** and **Table 3**. A set of queries were then run to extract catch weights for different combination of data summing the catch estimates over the 3 datasets for each year. The different combination of data aims to account for duplication and uncertainty issues. For the latter, the analysis was run using different hypothesis to capture key sources of uncertainty and its effects on catch estimates (see section below).

With regards to duplication, the overlap in the time period covered by the three different datasets (Forms 1, 2 and 3) could create double counting issues between the data if catch estimates for a given year are calculated as the sum over the 3 datasets. In order to address this, the three datasets were cross checked to identify records that might represent the same fish catches across the three datasets. To do so, we checked for records that appeared in more than one of the three datasets and had identical identification codes for the following categories: flag, gear type, origin, product form, area, and year. Although we could not confirm whether those records do represent duplicate information we can calculate the maximum bias that such records could create. This will happen if all of them are representing duplicate records but are still included in the calculations for the total catches.

The sources used to develop Form 3 dataset could also have led to duplication of records within that Form. This is because the data for that Form came from 3 different sources and the records were not cross-checked to ensure that duplicates were excluded. To check for duplicate records within Form 3 we first looked at the year coverage provided by each of the 3 sources; this was as follows:

- ICCAT Biannual BFT statistical reports: 2004-2011
- ICCAT CoC reports: 2007-2008
- ICCAT BCD database: 2008 -2014

The information above show that duplication might occur for the period from 2007 to 2011 as that is the period that is covered by more than one of the 3 sources used. All records from that period were compared to each other to identify those that could potentially represent duplicate entries.

An additional component of the analysis focused on calculating the length frequency of the catches to provide a more detailed picture of the fish groups that were represented in the catches. The weight at length relations used to convert weight into length was[2]:

$$RWT = (1.9607x10^{-5}) \text{ x } (SFL)^{3.0092} \text{ with } FL > 100 \text{ cm}$$

For farmed fish, the recorded weight was first converted into the round weight at catch before calculating the corresponding length. Only the Form 1 dataset was used for this calculation as this contains single record data specific to individual fish and we can therefore be confident that length data are for single fish. Although the Form 1 dataset has some records for year 2000 these are not great in number and therefore records from 2001 onwards have been used. The length frequency was calculated for each year separately.

[2] (Arena, unpublished) Mediterranean, https://normativapesquera.files.wordpress.com/2013/10/length-weight.pdf

3.3 Sensitivity analysis

As mentioned already, a number of assumptions were used to interpret the raw data that underpin the 3 datasets. The majority of those assumption were used to assign fish from Form 1 to different categories (catch year, geographical area, etc.). In addition to uncertainty stemming from those assumptions, there is uncertainty in the additional information utilised in the analysis presented here. Some of the main sources of uncertainty are:

- Official statistics include catches relating to fish that were caught and transferred to cages alive and were not weighed. So, their weight is an estimate.
- Furthermore, mismatch in number/weight of fish that went into farms (catch status “C”) and those harvested after fattening (catch status “D” and “E”) means that there is uncertainty in the estimates of total catches of tuna that were caught for fattening.
- Fattening ratios vary among different studies that have tried to estimate them (e.g. Dequara *et al.* 2010 and 2016, Anon. 2010, Galaz 2012, Gagem *et al.* 2013, Bregazzi 2015) and this is still work under development. Different values for the fattening ratios were used in the analyses presented here to reflect that (**Table 2**).
- The assumption used to assign farmed fish to the year they were caught was that they were farmed for up to 6 months if their weight was greater than 70 Kg. It is not possible to confirm whether that assumption is correct or what is the degree of error characterising it.
- For fish less than 70 Kg from Croatian farms, the assumption is that they are in cages for 2 years minimum; that assumption is in line with information available from other sources (e.g. Katavic *et al.* 2016) but again, there isn’t a way to verify that (unless a BCD and associated information exist).
- A considerable amount of records did not include weight information so, it had to be estimated using average weights creating another source of uncertainty.

This information was used to parametrise sensitivity runs and/or interpret results of the calculations.

Recommendations for additional work to incorporate a greater spectrum of uncertainty sources into the calculations were also provided in the Discussion section.

4. Results

4.1 General description

The final version of the database with the 3 datasets once unreliable/unfit records were excluded contained more than 280,000 records covering years from 1995 to 2014. However, the number of records for some of the years is very low (**Table 4**, 1995 -1998 and 2014) and are not considered to be representative of the magnitude of the fishing activity in those years so, they were not included in the analysis. Similarly, the records for years 1999, 2000, 2012, and 2013 are relatively low so, results for those years should be treated with caution.

4.2 Length frequency distribution

Calculations using the length estimates for catches recorded in Form 1 dataset showed that catches covered a wide spectrum of fish lengths spanning from small fish (approx. 80 cm FL and less than 20 kg) to fish of more than 2.5mm FL (**Figure 1**) providing a very good representation of the entire lifespan of BFT tuna from immature fish to older adults. Plotting the length frequency of the catches for all years covered in the database also highlighted some picks in length frequency for fish of length between 115 and 150 cm and between 170 cm and 220 cm.

The picks for catch years 2002-2005 in the area covering lengths 170 cm to 240 cm are particularly distinct showing a normal distribution moving to the right in the length axis and could reflect a single cohort exploited over those 4 years as the size of the individuals in that cohort increases (**Figure 2**). A similar pattern was also created by the length frequency data from catch years 2002 and 2003 for fish of length of less than 150 cm but the normal curve seem to disappear after those 2 years. These patterns could reflect a single cohort exploited over consecutive years but could also be partly due to changes in fish patterns; for example, it has been suggested that small fish were targeted for a limited period in the early 2000s as part of an experimental fishery (Di Natale *et al.* 2016).

These results suggest that there is preference for certain length classes and also that there has been a shift to focusing on smaller fish (<=160 cm) in the recent years (**Figure 3**). In particular, the maximum of the length frequency distributions from the last 5 years (2008 to 2012) corresponds to fish of 100 to 160 cm of length with a much smaller sample obtained for large fish sizes (i.e. greater than 170 cm).

One point to note is that the calculations to convert weight to length used only one equation to cover the entire spectrum of weights/lengths represented in the catch records instead of the two often used to describe the growth of EBFT. That makes this approach less detailed but it is not expected to change the high level picture and patterns presented here.

4.3 Total catch estimates – Base case

The results of the analysis using the base case assumptions for fattening ratios (**Table 2**) are shown in **Figure 4** for the case in which data for ranged fish come from the post-fattening records (catch status ID of "D" and "E").

The catches estimated from the 3 Forms are below those shown in Task I but estimates of catches in recent years are very close to the official statists and also show the same trend.

As the results show, the catches calculated from the database for years before 2008 are considerably lower than the reported catches and that is probably due to records missing from the 3 Forms so, they underestimate catches.

The results shown in **Figure 4** are considered to present an underestimate of the catches for another reason; this is because we have used the records from the post-fattening period to calculate the catches that went into tuna farms. That does not account for fish that died during the fattening period or for any missing BCD records describing the harvesting phase. This is in addition to gaps in describing the fishing activity that are due to the fact that, for certain years, the available data only cover the Japanese auction market and/or fishing carried out by European nations (including Mediterranean countries).

It should also be stressed that a number of uncertainties characterise these results; for this reason, the analysis also included calculations using different assumptions about parameter values to explore the sensitivity of these results to alternative parametrisation. The results of those calculations are presented in the sections below.

4.4 Sensitivity runs - duplicate records for farmed fish

There are a number of historic BCD records where the number of fish caged does not correspond well with that harvested. Small errors in the counting of fish entering a cage are understandable due to the limitations of observation when caging. A number of records however, show a difference of ±50% of the harvested number of fish. If we assume that all BCD records for a specific BCD are captured in Form 3 dataset, then such differences could indicate that either fish were underestimated entering the cage (either at the initial caging or through a subsequent transfer) or fish had been removed from the cage (either harvested or transferred) and not recorded on a BCD.

This can be seen in **Figure 5** where if data were correct the individual data points should sit around or just below the 1:1 ratio to account for minor errors in reporting or mortality seen during the period of caging. However a number of records can be seen both above the line indicating the 1:1 ratio, i.e. more fish have been taken out of the cage than were caged in the first place, a possible indicator of fish being added to a cage unobserved at a later date, and significantly below the line where fish were estimated as having been caged but then no record of harvest has been seen. Some records also show considerable duplication (NB: the group of data points to the bottom right hand corner of **Figure 5** that all show an identical number of fish entering a number of cages but the total number did not enter each cage, causing a discrepancy on the balance for each of the cages. Some transfers between cages may account for this but not on the scale observed). These discrepancies could also mean that the datasets analysed did not contain all relevant BCD records but it was not possible to check that in the context of this project.

As mentioned already, our base case analysis did not account for records with catch status "C" which show the number of fish going into the cage; instead we used the weight records of the fish once they had been harvested as we considered this to be a more accurate depiction of the catches. However, as a number of BCD records show a much greater number of fish going into the cage than that coming out, it is possible that the catch estimates used in our analysis for those BCDs is an underestimation of the actual catches (also see comments above about not counting for mortality during the fattening period).

To explore the effects of using post-fattening records, we also estimated total catches using the records for wild fish sold to the market (Catch status code "A" and "B") and records of fish that went to farms (pre-fattening estimates, catch status code equal to "C"). The results of the calculations are shown in **Figure 6**. The patterns are similar to those found under the base case with total estimates remaining lower than the Task I data for most of the years considered except in 2008 and 2010. Given that catches in the 3 Forms are expected to be an underestimate, these results suggest that total catches might be higher than what reported in Task I data for some of the recent years.

A significance difference is also found for 2007 for which the inclusion of data for fish that were sent for fattening reveal a significant number of fish caught that are not reflected in the post-fattening records. As discussed, a mismatch between estimates of fish that went for fattening and those that came out has been found for a number of records and the results for 2007 also reflect that. However, it is not clear whether that finding represents an actual discrepancy in reporting or it is due to records missing from Form 3.

Form 3 which represents data from official Member State records makes the biggest (or only) contribution to the estimated catches from 2008 onwards for both set of calculations. The catches coming from that dataset are very close to those from Task I for recent years; this suggests that the official datasets/reports included in Form 3 dataset provide a good representation of total catches. As those reports and datasets are available to ICCAT, they could be used in the future to cross check Task I data.

4.5 Sensitivity runs - assumptions about fattening ratios

As mentioned earlier, different fattening ratios were assumed depending on the final weight of the fish and their origin. However, there is considerable uncertainty about those ratios and in addition to that, we have no direct data confirming that the allocation of fish to the chosen fattening group was the right one. To explore the impact that our assumptions could have on the total catches we did sensitivity analysis for two components:

a) Calculations were done using values for the fattening ratio that were either higher or lower than the one applied for the base case (**Table 2**)
b) The contribution that each sub group of fattened fish (over 70 kg non-Croatian, under 70 Kgs, over 70 Kg Croatian farms) makes to the total weight of fish that was recorded each year was calculated to understand the potential impact that assigning fish to the wrong fattening group could have.

For the latter, the proportion of total catch weight that corresponds to each fattening group is shown in **Table 5**. To calculate these values we used the final weight of the fattened fish before any fattening ratios were applied to avoid adding bias that could come from the application of those ratios. The results show that ranched fish that weigh more than 70 Kg and come from non-Croatian farms make the biggest contribution ranging from 30% to more than 70% of total catches.

This group has the smallest fattening ratio (increase in weight between 0.2 and 0.4) which means that their pre-fattening weight is assumed to be very close to its final one so, the % of total weight they will contribute to the total catch using the pre-fattening weight will be even higher than the one shown in **Table 5**. This is because the weight of the other 2 groups of ranged fish will be reduced more than this one.

Therefore, if the assumption we have made about the fattening ratio of the Ranched >70 Kg group is not correct it will add positive bias to the final estimate of total catches. This means that our results will support total catches that would be greater than the actual catches.

With than in mind, our sensitivity analysis calculated total catches using:
- Scenario 1: applying the additional fattening ratios as shown in **Table 2** (sensitivity values)
- Scenario 2: assuming that all fish in the Ranched >70 Kg (Non-Croatian farms) category had the same fattening ratios as the fish in the Ranched <70 Kg category.

The results of the calculations showed a similar pattern as those under the base case scenario indicating that errors in the fattening ratio adopted do not affect the outcomes significantly. Estimates for recent years remain very close to those in Task I data suggesting that either the 3 datasets present an almost complete set of catch data for that period or, if they are still an underestimate, that Task I data also underestimate total catches.

4.6 Other sources of uncertainty - Duplication of records across datasets and Missing data on catch weight

The results of the calculations to identify duplicate records across the 3 datasets identified a small number of records that might represent the same catch events. The effects of those records if they are excluded from the catch calculations are shown in **Figure 8**. The effect is very small for all years except between 2005 and 2007 for which the bias is altering the results significantly and thus, the estimates for those years are less reliable.

Similarly, the sources used to develop Form 3 dataset could also have led to duplication of records within that Form for the period from 2007 -2011. All records from that period were compared to each other to identify those that could potentially represent duplicate entries. The results show that the proportion of catches that might come from duplicate records is negligible (**Table 6**) except for year 2007 for which duplicate records might contribute up to 11% to the total catches. In line with the previous calculations, these results also suggest that catch estimates for 2007 are less reliable.

A number of records in the 3 datasets did not have information about the weight of the catch. To address this, the weight information was filled using average weight estimates that were calculated using information from recorded with similar attributes (e.g. year, flag). However, this is another source of uncertainty and therefore, part of the analysis considered the contribution that those records make to the total catch estimates (**Table 7**). The results indicated that a considerable proportion of catches is made up by records that are missing weight information.

Therefore, if the average weight calculated here does not represent the catches for these records this could add considerable bias in the calculations. Further work to identify additional information that might help calculate the weight for those records with greater accuracy will therefore, improve the robustness of our estimates.

5. Discussion

The analyses presented here considers alternative ways to verify the catch data used for stock assessment. The data analysed are covering only a portion of the fishing activity that takes place in each year for EBFT and that means that the catch estimates found are likely to be an underestimate. Specifically, the data used do not cover certain segments of the fleet (e.g. Japanese vessels operating in the NE Atlantic) and did not fully map the volume of catches that went to all markets or sold frozen. Nevertheless, the estimates of the analyses provided catches that were very close to those from Task I for the recent period suggesting that, at least for some years, the data analysed provide a good representation of total catches in Task I. The results of the analyses though do not match the high estimates of BFT catches recorded in Task I for the period before 2007.

Although the analyses produced total catch estimates per year, it was not possible to achieve disaggregation at flag level. This is because catches in joint fishing operations are reported in an aggregated format not per single country so, catches per flag cannot be calculated. In future, we would recommend reporting be modified to ensure all reporting is linked to a specific vessel and single fishing entity.

Important gaps in the data such as missing weights mean that there is considerable uncertainty in the estimated catches and the same is true for problems with the use of BCD records. These inconsistencies in data reporting reduce the potential of these datasets in generating accurate estimates of removals and although some sensitivity analysis could be done to capture this, it is not possible to provide very informative estimates of catch boundaries without adding more assumptions about the attributes of the catches. For missing weights, further exploration to characterise the associating uncertainty possibly using estimates of variance coming from the calculation of average weights would be of value. Similarly, further examination of the reasons that have led to the high discrepancies between number of fish going into farms and those harvested could provide useful insight to improve recording of ranched fish in the future.

Despite those concerns, the data analysed here highlight the importance of considering multiple sources of data in calculating total catches and identify potential avenues for getting those additional data. Use of information from trade and other databases (e.g. Eurostat, GTIS) could also be used to cross reference the data from the 3 Forms to improve their robustness and fill gaps.

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Table 1. Elements included in the full data frame.

Element	Comment	Number of Factors
Flag State	Taken from selecting distinct flag States from form1, form2 and form3 (see Annex 3)	36 (all countries)
Gear	**LL** **PS** **TRAP** ~~BB~~ ~~GILL~~ ~~HAND~~ ~~MWT~~ ~~OTH~~ ~~RR~~ **UNCL**	10 (only 4 LL, PS, TRAP and UNCL are reported in forms 1 and 2, and all 10 in form 3). The 6 lesser used gear types will not be used in the full data frame instead converted to UNCL where appropriate.
Region	ADRI MED C MED E MED W MED W&C NEA TYRR	7 (all areas)
Product form	Fresh / Frozen / Live	3 (all product forms)
Wild / Ranched	Simple Boolean wild / ranched	2 (all)
Year	Form 1 – 2000 – 2012 Form 2 – 1995 – 2008 Form 3 – 2004 – 2014 Overall - 1995 – 2014 but restricted for final analysis	20 (but see specific restriction in analysis section)

Table 2. Increase in weight assumed for the conversion from fattened weight to weight at catch for ranched fish.[3]

Category of fattened tuna	Base case - Increase in weight	Other values for sensitivity analysis
Fish above 70 Kg (market weight). Origin: Other than Croatia	30%	20%, 40%
Fish above 70 Kg (market weight). Origin: Croatia	100%	80%, 120%
Fish below 70 kg (market weight) Origin: Any	80%	60%, 100%

Table 3. ICCAT conversion factors for bluefin tuna to round weight.[4]

Product Shape	Conversion Factor
Dressed	1.25
Fillets	1.67
Gilled and gutted	1.16
Other	2.00

[3]NB: For example, an increase of 100% means that the fish doubled its weight while in a cage.
[4]Source: ICCAT Conversion factors for fish products adopted by the SCRS for major species. https://www.iccat.int/Documents/SCRS/Manual/Appendices/Appendix%204%20V%20Product%20conversion%20factors.pdf

Table 4. Proportion of records in the 3 Forms for each year.

Year	% contribution to total number of records
1995	0.0%
1996	0.0%
1997	0.1%
1998	0.6%
1999	2.1%
2000	3.7%
2001	11.6%
2002	14.7%
2003	16.7%
2004	10.2%
2005	9.8%
2006	5.8%
2007	3.4%
2008	5.1%
2009	6.8%
2010	3.0%
2011	3.2%
2012	1.8%
2013	1.2%
2014	0.0%

Table 5. Contribution that each sub-group of fattened animals make to the total weight of catches recorded each year. The contribution is shown using the final weight of fattened fish (i.e. without the conversion to calculate their weight at catch).

Catch Year	RANCHED - < 70kg Non -Croatia	RANCHED - > 70kg	RANCHED > 70 Kg Croatia	WILD
2001	10.4%	51.4%	0.2%	38.0%
2002	25.9%	52.1%	0.3%	21.7%
2003	10.1%	75.0%	3.3%	11.6%
2004	16.3%	71.0%	0.1%	12.6%
2005	15.2%	69.4%	4.2%	11.2%
2006	11.6%	66.7%	1.4%	20.2%
2007	25.2%	30.5%	0.5%	43.8%
2008	16.1%	55.5%	9.8%	18.6%
2009	18.0%	55.3%	8.0%	18.8%
2010	24.2%	39.7%	0.0%	36.0%
2011	10.2%	48.1%	17.2%	24.6%
2012	8.0%	56.5%	0.0%	35.5%
2013	3.8%	65.8%	0.0%	30.4%

Table 6. Potential bias in catch estimates from duplicate records in Form 3 for the years when duplication might have occurred (2007 – 2011).

Year	Potential duplicate catch records (Kg)	Total catch weight captured in Form 3 (Kg)	% of total catch from Form 3 that might come from duplicate records
2007	1,078,894	9,649,718	11 %
2008	527,966	24,400,847	2 %
2009	109,576	17,591,846	0 %
2010	0	8,069,333	0 %
2011	0	11,452,857	0 %

Table 7. Contribution of records with missing weights to total catch estimates.

Harvest Year	**% catches calculated using average weight**
2000	0.48%
2001	4.69%
2002	11.09%
2003	**25.04%**
2004	**28.64%**
2005	**77.71%**
2006	**78.99%**
2007	**62.99%**
2008	1.11%
2009	1.02%
2010	0.25%
2011	0.21%
2012	0.03%
2013	0.00%

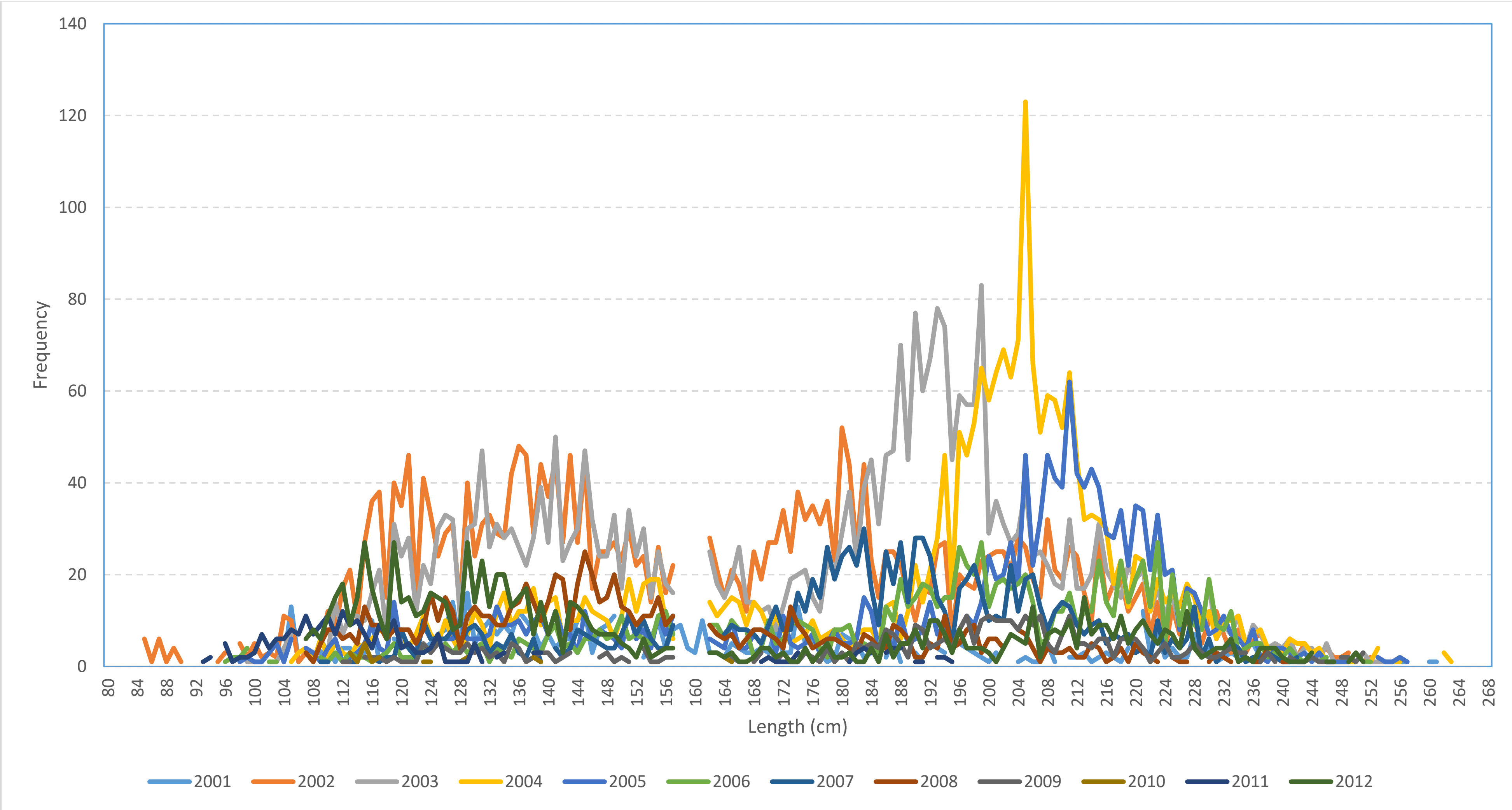

Figure 1. Length frequency of bluefin tuna as reported on the Japanese auction market (2001 - 2012). Note that for ranged fish, the length shown here corresponds to their catch length not the length at sale (source: Form 1 dataset).

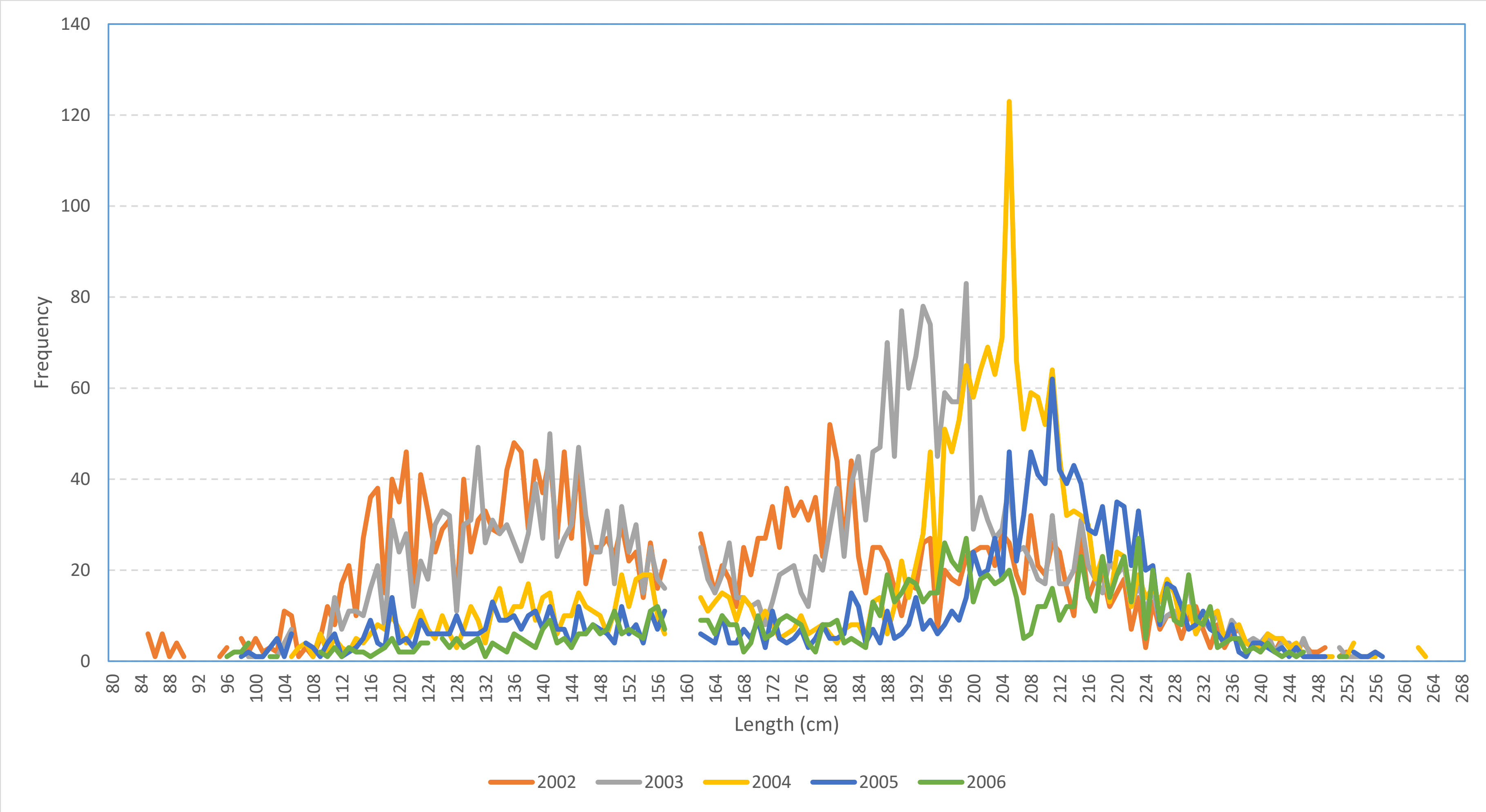

Figure 2. Length frequency of bluefin tuna as reported on the Japanese auction market (2002 - 2006). Note that for ranged fish, the length shown here corresponds to their catch length not the length at sale (source: Form 1 dataset).

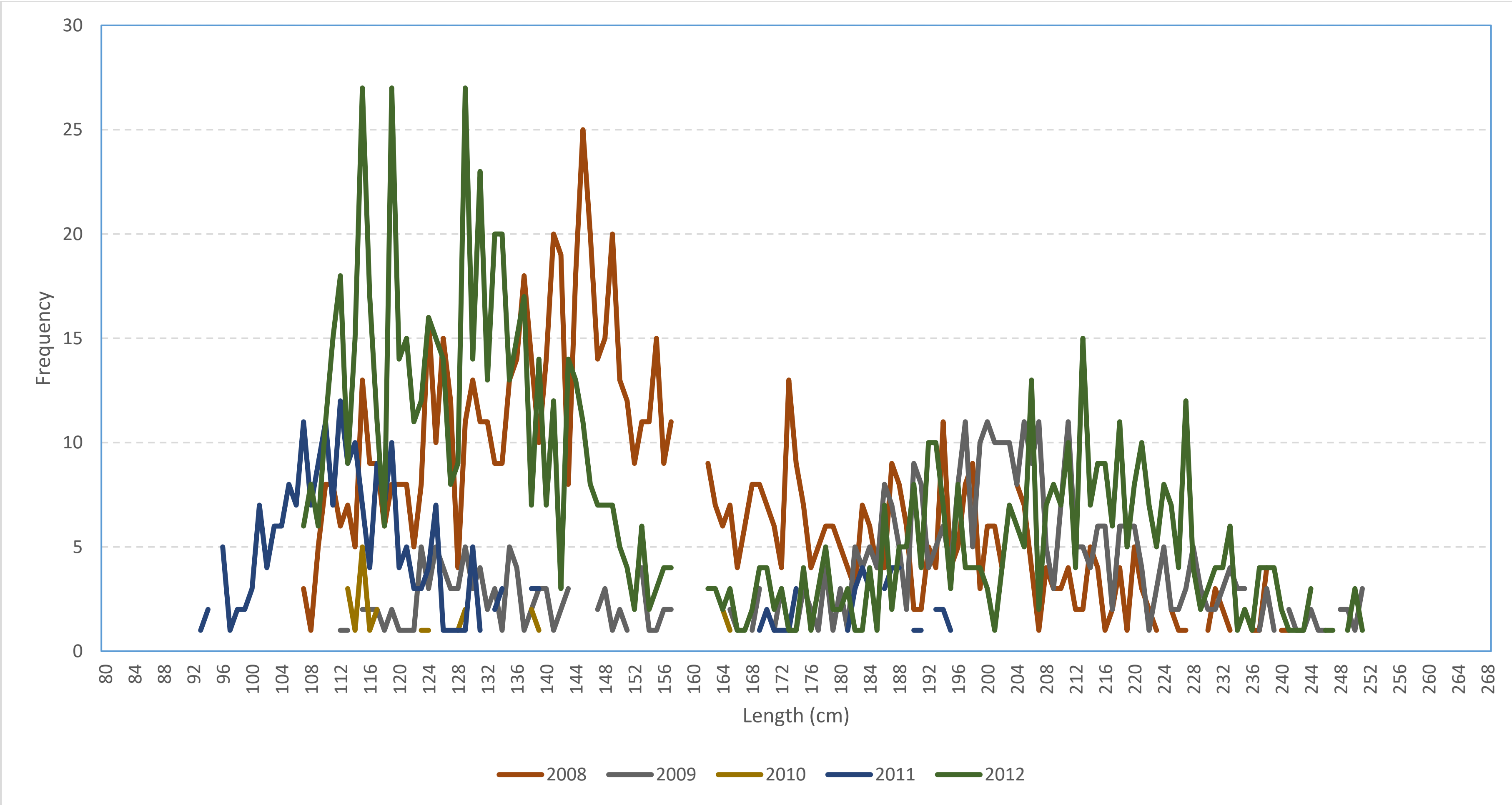

Figure 3. Length frequency of bluefin tuna as reported on the Japanese auction market (2008 - 2012). Note that for ranged fish, the length shown here corresponds to their catch length not the length at sale (source: Form 1 dataset).

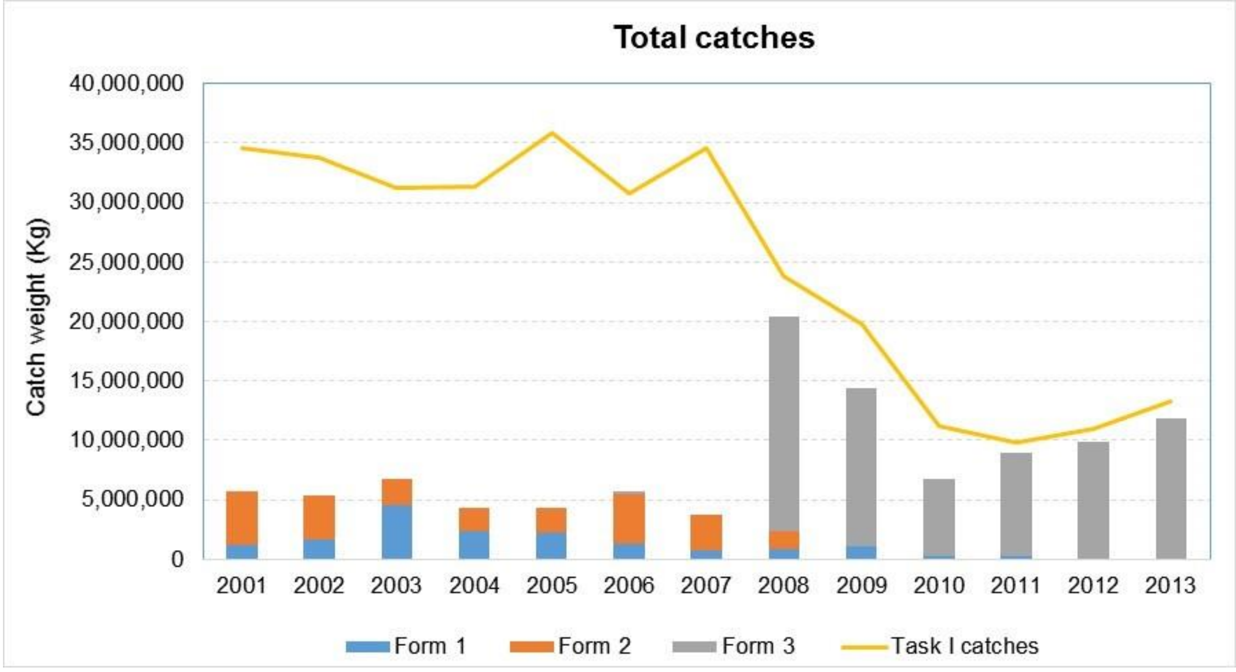

Figure 4. Total reported catch (Task I) of BFT compared to estimated values when the post-fattening records are used to calculate catches of fish that were ranged.

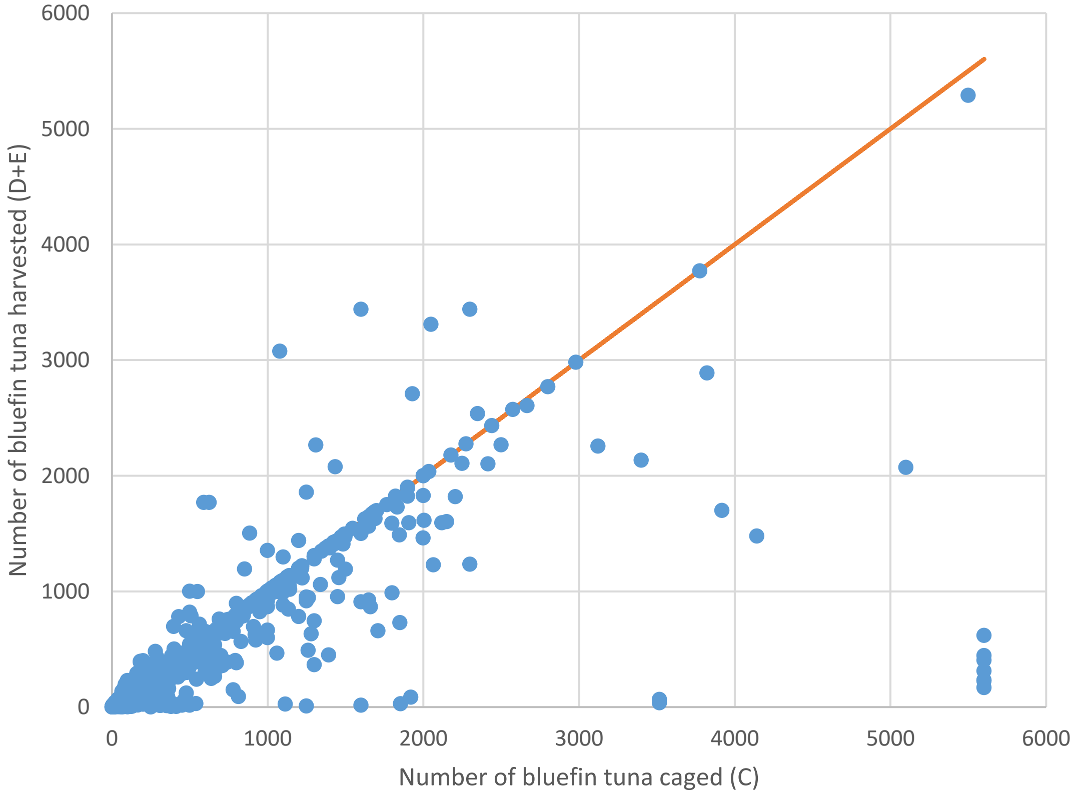

Figure 5. Comparison of BCD records of the number of bluefin tuna caged versus number of bluefin tuna harvested (source: Form 3 BCD records).

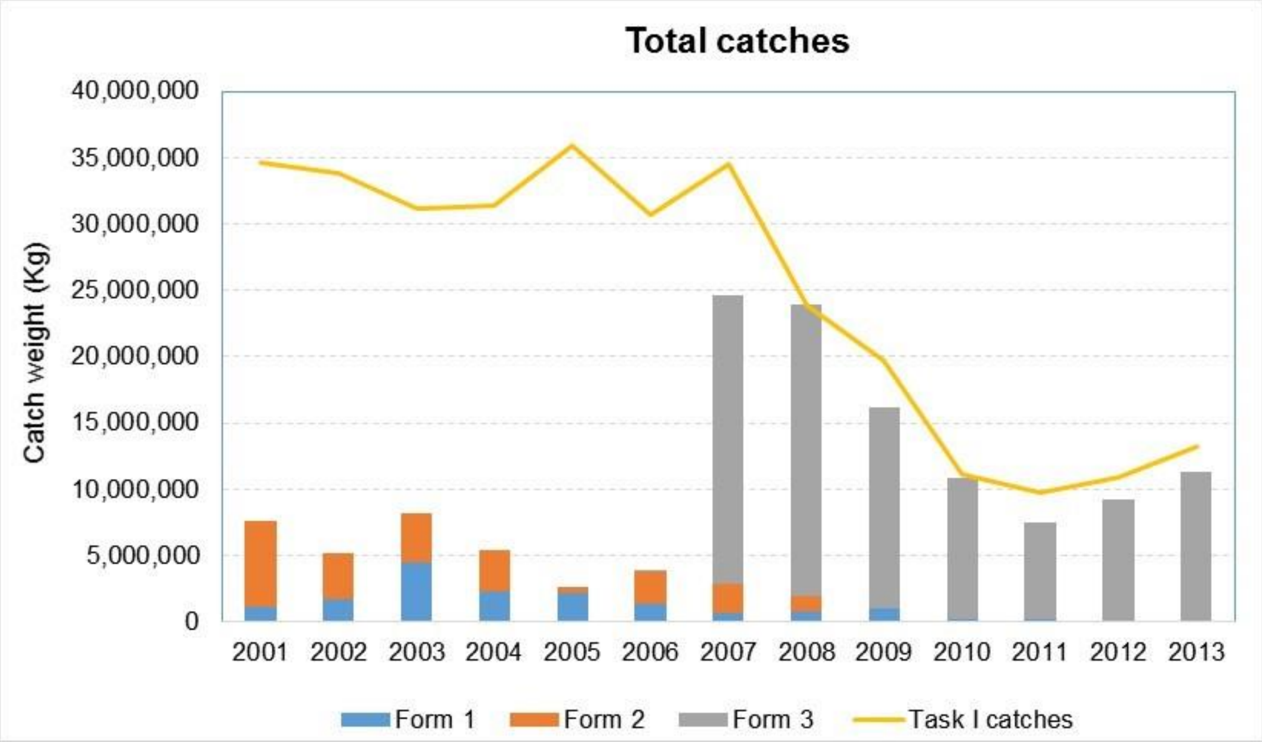

Figure 6. Total reported catch (Task I) of BFT compared to estimated values when the pre-fattening records are used to calculate catches of fish that were ranged.

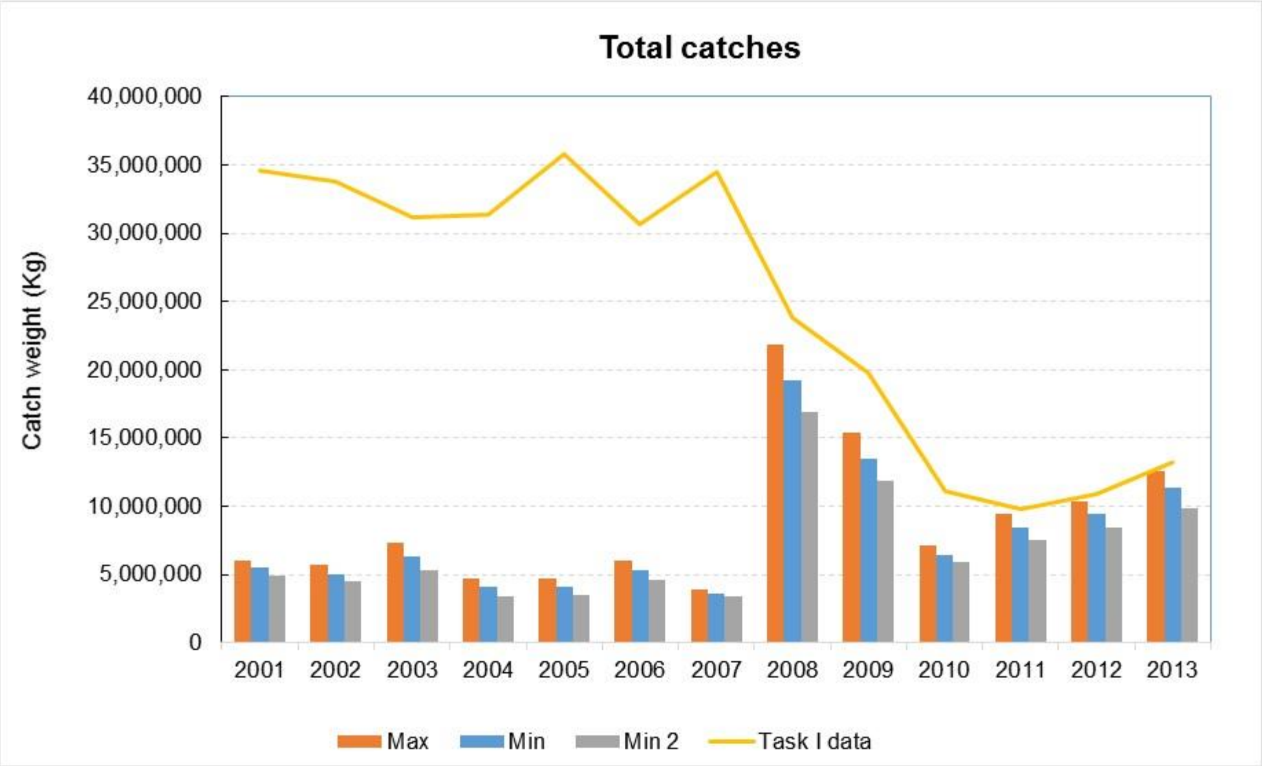

Figure 7. Minimum and maximum estimates of total catches for different assumptions about fattening ratios. Min and max denote estimates when the alternative fattening ratios shown in Table 2 (other values) are used. Min 2 assumes that all fish above 70 Kg have the same fattening ratios as fish below 70 Kg from non-Croatian farms.

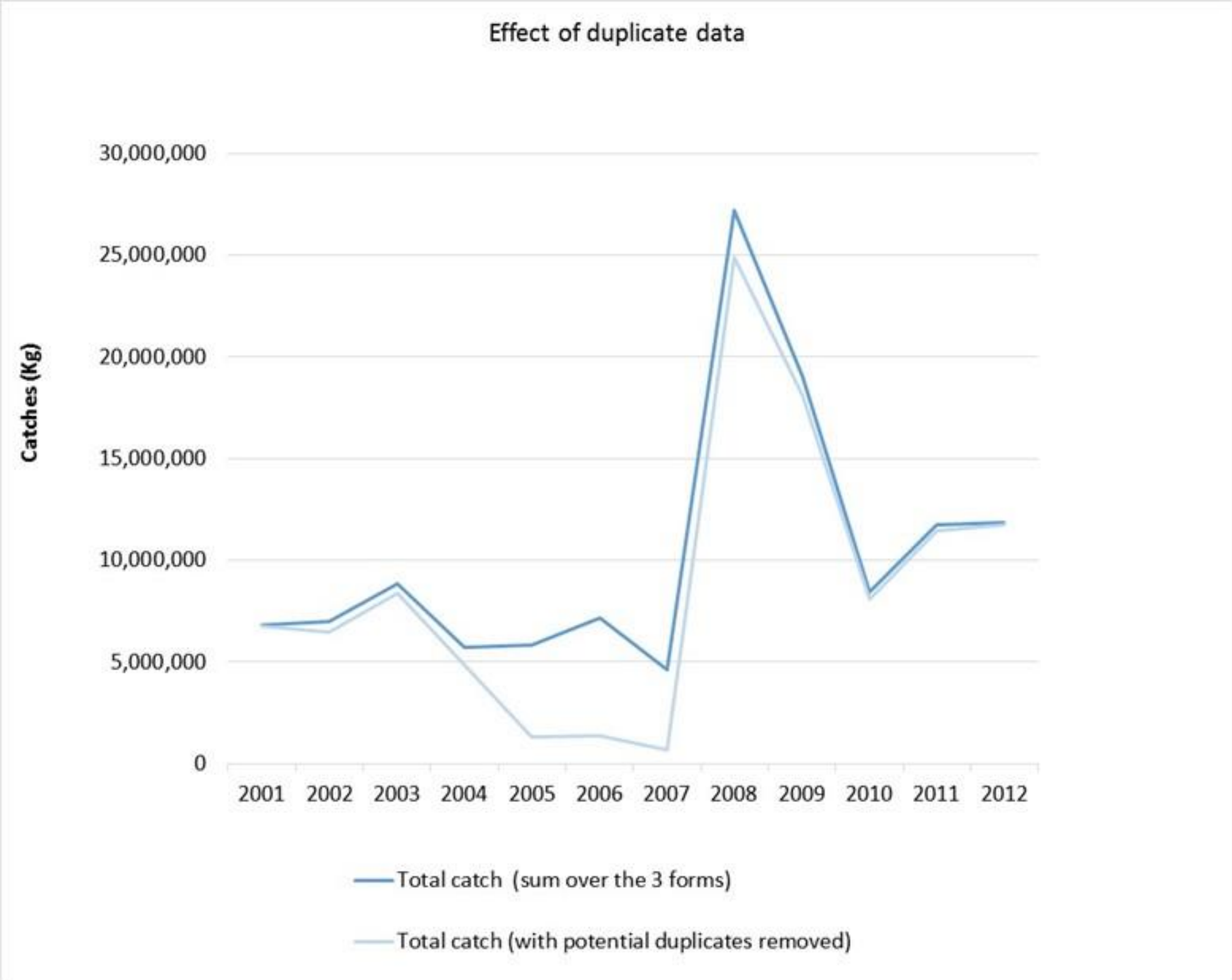

Figure 8. The effects of duplication of records across the 3 Forms on total catches (values are shown before weight conversions were applied). The sum over the 3 Forms to calculate total catches excludes catch records with status "C" to avoid duplication.