REVIEW AND PRELIMINARY ANALYSES OF SIZE FREQUENCY SAMPLES OF BLUEFIN TUNA (*THUNNUS THYNNUS*) 1952-2010

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SUMMARY

Task II size frequency data of bluefin tuna was reviewed and preliminary catch at size (CAS). The size data was also compared with historic data of size distributions recently obtained through the GBYP research program. Year, month, gear and fleet were evaluated as explanatory factors of the mean size observed variability. A GLM model was used to estimate the predicted annual mean size and to identify main explanatory factors.

RÉSUMÉ

Les données de fréquence de taille de Tâche II relatives au thon rouge ont été examinées ainsi que les données préliminaires de prise par taille (CAS). Les données de taille ont également été comparées aux données historiques sur les distributions de taille qui ont été récemment obtenues par le programme de recherche GBYP. L'année, le mois, l'engin et la flottille ont été évalués comme facteurs explicatifs de la variabilité observée dans la taille moyenne. Un modèle GLM a été utilisé pour estimer la taille moyenne annuelle prédite et pour identifier les principaux facteurs explicatifs.

RESUMEN

Se revisaron los datos de frecuencias de tallas de atún rojo de Tarea II y la captura por talla (CAS) preliminar. También se compararon los datos de talla con los datos históricos de distribuciones de tallas obtenidos en el marco del GBYP. Se evaluaron año, mes, arte y flota como factores explicativos de la variabilidad observada en la talla media. Se utilizó un modelo GLM para estimar la talla media anual predicha y para identificar los principales factores explicativos.

KEYWORDS

Mean size, bluefin tuna, size frequency, GBYP

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1. Introduction

Changes of mean size of the catch have been used as indicators of changes in the age/size distribution of fish populations, a potential proxy indicator of exploitation levels. However, it is important to account for changes in selectivity and or availability to the different fleets, and identify other possible factor(s) that can explain the observed variability in size frequency samples. Using a standardization model, available explanatory factors can be evaluated and removed, and in theory, estimate an annual mean size that reflects trends in the population age/size structure due to exploitation exclusively. Size frequency data from ICCAT database (Task IISZ) for Atlantic bluefin tuna was revised and used to estimate annual mean size (Fork length FL cm). The analyses also provided a minimum set of requirements for including a particular size frequency sample observation as input for integrated catch statistical models. Furthermore, the ICCAT size data was compared with historic records of size frequency recently recovered through the G-BYP research program.

2. Data

The ICCAT Task II-SZ database for bluefin tuna includes about 250,000 records from 1932 to 2010[2] (**Figure 1**). Of these, about 56% (143,617) are size frequency samples, 42% (103,789) are CAS records, and very few (6,077) are size samples from tuna farms (E-BFT only). There are size frequency samples from both the Eastern (53%) and the Western (43%) stock units, although the number of fish measured is much larger for the eastern-BFT (over 4.2 million fish, 90%) compared to the western-BFT (0.480 million fish, 10%) (**Figure 2**). Historically, E-BFT CAS and Size frequency samples have been equally reported since the 1970s up to 2000. Instead, in the western Atlantic, BFT size samples were predominant until 2000, when CAS became the main reports of Task II information (**Figure 1**). All size frequency samples were converted to fork length (FL cm) using the SCRS standard length conversion factors and for E-BFT samples reported in total length (TL) a conversion factor reported by (Cort, 2009) was used. Size frequency observations were rounded to 5 cm bins, as several flags reported in this bin size category. Few size samples have been reported in weight units (5% W-BFT), these were excluded from this analysis.

There are several types of gear reported (over 35) for size frequency samples, but combining them into major groups there are samples from 9 main gear types: longline, purse seine, baitboat, gillnets, rod & reel, traps, harpoon, farms, and others. **Figure 3** shows the number of fish measured by main gear type and flag for the E-BFT and W-BFT stock units. By far, the size frequency samples of the E-BFT come from the purse seine fleets (PS, 86%), particularly from (EU-France) (**Figure 3**). Although the W-BFT samples are more proportionally distributed among rod & reel, longline, harpoon and trap fisheries (**Figure 3**); it was noticed that an unusual large size frequency sample corresponds to a single year (1961) and flag-gear (USA-Trap). There are also few records with no gear information (< 3%).

By season, the size samples of the E-BFT are predominantly from April through November, with a peak sampling in June, August and September (**Figure 4**). Regarding the W-BFT, samples cover all months, with more sampling in August and September (**Figure 5**). For the W-BFT excluding 1961, consisting size samples are available since 1976. **Figure 6** shows the size frequency distributions by main gear and flag of the W-BFT 1976-2010. There are four main gears: rod & reel, purse seine, longline and harpoon size samples. USA and Canada cover all these four main gears, while Japan (and Japan foreign fleet) only includes longline size samples. Sizes range from 30 cm up to 435 cm FL, with 80% quartile between 100 cm and 254 cm FL. There are clear differences in size distributions by gear, with smaller size bluefin caught by purse seine, while larger size fish are caught by rod & reel and longline gears. However, there are differences by flag-fleet for the same gear, for example the small size fish reported from the Japan foreign fleet on longline. **Figure 7** shows the size frequency distributions by main gear and flag of the E-BFT. Flags with less than a thousand size samples were excluded. There are seven main fishing gears and eleven flags. By far, most samples come from the purse seine fishery (86%) followed by the longline (4%), baitboat (3%) and traps (2%). The E-BFT size ranges from 10 cm to 490 cm FL, but the 80% percentile extends from 60 cm to 140 cm FL. Gillnet, purse seine and baitboat fisheries caught the smallest E-BFT. Longline and trap caught the largest fish; however, the longline fleet for some flags in particular reported catches of small bluefin. There were also several examples of bimodal size distributions within the same gear-flag combination.

The Atlantic-wide research program for bluefin tuna (ICCAT-GBYP) formally started from October 2009, but the coordination activity started in March 2010; the first phase included, among other issues, data mining and

[2] Task II SZ for 2011 was not available for this analysis.

data recovery activities. The second phase of GBYP started in December 2010, including (a) continuation of data mining/recovery and data elaboration, (b) continuation of aerial surveys on spawning aggregations, (c) biological and genetic sampling and analyses, (d) conventional tagging, including awareness and rewarding campaign, and (e) first steps of the modeling approaches. This work will refer exclusively to the historical data recovered up to the end of Phase 2. As regards the Task II SZ database built during the data mining/recovery and elaboration process, it contains a total of 102,542 observations corresponding to the eastern Atlantic BFT stock for the period between 1915 and 2010. Of the total amount of records, 52.9% (54,289 records) present measured length information, while the remaining 47.1% are reported as weight measures or categories.

For this analysis, only measured length frequencies were used. The first preliminary data elaboration step reduced the quantity of single observations considered useful for the analysis to a total of 41,888. This selection of data corresponds to the period from 1953 to 2010, it includes data for two different fleets (Spain and Italy) and refers to several different gear types (trap, road & reel, purse seine, longline, gillnet and baitboat) (**Figure 8**). While frequencies from the Italian fleet dataset are distributed over a wide range of sizes, with specimens up to almost 300 cm; frequencies from the Spanish fleet are clustered between 50 and 180 cm, with a high peak on the 80 cm size class (**Figure 9**). These latter data correspond with baitboat fishing operations between 1950 and 1980, which is the gear type with the highest number of observations, followed by purse seine and gillnet (**Figure 10** and **Figure 11**).

All size frequencies were converted to fork length (cm); and quarter and year size samples were assigned to the mid-month of the time strata reported. Once the GBYP samples dataset was annexed to the ICCAT EBFT dataset, special attention was paid to the number of observations per size class, since only size frequency distributions with 25 or more fish measured were kept for the analysis.

3. Methods

After converting all size measurements to FL, sizes were grouped into 5 cm bin-size (mid-point). First, comparisons of size distribution were carried out for the major factors including gear, year, fleet and quarter. Size frequencies were estimated for the range from 50 to 500 FL cm, in 5 cm bin size, and general statistics of central tendency (mean, median) were estimated including statistics of dispersion and shape distribution (CV, kurtosis and skewness). These analyses were used to identify potential outliers and sample size series that departure substantially from main trends. Analyses of variance associated with number of size-frequency strata were conducted to infer minimum number of samples per size-frequency observation.

Evaluation of influence of available factors on the annual trend of mean size for bluefin tuna were done by fitting the observed mean size with a Generalized Linear Model. The factors considered as explanatory variables included: year, month, gear and flag-fleet. The GLM assumed a normal distribution on the dependent variable (mean size), and used the number of fish measured per observation as weighting factor in the models. Due to the unbalanced distribution of the data, some preliminary filtering was necessary. For the W-BFT, mean size was evaluated from 1976 forward, as sampling in prior years was scarce. Flag-fleets with less than one thousand size samples overall (Cuba, Mexico, Chinese-Taipei, Portugal, UK-Bermuda, and Morocco) were also excluded. For the E-BFT, mean size was evaluated from 1952 forward. Flag-fleets with less than one thousand size samples and frequencies reported as weight units were also excluded. Given the characteristics of gear configurations within each flag-fleet, in the case of the E-BFT the flag-fleet factor was considered as nested factor within the main gear factor. The mean standardized annual size was estimated as the LSMeans of the year factor.

With the integrated data from the G-BYP, the GLM models were fitted for the eastern bluefin tuna stock. There were two main objectives with these analyses; one was to evaluate consistency of information provided by the two datasets. The second one was to extend the results back in time. Because the G-BYP data includes primarily data from the baitboat and gillnet fisheries, further GLM models were run for each gear type, to evaluate their historic trends.

4. Results and discussion

E-BFT sizes ranged from 30 to 435 cm FL (**Figure 12**), but 99% of samples are between 60 and 290 cm FL. Comparing size distributions by major gear (**Figure 13**) shows two main modes: smaller fish [30-145 cm FL] caught by baitboat, gillnets, purse seines and rod & reel gears mainly; and large fish (150 – 300 cm FL) caught by trap, longline and other (trawl, troll) gears. W-BFT sizes ranged from 10 to 490 cm FL, with 95% of samples

between 79 and 274 cm FL (**Figure 14**). Comparison of size distributions by main gear shows also a bimodal distribution, with smaller fish [70-150] being caught primarily by longline gear but also by rod & reel and longline, while larger fish [150 and above] were caught by harpoon, purse seine and rod & reel (**Figure 15**). However, it is important to note that within a main gear type, there were significantly different size frequency distributions observed by flag-fleet (see **Figure 6** and **Figure 7**) for both the western and eastern stock units.

Plots of variance versus sample size (fish measured per size frequency observation) did not show any particular trend (**Figure 16**). The evaluation of factors as explanatory variables for changes in mean size of sampled BFT are summarized in **Table 1** and **Table 2**, for the west and east stock units respectively. In the case of the W-BFT, all three available factors: gear, month, and fleet-flag were statistically significant and did explain about 50% of the observed variability. This basically indicated that there are main differences in the mean size (and therefore in the frequency size distributions) of bluefin tuna due to gear type, month, and flag-fleet. Thus, size samples should be at least stratifying according to these factors. The estimate LSMeans for each factor reflect the 'overall' mean value given the balance composition of the other factors. For the W-BFT, by gear, larger size fish are caught by the harpoon fishery, while mean size did not vary substantially between longline, purse seine and rod & reel (all years grouped). By month, there are differences in the mean size with larger fish being caught in the April and May months, then in August, September and October. Interesting is the small fish being caught in June and July. By flag-fleet, smaller fish were reported from the Japan foreign observations. The estimated annual trend of mean size shows larger variation in the early years 1976-1992 and after 2000. Overall, there is an increasing trend in the latest 4 years. However, it is important to note that this annual mean size trends are preliminary, and likely interactions among factors are important, as indicated by the gear histograms of size distributions (**Annex 1**), that do show greater variability among years within each main gear type.

For the E-BFT, also the GLM standardization indicated that season, gear and flag-fleet were significant explanatory factors of the observed mean size variability. In this particular analysis, due to the large number of flag-fleets and gears, the flag-fleet factor was included as nested within major gear, to deal with the unbalance distribution of size samples. Overall there were less marked changes in mean size by season; but much greater changes in mean size by main gear, with baitboat and gillnets catching the smallest size bluefin, while longline and trap caught the largest specimens. However, there is also variability within a given gear in association with the flag-fleet. For example, longliners show great variance in mean size with the Japan, Libya, Chinese Taipei fleets catching larger size fish, while the Italy and Spain fleets caught fish of size similar to the baitboat fleets. Greater variation was also observed for the purse seine and rod & reel fleets. The histograms of the annual size distribution by main gears also reflect a large size frequency variation among years (**Annex 1**). Overall the estimated mean size for E-BFT has varied since 1952 between 100 to 180 cm FL with some drastic changes particularly in the 1980s and 1990s. It is, however, unclear if these changes are correlated with different proportion of sampling between gears and main flag-fleets.

This preliminary analysis of size frequency samples of bluefin indicate that there is a substantial number of samples, although not evenly distributed by main gear, particularly for the E-BFT stock unit. There are however, some samples that need to be reviewed and checked by the CPCs to confirm them. Briefly, size samples from the U.S. for 1961 and the size samples series of EU-France PS 1980-1990s. Balanced numbers of samples are available since 1976 for the western, and since 1982 for the eastern stock, respectively. The G-BYP samples have recovered size frequencies for earlier years of the eastern stock (1952 and after), some of them were recorded in weight categories rather than size. The size frequencies show greater variability even between specific gear types, likely associated with flag-fleet operations and or area of fishing. The samples also reflect seasonality size trends particularly for the western unit, which are likely associated to the size/age schooling and migratory patterns described for bluefin. The standardization models indicated that size samples should at least be including strata samples for main gear, season (month) and flag-fleet. Not clear size samples can be determined from the variance-number of samples trends; however, size samples over 100 fish per strata may be required.

When the G-BYP data was integrated with the ICCAT Task II-SZ, the GLM fitted models showed the same results and the overall fitting was improved (r squared increased to 0.555) (**Table 3**). A summary of the frequency size distributions by main gear and flag-fleet is show in **Figure 17**. Some of the histograms would require review and confirmation with scientists familiar with these fisheries; for example, EU-Portugal trap purse seine and baitboat and Libya purse seine and longline. The analyses of single gear type are summarized in **Table 4** and **Table 5** for baitboat and gillnet, respectively. In the case of the baitboat, there were minimum differences due to the source of the data (ICCAT Task II SZ or G-BYP). The overall trend of mean size shows a decline since the late 1950s, to the lowest size in the middle of 1990s, followed then by an increase with a notorious peak in 1997. It is important to note that mean size for the baitboat fishery may be influenced after the mid 1990s

by changes in the fleet operations in response to management measures and local fishery policies (Bay of Biscay). For the gillnet fishery, the mean size GLM fit shows also that different data sources do not make a difference, while season and year were significant explanatory factors. With gillnet fisheries, smallest bluefin tuna were caught during the season 4 (Oct-Dec). Overall the mean size of the eastern bluefin tuna gillnet fishery oscillate between 50 and 95 cm FL, without any particular trend. Including the G-BYP size data of gillnet in particular did reduce the mean size of caught bluefin tuna.

Literature cited

Cort, J. L., 2009. Growth and the equation applied to the eastern bluefin tuna (*Thunnus thynnus*) stock of the North Atlantic, 20 years on ICCAT. SCRS/2009/124, 29p

Table 1. Summary report of the GLM fit to the mean size W-BFT ICCAT SZ DB.

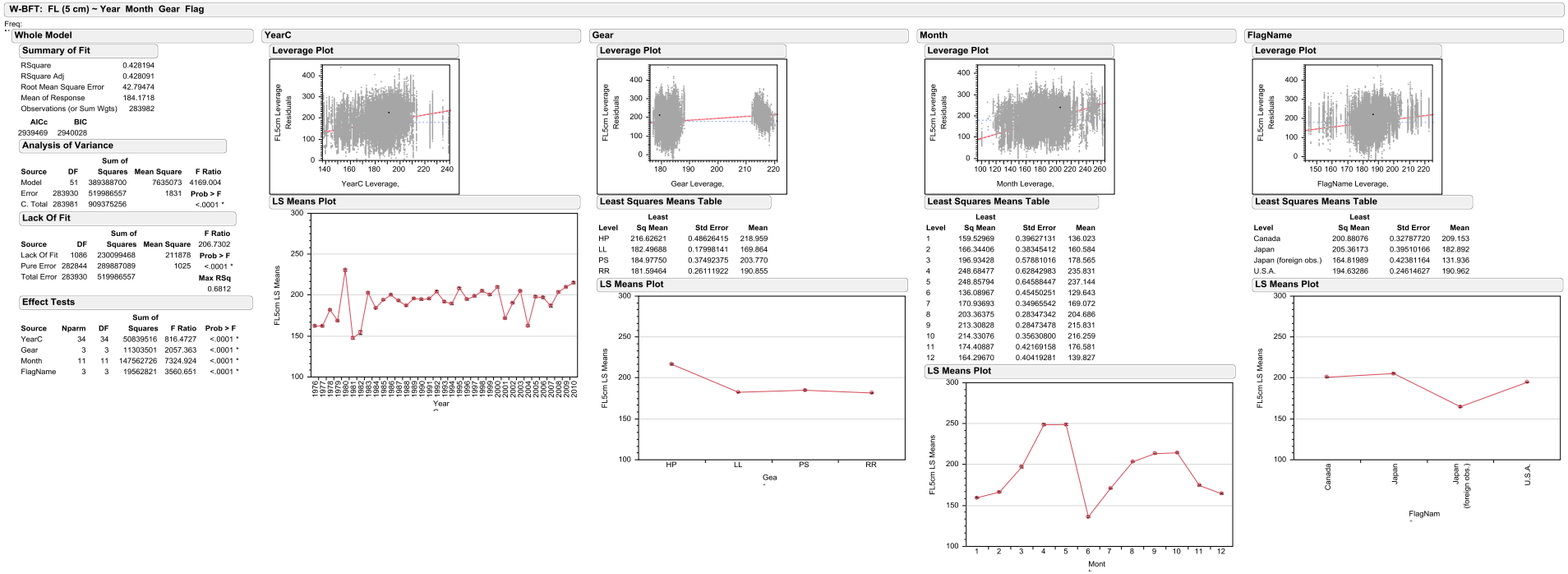


Table 2. Summary report of the GLM fit to the mean size E-BFT ICCAT SZ DB.

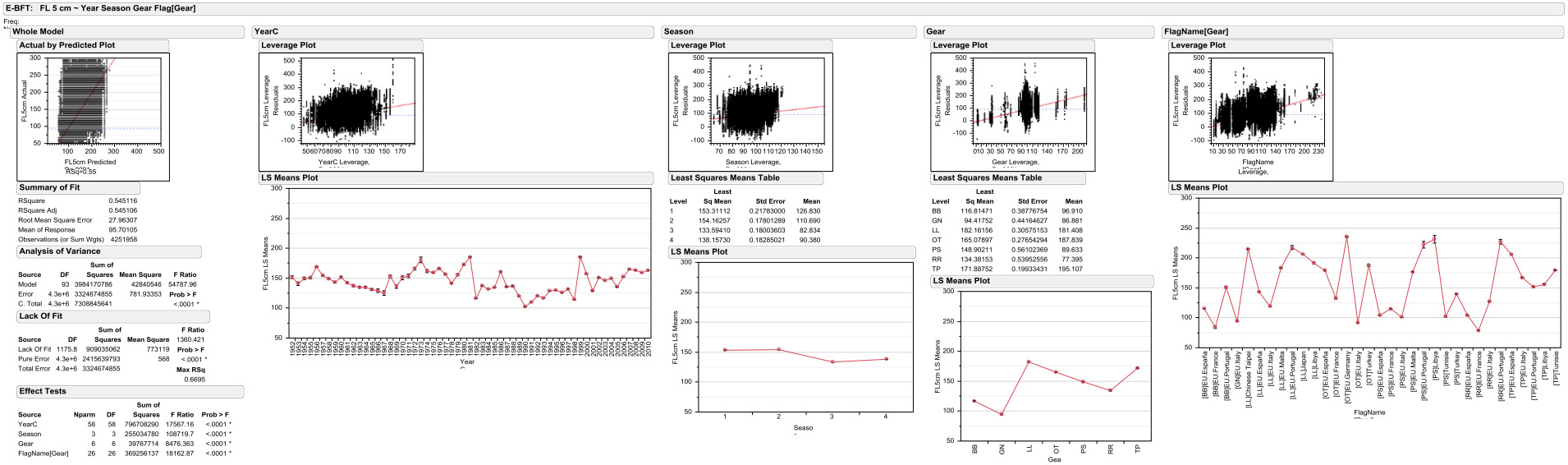


Table 3. Summary fit of GLM for eastern Bluefin including ICCAT Task IISZ and the G-BYP size data.

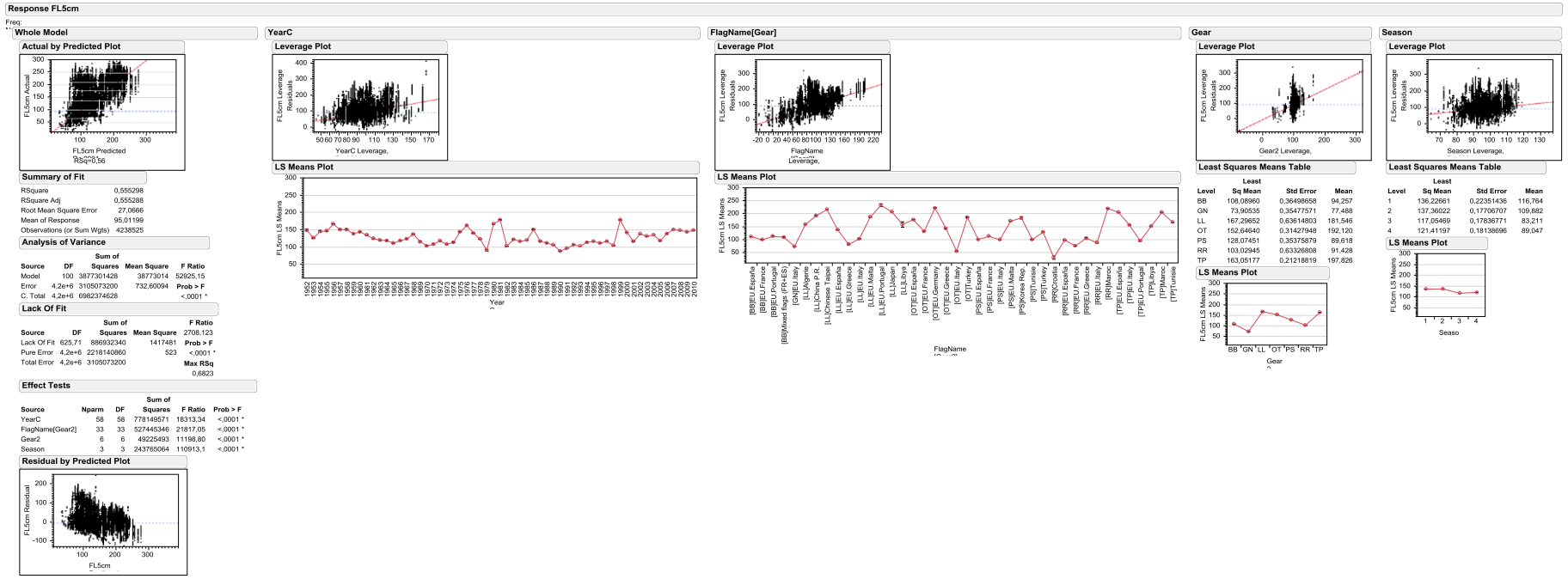


Table 4. Summary fit of GLM for eastern Bluefin including ICCAT Task IISZ and the G-BYP size data only for the baitboat gear 1953-2010.

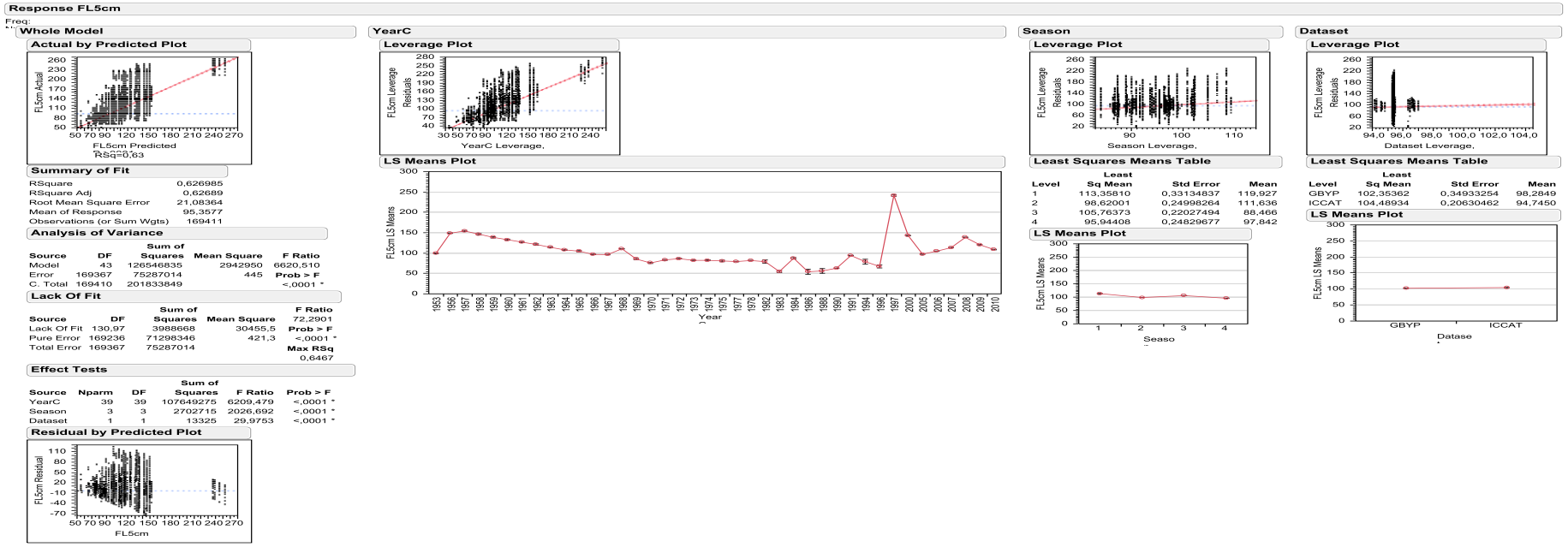


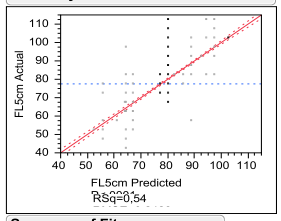
Table 5. Summary fit of GLM for eastern Bluefin including ICCAT Task IISZ and the G-BYP size data only for the gillnet gear 1990-2008.

Response FL5cm

Freq:

Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0,537913
RSquare Adj	0,53708
Root Mean Square Error	9,242839
Mean of Response	77,488
Observations (or Sum Wgts)	6666

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	12	661632,8	55136,1	645,3942
Error	6653	568366,2	85,4	Prob > F
C. Total	6665	1229999,0		<,0001 *

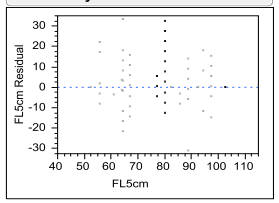
Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	2	4335,98	2167,99	25,5648
Pure Error	6651	564030,23	84,80	Prob > F
Total Error	6653	568366,21		<,0001 *
				Max RSq
				0,5414

Effect Tests

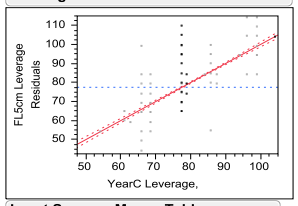
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
YearC	9	9	434750,84	565,4409	<,0001 *
Season	2	2	201343,71	1178,412	<,0001 *
Dataset	1	1	905,36	10,5976	0,0011 *

Residual by Predicted Plot



YearC

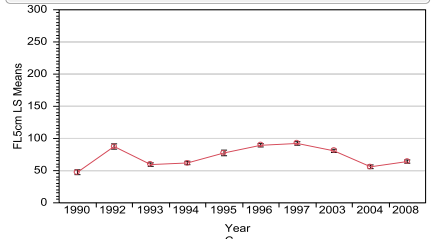
Leverage Plot



Least Squares Means Table

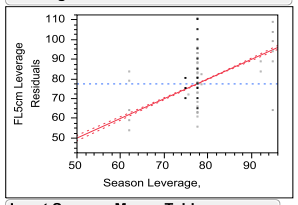
Level	Least Sq Mean	Std Error	Mean
1990	47,510373	1,9194650	52,5000
1992	87,510373	2,0898062	92,5000
1993	59,416504	1,3642798	64,4061
1994	61,933450	1,3645105	66,9231
1995	77,510373	2,2323468	82,5000
1996	89,385373	1,3029199	95,5357
1997	92,244551	1,3834301	97,2342
2003	80,755366	1,3026632	71,2022
2004	55,989920	1,4719737	62,8922
2008	64,128648	1,2862096	79,9172

LS Means Plot



Season

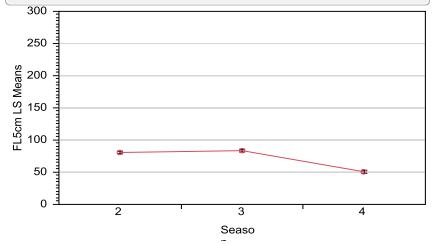
Leverage Plot



Least Squares Means Table

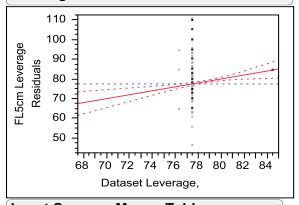
Level	Least Sq Mean	Std Error	Mean
2	80,690620	1,0206562	75,8602
3	83,559535	1,0809964	80,3172
4	50,665325	1,2300361	55,7197

LS Means Plot



Dataset

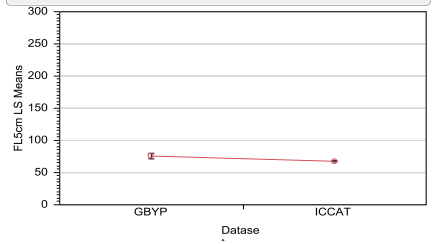
Leverage Plot



Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
GBYP	75,700993	2,2482127	80,0049
ICCAT	67,575993	0,4990184	73,4152

LS Means Plot



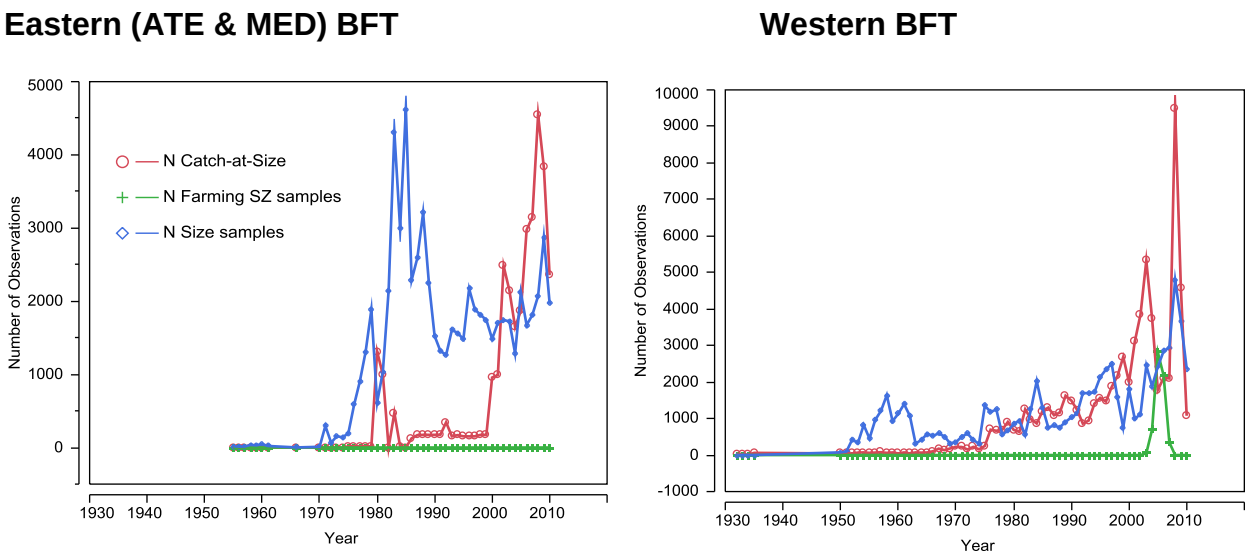


Figure 1. Number of Task II-SZ observations available at the ICCAT DB for the eastern (top) and western (bottom)
bluefin tuna stock units.

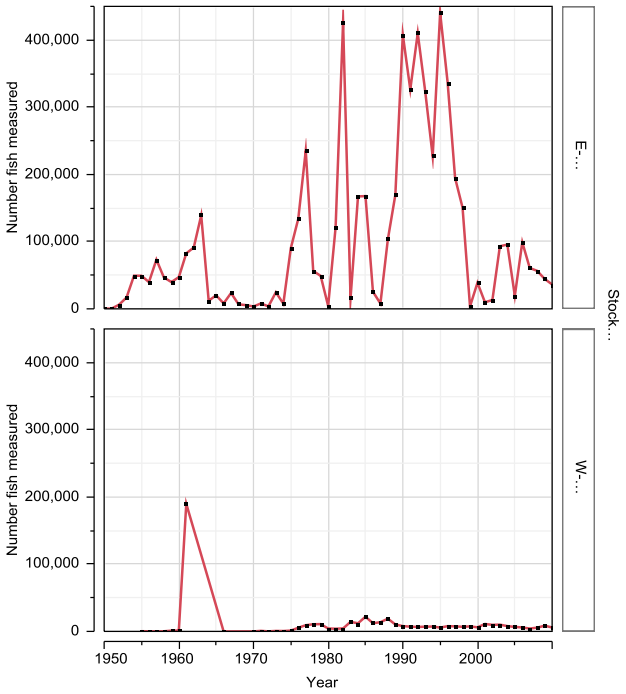


Figure 2. Number of fish measured as indicated from the Task II SZ ICCAT DB for the eastern (top) and western (bottom) bluefin tuna stock units.

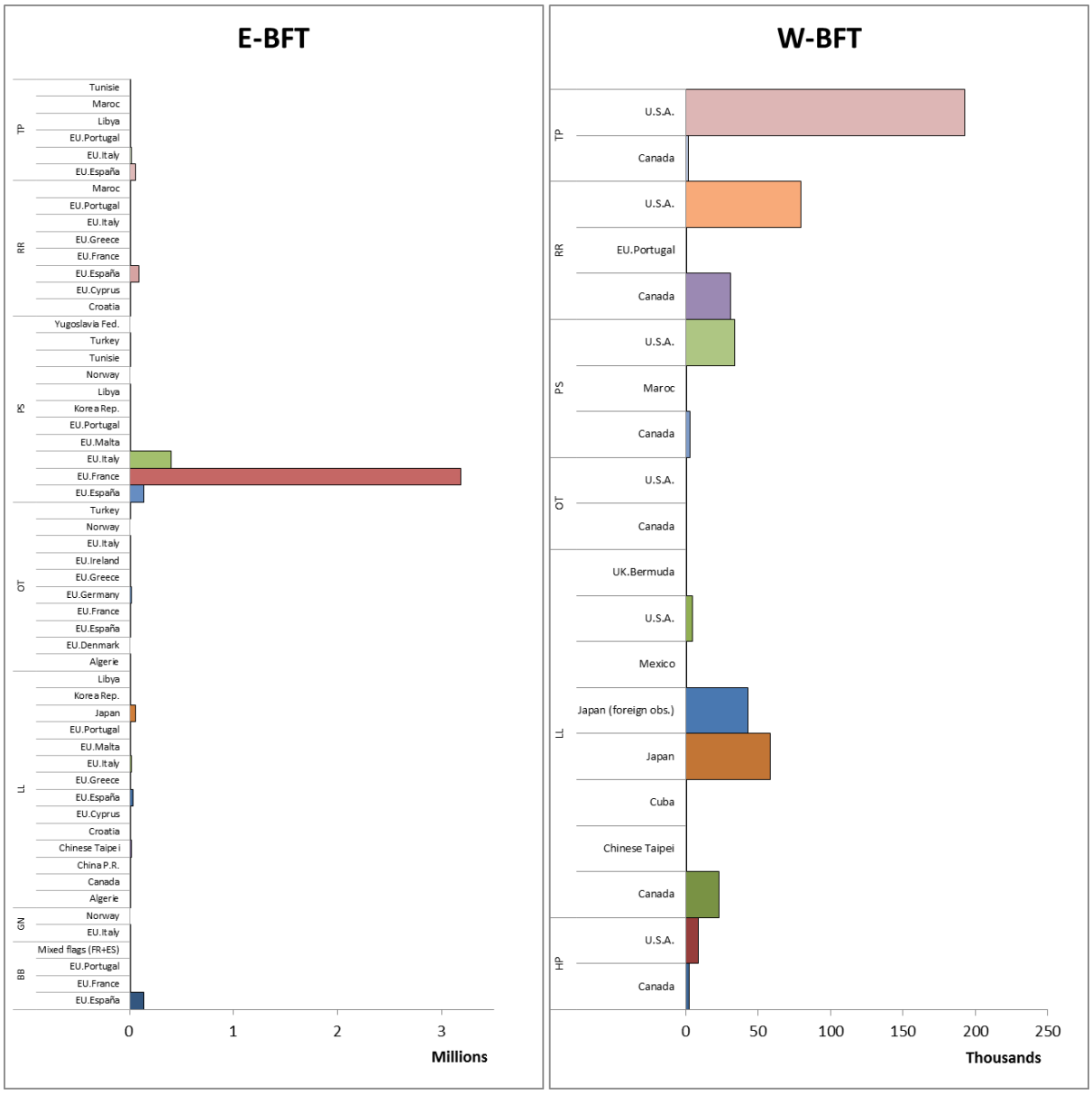


Figure 3. Number of fish measured Task II-SZ ICCAT DB by stock, main gear type and flag-fleet.

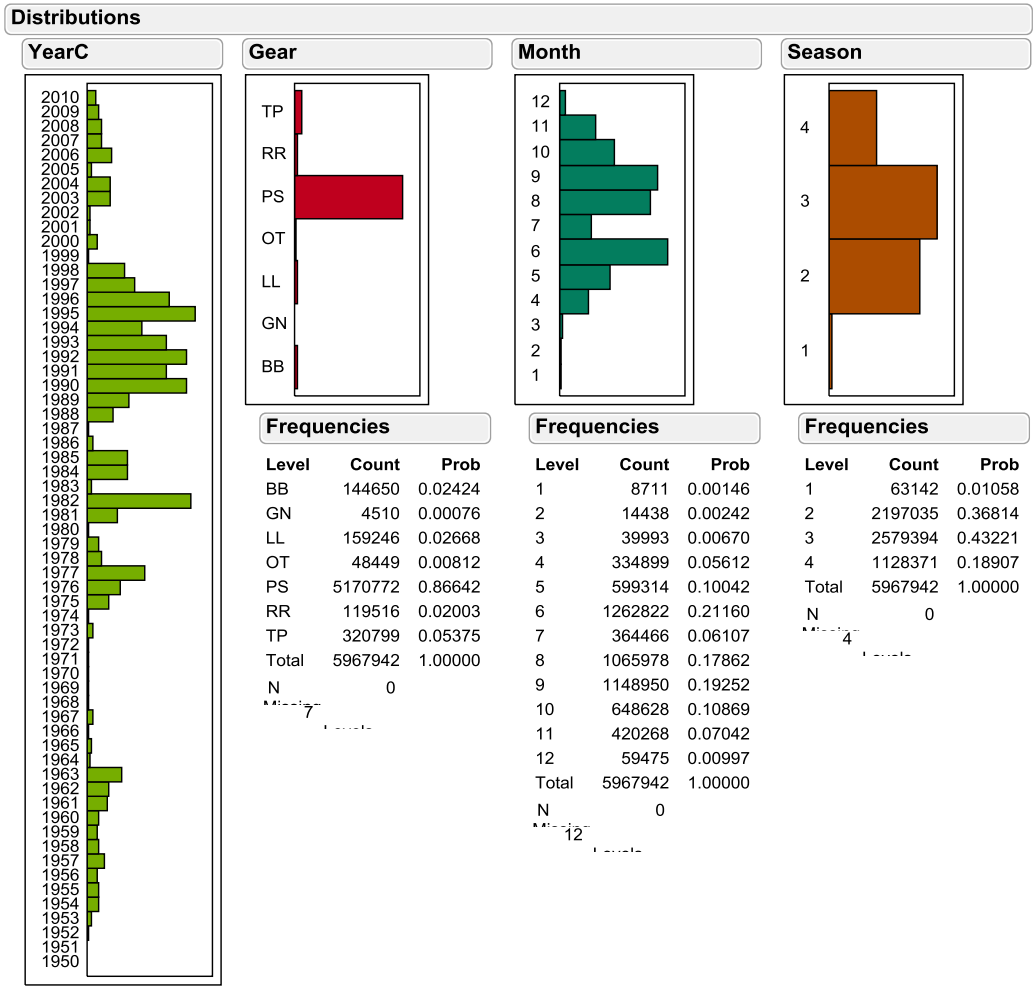


Figure 4. Eastern bluefin tuna distribution of Task II-SZ sample observations by year, main gear type, month and season.

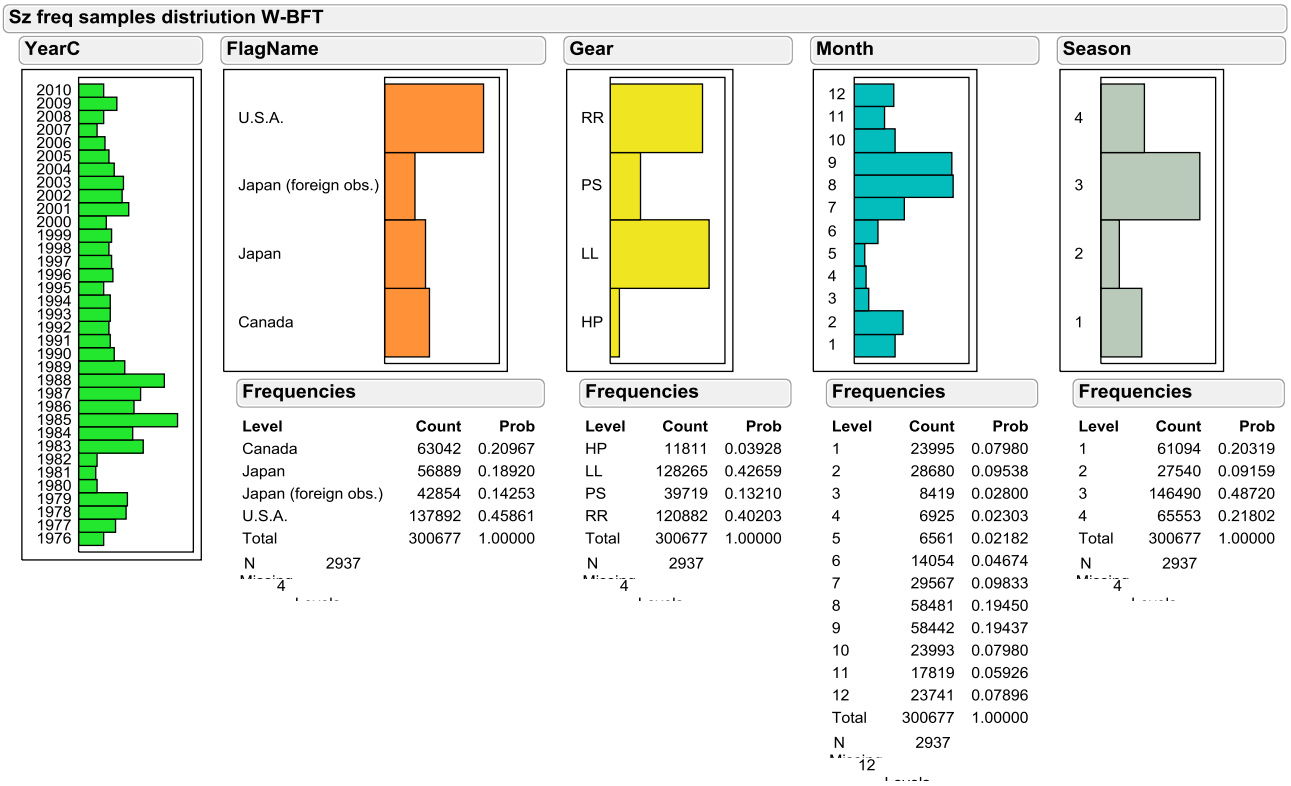


Figure 5. Western bluefin tuna distribution of Task II-SZ sample observations by year, flag-fleet, main gear type, month and season.

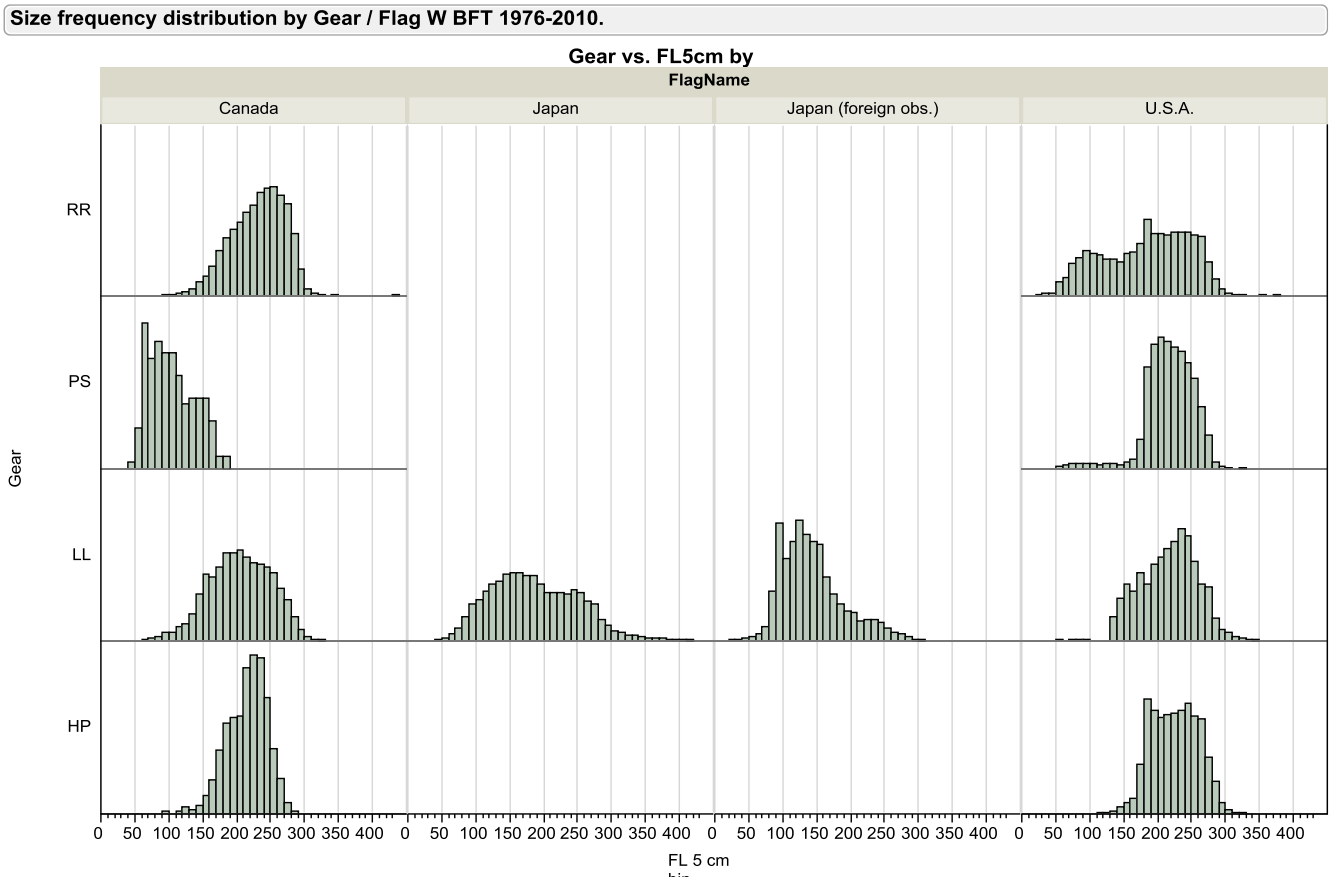


Figure 6. Size frequency distributions by gear / flag-fleet W-BFT 1976-2010 ICCAT DB.

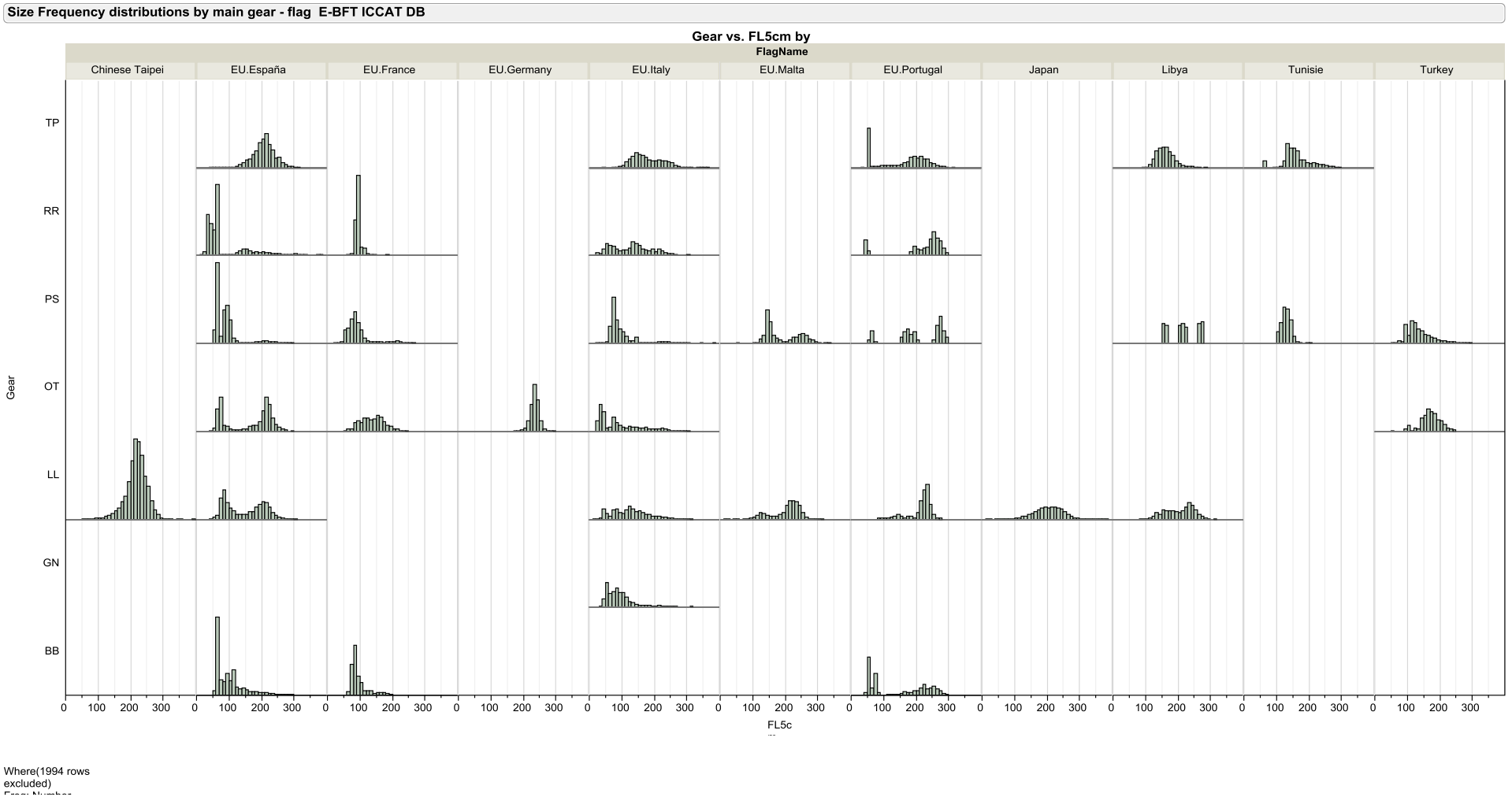


Figure 7. Size frequency distributions by gear / flag-fleet E-BFT 1976-2010 ICCAT DB.

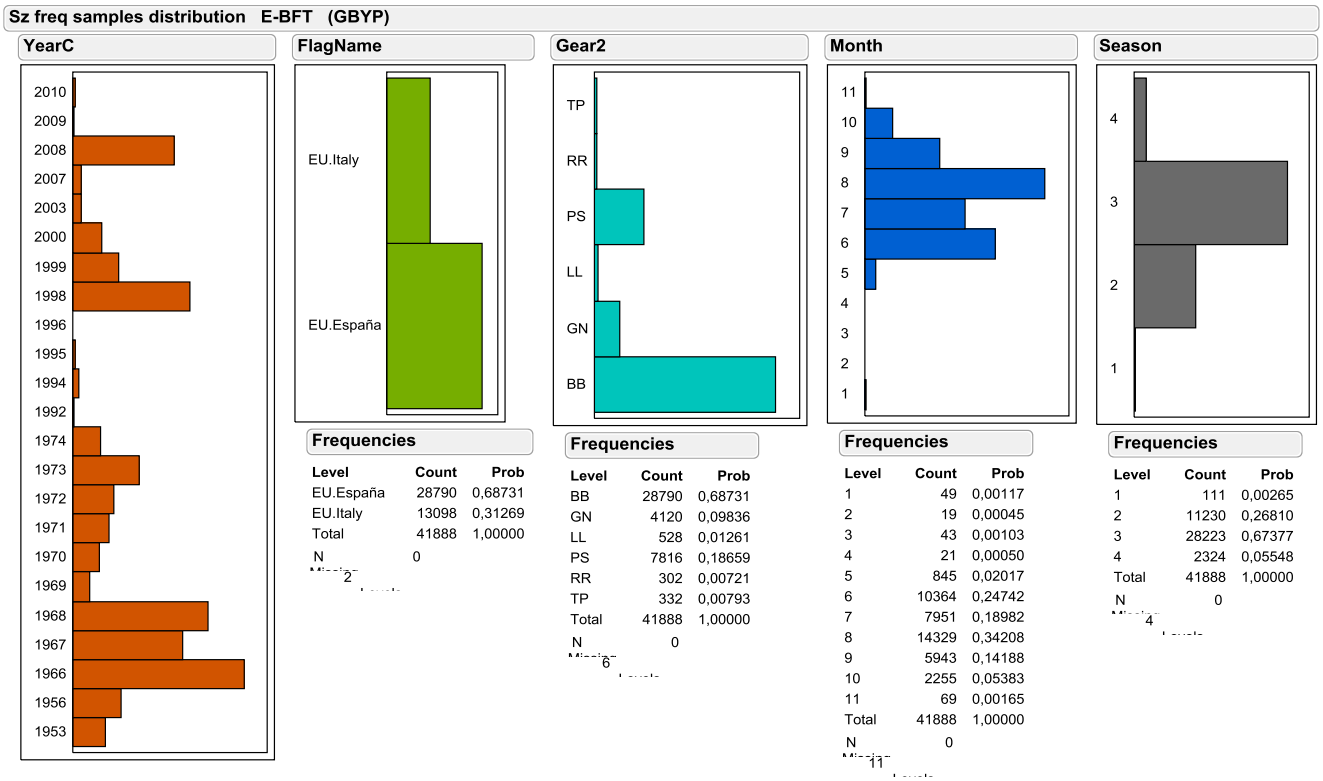


Figure 8. Eastern bluefin tuna distribution of Task II-SZ sample observations by year, flag-fleet, main gear type, month and season GBYP DB.

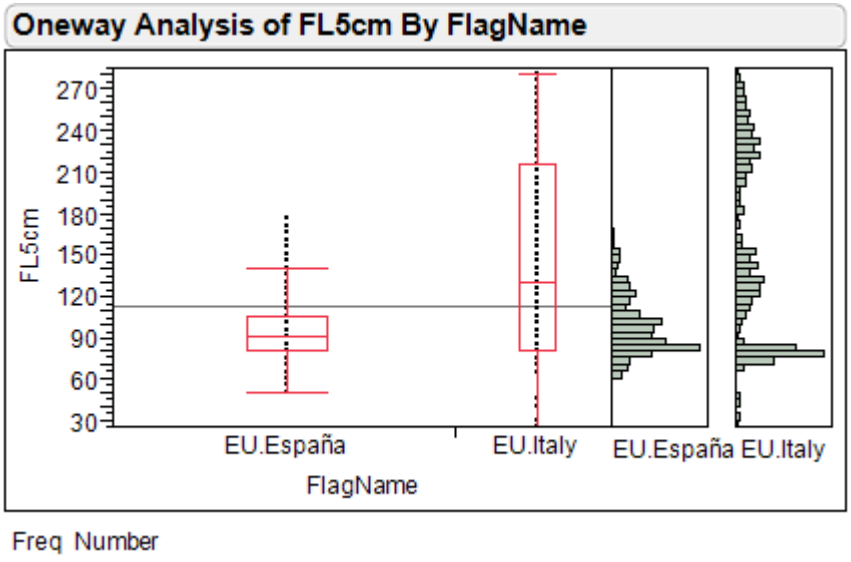


Figure 9. E-BFT Size distribution by flag-fleet GBYP DB.

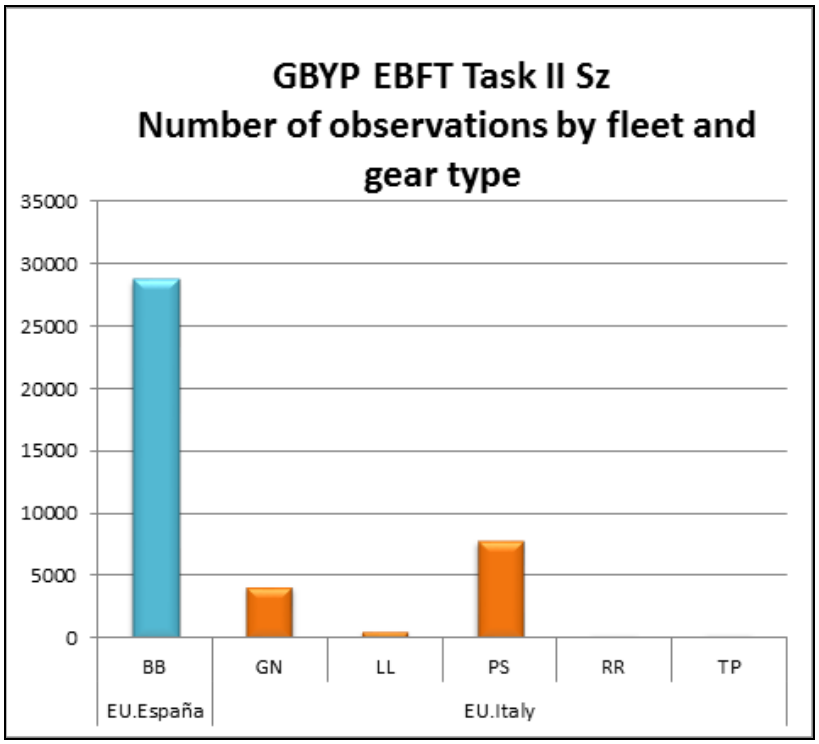


Figure 10. GBYP E-BFT Task II-SZ Number of observations by flag-fleet and gear type.

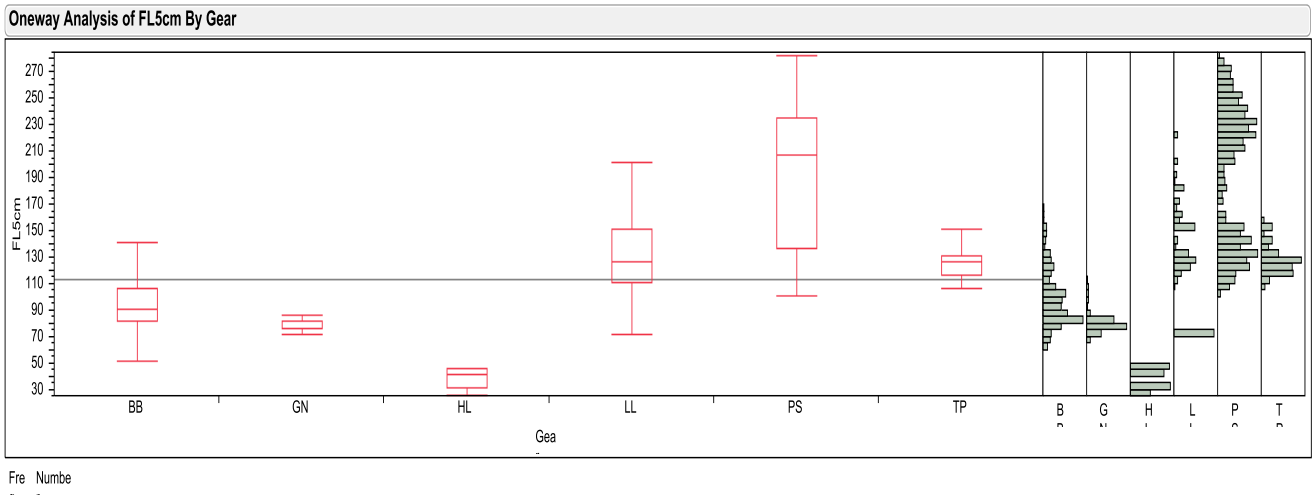


Figure 11. GBYP E-BFT Size distribution by gear type.

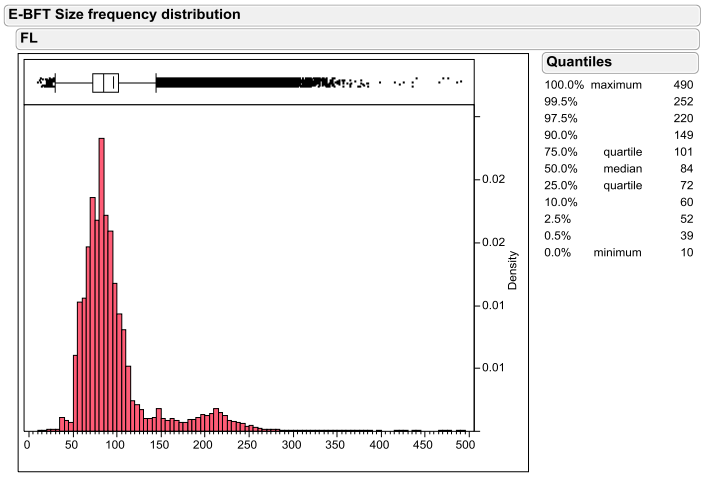


Figure 12. E-BFT Size frequency distribution ICCAT DB.

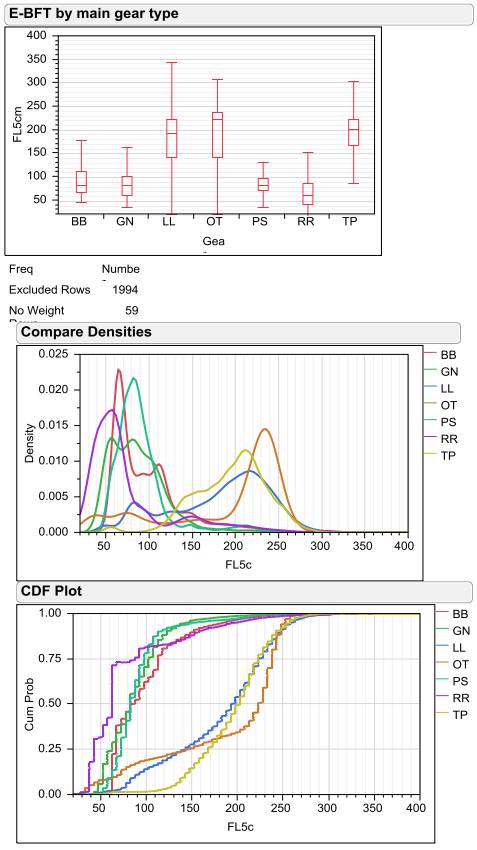


Figure 13. E-BFT Size frequency distribution by gear type ICCAT DB.

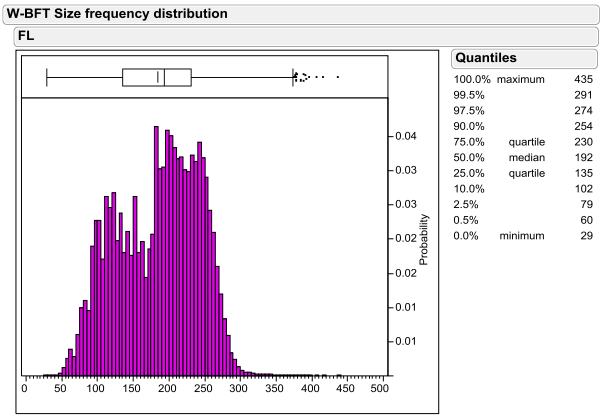


Figure 14. W-BFT Size frequency distribution ICCAT DB.

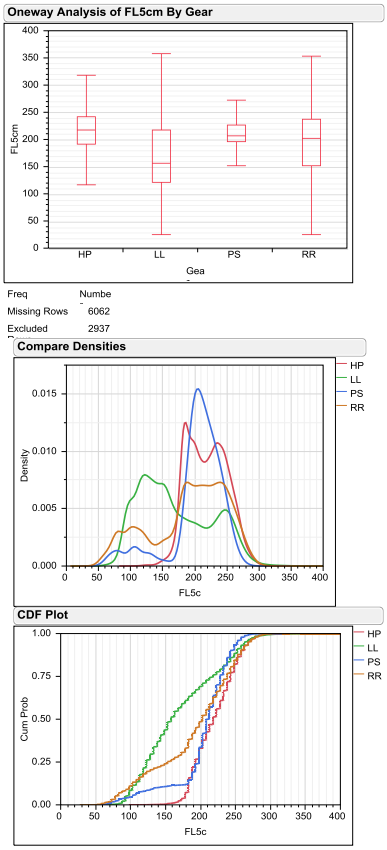


Figure 15. W-BFT Size frequency distribution by gear type ICCAT DB.

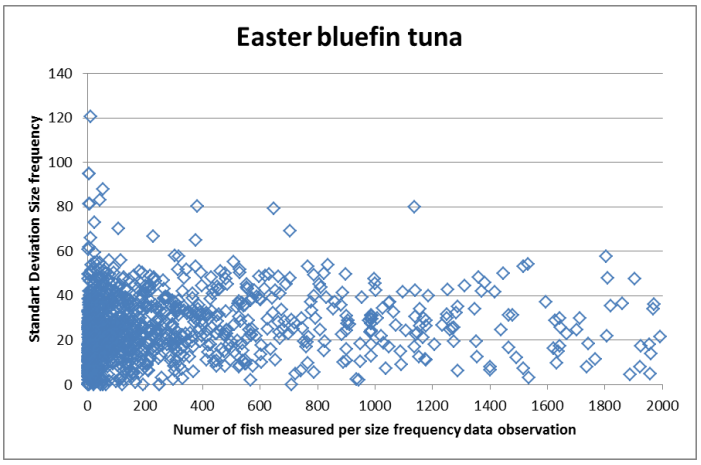


Figure 16. Scatter plot of the number of fish per size frequency observation and its standard deviation, for the E-BFT stock ICCAT Task II -SZ.

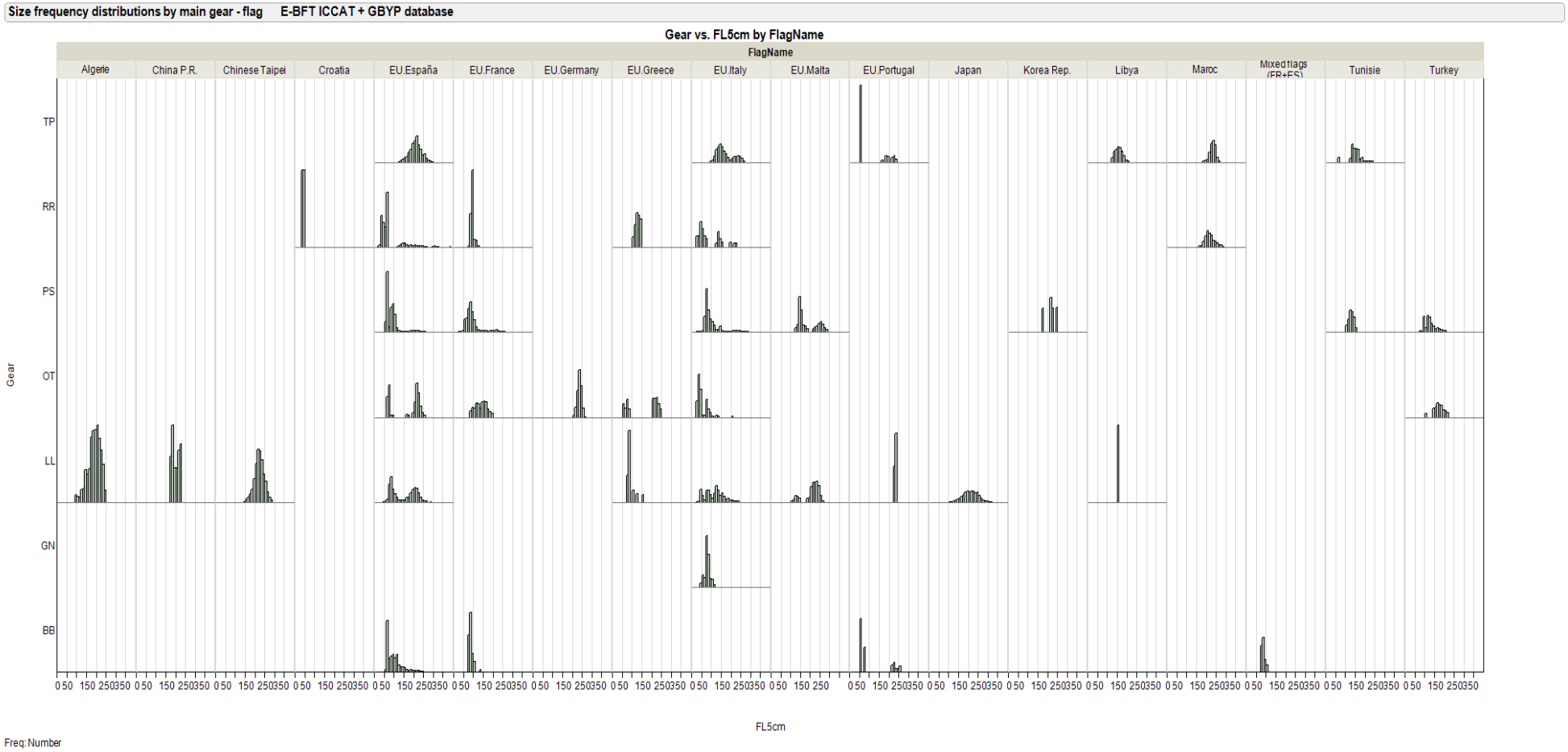
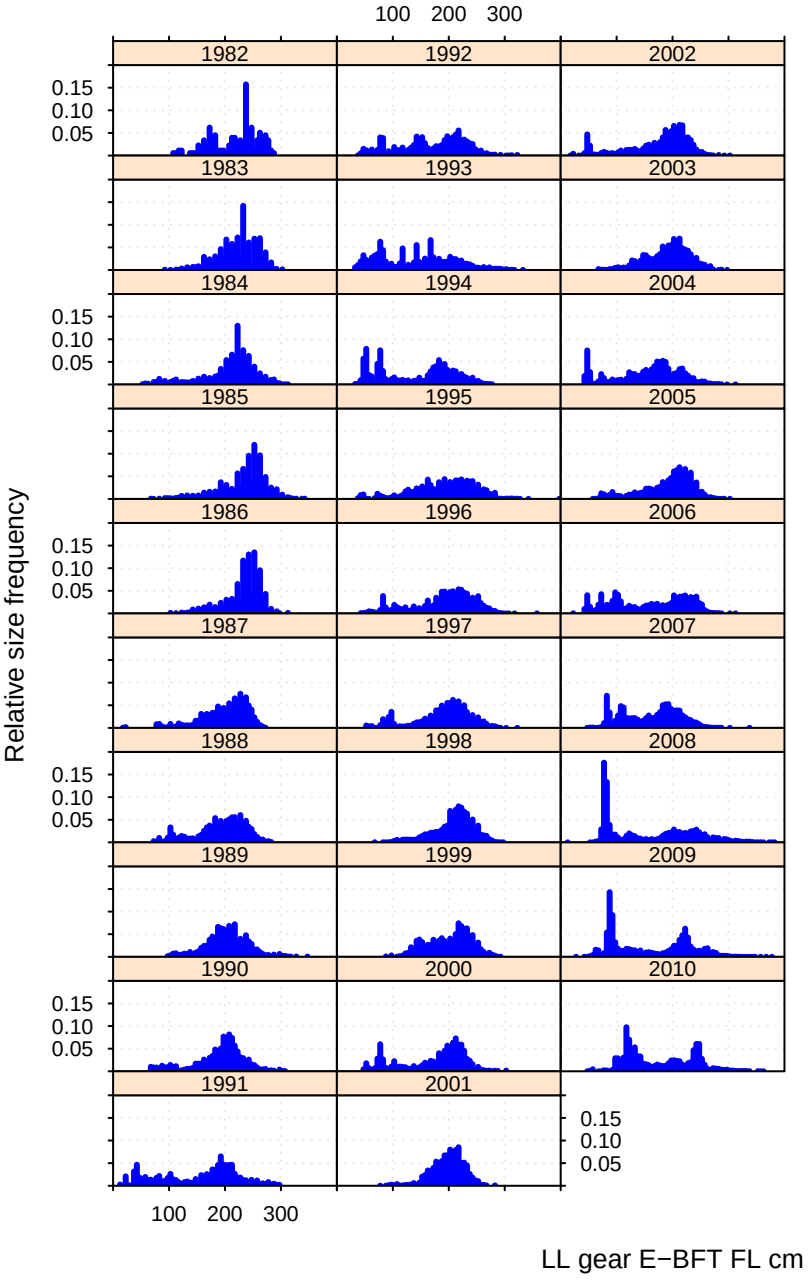


Figure 17. Size frequency distributions for eastern bluefin tuna by main gear type and flag-fleet of the ICCAT Task II-SZ and the G-BYP size data.

Annex 1. Relative size frequency distribution of West and East Bluefin tuna by main gear type and year. Data from the Task II SZ ICCAT DB.

(see attached pdf files : SzFrq_EBFTplots.pdf , SzFrq_WBFTplots.pdf)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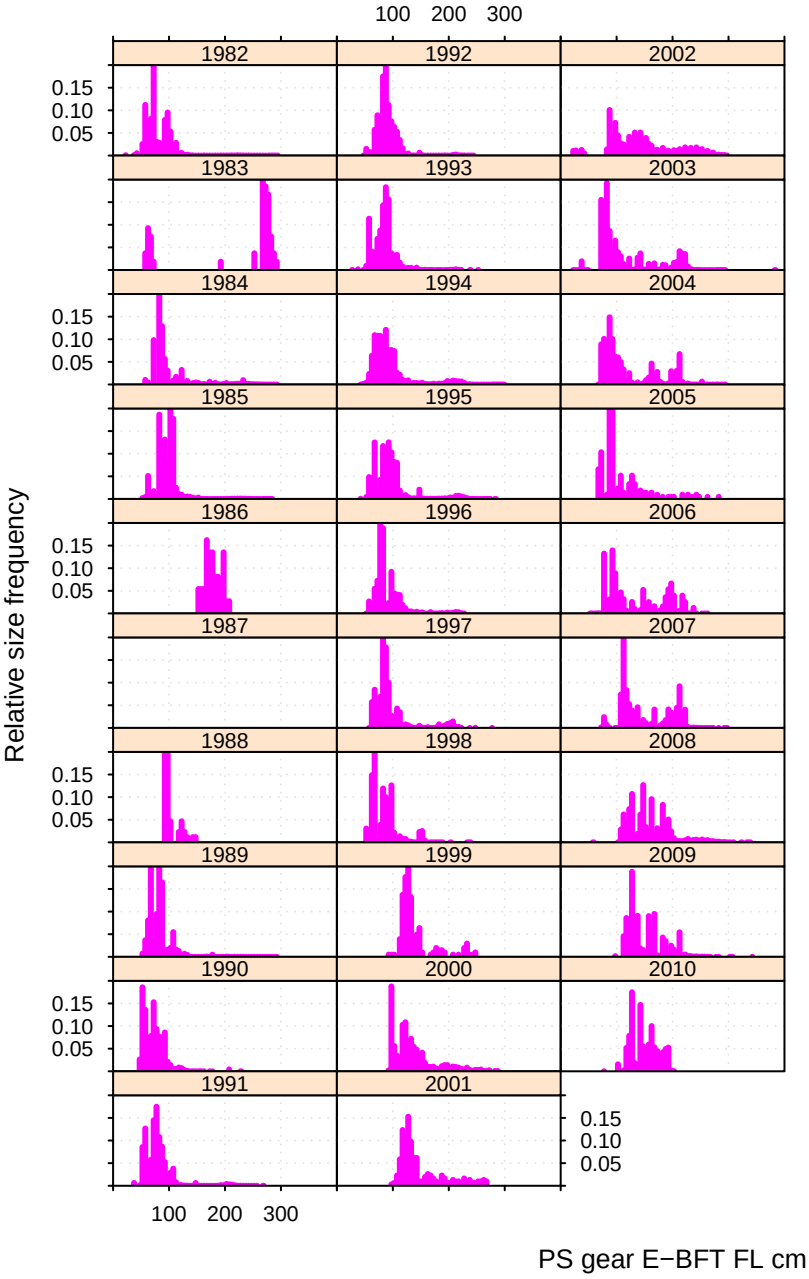
Relative size frequency
LL gear E−BFT FL cm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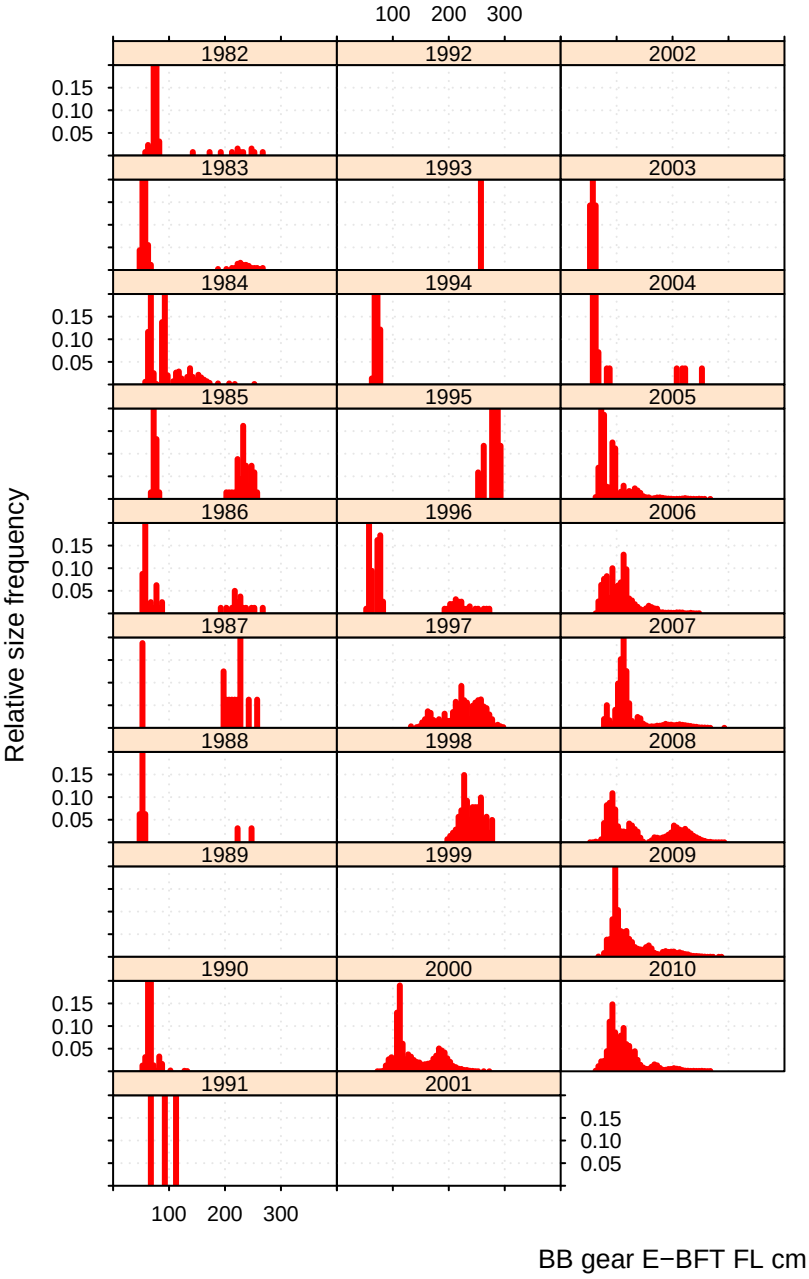
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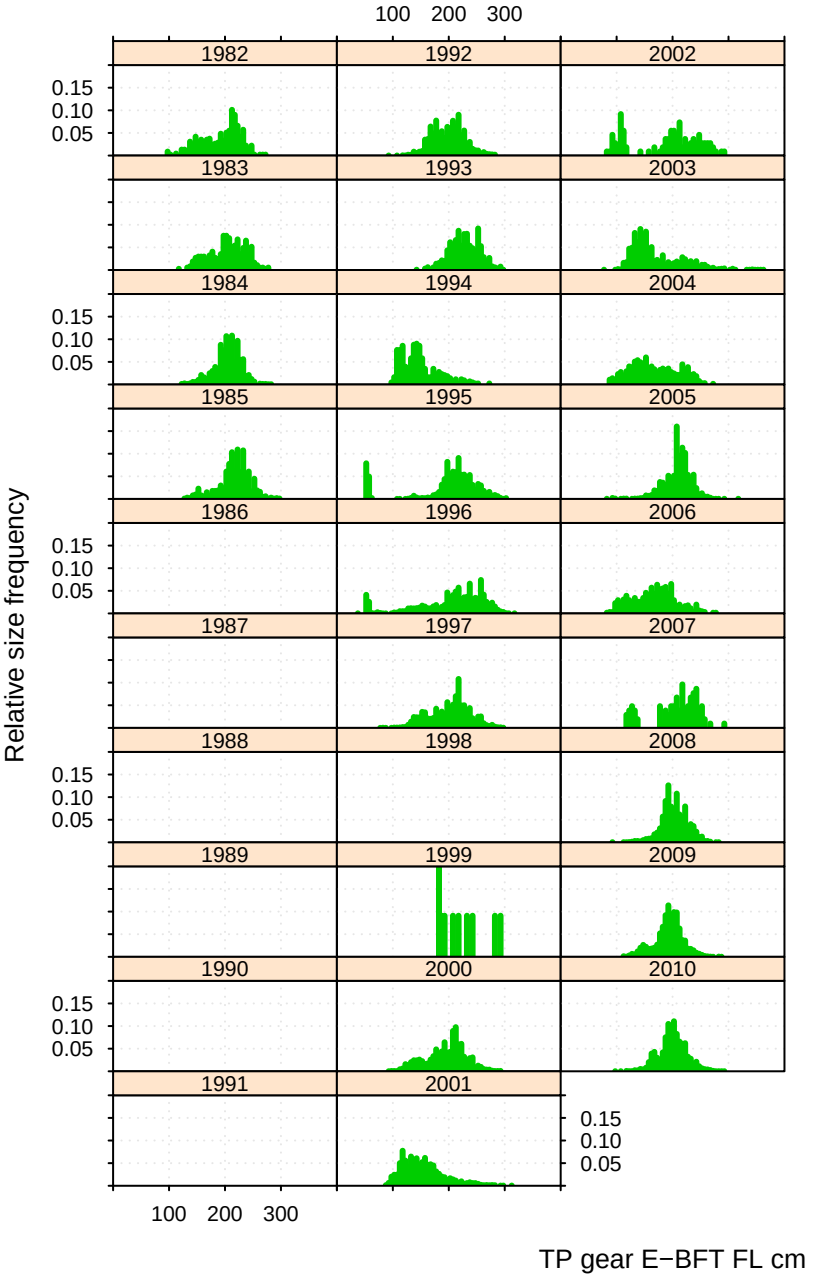
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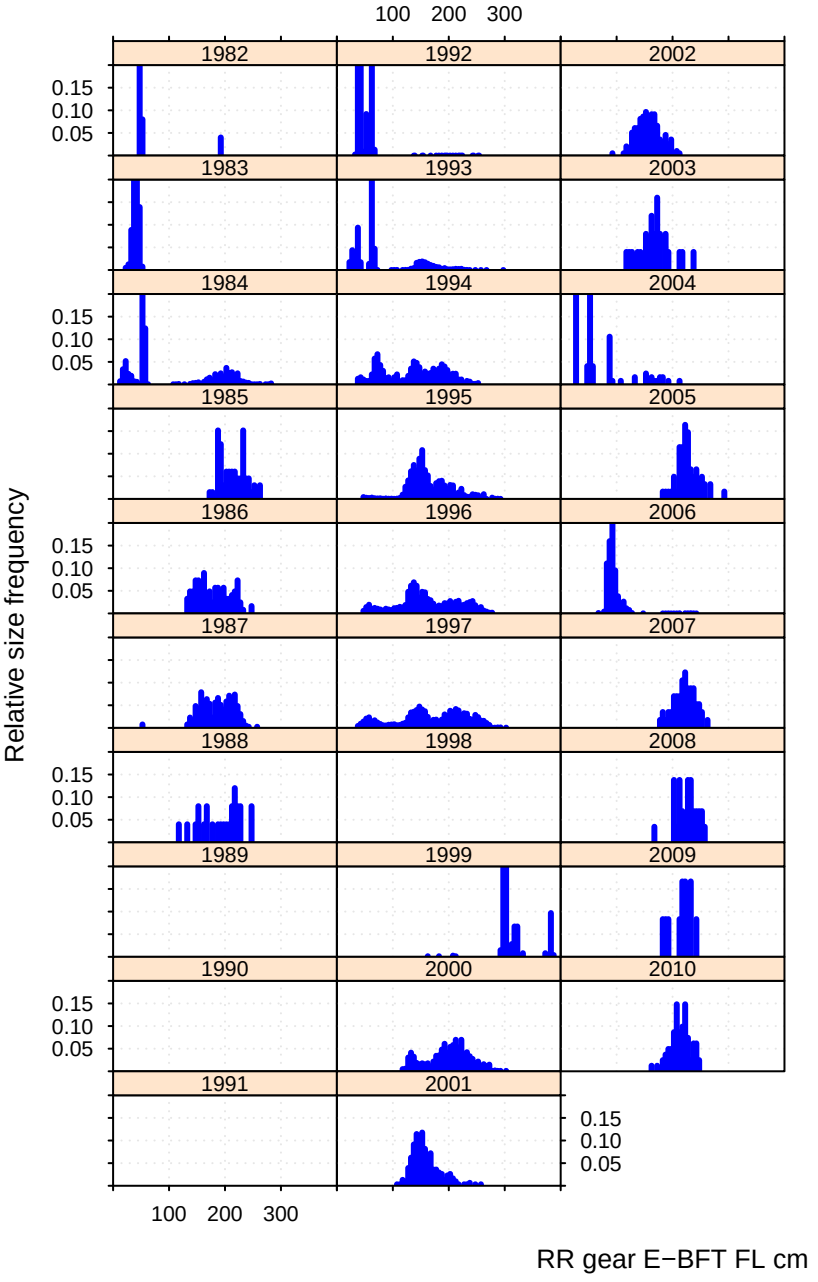
Relative size frequency
TP gear E−BFT FL cm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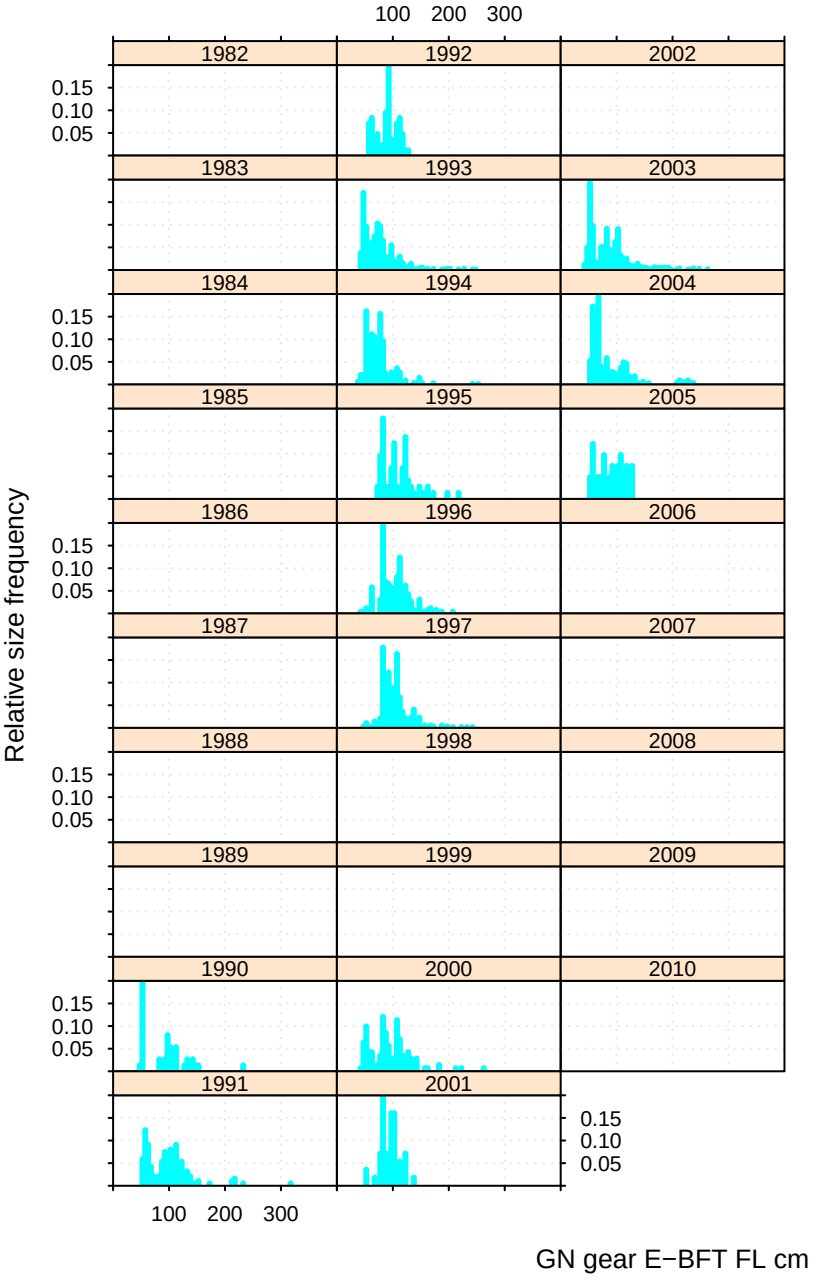
Relative size frequency
RR gear E−BFT FL cm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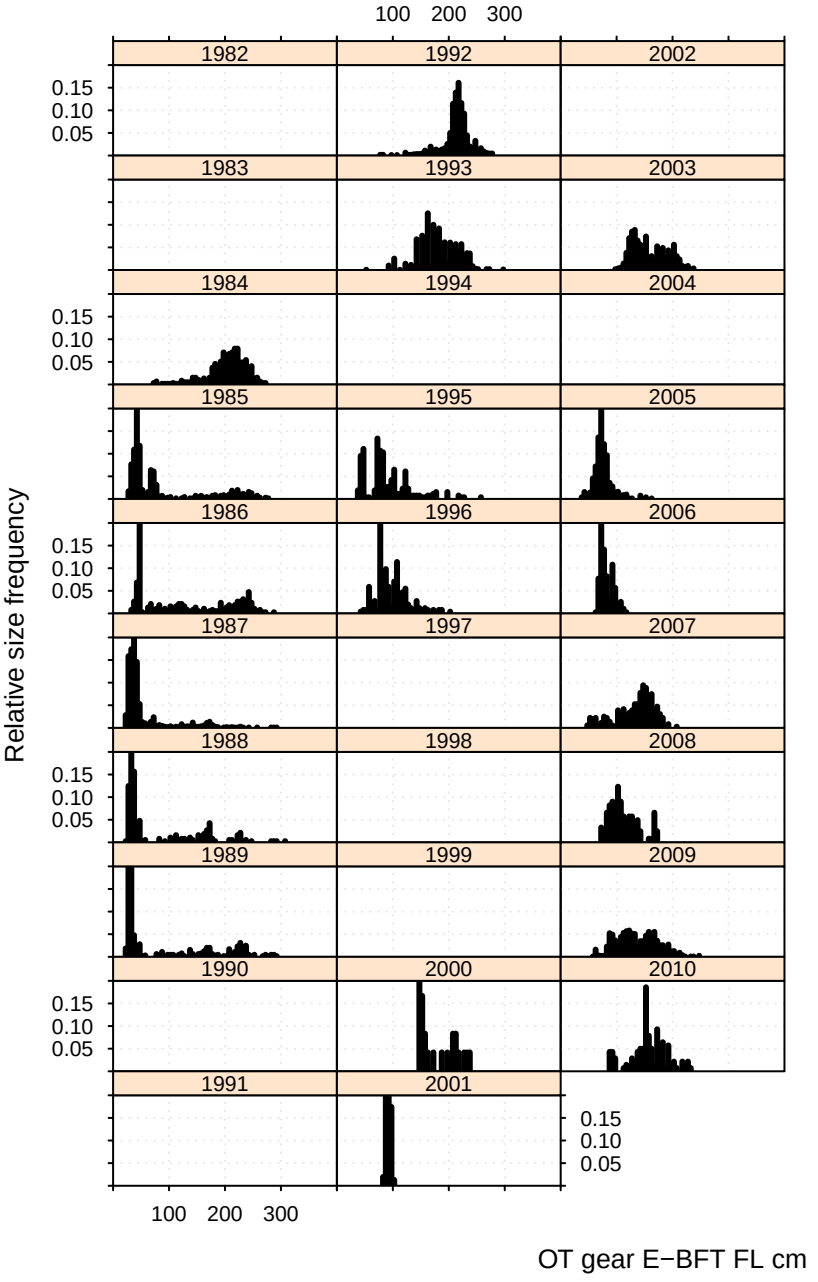
Relative size frequency
GN gear E−BFT FL cm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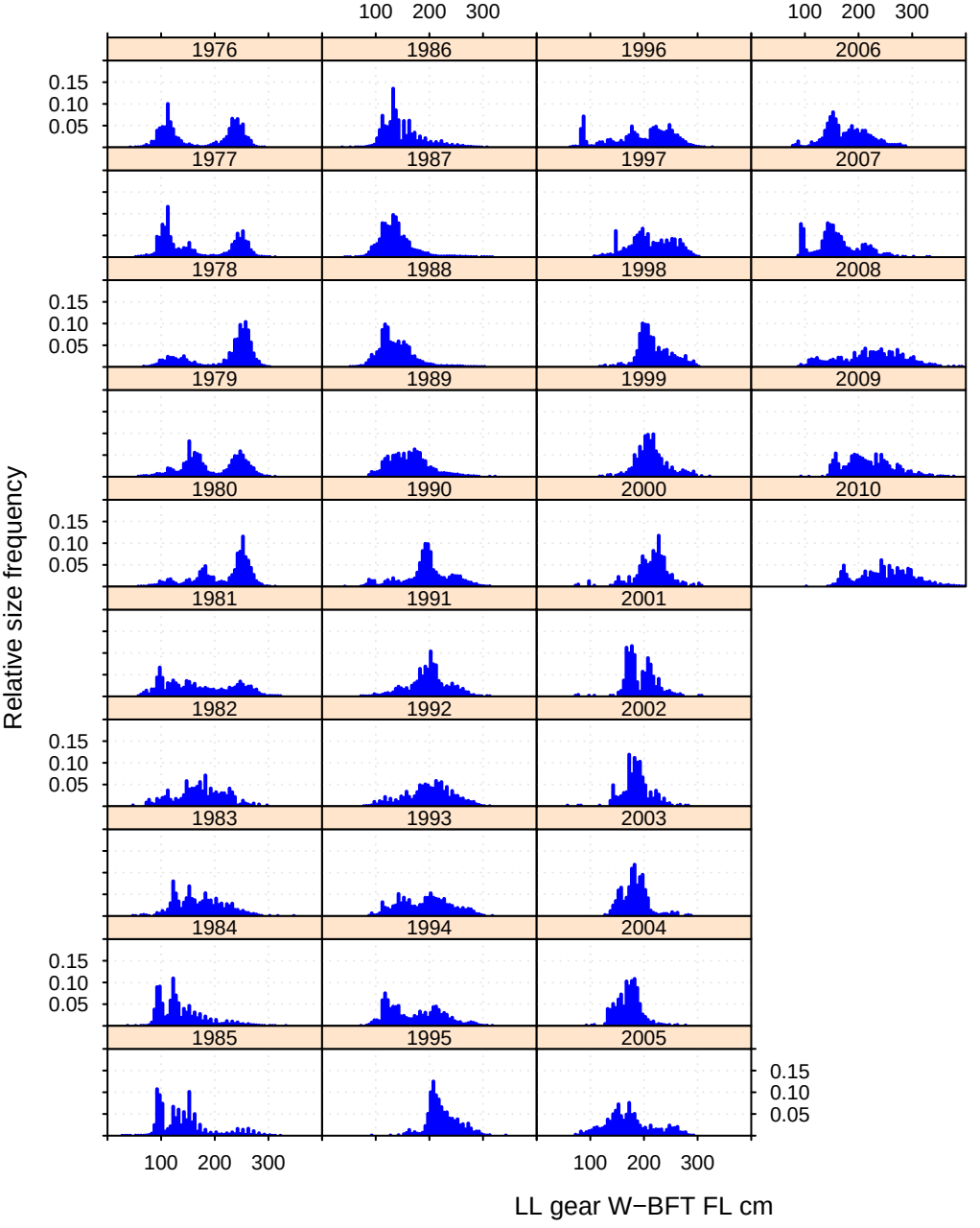
Relative size frequency
OT gear E−BFT FL cm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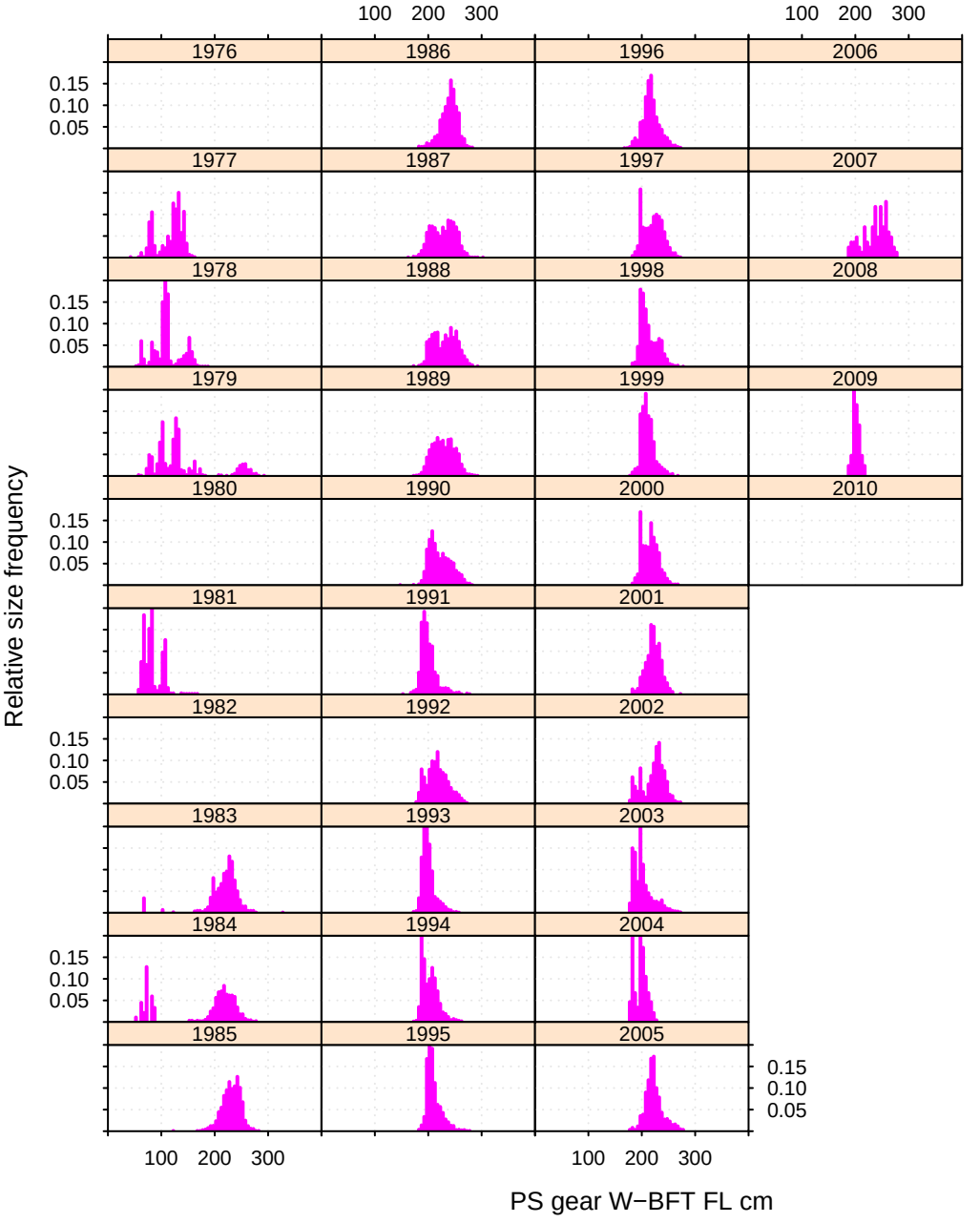
Relative size frequency
LL gear W−BFT FL cm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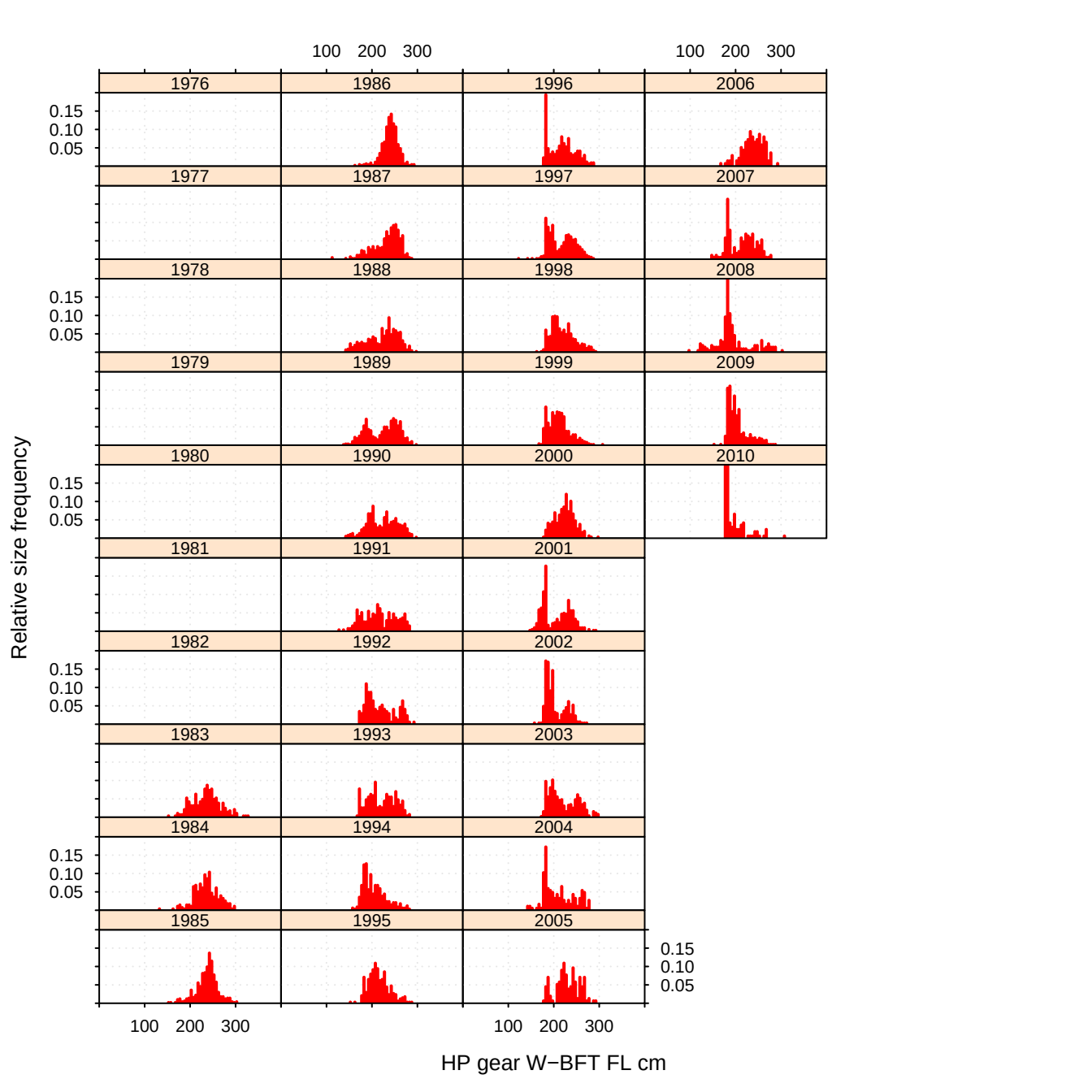
Relative size frequency
PS gear W−BFT FL cm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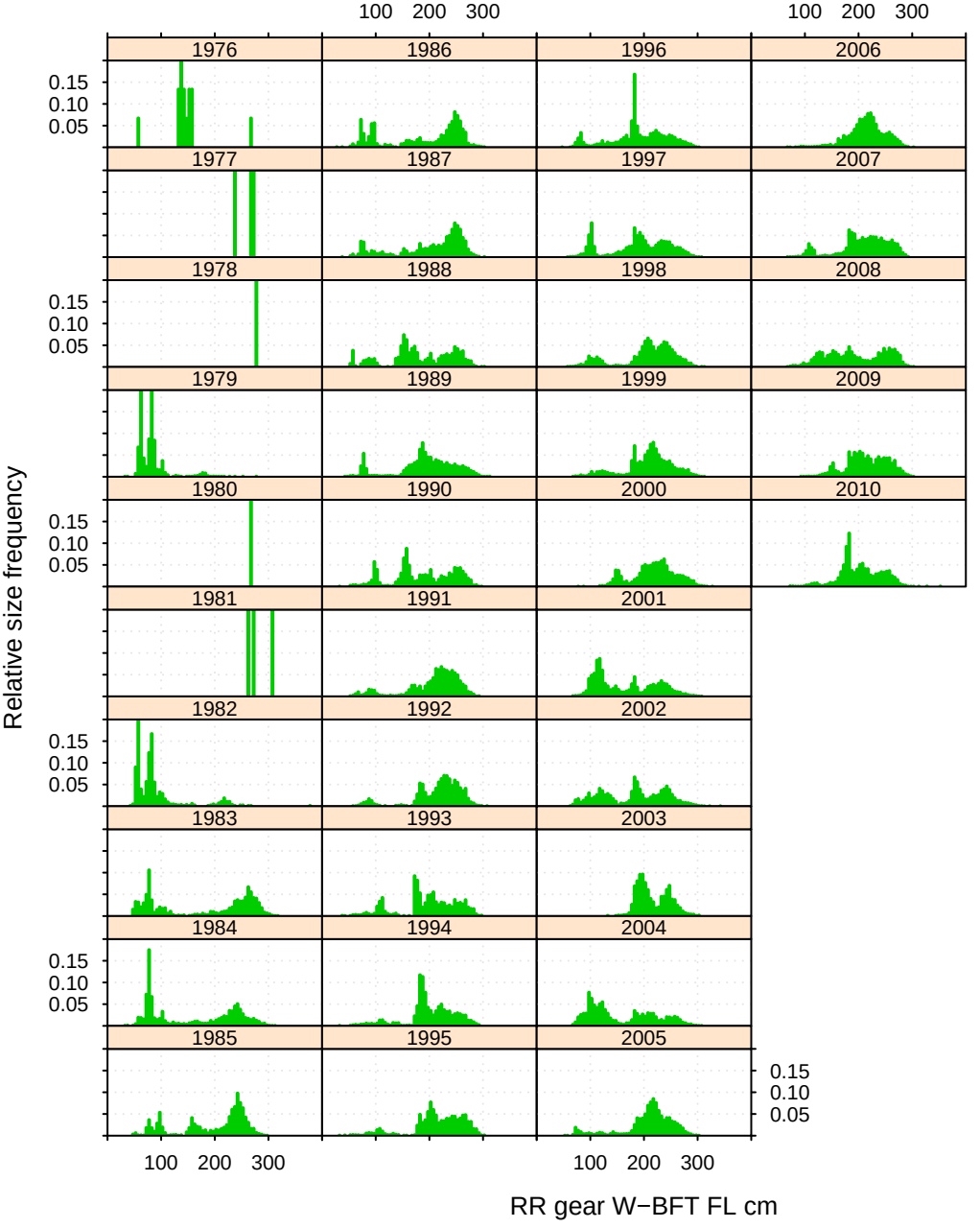
Relative size frequency
HP gear W−BFT FL cm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Relative size frequency
RR gear W−BFT FL cm