SIZE COMPOSITION OF ATLANTIC BLUEFIN TUNA *THUNNUS THYNNUS* THAT FARMED AND IMPORTED TO JAPAN CALCULATED FROM BCD INFORMATION

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SUMMARY

Accurate estimation of catch-at-size of farmed fish at the time of wild catch is important for the stock assessment of Atlantic bluefin tuna. This study aimed to provide information of size composition of catch of farmed fish imported to Japan based on analysis of accompanying BCDs. The data included information of fish harvested in seven CPCs mainly from 2011 to 2013 with the total exceeding 210 thousands fish. Those were caught by 13 CPCs. The size compositions among three categories, <100 kg, 100-200kg and >200kg, were largely different by harvest CPC or catch CPC. Various values obtained would be useful for estimation of catch-at-age of Atlantic bluefin tuna in ICCAT. It is suggested that direct evidence of growth during farming should be submitted form farming CPCs.

RÉSUMÉ

Une estimation précise de la prise par taille des poissons d'élevage au moment de leur capture à l'état sauvage est importante pour l'évaluation du stock de thon rouge de l'Atlantique. Cette étude visait à fournir des informations sur la composition par taille de la capture de poissons d'élevage importé au Japon sur la base de l'analyse des BCD qui les accompagnaient. Les données incluaient des informations sur les poissons mis à mort dans sept CPC essentiellement de 2011 à 2013, le total dépassant les 210.000 poissons. Ceux-ci ont été capturés par 13 CPC. Les compositions par taille parmi trois catégories, <100 kg, 100-200kg et >200kg, étaient très différentes par CPC de mise à mort ou CPC de capture. Les diverses valeurs obtenues seraient utiles pour estimer la prise par âge du thon rouge de l'Atlantique à l'ICCAT. Il est suggéré que les CPC d'élevage présentent les éléments de preuve directs de croissance pendant l'élevage.

RESUMEN

La estimación precisa de la captura por talla del atún rojo de granja en el momento de su captura en estado salvaje es importante para la evaluación de stock de atún rojo del Atlántico. Este estudio proporciona información sobre la composición por tallas de la captura de peces en granjas importados a Japón basándose en el análisis de los BCD que los acompañaban. Los datos incluían información sobre los peces sacrificados en siete CPC principalmente de 2011 a 2013, y el total superaba los 210 mil peces. Dichos peces fueron capturados por 13 CPC. Las composiciones de tallas, en tres categorías, <100 kg, 100-200 kg y >200 kg, eran muy diferentes entre CPC del sacrificio y CPC de captura. Los diversos valores obtenidos serán útiles para la estimación de la captura por edad del atún rojo del Atlántico en ICCAT. Se sugiere que las CPC de la granja deberían presentar evidencias directas de crecimiento durante la cría.

KEYWORDS

Atlantic bluefin tuna, Bluefin tuna catch documents, Harvest weights, Size frequency

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Introduction

Although accurate size information of fish destined for farming at wild capture is essential for stock assessment of Atlantic bluefin tuna *Thunnus thynnus*, it is difficult to obtain actually. Only sizes at harvest after farming for several months or even more than one year can be obtained usually. While size measurement at wild capture is possible by using the stereo video monitoring system, such data has not been available yet.

The Working Group for the 2014 Bluefin Tuna Data Preparatory Meeting held in May 2014 has to cope with a difficult task to estimate catch-at-size including bluefin tuna farmed.

This study provides information of harvest size of bluefin tuna imported to Japan, including catch CPCs and catch year that were retrieved from Bluefin tuna Catch Documents (BCDs), in order to contribute to the work of the group.

Data used

Information was obtained from BCDs submitted for Japanese custom clearance. The Fisheries Agency of Japan entered its information on Excel sheets.

The dataset covers bluefin tuna imported to Japan mainly from 2011 to 2013 (**Table 1**). Since our aim was for farmed fish, we extracted records with the harvesting activities for following analysis (3747 records).

A bluefin tuna school for farming caught by purse seine is separated into several farming cages then farmed for several months. Farmed fish in a cage are harvested and exported in several different times. Therefore, there were several different records of harvest coming from the same BCD or same cage ID. On the other hand, because several fish schools caught in different times or places were put into one farming cage, several BCDS often covers one farming cage. The numbers of unique record are 1670 in catch, 1511 in farming and 2871 in harvest (**Table 1, Figure 1**). The ranges of number of fish in a single record were 1-3784 in catch, 2-8541 in farming and 1-3657 in harvest.

Note that when farmed fish were harvested and exported from a cage that contains several schools caught in different times or places (hence have several different BCDs) as described above, because it was quite difficult to identify its true BCD, one of the BCDs covering the cage appears to be arbitrarily chosen to fish harvest in practice (Ota *et al.* 2012). Thus, using the information on fish harvested and the information on catches contained in the attached BCD is likely to cause unrealistic results in growth estimation. Ota *et al.* (2012) suggested that comparison between catch weight and harvested weight should be made on a cage basis instead of a BCD basis for analysis.

All the weight values were converted to round weight for analysis.

Representativeness of data

Total catch amounts in BCD in the dataset were calculated by CPC for both purse seine and trap net, which were capture gears for farming fish. Total catch amounts of those CPCs reported to ICCAT were obtained from Task I data in the Mediterranean and the northeast Atlantic for both gears, and then compared (**Figure 2 and Figure 3**).

The data used had high coverage larger than 80% of catch in 2011 and 2012 for purse seine. It is expected that the data represents wholly the farming fish in these years. For trap net catch, because a large part of them were exported as wild fish, it is not surprising that farming fish was in small proportion.

Weight frequency of bluefin tuna catch

Body weights were grouped into three categories by observing histograms of body weight; < 100 kg (small size fish), ≥ 100 kg and < 200 kg (middle size fish), and ≥ 200 kg (large size fish). While the aim was to obtain body weight frequencies at the time of wild capture by catch CPC and catch year, because of its complicate nature it was analyzed step by step.

First, weight frequency by harvest CPC in all years combined was obtained (**Figure 4**). It was assumed that all individuals in one data record had the same body weight as the average body weight of the record. There were seven harvest CPCs; Croatia, Greece, Italy, Malta, Spain, Tunisia and Turkey. Among the seven CPCs, Croatia harvested small fish exclusively (97% in number). Malta harvested small fish (74%) while included some middle and large size fish. Tunisia was similar to Malta. Turkey harvested equal proportions to small, middle and large size fish. Spain harvested mainly large size fish (64%).

Second, weight frequency by harvest CPC and by harvest year was obtained (**Table 2**). The harvest year ranged from 2010 to 2013. The weight compositions by the weight group were generally consistent among years in many CPCs. However, Spain had larger proportion for small fish in 2011 than other years, and Turkey had larger proportions for large fish in 2012 than other years.

The dataset contains record of product status in fresh or frozen. For reference, weight frequencies of fish imported to Japan were compared by fresh/frozen and by harvest CPCs (**Figure 5**). In many CPCs, the weight frequencies were different between fresh and frozen products. For fish harvested in Spain, where a large number of fish were recorded, the proportions in three size categories were similar to each other.

Third, weight frequency by catch CPC in all years combined was obtained (**Table 3, Figure 6**). The number of catch CPC recorded was 13; Algeria, Croatia, Egypt, France, Greece, Italy, Libya, Malta, Morocco, Spain, Syria, Tunisia and Turkey.

Fourth, weight frequency by catch CPC and by catch year was obtained (**Table 3**). The catch year was assumed in two cases. The first case assumed that BCD accurately corresponded to the fish harvested, while there appeared to be problems as described above. The second case assumed that fish were mixed from different catch in a cage and data were aggregated by cage ID. In the second case, data records were limited only for its catch year which was determined in a single year in the cage. Exclusion of the first case reduced the number of individuals included in the data by 30%. Results are shown in **Table 4 and Table 5**. CPCs that caught small fish in all years were Algeria, Croatia, Italia and Malta. The main component of size group varied by year in some CPCs; France, Greece, Libya, Morocco, Spain, Tunisia and Turkey.

Back calculation of size at capture

At present, there are two different hypotheses on the growth of bluefin tuna during farming. One is the value shown on Table 16.6 in the SCRS 2009 Report and the other is same growth ratios in body length between farmed fish and wild fish (Fonteneau 2013). Calculated growth in length and weight for one year farming are shown in **Figure 7 and Figure 8**, respectively. Length-weight relationship parameters of farmed fish derived in Ortiz *et al.* (2013) were used (alpha=3.91E-05, beta=2.874385). There are quite large differences between the two hypotheses. Therefore, we did not conduct back calculation for size in the present study.

Note that body length on **Figure 7** was calculated from length-weight relationship parameters in which length was used as the explanatory variable. Those in which weight being used as the explanatory variable is more appropriate. It can be corrected when those parameters are available.

Discussion

Because Japan is the CPC that imports the largest amount of bluefin tuna, the dataset analyzed in the present study contained a large number of bluefin tuna. The number of fish was larger than the farm size database in the Secretariat (Ortiz *et al.* 2013)

The body weight in a record of the present dataset is an average weight and lost individual variability. Even though anomalously large numbers in a specific weight were frequently seen on graphs, however, because it consisted of many records of imported, weight frequencies were relatively smooth in shape. The data could provide useful information at least in large categories such as small, middle and large size fish.

The results can be utilized to check the catch-at-size estimation from the ICCAT farm size database, if there is low coverage of harvest size measurement in any farm CPC in years during 2011 to 2013.

This study only provided size at harvest. Estimated size at capture changes largely by the assumption of growth during farming. For the growth during farming, it is essential that direct evidences of growth will be provided from farm CPCs.

The years of capture analyzed in the present study ranged from 2008 to 2012. The task of the Meeting is to estimate catch-at-size since 2003. For the catch-at-size estimation between 2003 and 2007, we need careful discussion for what size data should be used for substitution.

References

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Table 1. Number of records of catch, farming and harvest in the dataset of imported bluefin tuna in Japan by year and CPCs.

	2008	2009	2010	2011	2012	Total
Catch						
ALGERIA	0	0	0	0	1	1
CROATIA	24	72	317	430	0	843
EGYPT	0	0	0	1	1	2
FRANCE	1	0	129	41	35	206
GREECE	0	1	0	2	7	10
ITALY	0	3	1	34	16	54
LIBYA	1	0	24	0	11	36
MALTA	0	0	0	1	0	1
MOROCCO	0	0	2	10	1	13
SPAIN	1	0	36	65	40	142
SYRIA	0	0	0	1	0	1
TUNISIA	1	3	4	114	12	134
TURKEY	0	1	27	167	32	227
Farming						
ALGERIA	0	0	0	0	0	0
CROATIA	25	72	317	430	0	844
EGYPT	0	0	0	0	0	0
FRANCE	0	0	0	0	0	0
GREECE	0	3	3	3	5	14
ITALY	0	0	0	16	0	16
LIBYA	0	0	0	0	0	0
MALTA	2	0	25	23	29	79
MOROCCO	0	0	0	0	0	0
SPAIN	0	1	4	103	75	183
SYRIA	0	0	0	0	0	0
TUNISIA	0	1	4	113	13	131
TURKEY	0	3	29	181	31	244
Harvest						
ALGERIA	0	0	0	0	0	0
CROATIA	0	0	223	352	344	919
EGYPT	0	0	0	0	0	0
FRANCE	0	0	0	0	0	0
GREECE	0	0	0	10	29	39
ITALY	0	0	16	0	0	16
LIBYA	0	0	0	0	0	0
MALTA	2	2	79	89	5	177
MOROCCO	0	0	0	0	0	0
SPAIN	0	1	84	668	254	1007
SYRIA	0	0	0	0	0	0
TUNISIA	0	0	158	84	44	286
TURKEY	0	0	73	253	101	427

Table 2. Proportion in number of fish by weight group, harvest CPC and harvest year. The case of >100 fish are shown.

CPC harvest	Year harvest	<100kg	100kg-200kg	≧200kg	NumFish
CROATIA	All year	97%	3%	0%	70,557
GREECE	All year	44%	56%	0%	2,558
ITALY	All year	51%	49%	0%	2,244
MALTA	All year	71%	22%	7%	51,768
SPAIN	All year	18%	19%	64%	33,753
TUNISIA	All year	65%	23%	12%	28,463
TURKEY	All year	37%	39%	24%	23,985
Total					213,328
CROATIA	2011	97%	3%	0%	21,151
	2012	99%	1%	0%	30,670
	2013	93%	7%	0%	18,736
GREECE	2012	0%	99%	1%	980
	2013	72%	28%	0%	1,578
ITALY	2011	51%	49%	0%	2,244
MALTA	2010	100%	0%	0%	448
	2011	73%	20%	7%	10,133
	2012	70%	23%	7%	41,108
SPAIN	2011	47%	16%	37%	5,606
	2012	18%	18%	64%	13,619
	2013	6%	20%	74%	14,517
TUNISIA	2011	63%	25%	12%	9,876
	2012	63%	24%	13%	16,344
	2013	86%	14%	0%	2,243
TURKEY	2011	85%	7%	8%	3,484
	2012	30%	39%	32%	12,922
	2013	27%	54%	19%	7,579

Table 3. Proportion in number of fish by weight group, catch CPC and harvest year. The case of >100 fish are shown.

CPC catch	Year harvest	<100kg	100kg-200kg	≧200kg	NumFish
ALGERIA	All year	82%	0%	18%	1,221
CROATIA	All year	97%	3%	0%	70,408
EGYPT	All year	14%	86%	0%	2,524
FRANCE	All year	34%	22%	44%	18,285
GREECE	All year	53%	33%	14%	2,325
ITALY	All year	78%	19%	3%	35,546
LIBYA	All year	27%	39%	34%	8,220
MALTA	All year	100%	0%	0%	1,794
MOROCCO	All year	18%	46%	36%	1,659
SPAIN	All year	16%	22%	62%	21,974
SYRIA	All year	23%	77%	0%	2,168
TUNISIA	All year	65%	23%	12%	31,842
TURKEY	All year	45%	30%	25%	15,362
Total					213,328
ALGERIA	2012	73%	0%	27%	807
	2013	100%	0%	0%	414
CROATIA	2011	97%	3%	0%	21,151
	2012	99%	1%	0%	30,521
	2013	93%	7%	0%	18,736
EGYPT	2011	100%	0%	0%	345
	2012	0%	100%	0%	2,179
FRANCE	2010	100%	0%	0%	313
	2011	77%	3%	20%	4,911
	2012	27%	44%	29%	6,857
	2013	4%	15%	82%	6,173
GREECE	2011	14%	65%	21%	478
	2012	61%	24%	15%	1,482
	2013	73%	27%	0%	365
ITALY	2011	65%	31%	4%	6,250
	2012	81%	16%	3%	28,136
	2013	76%	24%	0%	1,160
LIBYA	2010	100%	0%	0%	146
	2011	1%	66%	33%	1,269
	2012	30%	34%	36%	6,677
	2013	9%	91%	0%	107
MALTA	2011	100%	0%	0%	1,274
	2012	100%	0%	0%	520
MOROCCO	2011	0%	100%	0%	110
	2012	27%	27%	46%	1,099
	2013	0%	79%	21%	450
SPAIN	2011	52%	19%	29%	3,801
	2012	9%	20%	71%	9,766
	2013	8%	24%	68%	8,407
SYRIA	2011	100%	0%	0%	488
	2013	0%	100%	0%	1,680
TUNISIA	2011	62%	24%	14%	10,070
	2012	66%	24%	11%	19,174
	2013	74%	17%	9%	2,598
TURKEY	2011	91%	6%	3%	2,347
	2012	37%	31%	32%	8,425
	2013	36%	40%	24%	4,590

Table 4. Proportion in number of fish by weight group, catch CPC and catch year. Assuming BCD was accurately corresponded to the fish harvested. The case of >100 fish are shown.

CPC catch	Year catch	<100kg	100kg-200kg	≧200kg	NumFish
ALGERIA	2012	82%	0%	18%	1,221
CROATIA	2008	96%	4%	0%	9,943
	2009	86%	14%	0%	11,789
	2010	100%	0%	0%	27,131
	2011	100%	0%	0%	21,545
EGYPT	2011	19%	81%	0%	1,827
	2012	0%	100%	0%	697
FRANCE	2008	100%	0%	0%	333
	2010	88%	11%	1%	2,417
	2011	61%	9%	29%	5,481
	2012	4%	33%	63%	10,054
GREECE	2011	19%	70%	11%	881
	2012	76%	9%	15%	1,422
ITALY	2009	75%	25%	0%	278
	2010	100%	0%	0%	239
	2011	51%	46%	3%	7,797
	2012	86%	11%	3%	27,232
LIBYA	2008	100%	0%	0%	167
	2010	1%	66%	33%	1,269
	2012	30%	35%	35%	6,784
MALTA	2011	100%	0%	0%	1,794
MOROCCO	2010	0%	26%	74%	219
	2011	26%	43%	31%	1,129
	2012	0%	69%	31%	311
SPAIN	2008	0%	100%	0%	318
	2010	87%	13%	0%	491
	2011	39%	28%	33%	5,703
	2012	5%	18%	76%	15,462
SYRIA	2011	23%	77%	0%	2,168
TUNISIA	2008	72%	28%	0%	149
	2009	0%	0%	100%	567
	2010	57%	43%	0%	491
	2011	54%	38%	8%	14,988
	2012	78%	10%	12%	15,647
TURKEY	2010	0%	22%	78%	2,446
	2011	56%	38%	6%	7,381
	2012	51%	22%	28%	5,474

Table 5. Another case of proportion in number of fish by weight group, catch CPC and catch year. Assuming mix of fish from different catch in a cage and data were aggregated by cage ID. The data records were limited only for its catch year was determined in a single year. "Diff Num" shows the number of decrease from **Table 4**. The case of >100 fish are shown.

CPC catch	Year catch	<100kg	100kg-200kg	≧200kg	NumFish	Diff Num
ALGERIA	2012	82%	0%	18%	1,221	0
CROATIA	2008	93%	7%	0%	5,301	4,642
	2009	86%	14%	0%	11,789	0
	2010	99%	1%	0%	16,541	10,590
	2011	100%	0%	0%	13,466	8,079
EGYPT	2011	19%	81%	0%	1,827	0
	2012	0%	100%	0%	697	0
FRANCE	2008	100%	0%	0%	333	0
	2010	100%	0%	0%	995	1,422
	2011	0%	30%	70%	761	4,720
	2012	5%	58%	38%	5,040	5,014
GREECE						881
	2012	65%	13%	21%	1,005	417
ITALY	2009	75%	25%	0%	278	0
						239
	2011	34%	66%	0%	3,398	4,399
	2012	82%	14%	3%	22,133	5,099
LIBYA	2008	100%	0%	0%	167	0
	2010	1%	63%	37%	1,139	130
	2012	30%	35%	35%	6,784	0
MALTA	2011	100%	0%	0%	1,274	520
MOROCCO	2010	0%	26%	74%	219	0
	2011	34%	25%	41%	799	330
	2012	0%	69%	31%	311	0
SPAIN						318
						491
	2011	25%	49%	26%	1,223	4,480
	2012	11%	20%	69%	6,190	9,272
SYRIA	2011	23%	77%	0%	2,168	0
TUNISIA	2008	72%	28%	0%	149	0
	2009	0%	0%	100%	567	0
	2010	0%	100%	0%	146	345
	2011	54%	38%	8%	14,988	0
	2012	78%	10%	12%	14,529	1,118
TURKEY	2010	0%	22%	78%	2,446	0
	2011	60%	34%	6%	6,788	593
	2012	53%	23%	24%	5,185	289

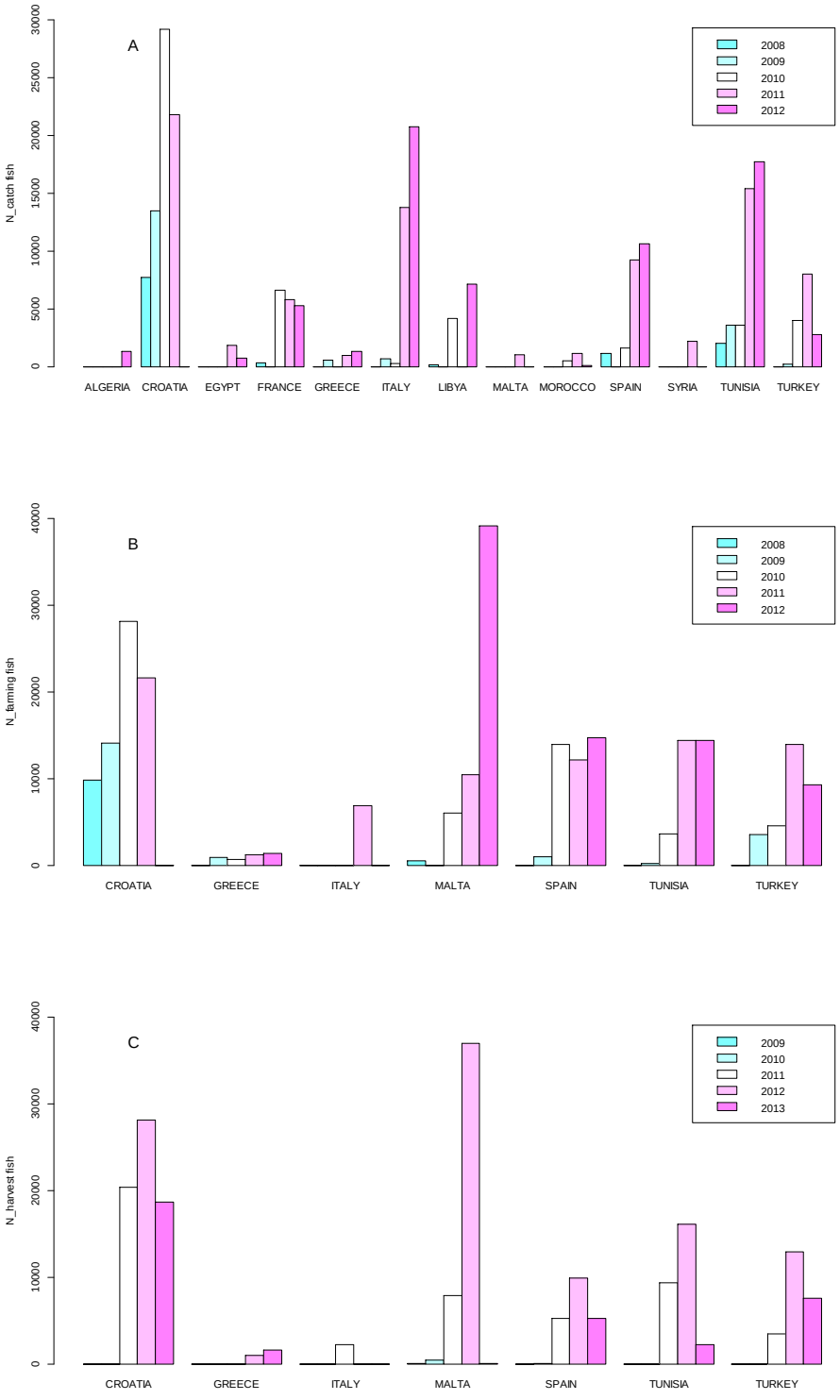
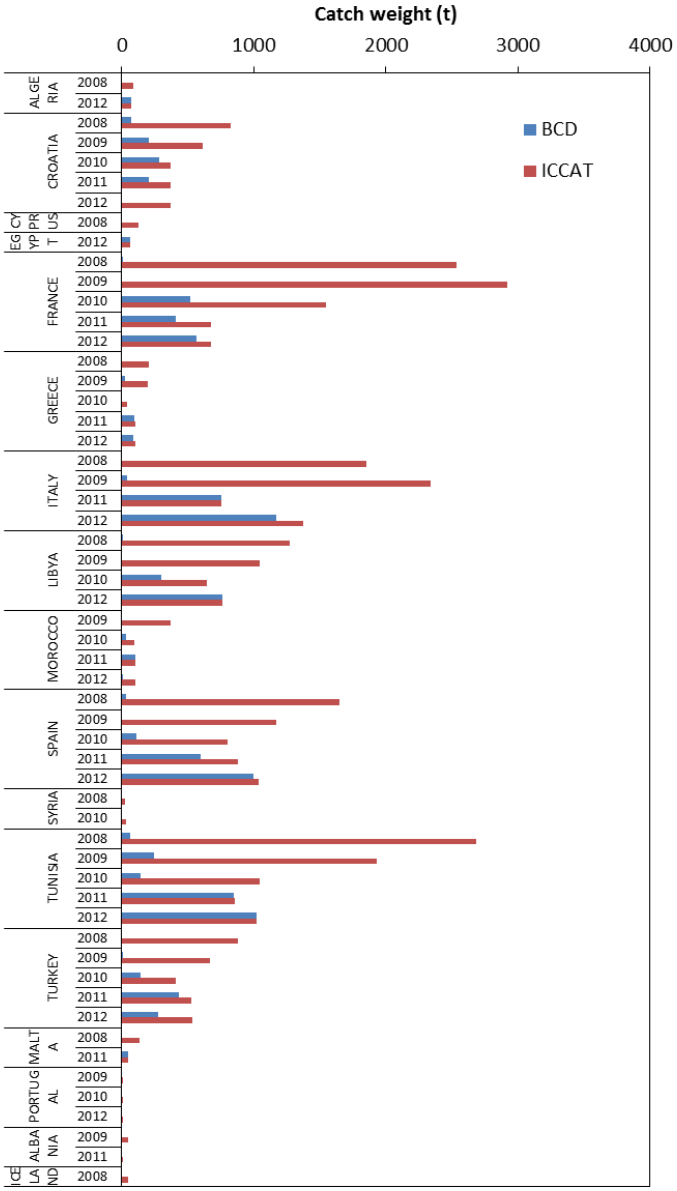
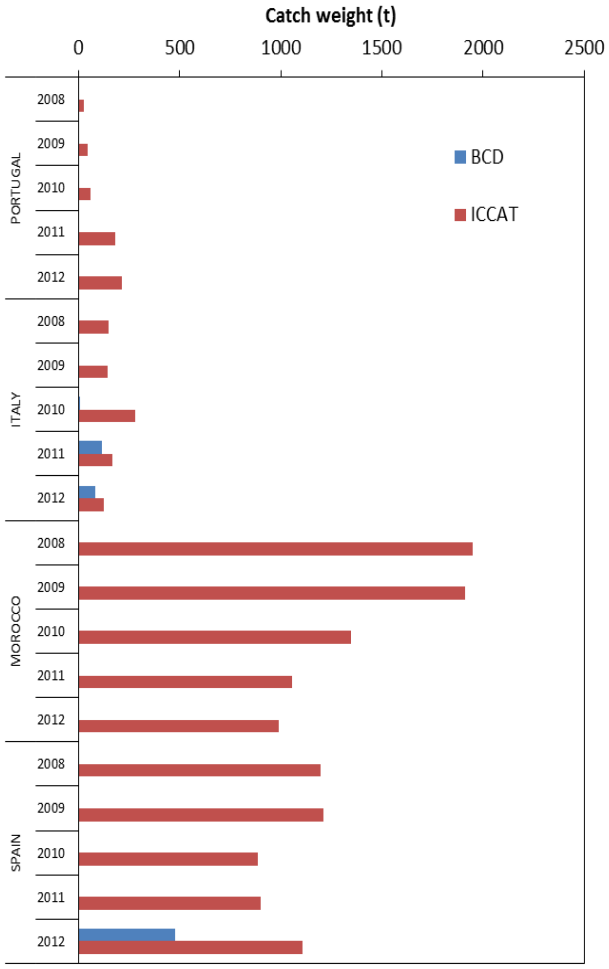


Figure 1. Number of fish in the dataset of imported bluefin tuna in Japan by year for A) catch, b) farming and c) harvest.



	(A) Weight recorded in BCD (t)	(B) Weight recorded in ICCAT (t)	A/B (%)
Total	10735.6	38995.3	27.5
2008	179.1	12306.3	1.5
2009	529.8	11292.9	4.7
2010	1519.5	4984.4	30.5
2011	3493.0	4306.1	81.1
2012	5014.2	6105.6	82.1

Figure 2. Comparison of purse seine catch in weight between the dataset of imported bluefin tuna in Japan and reported to ICCAT from CPC.



	(A) Weight recorded in BCD (t)	(B) Weight recorded in ICCAT (t)	A/B (%)
Total	681.0	13937.0	4.9
2008	0.0	3317.2	0.0
2009	0.0	3308.3	0.0
2010	8.4	2573.3	0.3
2011	114.7	2301.6	5.0
2012	557.9	2436.6	22.9

Figure 3. Comparison of trap net catch in weight between the dataset of imported bluefin tuna in Japan and reported to ICCAT from CPC

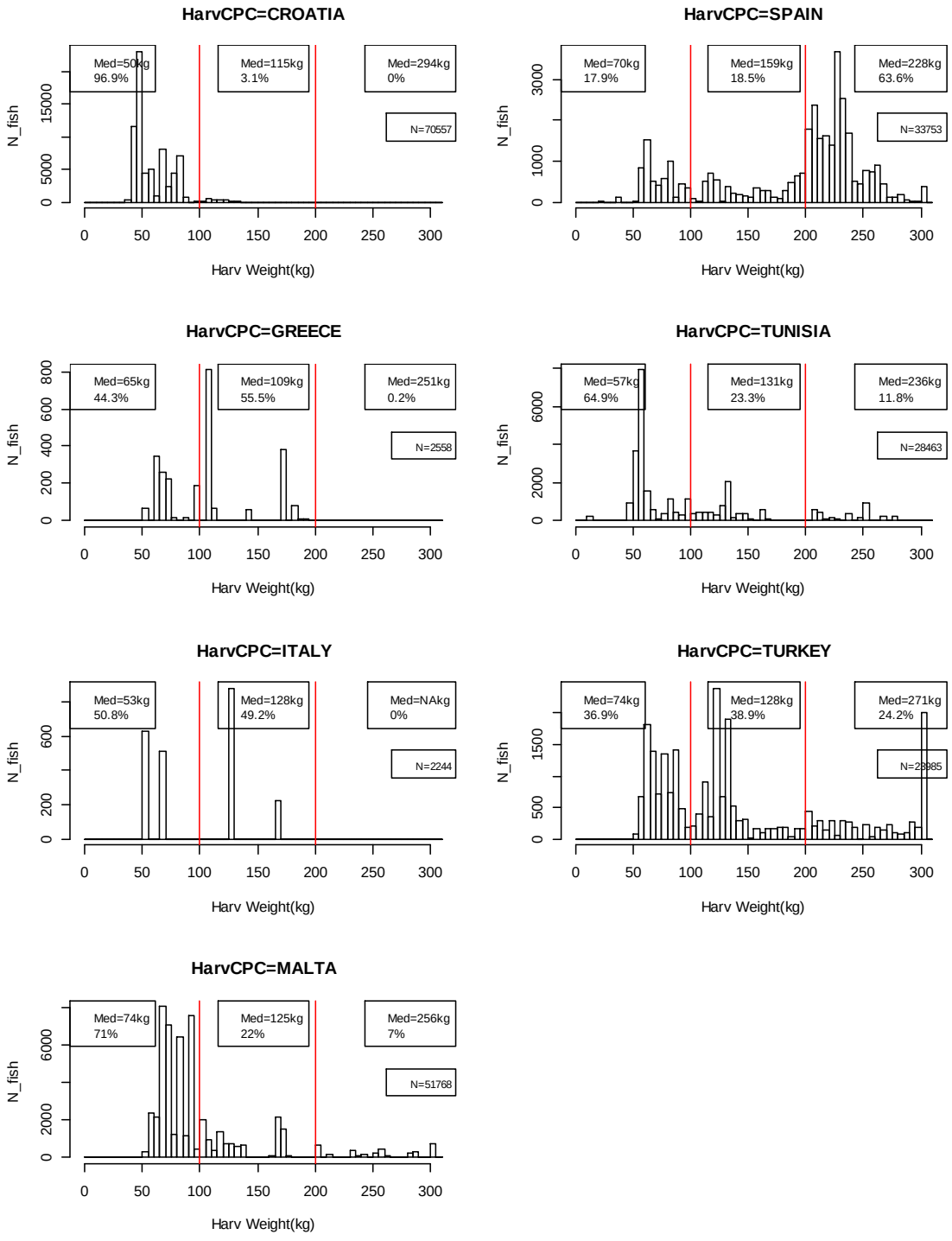


Figure 4. Round body weight composition of bluefin tuna at harvest by harvest CPC. Red lines denote 100 kg and 200 kg. Median weight and proportion in number are shown in each of three size groups. The total number of fish is also shown on the right side.

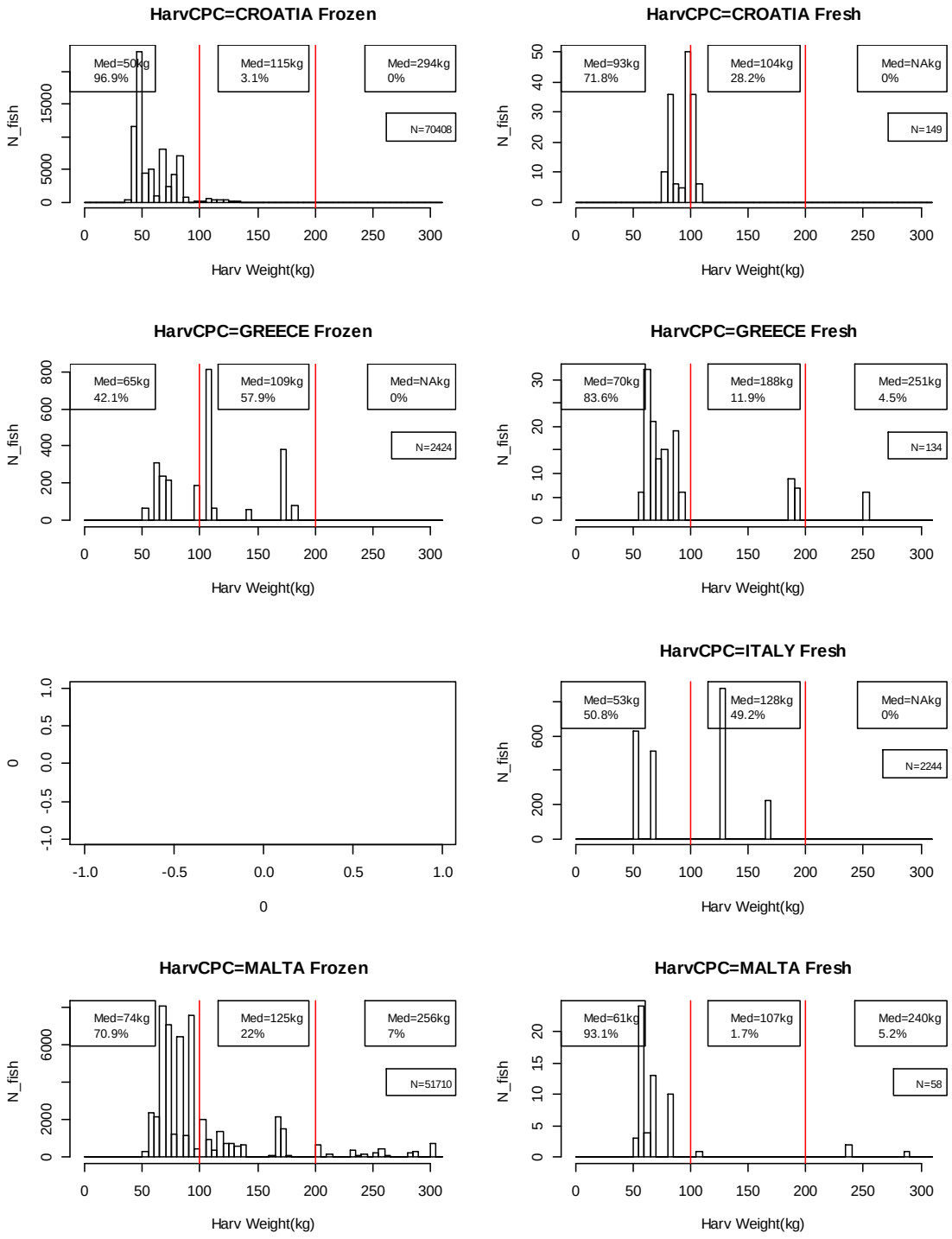


Figure 5. Round body weight composition of bluefin tuna at harvest by imported in fresh/frozen and harvest CPC.

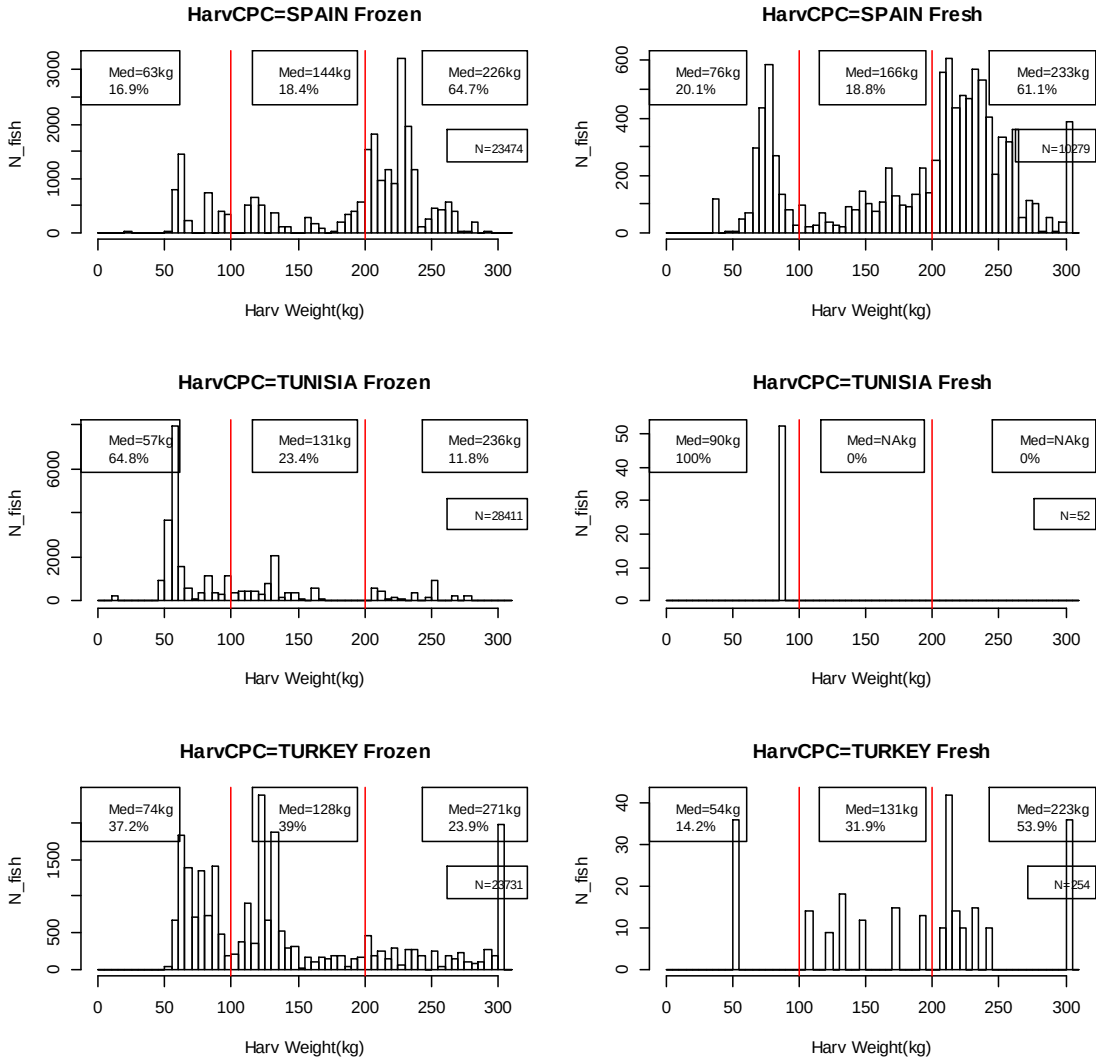


Figure 5. (cont.)

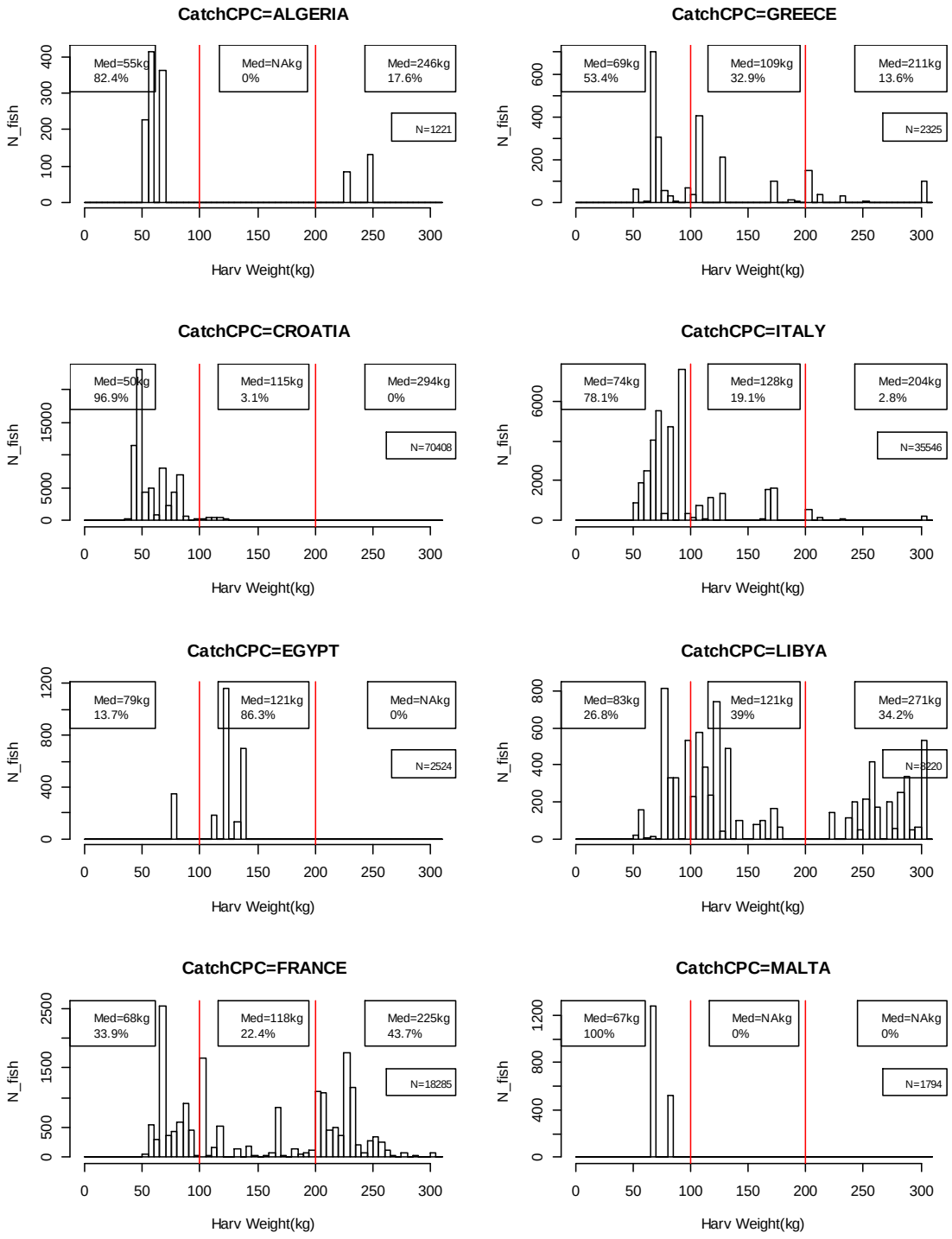


Figure 6. Round body weight composition of bluefin tuna at harvest by catch CPC. Red lines denote 100 kg and 200 kg. Median weight and proportion in number are shown in each of three size groups. The total number of fish is also shown on the right side.

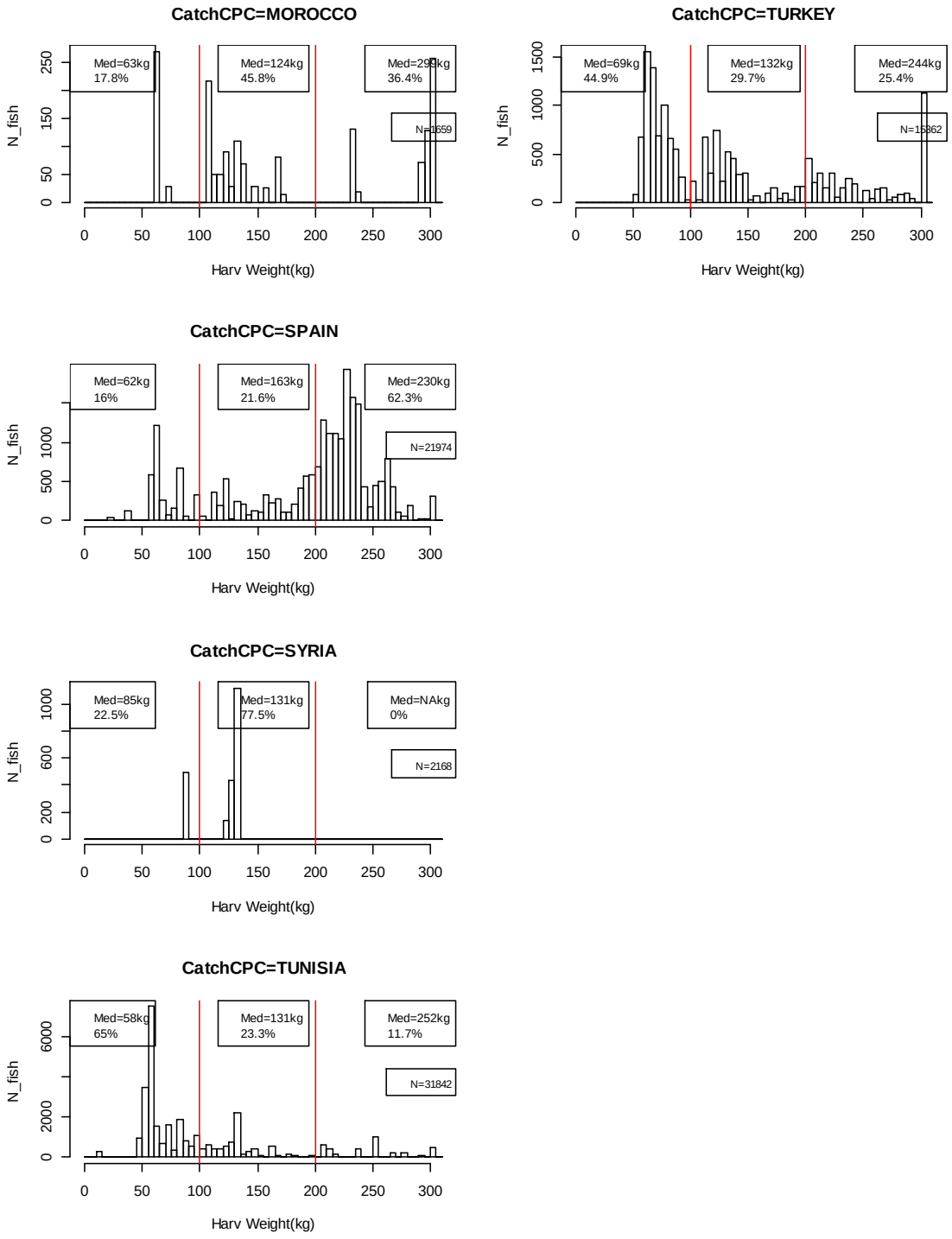


Figure 6. (cont.)

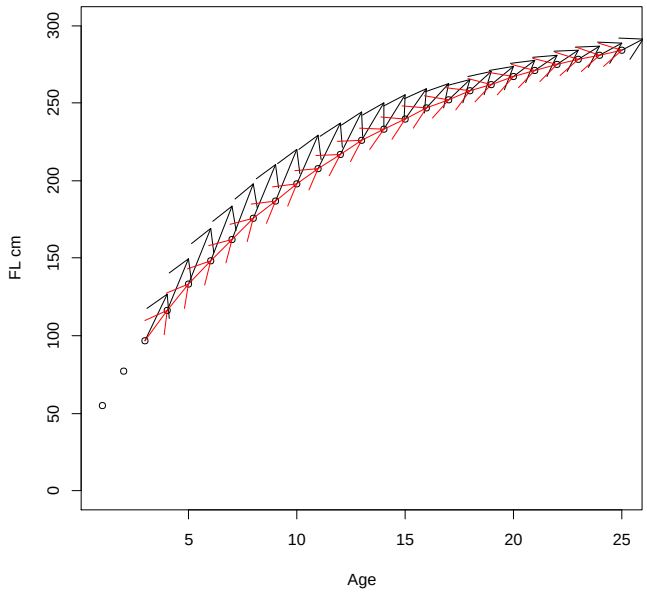


Figure 7. Growth of farmed fish in fork length. Open circles are fork length at the start of farming in each age on Table 16.6 of SCRS 2009 Report. Black and red arrows are fork length after one year that using the growth increment on Table 16.6 and that is same as wild fish assumed in Fonteneau (2013), respectively.

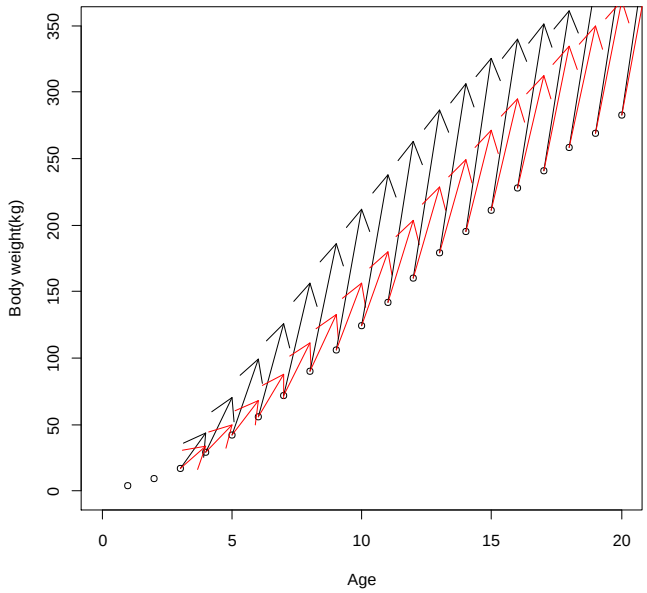


Figure 8. Growth of farmed fish in body weight. Open circles are body weight at the start of farming in each age on Table 16.6 of SCRS 2009 Report. Black arrows are fork length after one year using the growth increment on Table 16.6. Red arrows are body weight after one year assuming that growth in body length is same as that of wild fish (Fonteneau 2013) and used length weight relationship for farm fish (Ortiz *et al.* 2013).