

INTERPOLATION OF THE GROWTH TABLE FOR FARMING BLUEFIN TUNAS

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SUMMARY

This paper describes a method and the results of interpolation for the new farming growth table developed in 2022, which is requested from PA2 specified in PA2-30. The blanks in the table were filled by the average of weights in one-step before and after each size bin. Additionally, the gaps between each data point were linearly interpolated with 1-kg and 1-day intervals to be precise enough for the BFT export/import monitoring. This interpolated table is subject to review in the 2023 BFT SG and SCRS plenary meeting to propose it in the 2023 ICCAT Commission meeting.

RÉSUMÉ

Ce document décrit une méthode et les résultats de l'interpolation pour le nouveau tableau de croissance dans les fermes, développé en 2022, qui est demandé par la PA2 et spécifié dans le document PA2-30. Les cellules vides du tableau ont été remplies avec la moyenne des poids en une seule étape, avant et après chaque intervalle de tailles. En outre, les espaces entre chaque point de données ont été interpolés linéairement avec des intervalles de 1 kg et de 1 jour pour être suffisamment précis pour le suivi des exportations/importations de thon rouge. Ce tableau interpolé fait l'objet d'une révision au sein du Groupe d'espèces sur le thon rouge et à la réunion plénière du SCRS de 2023 pour proposition à la réunion de la Commission de l'ICCAT en 2023.

RESUMEN

Este documento describe un método y los resultados de la interpolación para la nueva tabla de crecimiento en granjas desarrollada en 2022, que solicita la PA2 y se especifica en el documento PA2-30. Los espacios en blanco de la tabla se rellenaron con la media de los pesos en un paso antes y después de cada intervalo de talla. Además, los espacios entre cada punto de datos se interpolaron linealmente con intervalos de 1 kg y 1 día para que fueran lo suficientemente precisos para el seguimiento de la exportación/importación de atún rojo. Esta tabla interpolada está sujeta a revisión por el Grupo de especies de atún rojo (BFT SG) y en la reunión plenaria del SCRS de 2023 para proponerla en la reunión de la Comisión de ICCAT de 2023.

KEYWORDS

Bluefin tuna, Growth rate in farm, Interpolation

1. Introduction

Last year, the SCRS suggested the new growth rate table for farming Bluefin tuna (SCRS/2022/178) as a Response to the Commission 17.16. The table provided is the expected average weight and the upper 95%tile weight gain after caging (**Table 1**) giving an initial size at caging and the time in the farm. Following the proposal from the SCRS, the ICCAT Commission agreed to use the new growth table as indicated in paragraph 26 Rec. 22-08 to ensure that the weight gain of harvested farm bluefin tunareported on the eBCDs are coherent with the new growth rates in the new growth table. The new growth rate table covers bluefin tuna caged from size 70 to 250 cm SFL and harvested from 1 to 35 months, being the first year by month and the 2nd and 3rd year by quarter. However, because of the methods to estimate farm growth rates, the table has a few empty cells, because no farm harvest data was available for these size-time in farm cell combinations. While further investigations and updates on this

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table are encouraged, the filling in the blanks and interpolations between each data point were explicitly requested in the PA2-30 for this table to be precise enough for monitoring the individual weight of import/export tunas. This document describes the way to fill in the gaps and interpolations. This interpolated table is subject to review by the BFT WG in 2023. If the way for the interpolation is acceptable, the SCRS will propose it in the 2023 ICCAT Commission meeting as it is the current best available estimate.

2. Filling in blanks

There are blanks in the tables due to the lack of data for GLMM estimation model (SCRS/2022/178). As the farm growth rates were estimated based on the size of fish, it was decided to use interpolation within a given size class bin, assuming that the growth rates are linear between months when missing data information. The values in blanks within a row (same size bin) were estimated as the averages of the neighbor (month + 1, and month - 1) values. When there are 2 or more consecutive blanks, the values in blanks are linearly interpolated between the nearest values. Consequently, the blanks between the existing values were filled in to be linear. For small fish (70 – 110 cm SFL), normally they are not harvested in the first six months, thus there are several blank cells in the top-left corner of **Table 1**. For this boundary condition, it was assumed that small fish do not gain weight during the first month at the farm and have the same weight as wild fish, then for months 2 and forward, there is a linear interpolation with the first month that has estimates of growth rates. Finally for cells in the last right column (e.g., last quarter of 3rd year), as there are no further estimates of growth, interpolation was calculated as the average of neighborhood values in a row above and below.

3. Daily interpolation with 1 cm-interval size bin

The eBCD has a record of the caging and harvest dates, estimated weight at caging, and actual weight at harvest. In order to monitor the weight gain of farming tunas from caging to harvest precisely, it was requested for the table to be precise enough, corresponding to the eBCD information. Therefore, we made a daily for the 1st year (1-365 farm-days) table with 1 cm SFL interval size bin by just linear interpolation for the expected average and 95thtile weight at harvest. Initially, it was requested a table with 1 kg at caging estimated, however, because the weight-size function is not linear, for large size fish 1 cm size increase covers about 3-4 kg in weight. If the length at caging is available in eBCD based on the measurement by stereoscopic camera, it would lead to the accuracy enhancement to utilize this table.

The linear interpolation assumed initial caging on May 1st and harvest during the year until April 30 of the following year, accounting for the actual number of days per month (365 days year). A part of the table is shown in the **Table 4** because the whole table is too large to put it in this document, examples of the daily growth trend for some initial size classes are shown in **Figure 1**, including the estimated upper 95thtile the proxy used as expected maximum growth in farming operations.

References

- Japan. (2023) The report of growth rate analysis and possible suggestion towards the update of growth table. PA2_30, Meeting document in intersessional Panel 2, Mar 2023.
- Ortiz, M., Mayor C., Alemany, F. and Paga, A. (2022) Analysis and results of weight gain Eastern Bluefin tuna (*Thunnus Thynnus*) in farms. Collect. Vol. Sci. Pap. ICCAT 79(3), 992-1021, SCRS/2022/178.

Table 1. Updated matrix table of the expected mean weight at harvest (kg) of farmed bluefin tuna as a function of size at caging (rows) and time in farms (columns, month at farm). The 1st year estimates are for each month, for the 2nd and 3rd year the estimates are for 3-month period, and the value indicated correspond to the mid-month. The values in parenthesis correspond to the estimated upper 95% confidence interval (CI). (SCRS/2022/178, Table 6)

Predicted wgt (kg) at harvest (95% upp CI) by month at farm																								
		Month at farm																						
Grp size	Start age	Size 10 bin	Wgt at cag	1	2	3	4	5	6	7	8	9	10	11	12	14	17	20	23	26	29	32	35	
small	1.9	70	7			12 (32)	23 (44)	28 (50)	29 (52)	34 (56)	36 (58)	38 (60)	29 (50)	29 (50)	44 (66)	43 (65)	49 (72)	50 (73)	51 (73)	56 (79)			72 (95)	
small	2.4	80	10			19 (39)	29 (51)	35 (57)	36 (58)	40 (63)	42 (65)	44 (67)	35 (57)	36 (56)	51 (73)	50 (71)	55 (78)	57 (79)	58 (80)	63 (85)	76 (98)	79 (101)	79 (101)	
small	2.8	90	14			11 (31)	29 (49)	39 (61)	45 (67)	46 (68)	50 (73)	52 (75)	54 (77)	45 (67)	46 (67)	61 (83)	60 (82)	66 (88)	67 (89)	68 (90)	73 (95)	86 (109)	89 (111)	89 (111)
medium	3.3	100	19			13 (60)	30 (79)	43 (92)	50 (99)	52 (101)	53 (102)	54 (103)	60 (110)	62 (111)	73 (122)	86 (135)	68 (117)	80 (130)	90 (139)	92 (140)	114 (162)	122 (171)		132 (180)
medium	3.8	110	25			24 (71)	41 (90)	54 (104)	61 (110)	63 (112)	64 (113)	65 (114)	71 (121)	73 (122)	84 (133)	97 (146)	79 (128)	91 (141)	101 (150)	103 (151)		133 (182)	140 (189)	143 (191)
medium	4.4	120	32	25 (69)	36 (83)	53 (102)	67 (116)	73 (123)	75 (124)	76 (126)	77 (127)	84 (133)	85 (135)	96 (145)	109 (158)	91 (141)	104 (153)	113 (162)	115 (163)	138 (185)	146 (194)	153 (202)		
medium	5.0	130	40	41 (85)	52 (99)	69 (118)	82 (132)	89 (138)	91 (140)	92 (141)	93 (143)	100 (149)	101 (150)	112 (161)	125 (174)	107 (157)	119 (169)		131 (179)	153 (201)	162 (210)	169 (217)	171 (219)	
medium	5.6	140	50	59 (103)	70 (117)	87 (136)	100 (150)	107 (156)	109 (158)	110 (159)	111 (161)	118 (167)	119 (168)	130 (179)	143 (192)	125 (175)	137 (187)	147 (196)	149 (197)	171 (219)		187 (235)	189 (237)	
medium	6.2	150	61	81 (124)	92 (139)	109 (158)	122 (172)	129 (178)	131 (180)	132 (181)	133 (182)	139 (189)	141 (190)	152 (201)		147 (197)	159 (209)	169 (218)	171 (219)	193 (241)	201 (250)		211 (259)	
medium	6.9	160	74	106 (150)	117 (164)	134 (183)	147 (197)	154 (203)	156 (205)	157 (206)	158 (208)	165 (214)	166 (215)	177 (226)	190 (239)		185 (234)	194 (243)		218 (266)	227 (275)	234 (282)	236 (284)	
medium	7.6	170	88	131 (175)	142 (189)	159 (208)		179 (229)	181 (231)	182 (232)	184 (233)	190 (239)	191 (241)	202 (252)	215 (264)	198 (247)	210 (259)	219 (268)	221 (269)	244 (292)	252 (301)	259 (308)		
large	8.4	180	104	118 (198)	142 (224)	175 (257)	196 (277)	205 (286)	207 (289)	206 (288)	206 (288)	216 (297)	216 (298)	238 (319)	239 (320)	225 (306)	239 (321)	249 (331)	267 (346)		274 (354)	279 (359)	299 (378)	
large	9.2	190	121	145 (225)	170 (251)	203 (284)	223 (305)	232 (314)	234 (316)	234 (315)	234 (315)	243 (325)	244 (325)	265 (346)	266 (348)	252 (334)		277 (358)	294 (374)	282 (361)		306 (387)	326 (405)	
large	10.1	200	141	175 (255)	200 (281)	233 (314)	253 (334)		264 (346)	264 (345)	263 (345)	273 (355)	273 (355)	295 (376)	296 (377)	282 (364)	296 (378)		324 (404)	312 (391)	331 (411)			
large	11.1	210	162	207 (287)	231 (313)	265 (346)	285 (366)	294 (376)		295 (377)	295 (377)	305 (386)	305 (387)	327 (408)	328 (409)	314 (395)	328 (410)	338 (420)		344 (423)	363 (443)	368 (448)	388 (467)	
large	12.2	220	186	240 (320)	264 (345)	297 (379)	317 (399)	326 (408)	329 (411)			337 (419)	338 (419)	359 (441)	361 (442)	346 (428)	361 (442)	371 (452)	389 (468)		395 (475)	401 (481)	420 (499)	
large	13.4	230	211	272 (352)	296 (377)	330 (411)	350 (431)	359 (440)	361 (443)	360 (442)	360 (442)					393 (474)	379 (460)	393 (475)	403 (485)	421 (500)	409 (488)		453 (532)	
large	14.8	240	239	304 (384)		362 (443)	382 (464)	391 (473)	394 (475)	393 (474)	393 (474)	402 (484)	403 (484)	424 (505)				436 (517)	453 (533)	441 (520)	460 (540)	465 (546)		
large	16.3	250	269	330 (409)	355 (434)	388 (468)	408 (488)	417 (497)	420 (500)	419 (499)	419 (499)	428 (508)	429 (509)	450 (530)	451 (531)	437 (517)	451 (531)			467 (545)	486 (565)	491 (570)	511 (589)	

Table 2. Table of expected weight at harvest for farmed bluefin tuna filling in the blanks of expected average values of **Table 1**. The values highlighted are interpolated values, in yellow by row linear interpolation between predicted values, in orange boundary estimates. For the first month (size 70-120) it was assumed the same weight as at caging, for the last quarter (month 35) interpolation is for adjacent rows above and below.

SizeCatch_ GrpSize	Time_Farm																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	14	17	20	23	26	29	32	35
70 small	7	7	9	12	23	28	29	34	36	38	29	29	44	43	49	50	51	56	64	72	76
80 small	10	10	14	19	29	35	36	40	42	44	35	36	51	50	55	57	58	63	76	79	79
90 small	14	14	11	29	39	45	46	50	52	54	45	46	61	60	66	67	68	73	86	89	89
100 medium	19	19	13	30	43	50	52	53	54	60	62	73	86	68	80	90	92	114	122	127	132
110 medium	25	25	24	41	54	61	63	64	65	71	73	84	97	79	91	101	103	118	133	140	143
120 medium	32	25	36	53	67	73	75	76	77	84	85	96	109	91	104	113	115	138	146	153	157
130 medium	40	41	52	69	82	89	91	92	93	100	101	112	125	107	119	125	131	153	162	169	171
140 medium	50	59	70	87	100	107	109	110	111	118	119	130	143	125	137	147	149	171	179	187	189
150 medium	61	81	92	109	122	129	131	132	133	139	141	152	150	147	159	169	171	193	201	206	211
160 medium	74	106	117	134	147	154	156	157	158	165	166	177	190	187	185	194	206	218	227	234	236
170 medium	88	131	142	159	169	179	181	182	184	190	191	202	215	198	210	219	221	244	252	259	268
180 large	104	118	142	175	196	205	207	206	206	216	216	238	239	225	239	249	267	270	274	279	299
190 large	121	145	170	203	223	232	234	234	234	243	244	265	266	252	264	277	294	282	294	306	326
200 large	141	175	200	233	253	259	264	264	263	273	273	295	296	282	296	310	324	312	331	344	357
210 large	162	207	231	265	285	294	295	295	295	305	305	327	328	314	328	338	341	344	363	368	388
220 large	186	240	264	297	317	326	329	332	335	337	338	359	361	346	361	371	389	392	395	401	420
230 large	211	272	296	330	350	359	361	360	360	368	377	385	393	379	393	403	421	409	428	433	453
240 large	239	304	333	362	382	391	394	393	393	402	403	424	426	428	432	436	453	441	460	465	482
250 large	269	330	355	388	408	417	420	419	419	428	429	450	451	437	451	457	462	467	486	491	511

Table 3. Table of expected maximum weight at harvest (95%tile) for farmed bluefin tuna filling in the blanks of expected average values of **Table 1**. The values highlighted are interpolated values, in yellow by row linear interpolation between predicted values, in orange boundary estimates. For the first month (size 70-120) it was assumed the same weight as at caging, for the last quarter (month 35) interpolation is for adjacent rows above and below.

SizeCatch_ GrpSize	Time_Farm																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	14	17	20	23	26	29	32	35
70 small	15	15	23	32	44	50	52	56	58	60	50	50	66	65	72	73	73	79	87	95	98
80 small	21	21	30	39	51	57	58	63	65	67	57	56	73	71	78	79	80	85	98	101	101
90 small	31	31	31	49	61	67	68	73	75	77	67	67	83	82	88	89	90	95	109	111	111
100 medium	45	45	60	79	92	99	101	102	103	110	111	122	135	117	130	139	140	162	171	176	180
110 medium	56	56	71	90	104	110	112	113	114	121	122	133	146	128	141	150	151	167	182	189	191
120 medium	88	69	83	102	116	123	124	126	127	133	135	145	158	141	153	162	163	185	194	202	205
130 medium	84	85	99	118	132	138	140	141	143	149	150	161	174	157	169		179	201	210	217	219
140 medium	87	103	117	136	150	156	158	159	161	167	168	179	192	175	187	196	197	219	227	235	237
150 medium	94	124	139	158	172	178	180	181	182	189	190	201	199	197	209	218	219	241	250	255	259
160 medium	104	150	164	183	197	203	205	206	208	214	215	226	239	236	234	243		266	275	282	284
170 medium	117	175	189	208	218	229	231	232	233	239	241	252	264	247	259	268	269	292	301	308	331
180 large	174	198	224	257	277	286	289	288	288	297	298	319	320	306	321	331	346	350	354	359	378
190 large	188	225	251	284	305	314	316	315	315	325	325	346	348	334	346	358	374	361	374	387	405
200 large	205	255	281	314	334	340	346	345	345	355	355	376	377	364	378	391	404	391	411	423	436
210 large	225	287	313	346	366	376	376	377	377	386	387	408	409	395	410	420	421	423	443	448	467
220 large	248	320	345	379	399	408	411	413	416	419	419	441	442	428	442	452	468	472	475	481	499
230 large	273	352	377	411	431	440	443	442	442	450	458	466	474	460	475	485	500	488	508	513	532
240 large	302	384	414	443	464	473	475	474	474	484	484	505	507	509	513	517	533	520	540	546	560
250 large	333	409	434	468	488	497	500	499	499	508	509	530	531	517	531	536	541	545	565	570	589

Table 4. Expected weight (kg) at harvest of farmed bluefin tuna by 1 cm SFL size at caging (cols) and days in farm (rows). Values estimated by linear interpolation from **Table 2**.

Expected wgt at harvest kg																
Weight at caging (kg)		6	6	7	7	7	8	8	8		281	285	288	291	294	298
Day in farm \ SFL cm		70	71	72	73	74	75	76	77		254	255	256	257	258	259
1		6.64	6.64	6.64	6.64	6.64	6.64	6.64	9.80		271.07	271.07	271.07	271.07	271.07	271.07
2		6.64	6.64	6.64	6.64	6.64	6.64	6.64	9.80		273.05	273.05	273.05	273.05	273.05	273.05
3		6.64	6.64	6.64	6.64	6.64	6.64	6.64	9.80		275.02	275.02	275.02	275.02	275.02	275.02
4		6.64	6.64	6.64	6.64	6.64	6.64	6.64	9.80		277.00	277.00	277.00	277.00	277.00	277.00
5		6.64	6.64	6.64	6.64	6.64	6.64	6.64	9.80		278.98	278.98	278.98	278.98	278.98	278.98
6		6.64	6.64	6.64	6.64	6.64	6.64	6.64	9.80		280.96	280.96	280.96	280.96	280.96	280.96
7		6.64	6.64	6.64	6.64	6.64	6.64	6.64	9.80		282.94	282.94	282.94	282.94	282.94	282.94
8		6.64	6.64	6.64	6.64	6.64	6.64	6.64	9.80		284.92	284.92	284.92	284.92	284.92	284.92
9		6.64	6.64	6.64	6.64	6.64	6.64	6.64	9.80		286.90	286.90	286.90	286.90	286.90	286.90
10		6.64	6.64	6.64	6.64	6.64	6.64	6.64	9.80		288.88	288.88	288.88	288.88	288.88	288.88
11		6.64	6.64	6.64	6.64	6.64	6.64	6.64	9.80		290.86	290.86	290.86	290.86	290.86	290.86
12		6.64	6.64	6.64	6.64	6.64	6.64	6.64	9.80		292.84	292.84	292.84	292.84	292.84	292.84
....
355		39.39	39.39	39.39	39.39	39.39	39.39	39.39	45.82		451.03	451.03	451.03	451.03	451.03	451.03
356		39.89	39.89	39.89	39.89	39.89	39.89	39.89	46.32		451.07	451.07	451.07	451.07	451.07	451.07
357		40.39	40.39	40.39	40.39	40.39	40.39	40.39	46.82		451.11	451.11	451.11	451.11	451.11	451.11
358		40.89	40.89	40.89	40.89	40.89	40.89	40.89	47.32		451.15	451.15	451.15	451.15	451.15	451.15
359		41.39	41.39	41.39	41.39	41.39	41.39	41.39	47.82		451.18	451.18	451.18	451.18	451.18	451.18
360		41.88	41.88	41.88	41.88	41.88	41.88	41.88	48.32		451.22	451.22	451.22	451.22	451.22	451.22
361		42.38	42.38	42.38	42.38	42.38	42.38	42.38	48.82		451.26	451.26	451.26	451.26	451.26	451.26
362		42.88	42.88	42.88	42.88	42.88	42.88	42.88	49.32		451.30	451.30	451.30	451.30	451.30	451.30
363		43.38	43.38	43.38	43.38	43.38	43.38	43.38	49.82		451.34	451.34	451.34	451.34	451.34	451.34
364		43.88	43.88	43.88	43.88	43.88	43.88	43.88	50.31		451.38	451.38	451.38	451.38	451.38	451.38
365		44.38	44.38	44.38	44.38	44.38	44.38	44.38	50.81		451.41	451.41	451.41	451.41	451.41	451.41

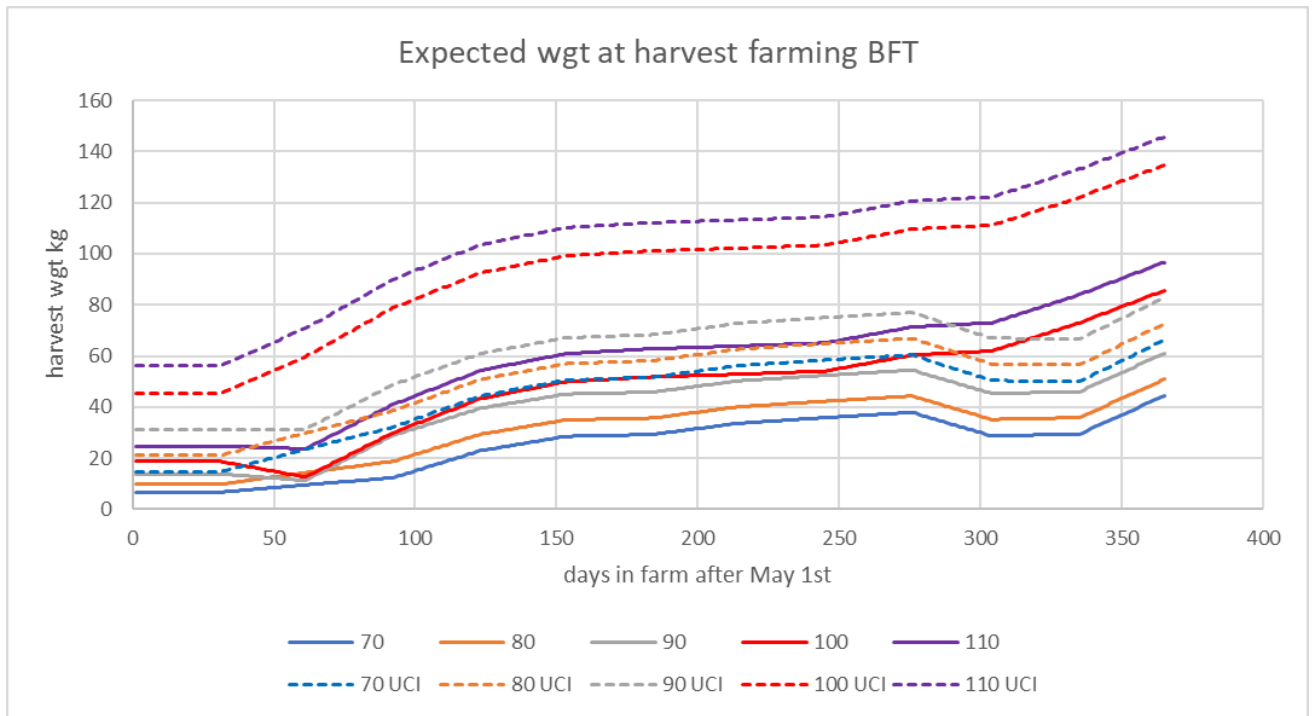


Figure 1. Expected weight at harvest for farmed bluefin tuna by size at caging (solid lines) and days in the farm. Dashed lines indicated the expected upper 95%tile, used as a proxy for maximum expected growth.