EU MALTA METHODOLOGY FOR THE USE OF STEREOSCOPIC CAMERA SYSTEMS AT TIME OF CAGING

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SUMMARY

In line with the standards and procedures for Stereoscopical Camera systems in the context of caging operations as outlined in Annex 9 of ICCAT Recommendation 14-04, additional information is hereby being provided on the methodologies used on the processing and data acquisition from these systems. The methodologies provided are the ones utilized during the 2014 caging season in Malta and were fully tested on the field. Additional information includes recording procedures used during caging operations and releases at farm sites, validation protocols for Stereoscopical length measurements together with step by step protocols for counting, taking measurements and choosing representative length samples for the determination of the average weight of fish caged.

RÉSUMÉ

Conformément aux normes et procédures pour les systèmes de caméra stéréoscopique dans le contexte des opérations de mise en cage, telles que décrites à l'annexe 9 de la Recommandation 14-04 de l'ICCAT, des informations supplémentaires sont fournies sur les méthodologies utilisées dans le traitement et l'acquisition des données à partir de ces systèmes. Les méthodologies fournies sont celles utilisées pendant la saison de mise en cage de 2014 à Malte et ont été entièrement testées sur le terrain. Les informations supplémentaires incluent les procédures d'enregistrement utilisées pendant les opérations de mise en cage et de remise à l'eau dans les fermes, les protocoles de validation pour les mesures de longueur stéréoscopique ainsi que les protocoles étape par étape pour le comptage, la prise de mesures et le choix d'échantillons de taille représentatifs pour la détermination du poids moyen des poissons en cage.

RESUMEN

En línea con los estándares y procedimientos para los sistemas de cámaras estereoscópicas en el contexto de las operaciones de introducción en jaulas establecidos en el Anexo 9 de la Recomendación 14-04 de ICCAT, a continuación se facilita información adicional sobre las metodologías utilizadas en la obtención de datos y su procesamiento a partir de estos sistemas. Las metodologías facilitadas son las utilizadas durante la temporada de introducción en jaulas de 2014 en Malta y fueron totalmente probadas sobre el terreno. La información adicional incluye procedimientos de grabación utilizados durante las operaciones de introducción en jaulas y las liberaciones en las granjas, protocolos de validación para las mediciones estereoscópicas de talla junto con protocolos paso por paso para contar, tomar medidas y elegir muestras de talla representativas para la determinación del peso medio de los peces enjaulados.

KEYWORDS

Atlantic Bluefin Tuna, Size composition,
Catch composition, Length-weight relationships, Fishery regulations

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1. Introduction

The ICCAT Commission adopted ICCAT Recommendation 14-04 to establish a multi-annual recovery plan for Bluefin Tuna (BFT) in the Eastern Atlantic and Mediterranean. Paragraph 83 of ICCAT Recommendation 14-04 calls for Contracting Parties (CPCs) to adopt a programme using Stereoscopical Camera (SC) systems to cover 100% of all cagings in order to refine the number and weight of the fish in each caging operation.

Malta as a member state within the EU Contracting party, committed itself to follow this recommendation and the SC was implemented in all full scale commercial caging operations as an enforcement and control monitoring tool. The use of the AM100 SC system currently in use in Malta for measuring biomass of BFT caged was developed in Australia for Southern BFT and Japan for Pacific BFT. The current development methods of the AM100 SC system includes reported and published results from use on Southern and Pacific BFT, which were scrutinized by BFT management authorities and through the academic publication process. While the same SC system has been adopted for use in the Mediterranean on Atlantic BFT, the methods adopted for deployment and processing have varied from those used on Southern BFT. Variations include methods of camera deployment, transfer gate sizes and data processing. This document is a first in describing the methodology currently in use in the central Mediterranean on Atlantic BFT. Operational methodologies for the AM100 system described in this document were developed following four successive years of use on the field during caging operations into Maltese farms.

2. Methodology

2.1 Stereoscopic Camera Equipment

The AM100 SC system utilised for underwater recordings in Malta is supplied by AQ1 Systems Pty Ltd. The system allows a non-invasive, rapid, accurate measurement and counting of any fish or marine organism. The system consists of two high resolution, high sensitivity 1.4 Megapixel Prosilica colour cameras (GigE digital Ethernet) in a rugged marine grade, powder-coated anodized aluminium underwater housing (Dimensions 924 x 368 x 224mm, mass 16kg, depth rated to 40m). The camera housing is connected by means of an underwater cable (high grade polyurethane CAT 5e) to a semi-rugged laptop (14' Panasonic Toughbook - C53 model) installed with the AM100 analysis software. The complete system is supplied by a power pack composed of two 12VDC 44AH batteries connected in series, with a dedicated DC supply for the laptop and a 24VDC industrial battery charger (**Figure 1**). Batteries in use are of a deep cycle marine grade gel type.

The AM100 analysis software (AM100 analyser, Version 2.0.7.4146, 2007-2013) based on Windows XP allows users to size and count BFT underwater and can export count and sizing data in 'csv' format. Sizing can be done by single or multiple point-to-point measurements that can be used to model functions such as mass. The AM100 analysis software can count objects moving past a fixed point, which is ideal as counts are made during recordings of transfers of BFT from cage to cage or from purse seine to cage.

2.2 Stereoscopic Camera Procedure at Farm Site

All operations recorded and monitored by SC camera in the water were carried out in accordance with the procedures as set out in Annex 9 of ICCAT Recommendation 14-04. Two diving inspectors from the Department for Fisheries and Aquaculture were present at each caging operation. An underwater inspection by divers was made in the recipient cage before the gate was opened. Before opening the gate for the transfer, a rod of known length was lowered in the water and recorded at different distances (**Figure 2**). Measurements from the SC were compared to the actual measurement of the steel rod for a validation of the SC length measurements as per Annex 9 of ICCAT Recommendation 14-04.

The camera was continuously held by a diver at the side of the transfer door to be correctly pointed at the gate/net opening. The entire transfer operation from the donor to the recipient cage was recorded from this position. This method provides the most reliable image/data quality, as the diver can rapidly correct for the effects of swell, current and movements of the net due to wash from vessel thrusters or movement of the cage. Tying the camera to the cage is highly problematic and is not recommended. The diver holding the camera positioned himself as close as possible to the Net opening/Gate, while maintaining full view of the opening in at least one of the two camera images.

The video footage included the caging details clearly displayed at the beginning or end of the video (**Figure 3**) and the SC video recording commenced with the transfer door still closed. This was useful for making final adjustments for achieving the best image quality possible. At the end of each caging transfer a diver from the Department for Fisheries and Aquaculture conducted an inspection in the donor cage to verify whether any fish were left behind; video recording was only stopped following this check and when the transfer door was closed.

A backup of all relevant recorded video footages was made on an external drive and uploaded to a secure server to have an additional backup.

2.3 Testing the Calibration of the Stereoscopic Camera

Prior to making any length measurements on the recorded footage a validation of the SC length measurements was undertaken by the use of a scale bar of known length as per Annex 9 of ICCAT Recommendation 14-04. The part of the video footage with the calibration rod was located and the necessary measurements were carried out with the sizing mode of the AM100 software. SC measurements on the scale bar were carried out as follows:

a) The video frame where the calibration rod reference points are clear in both images and at least very clear in one of the images was selected.
b) The 'enhance frame' brightness and contrast of the AM100 software was utilised to improve quality of image when necessary.
c) The best of the two frame images for making the initial point marks was selected, adjusting image quality as necessary with image enhance options.
d) The measurement was discarded when the range was > 4.5m away.
e) Acceptable FL% (% Fork Length) error was of the maximum of the software default value of 1.5% for measurement rods of 2 meters and longer. For measurement rods shorter than 2 meters in length the applicable FL% error was that as described in Table 1.
f) Best judgement was used to move point marks of the calibration rod edges in such a way that the nose and caudal fork errors were lower than 0.2 mm. If this was unable to achieve, the measurement was discarded.

Measurement procedure (a) to (f) was adopted from Deguara et.al, (2013). A minimum of three measurements were made on the calibration rod at the range of 2.0 - 4.5 m from the camera. Individual measurement errors were lower than 1% of the actual length of the calibration rod, which is in line with field tests carried out by the manufacturer (Dodd, 2013). For more extended measurement ranges (4.5 – 8 m) a maximum error of 2% is also acceptable according to manufacturer specifications (AQ1, 2009).

2.4 Making a Count with the SC system

The count mode within the AM100 software was selected and counts were carried out as follows:

a) The window with the best view of the transfer gate was selected from the footage.
b) The recorded footage was moved frame by frame from the opening to the closing of the transfer door.
c) Fish were counted by marking each fish with a cross. The AM100 analysis software produces reports on fish counting which consists of a video files with counted fish identified with a cross which fades away over successive frames. Each time a cross is placed on a fish the software records a count and the video frame the count was applied. The counts were made by scrolling back and forward through the recording and zooming in and out as necessary so that to identify each and every fish. An example of the AM100 counting software module is shown in **Figure 4**.

Before performing any counts, a cross-check to the video footage was made to ensure that all caging details (type of operation, BCD No/s., ITD No/s. and Reference number of relevant farming cage/s) were correct and clearly displayed at the beginning or end of the video (**Figure 3**). A verification was also carried out on whether the video footage included the opening and closing of the net/door and whether the receiving cages already contained bluefin tuna.

2.5 Estimation of the Average Weight with the SC system

2.5.1 Selection of a 20% Sample

Following the count carried out as explained in section 2.4 above, determination of the average weight and total biomass of fish caged was based on the measurement of a minimum of 20% sample of the fish, spread throughout transfer according to Annex 9 of ICCAT Recommendation 14-04.

The AM100 software consist of a 'counting module' (**Figure 4)** for making counts and a 'sizing module' (**Figure 5**) for the measurement of fish. The 20% sample was selected as follows:

a) The starting number of the first fish to be measured was selected between fish 'number 1' and 'number 5' from the 'counting measurements tab' of the AM100 file processed as explained per section 2.4. Subsequent fish were selected for measurement by advancing from one fish to the next in multiples of five, e.g. number sequence 5,10,15 ...., N. This was achieved by selecting the required fish identification number from the table displayed in the counting mode of the software (**Figure 4**). Once the desired fish was selected, the video was automatically advanced to the frame of the chosen fish. The software also highlighted the fish selected for ease of reference.

b) Once the selected fish was automatically highlighted in the counting mode of the software, the 'sizing measurements tab' was selected to allow the fork length measurement of the chosen fish.

c) Fish which did not conform to the sizing measurement procedure in Section 2.5.2 were discarded from the sample. If at the end of the footage a 20% sample was not achieved due to the exclusion of a number of fish, then a subsequent new measurement sequence was automatically generated by means of the excel algorithm as presented in **Annex 1** – 'Next Fish'. An excel screenshot of the selection sequence algorithm is provided in **Figure 6**.

2.5.2 SC Measurement Procedure by the SC Software

Sizing measurements followed the procedure below:

a) The frame where the nose and tail reference points were clear in both images and at least very clear in one of the images was selected.

b) The 'enhance frame' brightness and contrast of the AM100 software was utilised to improve quality of image when necessary.

c) The best of the two frame images for making the initial point marks was selected, adjusting image quality as necessary with image enhance options.

d) The measurements were discarded if range was > 8m away.

e) Acceptable FL% (% Fork Length) error was of a maximum of 1.5% for fish FLs of 2 meters and longer. For fish with FLs shorter than 2 meters in length the applicable FL% error was that as described in Table 1.

f) Best judgement was used to move point marks of the calibration rod edges in such a way that the nose and caudal fork errors were lower than 0.2 mm. If this was unable to achieve, the measurement was discarded.

As for section 2.3, measurement procedure (a) to (f) was adopted from Deguara et.al, (2013). Applicable fork length errors for fish measurements lower than 2m in fork length as presented in Table 1 were adopted during the 2014 BFT Maltese caging season according to the procedure explained in section 2.5.2.1 below. The length – weight conversion (**Figure 7**) utilized for converting the SC estimated Bluefin tuna fork lengths into weights during the 2014 caging operations was that of Rey and Cort (Unpublished).

2.5.2.1 Conversion of the SC Software 'FL error' for Fish Lower than 2m FL

Table 1 was developed to provide new values for the FL errors for fish lower than 2m FL. This was achieved by utilising the existing AM100 software and proceeding as follows:

a) The FL measurements from three 2014 cagings were utilised to calculate an overall mean FL of fish caged in 2014. Mean FL calculated was that of 1.996 m.

b) The default AM100 maximum FL error was of 1.5%. The calculated mean FL of 1.996 and the default FL error of 1.5% were used to calculate a mean measurement Standard Deviation as follows:

Mean Measurement Standard deviation= Mean FL X [FL Error/100]

c) The mean measurement Standard Deviation was then used to recalculate a new set of FL errors for smaller FL fish (< 2 m) according to the formula below. This enabled the immediate assessment of smaller fish without introducing a sample bias.

New Fork length error = Mean Measurement Standard Deviation / SC measured FL (m) X 100

d) The new values for the relative FL errors for fish lower than 2m FL were presented in a tabulated form (**Table 1**) for ease of use by the SC video processing operator, with the existing AM100 software.

2.6 Excess fish

In line with paragraph 83 of ICCAT Recommendation 14-04, if an outcome of an investigation indicates that the SC determined numbers or weight of Bluefin tuna caged in a single caging operation or from all cagings from a JFO are found to differ from the quantities reported caught and transferred, the catching CPC issued a release order for excess fish.

Releases during the Maltese 2014 caging season were carried out according to the following procedure:

1. The number of fish to be released were calculated as follows:

   Excess fish in weight/Average weight in kg determined by the SC = Number of pieces to be released.
2. The number of excess pieces authorized for release was transferred to a verification cage through an intra-farm transfer. Final release of fish into open sea was carried out from the verification cage and according to release protocol as per annex 10 of ICCAT Recommendation 14-04.
3. Verification cage was labeled with the format 'Release Verification/XX/Farm Name' where XX is the number of donor cage.
4. Following SC verification of the number of pieces for release, the verification cage was towed offshore and away from the farm.
5. Verification cage was towed at least 3 Nautical Miles outwards from the farm location prior to the release.
6. Final release from the verification cage into open water was recorded by SC as a final confirmation of the number of fish released.

3. Discussion

3.1 Making a Count with the SC system

At the moment there are variations in the use of the SC system in catch assessments between different EU Member states. The main variant is whether the SC system is used for both counting and size or just size estimates. In Malta the system is currently used for both counting and sizing estimates. The advantages and disadvantages of using the SC system for both counting and sizing are as follows:

a) Disadvantages

If the SC is not used for counting, then the camera can be moved closer to the gate enabling easier measurement processing because fish are closer to the camera.

b) Advantages

i. Traceability or transparency of data processing

Using the SC system for counting provides a record of each fish counted. This record is saved and can be reviewed by 3rd parties and is available for future reference. When counting off a conventional video, there is no record of the process for reviewing, other than repeating the whole process.

ii. Lower risk of data bias in sizing estimations

Moving the camera closer to the gate when the SC is used for sizing only, may lead to a section of the gate being consistently excluded from the video. This excluded section may be favored by a particular size class, with a risk of introducing a data bias. When the SC system is used for both counting and size, the whole gate is held within the field of view of the camera.

3.2 Estimation of the Average Weight with the SC System

In line with paragraph 83 of ICCAT Recommendation 14-04, the SC system was deployed to acquire both count and size data, with the latter based on measuring a 20% sample of the fish, spread throughout transfer.

3.2.1 Selection of a 20% Sample

The method described in section 2.5.1 for the selection of the 20% sample was developed to:

a) Save processing time when compared to replaying the video and manually counting the fish again to select 'one in every five specimens' for achieving a minimum of 20% sample as per Annex 9 of ICCAT Recommendation 14-04.
b) To achieve a non-biased sample, as the operator is not subjectively taking the decision as to which is the 5th fish to be measured.
c) Achieve traceability and transparency of the size sampling process.

The method adopted eliminates any possible operator bias as the operator is not put in a position to choose which fish to measure.

3.2.2 SC Measurement Procedure by the SC Software

The procedure presented in Section 2.5.2 was adopted from the one presented by Deguara et.al (2013) with quantified errors and precision values for SC measurements in field trials. The original procedure by Deguara et.al (2013) was clearly suitable for making accurate and precise BFT measurements at close range and ideal fish positioning in relation to the camera. However, it had the disadvantage that it was quite time consuming and stringent for commercial applications. The question therefore arises as to the effect on both accuracy and precision on the less stringent procedure adopted for commercial purposes as detailed in section 2.5.2. Although commercial SC applications do not allow the original procedure presented by Deguara et.al (2013) to be followed, accuracy of the measurements carried out will still be expected to be high. However, the percentage errors associated with deviations from the original procedure have not yet been quantified and further analysis to determine these should be carried out.

3.2.3 Conversion of the SC Software 'FL error' for Fish Lower than 2m FL

The maximum acceptable FL error parameter of 1.5% described in section 2.5.2 caused issues with the data processing. This FL error is a relative error and when a single value is used as a threshold, it is demanding a higher precision in length estimates for smaller fish. The current experience in Malta's 2014 caging operations was that the value of FL error of 1.5% resulted in more frequent rejection of smaller fish and hence risking of biasing the results of fish size estimates.

The FL error utilised by the SC software is defined as the standard deviation of the measurement, expressed as a percentage of the fork length measurement (i.e. a relative error):

FL error = Measurement Standard deviation/FL X100

Thus, if measurement standard deviation for two fish of different FL's is constant, an increase in FL would result in a decrease in FL error. For example, when comparing two fish one at 1.8m fork length and the other 0.7m, then a relative error of 1.5% for each of these gives an error in mm's as follows:

1800 X 0.015 = 27mm (Measurement Standard Deviation)
700 X 0.015 = 10.5mm (Measurement Standard Deviation)

So by using the FL error or relative error, it can be seen that the precision in mm's required for measurements of smaller fish is much higher than for larger fish, as measurement standard deviation for the former has to be lower for the same relative error of 1.5%.

As an alternative, new values for the relative FL errors for fish lower than 2m FL were developed according to the procedure as described in section 2.5.2.1. It may well be that the bias introduced when utilising the 1.5% FL for all the specimens sampled and more frequently discarding the smaller fish, is not large when compared with the variance associated with a 20% sampling of the population. However this requires more consideration, for example a sensitivity analysis for the whole sampling and measurement process. Given it is not good practise to knowingly have a biased sampling protocol; the approach adopted during the 2014 caging season was the simplest way to address the issue. In addition to the FL error the actual standard deviation of the FL estimate (in mm's) should be provided as an alternative measure for data quality.

4 Conclusion

As a consequence of the fact that analysis of the SC footage has to be carried out manually, it has been clear that a unifying methodology needs to be developed in order to standardise the FL measurement technique between ICCAT Contracting Parties. The document proposes a methodology fully tested on the field during commercial applications as a reference to other ICCAT CPCs involved in the use of SC during BFT during caging operations in line with Paragraph 83 of ICCAT Recommendation 14-04.

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Table 1: Conversion of the SC Software 'FL error' for Fish Lower than 2m FL

FL (m)	FL error (%)	FL (m)	FL error (%)	FL (m)	FL error (%)
0.30	9.98	0.90	3.33	1.50	2.00
0.35	8.55	0.95	3.15	1.55	1.93
0.40	7.49	1.00	2.99	1.60	1.87
0.45	6.65	1.05	2.85	1.65	1.81
0.50	5.99	1.10	2.72	1.70	1.76
0.55	5.44	1.15	2.60	1.75	1.71
0.60	4.99	1.20	2.50	1.80	1.66
0.65	4.61	1.25	2.40	1.85	1.62
0.70	4.28	1.30	2.30	1.90	1.58
0.75	3.99	1.35	2.22	1.95	1.54
0.80	3.74	1.40	2.14	2.00	1.50
0.85	3.52	1.45	2.06		

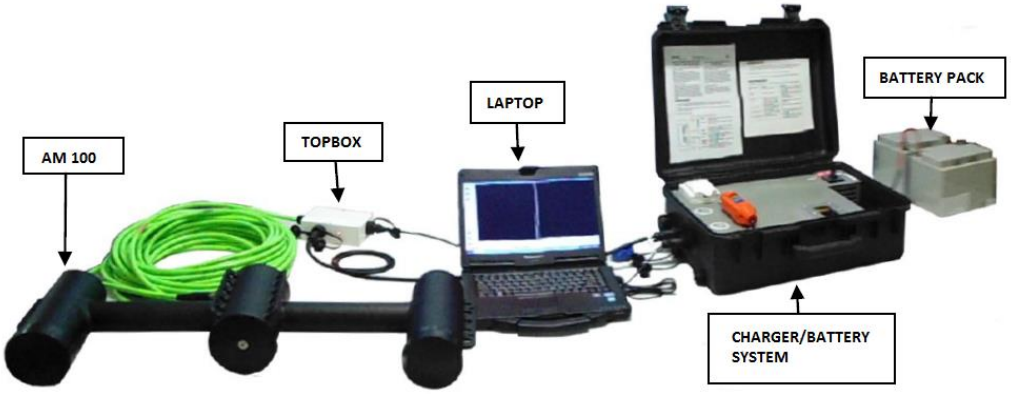

Figure 1. AM100, charger and battery system [Adapted from *AQ1 Systems Pty Ltd. AM100 Charger/Battery System User Manual*, (2013)]

Figure 2. Stainless steel rod of known length held by diver in front of the SC for validation of the SC length measurements.

Figure 3. Diver displaying transfer details in front of the SC for inclusion into the recorded footage.

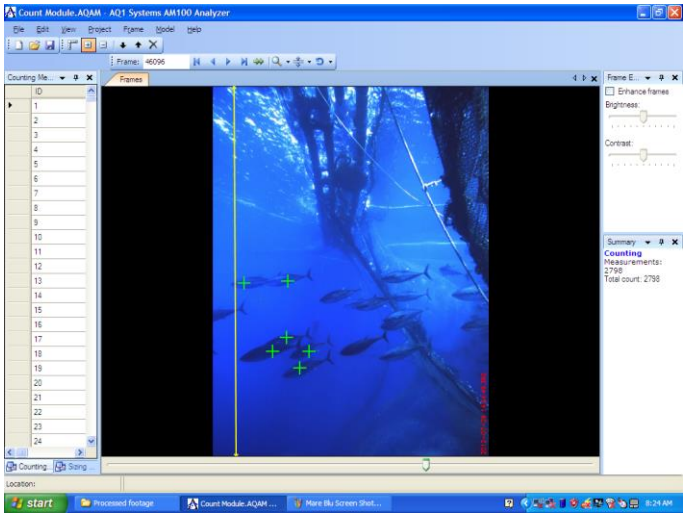

Figure 4. Screen shot from SC AM100 software counting module

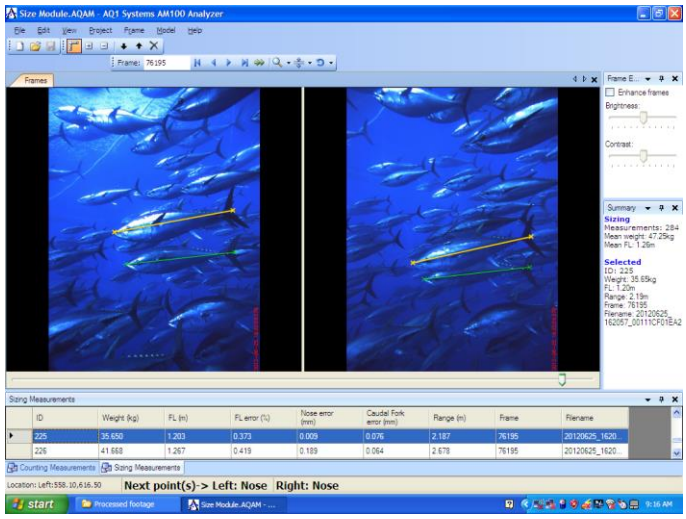

Figure 5. Screen shot from SC AM100 software module.

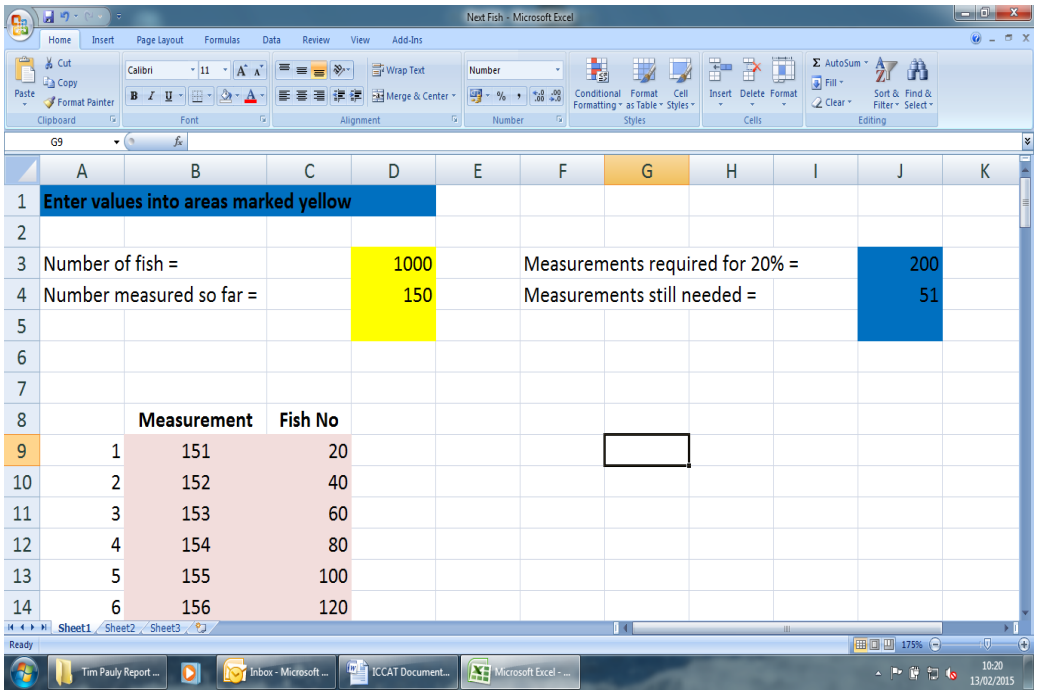

Figure 6. Screen shot from excel based algorithm for automatically selecting a new measurement sequence when 20% sample has not been reached in the first run.

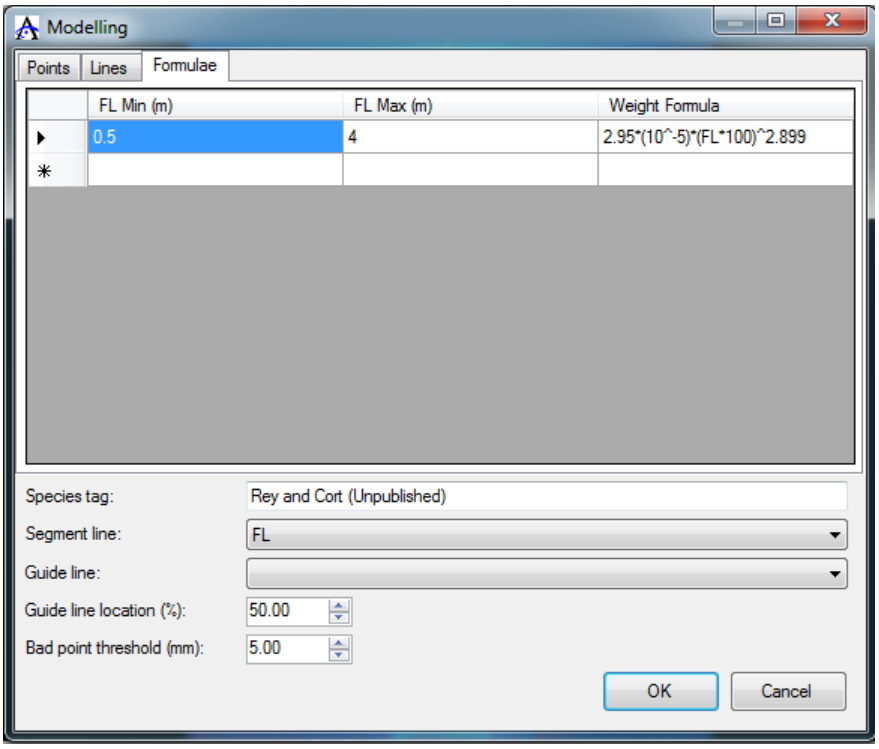

Figure 7. Screen shot from SC AM100 software module for the Length-weight formula used in the conversion of SC length measurements into weight for the 2014 caging season.

Annex 1 – ‘Next Fish’.

Enter values into areas marked yellow

Number of fish =	1000	Measurements required for 20% =	200		19,61
Number measured so far =	150	Measurements still needed =	51		20

	Measurement	Fish No		Measurement	Fish No
1	151	20	51	201	1020
2	152	40	52	202	1040
3	153	60	53	203	1060
4	154	80	54	204	1080
5	155	100	55	205	1100
6	156	120	56	206	1120
7	157	140	57	207	1140
8	158	160	58	208	1160
9	159	180	59	209	1180
10	160	200	60	210	1200
11	161	220	61	211	1220
12	162	240	62	212	1240
13	163	260	63	213	1260
14	164	280	64	214	1280
15	165	300	65	215	1300
16	166	320	66	216	1320
17	167	340	67	217	1340
18	168	360	68	218	1360
19	169	380	69	219	1380
20	170	400	70	220	1400
21	171	420	71	221	1420
22	172	440	72	222	1440
23	173	460	73	223	1460
24	174	480	74	224	1480
25	175	500	75	225	1500
26	176	520	76	226	1520
27	177	540	77	227	1540
28	178	560	78	228	1560
29	179	580	79	229	1580
30	180	600	80	230	1600
31	181	620	81	231	1620
32	182	640	82	232	1640
33	183	660	83	233	1660
34	184	680	84	234	1680
35	185	700	85	235	1700
36	186	720	86	236	1720
37	187	740	87	237	1740
38	188	760	88	238	1760
39	189	780	89	239	1780
40	190	800	90	240	1800
41	191	820	91	241	1820
42	192	840	92	242	1840
43	193	860	93	243	1860
44	194	880	94	244	1880
45	195	900	95	245	1900
46	196	920	96	246	1920
47	197	940	97	247	1940
48	198	960	98	248	1960
49	199	980	99	249	1980
50	200	1000	100	250	2000