DESIGN OF AN AERIAL SURVEY CALIBRATION EXERCISE AND AN UPDATED AERIAL SURVEYS SIGHTING PROTOCOL (ICCAT GBYP 08/2019) OF THE ATLANTIC-WIDE RESEARCH PROGRAMME FOR BLUEFIN TUNA (ICCAT GBYP Phase 8)

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1.- AERIAL SURVEY CALIBRATION EXERCISE DESIGN

1.1.- JUSTIFICATION

The estimation of the group sizes of large fish and marine mammal species is a key factor in obtaining the abundance of the target species and their trends over time. In distance sampling surveys, it is assumed that the participating observers are experienced. Despite performing training exercises, there are always differences of greater or lesser magnitude between them and, therefore, in most analyses the observer factor is included as a covariate to test whether or not it affects the detection function. Recently, Lennert-Cody, et al., (2019), in a review of line transect methodologies to estimate the abundance of dolphins in the Eastern Tropical Pacific suggests, among other improvements, to obtain more realistic estimates through the use of calibration factors. However, there are few studies that have addressed the question of the calibration of group size estimates among observers participating in marine fauna studies.

Gerrodete et al., 2002 carried out a study on the calibration of the dolphin group size estimates detected by visual observers during the annual ship surveys carried out in the eastern tropical zone of the Pacific Ocean. For the calibration of estimates, a helicopter was used. Every time a group of dolphins was detected, it took off from the deck of the ship and took aerial photos of the group of dolphins. After the analysis of 1978 estimates of 366 sightings of dolphins, correction factors were established for 52 observers. Although the type of bias varied greatly within observers and years, it was detected a general tendency to underestimate group size in sightings with more than 10 individuals, with the percentage of underestimation being greater the larger the actual size of the dolphin group was. On average, the percentage of subestimation was 25.8%.

Hammond et al. (2013). during SCANSII survey, applied the double platform method to correct perception and availability biases of cetaceans in the North East Atlantic. In such method, two teams of observers are located independently at different heights, making the search effort in different areas in front of the ship. Because the observers of the upper platform use high-magnification binoculars, in the case of duplicate sightings between the two platforms, the group-size estimates of the lower platform are corrected with the estimates registered by the observers on the upper platform, since the latter have much more time to obtain their estimates during the tracking of the detected groups. The correction factors obtained in this study were very diverse, varying between boats and species. In the case of the target species, the porpoise, the correction factors of the group size varied between 0.73 and 1.92

Evenson et al., 2018 calculated the differences between the observers estimating the biomass of the juvenile bluefin tuna detected in the aerial surveys over the "Great Australian Bight" (South Australia). The authors selected the data set from the observer with more participations in the historical sampling series (1993-2000 and 2005-2009) and calculated the differences between these biomass estimates and those from the observers who flew with him (5 among a totals of 11 observers). Except in the case of one observer, who systematically estimated downwards by 20%, the rest of the observers included in the analysis presents estimations close to those of thereference observer.

The aerial surveys of the Atlantic-Wide Research Programme for Bluefin Tuna (ICCAT GBYP) have been carried out in 2010, 2011, 2013, 2015, 2017 and 2018. Most of the years 4 teams have flown over the high-density areas of Balearic Islands, Tyrrhenian Sea, Malta and Turkey. In total, 86 different crew members (27 pilots, 18 professional spotters and 41 scientific spotters) have participated in those surveys. Although there are few cases of observers that have participated systematically in all the surveys, most of them have participated only once, introducing a potential bias in experience and hence in the abundance estimates. From 2017, during the training course, a practical exercise based on drawing and photographs of tuna schools taken in real working conditions is carried out to assess the differences between the observers when estimating the number of individuals present in a tuna school.

When analysing the results of the professional spotters in different years a huge variability is shown, not only between observers, but between the estimations of the same observer in different years, ranging from 50% underestimation to more than 200% overestimating (Figure 1).

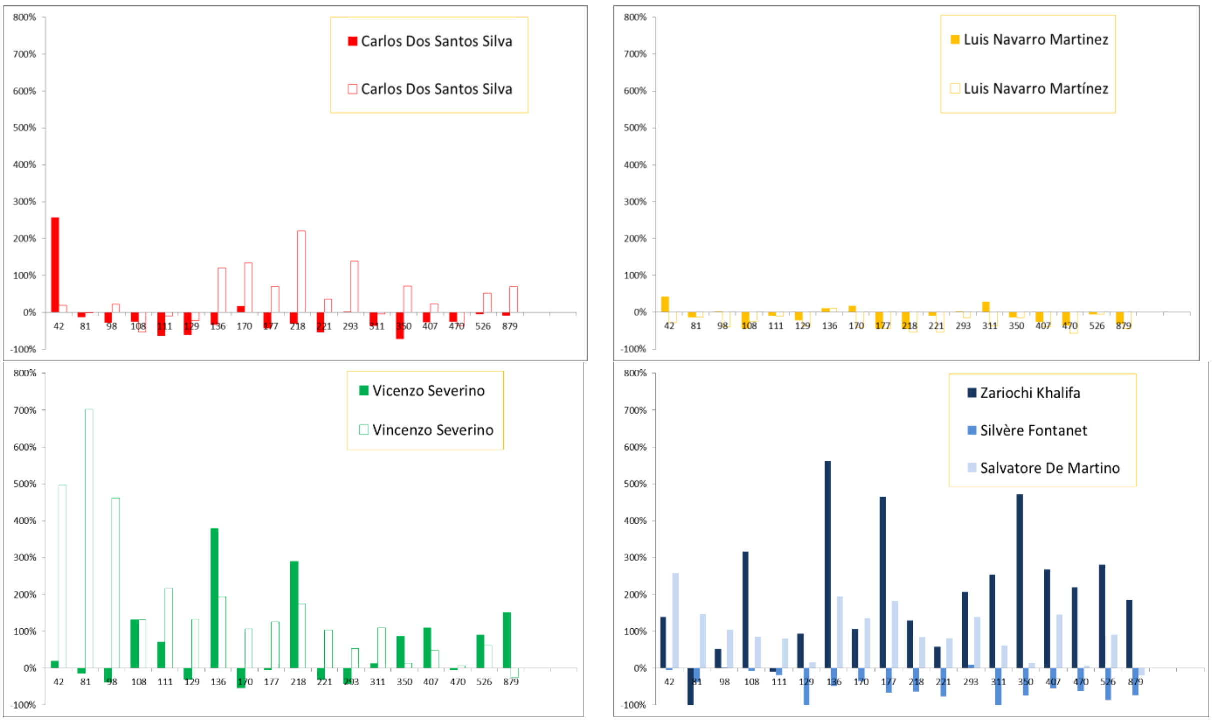


Figure 1. Differences between real numbers and estimates of different professional spotters during the practical exercise to estimate number of individuals in tuna schools.

From 2015, within the field surveys it is mandatory both for the professional spotter and for the scientific spotters located behind him to get independent estimates of number of individuals and their weight. Figure 2 and 3 shows the difference, by area, between both estimates, professional vs.

scientific spotters, in terms of numbers and kilograms, respectively. With the exception of area A in 2015 and area A and G in 2018, SS tend to underestimate the group sizes. Regarding weights, in area A and C in 2015, area E in 2017 and area A and G in 2018 SS clearly tend to overestimate weight, whereas in area E in 2015, area A, C and G in 2017 and area C, E and G in 2018 SS tend to underestimate weight. All these preliminary analyses suggest that some kind of differences between observers may occur in the study area and therefore a calibration exercise is highly recommendable in order to assess the magnitude of this potential source of bias.

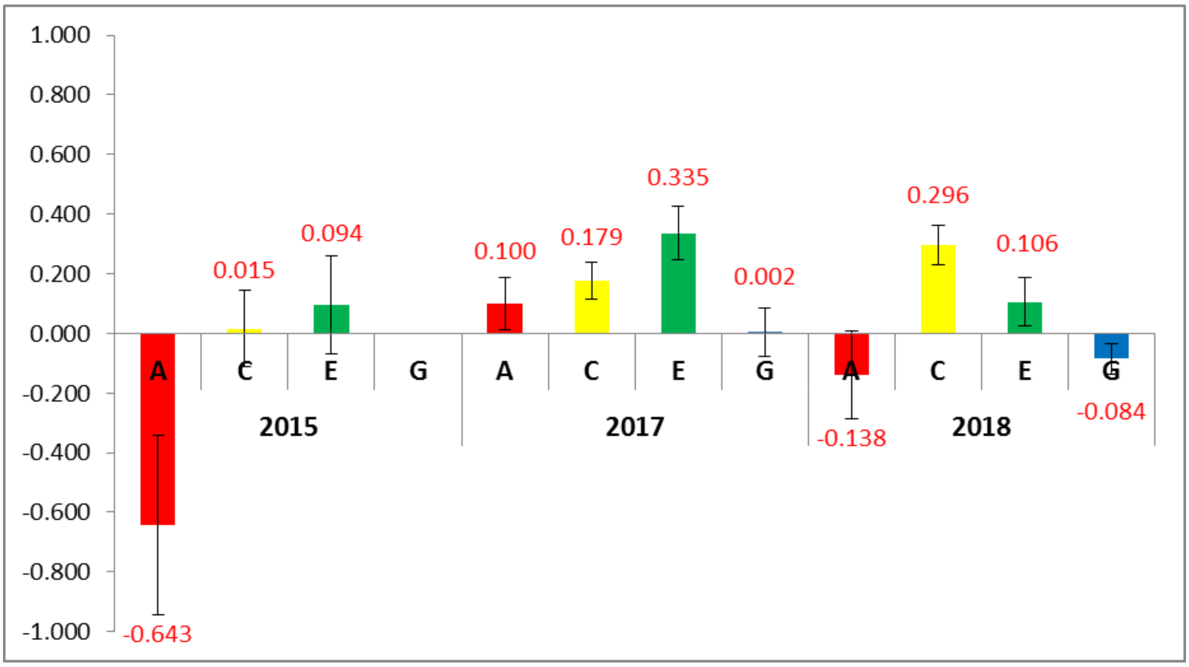


Figure 2. Differences between professional spotters and scientific spotter group size estimates of bluefin tuna per area and year (2015-2017-2018).

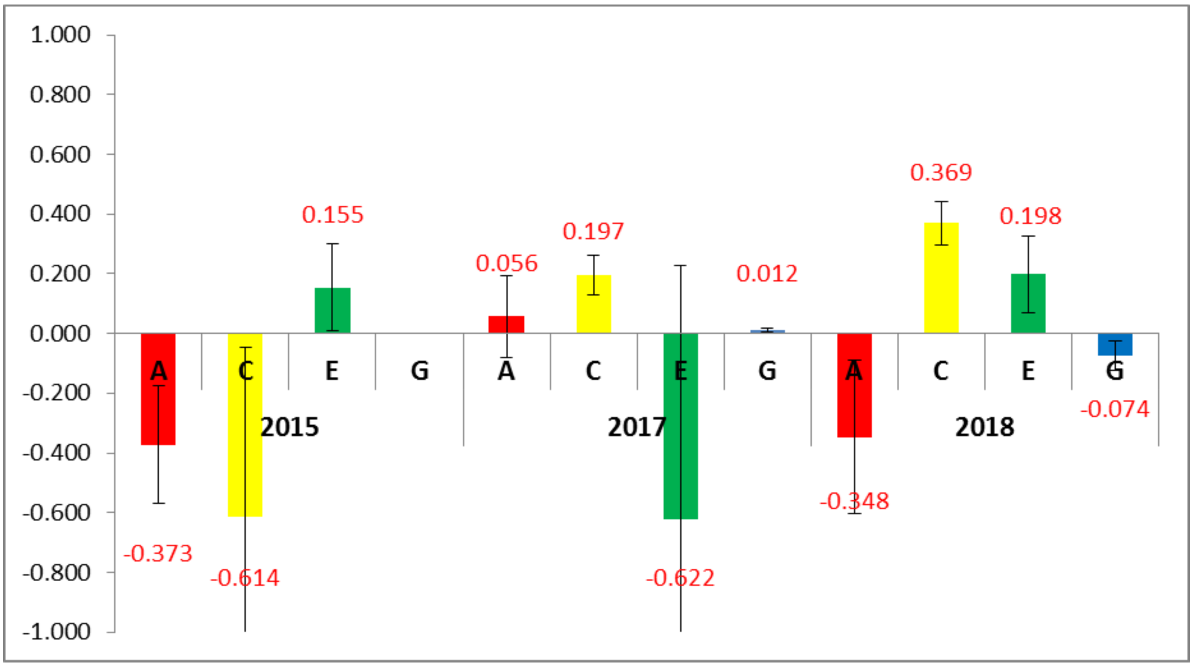


Figure 3. Differences between professional spotters and scientific spotter weight estimates of bluefin tuna per area and year (2015-2017-2018).

1.2.- OBJECTIVE

The main objective of the aerial survey calibration/validation exercise to be developed in the Balearic sea at the end of 2019 GBYP aerial survey is to calibrate the sightings of the professional spotters who have participated in at least two GBYP aerial surveys in a given area and/or two areas along the three last years, aiming at providing a series of "correction factors" useful for minimizing the additional variance when elaborating the aerial survey data.

1.3.- DETAILED DESCRIPTION OF REQUIERED EQUIPMENT

- AIRCRAFT

Taking into account that the crew members for this exercise will include the pilot, the scientific coordinator and 4 professional spotters (one per study area), the aircraft must be suitable for accommodation of 6 persons. In order to maximize the available financial sources, the aircraft must be able to fly a minimum of 4 hours per flight with the 6 crew members onboard.

The aircraft must have headphones for 6 persons and the communication system must be able to split the conversations between the pilot and the control tower from the conversations between the scientific coordinator and the 4 professional spotters. Although is not strictly necessary for this exercise it would be recommendable to have bubble windows for the professional spotters.

The aircraft must have 200v power supply for the scientific coordinator computer. The company would have to supply a GPS for the scientific coordinator and a computer suitable for this kind of work. The company must also supply a Reflex Camera with a 50-200mm zoom lens to take pictures of every detected school. The aircraft must have all the security elements, life jackets, smoke masks, life raft, etc. The company must give a security and rescue training course to all the crew members before starting the survey.

Among all the available aircraft models BN2 Islander would have preference. In case that it was no possible to get this model for the dates needed, the use of a Partenavia P68 could be considered, but in this case the minimum hours per flight must to be reduced due to security reasons. It would be taken into consideration if the aircraft have the possibility to install video/photo cameras just in the bottom part of the plane, just below the professional spotters' locations, in order to get pictures of the detected schools.

- SIGHTING STRATEGY

Figure 4 shows the positions of the blue fin tuna sightings recorded in the Balearic Islands area during the last week of June and first week of July (2010-2018), when the calibration exercise will take place. It seems that there are two areas with higher encounter rate; one in the northern part of Mallorca channel during then last week of June, and other in the southwest part of Ibiza and Formentera islands during the first week of July. This displacement could be indicating the movements of the schools towards the strait of Gibraltar after the spawning event. So, although these two areas will be selected as preferential ones, the final areas to search tuna schools will be decided in base of the sightings distribution of the GBYP aerial survey Phase 9, the historical data, and the additional data coming form the fishing and scientific vessels in the area.

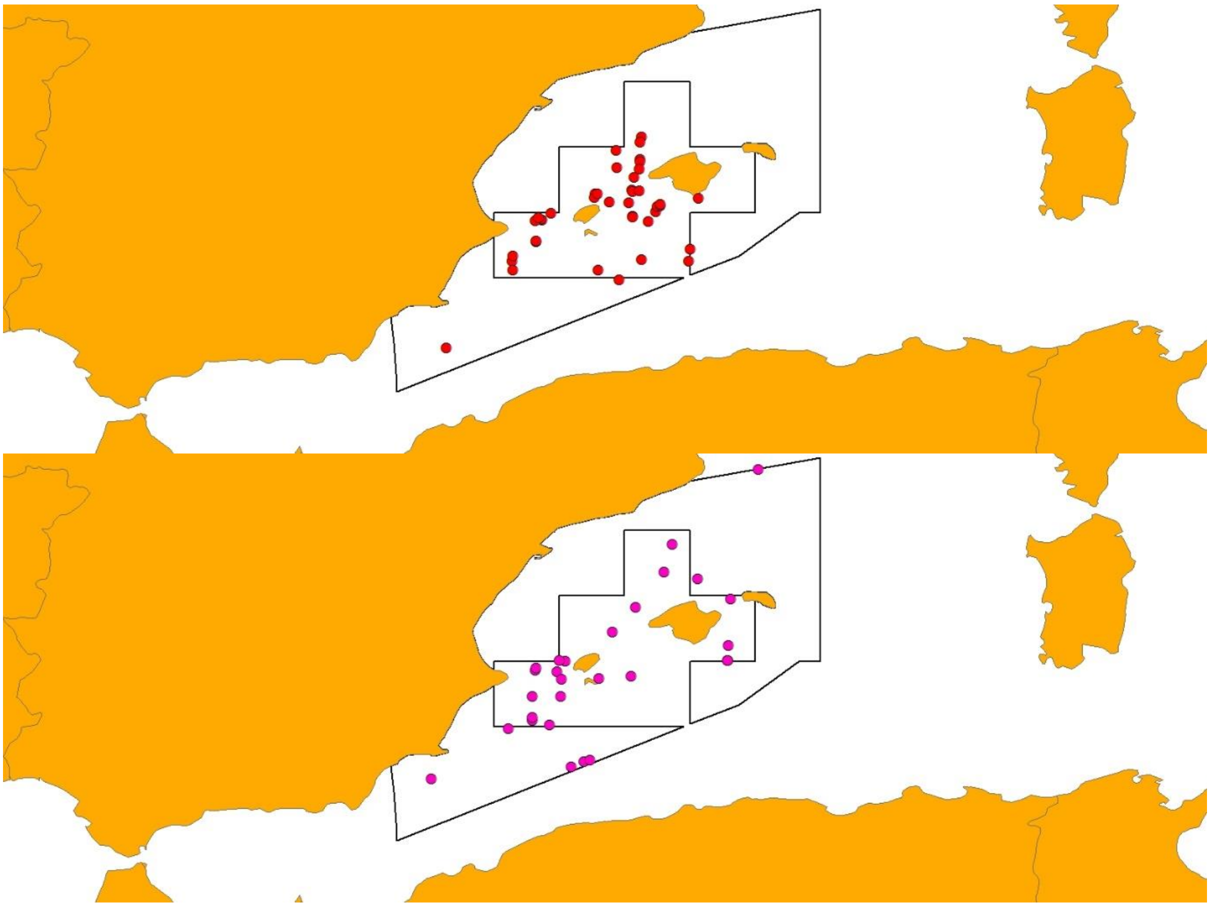


Figure 4. Positions of the BFT sightings registered during the study period (2010-2018) in Balearic Islands. Upper figure corresponds to the last week of June and lower figure corresponds to the first week of July

- SIGHTING PROTOCOL

While the requirement in the annual GBYP aerial survey is to cover the area in a homogenous and random way, in the calibration exercise the main objective is to find as many BFT schools as possible. Because of that, the survey protocol will be similar to the one used by the fisherman in the past. The area to be surveyed every fly will be discussed the day before between the scientific coordinator, the pilot and the local professional spotter. Every time that a BFT be detected the scientific coordinator will record the basic data, lat, lon, time, date, and will ensure that every PS write independently the number of individuals, the average individual weight and the school weight in kilograms. The plane will circle the school as many times as needed until all the PS have their estimates and the SS have a good picture of the school. If necessary, the SS can ask the pilot fly at lower height to take a better picture of the school.

- TARGET NUMBER OF SIGHTINGS

There is no target number of sightings because in this case the limitating factor is the money available to fly, so the team will fly as many hours as possible during the study period.

2.- IMPROVEMENT OF GBYP AERIAL SURVEY PROTOCOL

The GBYP aerial surveys have been carried out from the very beginning using the “line sampling transect” methodology, and the associated sighting methods have been explained in detail to all the participants within the framework of ad hoc training courses held every year in ICCAT Secretariat headquarters. In addition, a first written protocol and standard forms were produced and used in 2015 (GBYP Phase 5). Such protocol was refined in 2017, and this improved version has been used since then, in 2017, 2018 and 2019 surveys. However, within the in depth internal review of GBYP aerial surveys programme carried out in 2018, some potential sources of bias were detected, and it became clear that there was still some room for improvement. Specifically, the main detected potential problems, which require special attention, were:

- The standardization of methodologies to calculate declination angles.
- The potential loss of effective observation time due to the time dedicated to register previous sightings.
- The differences in the observation patterns between professional and scientific spotters.
- The alternative methods to get more accurate estimates of total number of animals, average weight of individuals and total weight of the group.

Thus, in order to address these issues and prevent any bias in data acquisition, a refined sighting protocol was required to Alnilam, the company in charge of aerial surveys design and data analysis in previous GBYP phases. A first version of this improved protocol was already used as reference for 2019 GBYP aerial surveys. The definitive version of this new improved protocol is that attached to this report as Annex 1.

2.1.- DECLINATION ANGLES

The distance sampling method applied in the Atlantic–wide research programme for Bluefin tuna to estimate spawners abundance in the Mediterranean waters is based on the one used in cetacean studies, as described in Hammond et al., (2013). Apart from the altitude and the distribution of the team inside the aircraft, basically the methodology is the same. In aerial surveys there are two types of distance sampling methods; strip transect and line transect. While in the former, marks in the wins or windows are used to register how many sightings there are in each band, in the later, clinometers are used to measure the individual perpendicular distance from each sighting to the transect line (Bucland et al., 2001). Although the ICCAT Atlantic-Wide Research Programme for Bluefin Tuna (GBYP) Aerial Survey Protocol suggests that the perpendicular distances of each BFT sighting be measured by clinometer, in some cases marks on the bubble windows have been used instead. The advantage of the use of marks on the bubble windows is that the observer has a better view of the school while estimating the angle, but if the bunk angle of the aircraft varies during the observation bias can be introduced. In conclusion, the declination angle must always be measured by clinometers.

Figure 5. Left and central pictures show the marks in wins and bubble windows used in strip transects. Right picture shows an observer using an inclinometer to measure declination angles in line transect surveys.

In relation to this matter, it is essential that the head of the observer inside the bubble window when recording the declination angle is in the proper position, that is, the observer must see all the time the imaginary line of the transect located just below the aircraft (see figure 6). If this is not the case, bias can be introduced.

2.2.- MISSING TIMES WHILE RECORDING OTHER SPECIES SIGHTINGS

It is mandatory that scientific observers enter all the required data in the effort and sightings forms provided by GBYP. As indicated in the protocol, "*The core objective of the ICCAT GBYP aerial survey is to provide annual relative abundance minimum estimates for bluefin tuna (Thunnus thynnus) spawners in the Mediterranean Sea. However, data will be also collected (whenever possible) for all species encountered (mainly other tunas and big fish, cetaceans, and turtle species) if this does not compromise data collection for the target species*". In general, up to now most of the teams write down the effort and sighting data into notebooks, but in some areas, like in area A, a laptop computer running the Logger 2010 software is used to collect the data.

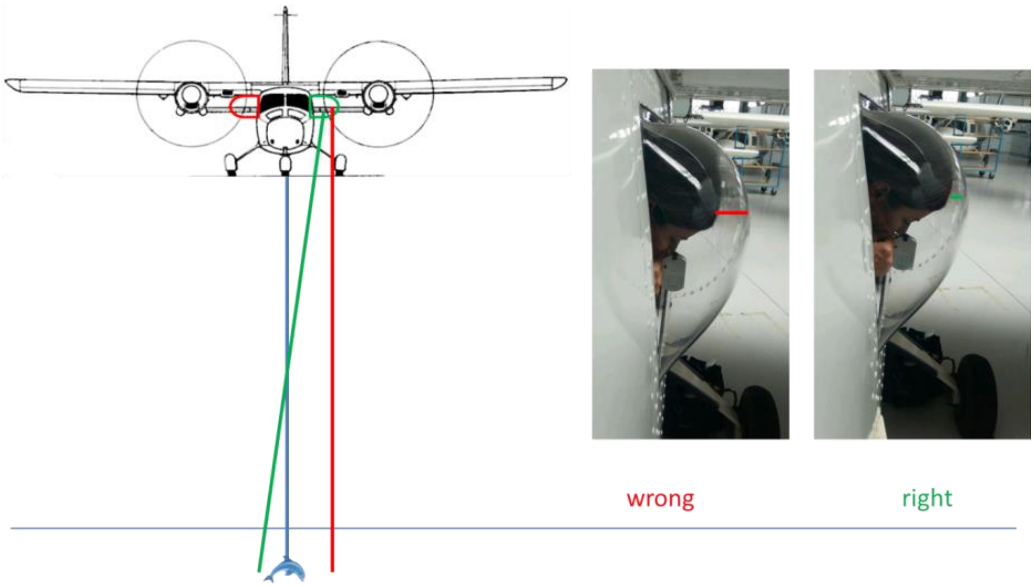


Figure 6. Position of the head that the observer must keep during the estimation of declination angle of the BFT schools.

In high density areas of cetaceans/turtles/manta rays, the time necessary to fill out all the data may imply that the observer in charge of recording the information is not actively searching for BFT during that period, affecting the effective searching time. Vazquez et al. (2018) analysed the data collected with Logger 2010 software during ICCAT-GBYP Phase 5 survey in area A, in order to estimate the time the observers need to fill the data of each sighting (Figure 7), since the Logger 2010 software allows to record in a very easy way the time when the animals are detected and the time when the sighting form is filled and stored.

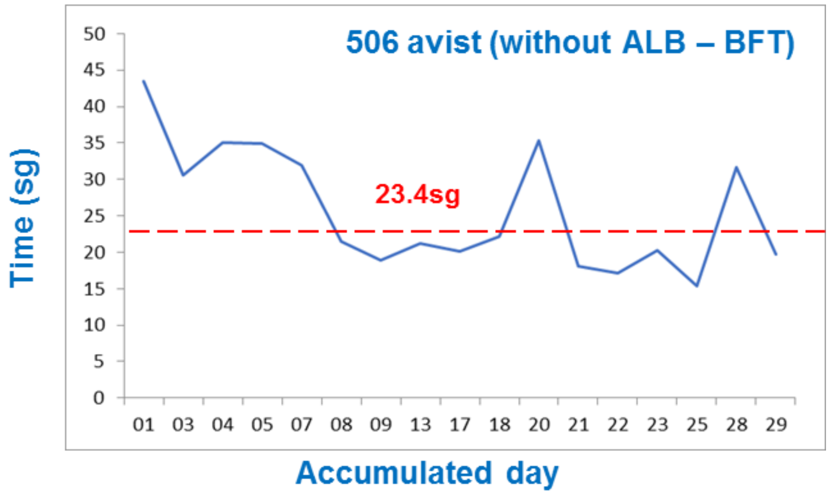


Figure 7. Average time needed to fill up the sighting form in Logger 2010 software throughout the study period.

The result shows that the average time needed to fill the sighting form of the "non target" species (cetaceans, turtles and other fish species) has a decreasing trend from 43.5 s the first day of the survey to 23.4s the last day of the survey, indicating that the observers need less time to fill the sighting form as they are familiar with the software (figure 7).

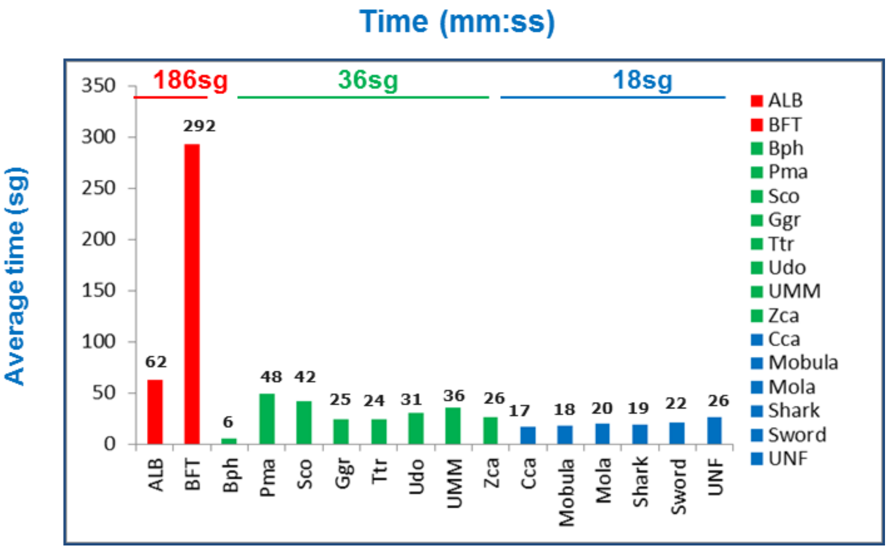


Figure 8. Average time in seconds needed to fill the sighting form in Logger 2010 software by group of species: red bars –tunas, green bars-cetaceans and blue bars- turtles and other fish species.

On the other hand, the time needed to fill out the sighting form is not the same for all groups of species detected. While for tuna species the average time required is 292s for Bluefin tuna and 32s for other tuna species, for cetacean species varied from 6s in the case of fin whales and 48s in the case of sperm whales, for turtles is 17s and for other fish species varied from 18s in the case of mantas and 22s in the case of swordfish (figure 8). Leaving aside the case of Bluefin tuna, the fact that cetacean species require more time than turtles and fishes is related with the difficulty to identify the species and the numbers of individuals, compared with turtles and other fish species that usually have lower group sizes, mostly 1 individual, which makes faster the filling procedure. The total amount of time needed for filling out all sightings of non-target species during 2015 area A was 197.81 minutes, which represent 610 km, representing 4% of the total effort done. That means that during this period of time the observer wasn't actively searching one side of the aircraft, so it should be taken into account in the analysis to remove the proportional length on one of the sides when estimating the effective strip width and total density.

Taking into account that at 300m height and 100knots speed the observer is covering a field of view from 40º ahead to 40º behind (714m), It means that theoretically the observer has approximately 13.9 s to spot a school. As a conclusion of this study, in order to prevent this potential bias factor, the following modification, which was already included in the reference protocol for 2019 survey operations, is proposed: "*If the time while recording the sightings is more than 10 s the data recorder must switch to search effort looking for BFT during at least 5 seconds, before finishing the collecting of the remaining data. In those cases of high density areas of cetaceans – turtles, with several sightings in very short period of time, the cruise leader must decide if all them should be grouped into a single sighting or the recording of sightings should be temporarily suspended, until the end of the high density area*."

In addition, in 2019 an automatic sound recorder was used within the Logger 2010 software in area A. This tool allows to record all the information regarding each sighting in a sound file. Thus, whenever the observer needs more time than 10 s to fill the data or in high density areas, the observer can keep the active searching and file the information of each sighting as an audio file, avoiding this potential source of bias.

The **RECOMMENDATION** is to use the Logger 2010 software in all the areas in future surveys. There should be necessary to include a training session on how to use the software during the annual course that takes place every year in the ICCAT headquarters.

2.3.- DIFFERENCES IN THE OBSERVATION PATTERNS BETWEEN PROFESSIONAL AND SCIENTIFIC SPOTTERS

Cañadas and Vazquez (2016) carried out in-depth analyses of the collected data from 2010 to 2015 in order to assess the reliably and consistency with which the survey protocols had been implemented within years among the different companies and airplanes. One of the conclusions of these analyses was that when pooling together all data coming from all years and teams, the overall pattern was good, but when looking at each team individually there were large differences. In Action Air both observers looked at close distances, stopping the search at 1000m and 500m for PS and SS respectively. In Group Air Med there was not a clear pattern for PS, with less detections in closest and longest distances and a relative peak at mid distances, around 1500m. The search pattern for SS was not bad with most of the detections in close distance but with a non-desirable relative second peak around 1000m. In case of Perigod, both search patterns were quite good. Lastly, Unimar presented similar problems as Grup Air Med for PS and no clear pattern for SS due to the small sample size.

It is somewhat strange that in all the companies the four PS have registered sightings at very short distances, between 0 and 250m, since according to the protocol the PS should be located in the place of the co-pilot without a bubble window. So, this could mean that the PS did not sit in the required place, at least not during all the flight time. Cañadas and Vazquez (2016) conclude that "*It is clear that in most cases PS tend to look further away than SS, despite having repeatedly insisted that the most important observations for the analysis are those at shortest distances. This searching pattern by the PS needs to be corrected so they understand the importance of searching more at closer distances*".

To prevent these detected anomalies affecting the data collection, a special effort was made during the training courses, insisting on the importance of following the protocol, in particular, on the importance of occupying the required seat and properly follow the required search pattern especially in the shortest distances.

Figures 9, 10, 11 and 12 show the frequency histogram of perpendicular distances at which schools of BFT were detected in areas A, C, E and G, respectively, for different periods; 2010-2015, 2017-2019 and 2019. Despite the insistence of following the protocols in the training course, during the analysis carried out in 2017 and 2018, it was noticed that some PS still recorded mostly sightings at long distances. To prevent this from happening again in the future, it is recommended to specifically include in the new improved protocol the following: "if the detected bluefin tuna groups are more than 5000m away, the aircraft should not leave the transect", in order to discourage scientific spotters to focus their sighting effort on longer distances. The adoption of this recommendation seems to solve the problem as shown in the frequency histograms of PS sightings in 2019

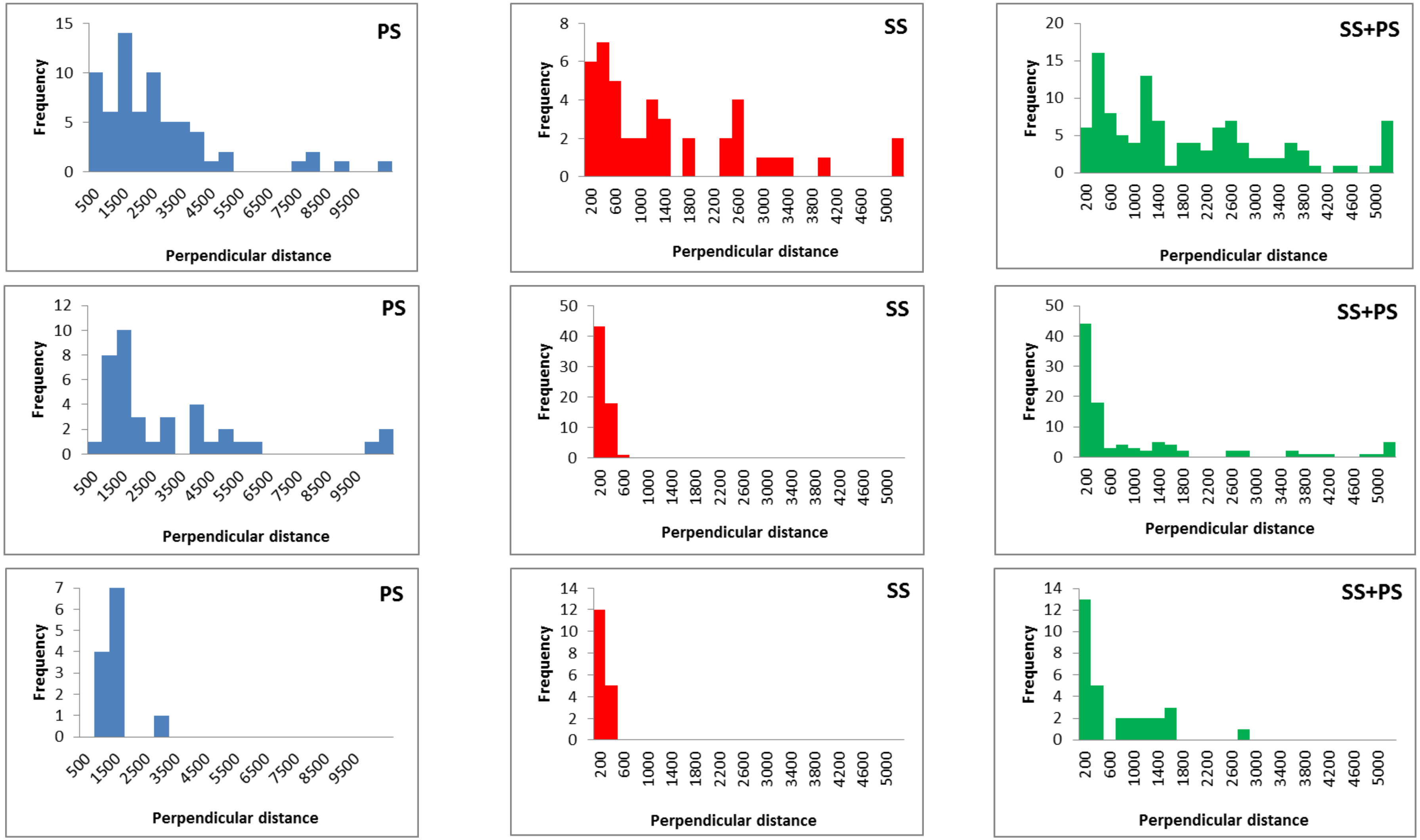


Figure 9. Frequency histogram of perpendicular distances at which schools of BFT were detected in area A. Upper graphics correspond to 2010-2015 period, middle graphics to 2017-2019 period, lower graphics to 2019. PS: professional spotter. SS: scientific spotter.

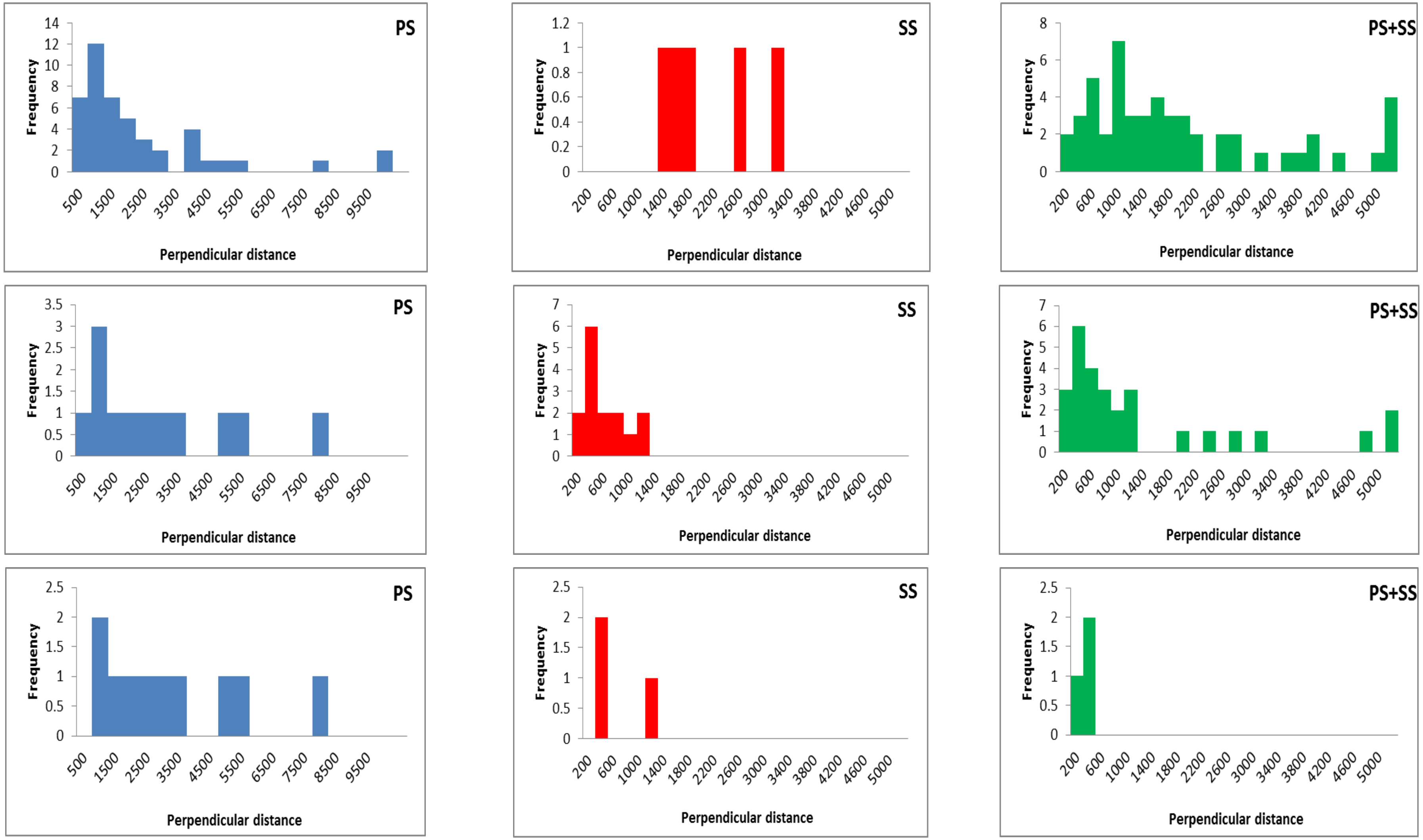


Figure 10. Frequency histogram of perpendicular distances at which schools of BFT were detected in area C. Upper graphics corresponds to 2010-2015 period, middle graphics to 2017-2019 period, lower graphics to 2019. PS: professional spotter. SS: scientific spotter.

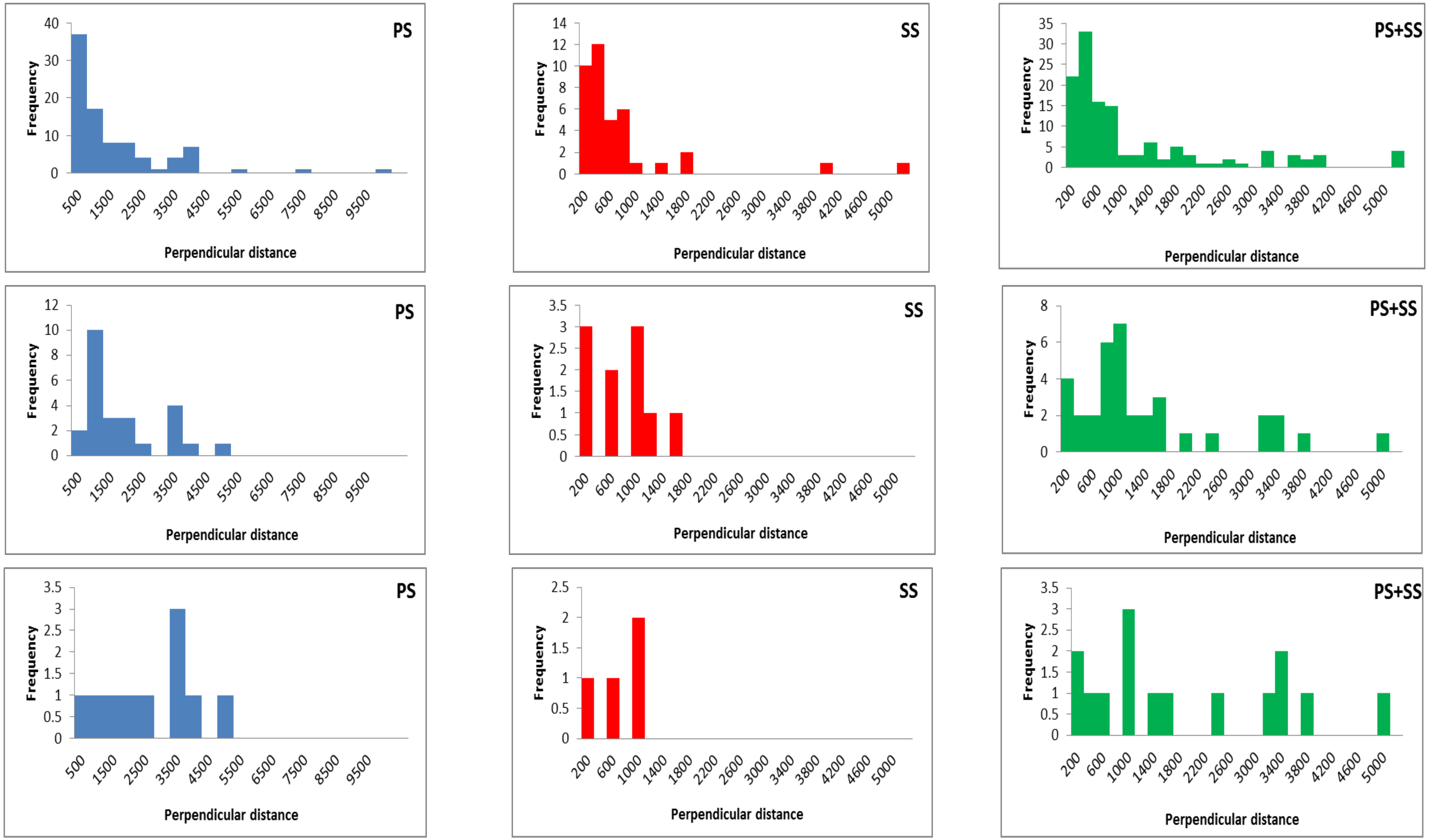


Figure 11. Frequency histogram of perpendicular distances at which schools of BFT were detected in area E. Upper graphics corresponds to 2010-2015 period, middle graphics to 2017-2019 period, lower graphics to 2019. PS: professional spotter. SS: scientific spotter.

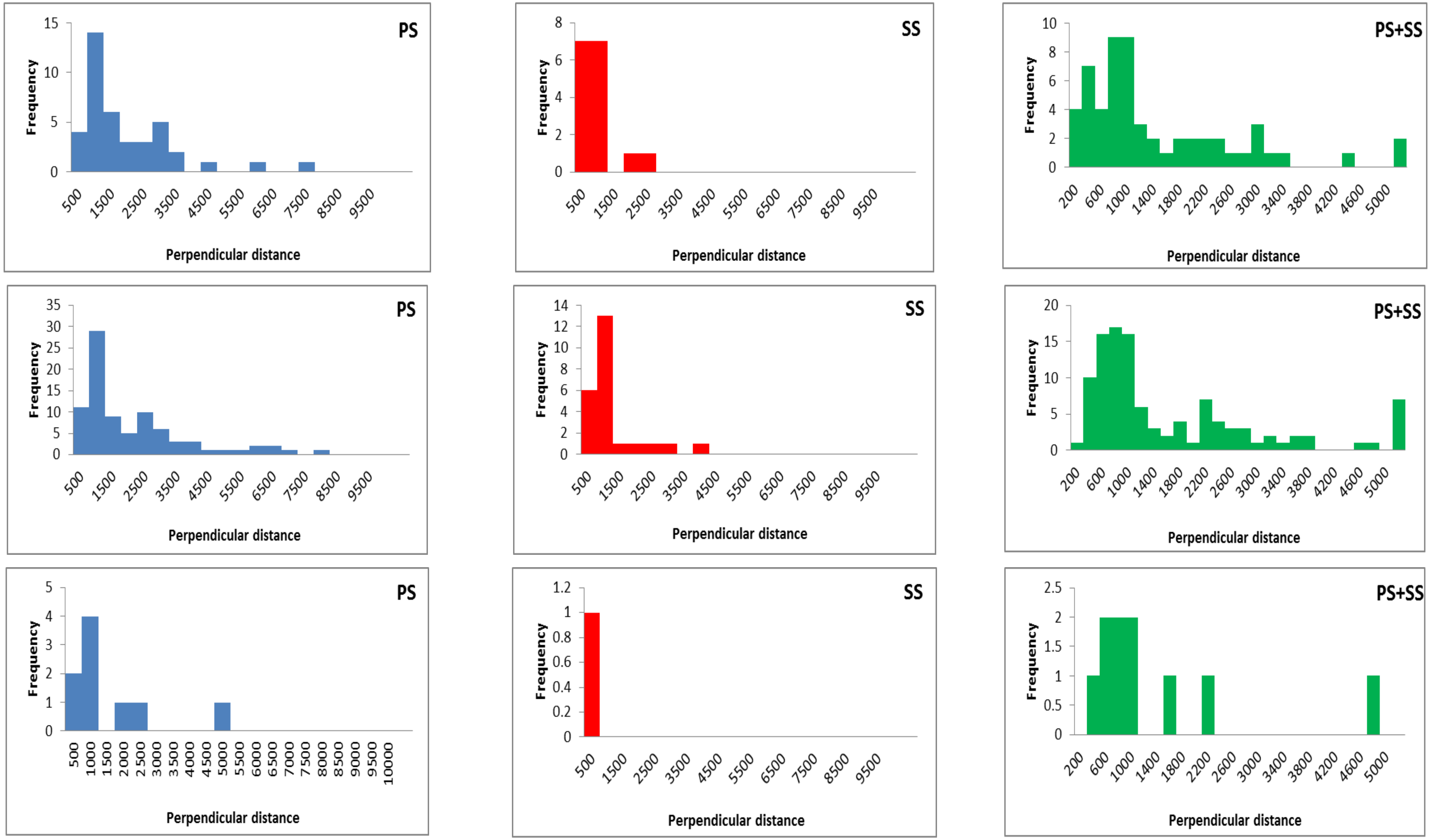


Figure 12. Frequency histogram of perpendicular distances at which schools of BFT were detected in area G. Upper graphics corresponds to 2010-2015 period, middle graphics to 2017-2019 period, lower graphics to 2019. PS: professional spotter. SS: scientific spotter.

2.4.- ALTERNATIVE METHODS TO GET MORE ACCURATE ESTIMATES OF TOTAL NUMBER OF ANIMALS, AVERAGE WEIGHT OF INDIVIDUALS AND TOTAL WEIGHT OF THE GROUP.

The studies of marine species abundance using the distance sampling methodology are based on estimations provided by experienced observers. Therefore, there is a potential bias in base data acquisition derived from differences in the skills of the spotters. There are two approaches that are normally used to reduce the bias produced by differences between observers. The first is to obtain quality images of the entire school and then manually count the exact number of individuals present and, subsequently, calculate correction factors (Connelly et al., 2015; Williamson et al., 2016; Gerrodete et al., 2019). In case quality photographs cannot be obtained, there is the option to calculate correction factors based on the estimations provided by the most experienced observer (Evenson et al., 2018).

The ICCAT aerial surveys are, due to their duration, frequency and geographic extension, an excellent platform to try to incorporate photographic systems to obtain photographs of good quality, which later can be processed with IAS software to get more reliable estimations of school size. One example of that type of software is ImageJ, a public domain digital image processing program developed in Java by the National Institutes of Health of the United States of America, which is currently used in various scientific applications as, for example, cell counting in histology or stars counting in astronomy.

Thanks to the collaboration among the companies GRUPAIRMED, ADANAIR and SUNFLY, S.L., during 13 to 17 May2019, a series of tests were carried out with several photographic systems to determine their adequacy for taking high quality images of tuna schools. Table 1 shows the models of tested cameras and their characteristics.

Table 1. Camera models test in May 2019.

COMPANY	MODEL CAMERA	ZOOM LENS	IMAGE FORMAT	MAX SIZE	TIME MIN
GRUPAIRMED	NIKON D5200	NIKON 18-200mm	JPG/NEF	10/25 MB	2sg
SUNFLY	SONY ALPHA 7	SONY 50mm	JPG/ARW	21/42 MB	1 sg
ADANAIR	GOPRO HERO 6 BLACK		JPG/RAW	2.5/5 MB	1sg

In the case of Nikon D5200 and Sony Alpha 7 cameras, plastic boxes were built to properly place the cameras inside during flights (see figure 13). Both boxes were anchored to a steel plate located at the base of the seat behind the copilot. The steel plate was properly perforated in order not to cover the objective. To test the cameras, two flights of approximately 2 hours each were made. In order to evaluate the photos taken by each camera, it was decided to fly over the bluefin tuna farms that the GRUP BALFEGO company has at 2.5 miles southwest of L'Ametlla de Mar in Tarragona. The company GRUP BALFEGO provided a document with the exact dimensions of each of the cages as well as their position (latitude and longitude) (figure 14), so that the flight plans could be designed to pass several times over the cages with different settings.

Figure 13. Details of cameras Sony alpha 7 (upper left picture), Nikon D5200 (upper right picture) and the anchorage system in the Steel plate (lower pictures).

The flight height and speed were the same as those used during the annual ICCAT sampling, that is, 300 meters and 100 knots. During the first flight made on May 15, the Sony Alpha 7 cameras and the Go-pro Hero 6 black were tested. During the second flight made on May 16, the Sony Alpha 7 camera and the Nikon D5200 were tested.

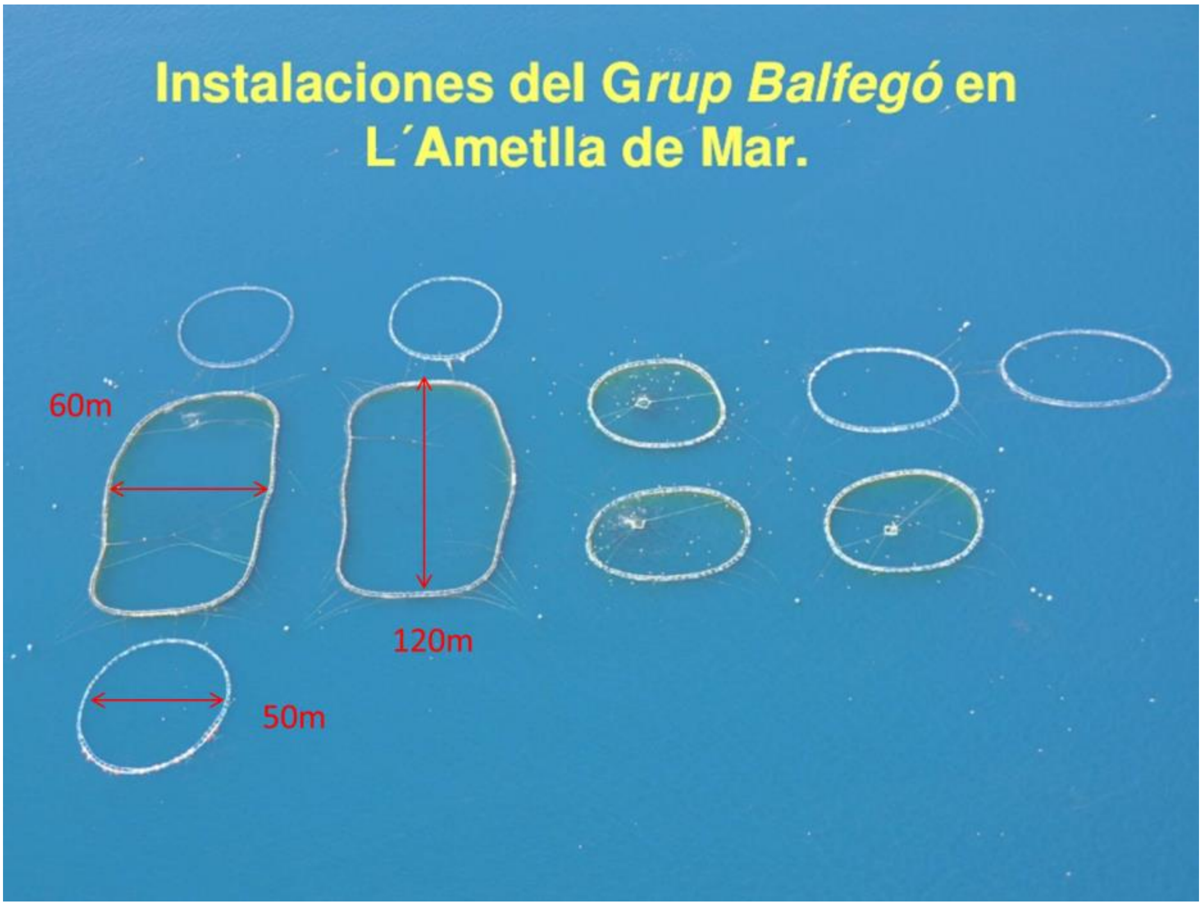


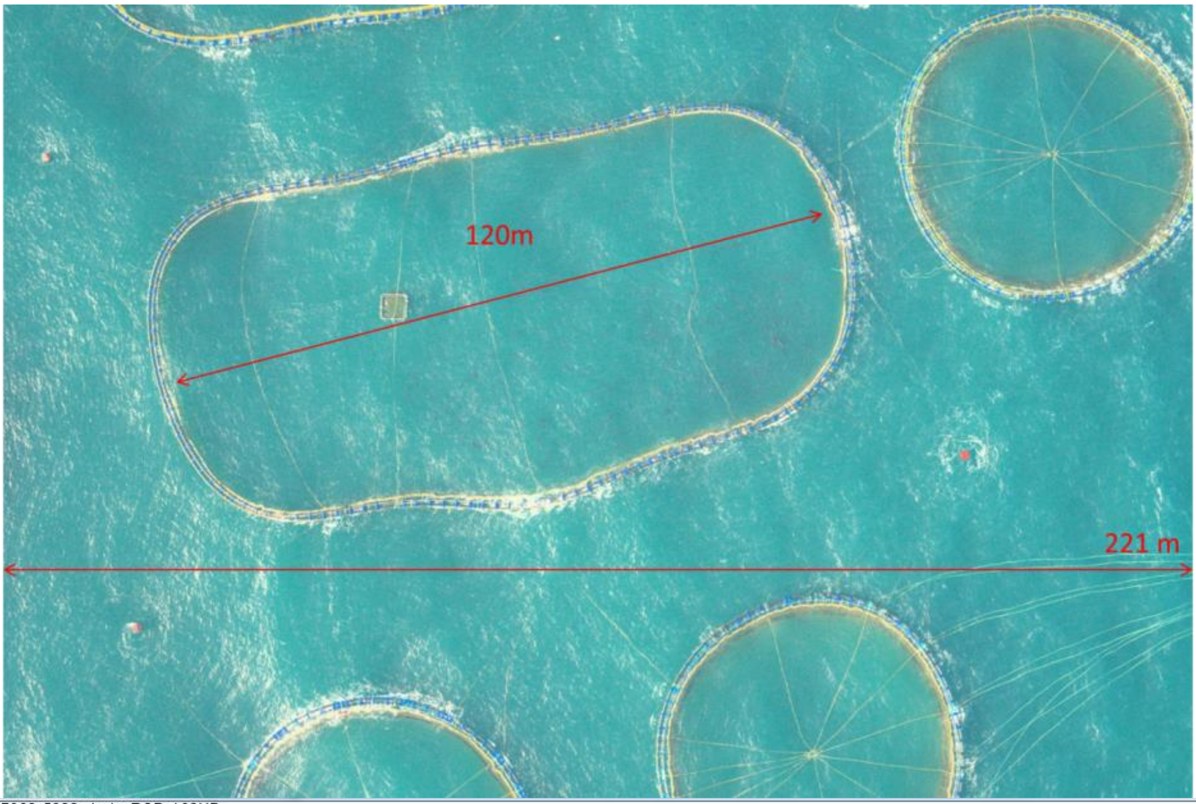
Figure 14. Dimensions of two types of bluefin tuna cages kept by GRUP BALFEGO

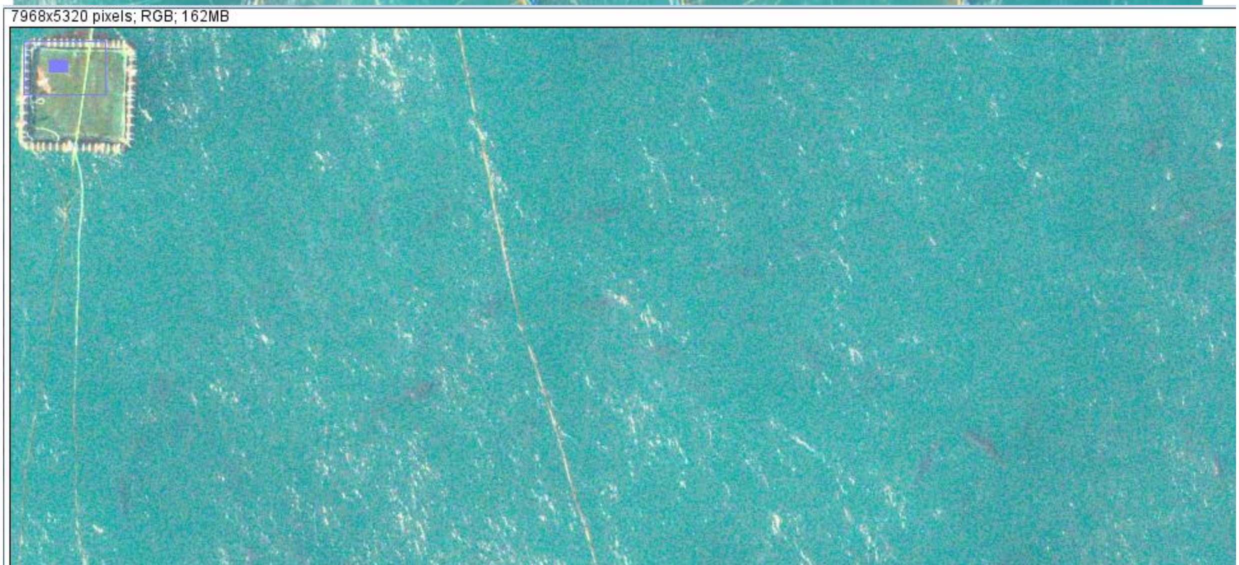
SONY ALPHA7 CAMERA

The Sony Alpha 7 camera system had an automatic Wi-Fi on-off system, an external hard disk for storing images, and a control system through an interface created “ad hoc” to be managed from a laptop. During the first flight, the contact between the computer and the camera could not be established, so no quality picture could be obtained. During the second flight the problem was solved and several photos were taken of the tuna cages during the different passes.

Figure 15 shows one of the photos obtained with the Sony Alpha 7 camera. Taking as reference the known measurements of the cages, it can be concluded that, with the 50mm zoom lens flying at 300m, the maximum field of view is 221m. If the zoom is enlarged 50% and 100%, the photo does not lose quality. From an increase of 150%onwards the pixels can already be observed.

The main problem of this system is that the photographs taken during the flight cannot be reviewed until landing at the airport and taking the camera out of the box. It would be convenient that this system could incorporate the possibility of viewing the photographs during the flight and changing the settings remotely to obtain better quality photos. The fact of using a lens with a fixed focal length greatly limits the possibilities of adjustment by the operator since normally flight heights are constant and are previously set in the data collection protocols.


120m
221 m


7968x5320 pixels; RGB; 162MB

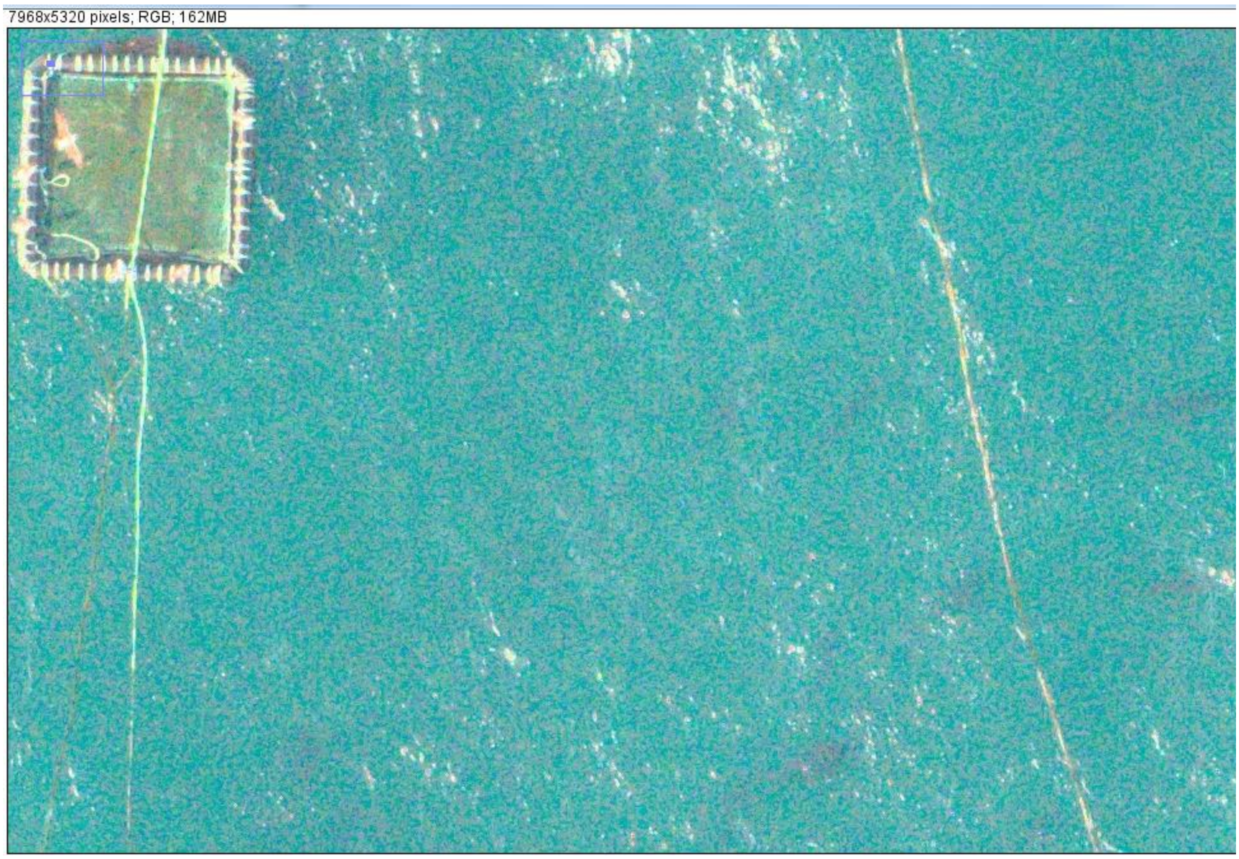


Figure 15. Picture of the cages taken with camera Sony Alpha 7.

NIKON D5200 CAMERA

The Nikon D5200 camera system was much simpler than the Sony Alpha 7 camera. The camera was connected directly to a laptop via a micro USB connection and controlled by the Nikon Camera Control Pro 2 software. This system has the advantage that at any time taking pictures process can be stopped and the results can be displayed on the connected computer. So it is possible to modify any parameter if necessary. Figure 16 shows one of the photos obtained with the Nikon D5200 camera. Unfortunately, during the second flight, not all passes flew over the cages and good photos only were taken during the lasts passes, when the target was set at a focal length of 100mm. Taking as a reference the known measurements of the cages, it can be concluded that, with the Nikon lens adjusted at a focal length of 100mm and flying at 300m height, the maximum field of view is slightly less than 50 m.

GOPRO HERO 6 BLACK CAMERA

The GoPro Hero 6 Black represents the best user friendly system. The camera settings can be adjusted from the mobile using the ”GoPro” application, which also allows to see the images that are being taken *in situ*. The Hero 6 black model has two modes with different focal lengths; the "wide" mode is equivalent to a wide angle and the "lineal" mode is equivalent to a focal length close to 35mm. At the flight height and standard speed used in the ICCAT aerial surveys (300m and 100 knots), the average time it takes for an object to pass from the front to the rear is 10 seconds in the case of the "wide" mode and 8 seconds in "linear" mode.

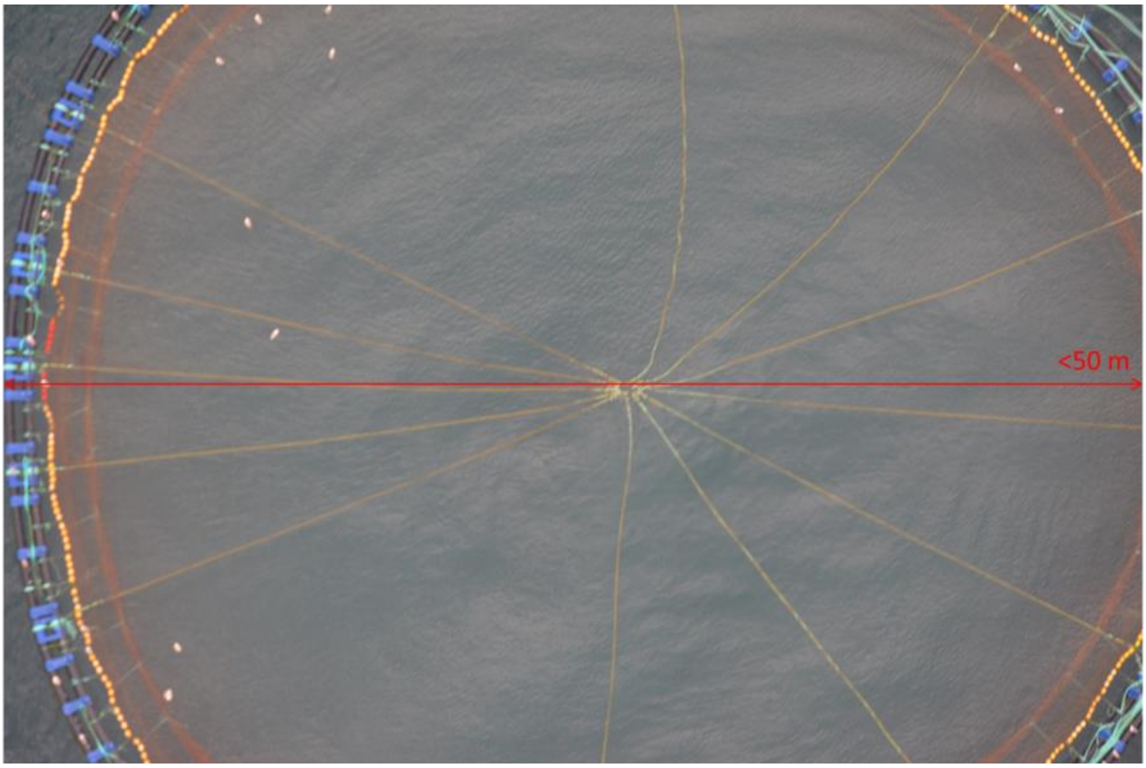
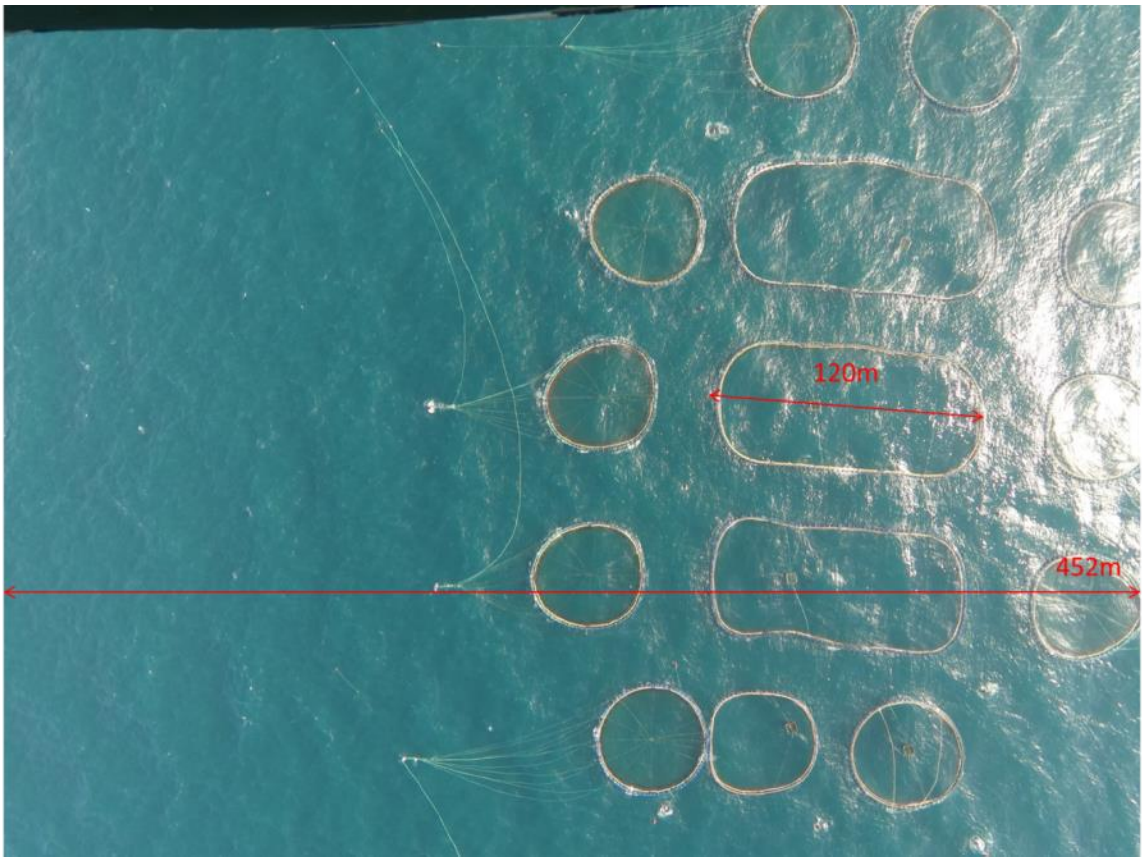


Figure 16. Picture of one of the small cages taken with Nikon D5200 at focal length of 100 mm.



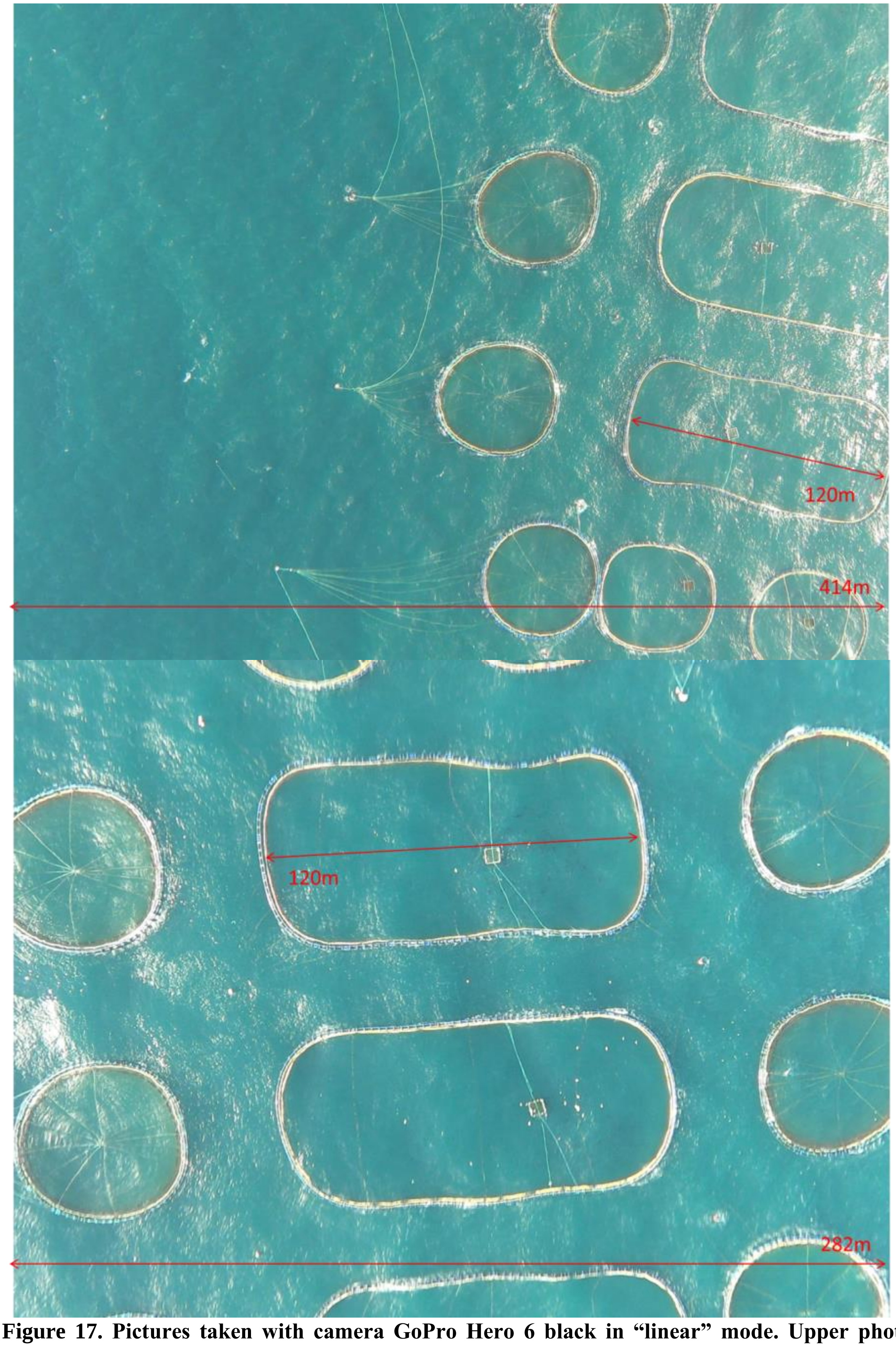


Figure 17. Pictures taken with camera GoPro Hero 6 black in "linear" mode. Upper photo: minimal zoom; middle photo: medium zoom; lower photo: maximal zoom.

Figure 17 shows the photographs of the cages obtained with GoPro Hero 6 Black camera at three different zoom levels; minimum, medium and maximum. Taking into account that the length of the largest cage is 120 m, the maximum distances covered with the different zooms are 452m, 414m and 282m respectively. Figure 18 shows the images resulting from increasing by 100% the original images of figure 17. Both images corresponding to the medium and maximum zoom level show the bodies of tuna inside the cage, however, the quality of the images is not good enough to make a real count of the total number of individuals.

In summary, the GoPro camera, despite being the easiest to install and adjust during the flight, does not provide images of enough quality to be able to count manually the individuals that are part of the tuna schools. Conventional SLR cameras provide higher resolution images, however, the focal lengths tested are not adequate to ensure that all members of the school were photographed. It would be necessary to do more tests to determine the optimal settings. In any case, the tests were performed only on one side of the plane, so that, once the appropriate system has been developed, cameras should be placed on both sides. Annual ICCAT aerial surveys constitute an excellent platform, due to the number of flight hours, to continue testing different photographic systems to estimate the abundance of bluefin tuna schools. In relation to this, it must be pointed out that the installation of photographic systems, such as those described above, require an aeronautical certification that implies a considerable economic cost.

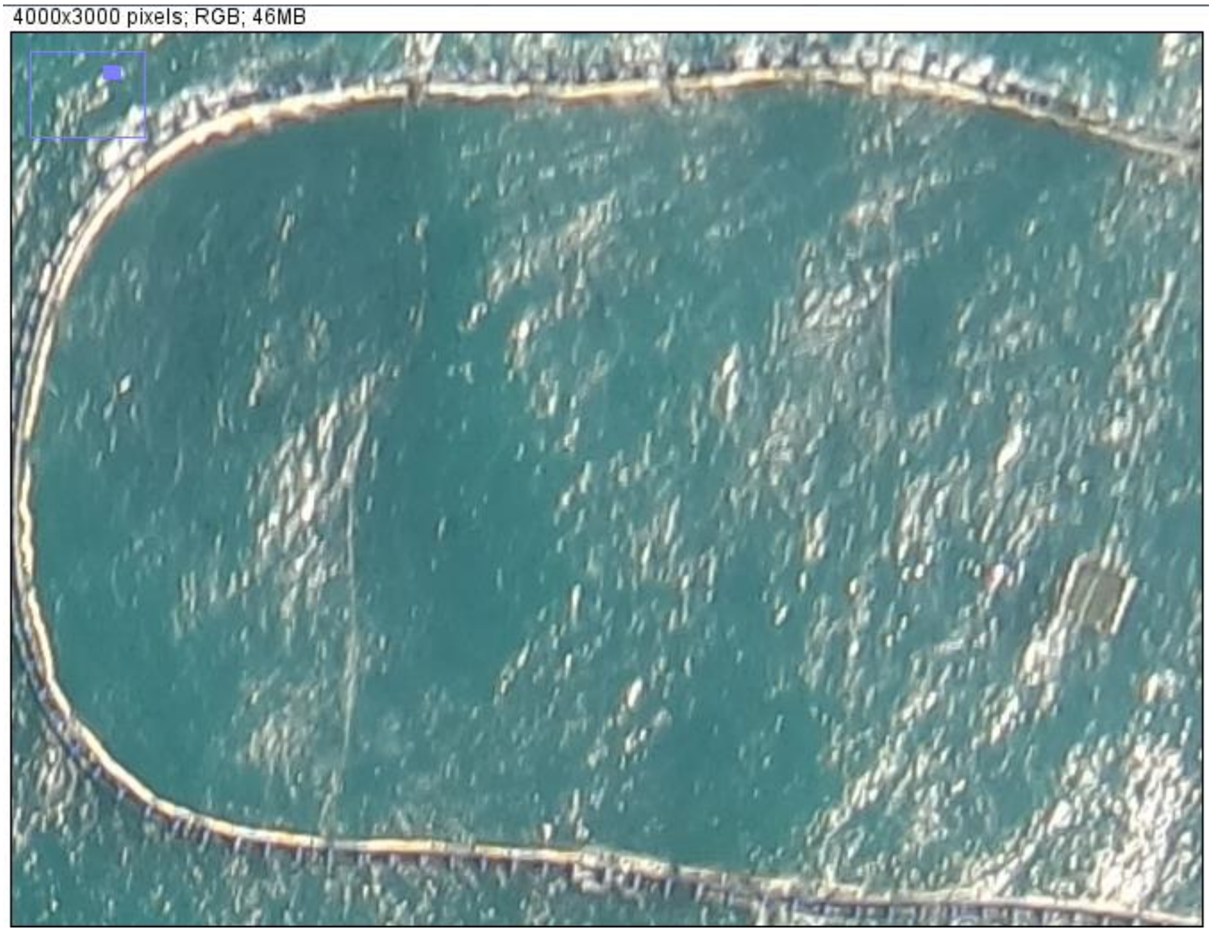


Figure 18: Pictures obtained with GoPro Hero 6 black camera in "linear" mode. Upper picture: minimum zoom, middle picture: mid zoom, y lower picture: maximum zoom.

3- STRATEGIC PLAN TO GUARANTEE THE STRICT APPLICATION OF THE SIGHTING PROTOCOLS REQUIRED BY THE DISTANCE SAMPLING AERIAL SURVEY METHODOLOGY IN THE FUTURE, TAKING INTO CONSIDERATION THE POTENTIAL LACK OF PROFESSIONAL SPOTTERS

In the last 3 years GBYP has made a great effort to identify the sources of bias in the GBYP aerial surveys to estimate spawners abundance in the Mediterranean. Most of them come from the different skills of the observers to estimate the number of individuals present in each detected group, as well its average and total weight, but also from the problems to apply correctly the distance sampling methodology, mainly in the case of professional spotters

The use of professional observers in aircrafts for bluefin tuna fishing began in the 1990s. Later, in the year 2006, when aircrafts were banned in bluefin tuna fisheries, professional spotters were used only for scientific studies. Some of them, despite being retired, continue to participate in the Atlantic-wide research programme for bluefin tuna aerial surveys, but presumably they will stop doing so in the near future due to their advanced age. This fact would imply a serious problem for the development of the program in the coming years. Therefore a strategic plan to assess the possibilities to solve these problems is needed Such a strategic plan should focus in the following four main aspects:

- ✓ Correct application of the protocol by the professional spotters.
- ✓ Loss of precision in the estimates by the professional spotters.
- ✓ Retirement of the professional spotters.
- ✓ Keep experienced scientific spotters involved in future years.

3.1.-CORRECT APPLICATION OF THE PROTOCOL BY THE PROFESSIONAL SPOTTERS.

As explained before, in point 2.3 of, the main problem found regarding to the professional spotters is their difficulty to concentrate the search effort in close and mid distances. Despite to insist on this issue during the training courses, the professional spotter have continued to apply an unbalanced search mode, focusing mainly on long distances. As a final attempt to minimize this bias, the GBYP sighting protocol has been modified, adding the following statement; “if the detected bluefin tuna groups are more than 5000m away, the aircraft should not leave the transect”. As consequence of this, in 2019 survey only one bluefin tuna sighting was recorded at a distance longer than 5000m.

So the recommendation for future surveys is to keep this mandatory requirement in the protocol and take time during the upcoming training courses to highlight the importance of this aspect for the analysis. Another recommendation that could help to improve the data collection would be to place a mark in the window corresponding with 5000m to help the professional spotter to concentrate the effort in the right area.

3.2.- LOSS OF PRECISION IN THE ESTIMATES BY THE PROFESSIONAL SPOTTERS.

During the period when the professional spotters flying on the aircrafts were used to detect and guide the ship towards the school, they spent to many time flying over the tunas, and consequently have more time to get a best estimate of number of animals, average and total size. Besides, once the ship finished the fishing manoeuvre, the professional spotter had the real numbers of the school, so each fishing event was indeed a calibration exercise. However, since 2006 when aircrafts were banned in bluefin tuna fisheries, the professional spotters don´t have any feedback from their estimates, and because of this calibration exercises are needed. Results from the calibration exercise carried out recently show the existence of significant differences between professional spotters from different study areas.

There are two possible strategies that potentially could help to improve this issue. The first one would be to develop a photographic system to collect high quality pictures during the flights and use them to count and measure the individuals present in each detected school, and use this information to calibrate the direct estimations from spotters. The second one would be to implement a sampling strategy based on the coordination with the purse seine fishing fleet, in such a way that the aircraft carrying out the scientific aerial survey be informed of all fishing operations in the area, and consequently could adapt the flight plans to flight over the school just before the fishing operation, whenever possible. If this protocol was implemented the values estimated by the professional spotters could be compared with real values coming from the fishing companies, and hence providing the spotters with the necessary feedback to improve their estimation skils.

3.3.- RETIREMENT OF THE PROFESSIONAL SPOTTERS.

As pointed out before most of the professional spotters involved in the GBYP aerial surveys, bias are aged people who presumably will not be available anymore in near future. This scenario highlights the necessity of developing a strategic plan to guarantee the participation of the same group of well-trained spotters, professional and scientific ones, year after year.

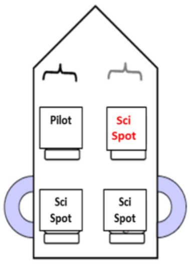
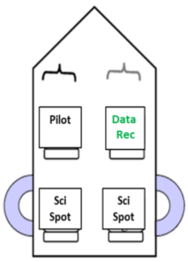
There are two possible ways to address the problem of lack of professional spotters due to retirement:

a) Only replace the professional spotter by an experienced scientific spotter, who would maintain the same role played up to now by professional spotters
b) Replace the professional spotter by a scientific spotter, but with a different role. Thus, the additional scientific spotter would occupy the position besides the pilot, as the professional spotters, but would act exclusively as data recorder

Both options have advantages and disadvantages. In the case of the first option, the main advantage would be that the distribution and functions of the crew within the plane would be maintained. The effort and the searching areas covered by each crew member would be the same as in previous years and, therefore, basic aspects of the methodology would not be significantly modified. However, the main disadvantage would be that the encounter rates and the values of the estimates of number of animals, average weight and total weight, would be different (predictably lower) in relation to those obtained by professional observers, as demonstrated throughout the study period,. Therefore, if this change is adopted, the number of sightings and the estimated biomass of bluefin tuna spawners will probably decrease.

One way to avoid the possible decrease in the school tuna encounter rates may be to ensure that the scientific spotters participating in future surveys have participated in at least 3 previous years, that is, to ensure that the scientific spotters have enough experience to recognize and detect schools of bluefin tuna at a level comparable to a professional spotter. As for the estimates of biomass, scientific spotters would have to be trained first in order to ensure that the estimates of number and weight of animals they provide are similar to the ones that would be provided by the professional spotter. In general, it is difficult to ensure that same scientific spotters are engaged in the aerial survey campaign during consecutive years because they are normally hired by aerial companies on temporal basis, only for the purpose of the campaign, so as soon as they find a full time job elsewhere, they are not available any more.

Table 2. Resume of the advantages and disadvantages of the different options of replacement professional spotter by scientific spotters.

OPTION	ADVANTAGES	DISADVANTAGES
1.- Replace PS by SS with the same function 	- Same effort and searching coverage.	- Reduce encounter rate and reliability of variables estimates.
2.- Replace PS by SS with the different function (data recorder)	- Eliminate the problem of time lost due to other species data collection.	- Different effort and searching coverage.
	- Obtain better quality photos of the schools.	- Predictably lower encounter rates and variables estimates.

In the case of the second option, which would be the replacement of the professional spotter by a scientific spotter who would be in charge of data recording, the two main advantages would be that, first, it would prevent the lose of time used by the scientific spotters to fill in the sightings data of other species that are not the direct objective of the survey. and, secondly, , the scientific spotter sitting in the co-pilot place would have the possibility of taking better quality photos of the schools through the holes that have the front windows and, therefore, wouldallow to make a manual count with the ImageJ software. The main disadvantage is that the effort and search areas would be modified in relation to previous years. The number of sightings detected would be predictably reduced, and the effective bandwidth would be smaller, which would affect the density estimates.

Table 2 shows a resume of the advantages and disadvantages of the different options of replacement of professional spotter by scientific spotters. Given that any of those two options imply that professional spotters would not be involved anymore, the change would need to be done gradually. During at least the next three years the most experienced scientific spotter must be trained intensively by the professional spotters in order to improve their skills, and hence the quality of the data.

3.4.- KEEP EXPERIENCED SCIENTIFIC SPOTTERS INVOLVED IN FUTURE YEARS.

In this sense, two possible strategies could be adopted to promote the participation of the same observers year after year. The first could be to develop agreements with consolidated research groups including stable observers trained in the distance sampling methodology, in such a way that they would integrate GBYP ICCAT aerial surveys within their annual work schedule, and hence ensuring the availability of well trained scientific spotters. The second would be to change the method of hiring observers. To date, the ones that hire the observers are the aerial companies that worked in the past for the bluefin tuna fishing industry, and the majority of scientific observers they hire have never participated in a bluefin tuna survey before. One way to prevent this from happening again in the future is that ICCAT makes the list of scientific observers crediting acceptable skills and oblige the aerial company that will be engaged in the GBYP aerial surveys to contract the scientific spotters among the people include in this list. An attractive salary should be offered to the observers during the month that the survey lasts, to encourage them to repeat in consecutive years.

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ANNEX 1

ICCAT Atlantic-Wide Research Programme for Bluefin Tuna (GBYP) AERIAL SURVEY PROTOCOL 2019

1 Introduction

The objectives of the comprehensive ICCAT Atlantic-Wide Research Programme for Bluefin Tuna (GBYP) are to improve basic data collection and our understanding of key biological and ecological processes in the Mediterranean Sea, and to develop a robust scientific management framework.

An important element of this programme is to develop fisheries independent indices of population abundance. Therefore, since 2010 aerial surveys have been conducted in the Mediterranean on the most documented spawning grounds. The frequency and study areas of these surveys have been variable over the years, and because of this there are some statistical problems in obtaining accurate and comparable abundance estimates for this period of time.

There have also been some differences in the data collection protocols which have partly biased and affected further analyses and results. If yearly comparable abundance estimates are needed, it is essential to carry out surveys following exactly the same data collection and analysis methodology.

This aerial survey protocol will be an agreed reference document that will have to be followed by all companies contracted by ICCAT in 2019.

1.1 Target species

The core objective of the ICCAT GBYP aerial survey is to provide annual relative abundance minimum estimates for bluefin tuna (*Thunnus thynnus*) spawners in the Mediterranean Sea. However, data will be also collected (when possible) for all species encountered (mainly other tunas and big fish, cetaceans, and turtle species) if this does not compromise data collection for the target species. If the time while recording the sightings is more than 10 sg the data recorder must to back to search effort looking for BFT during at least 5 seconds , before finishing the collecting of the remaining data. In those cases of high density areas of cetaceans – turtles, with several sightings in very short period of time, the cruise leader must decide if group all them into a single sighting or suspending temporally the recording of sightings until the end of the high density area.

1.2 Overview of methodology

The ICCAT GBYP surveys will use line-transect DISTANCE sampling to estimate abundance. The survey aircrafts will follow pre-designed tracklines in the survey blocks as described in **Figure 1**. As required by GBYP in phase 9, block A was redesigned taking into account the known details on the biology of the BFT spawners in the area.

The main idea of the line-transect DISTANCE sampling method is to obtain a precise abundance estimate of a highly representative sample area, and extrapolate its density to the total area in each survey block. In those studies where the objects of interest are sessile and easily detectable it is possible to define the sample area before carrying out the survey, whereas when observing non-easily detectable species such as other fish or cetaceans, the sample area must be estimated afterwards.

Therefore, it is essential to obtain a precise sample area to avoid bias during the extrapolation process.

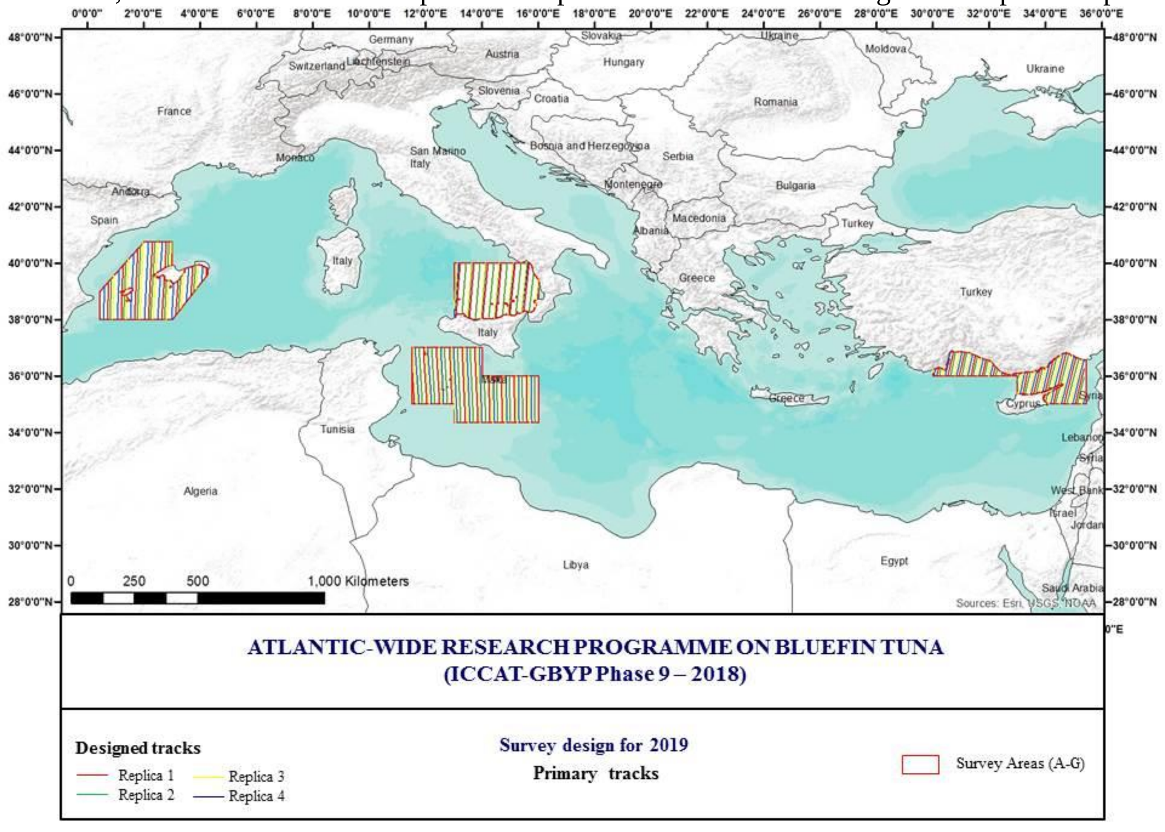


Figure 1. Survey blocks for 2019.

1.3 How to estimate a sample area

The estimated sample area is calculated by collecting perpendicular distances to the study objects, bluefin tuna in this case. When spotting sessile objects, perpendicular distances (p) can be measured directly when the object is abeam (**Figure 2A**), but when working with moving animals, traditionally perpendicular distances (p) are calculated from angles (ϴ) and radial distances (r) (**Figure 2B**).

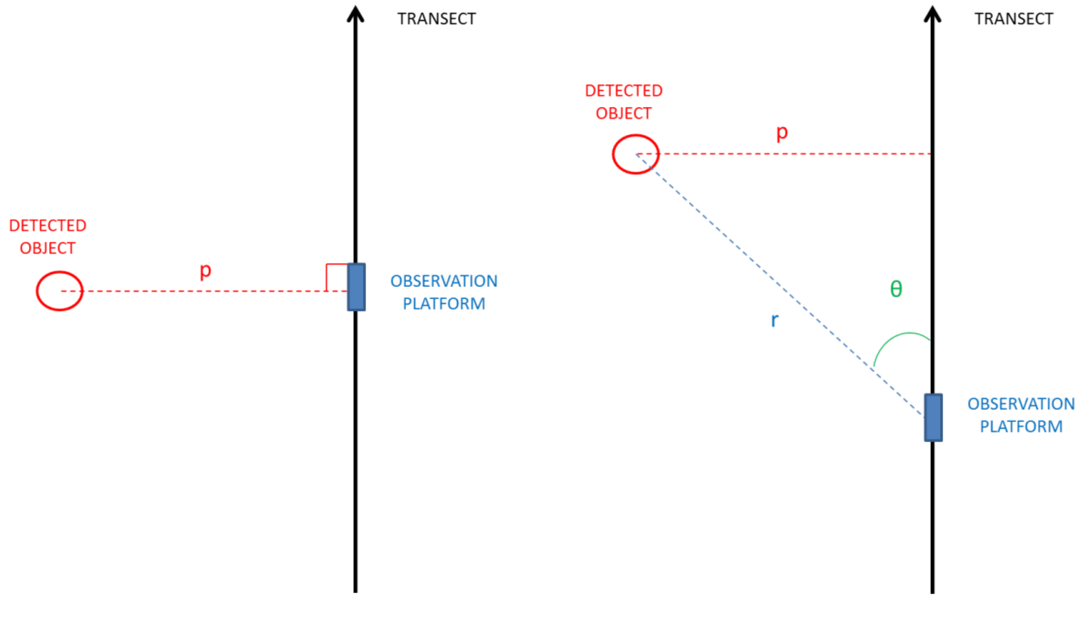


Figure 2A **Figure 2B**

In shipboard line transect surveys the second method is usually used to estimate perpendicular distances. In contrast, in aircraft line transect surveys where the aircraft is travelling at a much faster speed and the observers are in the rear seats looking through the bubble windows, perpendicular distances are recorded when animals are detected abeam. In aerial surveys the observation platform is located above sea level, where animals are detected, and therefore declination angles (α) as provided by the inclinometer are recorded in order to estimate perpendicular distances between detected objects and the transect (**Figure 3**).

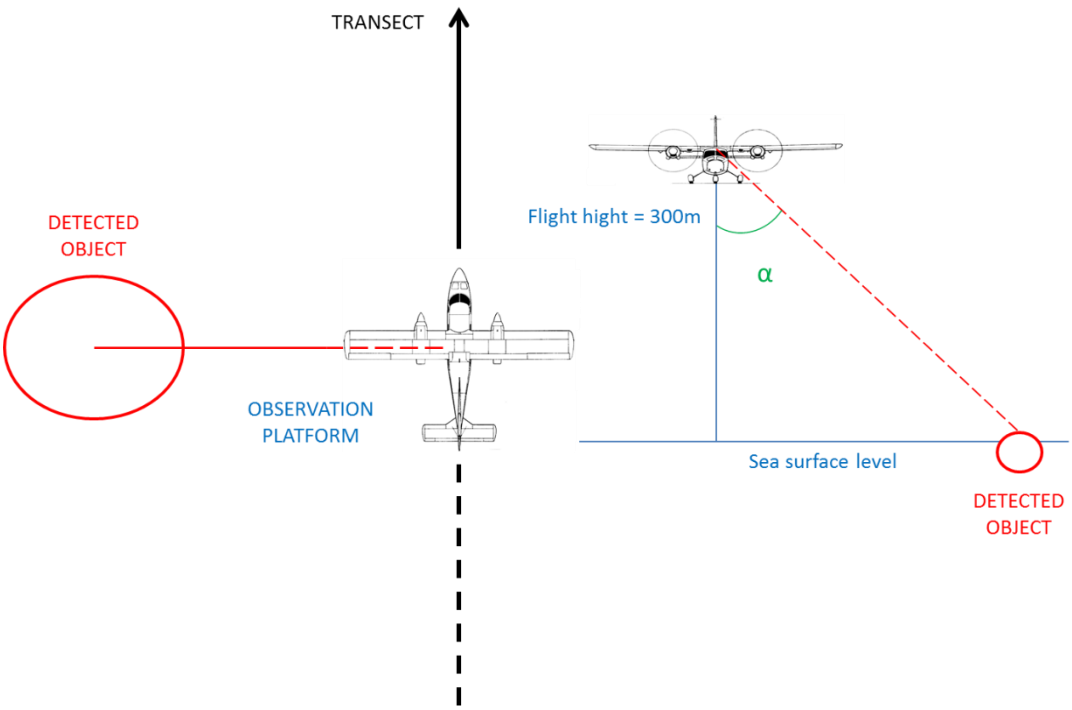


Figure 3. Traditional procedure to estimate perpendicular distances in aerial surveys using inclinometers.

The specifications on how the declination angle must be recorded will be described later in this protocol.

After the survey has been conducted, the so-called "effective strip width" is calculated using DISTANCE software, by adjusting the shape of the perpendicular distance frequencies histogram to a mathematical "detection function". Once the sample area has been calculated, it is possible to obtain the sample density.

1.4 Why is it important to obtain accurate declination angles and perpendicular distances?

As explained earlier, in order to establish the sample area and density, it is necessary to record perpendicular distances. If declination angles, and therefore perpendiculars distances, are not recorded properly, significant bias can occur as shown in the next example.

Let us suppose that our block area is 100 square kilometres, our total transect length is 20 km and 45 schools have been detected during the survey carried out. If we estimate an "effective strip width" of 0.25 km on each side of the aircraft, the sample area would be 20x0.25x2 = 10 square kilometers. The sample density would be 45/10 = 4.5 animals per square kilometre and in extrapolating this density value to the total block area the abundance would be 450 animals.

However, the declination angles and perpendicular distances can be overestimated. For example, for an "effective strip width" of 0.5 km, the sample area would be 20x0.5x2= 20 square kilometres and the sample density 45/20= 2.25 animals per square kilometer. Therefore, the abundance in the total block area would be 225. This is exactly half the number of animals.

IN CONCLUSION, IT IS ALWAYS ESSENTIAL TO OBTAIN ACCURATE RECORDS OF DECLINATION ANGLES!

2. The team

The aircrafts must have upper wings and bubble windows. When flying over the designed transects and between transects the speed and altitude must be constant at 100 knots and 300m respectively. As the priority of each flight is to survey "on effort" as much transects as possible, the displacements from the airport to the starting point of the first designed transect and from the ending point of the designed transect to the airport can be covered at higher speeds and altitudes according with the pilot considerations.

The survey team consists of a pilot (having previous experience in bluefin tuna spotting activities), a professional spotter (with previous experience in bluefin tuna spotting activities), and two scientific spotters (with experience in aerial surveys, preferably in bluefin tuna ones).

Pilot (P): This person is the authority inside the aircraft, is responsible for flight safety and his/her decisions are mandatory for all the crew members.

- Before starting the journey, once all checks have been made, he/she will ensure that the aircraft is ready for flying.
- During the flight, his/her duties (among the usual ones) will be to keep the aircraft just on the trackline (no more than 200-400 m far away from the line), at a constant speed (100 knots) and altitude (300 m). When a bluefin tuna school is detected and once it is abeam, he/she will leave the transect and fly around the school to take better estimates of size and weight.
- After the journey he/she will be responsible for checking the weather forecast and for deciding if the conditions are secure to fly the next day. The effort starting point must be discussed with the Scientific Spotter responsible for data collection.

Professional spotter (PS): This person is usually the most experienced in detecting bluefin tuna schools and estimating weight and school size. His/her task will be to search for BFT schools and give all the requested data to the scientific spotter (species, group size and weight). He/she should train the other team members how to detect BFT schools and how to estimate weight and size. He/she will always be in the front right seat in "on effort" mode (**Figure 4**).

Although the target species is BFT, provided that the main objective of the survey is not compromised, he/she shall also give the same data when detecting other tuna species, big fish, cetaceans and turtle species.

***Scientific spotter* (SS)**: The most experienced SS will be the person mainly responsible for data collection, check the weather forecast every day, determining with the pilot the starting point for each day, and ensuring good effort coverage, as required by the DISTANCE sampling methodology. He/she will be the called *"Cruise Leader (CL)"*. The other SS will help him/her.

In "on effort" mode, one of the SS will record the effort search conditions at every starting / finishing point and whenever any of the search conditions change. The two SS will alternate in carrying out this task. Whenever the CL decide to keep “on effort” mode after finishing a transect (for example when flying form one transect to another), there should be necessary to fill the “transect” field in “effort” form with “OFF-TRACK”.

The sighting data will be recorded by the SS who is on the opposite side from where the sighting is detected. The other SS shall provide or check the basic data on declination angle, species, group size and weight**; the spotters on the same side will provide their personal independent estimate of the school size and possibly the weight and those data shall be both recorded on the sighting form.** When circling over the school, the SS on the side closer to the sea will be in charge of taking photos.

The SS will rotate every time the aircraft lands or at mid cruise time in case of long cruises.

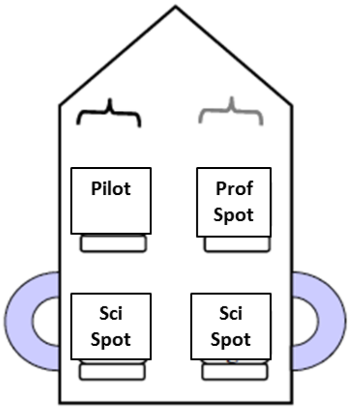


Figure 4. Positions of each team member in the aircraft.

3. Conditions for survey

Generally, a sea state of 3 or less on Beaufort scale, in conjunction with other minimum requirements (e.g. minimum visibility of around 3.5 km) are necessary to have survey conditions good enough for BFT spotting. Bad weather conditions mean winds over 3 on Beaufort scale, or low clouds (less than 300 m from the surface), or heavy rain, or very limited visibility due to fog. Bad weather conditions prevent reliable observation of tuna schools close to the sea surface.

It is the responsibility of the CL to determine if conditions are acceptable from a scientific point of view and the pilot determines whether conditions are appropriate from a safety point of view; <u>in case of discrepancy the pilot’s decision is final.</u>

The decision whether it is appropriate to carry out the survey on any particular day (or to abort a survey) will be taken by the CL and the pilot, based on the best available weather forecast and the prevailing conditions. Information for this can be obtained from a number of sources including airports, various internet sites, shipping forecasts, etc. Operative time shall be limited by good light conditions. In addition to the objective parameters (sea state, turbidity, cloud cover, glare, etc.), it has been found that “subjective” estimation of overall sighting conditions best correlate with actual sightings data. As BFT is the primary target species for the ICCAT GBYP aerial surveys, the estimation of overall sighting conditions is based on the observers’ opinion as to the probability of seeing BFT in the primary search area (i.e. from dead ahead to abeam and out to a declination angle of 20°). Conditions may vary on either side of the plane (particularly, but not exclusively, due to glare). Three categories can be chosen to be filled for each side (note that their definitions are necessarily vague as they represent a subjective estimation of a variety of factors):

Good: This is when the observer believes that the likelihood of seeing BFT within the search area is reasonably good. Normally, good subjective conditions will require a sea state of 2 or less on a Beaufort scale and a turbidity of less than 2.

Moderate: This is when the observer believes that the likelihood of seeing any BFT within the search area is lower than good.

Poor: This is when the observer is not able to detect any BFT within the search area. For example when the searching area of one side is completely covered by strong glare. If both sides are assessed as "poor" the searching effort has to stop and change to "OFF".

In an ideal world, we would survey the whole area in "good" conditions, which should be the aim. However, there must be a balance between coverage in good conditions and the need to cover as much of the survey area as possible; it is better to cover an area in moderate conditions than not to cover it at all. Therefore, depending on the time available, it may be necessary to cover some areas in moderate conditions. This will ultimately be the cruise leader's decision, in consultation with the pilot.

There is no advantage in extensive flying in poor conditions hoping for improvements (of course, never circle in poor conditions). Data collected in poor conditions (on both sides of the trackline) will not be included in the analyses and thus extensive surveying in poor conditions is simply an inefficient use of expensive flying hours. Again, it is the cruise leader's responsibility, after consultation with the pilot, to decide to abandon surveying for the day.

4. Equipment

4.1 Essential equipment

- Clinometers (3 or 2) – mandatory
- Effort and sighting forms (ring binder preferred) – mandatory
- 2 GPS and rechargeable batteries – mandatory
- 1 camera with high sensitivity, and zoom lenses 70-200 or 75-210 or 80-200, equipped with a polarized filter and memory cards – mandatory
- Laptop with external hard disk – mandatory
- 4 notebooks, 4 pens and 4 pencils
- 2 permanent waterproof marker and alcohol 96º
- 1 videocamera
- Binoculars 7x50
- Digital recorders

4.2 Personal equipment

- Passport (mandatory when the area includes non-EU countries) or national identity document – mandatory
- ICCAT ID cards – mandatory
- Sunglasses (if possible polarised) and watch
- Water and food
- Sickness pills
- Comfortable clothes
- Windscreen cleaners

5. Searching behaviour

DISTANCE sampling methodology suggests selecting the proper speed and altitude after some preliminary survey work. As shown in the 2013 survey reports, the altitude and speed during field work were approximately 1000 ft and 100 knots, respectively. As reference, **Figure 5** shows the correlation between the key declination angles and perpendicular distances at the altitude of 1000 ft.

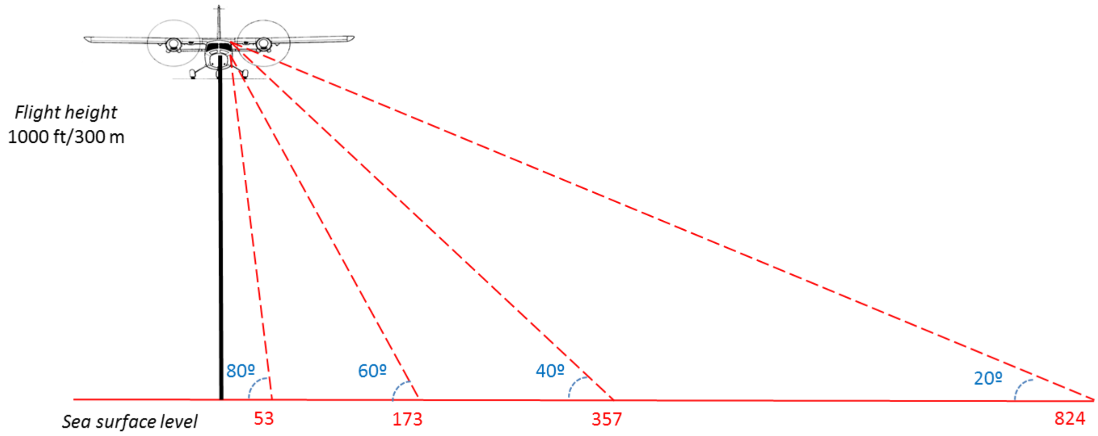


Figure 5. Correlation between the key declination angles and perpendicular distances at an altitude of 1000ft = 300m.

Ideally, the altitude would be high enough so that the animals would be undisturbed, thus avoiding movement prior to detection. Nevertheless, the aircraft should be flown as low as possible to enhance detection of animals and ICCAT GBYP has decided on an altitude of 300 m. Line transect methods are appropriately named because the distance is critical; the closer to the vertical sighting the better the methodological approach and the quality. Search behaviour must try to optimize the detection of animals in the vicinity of the line, and search effort or efficiency should decrease smoothly with distance. The aims are to ensure that the detection function has a broad shoulder and the probability of detection at the line is unity (Buckland, *et al.*, 1993).

According to this, observers must be trained in how to search for animals and which proportion of areas (declination angles) should be sampled with more intensity. Always concentrate most of the effort in the closest area, between 90º and 40º, and less effort for animals up to 20º (**Figure 6**). Occasional effort should be devoted in looking at a lower angle (higher distance) but never more than 5 km far from the aircraft. All sightings further than 5000m will be **NOT INCLUDED** in the analysis, so in those cases the angle data will be recorded but the plane will **NOT LEAVE** the transect

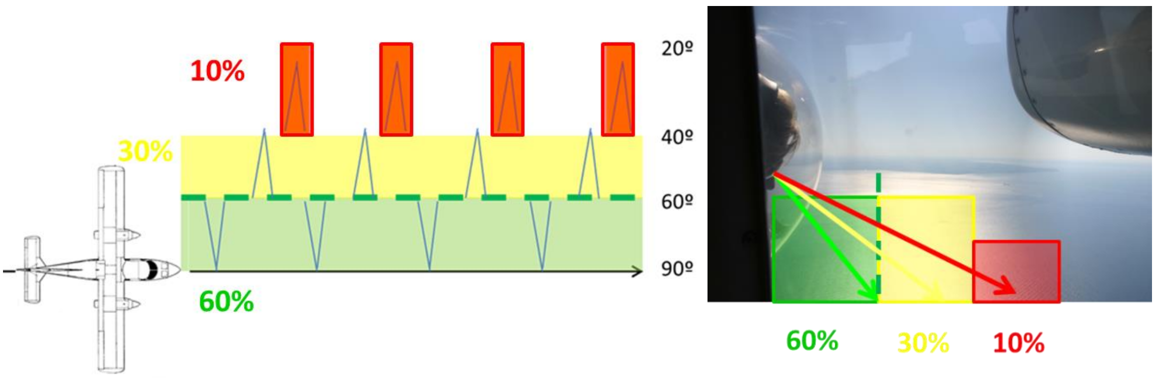


Figure 6. Scheme of searching behavior in aerial surveys.

Table 1 provides a list of distances from the perpendicular of the aircraft according to various declination angles at 300 m altitude. Sightings at a distance more than 7.5 km, even if recorded, will not be included in the analysis.

Declination angle	Perpendicular distance(m)
90	0
85	26
80	53
75	80
70	109
65	140
60	173
55	210
50	252
45	300
40	358
35	428
30	520
25	643
20	824
15	1120
10	1701
5	3429
3.5	4905

Table 1. Correlation between declination angles and perpendicular distances.

6. Collecting data

It is mandatory to provide ICCAT GBYP with effort forms, daily weather forecast backups (wind speed, swell, clouds-rain, visibility…) sighting forms and all GPS track data in Excel format.

6.1 Effort data form

Aerial surveys are conducted at relatively high speed (100 knots), so generally effort conditions should not change in full "on effort" period. One of the SS shall fill out the effort form just before starting the transect, when the aircraft is at the right altitude and speed and on the correct course. If any of the search conditions changes in the "on effort" period, then a new "on effort" line must be completed by the SS. The effort form must also be filled at the end of each transect, while the aircraft is still at the same altitude and speed and on the same course.

Date	Enter the **day/month**.
Time	Enter **GMT** Hour (hh:mm:ss)
Event	**ON**: start effort. **OFF**: end effort. **LA**: flying over land. **LE**: leaving transect. **RE**: rejoin transect.

<table>
<tr><td>LAT</td><td>Enter latitude (example: 35º 14.45 or 35.24583) decimals are preferred
https://www.fcc.gov/encyclopedia/degrees-minutes-seconds-tofrom-decimal-degrees</td></tr>
<tr><td>LON</td><td>Enter longitude (example: 2º 18.33 or 2.30916) decimals are preferred
https://www.fcc.gov/encyclopedia/degrees-minutes-seconds-tofrom-decimal-degrees</td></tr>
<tr><td>Subarea</td><td>Survey area in Figure1 (A-I, C-I, E-I or G-I).</td></tr>
<tr><td>Survey</td><td>Number of survey. Each flight is a new survey.</td></tr>
<tr><td>Transect</td><td>Code of the transect that is going to be surveyed. If you are "on effort" while travelling from one transect to another fill this field as "OFF TRACK"</td></tr>
<tr><td>Pilot</td><td>Enter the numeric code (XX) for the pilot</td></tr>
<tr><td>Front spotter</td><td>Enter the numeric code (XX) for the spotter on the front seat.</td></tr>
<tr><td>Spotter on the left rear sit</td><td>Enter the numeric code (XX) for the spotter on the left rear seat behind the pilot</td></tr>
<tr><td>Spotter on the right rear seat</td><td>Enter the numeric code (XX) for the spotter on the right rear seat</td></tr>
<tr><td>Altitude</td><td>Enter the flight altitude in meters</td></tr>
<tr><td>Sea State</td><td>Enter the sea state following the Beaufort wind scale:
<table>
<tr><th>Beaufort Force</th><th>Sea State</th><th>Description</th></tr>
<tr><td>0</td><td>Calm</td><td>Sea like a mirror</td></tr>
<tr><td>1</td><td>Very Light</td><td>Ripples with appearance of scales, no foam crest</td></tr>
<tr><td>2</td><td>Light breeze</td><td>Wavelets, small but pronounced. Crest with glassy appearance but do not break</td></tr>
<tr><td>2.5</td><td></td><td>Start to appear some isolated whitecaps</td></tr>
<tr><td>3</td><td>Gentle breeze</td><td>Large wavelets, crests begin to break. Glassy looking foam, occasional white horses</td></tr>
<tr><td>4</td><td>Moderate breeze</td><td>Small waves becoming longer, frequent white horses</td></tr>
</table></td></tr>
<tr><td>Haze</td><td>Enter the haze intensity. 0: no haze; 1: slight; 2: moderate; 3: diffused; 4: heavy/foggy</td></tr>
<tr><td>Turbidity</td><td>Enter turbidity parameter based on the following:
0 - clear water: animals visible at many m depth
1 - moderately clear water: animals visible under the surface
2 – moderately turbid water (e.g. mud): animals visible just under the surface
3 – turbid: full lack of transparency</td></tr>
<tr><td>Clouds</td><td>Use the octaves system (i.e. full cloud cover = 8, clear sky = 0)</td></tr>
<tr><td>Glint</td><td>Glint is the refection of the light over the sea when it is cloudy. (0- no glint; 1- glint).</td></tr>
<tr><td>Glare Side</td><td>Enter the side where glare is: P: port; S: starboard, SP: port and starboard</td></tr>
</table>

Glare Sector	Use the 360° system (NB dead ahead is 360 not 0) with glare from XX° to XX° measured clockwise - e.g. 360° to 180° means the right side of the plane is covered in glare whereas 180° to 360° means the left side of the plane is covered by glare
Glare Intensity	Enter glare intensity based on the following: 0 - no glare 1 - slight glare - very little effects on observations 2 - moderate glare - may affect sightings in the sector 3 - strong glare - severely affecting sightings
Subjective Search Conditions (PORT)	This represents subjective view of the scientific spotter behind the pilot, of the likelihood that, considering all of the conditions (Beaufort, glare, turbidity,..etc), they would see a BFT within the primary search area if present. The primary options are: **Good** (G): the spotter believes that the likelihood is good. Normally will require at least a sea state of 2 or less and a turbidity of less than 2. **Moderate** (M): the spotter believes that the likelihood while not good, is not poor. **Poor** (P): the spotter is not able to detect any BFT within the search area. For example when the searching area of one side is completely covered by strong glare.
Subjective Search Conditions (STARBOARD)	This represents subjective view of the scientific spotter behind the professional spotter, of the likelihood that, considering all of the conditions (Beaufort, glare, turbidity,..etc),, they would see a BFT within the primary search area if present. The primary options are: **Good** (G): the spotter believes that the likelihood is good. Normally will require at least a sea state of 2 or less and a turbidity of less than 2. **Moderate** (M): the spotter believes that the likelihood while not good, is not poor. **Poor** (P): the spotter is not able to detect any BFT within the search area. For example when the searching area of one side is completely covered by strong glare.
Comments	Enter any relevant comment if needed.

6.2 Sighting data form

Aerial surveys are conducted at high speed, so the spotter has around 10 seconds to detect animals in the search area. Every crew member must know what to do when a sighting is announced. Some examples about who has to do what are explained below in point 7.

THE SIGHTING DATA MUST BE FILLED BY THE SCIENTIFIC SPOTTER LOCATED ON THE SIDE OPPOSITE FROM THE DETECTED ANIMALS.

<table>
<tr><td>Number</td><td>Enter the accumulated sighting number</td></tr>
<tr><td>Date</td><td>Enter the day/month.</td></tr>
<tr><td>Time</td><td>Enter GMT Hour (hh:mm:ss)</td></tr>
<tr><td>Event</td><td>Enter the event code. F: when animals first sighted, A: when animals abeam, C: when arriving over the animals for circling</td></tr>
<tr><td>LAT</td><td>Enter latitude (example: 35º 14.45 or 35.24583)
https://www.fcc.gov/encyclopedia/degrees-minutes-seconds-tofrom-decimal-degrees</td></tr>
<tr><td>LON</td><td>Enter longitude (example: 2º18.33 or 2.30916)
https://www.fcc.gov/encyclopedia/degrees-minutes-seconds-tofrom-decimal-degrees</td></tr>
<tr><td>Abeam?</td><td>Enter Y if the angle has been recorded abeam or N if the angle has not been recorded abeam.</td></tr>
<tr><td>Angle abeam</td><td>Enter the angle abeam in degrees</td></tr>
<tr><td>Altitude</td><td>Enter the flight altitude in meters at the moment of taking the angle abeam</td></tr>
<tr><td>Observer</td><td>Enter the two numbers identifying each spotter (XX)</td></tr>
<tr><td>Cue</td><td>Enter cue code based on the following:

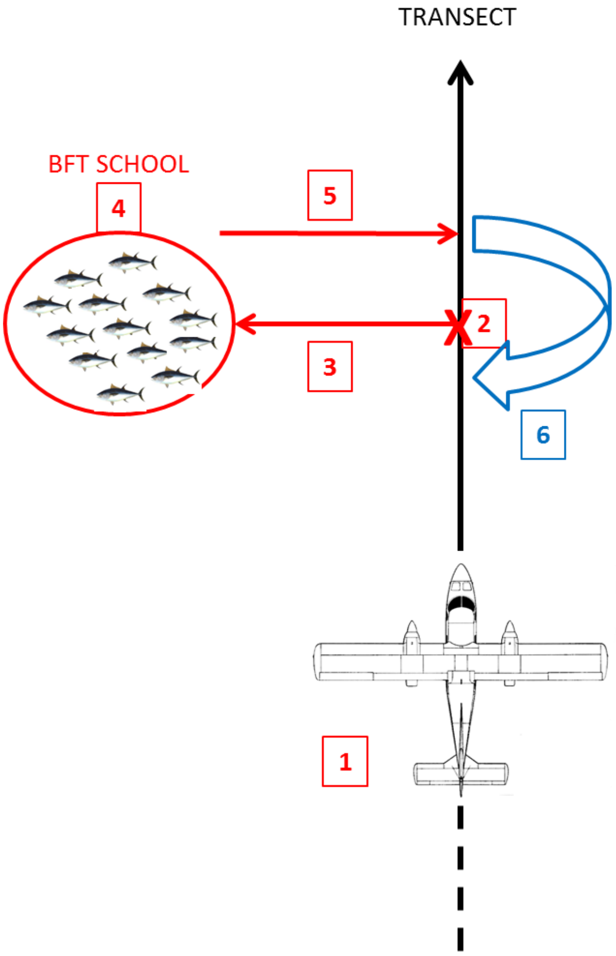
SP: splash = fish jumping clear off the water or splashing on a side.
RI: ripples = fish swimming just below the surface, with the dorsal side moving the surface.
SH: shining = classical behaviour of spawners, when fishes come to the surface, swimming on a side for a few seconds, reflecting the sun light like mirrors.
TR: travelling = fish going clearly in a certain direction.
UN: underwater = body seen under water surface.
SU: surface = body seen at surface.
VG: vessel/gear = vessel or gear detected just before animals.
BL: blow (cetaceans).
JU: jump (cetaceans).
SL: slick, flukeprint (cetaceans).
BI: birds.
CE: cetaceans.
FI: fish.
OT: other.</td></tr>
<tr><td>Species</td><td>Enter species identification code based on the following:
<table>
<tr><th>FISH SPECIES</th><th>CETACEAN SPECIES</th><th>OTHER MARINE SPECIES</th></tr>
<tr><td>BTF: bluefin tuna</td><td>SPE: sperm whale</td><td>MOS: monk seal</td></tr>
<tr><td>ALB: albacore</td><td>FIN: fin whale</td><td>CAR: loggerhead turtle</td></tr>
<tr><td>SWO: swordfish</td><td>MIN: minkie whale</td><td>LEA: leatherback turtle</td></tr>
<tr><td>SHA: shark</td><td>WHA: other whale</td><td>UNT: unidentified turtle</td></tr>
<tr><td>MOB: manta</td><td>COD: common dolphin</td><td>OTH: other</td></tr>
<tr><td>UNF: unidentified fish</td><td>SDO: stripped dolphin</td><td></td></tr>
<tr><td></td><td>BOT: bottlenose dolphin</td><td></td></tr>
<tr><td></td><td>RDO: roughtooted dolphin</td><td></td></tr>
<tr><td></td><td>UDO: unidentified dolphin</td><td></td></tr>
<tr><td></td><td>KIL: killer whale -Orca</td><td></td></tr>
</table></td></tr>
</table>

	<table><tr><td></td><td>**RIS:** Risso´s dolphin</td><td></td></tr><tr><td></td><td>**PIL:** pilot whale</td><td></td></tr><tr><td></td><td>**CUV:** Cuvier´s beaked whale</td><td></td></tr><tr><td></td><td>**UMM: unidentified cetacean**</td><td></td></tr></table>
Number PS	Enter the school size estimated by the Professional Spotter. If there are different groups with different individual size enter the numbers of animals in each group consecutively Example: Group 1: 700 ind. Group 2: 300 ind. Total: 700-300
Individual size PS	Enter the weight in kilograms estimated by the Professional Spotter. If there are different groups with different individual size enter the individual average weight of each group consecutively Example: Group 1: 150kg. Group 2: 300kg. Total: 150-300
Weight PS	Enter the school size estimated by the Pilot or the Scientific Spotter. If there are different groups with different individual size enter sum of all groups. Example: Group 1: 700indx150kg= 105000kg. Group 2: 300indx300Kg= 90000kg. Total: 195000
Surface/Under	If all the individuals of the school are at the surface enter "SUR". If all the individuals of the school are under the surface enter "UND". If there are some individuals at the surface and others below the surface enter "SUR-UND"
Number SS	Enter the school size estimated by the Scientific Spotter. If there are different groups with different individual size enter the numbers of animals in each group consecutively Example: Group 1: 400ind. Group 2: 200ind. Total: 400-200
Individual size SS	Enter the average size of the individuals estimated by the Scientific Spotter. If there are different groups with different individual size enter the individual average weight of each group consecutively Example: Group 1: 150kg. Group 2: 300kg. Total: 150-300
Weight SS	Enter the school size estimated by the Scientific Spotter. If there are different groups with different individual size enter sum of all groups. Example: Group 1: 400indx150kg= 65000kg. Group 2: 200indx300Kg= 60000kg. Total: 125000
Leave?	Enter **Y**: yes if have leaved the transect to get closer to animals, and **N**: if not
Photos?	Enter **Y**: yes if photos of the school have been taken, and **N**: if not
Numbers	Enter the number of the first and last photo that have been taken, as in the LCD camera. Set the same time of the GPS.
SCHOOL COMPONETS	Enter estimates (in number of individuals) based on the following: % Small: individuals < 25 kg. (include in comments if they are juveniles or spawners) % Medium: individuals from 25 to 150 kg. % Large: individuals from 150 to 300 kg. % Giant: individuals > 300kg.
Cetaceans	Enter **Y**: yes if there were cetaceans associated with BFT, and **N**: if not
Birds	Enter **Y**: yes if there were birds associated with BFT, and **N**: if not
Comments	Enter any relevant comment if needed

7. Actions to follow when a BFT sighting is detected

7.1 Case 1. The school is close enough to obtain all data

1. The crew member who sees the animals first shall communicate it to the others. The



SS on the opposite side from where the animals were detected shall fill out the number, date, hour, event (F) lat and lon.

2. The aircraft keeps the course until animals are abeam. In that precise moment the SS on the side of the sighting shall take the declination angle. The other SS shall once again fill out the hour, event (A), lat, lon, angle, observer, cue, and species, and fill with "Y" in column "Abeam

3. Except for those sightings further than 5km, it is mandatory in all BFT sightings to leave the transect to obtain a better estimate of the school weight and size, when the CL gives the signal to leave, the SS shall note time, event (LE), lat and lon.

4. When starting the circles around the individuals, the PS/pilot shall notify the SS who will note again, time, event (C), lat and lon. This position shall correspond to the limit of the circle so the position of the sighting shall be calculated after the survey with GIS tools. Circles must always be clockwise; therefore, the PS has the best view of the school. ". **It is MANDATORY always to record both estimates by the PS and the SS independently .** In the case where the school has been detected by another crew member, SS shall note both separate estimates (from the pilot or the other SS plus the PS). The SS on the same side is in charge of taking photos when possible.

The PS shall look at the school for improved estimates and the SS on the same side can take better photos.

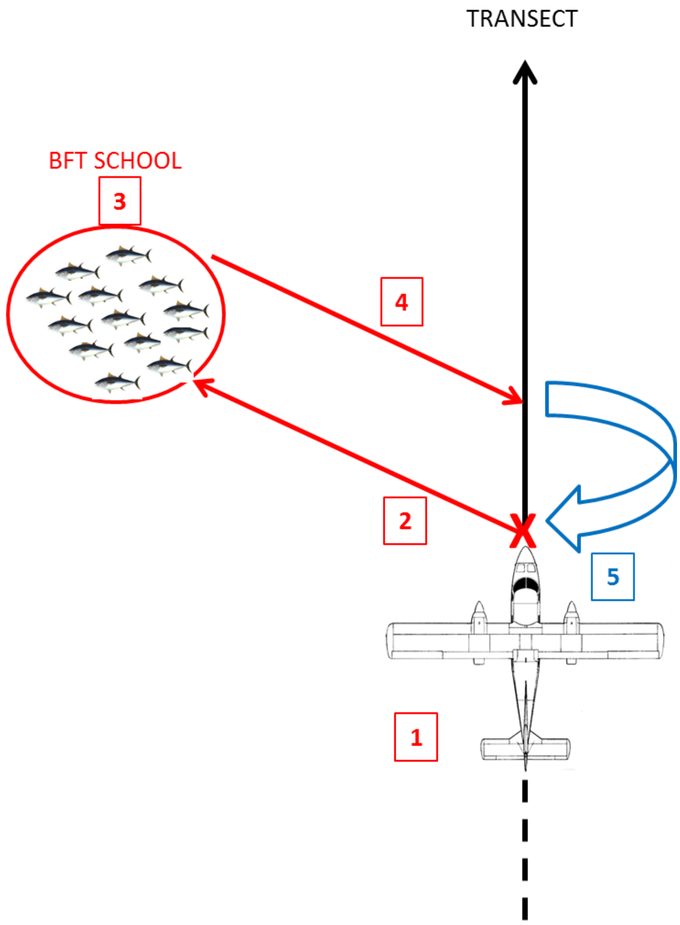
5. After 1 or 3 circles (depending on the difficulty of the estimate), the aircraft shall return to the point where it left the transect. During this short period, the SS ensures that all data have been properly recorded.

6. The pilot shall manoeuver as shown in **Figure 7** and shall notify the SS when the aircraft returns to the transect is reached. SS shall note hour, event (RE), lat and lon.

Figure 7. How to proceed in a normal sighting situation.

7.2 Case 2. There is a high risk of losing the school before being abeam

1. The crew member who sees the animals first shall communicate it to the others,



pointing out that there is a high risk of losing the animals. The SS on the opposite side from where the animals are detected shall fill out the number, date, hour, event (F) lat and lon. The pilot shall notify when leaving the transect (please note that you are leaving the transect before sighting is abeam). If is possible to measure the angle before leaving the transect, notice that it was taken before being abeam by writing “N” in column Abeam. When the aircraft leaves the transect the SS shall write in event (LE) and record time, lat, lon.

2. While the aircraft maintains the course towards the animals, the SS shall fill out observer, cue and species.

3. When starting the circles around the individuals, the pilot shall notify the SS who will again note time, event (C), lat and lon. This position shall correspond to the limit of the circle so the position of the sighting shall be calculated after the survey with GIS tools. Circles must always be clockwise; therefore, the PS will have the best view of the school.

It is MANDATORY always to record both estimates by the PS and the SS independently . In the case where the school has been detected by another crew member, SS shall note both separate estimates (from the pilot or the other SS plus the PS). The PS shall look at the school for improved estimates and the SS on the same side can take better photos.

4. After 1 or 3 circles (depending on the difficulty of the estimate), the aircraft shall come back to the point where it left the transect. During this short period, the SS ensures that all data have been properly recorded.

5. The pilot shall manoeuvre as shown in **Figure 8** and shall notify the SS when the aircraft returns to the transect is reached. SS will note hour, event (RE), lat and lon.

Figure 8. How to proceed if there is a high risk of losing the school before being abeam.

7.3 Case 3. Two or more schools are detected at the same time.

Although is not common, during the survey it is possible to detect two or more schools of BFT at the same time, on the same side or on both sides. Whenever is possible, each group should be registered as a single sighting as shown in Case 1. However, in the field it is not always possible to do this, for example, when there is a high risk to lose the location of the first sighting while trying to being abeam of the second one to get a precise angle measurement.

So, in this tricky situation, the CL should assess the situation and identify the easiest group to be tracked. Before leaving the transect, perpendicular distances of all sightings should be registered and only then the aircraft can leave the transect and start circling around the schools that was previously identified as the easiest one. Once finished circling around the first school, and if still possible, the aircraft can immediately fly towards the other school, without returning to the transect, and start circling around the second one. If the conditions allow for it, the same should be repeated with the third and any further school, provided that their perpendicular distances had been taken. Once circling around all schools has been done, the aircraft should return to the same point of the transect from which it has left (**Figure 9a, 9b**).

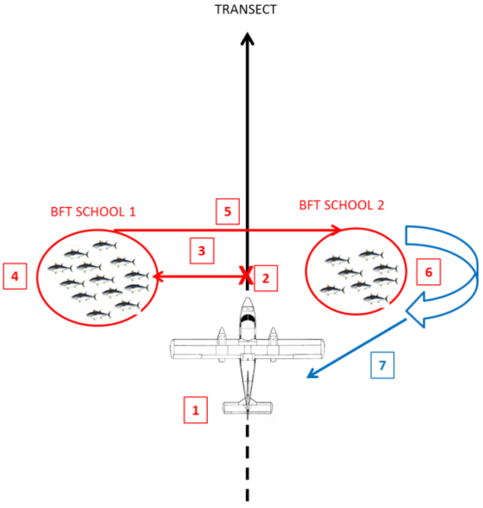


Figure 9a. Two sightings detected at the same time on two sides located relatively close one from the other.

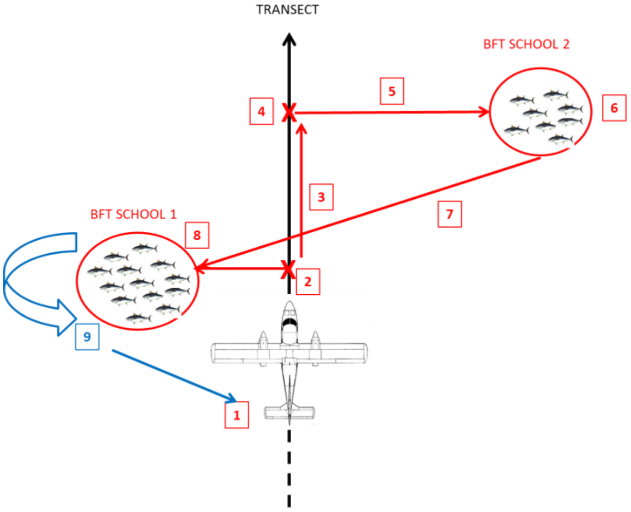


Figure 9b. Two sightings detected at the same time on two sides located relatively far one from the other.

If a secondary sighting was detected after leaving the transect to circle a primary sighting, the CL should prioritize the collection of size and weight of the first one and after that fly to the secondary sighting (**Figure 10**).

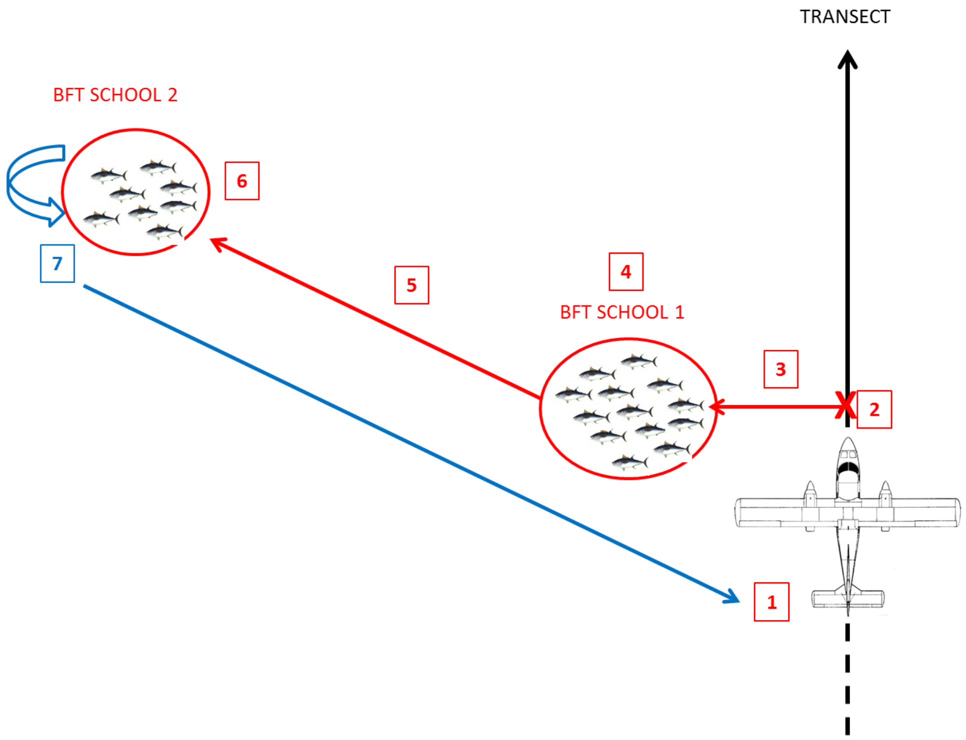


Figure 10. A secondary sighting detected after leaving the transect to circle a previous one.

In the case that the two sightings were too close to distinguish angles, both should be considered as only one sighting **(Figure 11).**

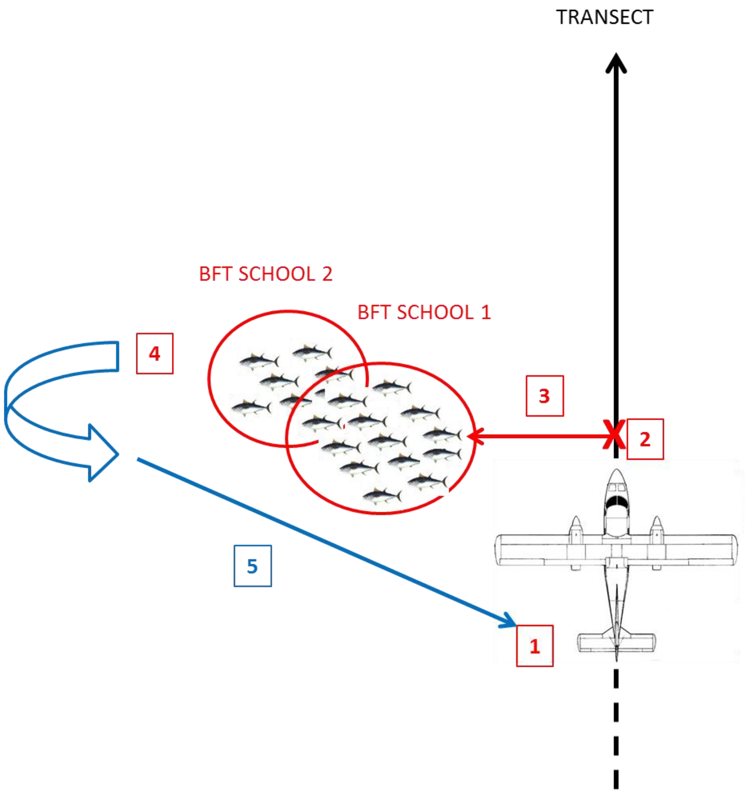


Figure 12. When two sightings are detected very close one from the other, they must be considered as only one sighting.

8. Contact details

Whenever you are in doubt, please ask for clarification:
gbyp: gbyp@iccat.int
José Antonio Vázquez: ggbvaboj@yahoo.es
Ana Cañadas: anacanadas@alnilam.info

9. Weather forecast options

The CL should check the weather forecast and do backups every day, using this website: https://www.passageweather.com/. The CL should check other available weather forecast with more detailed data such us, https://www.windy.com, and https://es.windfinder.com . The latter allows checking the forecast every hour selecting "superforecast" option. In case that was not possible to fly one day, in addition to the daily backups saved from "passageweather", CL will save screenshots from previously mentioned websites whenever was considered to support the decision taken.