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Sampling Plan for an Acoustic Survey of Kükenthal Peak (NAFO Division 6G) to Quantify Alfonsino (*Beryx splendens*) Biomass, Abundance and Size Composition

by

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ABSTRACT

NAFO Commission requested that the Scientific Council review the protocols for survey methodology, to inform the alfonsino assessment. Thus, this document presents an possible acoustic survey plan of the alfonsino population inhabiting Kükenthal Peak, located in the Corner Rise Seamount Chain, following the Commission's request.

The main objective of this survey plan will be to estimate the distribution, abundance, biomass and size composition of alfonsino (Beryx splendens) on Kükenthal Peak (NAFO Div. 6G) by conducting a hydroacoustic survey during February. Specific objectives will be: estimate the abundance (in number) and biomass (in weight) of alfonsino in Kükenthal Peak. Estimate the alfonsino size composition, length-weight relationship, sex ratio and sexual maturity characterization by sex. Collection of alfonsino gonad and otolith samples for future studies of maturity and age. And characterize the biological environment and the physical environment (Tº, S ‰,) of the pelagic habitat of this species to produce a map of these variables within the survey area in association with alfonsino abundance estimates. It is advisable for economic reasons to conduct the subject acoustic survey with a commercial vessel.

Two strata with different levels of sampling effort are proposed due to the patchy distribution of alfonsino as revealed by the echograms provided by the skipper, and also the major occurrence of the species around the slope of the mountains, with little extension towards deeper water (i.e., no extension towards open waters). The survey design will consist on a systematic parallel transects with random starting point, with two different levels of sampling intensity, allocating the maximum effort in the area that historically contained the bulk of the acoustic and trawl commercial records. Transects will be placed to ensure they are perpendicular to the bathymetry of the survey area.

There is some evidence that relates vertical migrations of alfonsino concentrations to the illumination of the sea (by the Sun and the Moon). The acoustic survey will carry during moon rising season in February and only collect acoustic data during the daylight hours (0800-2000 hours). Trawl hauls will be conducted only for fish identification and the collection of alfonsino length distribution and biological data. Therefore, trawl station locations will be selected according to the acoustic records.

Background

A closure of the Splendid Alfonsino (*Beryx splendens*) trawl fishery, on Kükenthal Peak (NAFO Div. 6G), was recommended for 2020 by the NAFO Scientific Council (SC) based on the trend in fishery catch-per-unit-of-effort (CPUE) data. Total catch and CPUE data are the only data currently available for stock assessment (NAFO, 2019). The most recent evaluation of the stock indicated that it appeared to be depleted. Neither biomass nor fishing mortality reference points are available for the stock (NAFO, 2019). Because of the fishery closure and the fact that the alfonsino assessment is data-poor, the SC recommended that fishery independent data useful for stock assessments should be collected for the Kükenthal Peak stock (NAFO, 2019). Both acoustic and longline surveys have been previously conducted on other alfonsino stocks to quantify biomass, abundance, size composition and maturity characteristics (FAO, 2016). For the subject alfonsino stock, the NAFO Commission requested that the Scientific Council review the protocols for survey methodology, to inform the alfonsino assessment. Thus, this document presents an acoustic survey plan of the alfonsino population inhabiting Kükenthal Peak, located in the Corner Rise Seamount Chain (Figure 1), following the Commission's request.

The objective of the subject acoustic survey is to quantify the biomass, abundance, size composition and maturity characteristics of the alfonsino population inhabiting Kükenthal Peak within the area shown in Figure 2 based on the coordinates shown in Table 1. An acoustic survey, rather than a trawl survey, was chosen because it is a non-invasive, quantitative survey method that should not impact either the seamount or VMEs inhabiting the seamount and it should not further reduce the size of the alfonsino stock. This document describes the protocols of the proposed acoustic survey and the specific survey products that will be presented to the SC.

Alfonsino

B. splendens, hereafter referred to as alfonsino, is a benthopelagic fish species found in waters of 25-1 300 m depth, commonly in aggregations over rocky bottoms. It normally lives close to, or within 5–20 m, of the bottom of the upper slope between 200 and 1 240 m in depth, but typically around seamounts and deepwater reefs in waters 200-800 m deep. It may be found above seamounts in schools about 10–50 m in vertical extent (Maul, 1981). The species is distributed along the European and African coasts and around oceanic islands of the Atlantic and Indian Oceans (Alekseev *et al.*, 1986). Alfonsino is also found in the northern Tasman Sea, along the Pacific coast of the Japanese Archipelago, the Southern Emperor and Northern Hawaiian ridges and westwards towards Chile.

Acoustic Data

Fishery acoustics is unique in its ability to characterize the distribution of some aquatic organisms with high spatial and temporal resolution while also recording information on bathymetry and, in some cases, substrate characteristics. Acoustic surveys can be conducted relatively quickly and, although directed (net) sampling is almost always required to support the research objectives, state-of-the art methods for collecting and interpreting multi-frequency acoustic data now allow characterization of fish aggregations by species or species group in some instances.

The main objective of acoustic data collection is usually to provide quantitative estimates of biomass, abundance and size composition for use in determining stock status for single-species assessments. Quantitative metrics for single-species stock assessments derived from acoustic data generally fall into one of two estimated quantities: relative abundance (indices) or absolute abundance. The key difference between relative and absolute estimates of stock size is the way in which survey bias or systematic errors are incorporated. In a relative series, the acoustic indices can be biased owing to systematic errors such as the proportion of stock sampled or target strength, but it is assumed that the bias does not change over time. This means that a time-series of relative estimates can be used to monitor changes in stock abundance. In this way, a relative acoustic series is similar to a series of trawl surveys with standardized gear. An absolute acoustic estimate is assumed to be an unbiased measure of stock size ($q = 1$) and the biomass and abundance of the stock can be determined after only one survey. However, in an absolute abundance estimate, systematic errors must be incorporated into the overall measure of uncertainty associated with the estimate. Evaluation of the accuracy and precision of the biomass estimate is an important aspect of a quantitative fishery assessment. When acoustic data are used in a fisheries stock assessment to provide relative or absolute estimates of stock biomass, associated estimates of accuracy and precision are also generally required. When designing a monitoring programme, it is important to undertake a study to reduce the potential for systematic and random errors.

Sampling platforms

When a deep-sea fishery is small, it is difficult to justify the expense of a research vessel survey because the survey cost may not be justified by the value of the fishery, such as for the NAFO alfonsino fishery in Div. 6G. In this case, using a commercial vessel for collecting acoustic data may be the only feasible way of obtaining biomass, abundance and size composition estimates (FAO, 2012).

Recently, high-quality commercial echosounders have become closer in quality and capacity to scientific echosounders. This convergence is the result of several technological developments. Software and applications developed for scientific work can now be adapted easily for commercial echosounders. Commercial vessel selection based on acoustic performance is therefore an important criterion in any fishing vessel-based monitoring programme but it should be noted that selection of an appropriate vessel will not necessarily improve overall survey accuracy if errors associated with factors such as sampling design, fish migration, and species identification are substantial. As these modern instruments have been installed on commercial fishing vessels, fishery scientists in many countries have taken advantage of the opportunity to collect acoustic data from fishing vessels in support of a range of stock management and ecosystem monitoring objectives (ICES, 2007).

Sampling programmes

It is important to match study objectives with appropriate tools and survey designs to achieve the level of accuracy required. There are two main acoustic survey methods for providing quantitative abundance and biomass estimates of deepwater species from industry vessels (FAO, 2012): we have termed these “aggregation-based” surveys and “area-based” surveys:

Aggregation-based surveys aim to cover the main target-species aggregation(s) using an adaptive design. The main advantage of aggregation-based surveys is that they can be carried out quickly over a small area if the fish are highly aggregated. A disadvantage of aggregation-based surveys is that they are hard to do well. The vessel crew or scientist directing the acoustic data collection needs to have a good understanding of survey design and be adaptive. Often the surveys do not adequately encompass the area of high-density fish aggregations. Even when the surveys appear to cover the main aggregation(s), there is considerable uncertainty about what proportion of the total stock size occurs in these aggregation(s). The resulting biomass estimate is used as an absolute estimate of fish abundance in the aggregation. Because the proportion of the stock surveyed will vary between snapshots and between survey years in relation to the amount of survey time available, it is difficult to know how to incorporate aggregation-based abundance estimates into a formal stock assessment model. There are two main types of survey designs for aggregation-based surveys: parallel transects and stars (FAO, 2012), but neither method will be used for the subject survey. Most research vessel surveys (trawl and acoustic) are area-based surveys. The areas of fish occurrence are usually known and defined prior to the survey. Often the area is stratified based on bathymetry or the fish density determined from previous surveys. Transects are assigned to each area or stratum prior to the survey. This survey design is simple to implement and analyse. These surveys with a survey design predetermined by a scientist are generally more suitable for abundance estimation. By standardizing the timing, area and equipment used in each survey, time series can be developed that provide relative or absolute (for trawl surveys if catchability is known) estimates of fish abundance. Such time series provide the major input to most stock assessment models used to determine stock status. An added advantage of relative acoustic time series is that these are not so reliant on the correct choice of the backscattering cross-section value. The major disadvantage of an area-based survey is that the areas must be defined to be sufficiently large to encompass the entire distribution of the stock. Area-based acoustic-trawl surveys have been carried out successfully from industry vessels (FAO, 2012) and this type of survey will be used in the subject study.

As all survey design-based estimation methods, acoustic trawl-surveys of deep-sea species have several sources of uncertainty that should be addressed to improve both the accuracy and precision. The spherical nature of the acoustic wave front, makes it impossible to distinguish between the seafloor and acoustic scatter of the organisms located close to the seafloor. This area is called dead zone, and its height is greater on sloping ground because there is a larger range of seafloor depth in the beam. There is an abundant bibliography on how to address this issue (Ona and Mitson, 1996; Mello and Rose, 2009; Totland et al, 2009). More specifically for mesopelagic species, Kloser et al (2001) and Ryan and Kloser (2013) proposed a methodology to estimate the abundance of fish contained in the acoustic dead zone, similar to the area to be surveyed on Kükenthal peak. This approach has been implemented in Echoview, the same data processing software that will be used in the subject study.. Moreover, the behaviour of alfonsino has revealed diel changes in the species vertical distribution in the water column, with the bulk of fish being concentrated on top of the rise during daylight hours. Therefore, for assessment purposes, acoustic records will be recorded during the daytime, although with the aim of understanding the diel behaviour of alfonsino during the first year, nighttime echograms will be also recorded over the same sampling grid for a diel distribution analysis.

Another potential bias with respect to the use of acoustic data for stock abundance estimation is vessel noise (FAO, 2012). The noise refers both to any unwanted source that affects the acoustic signal (e.g. electromagnetic noise) and also to radiated noise that could affect the fish behaviour (noise signature). The shipping industry is the largest contributor to the oceanic background noise level (Pettersen, 2017; Southall et al, 2017) and most of the commercial fishing vessels built before 2010 does not match any recommendation to reduce radiated noise. Indeed, ancient research vessels don't match as well such recommendations (Mitson, 1995). Yet, while the impact of the radiated noise on fish behaviour has been observed in many species (see Robertis and Handegard 2012 for further details), the impact on the echointegration measurements were negligible in one study conducted by De Robertis et al (2008). On the other hand, ICES has addressed this important issue when fishing vessels are used to collect acoustic data (ICES, 2007). For vessels with propulsion systems consisting of diesel engines that are bolted to the hull and gearboxes that drive controllable-pitch propellers, such vessels may disturb sensitive fish species at distances >200 m. In the present case, with fish located between 400-700 depth, the impact of the radiated noise will be minimal and therefore the contribution in terms of uncertainty on the echo integration estimates would be assumed to be low. Regarding electromagnetic noise sources, impacts will depend on how any electromagnetic source of noise has been isolated on board (e.g. proper grounding of electrical instruments) as well as the transducer cable. To account for any interference related to noise (even due to weather), acoustic echograms will be filtered. Among others, depending on the quality of the acoustic signal, the following filters, available on Echoview, will be used:

- Background noise removal, based on concepts from De Robertis and Higginbottom (2007)
- Impulse and transient noise removal, based on the algorithms and definitions described in Ryan et al (2015)
- Attenuated signal removal, based also on the algorithms and definitions described in Ryan et al (2015)

Other acoustic surveys of alfonsino stocks

Acoustic surveys have previously been used to assess alfonsino stock size, distribution and size composition (Niklitschek et al. 2011, Wiff *et al.*, 2012). These surveys have shown that the species undergoes diurnal vertical migrations, whereby aggregations are generally found closer to the seabed during the night and rise up in the water column during the day (FAO, 2016). As a result, acoustic surveys of alfonsino carried out in the Archipelago of Juan Fernández have been conducted only during 7:00 a 19:00 hrs. Acoustic sampling designs used by Niklitschek et al. (2011) for other alfonsino stocks have consisted of a semi-random design. Stratified and semi-adaptive, based on iterative cycles made up of a global survey of each zone (coarse grid, average distance 1 min.), followed by repeated surveys of greater resolution (fine grid, average distance equal to 0.2 - 0.5 min) in the areas of highest concentration of the resource. In the largest peaks, the grids consisted of an arrangement of transects, parallel or zig-zag, perpendicular to the depth isolines. In the mountains of smaller-size, radial surveys were carried out, centered on the top of the mount and randomly oriented. The bathymetric layer of the study included from 200 to 600 m deep.

The estimates of abundance and biomass will be made using the geo-statistical method based on maximum likelihood and generalized linear models of mixed type developed by Roa & Niklitschek (2007) using the target strength (TS) value of Niklitschek et al. (Niklitschek et al. 2007),

Use of fishermen and scientific observer knowledge about alfonsino on Kukenthal Peak

Design of the subject acoustic survey was, in part, based on the knowledge of the skipper of a vessel that has fished for alfonsino on Kukenthal Peak since 2005. His 82.4-m fishing vessel, the *Esperanza de Menduiña*, could be used to conduct the proposed acoustic survey in order to utilize his knowledge about alfonsino behavior, spatial distribution and aggregation patterns on Kukenthal Peak. Figure 3 shows a plot of all of the hauls and prospected tracks provided by this skipper. Most of the information is concentrated over the rising peaks (e.g. between 1 000 and 700 m). The knowledge of Spanish scientific observers who have collected data during alfonsino trips conducted on Kukenthal Peak was also used to design the subject survey. There is no information on the distribution and concentrations of alfonsino on Kukenthal Peak throughout the year. However, the alfonsino fishery in recent years has been carried out during January-March. Around 60% of the total effort occurred in February, 30% in March and 10% in January based on data from Spanish scientific observers. Thus, the proposed acoustic survey will be conducted during February.

Additionally, the distribution of the alfonsino fishery on Kukenthal Peak has been also analyzed through the Spanish Scientific Observers data and it is presented in Figure 4. More than 95% of the effort observed by the Spanish Scientific Observers was carried out during daylight hours and the median of the duration of the hauls was around 1.5 hours of trawling. Taking into account that the fishing gear has to descend up to 500-700 m depth and has to be stable before the effective catch starts, effective towing time is very short, around 20 minutes (skipper personal information). At an average speed of 3-4 knots, means that the effective towing distance is around 1.6 nautical miles. As observed in other areas, the distribution of alfonsino on Kukenthal is very patchy, with high spatial autocorrelation, which was confirmed by the skipper. The skipper also observed a diel change in the aggregation pattern of alfonsino, with fish being scatterd at night, in deeper waters on the slope of the peaks, and rising upward towards the peaks while concentrating and forming more denser schools during daylight hours. Thus the fish become more accessible to pelagic fishing gears during the day, and therefore the bulk of the fishing activities and during this survey as well will take place during the daytime.

As observed in Figures 3 and 4, the main alfonsino distribution area seems to be very stable. Besides, fish mainly occur near the top of the seamounts, with depths ranging between 700 and 900 m, which restricts the preferential distribution area to a small box, where precisely the bulk of the fishing stations are located. Besides, fishermen always prefer fish be distributed in open waters, far from seamounts, as long as the target species is present in the water column (as for instance occurs with blue whiting off the British Islands, another fishery exploited by this vessel) in order to maximize the efficiency of the fishing gear while ensuring the risk of any gear damage will be negligible. With regards to the proposed survey area, the skipper has confirmed that the bulk of his fishing operations take place in the area shown in Figures 3 and 4 because alfonsino availability in this area is higher.

Alfonsino catch length distribution for the Kukenthal Peak population during 2005-2017 were in the 30-50 cm range with a mode around 40 cm. This length distribution is very similar to the length distribution for the period prior to 1997 (González-Costas, 2018).

Acoustic Survey Plan

1. MAIN OBJECTIVE
   Estimate the distribution, abundance, biomass and size composition of alfonsino (*Beryx splendens*) on *Kükenthal Peak* (NAFO Div. 6G) by conducting a hydroacoustic survey during February.

2. SPECIFIC OBJECTIVES
   2.1 Estimate the abundance (in number) and biomass (in weight) of alfonsino in *Kükenthal Peak*.

2.2 Estimate the size composition, length-weight relationship, sex ratio and sexual maturity characterization, by sex, of alfonsino.
2.3 Collection of alfonsino gonad and otolith samples for future studies of maturity and age.
2.4 Characterize the biological environment and the physical environment (Tº, S ‰,) of the pelagic habitat of this species to produce a map of these variables within the survey area in association with alfonsino abundance estimates.

3. METHODOLOGY

3.1. Survey Area: The study area of this survey will be the delimitation of Kükenthal Peak proposed by the SC in 2019 (Table 1 and Figure 2), which has a surface area of about 148 nmi^2.

3.2. Survey Period:

There is some evidence that relates vertical migrations of alfonsino concentrations to the illumination of the sea (by the Sun and the Moon) and hydro-meteorological conditions in the area of Corner Rise seamounts (Vinnichenko, 2015). This information has been confirmed with the fishing skipper working in the area. The skipper suggests that the best time to see the concentrations is when the moon is rising and during the daytime. Therefore, we will carry out the acoustic survey during moon rising season in February and only collect acoustic data during the daylight hours (0800-2000 hours). Nevertheless, as stated, the area will be also surveyed at night during the first year in order to obtain insights on the alfonsino behaviour (i.e. diel aggregation and distribution patterns)

3.3. Survey Time Frame: It has been estimated that a minimum of 5- 7 working days, depending of the weather, would be needed to conduct the acoustic survey taking into account the size of the ssurvey area and the chosen sampling method (see Section 3.5).

3.4. Vessel and equipment: It is advisable for economic reasons to conduct the subject acoustic survey with a trawl vessel due to the availability of the same vessel that has been fishing in the area since 2004. This vessel has the appropriate technical and operational characteristics to carry out the study. The *ESPERANZA MENDUINA* fishing vessel (IMO: 8610813) was built in 1988 and sails under the flag of Spain. The vessel characteristics and relevant equipment is shown in Table 2.

3.5. Survey area and strata. The proposed survey design is based, in part, on the previous knowledge of alfonsino distribution through the observations obtained from the Spanish fleet operating in Kükenthal Peak during 2005-2018. Most of the hauls are restricted to the central part of this seamount, over an area of 8x6 nmi, as shown in Figure 4. Whether this is because fish availability is restricted to this area or because fishing accessibility (e.g. best trawlable locations within the distribution area), will be also determined by extending the survey area across the entire Kükenthal box proposed by the NAFO Scientific Council (NAFO, 2019). Given the homogeneity in length distributions observed in the commercial catches, a single stratum would be a reasonable choice (i..e entire Kükenthal box). However, the patchy distribution of alfonsino, as revealed by the effective mean tow distance, the echograms provided by the skipper, and also the major occurrence of the species around the slope of the mountains, with little extension towards deeper water (i.e., no extension towards open waters), two strata with different levels of sampling effort are proposed (Figure 5):

- Core stratum: a box delimited by the coordinates 35º35'N-52W as northwest corner and 35º28'N-51º52'W as southeast corner. This is the area in which most of the fishing activity is located
- Outer stratum: the area surrounding the core stratum, extending across the entire Kükenthal box with a random start location (random longitude in the eastern part). This design aims to ensure transect coverage is not replicated and is randomized

The survey design will consist of parallel transects, instead of star transects (because of the highly patchy distribution of alfonsino and the differences in transect density, increasing towards the center of the star, which forces the c.v. to be estimated from model-based (e.g. geostatistics, GAM's or weighted probability-based methods among others) rather than design-based methods. Transects will be placed to ensure they are perpendicular to the bathymetry of the survey area. This will ensure that in case of depth dependence in fish spatial distribution, the stock is properly surveyed. Otherwise, given the patchy distribution, both the accuracy and precision of the estimates would be lower. As shown in Figure 5, the main bathymetric contours follow an E-W direction, and therefore, transects will be placed in a N-S direction. Sampling intensity in the core stratum will be maximized, with a distance of 0.2 nmi between transects while increasing up to 1 nmi in the outer ostratum. The survey grid will have a random start location (random longitude in the eastern part). This design aims to ensure transect coverage is not replicated and is randomized between years.

A major problem affecting the outcome of the survey relates to adverse weather conditions that would be encountered in the Northwest Atlantic at the time of the survey. This may result in reduced area coverage because bad weather forces vessels to seek shelter or to slow down during sampling. This also may affect acoustic records by attenuating backscattering energy by bubbles that are swept-down, and, thus, may underestimate alfonsino biomass. To avoid these problems, acoustic data collection is proposed to be carried out only with winds of less than 25 knots and a swell of less than 5 meters in the case of large periods or even lesser height in the case of short periods. These are similar to the recommendations observed in FAO (2012).

3.5.1. The acoustic sampling grid, as previously stated, will consist on a systematic parallel transects with random starting point, with two different levels of sampling intensity, allocating the maximum effort in the area that historically contained the bulk of the acoustic and trawl commercial records (i.e., the core stratum). Inter-transect distance will be 0.2 nmi within this core stratum and 1 nmi in the outer stratum (Figure 6). In order to optimize survey time, the whole area will be sampled rather than sampling each stratum separately. Acoustic data will be recorded between 0800 and 2000 hours (i.e., daytime). Besides, the transects will be also traversed at night in order to analyse day/night differences in fish behaviour and abundance estimates. Trawl hauls will be conducted only for fish identification and the collection of alfonsino length distribution data. Therefore, trawl station locations will be selected according to the acoustic records (i.e., opportunistically) and haul duration will be as short as possible, to ensure a representative fish sample is obtained. Net sounder and sonar readings together with catch sensors will be used for this purpose. Based on the information provided by the skipper, the trawls hauls would be carried out at a speed of 3-4 knots and with an effective trawling duration of around 20 minutes.

3.6. Data collection

The data collection (acoustic, biological, etc.) at sea during the survey will be carried out by a trained Spanish Scientific Observer who has previous experience with fishing for alfonsino on Kükenthal Peak. This observer will serve as the Chief Scientist and will be in charge of following the survey protocols and the accurate collection and recording of all scientific data. All the information and samples collected will be saved for further processing in the laboratory by the IEO acoustic team. The captain of the survey vessel and Chief Scientist will abide by the NAFO research survey protocols listed in Section I Article 4 of the 2020 CEM described in Annex I (NAFO, 2020).

3.6.1. Acoustic. Acoustic data will be collected using a commercial Simrad ES70, with a ES38B, split-beam transducer mounted on the hull. The 38 kHz data is able to cover the depths where alfonsino usually occurs (400-700 m) and the resulting data will be used to generate the abundance estimates. This transducer will be calibrated directly prior the survey. This will be done in Vigo Bay, according to the standard procedures described in Demer *et al.* (2015). Acoustic data will be recorded at water depths of up to 1 000 m at maximum ping range. At the start of the survey, the vessel log (GPS distance over ground) will be reset to 'zero' to ensure consistency in log output files. All off-track incidents and transect start/end points will be recorded using the annotation menu of the ES70 software. Besides, a logbook will be also filled in with the main characteristics (time, position, latitude, longitude, log number and comments, see Annex II for further details).

3.6.2. Biological. Biological sampling will be obtained from pelagic trawl hauls conducted to allow a correct identification of the alfonsino echo traces and to achieve objectives 2.1 and 2.2. The distribution of fishing sets will be opportunistic and will not follow a statistical design since the objective is to characterize the acoustic information. As a minimum, it is intended to perform one trawl haul per day, This number may be higher depending on the diversity of species and the size distributions of the target species. The hauls will be made with a "Manuco" commercial pelagic trawl (Figure 7) that is used in the alfonsino fishery with 140 mm diamond codend mesh.e. Besides, a codend liner with 20 mm mesh will be put aiming of identifying the smaller scatter organisms and to ensure the highest catchability of the entire alfonsino length distribution in order to obtain a ground-truth representation of the stock length distribution instead a commercial catch one.

The catch information will be recorded on a haul log and will include: date, time, location, depth (m), temperature, tow duration (in minutes) and catch weight (kg) by species (see Annex III for further details).

For all hauls, the catches will be sorted by species which will then be weighted to calculate species relative composition both in weight and number. A random subsample of the catch will be collected and weighed depending on the total catch weight of each haul. The weight of this subsample will depend on the number of species caught. For a monospecific catch, a sample of 50 kg will be collected. For multispecific catches, the subsample weight will be increased by a factor of 50 kg per relevant species observed in the catch. In addition to alfonsino, relevant species are defined as the species whose contribution to the total catch is greater than 10%. For all relevant fish species, length measurements will be performed within 1 cm length classes. The number of length frequency samples will depend on the total catch, with a minimum of 31 up to 130 specimens from a random sample, and ultimately depending on the shape of length distribution (e.g.uni-multimodal) and will be collected in the length distribution form (Annex IV). Total sample taken for measurement purposes will be then weighted and raised to the total catch, with an intermediate step if the total catch was also sub-sampled. Additionally, for alfonsino, length, weight (nearest g), sex and maturity stage will be recorded (Annex V). The length of the individuals will be taken with an ichthyometer. Total length (TL) and fork length (FL) will be measured to the nearest centimetre (and rounded down). The maturity states will be established based on the macroscopic maturity scale recommended by ICES (2014) for fish. Otoliths and gonads of alfonsino will also be collected across the entire length distribution of the catches for later study in the laboratory.

3.6.3. Hydrographic. Temperature and salinity data will be collected during all trawl hauls using a sound profiler or a small CTD. In addition, water temperature will be recorded through the temperature sensor installed in the trawl sensors (door and fishing gear).

3.7. Data Analysis

3.7.1. Scrutinisation. The elementary sampling distance unit (EDSU) will be fixed at 0.2 nm. Acoustic data will be obtained during daylight hours (0800-2000 hours). Data will be then stored in raw format and post-processed using SonarDataEchoview software (Myriax Ltd.) (Higginbottom et al, 2000). All echograms will be first scrutinized, the bottom line incorporated, and background noise will be also removed according to De Robertis and Higginbottom (2007). On the other hand a specific filter to identify those pings which show an attenuated signal when compared to surrounding pings will be used. Attenuated signal can arise from air bubble attenuation within the water column below the transducer. ICES WKQUAD addressed this problem for deep sea surveys (e.g. orange roughy). Turning to zero ("empty water") those attenuated pings will keep s_V values from those scatters not affecting by signal attenuation. Echoview v9.0 includes an operator based on the "attenuated signal (AS) filter" algorithm and definitions described in in Ryan et al (2015). After this preliminary process, acoustic scrutiny will be based on trawl information and subjective categorization. School processing will be done on echotraces. Data (*schools or echotraces*) will be partitioned into different categories that could include, among others, pure alfonsino schools; mixed schools; other than alfonsino fish schools (e.g., mesopelagic fish such as lantern fish or myctophids); or low scattering echotraces (e.g. plankton). The different categories will be ground-truthed based ontrawl catches. When possible, echotraces will be assigned to a particular fish species, based on several schools descriptors provided by the school detection module of Echoview. In mixed areas (e.g. several species) backscattering energy will be allocated into fish species accounting the Nakken and Dommasness method (1975, 1977) for multiple species, but instead of using the mean backscattering cross section, the full length class distribution (1 or 0.5 cm length classes) will be used, as follows:

$$NASC_l = NASC \cdot \left(\frac{\sigma_{l,\rho}}{\sigma_\rho}\right)$$

Where *NASC* is the total backscattering energy to calculate densities by length, $NASC_l$ is the proportion of the total *NASC* which can be attributed to length group l for a particular fish species. $\sigma_{l,p}$ is the backscattering cross-section at length l for a particular species at length l multiplied by the proportion of (p_l) of length of this particular species on the overall catch and σ_p is the sum of all $\sigma_{l,p}$ for all species,

$$\sigma_{l,\rho} = \rho_l * \sigma_l$$

$$\sigma_\rho = \sum_l \sigma_{l,\rho}$$

finally σ_l, is backscattering cross-section (m^2) for a fish of length l for a particular species and is computed as follows:

$$\sigma_l = \frac{l^{\left(\frac{m}{10}\right)} * 10^{\left(\frac{b_{20}}{10}\right)}}{4 * \pi}$$

This is computed from the formula TS =20 $\log L_T + b_{20}$ (Simmonds and MacLennan, 2005), where L_T is the length class.

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3.7.2. Abundance estimation.

The allocation of the scattered acoustic energy (s_A-values) to alfonsino and other acoustic targets will be based on the species composition of the trawl catches and the appearance of echo recordings, assigning to alfonsino those echotraces extracted using the school processing analysis included in Echoview. Acoustic data will be analysed using the StoX software package. A description of StoX can be found at: http://www.imr.no/forskning/prosjekter/stox/nb-no. An example of StoX procedures can be found in Mehl et al (2018). Estimation of abundance from acoustic surveys with StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990). This method requires pre-defined strata, and the survey area is therefore split into strata with pre-defined acoustic transects. This approach allows for robust statistical analyses of uncertainty of the acoustic estimates. All trawl stations within the stratum with catches of alfonsino will be assigned to all transects within the stratum, and the length distributions will be weighted equally within the stratum.

To obtain an estimate of alfonsino length distribution within the stratum, all length samples within it will be used. Briefly, the estimates are based on the method described in Nakken and Dommasness (1975; 1977) and fully described in StoX manual and previously in this survey plan. For alfonsino, estimates will be done within each stratum using the arithmetic mean of the backscattering energy (NASC, s_A) attributed to alfonsino and the surface expressed in square nautical miles using the following formula:

$$\rho_l = \frac{NASC_l}{\sigma_l}$$

$$N_l = \rho_l * A_p$$

Where ρ_l is the areal density of fish (numbers per square nautical mile in length group l); the total number for length group l (N_l) within each stratum is calculated as the product of ρ_l times the total surface of the stratum (A_p) expressed in square nautical miles.

Due to the lack of studies of TS of this species in the NAFO area, the estimated TS value for alfonsino in studies conducted in Chile will be used (Niklitschek et al., 2007):

$$TS = 20 \cdot \log(LE) - 67{,}7 \text{ (dB)}$$

For comparative purposes, biomass will also estimated using the generalization of Foote (1987) for physoclistous fish, in which:

$$TS = 20 \cdot \log(LE) - 67{,}4 \text{ (dB)}$$

3.7.3. Estimate of relative sampling error.

For the baseline run, StoX estimates the number of individuals by length group which are further grouped into population characteristics such as numbers at age or sex.

A total length distribution will be calculated, by transect, using data from all the trawl stations assigned to each transect. Conversion from NASC (by transect) to mean density by length group and stratum uses the calculated length distribution and a standard target strength equation with user defined parameters. Thereafter, the mean density of alfonsino by stratum will be estimated by using a standard weighted mean function, where each transect density is weighted by transect distance. The number of individuals by stratum will be computed as the product of stratum area and area density.

A bootstrap procedure (1 000 iterations) will be used to estimate the coefficient of variation (RStoX V1.11) whereby the procedure randomly replaces transects and trawl stations within a stratum on each successive run. The output of all the runs is stored in an RData-file, which will be used to calculate the relative sampling error (Standard Deviation · 100/mean, both parameters calculated from the bootstrap).

3.8. Correction for bias

In ES70 system, as explained in Demer et al. (2015), raw data are modulated with a triangle-wave error sequence (TWES), with a 1-dB peak-to-peak amplitude and a 2720-ping period. While TWES has negligible effect over a complete period (e.g. insignificant contribution to sampling error), it may bias calibration by as much as ±0.5dB. Therefore, prior to calibration, the TWES should be removed from the received power data as explained in Demer et al. (2015).

On the other hand, as the vessel will be calibrated in Vigo, with different oceanographic characteristics than those expected in the survey area, echosounder parameters have to be corrected in relation to the differences in sound speed (Demer et al., 2015). This is because the local c_w affects λ (wave length), Λ (angle sensitivities) ,θ_{-3dB} (beamwidths) , ψ (equivalent beam angle), and g_0 (the transducer on-axis (peak) gain, and, therefore, measures of TS and S_v (Bodholt, 2002).

- ψ and g_0 will change as the function of the square of the ratio of the calibrated celerity to the local celerity, $\psi = \psi'(c_w^2/c_w'^2)$; $g_0 = g_0'(c_w'^2/c_w^2)$.
- Λ and θ_{-3dB} will change as the function of the ratio of the calibrated celerity to the local celerity, $\Lambda = \Lambda'(c'_w/c_w')$; $\theta_{-3dB} = \theta_{-3dB}'(c_w/c_w')$.

These parameters, together with the absorption coefficient, α_a (dB m^{-1}), and sound speed, c_w, will be updated using the Echoview Calibration Supplement file (*.ecs) accordingly.

This survey plan will be reviewed for its appropriateness of use in future surveys as more information and experience about of the species and the problems encountered in carrying out the surveys is obtained.

Reporting of survey results

A report in the form of an SCR document will be presented at the June SC meeting that occurs during the subsequent year in which the survey is conducted. The report will describe the methodology used to conduct the survey and, at a minimum, will contain the following survey results for review by the SC:

1.) Population estimates of alfonsino abundance and biomass, including precision estimates, and size composition by sex and for combined sexes.

2.) Station map of the study area showing trawl haul locations and acoustic survey transects and actual tracklines.

3.) Length conversion factor for standard to fork length. Length composition (by sex and combined sexes), length-weight equations (by sex and combined sexes), male and female median lengths at maturity based on the macroscopic maturity scale, and sex ratios for the alfonsino stock.

4.) A table listing trawl catches of alfonsino and all bycatch species (including any VMEs), by haul and for all hauls combined, as weights and numbers for each species. All trawl haul logs should be included in the report as an annex.

5.) Distribution maps of alfonsino based on the acoustic results.

6.) A list of the numbers of alfonsino otolith and gonad samples collected at each station for future analysis.

7.) Describe any difficulties encountered during the survey and provide recommendations for their improvement.

Acknowledgement:

We would like to express our deep gratitude to Joaquín Pousa (Esperanza Menduiña skipper) and Joaquín Gandón (Hermanos Gandón S.A.), for their valuable technical information on the alfonsino fishery in the NRA.

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Table 1. Coordinates of the rectangle containing Kükenthal Peak in Division 6G.

Coordinate number	Latitude	Longitude
1	35°38'13"N	52°03'00"W
2	35°38'13"N	51°47'42"W
3	35°26'42"N	51°47'42"W
4	35°26'42"N	52°03'00"W

Table 2. Technical characteristics and acoustic equipment of the trawl vessel "Esperanza de Menduiña".

Vessel	Esperanza de Menduiña
Type	Fishing Trawler
IMO	8610813
IRCS	EGXZ
DWT	1930 t.
LOA	84.2 meters
Width	12.5 meters
Power	1467 kW (1995 CV)
Echo sounder	SIMRAD ES70
Transducer	SIMRAD ES38B
Trawl doors	Poly-Ice Viking o V8 Area=8 m^2 Weight=2200 kg.
Trawl door sensor (Door spread; distance to vessel; depth temperature; pitch and roll)	Marport Scanmar
Net sonar	Wire Simrad FS70
Net sounder	Marport trawl eye (wireless) Scanmar trawl eye (wireless)

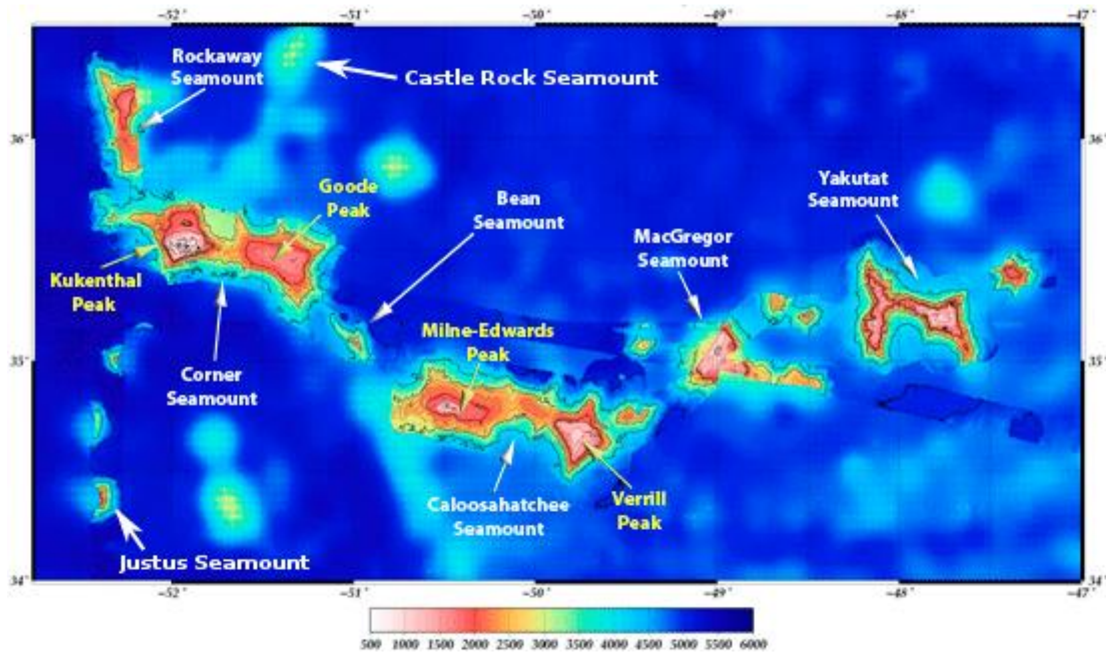

Figure 1. Corner Rise Seamounts area with names of some of the Corner Rise seamount peaks. NOAA - http://www.whoi.edu/oceanus/viewImage.do?id=57092&aid=33769

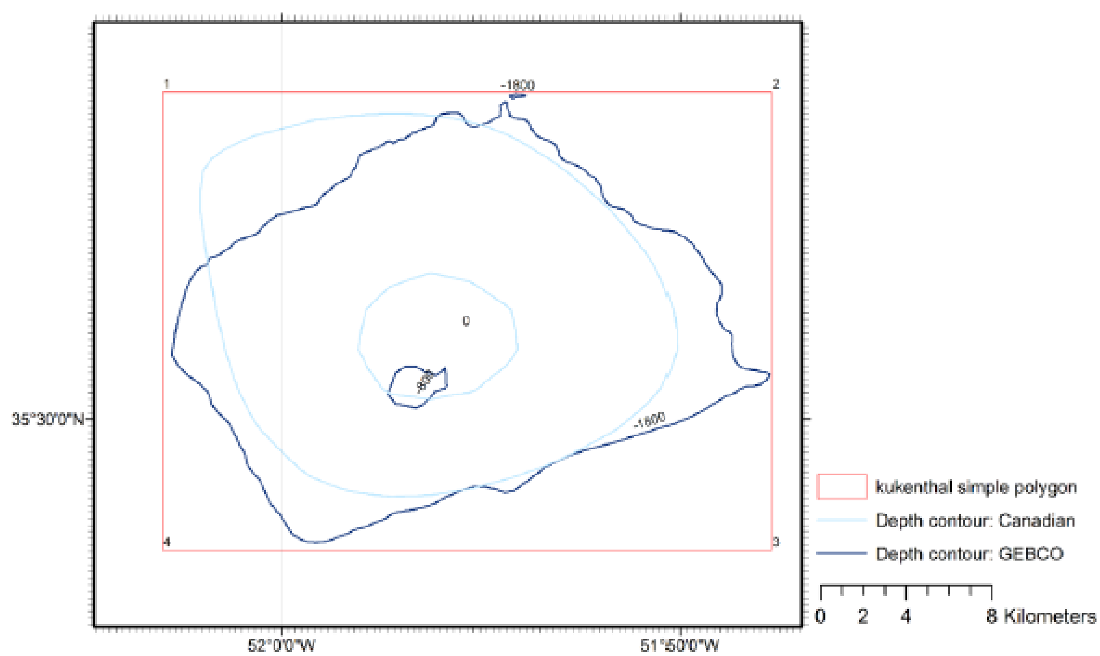

Figure 2. Location of Kükenthal Peak mapped according to the 800m and 1800 m depth contours from GEBCO and Canadian hydrographic service, with a polygon (red line) proposed to delineate the Kükenthal peak.

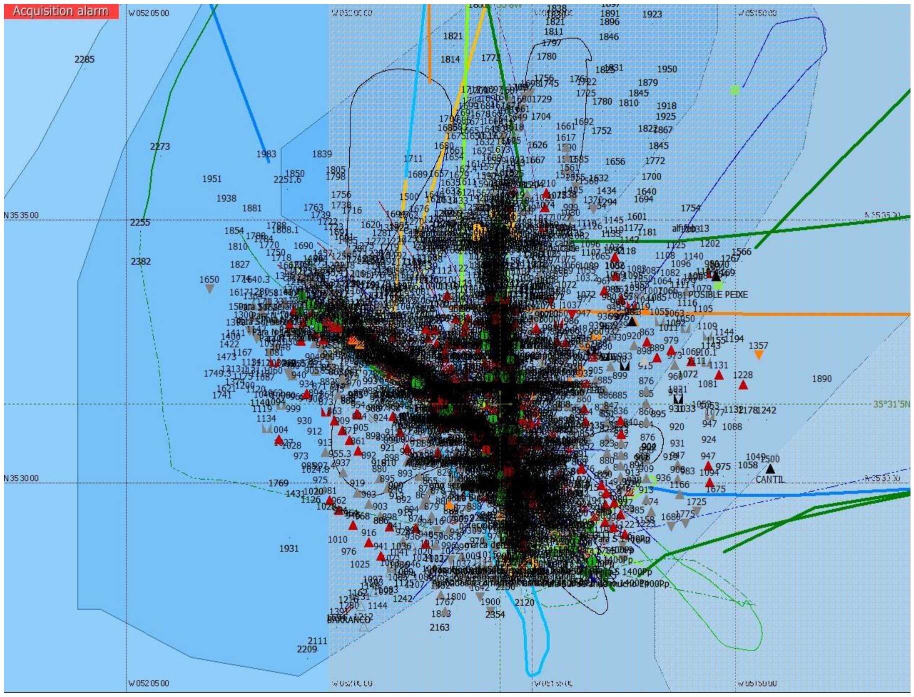

Figure 3. Different positions of the Spanish commercial hauls track in Kukenthal Peak (Joaquin Pousa personal communication).

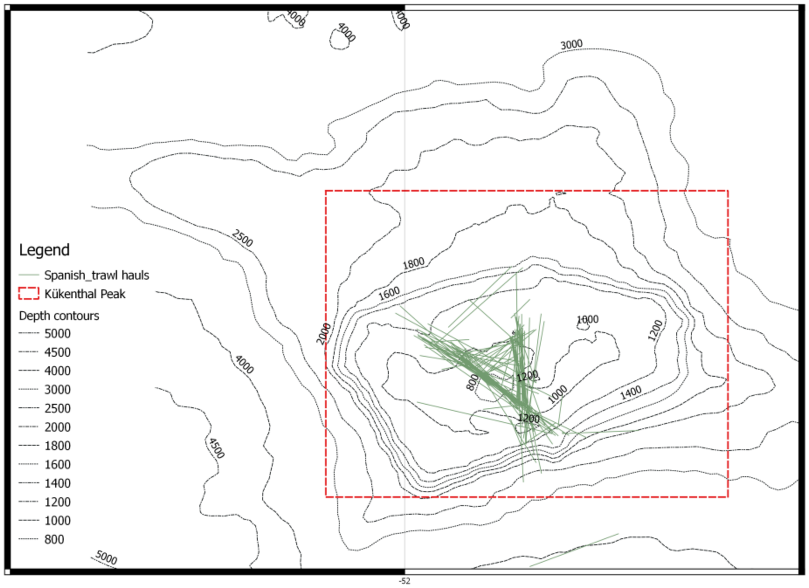

Figure 4. Distribution of the Spanish commercial fishing hauls based on the Spanish Scientific Observers information (2009-2018).

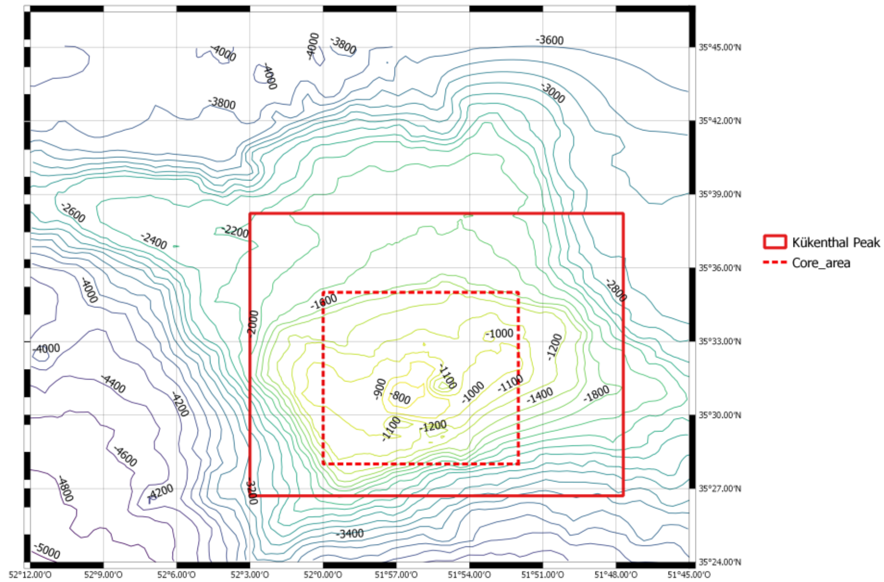

Figure 5. Proposed strata (i.e., the core stratum represented by the dashed line and outer stratum represented by the rectangle surrounding it) for the alfonsino acoustic survey in Kukenthal Peak.

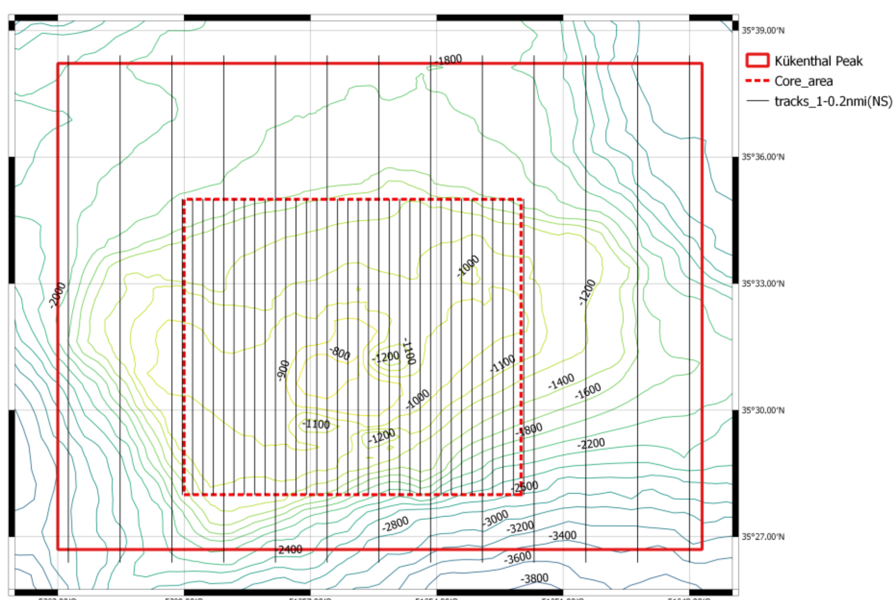

Figure 6. Survey tracks within the two survey strata (represented by the red rectangles) for the alfonsino acoustic survey in Kukenthal Peak.

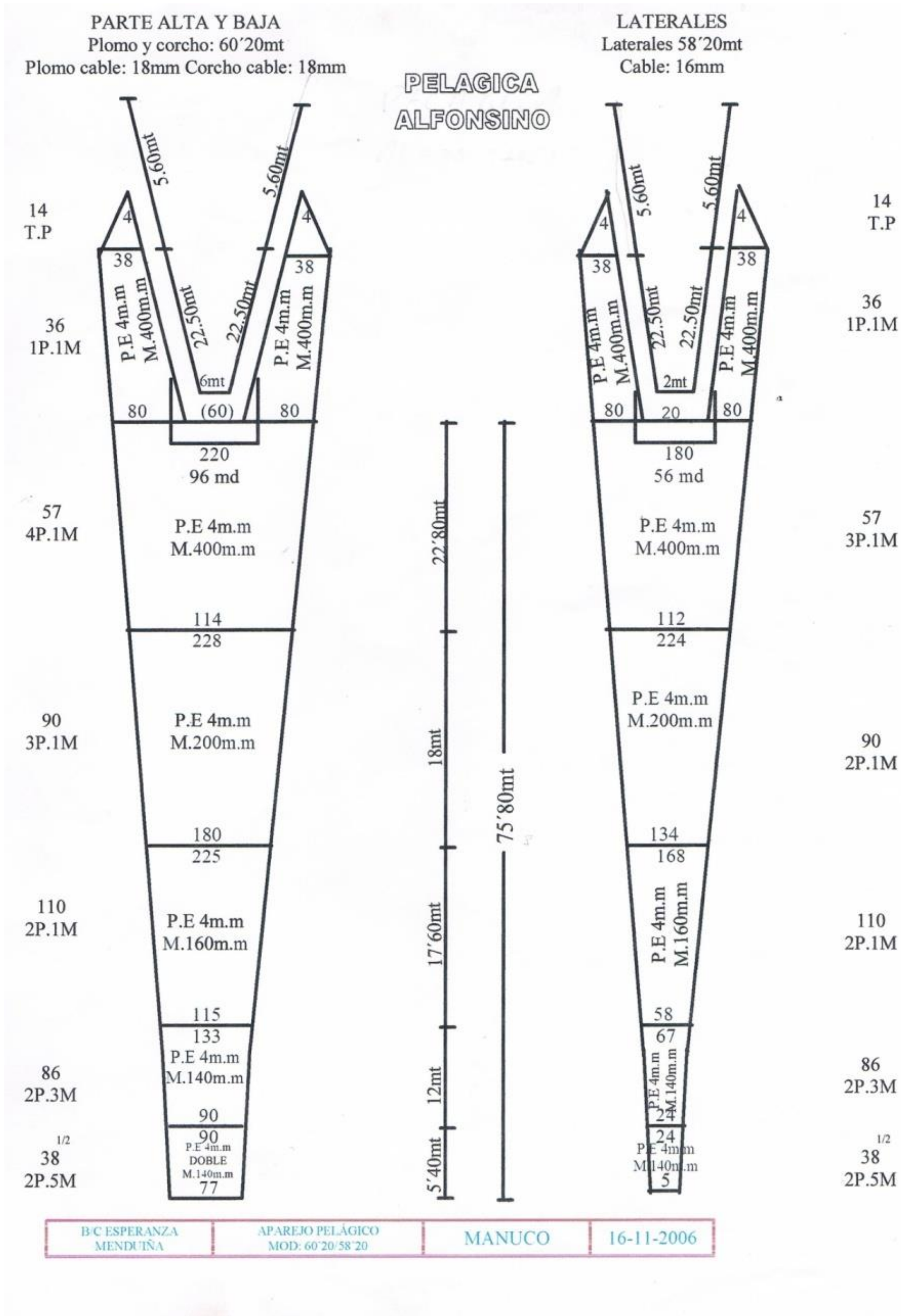

Figure 7. "Manuco" pelagic trawl plan.

ANNEX I. Section I Article 4 of the 2020 Conservation and Enforcement Measures which describes the NAFO requirements that the proposed acoustic survey is required to abide by.

CHAPTER I
CONSERVATION AND MANAGEMENT MEASURES

Article 4 – Research Vessels

1. Unless otherwise provided, research vessels shall not be restricted by conservation and management measures pertaining to the taking of fish in the Regulatory Area, in particular, mesh size, size limits, closed areas and seasons.

2. A research vessel shall not:

   (a) conduct fishing activities inconsistent with its research plan; or

   (b) take 3L shrimp in excess of the allocation of the flag State Contracting Party.

3. No less than seven days prior to the commencement of a fishery research period, the flag State Contracting Party shall:

   (a) by electronic transmission in the format prescribed in Annex II.C, notify the Executive Secretary of all research vessels entitled to fly its flag it has authorized to conduct research activities in the Regulatory Area; and

   (b) provide to the Executive Secretary a Research Plan for all vessels entitled to fly its flag it has authorized to conduct research, including the purpose, location and, for vessels temporarily engaged in research, the dates during which the vessel will be engaged as a research vessel.

4. For vessels temporarily employed in research, the flag State Contracting Party shall immediately upon termination of research activities so notify the Executive Secretary.

5. The flag State Contracting Party shall notify the Executive Secretary not less than seven days before the effective date of any changes to the research plan. The research vessel shall maintain a record of the changes on board.

6. Vessels engaged in research shall at all times keep on board a copy of the Research Plan in the English language.

Duties of the Executive Secretary

7. Following notification in accordance with paragraph 3(a), the Executive Secretary without delay posts the names of all research vessels in the vessel registry to the NAFO website and includes in such posting any supporting documents provided by the flag State Contracting Party, including the ResearchPlan.

	ACOUSTIC LOGBOOK	SURVEY: ________________	DATA:___/_____/_____
		VESSEL: _________________	SHEET No.:
		RESPONSIBLE:	

TRACK	LOG	OBSERVATIONS (Put time, position and event)
	1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	0	
	1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	0	
	1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	0	
	1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	0	

Annex II. Acoustic logbook form.

ANNEX III. Data log for recording station and catch data at each survey haul location.

	Fishing station Datasheet	SURVEY: ________________	DATA: ____/____/___
		VESSEL: _________________	Fst No.: _________
			AREA:

WEATHER CONDITIONS										
Wind		Wave		Value	FISHING GEAR					
Dir	Speed	Dir	Height		TYPE	Clumbs w.	Winds len.	Trawl eye	Door w	Door sens.
Observations:										

SHOOT	START	READY	FISHING		
TIME				LONGITUDE	LATITUDE
DEPTH					
Obervac.					
RELEASE	START	DOORS	END		
TIME				LONGITUDE	LATITUDE
DEPTH					
Observat.					

OVERALL PERFORMANCE							VALUE:	
Time	Groun speed	Warp leng	Total depth	Gear depth	Door depth	Door spread	Gear geom (vert vs horiz)	OBSERVATIONS

CATCH			
SPECIE	No	Kg	% No

ANNEX IV. Data log for recording the length distribution samples from VÁzquez *et al*.(2014)

Campaña FLEMISH CAP 20 ___

Pesca ________________
Día/mes ______________ ESPECIE ____________________________
Peso muestra __________

talla (cm)	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	

talla (cm)	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	

. ANNEX V. Data log for recording the alfonsino biological samples from VÁzquez *et al*.(2014

Campaña FLEMISH CAP 20

Pesca ________________
Día/mes ______________ ESPECIE __________________________

	talla (cm)	sexo	peso (g)	peso eviscer.	G
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					

	talla (cm)	sexo	peso (g)	peso eviscer.	G
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
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50					