SPRFMO
South Pacific Regional Fisheries Management Organisation

7th MEETING OF THE SCIENTIFIC COMMITTEE

La Havana, Cuba, 7 to 12 October 2019

SC7-SQ08

Direct evaluation of Jumbo squid in Chile

Chile

DIRECT EVALUATION OF JUMBO SQUID (*Dosidicus gigas*) IN CHILE

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1. ABSTRACT

Some of the results of the FIPA project 2015-16 "Direct evaluation of jumbo squid (*Dosidicus gigas*) in the south central zone of Chile, methodological proposal" is presented. This project was funded by the Fondo de Investigación Pesquera y Acuicultura and developed by the Instituto de Fomento Pesquero, Instituto de Investigación Pesquera and the Universidad de los Lagos. The studies carried out on the jumbo squid have been oriented to its behavior, trophic dynamics, but few destined to estimate the size, distribution and geographical structure of its stock.
First, a literature review available was made for direct evaluation of jumbo squid, of which four methods were pre-selected and analyzed; marking- recapture, swept area, hydroacoustic and fishing with jigging / lights. Secondly, a workshop was held with international experts, where the four selected methods were presented and the need to have an adequate tool to evaluate the stock of jumbo squid was discussed, having a consensus in not to only evaluate this resource with a single method. Finally, an exploratory cruise was carried out to test the methods selected for the evaluation (swept area, acoustics, and jigging / lights), discarding the mark-recapture method because the jumbo squid is considered to have an open population. The prospecting cruise was carried out between June 3th and 29th, 2016, obtaining as a result that, in general, the three methods considered could be applied in the evaluation of the jumbo squid stock, however, the choice of some they are still not entirely clear, since adjustments are still needed to adapt the methodology and obtain the expected result, so the use of these should be considered with the caution required by the methodological nature of the study.

2. INTRODUCTION

The sustainable management of stocks subject to commercial exploitation requires timely and quality information regarding the condition of the population exploited, understanding their population dynamics and distribution, especially when dealing with a previously untapped or underexploited stock. Short-lived fishery resources, such as squid, are particularly vulnerable to over-exploitation due to inadequate understanding of population dynamics and stock distribution, as they are prone to high population fluctuations, which may be the result of environmental changes, changes in the levels of exploitation of the stock, changes in the abundance of prey and / or predators (Goss *et al*., 2001) or the combination of all of them.
Squids are among the most difficult animals to evaluate biologically by any method, precisely because of their very rapid individual growth rate and very low longevity (1 to 2 years). However, there is extensive bibliographical information that squids are important components in their ecosystems (Arnaya *et al*., 1988), either as a predator or as a prey or both.
In the case of the evaluation of squid by direct methods, and particularly of cuttlefish, several techniques have been used, among which are (1) tag-recapture, (2) swept area, (3) acoustics and (4) the use of fishing gear (traps, hooks, jiggers, etc.
According to the above, in the present study different methods of direct evaluation were analyzed to determine which would be the appropriate methods to estimate the abundance and demographic structure of the jumbo squid in the south central zone of Chile.

3. EVALUATION METHODS

Although during the last decade, jumbo squid has gained great ecological, social and economic relevance in Chile, there are no studies aimed at estimating its abundance and distribution, but the information comes from the fishing activity. However, this situation occurs not only in Chile, but is also transversal in other countries where jumbo squid represents an important fishing resource.

On the other hand, the review carried out showed that the direct evaluation studies developed to estimate the size, distribution and geographic structure of the jumbo squid stock are scarce and dispersed (Table 1) and that they have mainly been applied to behavioral studies and estimates of white strength.

3.1 METHOD OF MARKING, RELEASE AND RECAPTURE.

This method is used to estimate the size of a population and some characteristics such as spatial distribution, growth, migrations, among others (Borchers *et al*., 2002). Its application is based on a series of assumptions such as:

- Individuals from the same population have a similar probability of being captured.
- The proportion of marked animals with respect to unmarked animals remains constant in the period between capture and recapture.
- Marked individuals, once released, are redistributed homogeneously among the population of unmarked individuals, in the same way they were before they were captured.
- Marked animals do not lose their marks.
- The population is closed. During the sampling period no emigration or immigration processes are verified.

In the scenario of spatial distribution presented by the jumbo squid fishery in Chile, with a dynamic that depends heavily on immigration (juvenile) and emigration (adult) processes (Arancibia *et al*., 2016), the marking/recapture method of no It presents adequate characteristics for the direct evaluation of the resource, although the importance for other types of studies such as growth, migration, distribution, among others is recognized.

3.2 SWEPT AREA METHOD.

This method developed by Alverson and Pereyra (1969) allows estimating the size of the stocks of a resource or a particular component of it (e.g. adults, juveniles, spawners) and monitoring its spatio-temporal changes.

The wide distribution of jumbo squid can have a significant impact on the results of studies conducted with this method. This highlights the importance of fishing gear, particularly in estimating the catchability coefficient (Munro and Somerton, 2002), especially in the vertical component.

3.3 ACOUSTIC METHOD.

This method appears as another alternative since it allows covering large surfaces in relatively short times. Based on the use of echo sounders that emit high frequency and short duration sonic pulses that travel forming a directional beam that samples the column. When the sound finds an element of density other than seawater, part of the sound is reflected, forming an echo that returns to the vessel that is received by the echo sounder and allows quantitative information of the target to be obtained as position, size and abundance, in addition to global view of the water column (Simmons and MacLennan, 2005).

However, despite the advantages that the acoustic method would have to face the weak acoustic response generated by jumbo squid and that it is reflected that most of the acoustic studies developed have been oriented to estimate its target strength, critical value to transform the acoustic density in biological density.

In this regard, there is only one TS-size relationship published and corresponding to Benoit-Bird et al., 2008 for individuals between 28 and 71 cm. On the other hand, Villalobos et al., 2013 made measurements in the Gulf of Mexico and reported target strength values 11 dB lower than those observed by Benoit-Bird *et al*., 2008 (Table 2), but does not propose a relationship.

When considering the relationship of Benoit-Bird et al. (2008) the impact on the biomass estimate would reach a factor of 13 between both estimates. The above indicates the need to obtain reliable TS-size ratios before applying the acoustic method to estimate the jumbo squid biomass and it would be appropriate to initially estimate the relative abundance index rather than an absolute estimator, moreover, when all estimates made by direct evaluation methods can be classified as relative.

3.4 METHOD OF USE OF JIGGING AND LIGHTS.

The use of "jigging" is the most widely used method of catching squid and jumbo squid in particular. It is based on taking advantage of the jute squid nictemeral migrations which moves towards the surface during the night, where it is attracted to the vicinity of the fishing vessel by lights installed on the deck where they are captured by "jiggs" that are lures and hooks defined by the number of axes and crowns. In each line you can install from one to several jiggs arranged at distances of 70 to 90 cm between them.

4. PROSPECTION CRUISE

4.1 CRUISE PERIOD

When a method of direct evaluation is generally applied, the definition of the area and period of study is generally associated with a biological milestone that favors the characteristics of the method to be used. Among the processes considered are those of a reproductive and recruitment nature, especially when they develop with the resource, forming spatial and temporally limited aggregations.
In the case of jumbo squid there are no indications of a spawning area within the maritime space of Chile, but instead a recruitment process that takes place during the second semester with the entry of young individuals who remain in the process of feeding and growth is verified until the end of the following winter (Figure 1), then leaving the area in a reproductive migration.
In this scenario and in order for the results of the cruise to project the size of the stock evaluated during the period of permanence in the fishery, the execution period should consider the period of the jumbo squid migration process. However, taking into account the exploratory nature of the cruise, the availability of ships and the need to have a knowledge of the jumbo squid acoustic record, as well as its behavior, the cruise took place between June 3 and 29, 2016 and participated in it the BI ships Abate Molina and the PAM Biomar IV (Table 4).

4.2 STUDY AREA AND SAMPLING PLAN.

The study area comprised between latitudes 29 ° 10´S and 40 ° S and up to a distance of 20 miles. For the analysis of the data, the study area was divided according to the vessel that operated on it. This gave rise to two sub-zones for BI Abate Molina, which were Coquimbo (29 ° 10´S-30 ° 40´S) and Papudo-Topocalma (32 ° 30´S-34 ° 00´S), while for the PAM Biomar IV were Papudo-Topocalma (32 ° 30´S-34 ° 00´S) and Constitución-Corral (35 ° 10´S-40 ° 00´S).

The sampling plan did not come from a statistical design, but was adapted to the days / vessel available and the extent of the main fishing areas. Both vessels carried out a sampling plan composed of acoustic sampling transects and fishing stations, with bright powerhouses in the BI Abate Molina and fishing with a water network in the

Biomar IV PAM. Figure 2 shows the layout of the transects and the stations made by each ship. During the study, 40 transects were made, 29 of them made by the PAM Biomar IV and 11 by the BI Abate Molina. There were 21 mid-water trawl fishing sets and 35 fishing stations with two jigging lines, lasting 30 minutes.

4.3 ACOUSTIC AND FISHING SYSTEM.

In the acoustic sampling transects a Simrad model Ek60 system with split beam transducers and operating at frequencies of 18, 38, 120 and 200 kHz was used.

The mid-water trawl fishing sets were carried out with an Atlantic model network of 148 meters of relinga. It develops a vertical opening or net height of 40 meters, while its opening between the tip of the wings reaches 48 meters. The fishing stations of the Abate Molina B / C were carried out using 1-axis and 3-crown luminous potras (Figure 3).

5. RESULTS

5.1 SPATIAL DISTRIBUTION OF JUMBO SQUID.

The Figure 4 shows the spatial distribution of jumbo squid estimated from the local density index estimated from the data obtained from acoustic sampling, jigging and mid-water trawl, showing its presence in most of the surveyed area.

When differentiating according to the method used, the highest densities were observed with the acoustic method between latitudes 35 ° S and 38 ° S, an area that coincides with the main capture area of the fishery, while, towards the north, the local densities reached lower values. On the other hand, the local densities estimated from the use of jigging were represented by the predominance of the average levels in the northern sector (29 ° S-31 ° S) and high density values in the central sector of the study area (32 ° 40´S - 34 ° 00´S).

Regarding fishing sets, they showed different levels of density, without highlighting the predominance of any particular class. The jumbo squid aggregations showed a circadian pattern similar to the deep dispersion layer (DSL), with a distribution whose upper limit reached lower depths during the hours of darkness and in greater during the hours of daylight. The bathymetric range was located between 6 and 485 meters, with an average depth centered at 91 m ((± 84.9 m), with aggregations located near the area of the continental slope. On the other hand, the highest densities of jumbo squid located west of the continental shelf break zone.

5.2 ESTIMATION OF ABUNDANCE AND BIOMASS.

The estimated stock size from acoustic prospecting and using the geostatistical method is presented in Table 5. The results show that the majority fraction of the stock was concentrated in the south central area of the study area (35 ° S-38 ° S).

The total abundance was estimated at 62,061,431 individuals and the biomass at 907,288 tons when considering the estimates obtained by the BI Abate Molina and the one corresponding to the Constitution-Corral area of the PM Biomar IV and of 61,405,905 copies and 876,418 tons when consider the estimates of the Biomar MAP and the estimate associated with Coquimbo.

In the case of the estimator obtained with the fishing sets, only the average density was estimated, which reached 59.5 t / mn2, a value that considering the vertical amplitude in the distribution of jumbo squid in relation to the net height would be underestimated , due to a vertical capture coefficient less than 1.

5.3 DEMOGRAPHIC STRUCTURE

The jumbo squid size structure analysis considered the total samples observed, 333 captured with jigging and 3,038 with mid-water trawl covering a range of total lengths between 40 and 180 cm, while with jigging it was more limited, between 90 and 180 cm in total length.

In addition to the total length, the dorsal length of the mantle was also measured, the size structures of the samplings taken at the sets and fishing stations are shown in Figure 5. It shows a structure with fashions of greater relative importance centered between 70 and 90 cm in length of the mantle and an extended distribution to the left in the PAM Biomar IV and that could be indicating the presence of individuals who would belong to more than one cohort in the south central area of the area

When disaggregating the structure by subzone (Figure 6), it is observed that the size distributions registered with jigging show few variations in the two subzones evaluated with this rig, a situation that is repeated in the structures registered with the mid-water trawl network. However, in the central area where it was sampled with jigging and mid-water trawl network, there was a greater participation of specimens of sizes smaller than 70 cm in the structure coming from the sets with a mid-water trawl network. This difference could be the effect of jigging selectivity with respect to mid-water trawl, a situation that has also been observed in industrial fishing (Payá 2016).

When considering capture by sex and fishing gear, it was observed that jigging captured 57.1% of females, compared with 51.2% of mid-water trawl.

6.0- ANALYSIS OF RESULTS

6.1 Advantages and disadvantages of methods to evaluate jumbo squid

In the present study, four methods of direct evaluation were considered, from which the use of labeling and recapture should be ruled out because the spatial distribution of the jumbo squid stock present in national waters does not allow to comply with the assumption of closed population that supports the method. However, its undoubted strength is recognized in other studies such as growth, migration, behavior, among others.
The other three methods present strengths and weaknesses whose impact on the results are variable and can be summarized in Table 3.

Taking into account the wide bathymetric distribution of jumbo squid in the water column, the hydroacoustic method would appear to be the most suitable for its evaluation. However, its mixture with other components of the planktonic community, its low capacity for acoustic reflection and the variability in estimates of its target strength generate uncertainty and whose impact on the evaluation needs to be evaluated (Horne and Parker 2010).

In the case of the swept area method, the use of trawls to evaluate a resource of a wide vertical distribution, would only be accounting for a fraction of the stock and a high probability of estimating a biased result.
Finally, the jigging / lights method makes use of nictemeral behavior and positive phototropism of jumbo squid and is the most widely used way to capture it. The development of estimation is analogous to that applied to direct evaluations carried out with networks, traps and spins (Alverson and Pereyra 1969, Arana 2000, Ettiene *et al*., 2013).

In a data-scarce fishery such as jumbo squid, it is not convenient to focus on a particular method, but rather it should be aimed at estimating at least a couple of direct evaluation indicators until their results are validated.
In the study carried out, we explored in an exploratory manner with the three feasible methods to apply, but the swept area was oriented to estimate a local density indicator that could be compared with estimators achieved in acoustic and jigging methods.

7 CONCLUSIONS

The results obtained during the direct evaluation cruise to estimate the abundance and demographic structure of the evaluated stock, shows that in general the three methods considered could be applied in the evaluation of the squid jumbo stock, however, the choice of some (s) of this (s) is not yet entirely clear, since it remains to make adjustments that allow its adaptation to obtain the expected result and therefore the use of these should be considered with the precaution that the methodological character of the study demands.

Among the relevant issues that must be addressed in order to carry out a direct evaluation are the relationship of target strength for the acoustic method, and the efficiency and selectivity of powerhouses and mediagua nets.

The target strength ratio makes it possible to transform acoustic densities into biological densities and is a key factor in any acoustic evaluation. There are relationships that have been used to make abundance estimates in jumbo squid (Imarpe, 2015a, b; Rosas et al., 2011) and that show differences between them greater than 20 dB, which significantly impacts the estimates. In this scenario, the most precautionary relationship was applied in the study, which corresponds to the one proposed by Bennoit Bird et al. (2008). Due to the above, it is advisable to consider jumbo squid evaluations as relative until the TS-Size relationship is validated, so that this method can be used effectively in jumbo squid.

The other two methods considered could also be feasible to apply, but the results obtained up to this report must be analyzed and subjected to statistical tests in order to have some information on their efficiency, especially as regards the coefficient of vertical catchability in the case of trawl and selectivity network in the poteras.

The importance of analyzing jigging selectivity becomes evident when comparing the size structure obtained by this method in relation to mid-water trawl. Although both compositions show a main fashion of individuals 70 to 90 cm in length of the mantle, the one obtained with mid-water trawl also has a persistent presence of individuals smaller than 70 cm in size, which in the composition with poteras appear marginally.

Of the applied methods, the selectivity of the capture methods with which the sampling for species identification is obtained is of particular interest. In the case of jigging it is necessary to use a scheme that allows to extend its selection range, as it would also be convenient to use automatic systems, which would allow standardizing the sampling effort, in a method that can be implemented in different vessels

It is considered necessary to implement more than one direct evaluation method, until they are validated. In this scenario, a scheme is recommended in which the acoustic-jigging or mid-water trawl-jiggins methods are used, taking into account the observations indicated in this report.

The fact that the results obtained during the present study should be considered preliminary, given the methodological nature of the study, is recommended, and it is recommended that they not be used for the administration of the resource.

On the other hand, in a resource such as jumbo squid with a spatial dynamic not fully known and impacting the availability of the resource, the execution of direct evaluation studies should consider these aspects for its planning, particularly when it is necessary to define what fraction of the resource you want to evaluate, as this could mean that the time window as space are different.

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Table 1. Direct evaluation methods used in *Dosidicus gigas* studies.

Method	Reference	Objective	Specie
Recapture Release Marking	Gilly *et al.*, 2006, Bazzino 2008; Benoit-Bird y Gilly 2012.	Migrations	*Dosidicus gigas*
	Morales-Bojórquez *et al.*, 2012	Stock size	*Dosidicus gigas*
	Markaida *et al.*, 2003	Increase	*Dosidicus gigas*
Swept area	Alarcón-Muñoz *et al.*, 2008	Stock size	*Dosidicus gigas*
Acoustics	Bennoit-Bird *et al.*, 2008, Robinson *et al.*, 2014	White force	*Dosidicus gigas*
	Rosas *et al.,* 2011, Imarpe 2015a, 2015b	Tamaño del stock	*Dosidicus gigas*
Lights / jigging	Nevárez-Martínez *et al., 2000;* Rivera, 2001; Velásquez 2011,	abundance index	*Dosidicus gigas*
	Valles-Meza *et al.*, 2013	CPUE	*Dosidicus gigas*

Table 2. Estimates of the TS-size ratio.

Relationship	Size (cm)	Autor	Δ TS (dB)
$TS = 20*\log_{10}(LM) - 62$	28-71	Benoit-Bird *et al.,* 2008	0
$TS = 20*\log_{10}(LM) - 73^{(1)}$	49-67	Villalobos *et al.,* 2013	-11

(1): Assuming a TS-size quadratic relationship.

Table 3.- Strengths and weaknesses of the direct evaluation methods of jumbo squid.

	Acoustics	Swept area	Lights / jigging
Vertical coverage	Sample the entire water column	Sample only in the range associated with the vertical opening of the mouth of the net	Sample only in the range of influence of the attraction light.
Special coverage	Covers large areas in a short time	Covers large areas in a short time	large areas in a short time
Biological information l	Requires additional sampling to identify echo-strokes.	Provides information on the specific composition and size structure.	Size structure information.
Additional Information	TS-size ratio.	Efficiency of the fishing net	Influence area
Background of application of the method	Low	No	Half

Table 4. Characteristics of the participating ships

Characteristic	B/C Abate Molina	PAM Biomar IV
Length (m)	43,6	47,2
sleeve (m)	8,3	11,0
Calado (m)	3,3 m	3,6
Cruising speed (knots)	9	12
Thick Log Tonnage (t)	426	1.037
Type of boat	trawl	trawl
Acoustic system	Simrad EK60	Simrad EK60
Transducer frequency (kHz)	18, 38, 120, 200	38

Table 5. Estimates of jumbo squid stock size in the prospected area.

		Abate Molina		Biomar IV	
Acústico	Estimator	Coquimbo	Valparaíso-San Antonio	Valparaíso-San Antonio	Constitución-Corral
Geo estadistic o	Abundance (N°) Cv(%)	9.311.958 (16%)	4.307.783 (32%)	3.652.257 (21%)	48.441.690 (14%)
	Biomas (t) Cv(%)	173.202 (33%)	80.124 (18%)	49.254 (23%)	653.962 (15%)
Jigging	Estimator	Coquimbo	Valparaíso-San Antonio	Valparaíso-San Antonio	Constitución-Corral
Geo estadistico	Abundance (N°) Cv(%)	2.736.964 (12%)	3.505.471 (15%)		
	Biomas (t) Cv(%)	50.907 (12%)	65.201 (16%)		

FIGURES

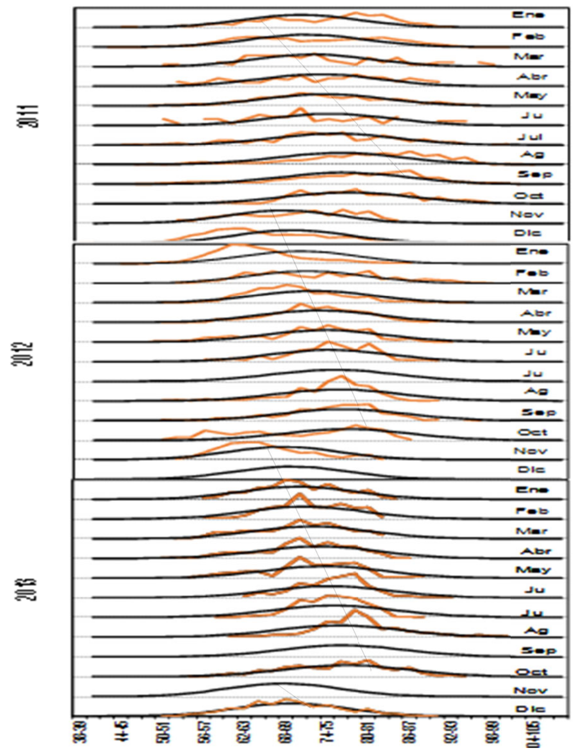
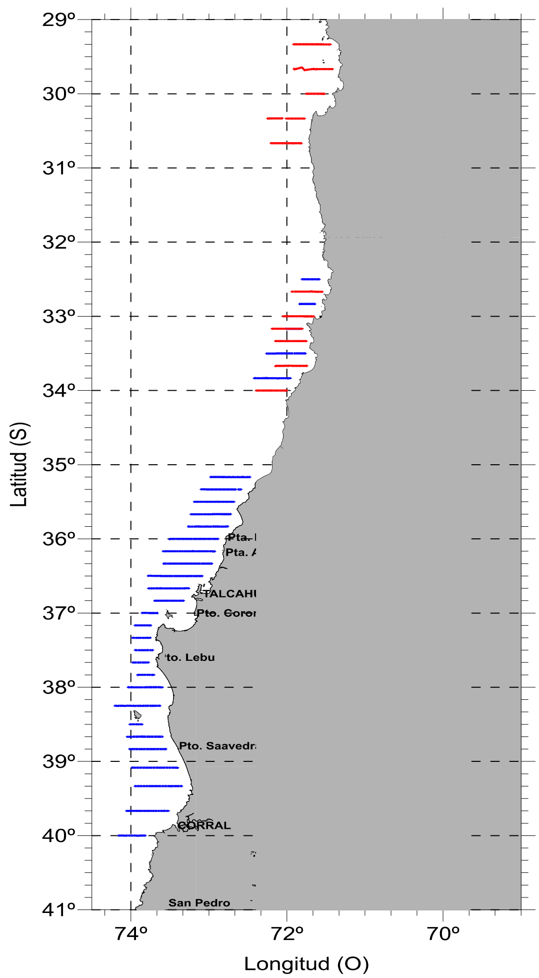


Figure 1. Structures of monthly sizes recorded in the artisanal fishing of San Antonio (coffee line) from 2011 to 2013. (Taken from Payá 2016).



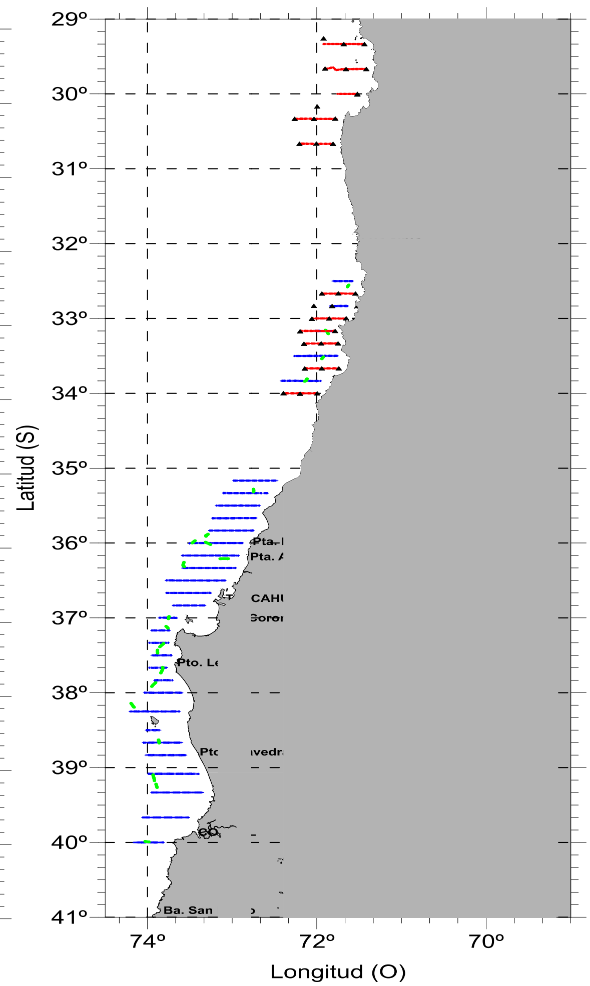


Figure 2. Sampling plan executed for jumbo squid evaluation cruise. The blue lines and green symbol correspond to transects and fishing sets made by the PAM Biomar IV and the red lines and black symbol to transects and fishing stations with fillers of the B / C Abate Molina.

Figure 3. Jigging used to capture jumbo squid in the Abate Molina B / C

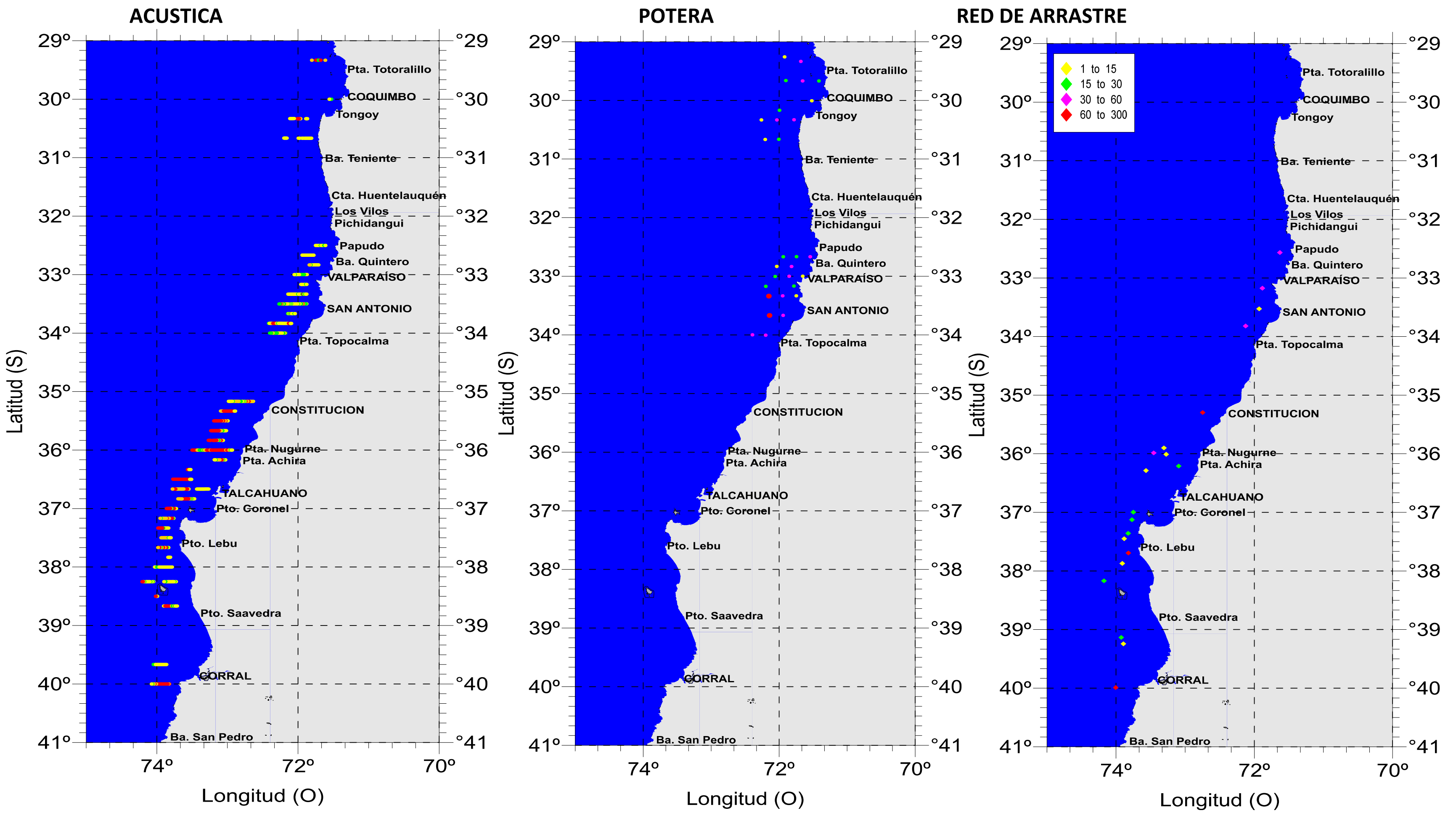


Figure 4. Spatial distribution and local density of jumbo squid in the prospected area. The density scale (t / mn^2) is shown in the figure on the right.

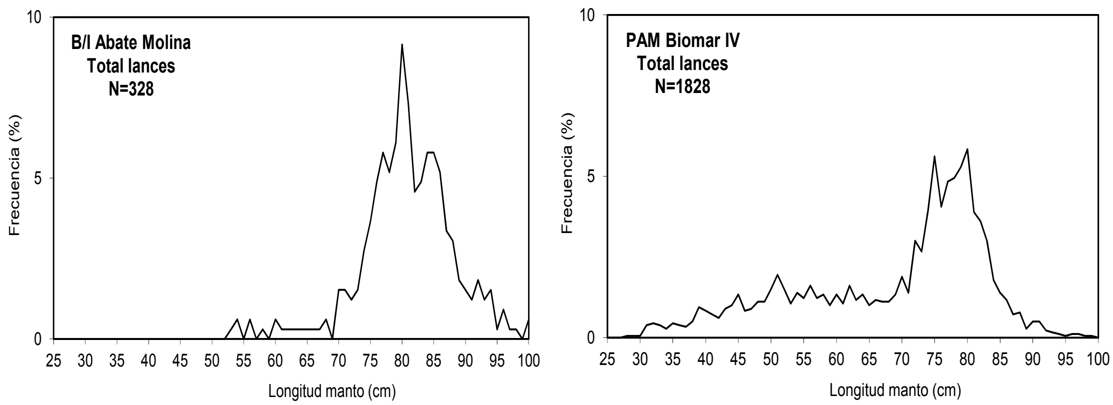


Figura 5. Overall size distribution B / I Abate Molina and PAM Biomar IV.

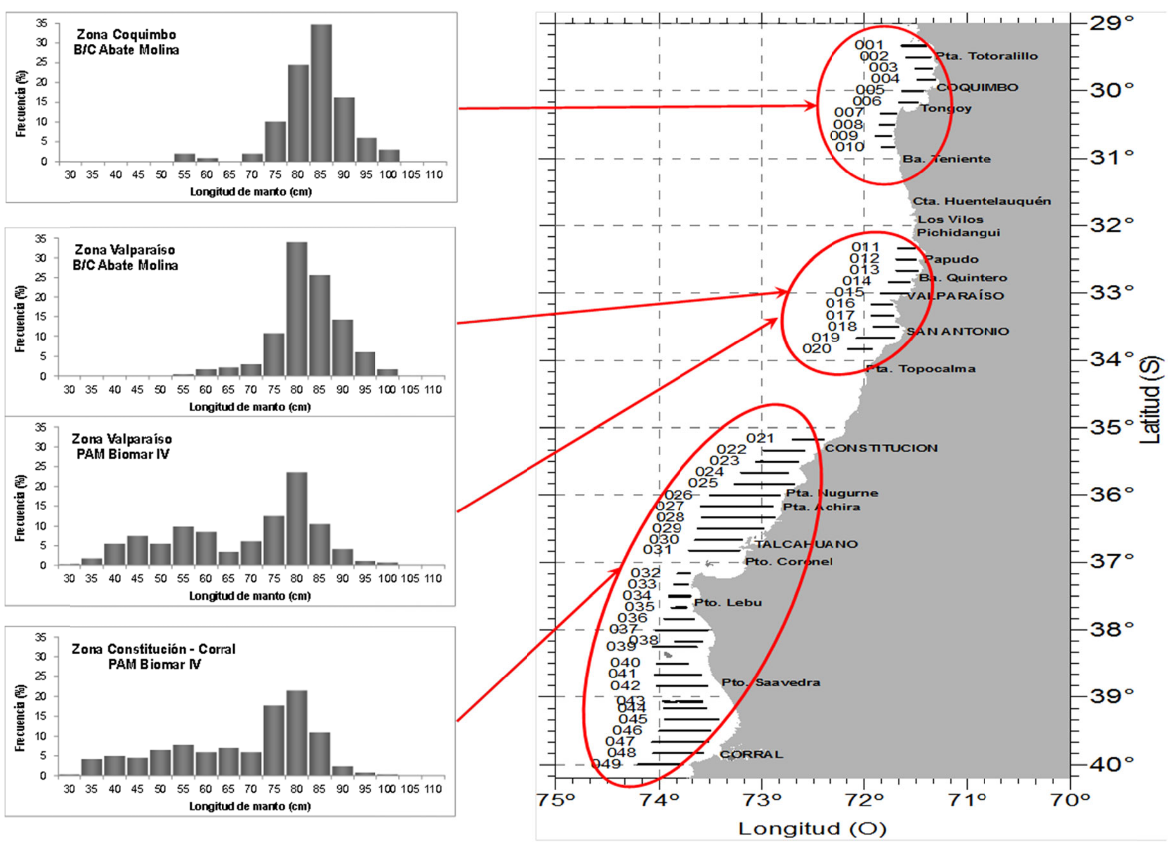


Figure 6. Spatial distribution of jumbo squid size structure by subzone and fishing system. B / C Abate Molina with jigging. PA