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Research Article

Factors that affect the mean size of Chilean hake (*Merluccius gayi gayi*) caught with gillnets in 2001-2018 in central Chile

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ABSTRACT. Chilean hake (*Merluccius gayi gayi*) is one of central Chile's most important demersal resources, and its fishery involves an artisanal fleet that mainly uses gillnets. In the recent history of the fishery, there has been a decrease in catch sizes and a progressive reduction in mesh sizes. This study aimed to analyze the factors that influenced the mean catch sizes of Chilean hake between 2001 and 2018 to understand this situation, correlating the response of fishermen with the capture efficiency of the nets used. Applying a generalized linear model, a significant effect of the factors year, port (zone), and mesh size were observed on the mean size of individuals caught. The model explained 85% of the deviation, the greatest relative contributions being made by the factors year (53.6%) and port (30.2%). A lower effect was estimated for the mesh size factor with 1.2% deviance. These findings suggest that the progressive reduction in mesh sizes is associated with a response to the demographic change in the stock. Differentiated management measures by zones could be considered in the fishery, given the estimated differences.

Keywords: *Merluccius gayi gayi*; Chilean hake; gillnet; mesh size; artisanal fleet; central Chile

INTRODUCTION

Chilean hake (*Merluccius gayi gayi*) is one of the main fisheries resources of central Chile and has been caught since the 1940s (Gatica et al. 2015). Although its relative importance has changed over time, according to the state of the stock, this fishery is emblematic of fishing fleets operating between the regions of Valparaíso and Biobío. This resource is overexploited (CCT-RDZCS 2021), and the annual catch quota for 2021 is 38,000 t; however, in 2003 and 2004, the authorized quotas were significantly higher, at 139,000 t per year.

Two fleets participate in its capture: one industrial and one artisanal. The industrial fleet is currently composed of four small stern trawlers (length overall between 17 and 18 m) and five large stern trawlers (length overall between 36 and 56 m) that operate between 33°30' and 41°28.6'S (Gálvez et al. 2019). The artisanal fleet comprises more than 1000 vessels (mainly boats) with lengths between 4.6 and 15 m, mainly using gillnets and secondary longlines. This fleet's main operation area is between 32°10' and 38°28'S (Gálvez et al. 2019).

Between 1992 and 2000, Chilean hake stock showed high biomass levels and a healthy demographic structure (Gatica & Cubillos 2004). However, since 2004, drastic changes have been evident due to a significant reduction in biomass (reduction of 70%) for the 1999-2001 period and to the progressive relative decrease of adults in the stock, so that it has become mainly dominated by juveniles (Lillo et al. 2005). These changes have been associated with natural factors such as predation by jumbo flying squid

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(*Dosidicus gigas*) (Alarcón et al. 2008, Neira & Arancibia 2013) and cannibalism (Jurado-Molina et al. 2006, Cubillos et al. 2007, Arancibia & Neira 2008), as well as to other factors dependent on fishing activity, such as high fishing mortality (Ernst et al. 2011, Gatica et al. 2015), discards and underreporting fishing (Arancibia et al. 2017, Gálvez et al. 2019).

These drastic changes in biomass and population size structure have negatively affected catch yields in both fleets (Tascheri et al. 2019), with a severe impact on the size of the fish caught (Arancibia et al. 2017). The above have motivated various interventions by the fishing authority, but the deteriorated condition of the stock persists (Molina et al. 2019). Several operational arrangements were made specifically in the artisanal fleet to counteract the reductions in yields, including the change from longlines to gillnets since 2003-2004 (Tascheri et al. 2005), the progressive decrease in mesh sizes, and the gradual increase in the length of gillnets (Gálvez et al. 2019), as well as implementing high-grading practices (Bernal et al. 2018). The gillnet is a versatile fishing gear that is easy to use and is selective in terms of the target-specific size range allowing the effective exclusion of small and large fish (Suuronen et al. 2012). Fish within 20% of the modal length of capture, as indicated by Baranov (1948), have a higher retention probability. The selectivity of gillnets used in Chilean hake fishery has been studied by Queirolo et al. (2013), while the Undersecretary of Fisheries and Aquaculture (SUBPESCA by its Spanish acronym) through R.Ex. Nº2432/2015 established a minimum mesh size (63.5 mm) to protect the smallest fraction of the population in 2015. Although it is recognized that this measure is an advance, it is important to understand that the selectivity of the fishing gear should not be considered an objective in itself but should be part of a set of management tools to achieve wider objectives (Fauconnet & Rochet 2016). In this sense, and given the importance of understanding the crisis suffered by this fishery, this study aimed to analyze the factors that influenced the average catch sizes of Chilean hake obtained by the artisanal fleet using gillnets from 2001 to 2018, correlating the adaptive response of the fishermen with the capture efficiency of the nets used.

MATERIALS AND METHODS

The data used in this study come from the scientific monitoring program of the Chilean hake fishery executed by the Instituto de Fomento Pesquero (IFOP) under the requirements established by SUBPESCA.

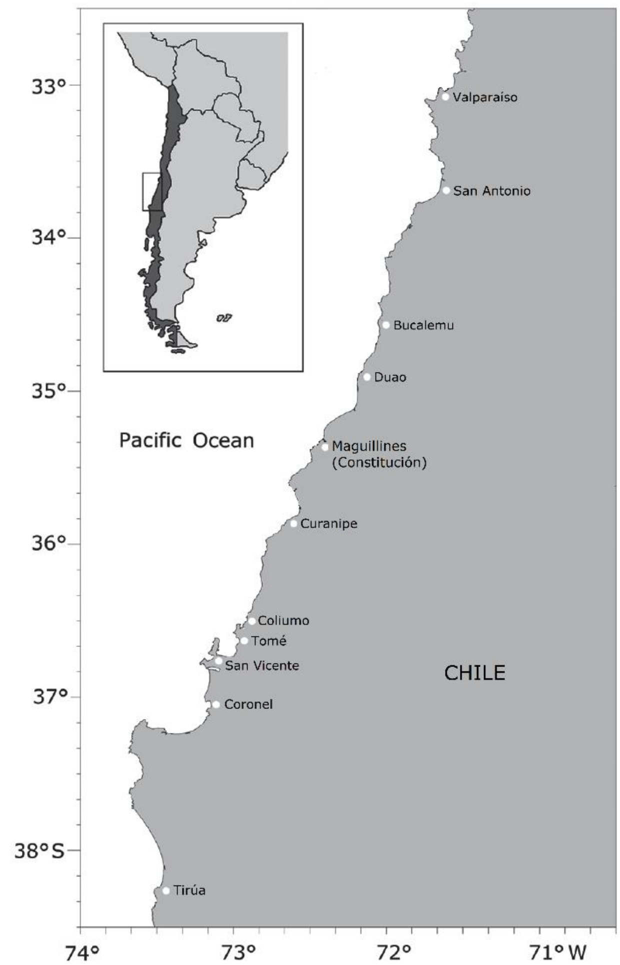

Figure 1. Spatial distribution of the fishing ports where the data were recorded in the artisanal fishery of Chilean hake *Merluccius gayi gayi* between Valparaíso and Biobío regions. Modified from Queirolo & Flores (2017).

The data covers 18 years (2001 to 2018) in Valparaíso and Biobío regions. Specifically, in 11 fishing ports: Valparaíso, San Antonio, Bucalemu, Duao, Maguillines, Curanipe, Tomé, Coliumo, San Vicente, Coronel, and Tirúa (Fig. 1). An artisanal fleet operates in these localities using mainly bottom gill nets, with meshes that have varied over time between 50.8 and 114.3 mm.

In total, 10 mesh sizes were recorded during the study period. The retention length of the fish was obtained from random samples of the total length (TL, in cm), corresponding to 623,867 individuals measured in the period analyzed (Table 1).

Frequency distributions for each year, mesh size, and the port was constructed; and the respective mean size of individuals caught was calculated. These mean

Table 1. Total number of fishes sampled considered in the analysis according to location (port), mesh size, and period.

Port	Mesh size (mm)	Year	Fishes sampled
Valparaíso	50.8	2010-2014	8841
33°3'S	63.5	2008-2016	16615
	76.2	2003-2004, 2006, 2009	629
	82.6	2005-2006	962
	101.6	2003-2004	1603
San Antonio	63.5	2011-2013, 2015-2018	9530
33°35'S	69.9	2009-2018	45541
	76.2	2004-2013	9395
	82.6	2005-2010, 2014	9411
	88.9	2004	219
Bucalemu	63.5	2011-2018	26990
34°38'S	69.9	2010-2012, 2015-2018	2207
	76.2	2006, 2010, 2013, 2016	248
	82.6	2006	471
Duao	63.5	2009-2018	108782
34°54'S	66.8	2009-2010	7250
	69.9	2008-2009	13656
	76.2	2006-2011	2791
	82.6	2006-2007	3752
	88.9	2007-2009	9964
	101.6	2008	80
Maguillines	63.5	2007-2018	86358
35°20'S	66.8	2009-2010	1148
	69.9	2007-2011	10302
	76.2	2007-2012	2502
	82.6	2006-2007	1118
	88.9	2007, 2009	260
Curanipe	63.5	2011-2018	86648
35°51'S	76.2	2011	324
Coliumo	63.5	2013	416
36°32'S	69.9	2008, 2010-2018	35978
	76.2	2007-2010	19929
	82.6	2007-2008, 2010	1443
	101.6	2008	125
Tomé	63.5	2009	70
36°37'S	76.2	2003-2006, 2008-2010	12973
	82.6	2006	435
	88.9	2004-2005, 2008	590
	95.3	2001-2002	2556
	101.6	2003-2004	2059
	114.3	2002	741
San Vicente	63.5	2013, 2015	616
36°44'S	69.9	2011-2018	29042
	76.2	2003-2004, 2008-2011	25121
	82.6	2016	254
	95.3	2001-2002	600
	101.6	2003-2004	80
	114.3	2002	458
Coronel	69.9	2013	204
37°S	76.2	2008-2010, 2013-2014	2401
	82.6	2006-2010, 2014	12715
	88.9	2014	1970
	101.6	2008	98
Tirúa	76.2	2016-2018	5396
38°20'S			
Total			
33°3'-38°20'S	50.8-114.3	2001-2018	623867

sizes were compared with the modal or optimal catch lengths corresponding to the respective mesh sizes used for fish retention. The modal lengths were obtained from the selective parameters estimated by Queirolo & Flores (2017) from field experiments with mesh sizes between 50 and 90 mm. Due to the Gaussian-type selectivity of gillnets, a reduction in retention efficiency is expected as the difference between the mean size of individuals caught and the optimal length of the mesh used increases. In contrast, when the size difference tends to zero, it is assumed that there is a confluence between the capture result and the target size of the fish caught.

Subsequently, the mean size of individuals caught was modeled as a function of the available predictor variables using a generalized linear model (GLM) (McCullagh & Nelder 1989). Due to their limited related data, mesh sizes 66.8, 95.3, and 114.3 mm were excluded from the analysis. Using the forward selection method, the variables to be considered in the model were selected, and collinearity was explored using the variance inflation factor (VIF). The model considered three fixed effects as an explanatory variable in a combination of linear predictors: year (16 years), port (11 ports), and mesh size (7 mesh sizes). Different model structures were tested, assuming a normal statistical distribution with an identity link function and selecting the best model according to the lowest value of Akaike's information criterion (AIC). The R function drop1 package lme4 was used to measure the relative increase in the value of AIC when each variable was excluded from the model. All analyses were performed using R software (R Core Team 2022).

RESULTS

From the available data, 218 size frequency distributions were obtained for the port, mesh size, and year combinations. In most ports, more than one mesh size was used in the period, the smallest being 50.8 mm, used only in Valparaíso, while the largest was 114.3 mm, used in Tomé and San Vicente. The size frequency distributions in the catches showed that the modes of specimens of shorter length (<30 cm TL) and greater length (>47 cm TL) were correlated with smaller and bigger mesh sizes, respectively. Valparaíso had an atypical pattern, where small fish were caught with large mesh sizes, although the modes followed the general pattern. In this port, the smallest fish of the period and study area were recorded, with a high proportion of individuals of mean size less than 30 cm TL, which seldom occurred in other ports. In general, the mode of the size distributions increased as the mesh size increased, an effect that weakened when comparing some similar mesh sizes. The observations show, in general, normal distributions, even in those cases with small sample sizes (Table 1; Figure Supplementary).

The information shows the continuous use of gillnets in ports between 2005 and 2018 (Fig. 2a).

The data show a progressive reduction in mesh size over time, with mesh sizes ranging from 90 to 75 mm (Fig. 2d). Between 2010 and 2015, the use of 50 mm mesh was recorded in Valparaíso north of the study area (33°3’S).

Toward the end of the series available (2017-2018), the mesh sizes were between 60 and 75 mm. However, in most locations, a wide range of mesh sizes was used in the whole period (Fig. 2b). Only in Valparaíso were the smallest catch sizes recorded, with mean sizes between 27 and 36 cm TL, except for some larger records that originated in the first years of the series. In contrast, the largest sizes were recorded in San Antonio (33°58′S) and from Coliumo (36°53′S) to the south, with mean sizes between 35 and 50 cm TL (Fig. 2c).

The mean sizes of individuals caught progressive reduction were observed between 2001 and 2011, decreasing from approximately 50 cm TL to lengths close to 35 cm TL. This condition was maintained until 2015 (Fig. 2e), and between 2016 and 2018, a slight increase was observed to nearly 37-38 cm TL (Fig. 2e). The year and mesh size factors correlated with the mean size of individuals caught.

Although there was a positive correlation between mesh and mean size of individuals caught (0.69), there was high variability associated with the different locations and years (-0.56) (Fig. 2f).

Mesh size was inversely correlated with the year, with an R-value of -0.64 (Fig. 2d). It was ruled out, using VIF, that the predictors presented high collinearity influencing the analysis. The VIF values were less than 2, at 1.96 for the predictors of mesh size and 1.95 for the year.

Significant changes in mean sizes of individuals caught were recorded between 2001 and 2009, with a reduction of approximately 1 cm per year between 2001 and 2005, then decreasing by 5 cm between 2005 and 2006, which accounted for the drastic change observed in the population structure (Fig. 3a). A mean size of individuals caught of approximately 40 cm TL was maintained between 2006 and 2008 and then decreased again from 2009 until reaching the minimum recorded size of approximately 35 cm TL in 2012-2013. Although the situation tended to improve slightly after that, the mean size of individuals caught in the most recent years (2016-2018) stabilized at approximately 37 cm TL, comparable to that observed in 2010 (Fig. 3a).

The difference between the mean size of individuals caught and the modal length shows drastic changes in the period analyzed. In 2001 and 2002, it became negative; however, between 2003 and 2005, higher values were estimated, covering a wider difference range between -10 and 10 cm TL about the expected modal length (Fig. 3b).

Then, due to an adaptive process of the fleet, the tendency falls, between 2006 and 2015, directly related to the progressive mesh size reduction in different locations. Later, between 2016 and 2018, this relationship was reversed, giving way to catching larger fish than those expected to be caught with the mesh sizes used in that period (Fig. 3b).

Figure 3c shows the relationship between mesh size and the mean size of individuals caught, where a generally decreasing trend was observed, from values close to 2.2 to 1.7. As a reference, the figure shows the minimum, mean, and maximum values of the selectivity factor estimated by Queirolo & Flores (2017), which can indicate the fleet's adjustment process to approximate the maximum capture efficiency.

The analysis of deviance indicated that all predictor variables were significant and contributed to explaining the mean size of individuals caught. The best model fitted explains 85% of the total variance (Table 2), showing an adequate distribution of the residuals without showing trends in the fit (Figs. 4a-b). The

Figure 2. Relationships between the variables considered in the analysis. a) Relationship between year and port, b) relationship between mesh size and port, c) relationship between mean length and port, d) relationship between mesh size and year, e) relationship between mean length and year, f) relationship between mean length and mesh size. Dots and bars indicate the existence of data. Colors represent ports. Black dots in boxplots represent outliers. Corr.: the correlation coefficient, VIF: variance inflation factor.

values predicted by the model were generally consistent with the observed data. A good fit was also observed for extreme data (Fig. 4c). Of the total variation explained by the model, the year predictor made the greatest individual contribution, at 53.6%, followed by port with 30.2% and mesh size with 1.2%. The differential effect of excluding each predictor was also analyzed, particularly in the AIC value. The exclusion of the year factor increased AIC by 23.3%, while the exclusion of the port caused an 18.6% increase. On the other hand, it was estimated that the exclusion of mesh size increased the AIC value by only 0.5% (Table 3).

Regarding the port predictor, in all cases, higher coefficients were estimated than in the standard port of Valparaíso (Table 3). The highest coefficients corresponded to Coronel (8.17) and Tirúa (7.01), followed by San Antonio (5.2) and Coliumo (4.6). For these ports, the mean sizes of individuals caught were estimated at

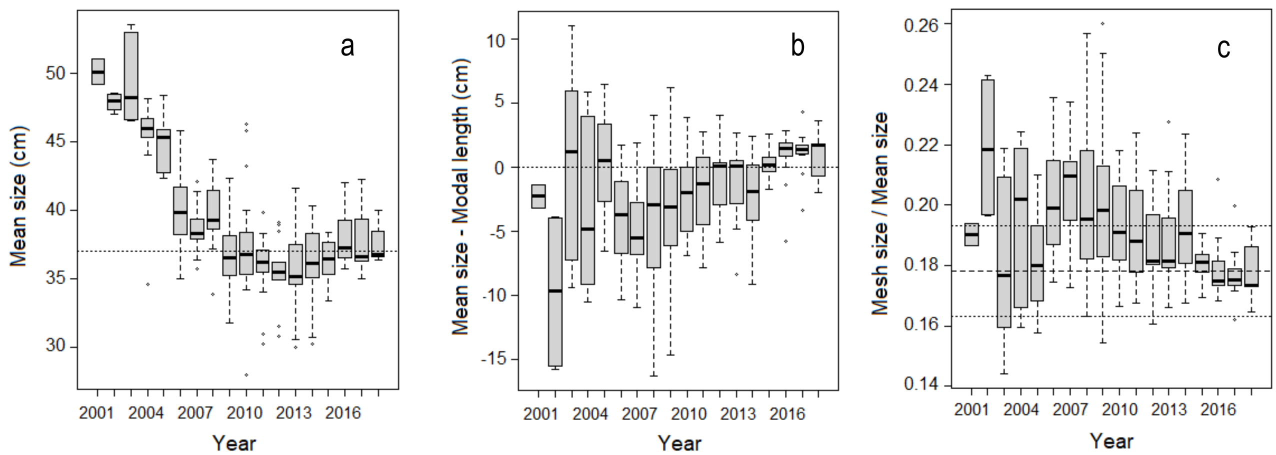

Figure 3. a) Boxplot of the mean catch length per year obtained. The segmented line represents a reference size of 37 cm, b) boxplot of the differences between the mean length of capture and the modal length expected to be obtained with each size used for capture, c) a relationship between the mesh size and the mean size of the fish caught. The segmented lines represent the minimum, mean, and maximum values of the selectivity factor estimated for this species by Queirolo & Flores (2017). The locality is not considered in these figures.

Table 2. Explained deviance (%) by the generalized linear model applied to the mean size of Chilean hake with gillnets using predictors year, port, and mesh size. df: degrees of freedom. AIC: Akaike's information criterion. RD: residual deviance.

Predictor variables	df RD	RD	% Explained deviance	AIC
Year	192	1875.1	44.1	1032.5
Year + Port	182	544.6	83.8	844.6
Year + Port + Mesh size	176	502.8	85.0	839.9

39 to 43 cm TL (Fig. 5a). The lowest values were found in the ports located in the regions of O'Higgins (Bucalemu) and Maule (Duao, Maguillines, and Curanipe), with values between 2.73 and 2.88 (Table 3), for which the mean size fluctuated between 37 and 38 cm TL. The ports of Tomé and San Vicente had intermediate coefficients, at 3.52 cm greater than that of Valparaíso and, therefore, an estimated mean size of 38 cm TL (Table 3; Fig. 5a).

For Valparaíso, it was estimated that the mean size of individuals caught was less than 35 cm TL (Fig. 5a), which was significantly lower than that in the other locations.

The maximum interannual difference between 2005 and 2006 was estimated. The mean height decreased by 5 cm TL (Table 3), from approximately 45 to 40 cm TL in a single year (Fig. 5b). For 2003, the mean size of individuals caught close to 50 cm TL was estimated, while the lowest value corresponded to 2013, at 36 cm TL (Fig. 5b).

Regarding the year predictor, the estimated coefficients accounted for the drastic reduction in the mean size of individuals caught over the period analyzed. Between 2004 and 2009, reductions between 4.80 and 13.12 cm TL were estimated for 2003 (Table 3). Then a certain stabilization of the coefficient was seen at approximately -12.5 cm TL (Table 3). In the following years, the estimated value continued to decrease, although with a lower slope, resulting in an estimated maximum difference of 14.2 cm TL in 2013 for 2003 (Table 3).

Finally, concerning mesh size, the estimated coefficients were significantly higher than the reference mesh of 50.8 mm, fluctuating between 2.22 and 3.82 (Table 3). The general trend showed an increase in the value of the coefficients proportional to the increase in mesh size, except for the 88.9 mm mesh (Table 3). The individual effect of mesh size allowed us to estimate that the mean catch size with the smallest mesh (50.8 mm) was 35.7 cm TL, while for the 101.6 mm mesh, it was 39.2 cm TL (Fig. 5c).

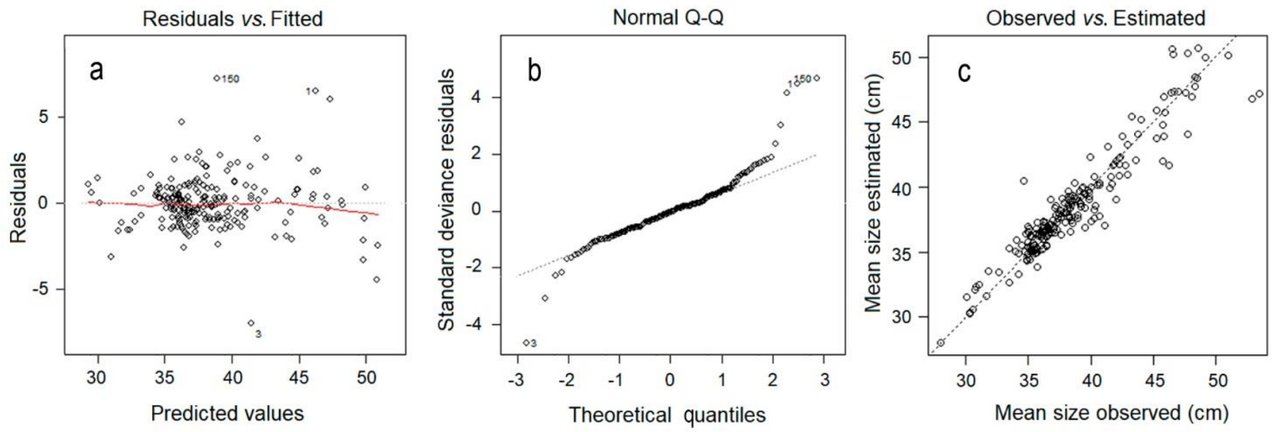

Figure 4. a-b) Performance of the fitted model in the distribution of residuals, c) relationship between mean size observed and mean size estimated.

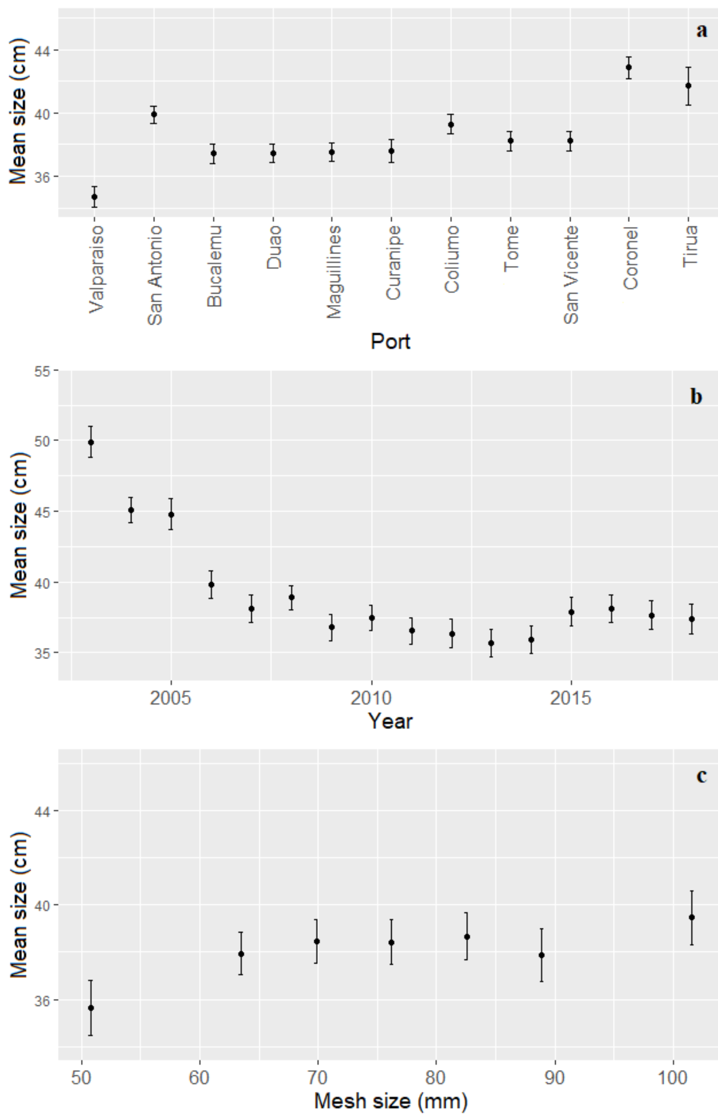

Figure 5. Effect of the predictors of mean size of individuals caught a) port, b) year, and c) mesh size estimated by the generalized linear model.

Table 3. Main statistics of the generalized linear model applied to the mean size of Chilean hake caught in ports located between the regions of Valparaíso and Biobío. Δ AIC represents the increment of Akaike's information criterion value when each factor was excluded.

Predictor	Δ AIC	Level	Estimate	t value	*P*-value
Port	18.6%	San Antonio	5.20	9.65	<0.001
		Bucalemu	2.73	4.53	<0.001
		Duao	2.78	4.90	<0.001
		Maguillines	2.84	5.09	<0.001
		Curanipe	2.88	3.96	<0.001
		Coliumo	4.60	7.27	<0.001
		Tomé	3.52	5.85	<0.001
		San Vincente	3.52	5.79	<0.001
		Coronel	8.17	11.83	<0.001
		Tirúa	7.01	5.86	<0.001
Year	23.3%	2004	-4.80	-5.28	<0.001
		2005	-5.11	-4.62	<0.001
		2006	-10.10	-10.48	<0.001
		2007	-11.76	-12.07	<0.001
		2008	-11.01	-12.61	<0.001
		2009	-13.12	-14.48	<0.001
		2010	-12.43	-13.56	<0.001
		2011	-13.36	-14.19	<0.001
		2012	-13.54	-13.77	<0.001
		2013	-14.20	-14.66	<0.001
		2014	-13.99	-14.17	<0.001
		2015	-13.02	-12.76	<0.001
		2016	-11.82	-11.94	<0.001
		2017	-12.25	-11.93	<0.001
		2018	-12.51	-12.19	<0.001
Mesh size	0.5%	63.5	2.28	2.55	0.012
		69.9	2.81	2.98	0.003
		76.2	2.78	2.92	0.004
		82.6	3.31	3.23	0.001
		88.9	2.22	2.01	0.046
		101.6	3.82	3.28	0.001

DISCUSSION

The artisanal fleet that operated on Chilean hake during the period analyzed made changes in their fishing gear in response to the reduction in the size of the target resource over time, particularly by using smaller mesh sizes. Along with this change, Gálvez et al. (2015) indicated that the fleet increased its gillnets length, a trend that was only reversed in recent years due to the regulations on their length. We interpret the above as meaning that both factors were part of an adaptive response of the fleet to maintain catch levels that would allow them to achieve economic profitability in the activity. Clear evidence of an overexploited stock, reflected in low biomass levels and a population structure with a narrow range of annual classes (juvenile) (Molina et al. 2019), led to the capture of smaller specimens and lower fishing yields.

The response of the fisheries administration was mainly focused on the progressive reduction of catch quotas until they reached their lowest value in 2014. In 2015, a regulation of gillnets was implemented, establishing a minimum mesh size of 63.5 mm and limiting the maximum length of the gillnets, which was done to increase the mean size of individuals caught and to reduce the catch per trip. The process of reducing the mesh size was self-managed by the artisanal fleet, which took a long time and probably had variable consequences on catchability, which needed to be more monitored and evaluated. As in any productive activity, the fisherman seeks to obtain an economic benefit from the effort made, which needs to be properly analyzed to support the various management measures indicated above. In this sense, Muñoz & Godelman (2016) point out that drastic reductions in quotas, insufficient economic compensation for thousands of fishermen, and deficiency of the fisheries control system, exacerbated the phenomenon of unreported fishing.

The results of this study show a slight increase in the mean size of individuals caught obtained by the fleet from 2015, which is consistent with the establishment of the minimum mesh size and suggests that such adjustments should be considered and evaluated in due course to contribute to the sustainability of the stock. The use of 50.8 mm mesh from 2010-2014 was ineffective in the artisanal sector because they captured small specimens with comparatively lower commercial value. More timely regulations on selective factors related to the gillnet could have prevented these critical removals of the Chilean hake stock that had already for several years been overexploited and whose evaluation suggested a historical exploitation pattern (Tascheri et al. 2015).

The increase in mean sizes of individuals caught from 2015 is not comparable to those caught until 2004. The mesh sizes used in gillnets remain small compared to those previously used, which may be a response to the catch efficiency sought by the artisanal fleet and the still high levels of exploitation occurring on the stock of Chilean hake. In this sense, Gálvez et al. (2020) report that artisanal fishing quotas must have been greatly exceeded, with underreporting levels that increased from 2015 to three times what was officially declared, while in most ports, nets had the minimum mesh size authorized by current regulations. The facts demonstrate the need to establish and consider in management rules certain economic and social objectives that contribute to the recovery of the fishery, which must be adaptable to the status of the stock.

Regarding the fishing gear, in particular, the analytical approach used in this study allowed us to approximate the efficiency of the gillnets based on the differences between the mean size of individuals caught and the modal length expected to be obtained from the selectivity of the meshes used. In several periods, it can be seen that the mean size of individuals caught was below the expected value, which surely triggered the progressive reduction in mesh sizes. In 2001, this difference was smaller and within a narrow range because the extraction was carried out exclusively in the southern zone (Tomé-San Vicente), which did not spur changes in mesh size and was affected by the crisis later. In 2002-2009, the differences were the greatest, and high variability was observed because the use of gillnets expanded in the fishery (Valparaíso-Constitución). There were chaotic changes in mesh size as the net collapsed. The mean and optimal size differences narrowed from 2010 to 2018, again due to greater standardization of mesh sizes in the area of the artisanal fishery (Valparaíso-Tirúa), forced by the narrow range of cohorts present in the structure of the stock and the existence of a regulation that established the minimum mesh size allowed.

The maximum efficiency point from this perspective was achieved in 2015 (Fig. 3b). In the following years (2016-2018), the mean size of individuals caught was greater than the expected modal length based on selectivity. In this way, the fleet will probably begin a progressive change in its mesh sizes in the future, specifically an increase, in such a way as to maintain the operation on the more abundant fraction of the stock and maintain better profitability in terms of economic return. In fact, according to recent results in the fishery, Gálvez et al. (2020) indicate that the mean catch sizes increased in 2019 in both males and females. Under this same perspective, it is appropriate to reflect on the need not to keep the minimum size of the meshes constant but periodically review them as a mechanism that accompanies the process of stock recovery so that the fishing gear selectivity is not considered an operational objective only. Fauconnet & Rochet (2016) indicates the need to evaluate the fundamental role of fishing gear on the exploitation pattern of a fishery and then recognize its ability to influence the impacts of the fishing activity.

The results obtained also show the existence of spatial differences in the catch sizes of the artisanal fleet. The results are consistent with the known distribution pattern of the population described by Molina et al. (2019), that is, larger fish toward the south and at greater depths. In this work, the depth of capture of the sampled individuals was unavailable because the scientific observation in the artisanal fleet is mainly conducted at landing. Nevertheless, the results suggest establishing different regulations according to the locality, where the minimum mesh size could be greater toward the south. However, relatively near ports showed significant differences in estimated mean sizes. Such as between Valparaíso and San Antonio, which must be interpreted in the context activity itself, where the fleet's operational result due to the mesh sizes used in the gillnets can also be related to the level of mechanization for the hauling and the use of echo sounders to operate at greater depths.

According to Kritzer (2020), fisheries are complex systems composed of scientific, management, fishing fleet, and ecological subsystems. Effective monitoring of activities at sea, combined with other measures, can keep fisheries away from overexploitation. In this sense, the results of this work show the importance of undertaking scientific observation to provide information that can guide management measures. The condition of the Chilean hake stock during the period analyzed influenced adaptive measures in the fleet (suh as in their gillnets) and determined changes in size of the individuals caught, being relationships that should be understood and considered to improve the management of the fishery.

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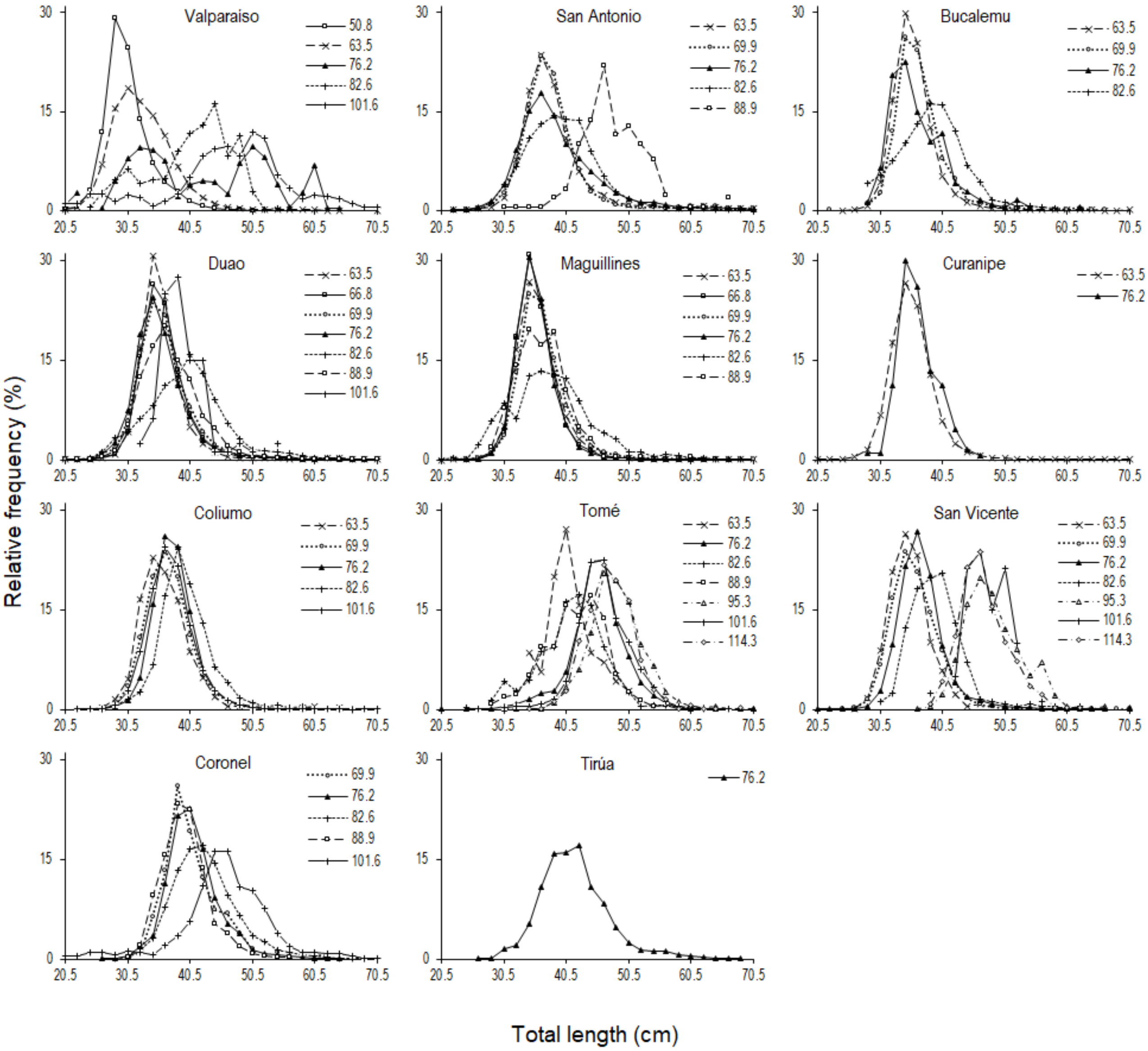

Figure Supplementary. Size structures of Chilean hake according to location and mesh size (mm).