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ALTERNATIVE MANAGEMENT MEASURES FOR TROPICAL TUNAS IN THE EASTERN PACIFIC OCEAN

1. INTRODUCTION

This report outlines alternative approaches to managing tropical tunas (yellowfin, bigeye, and skipjack) in the eastern Pacific Ocean (EPO). Current management includes a number of measures as outlined in Resolution C-13-01[1], which entered into force in 2014 and expires at the end of 2016. The main components of this resolution include:

1. All purse-seine vessels covered by the resolution must stop fishing in the IATTC Convention Area for a period of 62 days, either from 29 July to 28 September or from 18 November to 18 January of the following year.
2. Purse-seine fishing for tropical tunas is prohibited within the area from 96° to 110°W between 4°N and 3°S (known informally as the "*corralito*") from 29 September to 29 October.
3. Annual longline catches for bigeye tuna in the Convention Area must not exceed the following levels: China, 2,507 t; Japan, 32,372 t; Korea,11,947 t, and Chinese Taipei 7,555 t. Other Members are limited to the greater of 500 t or their respective catches of bigeye in 2001.
4. All purse-seine vessels are required to land all tropical tunas caught, except fish considered unfit for human consumption for reasons other than size.

The management of tunas in the EPO is complicated by the existence of an overlap area under the jurisdiction of both the IATTC and the Western and Central Pacific Fisheries Commission (WCPFC), where flag States that are members of the two commissions may choose which of the two regimes their vessels shall follow.

The stock assessments of yellowfin (YFT) and bigeye (BET) tunas estimate that recent fishing mortality (F) under Resolution C-13-01 has remained around the target reference point (the fishing mortality corresponding to the maximum sustainable yield (MSY)), with an F multiplier[2] (F_{MSY}/F_{cur}) of 1.02 for yellowfin and 1.05 for bigeye. However, the capacity of the purse-seine fleet, expressed in cubic meters of well volume, has recently increased by about 25,000 m^3. Therefore, additional management action is needed.

The 25,000 m^3 increase in capacity corresponds to approximately 25 additional days of closure based on the F multiplier for yellowfin, which is more restrictive. The management options evaluated here are intended to be applied in conjunction with Resolution C-13-01; they are alternatives to the 25 additional days of closure, and thus in addition to, not instead of, the 62-day closure established in the resolution. For this reason, the predicted consequences of the management options are expressed in this document in a common currency, which is their equivalent in additional days of closure.

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[1] http://www.iattc.org/PDFFiles2/Resolutions/C-13-01-Tuna-conservation-in-the-EPO-2014-2016.pdf

[2] The number of times that current effort must be multiplied in order to achieve F_{MSY}; thus, Fmult = 1 means that the stock is being exploited at the level that will produce the maximum sustainable yield.

2. CALCULATING THE EQUIVALENT DAYS OF CLOSURE

Adjustments of the closure to account for the stock assessment results[3] and the change in fishing capacity of the fleet should be based on the period open for fishing[4], such that change in the new open period is inversely proportional to the change in capacity and proportional to Fmult[5].

$$\text{New\_Open} = \text{Fmult} \times \frac{\text{Old\_Capacity}}{\text{New\_Capacity}} \times \text{Old\_Open} \qquad \text{Equation 1}$$

To determine the number of days of closure that is equivalent to a management strategy, it is assumed that catch is proportional to effort, and, as a result, the equivalent in days of closure is proportional to the change in catch when the additional management measure is applied.

$$\text{Equivalent\_Days} = \frac{(C - C^*)}{C} \times \text{New\_Open} \qquad \text{Equation 2}$$

where C is the catch without additional management and C* is the catch with additional management.

The following parameter values are used to calculate the additional days of closure based on the bigeye and yellowfin assessments and the increase in capacity.

Fmult_YFT = 1.02

Fmult_BET = 1.05

Old_Closure = 62 days

Old_Open = 365 – Old_Closure = 303 days

Old_Capacity = 230,148 m^3 (2013-2015 average)

New_Capacity = 255,972 m^3 (as of 17 April 2016)

Data used in this analysis cover the period of 9 January 2011 to 18 January 2016. The use of this limited range of data is based on the assumption that current dynamics and those in the near future are similar to the recent past.

3. EXTENDING THE CURRENT CLOSURES

The average capacity for the 2013-2015 period, which is the basis for the F multiplier calculated in the stock assessment, is 230,148 m^3. The capacity as of 17 April 2016 was 255,972 m^3, an increase of 11.2%. Applying equation 1 to yellowfin and bigeye results in an additional 25 and 17 closure days, respectively. Given the current global application of closures to the purse-seine fleet, the closure would be based on yellowfin, the more heavily exploited species. Since the catch rates can differ with the time of year, the direct impact on F will vary to some degree depending on the closure period chosen by the vessels and whether the additional days are added to the start or the end of the existing closures.

4. REDUCING CAPACITY

4.1. 25,000 m^3 capacity reduction

The most straightforward management measure to evaluate, other than an extension of the current closure, is a reduction in purse-seine capacity to its 2013-2015 level, which is the baseline for calculating management advice from the stock assessments. This would require a reduction of about 25,000 m^3. This level is only an approximation of what is needed, because not all capacity is equal and the capacity varied during the 2013-2015 period.

[3] The estimate of current fishing mortality, F_{cur}, relative to the fishing mortality corresponding to maximum sustainable yield, F_{MSY}

[4] 365 minus the number of days of closure

[5] Fmult = F_{MSY}/F_{cur}

5. ESTABLISHING CATCH LIMITS

Catch limits can be applied in a variety of ways, but the simplest would be species-specific global limits for the whole EPO. Catch limits are easy to understand; also, the IATTC has a long history of working with catch limits, and its existing weekly report system could be used to monitor the catch. If capacity decreases, this approach automatically reduces the duration of a closure because the catch will be lower (assuming no change in abundance or fishing efficiency). If the capacity added since Resolution C-13-01 was adopted is mainly directed at a single set type, then the species-specific limits will automatically take that into account, given that yellowfin and bigeye are typically caught in different types of set.

A closure would start whenever the catch of either of the two species reached its limit: therefore, any vessel targeting the species that had not reached its catch limit would also have to stop fishing regardless. As often happens with catch limits, this could cause a “race” for fish, with vessels rushing to catch as much as possible before either limit was reached. The resulting fishing mortality would be dependent on the population size, which may change over time.

5.1. Catch limits for bigeye and yellowfin

Catch limits for bigeye and yellowfin could be based on some predetermined value. For instance, the 2016 limits could be based on the average annual catch (including discards) of these two species by Class-6 purse-seine vessels during 2013-2015, 57,900 and 232,800 t, respectively. The purse-seine fishery would be closed when the limit for either species was reached.

5.2. In-season adjusted catch limits for bigeye and yellowfin

Catch limits for bigeye and yellowfin could be adjusted for changes in catch per unit of effort (CPUE). As with the previous option, the purse-seine fishery would be closed when the limit for either species was reached. This approach is similar to the in-season catch increments used previously by the IATTC.

The catch limits (CLs) for 2016, for example, would be calculated by adjusting the average catch (C) during 2013-2015 by the ratio of the cumulative mid-year CPUE in 2016 to the average mid-year CPUE during 2013-2015. The CPUE is calculated as the cumulative catch in the IATTC weekly report (CWR) at the midpoint of the year divided by the sum of the weekly operative capacity during the first half of the year (CPUE = CWR/sum(weekly capacity)). Thus:

$$CL2016 = [(C2013+C2014+C2015)/3]*CPUE2016/[(CPUE2013+CPUE2014+CPUE2015)/3]$$

In addition to the general advantages of catch limits outlined above, adjusting the catch limit for CPUE takes into account the changes in biomass from one year to the next, which reduces the chances of overfishing. However, in addition to the general disadvantages of catch limits, a number of quantities in the formula for calculating the closure contain measurement error; furthermore, catchability might change over time, and the catch per unit of capacity may not be proportional to abundance.

6. CATCH LIMITS BASED ON CATCHES IN THE EXCLUSIVE ECONOMIC ZONES (EEZS) AND THE HIGH SEAS

A hybrid approach could be used, in which various catch limits are established, each based on the average catch within each one of the EEZs in the EPO and an additional one based on the average catch in the high seas. Once the catch limit in one of these areas was reached, fishing could continue in the other areas until the individual limit established for each one of these areas was reached.

7. TEMPORAL CLOSURES

Closing the whole EPO to purse-seine fishing for a given time period is one of the main current management measures for tropical tunas in the EPO (see introduction). This could be modified in several ways. The temporal closures evaluated here are based on the current closure, and involve reallocating effort from one closure period to another. Effort is measured in days fished, since quantifying it by number of sets made will be dependent on the abundance of tuna and on set type. Additionally, vessel category is taken into account, in order to ensure that the reallocation of effort does not create unreasonable changes in the set types used. Four vessel categories are defined: 1) vessels that make more than 50% of their sets on dolphin-associated fish; 2) vessels that make more than 50% of their sets on floating objects; 3) vessels that make a variety of sets, 10 to 50% of which are on dolphin-associated fish; and 4) vessels that make a mixture of floating-object and unassociated sets but few, if any, dolphin-associated sets. Because the current second closure extends to 18 January of the following year, we present the results based on a "fishing" year, defined as 19 January of one year to 18 January of the following year.

7.1. Eliminate the second closure period

Eliminate the second closure period, so that all vessels covered by the measures are allowed to fish from 18 November to 18 January but must not fish from 29 July to 28 September.

7.2. Eliminate the first closure period

Eliminate the first closure period, so that all vessels covered by the measures are allowed to fish from 29 July to 28 September but must not fish from 18 November to 18 January.

7.3. Divide the 62-day closure in two periods of 31 contiguous days each

Require vessels to divide the current 62 contiguous days of closure into two periods of 31 contiguous days within the two current closure periods (29 July-28 September and 18 November-18 January) For the purposes of this analysis, the 31-day closures could be assumed to start on 29 June and 18 November.

This option was not evaluated, but the results are likely to be somewhere between the previous two options.

8. SPATIAL CLOSURES

The evaluation method for spatial closures is the same as that used for the temporal closures. Unless otherwise noted, spatial closures are assumed to be in force for the period of 1 February to 30 June.

Two advantages of spatial closures over temporal closures is that they allow fishing outside the closure area, and can be adapted to protect the species most in need of management.

Spatial closures have several disadvantages. It is unlikely that the two species will be equally vulnerable within the closure area, so additional measures would be necessary for the less vulnerable species. Errors can occur with the choice of area and timing of the closure. Overall fishing effort would not be reduced, but would be redistributed spatially; it is not clear to what extent this might cause local depletions, given the evidence for regional fidelity of yellowfin (and to a lesser extent, bigeye) in the EPO. Also, temporal variations in the spatial distribution of the two species will cause variations in the effectiveness of the spatial closures. Monitoring and compliance of spatial closures would be improved with the adoption of a procedure for accessing all data from the obligatory Vessel Monitoring System for all vessels.

A number of spatial closures may be considered, for instance the following:

8.1. Closure between 120° and 150°W and 5°N and 5°S

8.2. Extend the duration of the closure of the *corralito*

8.3. Closure of 5°S to the Equator, 95°W-110°W

8.4. Closure of 5°S-5°N, 120°W-150°W

8.5. Closure south of 15°S

8.6. Closure between the coast of Mexico and 125°W, north of 23°N

8.7. Closure between the coast of South America and 85°W, 5°N-5°S.

8.8. Guatemala EEZ closure: this option is not evaluated because the Guatemalan EEZ is already closed, and not much data is available for when it was open. The impact is expected to be small.

8.9. Closure of all EEZs

8.10. High seas closure: all areas outside national EEZs would be closed for a full month or for the full February-June period. For the month-long closure scenarios, the consequences would vary according to the month chosen, as illustrated in Figure 4.

9. OTHER MEASURES

9.1. Eliminate exemptions in Resolution C-13-01

Eliminate the exemptions for certain purse-seine vessels in paragraphs 1 and 4 of Resolution C-13-01. This option was not evaluated.

9.2. Ban FADs in the ocean during the closure

All fish-aggregating devices (FADs) must be removed from the ocean at the start of a closure, and may not be redeployed until after the closure has ended. This option was not evaluated.

10. RESULTS AND DISCUSSION

The effectiveness of the proposed alternative management options varies in terms of reducing catches of yellowfin and bigeye tunas (Table 1), and consequently the equivalent number of days of closure (Table 2, Figure 4) and the impact on the skipjack catch (Table 1) also varies. None of the options, except capacity reduction and catch limits, led to substantial reductions in yellowfin catch. Only two options included the minimum of 17 days required for bigeye (closure of 5°S-5°N from 120°W to 150°W (7.4), and closure of the high seas (7.10)). The duration of the closures for these two options could be reduced, particularly for the closure of the high seas.

Many of the options have an unequal effect on the different species, which is a consequence of the spatial distribution of the three different purse-seine set types (Figures 1-3). Dolphin-associated sets catch predominantly yellowfin, while floating-object sets catch predominantly skipjack, but also a large proportion of the bigeye catch. Therefore, options may have to be combined to produce the desired management effect on all species. For example, a spatial closure that mainly reduces the catch of bigeye may need to be combined with a catch limit for yellowfin. However, if the catch limit for yellowfin is reached, it may not be desirable to stop fishing on bigeye. Therefore, rather than stopping all fishing once a catch limit has been reached, restrictions can be put on fishing. For example, catch for a trip could be limited to 15% yellowfin, or a ban put on fishing on dolphin-associated schools, or, in the case of a bigeye catch limit, a ban put on floating-object sets.

Historically, spatial closures have sometimes reduced the amount of small yellowfin or bigeye caught without necessarily reducing the total catch. Determining the impact on the fishing mortality rate (F) relative to that corresponding to MSY (F_{MSY}) would require taking the size of the fish in the catch into consideration, using the stock assessment model, and is outside the scope of this analysis. In general, when small fish are caught, the exploitation rate for a given tonnage of catch is higher due to the larger number of fish that are caught. However, the fishing mortality rate corresponding to MSY will also change, and the results will also be sensitive to the assumptions about natural mortality at different ages. Therefore, it is difficult to evaluate the impact of the size of the fish caught. Appendix A presents the size distributions of the catch by 5-degree square, and can be used to evaluate qualitatively the size of the tuna caught in a spatial closure if the size of the fish is a consideration for evaluating management measures.

There are some differences between the results presented here and those presented at the annual meeting of the Commission in June 2016. The analysis presented here is more thorough, because it is based on days fished rather than number of sets, and divides vessels into categories.

These options focus on the purse-seine fishery, since the need for additional measures is due to the increase in the capacity of the purse-seine fleet. Limits on longline catch or other gears were not considered.

TABLE 1. Proportional change in catch resulting from various spatial and temporal closures.

Management measure	Proportional catch reduction		
	YFT	**BET**	**SKJ**
Eliminate second closure period	1.00	0.99	1.02
Eliminate first closure period	1.01	1.02	0.99
Reduce length of both closure periods to 31 days each	Not evaluated	Not evaluated	Not evaluated
Eliminate the capacity exemption in paragraphs 1 and 4 of Resolution C-13-01	Not evaluated	Not evaluated	Not evaluated
Extend the duration of the *corralito* closure	1.01	0.96	1.01
Closure of 5°S to the equator, 95°W-110°W	1.00	0.97	1.01
Closure of 5°S-5°N, 120°W-150°W	0.99	0.93	0.99
Closure south of 15°S	1.00	1.00	0.95
Spatial closure between the coast of Mexico and 125°W north of 23°N	1.01	1.00	1.01
Spatial closure between the coast of South America and 85°W from 5°N to 5°S	1.00	1.03	1.01
Close Guatemalan EEZ	Not evaluated	Not evaluated	Not evaluated
Close all EEZs	1.00	1.17	0.99
Close high seas	1.00	0.66	1.03

TABLE 2. Equivalent days of closure for each of the conservation measures. The capacity reduction and catch limit proposals are assumed to produce the required equivalent days of closure to compensate for the increased capacity.

Management measure	Equivalent days		
	YFT	**BET**	**SKJ**
25,000 m^3 capacity reduction	25	25	
Catch limits for bigeye (57,900 t) and yellowfin (232,800 t)	25	25	
In-season adjusted catch limits for bigeye and yel-lowfin	25	25	
Eliminate second closure period	0	2	-6
Eliminate first closure period	-2	-4	3
Reduce length of both closure periods to 31 days each	≈ -2 to 0	≈ -4 to 2	≈ -6 to 3
Eliminate the capacity exemption in paragraphs 1 and 4 of Resolution C-13-01	Not evaluated	Not evaluated	Not evaluated
Extend the duration of the *corralito* closure	-2	11	-2
Closure of 5°S to the equator, 95°W-110°W	-1	8	-2
Closure of 5°S-5°N, 120°W-150°W	3	20	2
Closure south of 15°S	-1	1	15
Closure between the coast of Mexico and 125°W north of 23°N	-2	0	-2
Closure between the coast of South America and 85°W from 5°N to 5°S	0	-10	-4
Close Guatemalan EEZ	Not evaluated	Not evaluated	Not evaluated
Close all EEZs	0	-49	2
Close high seas	1	97	-9
Ban FADs in the ocean during the closure	Not evaluated	Not evaluated	Not evaluated

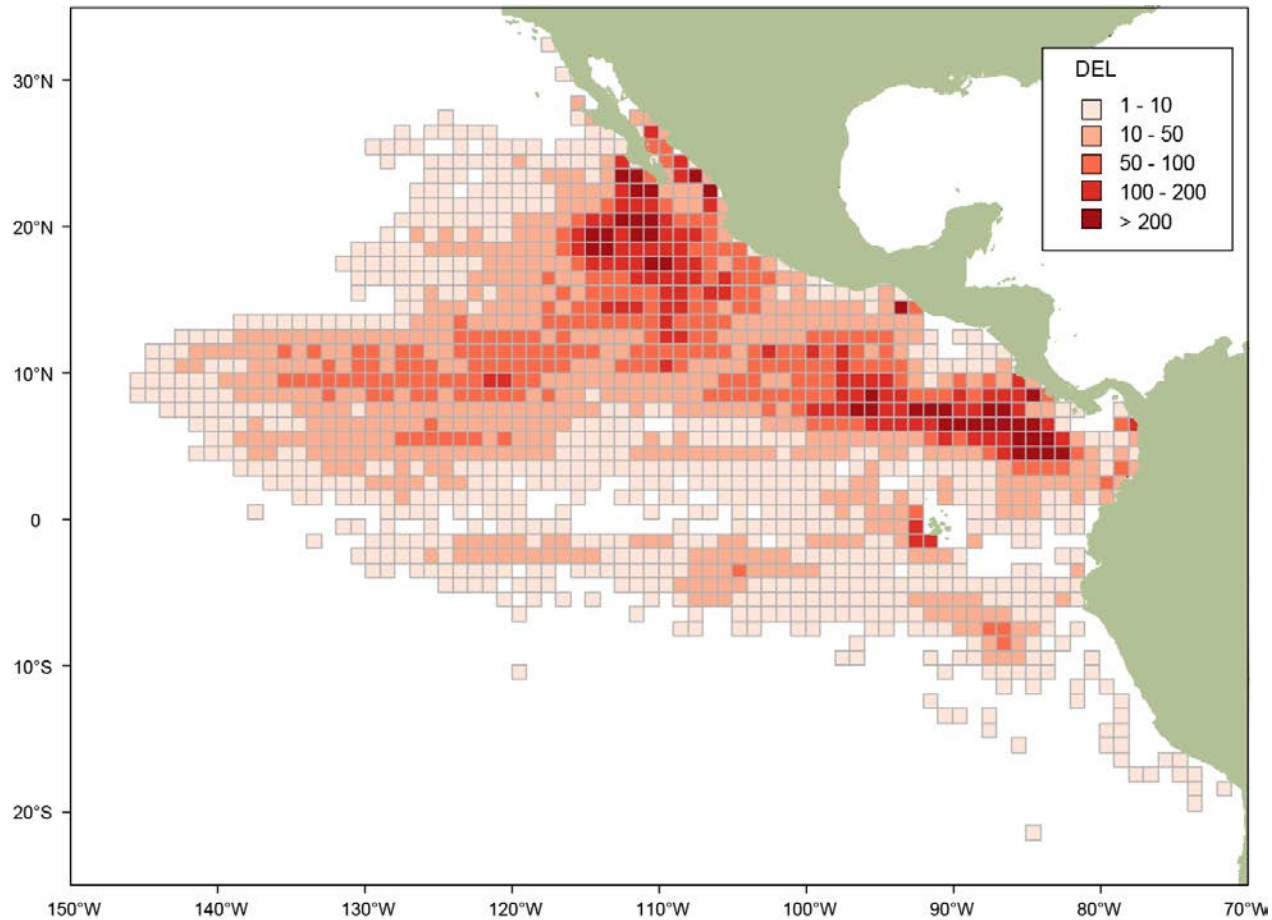

FIGURE 1. Spatial distribution of dolphin-associated (DEL) sets, 2011-2015 for all purse seine vessels (classes 1-6) based on both logbook and observer data.
FIGURA 1. Distribución espacial de lances asociados a delfines (DEL), 2011-2015para todos los buques cerqueros (clases 1-6) en base a los datos de las bitacoras y de los observadores.

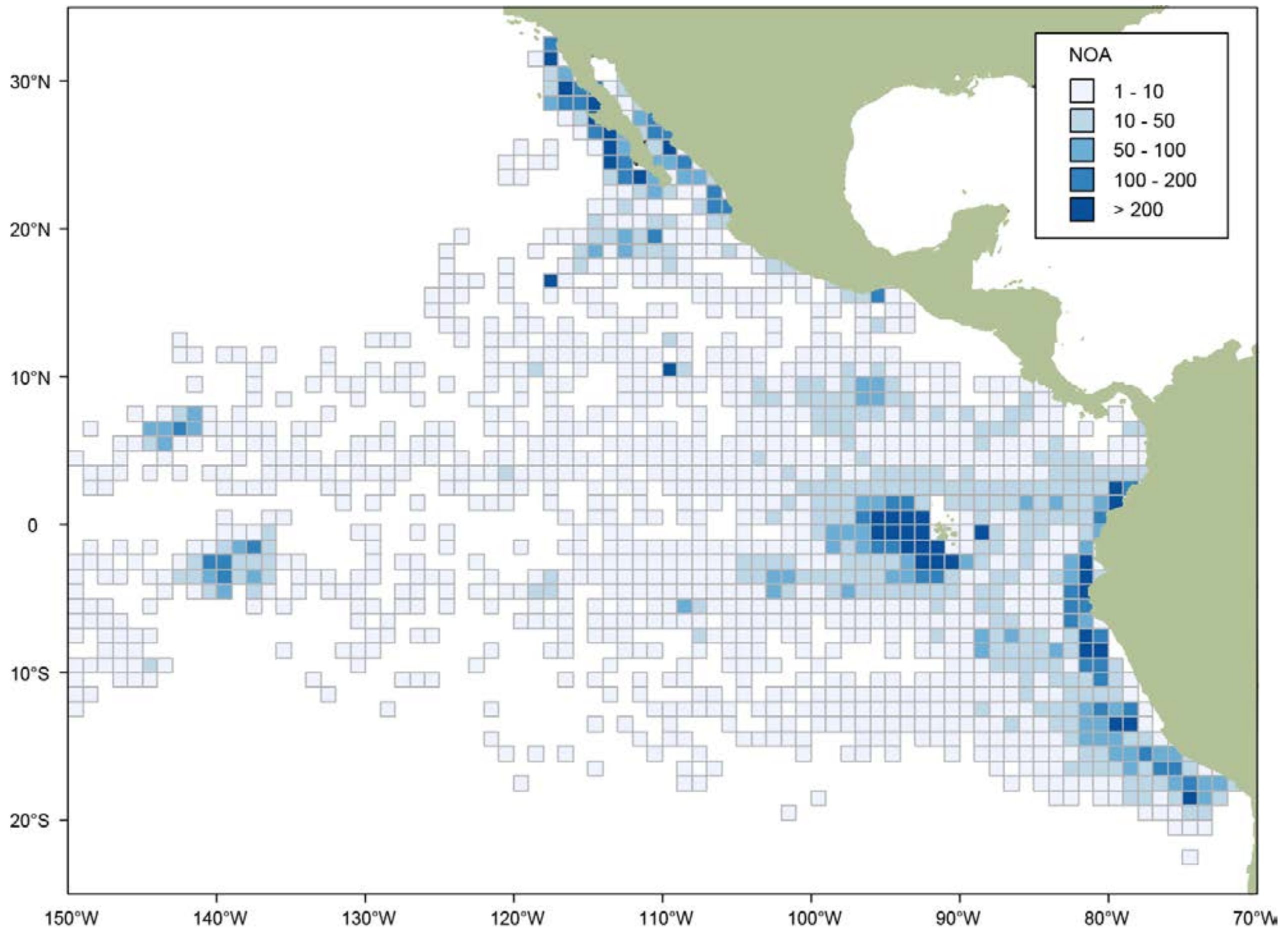

FIGURE 2. Spatial distribution of sets on unassociated tunas (NOA), 2011-2015 for all purse seine vessels (classes 1-6) based on both logbook and observer data.
FIGURA 2. Distribución espacial de lances sobre atunes no asociados (NOA), 2011-2015 para todos los buques cerqueros (clases 1-6) en base a los datos de las bitacoras y de los observadores.

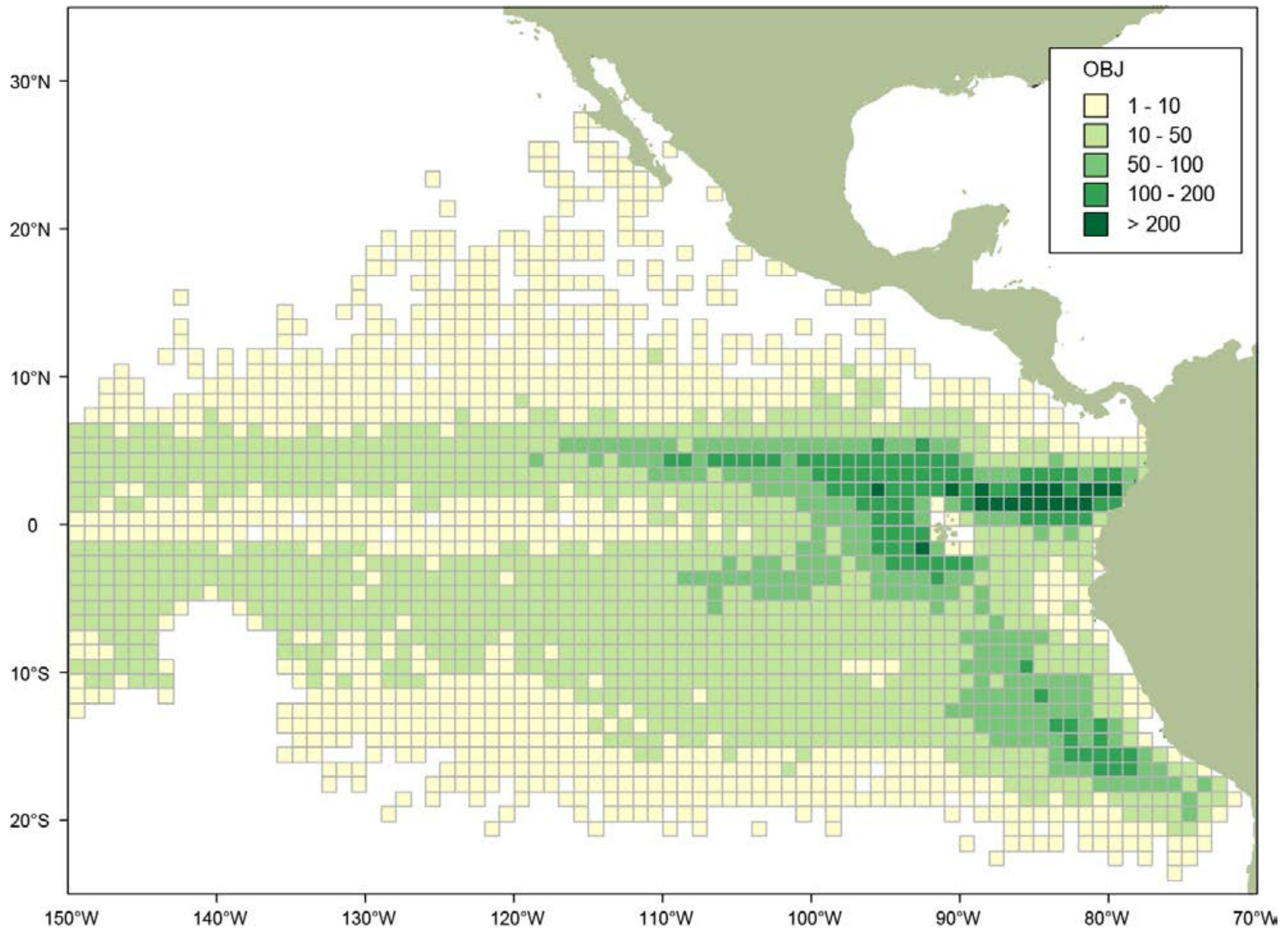

FIGURE 3. Spatial distribution of sets associated with floating objects (OBJ), 2011-2015 for all purse seine vessels (classes 1-6) based on both logbook and observer data.
FIGURA 3. Distribución espacial de lances asociados a objetos flotantes (OBJ), 2011-2015 para todos los buques cerqueros (clases 1-6) en base a los datos de las bitacoras y de los observadores.

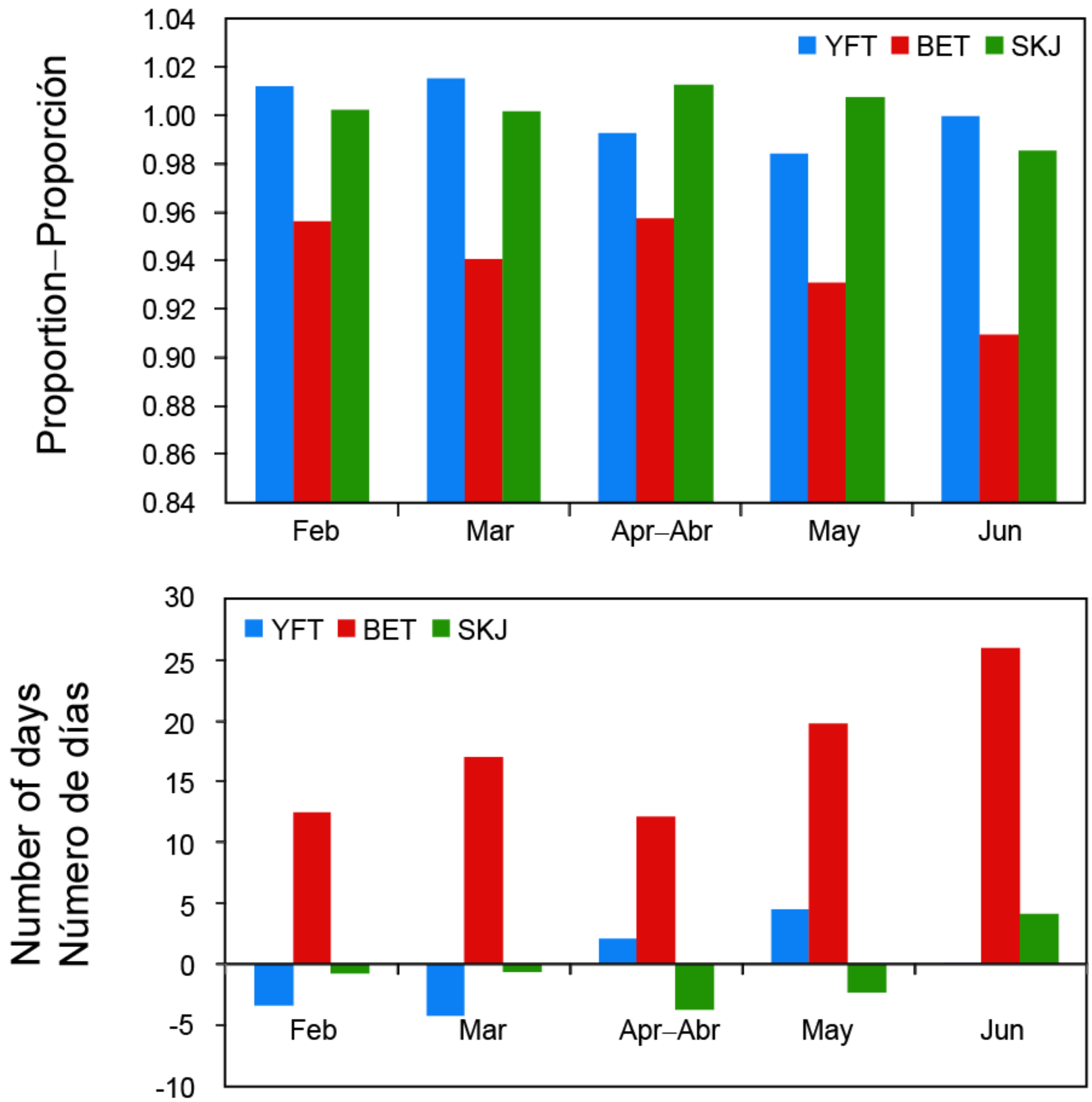

FIGURE 4. Monthly change in catch, by species, with a closure of the high seas, as a proportion of the catch with no closure (top panel) and the equivalent number of days of closure (bottom panel). YFT: yellowfin; BET: bigeye; SKJ: skipjack.

FIGURA 4. Cambio mensual en la captura, por especie, con veda de alta mar, como proporción de la captura sin veda (recuadro superior) y el número equivalente de días de veda (recuadro inferior). YFT: aleta amarilla; BET: patudo; SKJ: barrilete.

Appendix A: Length composition of the catch, by 5° square.
Anexo A: Composición por talla de la captura, por cuadrángulo de 5°.

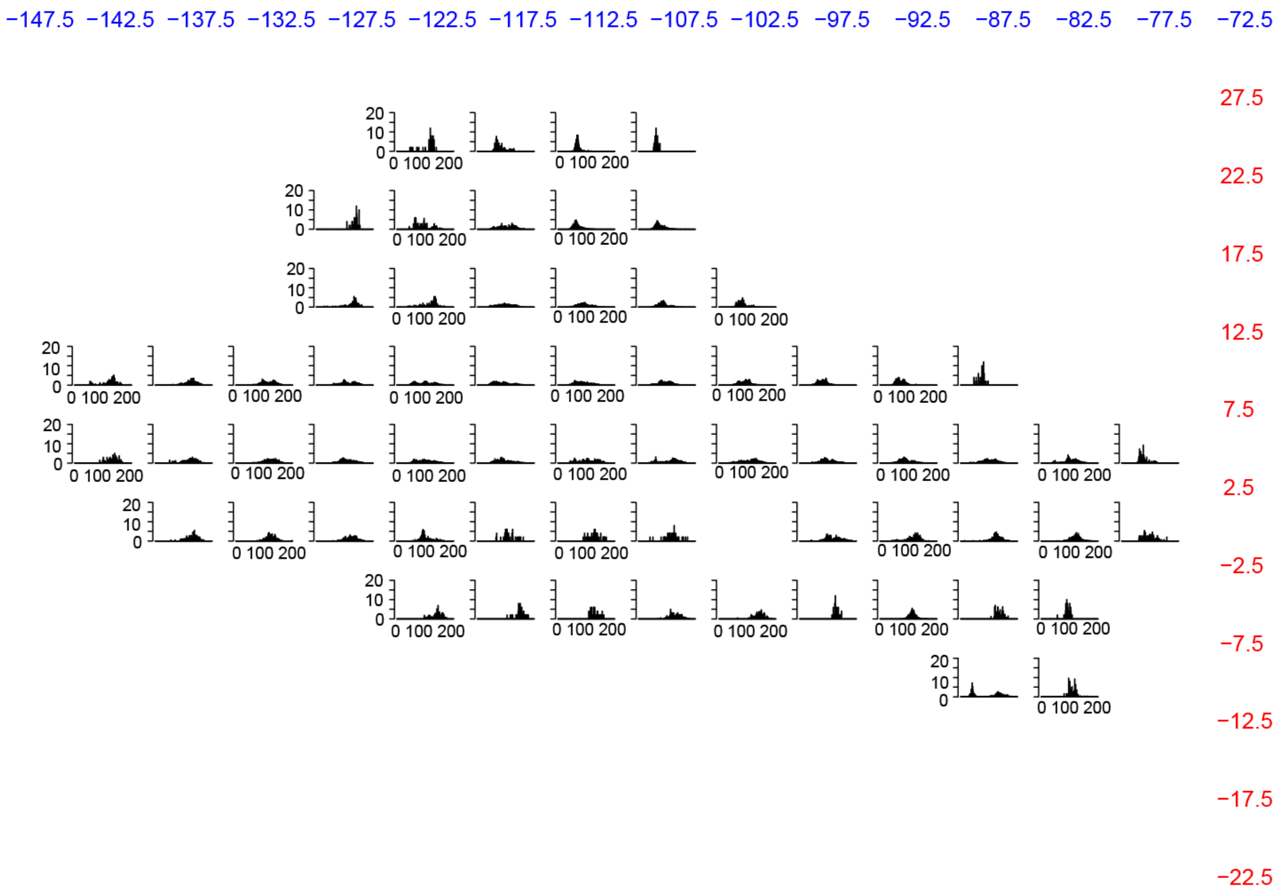

FIGURE A1. Percent length frequencies of yellowfin caught in the dolphin-associated purse-seine fishery averaged over the 2011-2015 period.
FIGURA A1. Frecuencia de tallas porcentual de aleta amarilla capturado en la pesquería de cerco asociada a delfines, promedio del periodo de 2011-2015.

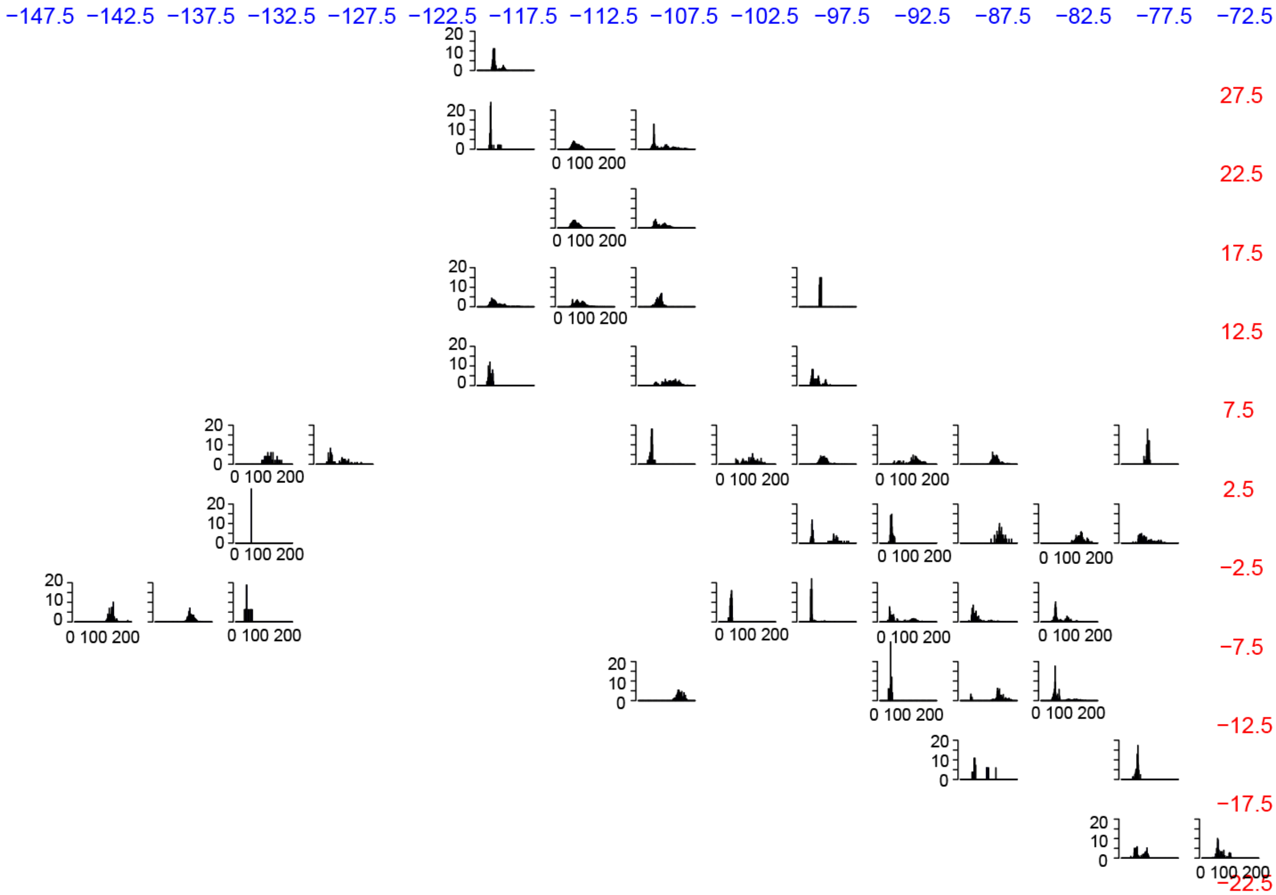

FIGURE A2. Percent length frequencies of yellowfin caught in the unassociated purse-seine fishery averaged over the 2011-2015 period.
FIGURA A2. Frecuencia de tallas porcentual de aleta amarilla capturado en la pesquería de cerco no asociada, promedio del periodo de 2011-2015.

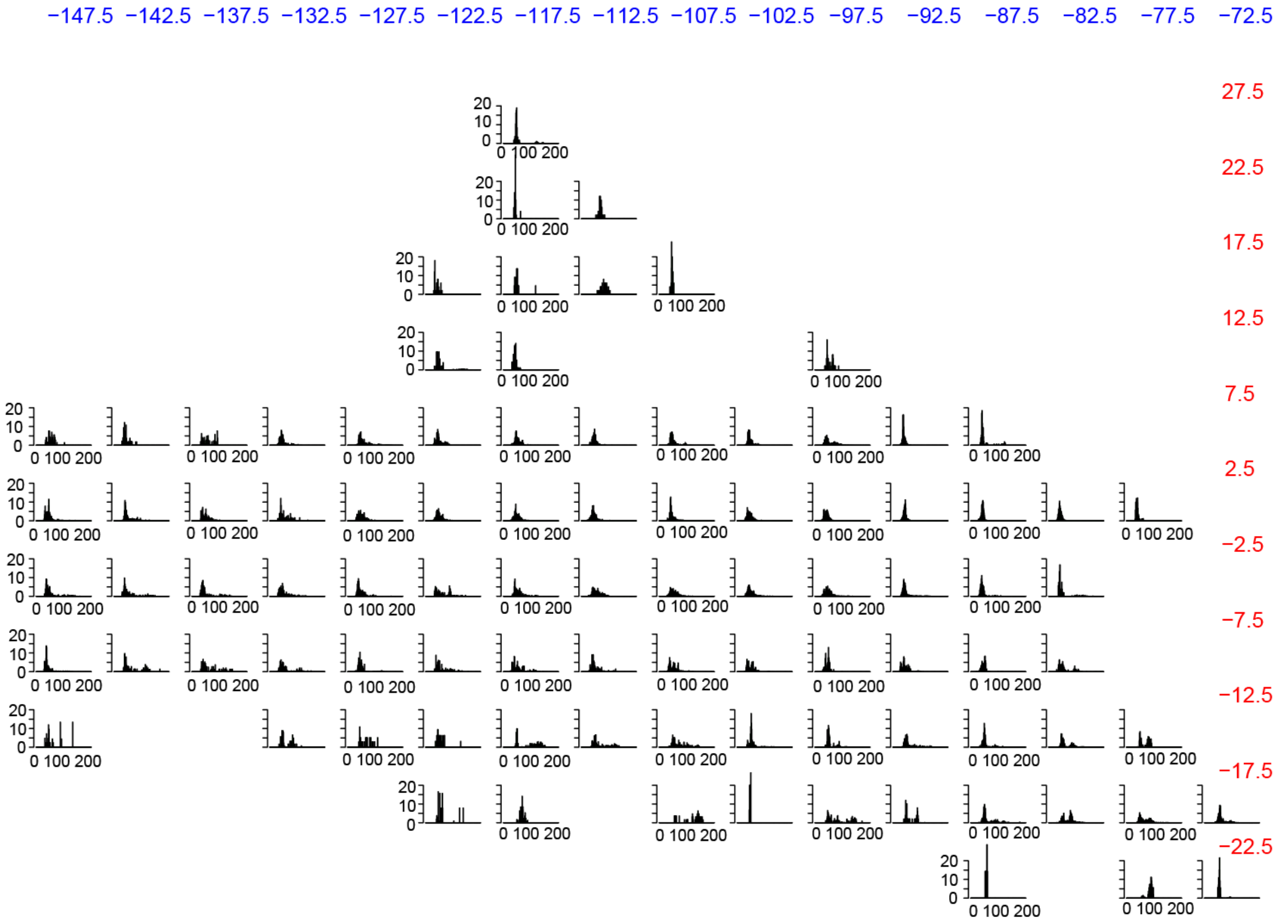

FIGURE A3. Percent length frequencies of yellowfin caught in the purse-seine fishery associated with floating objects, averaged over the 2011-2015 period.
FIGURA A3. Frecuencia de tallas porcentual de aleta amarilla capturado en la pesquería de cerco asociada a objetos flotantes, promedio del periodo de 2011-2015.

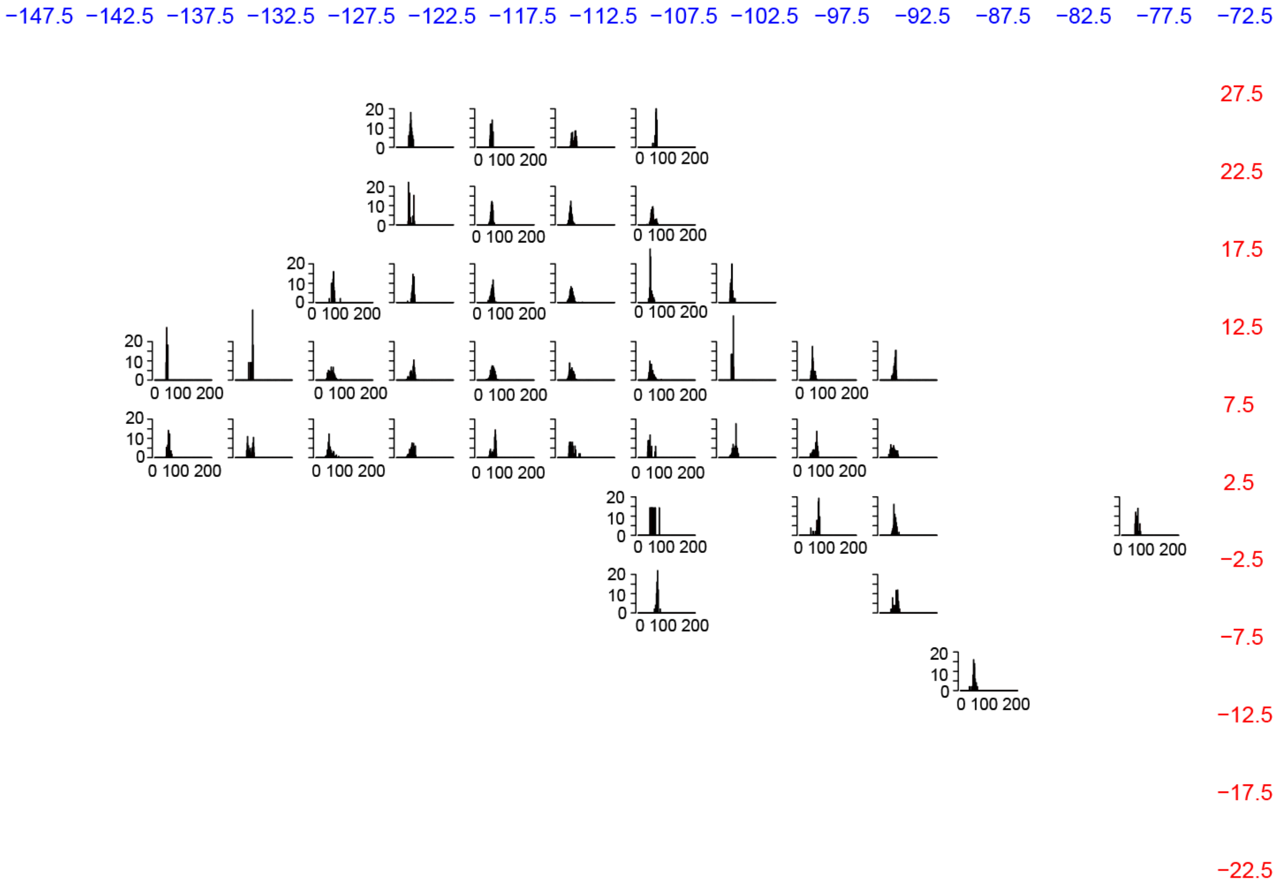

FIGURE A4. Percent length frequencies of skipjack caught in the dolphin-associated purse-seine fishery averaged over the 2011-2015 period.
FIGURA A4. Frecuencia de tallas porcentual de barrilete capturado en la pesquería de cerco asociada a delfines, promedio del periodo de 2011-2015.

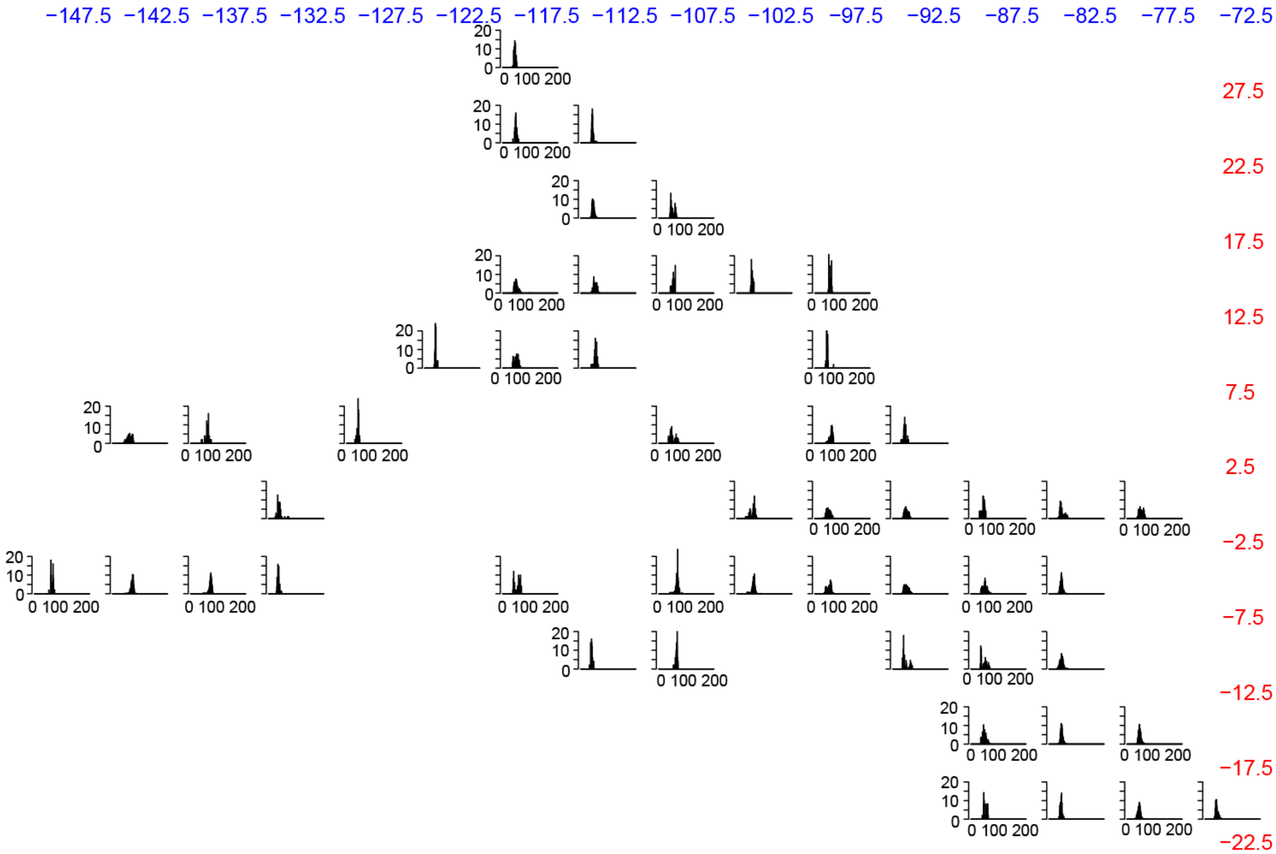

FIGURE A5. Percent length frequencies of skipjack caught in the unassociated purse-seine fishery averaged over the 2011-2015 period.
FIGURA A5. Frecuencia de tallas porcentual de barrilete capturado en la pesquería de cerco no asociada, promedio del periodo de 2011-2015.

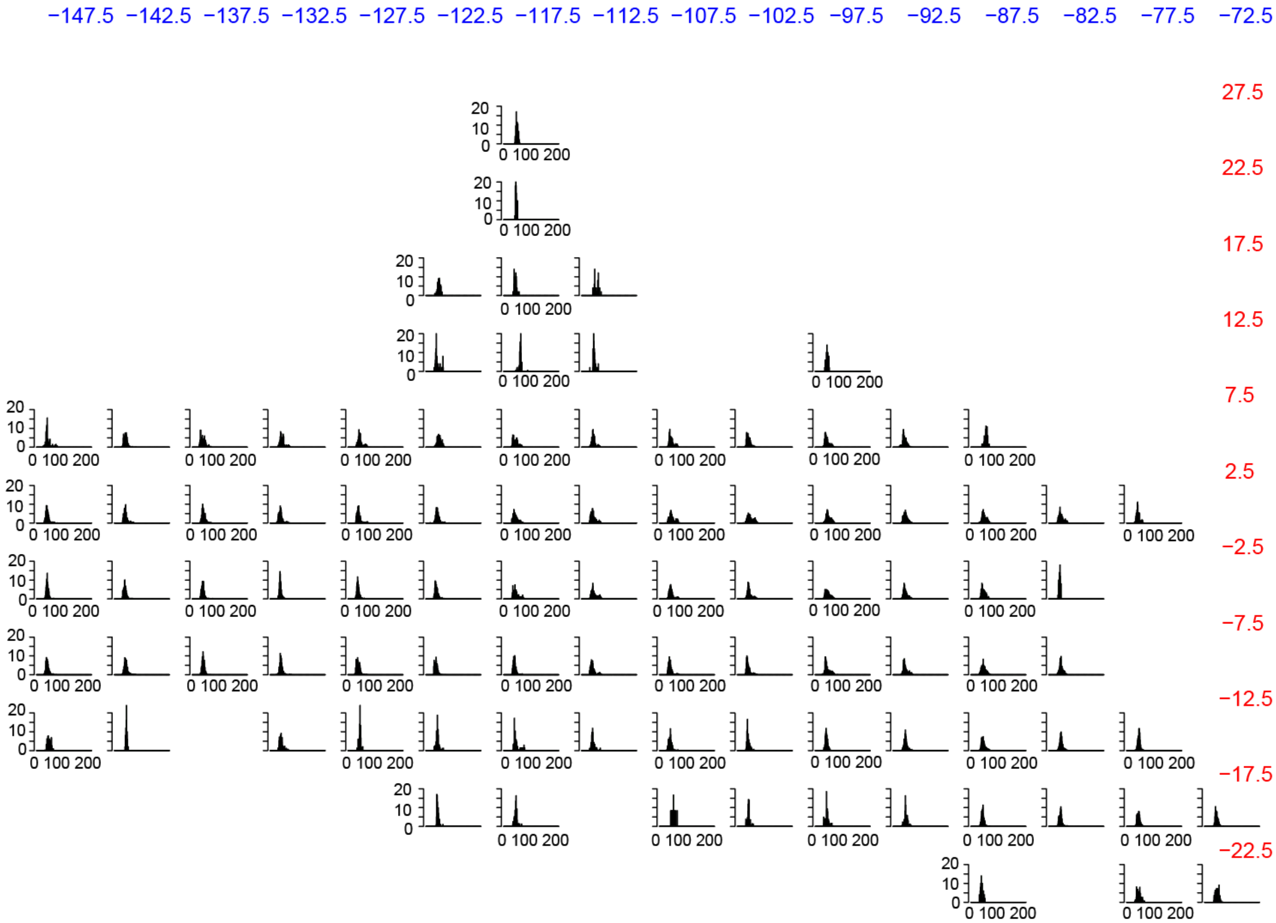

FIGURE A6. Percent length frequencies of skipjack caught in the purse-seine fishery associated with floating objects, averaged over the 2011-2015 period.
FIGURA A6. Frecuencia de tallas porcentual de barrilete capturado en la pesquería de cerco asociada a objetos flotantes, promedio del periodo de 2011-2015.

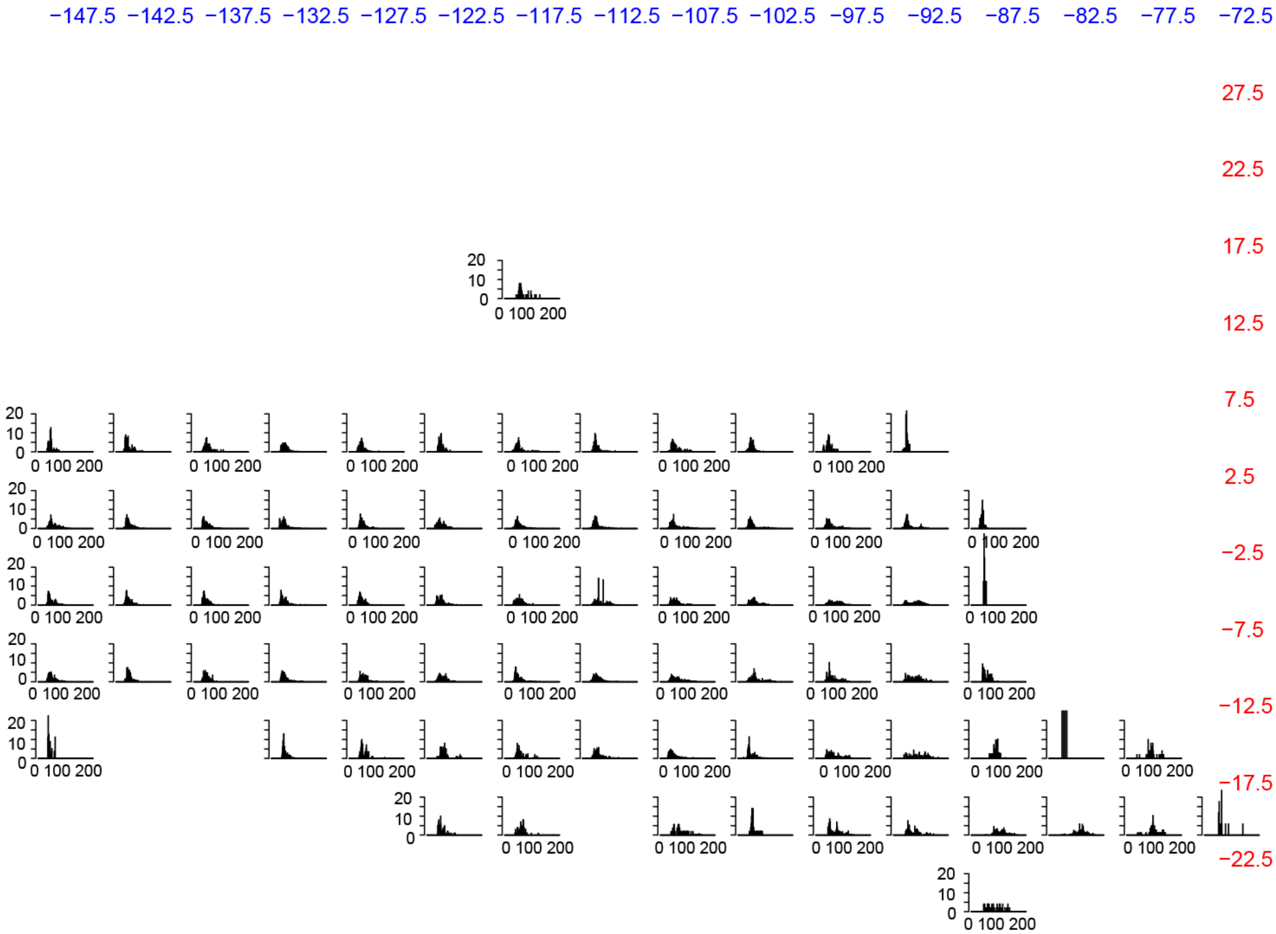

FIGURE A7. Percent length frequencies of bigeye caught in the purse-seine fishery associated with floating objects, averaged over the 2011-2015 period.
FIGURA A7. Frecuencia de tallas porcentual de patudo capturado en la pesquería de cerco asociada a objetos flotantes, promedio del periodo de 2011-2015.