INTER-AMERICAN TROPICAL TUNA COMMISSION

***AD-HOC* PERMANENT WORKING GROUP ON FADS**

FOURTH MEETING

Bilbao (Spain)
19 July 2019

DOCUMENT FAD-04-01

ADJUSTING CURRENT FAD LIMITS TO MEET 2019 STAFF RECOMMENDATIONS FOR TROPICAL TUNA MANAGEMENT IN THE EASTERN PACIFIC OCEAN

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CONTENTS

SUMMARY

The staff's stock assessments of bigeye and yellowfin tunas in the eastern Pacific Ocean were found to be extremely sensitive to new data and to previously-identified issues in the assessment. Because of this, the results of the assessments, particularly the *F* multiplier, could not be used as a basis for management advice. However, the stock status indicators suggested that fishing mortality is continuing to increase, especially due to increases in the number of floating-object sets.

In 2018 and 2019, the staff recommended limiting the number of floating-object and unassociated sets combined. However, this recommendation was not supported by the Scientific Advisory Committee, due mainly to concerns about a "race to fish" on floating objects that would offset the desired reduction in such sets. In response to requests to investigate alternative measures, the staff has developed an approach that meets conservation and management needs by adjusting the active fish-aggregating device (FAD) limits currently in force under Resolution C-17-02, thus affecting only sets on FADs, not the other types of purse-seine sets.

Based on data on active FADs[1] and numbers of floating-object sets, the staff has estimated the reduction in the active FAD limits that would correspond to its recommendation to restrict effort to the 2015-2017 average level. Per the staff's precautionary recommendation to restrict effort, floating-object sets should be reduced by 13%. Because the number of active FADs used by most vessels is well below the limits in Resolution C-17-02, this 13% reduction in floating-object sets translates into to a 30% reduction in active FAD limits, as follows:

[1] Resolution C-17-02 defines 'active' in terms of the presence and functioning of a satellite-transmitting buoy. Therefore, often no distinction is made between the terms 'FAD' and 'buoy', although the IATTC staff recognizes that there are important differences between the two.

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Class 6 (< 1,200 m^3)	300	210
Class 4-5	120	85
Class 1-3	70	50

1. INTRODUCTION

The staff has concluded that both the bigeye (2018) and yellowfin (2019) tuna assessment models have become overly sensitive to both the inclusion of new data and previously-identified issues in the assessment (*e.g*. SAC-09 INF-B, SAC-10 INF-F, SAC-10-07). For this reason, the *F* multipliers[2] derived from the assessments are considered compromised, and the staff does not recommend using them as a basis for management measures. In 2019, stock status indicators (SSIs), used previously for skipjack tuna only, were used to monitor all three species of tropical tunas (SAC-10-08, SAC-10-09). The SSIs suggested that fishing mortality (*F*) is continuing to increase for all three species, mainly due to increases in fishing effort in the purse-seine fishery, specifically in the number of sets on floating objects.

Because it is not practical to limit floating-object (OBJ) sets alone, in 2018 and 2019 the staff recommended limiting the total number of OBJ and unassociated (NOA) purse-seine sets combined (OBJ+NOA). However, the Scientific Advisory Committee (SAC) did not endorse this recommendation, and in May 2019 requested that the staff present alternative options for managing the purse-seine fishery for tropical tunas in 2020.

Currently, Resolution C-17-02 restricts purse-seine fishing activity during 2018-2020 through spatio-temporal closures (72-day total closure of the fishery, additional 30-day closure for the area known as the "*corralito*") and limits on the number of active[3] fish-aggregating devices (FADs) that each vessel can have at any one time. However, other components of the fishery, such as number of sets and number of FAD deployments, are unrestricted. While the staff's proposal to limit the number of sets directly affects fishing mortality, limiting FAD deployments may not be effective for a variety of reasons (*e.g*. re-deployments, night deployments, vessels without observers, vessels deploying FADs owned by other vessels, combined with the current impossibility of tracking FADs across trips and among vessels).

This document proposes revised active FAD limits as an alternative to limiting the number of sets in order to achieve a similar effect on *F*. Following the approach outlined in the staff proposal in IATTC-94-03 for a reduction in NOA and OBJ sets combined, the 2018 total of OBJ sets made in the eastern Pacific Ocean (EPO) for IATTC Class-6 vessels (11,871) should be reduced to the average level in 2015-2017 (10,303) (from Table A-7 of IATTC-94-01). A 13% reduction in OBJ sets would be necessary to achieve this (*i.e*. 1-(10,303/11,871) = 0.13209). This percent reduction was therefore used as the target level for the analyses of active FADs presented in this document.

2. MATERIALS AND METHODS

2.1. Data

Three main datasets were used in the study:

a. Daily active buoy data for 152 vessels (Classes 1-6) reporting under Resolution C-17-02 during

[2] *F* multiplier = F_{MSY} (the fishing mortality that will produce the maximum sustainable yield) divided by $F_{current}$ (the average fishing mortality for the three most recent years). An *F* multiplier of 1.0 means that the fishery is meeting the management goal of fishing at the MSY level ($F_{current} = F_{MSY}$); if it is below 1.0, fishing mortality is excessive ($F_{current} > F_{MSY}$).

[3] A FAD is considered active when it (i) is deployed at sea, and (ii) starts transmitting its location and is being tracked by the vessel, its owner, or operator (C-17-02, paragraph 10).

2018 (Figure 1). Daily vessel coverage and reporting rates vary by size class and month (min = 99, mean = 123, max = 138), with not all vessels present in the active buoy dataset at any one time. See 2018 report of the Review Committee for further details on data reporting rates and categories.

b. 2009-2018 AIDCP observer data for Class-6 vessels, which contain FAD-related information such as deployment, origin, and other characteristics, as well as on fishing activities on FADs.
c. Catch and effort data for all vessels (Classes 1-6), from observers and vessel logbooks. This dataset provided information on a series of fisheries metrics per vessel used in the exploratory and modelling stages, including number of OBJ sets, days fishing, OBJ catch, catch per days fished.

2.2. Methods

The following assumptions were made in this study:

a. All FADs deployed or modified were identified (Resolution C-18-05). Since no vessel is using the IATTC identifiers for FADs, it is assumed that all FAD identifiers were in fact buoy identifiers.
b. All FADs were deployed with an active buoy (Resolution C-17-02).
c. Buoys that were deactivated were not remotely reactivated (Resolution C-17-02).
d. The numbers of FADs used, and buoy management and use practices, are similar for vessels that reported and for vessels that did not report buoy data.
e. The maximum number of active FADs used by a vessel is a better index of actual buoy use than the average number of active FADs, due to the fishing strategies (*i.e*. vessels usually deploy FADs at the beginning or end of the trip).
f. The buoy management and use practices of vessels that fish mainly on floating objects are more representative for the current analysis than those of vessels that interact with FADs in a more opportunistic manner.
g. A vessel's fishing activity is positively related with the availability of, and access to, monitored FADs. Therefore, a reduction of a vessel's active FADs should lead to a reduction in the number of FAD sets, and hence OBJ sets, by the vessel.
h. Because vessels that fish on FADs opportunistically rely on the general availability of FADs at sea, an overall reduction in the number of FADs will affect their OBJ-related fishing activities, and the OBJ-related fishing activities of vessels fishing primarily on their own FADs, in a similar way.
i. When new active FAD limits are implemented, only vessels using more FADs than the limit are impacted (*i.e.* vessels using less FADs than the limit do not increase their FAD use to the limit).

Three types of analyses, described in detail below, were conducted:

1. Clustering methods were used to identify homogeneous groups of vessels (fleet segments) for 2018, to provide insights into very recent fishing behavior.
2. The relationship between the number of active FADs and numbers of OBJ sets per vessel was evaluated for the fleet segment that focused on fishing on its own FADs in 2018.
3. New active FAD limits were estimated that would achieve the desired 13% reduction in OBJ sets.

2.2.1. Identification of fleet segments for Class-6 vessels

Only vessels making at least five OBJ sets during 2018 were considered. The methodology described in Lennert-Cody *et al*. (2018) was applied, where vessels were grouped into different fleet segments based on the following variables: (i) proportion of OBJ sets by object "origin" category; (ii) proportion of sets made by type (associated with dolphins, associated with floating objects, or unassociated); and (iii) proportion of OBJ sets made in the western EPO (west of 100°W).

2.2.2. Relationship between FADs and number of OBJ sets for Class-6 vessels

Various metrics were explored for the fleet segment that focused on fishing on its own FADs, as there is a more direct connection between the number of FADs used by the vessel and the number of OBJ sets. However, number of sets was chosen as the best metric for use in this study because: (i) it is the metric most directly related to *F*; (ii) it is used by the staff to determine target *F* levels under a precautionary approach; and (iii) there is no clear evidence that links other metrics to *F*, especially in an absence of appropriate measures of effort for the purse-seine fishery (Fonteneau *et al*. 2013) and data with which to estimate effort (Lopez *et al*. 2018), which can ultimately lead to misleading results.

Not all vessels fish exclusively on FADs they deployed themselves, and the efficiency of vessels that fish primarily on FADs encountered by chance will be impacted by the total number of FADs in use by all vessels. Ideally, multiple years of data would be used to evaluate, at the fleet level, the relationship between active FADs and OBJ sets, but no historical data on active FADs are available to the IATTC staff. Thus, to supplement the analysis described in the previous paragraph, the relationship between total annual deployments and OBJ sets was evaluated for 2009-2018. The number of OBJ sets used in this analysis was that of vessels that made more than 20% of their sets on FADs encountered opportunistically (*i.e*. deployed by other vessels and encountered by chance).

2.2.3. Estimating new active FAD limits

This analysis focused on large Class-6 vessels (≥ 1,200 m^3). To estimate a new active FAD limit for this vessel category, the relationship between the FAD limit and the number of active FADs was estimated. To do this, the current active FAD limit for these vessels (450) was reduced incrementally to zero, and the corresponding estimate of the reduction in actual FADs in use was computed as the proportion of active FADs reported that would have to be "removed" to meet the new hypothetical limit. The new active FAD limit is then that hypothetical limit necessary to reduce the total number of active FADs in use by 13%.

3. RESULTS

The results of the cluster analysis indicate vessel groupings with different fishing behaviors (Figure 2), based on the types of sets the vessels made and on their OBJ-fishing activities. For example, at a level of seven groups in the dendrogram, there are three fleet segments (clusters 1, 2, and 5) that mainly fished on floating objects; however, two of them (clusters 2, 5) relied on floating objects encountered opportunistically, such as FADs deployed by other vessels or unmonitored drifting objects (presumably natural objects such as logs). The other four fleet segments did not target floating objects heavily. These general patterns are similar to those found by Lennert-Cody *et al*. (2018) for 2012-2015, suggesting that these fleet segment characterizations are not the result of an anomalous year. One fleet segment (cluster 1; 21 vessels) was considered to best represent pure OBJ-oriented fishing (*i.e*. fishing on one's own FADs, so there is a clear connection between active FADs and number of sets), and was used to evaluate the relationship between active FADs and OBJ sets.

There was a positive relationship between the maximum number of active FADs per vessel and the number of OBJ sets per vessel in 2018 for vessels of cluster 1 (Figure 3). Although the data set is small, a preliminary analysis of this relationship did not show any strong indication of nonlinearity (*i.e*., the effective degrees of freedom of the smooth term for a generalized additive model fitted to these data was close to 1). There was no significant difference in the fit to these data of linear models with and without an intercept term (ANOVA, $P > 0.23$). Whether a linear relationship between active FADs and OBJ sets would be obtained for vessels fishing on FADs encountered by chance is not known. Over the last 10 years, the relationship between total annual deployments by Class-6 vessels and the total number of OBJ sets by vessels fishing on FADs encountered by chance was also positive (Figure 4), although there is an indication that the relationship may be non-linear. Thus, what can be concluded from the available data is that the level of OBJ fishing operations increases with the availability of FADs, either monitored or encountered opportunistically. To estimate the new active FAD limits, it was assumed that the desired

13% reduction in OBJ sets translates directly into a 13% reduction in current active FADs; *i.e*. there is a linear relationship (that passes through the origin) between the number of active FADs and the number of OBJ sets.

The staff recommendation for tropical tuna management is to keep effort at the 2015-2017 average, as a precautionary measure, which means that 2018 OBJ sets should be reduced by 13%. When this is translated into a reduction of the actual number of active FADs used by the fleet, current limits need to be readjusted to be 30% less than those in Resolution C-17-02 (Figure 5), because the actual number of active FADs in use by most vessels (Figure 1) is well below the limits specified in the resolution. Thus, the new active FAD limits would be:

Class 6 (≥ 1,200 m^3)	450	315
Class 6 (< 1,200 m^3)	300	210
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The potential impact of these 30% reductions on the fleet, based on 2018 data, would be (sd: standard deviation):

Class	Number of vessels	Limit		Using maximum active FADs		Using average active FADs	
		C-17-02	New	Average FAD reduction (sd)	Affected vessels (%)	Average FAD reduction (sd)	Affected vessels (%)
3	7	70	50	17 (0)	1 (14.3)	0	0
4	28	120	85	14 (2.1)	2 (7.1)	0	0
5	11	120	85	19 (0)	1 (9.1)	0	0
6.a	50	300	210	58 (16.6)	7 (14)	0	0
6.b	56	450	315	91 (44.1)	19 (33.9)	23 (10.7)	4 (7.1)

Between about 7 and 34% of the vessels would be affected when compared to vessels' maximum number of active FADs used, whereas only 7% would be affected when compared to vessels' average values. Affected vessels would need to reduce their number of active FADs by an average of between 14 and 91 to comply with the proposed limits, depending on vessel size class.

4. DISCUSSION

Although the staff maintains its 2018 recommendation to limit the number of OBJ and NOA sets combined, it has developed, in response to a request from the SAC, an alternative approach to meet conservation and management needs by reducing the current active FAD limits, which directly relates to sets on FADs but not other types of purse-seine sets. Ideally, these new limits should be used in combination with the limits on the number of OBJ and NOA sets combined, because skipjack is also a conservation concern and is caught in unassociated sets. However, the new active FAD limits could also be used independently. Discussions within this working group and the Joint t-RFMO FAD working group revealed that current limits were both arbitrary, with no scientific basis, and very likely too high. This study supports this, and indicates that the limits should be revised to meet specific management needs. Here, we connect the staff's management recommendation with a 30% reduction of current active FAD limits, with the intention that a reduction in the number of FADs at sea will help to prevent further increases in fishing mortality.

Understanding the link between fishing mortality and alternative metrics for the purse-seine fishery is particularly difficult, since the conventional unit of effort (*i.e*. search time) can no longer be used (Fonteneau *et al*. 2013) and the data used to assess fishery evolution and impacts are not ideal (FAD-03

INF-A). However, in the absence of better data and longer time series to refine the analyses, this approach provides a reasonable understanding of the relationship between number of sets and monitored active FADs, and shows that this link can be used to improve scientific advice. Nonetheless, the relationship between mortality and operational characteristics needs to be better understood if additional or improved conservation and management measures are to be developed. Document FAD-03 INF-A, presented in May 2018, was very clear about gaps, needs and potential improvements in FAD data, but data reporting has barely improved since then. Very few vessels are reporting daily positions for active FADs, and the summarized data[4] reported by the vast majority of the fleet are of limited use for scientific studies. Despite recommendations by the Working Group on FADs, the 9th and 10th meetings of the SAC, and the joint t-RFMO working group on FADs, high-resolution buoy data have yet to be provided to the IATTC staff. Access to these data would improve understanding of fleet behavior, allow various data sets (active buoy data, observers, FAD forms, logbooks) to be connected and checked for accuracy, improve estimates of catch rates and catch per unit of effort, allow integration of environmental information with the life history of individual FADs to better understand environmental effects on catch rates, improve tracking and monitoring of FADs, and improve assessment of impacts of FADs on the ecosystem, among others. Therefore, the staff reiterates the need for access to high-resolution buoy data, with which it will be able to develop and improve the conservation and management advice that the Commission requires.

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Fonteneau, A., E. Chassot and N. Bodin (2013). "Global spatio-temporal patterns in tropical tuna purse seine fisheries on drifting fish aggregating devices (DFADs): Taking a historical perspective to inform current challenges." Aquatic Living Resources 26(01): 37-48.

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Lopez, J., E. Altamirano, C. Lennert-Cody, M. Maunder and M. Hall (2018). "Review of IATTC resolutions C-16-01 and C-17-02: available information, data gaps, and potential improvements for monitoring the FAD fishery." FAD-03 INF-A.

[4] Containing no spatial information, and trajectories of floating objects are not available.

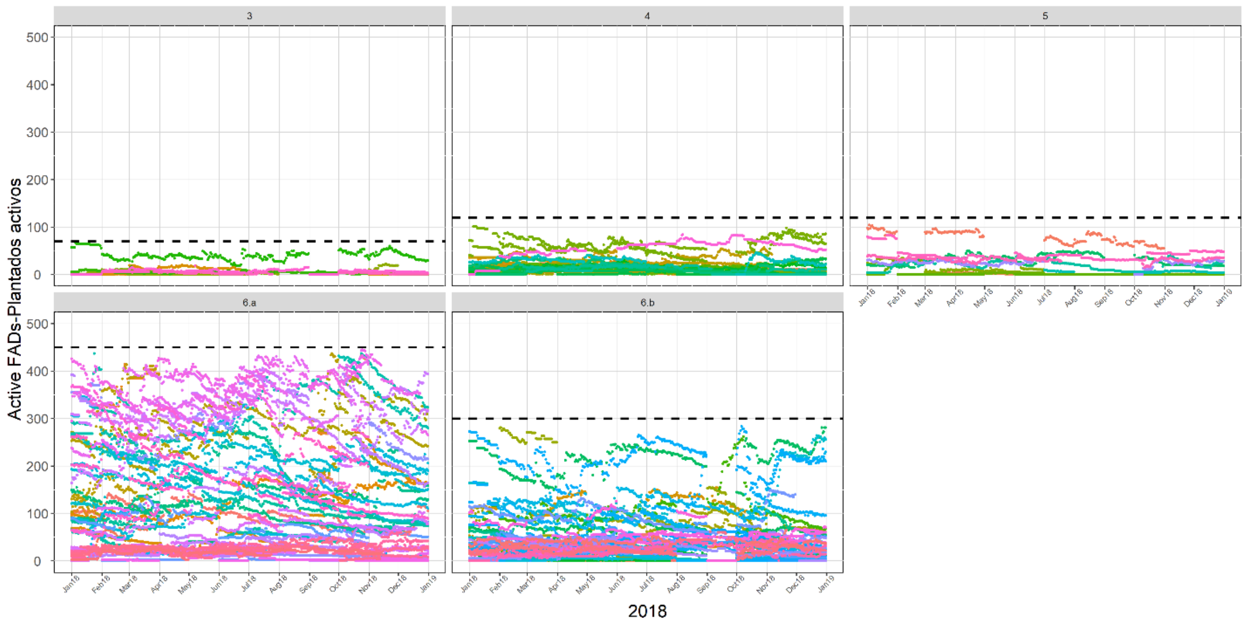

FIGURE 1. Daily active FAD levels, per vessel and capacity class, 2018. Each color represents a vessel; points are used to show data reporting gaps. The dashed lines represent the limits in Resolution C-17-02.

FIGURA 2. Niveles diarios de plantados activos, por buque y clase de capacidad, 2018. Cada color representa un buque; se usan puntos para indicar huecos en la notificación de datos. Las líneas de trazos representan los límites en la resolución C-17-02.

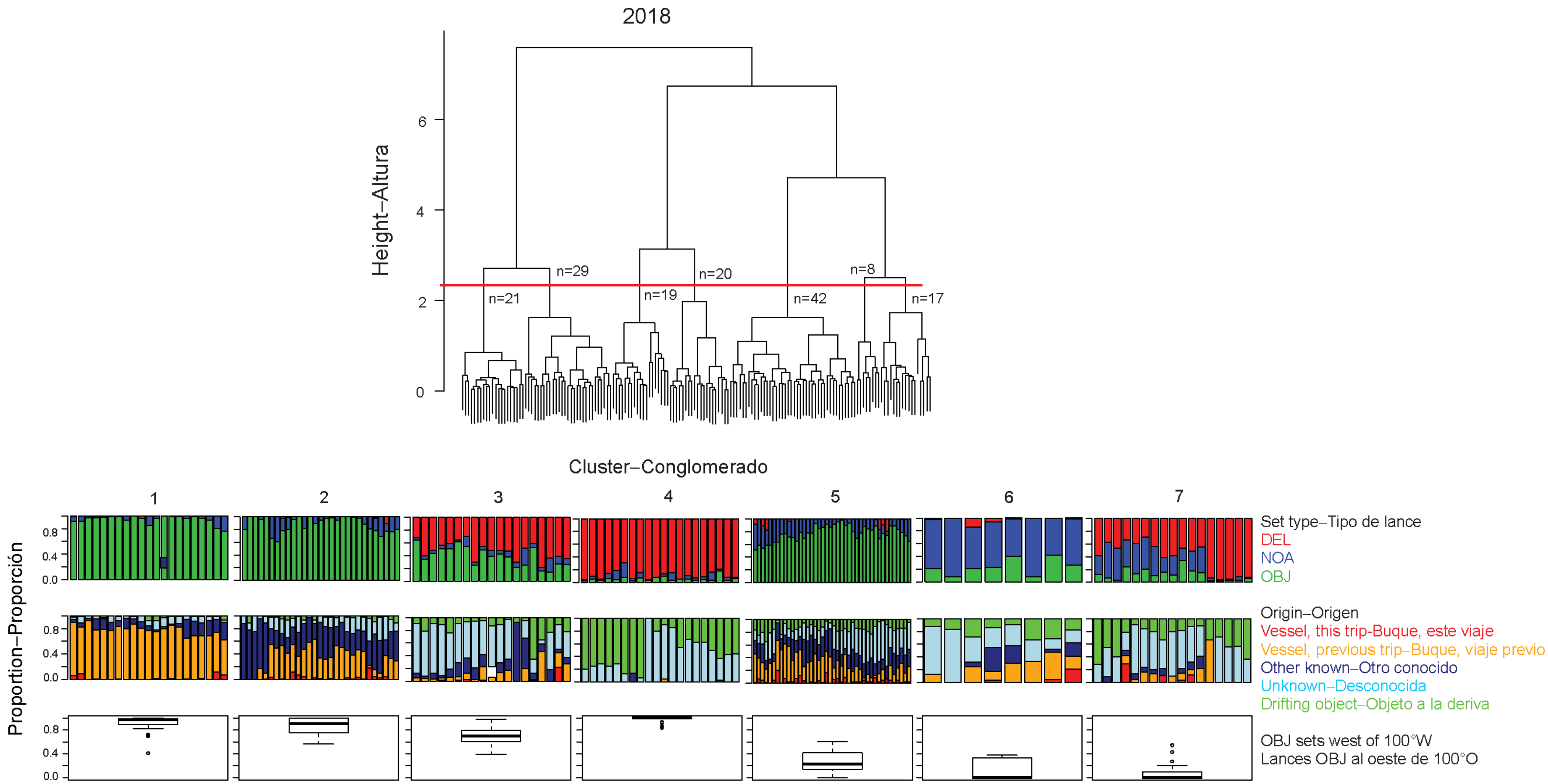

FIGURE 3. Fleet segments identified by the cluster analysis, 2018.
FIGURA 4. Segmentos de flota identificados por el análisis de conglomerados, 2018.

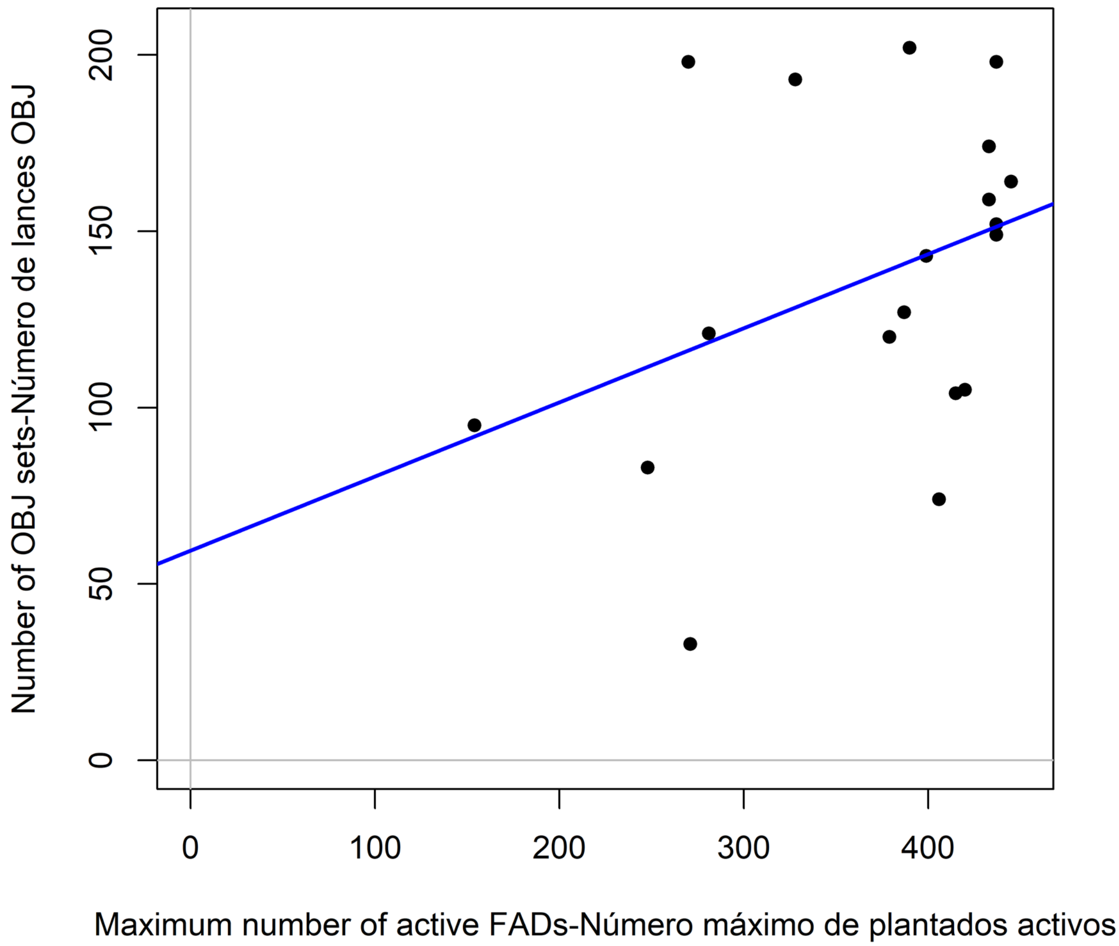

FIGURE 5. Relationship between maximum number of active FADs and number of OBJ sets per vessel, for vessels in cluster 1 (Figure 2; the fleet segment that mostly used its own FADs), 2018.
FIGURA 6. Relación entre el número máximo de plantados activos y el número de lances OBJ por buque, para buques en el conglomerado 1 (Figura 2; el segmento de flato que usó principalmente sus propios plantados), 2018.

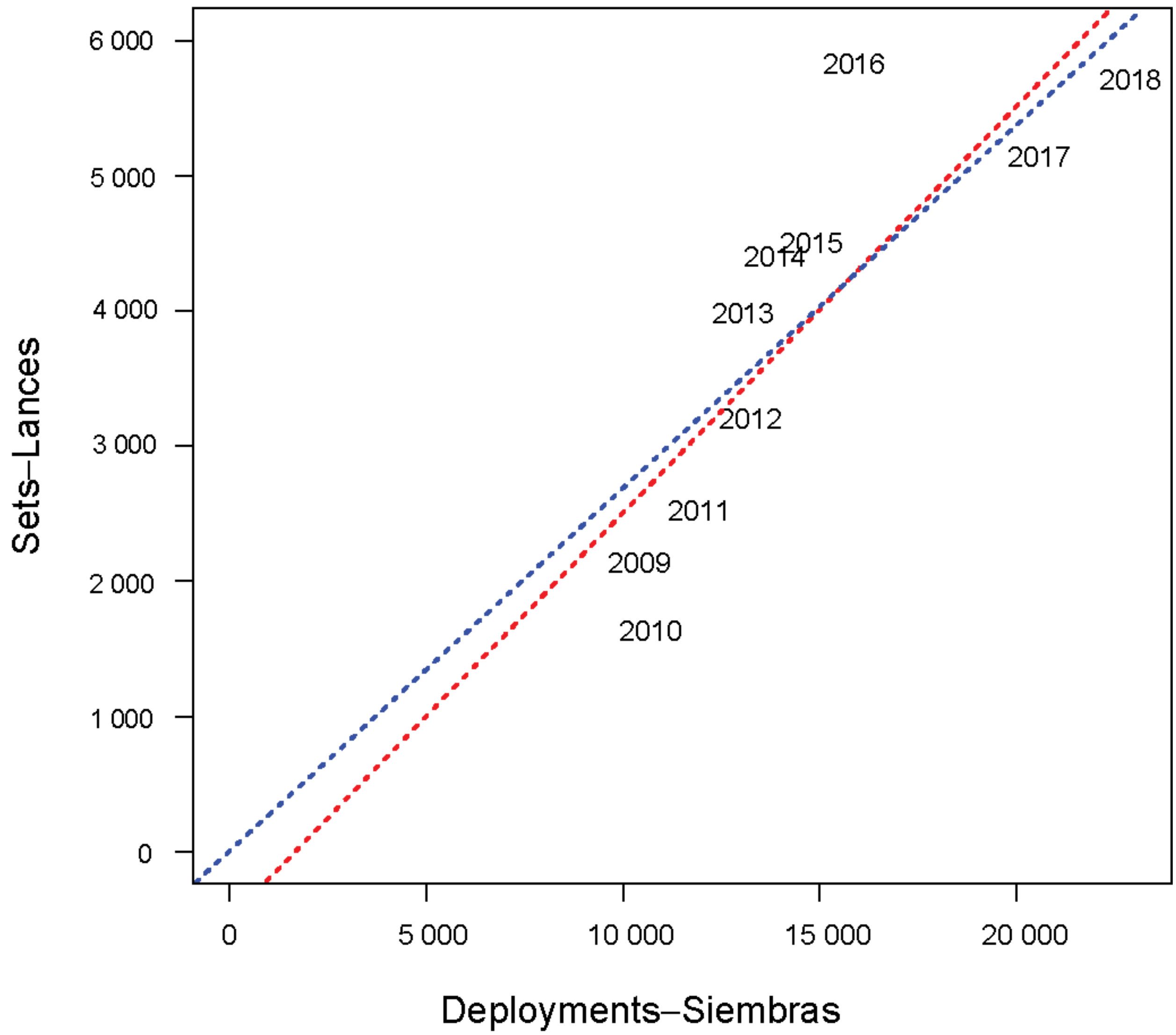

FIGURE 7. Relationship between FAD deployments by all Class-6 vessels and the total number of OBJ sets made by Class-6 vessels with more than 20% of sets on FADs encountered by chance, 2009-2018. Red dashed line: fitted linear model, assuming non-zero intercept term; blue dashed line: fitted linear model, assuming an intercept value of zero.

FIGURA 8. Relación entre siembras de plantados por todos los buques de clase 6 y el número total de lances OBJ realizados por buques de clase 6 con más de 20% de lances sobre plantados encontrados por casualidad, 2009-2018. Línea de trazos roja: modelo lineal ajustado, suponiendo término de intercepto no cero; línea de trazos azul: modelo lineal ajustado, suponiendo un valor de intercepto cero.

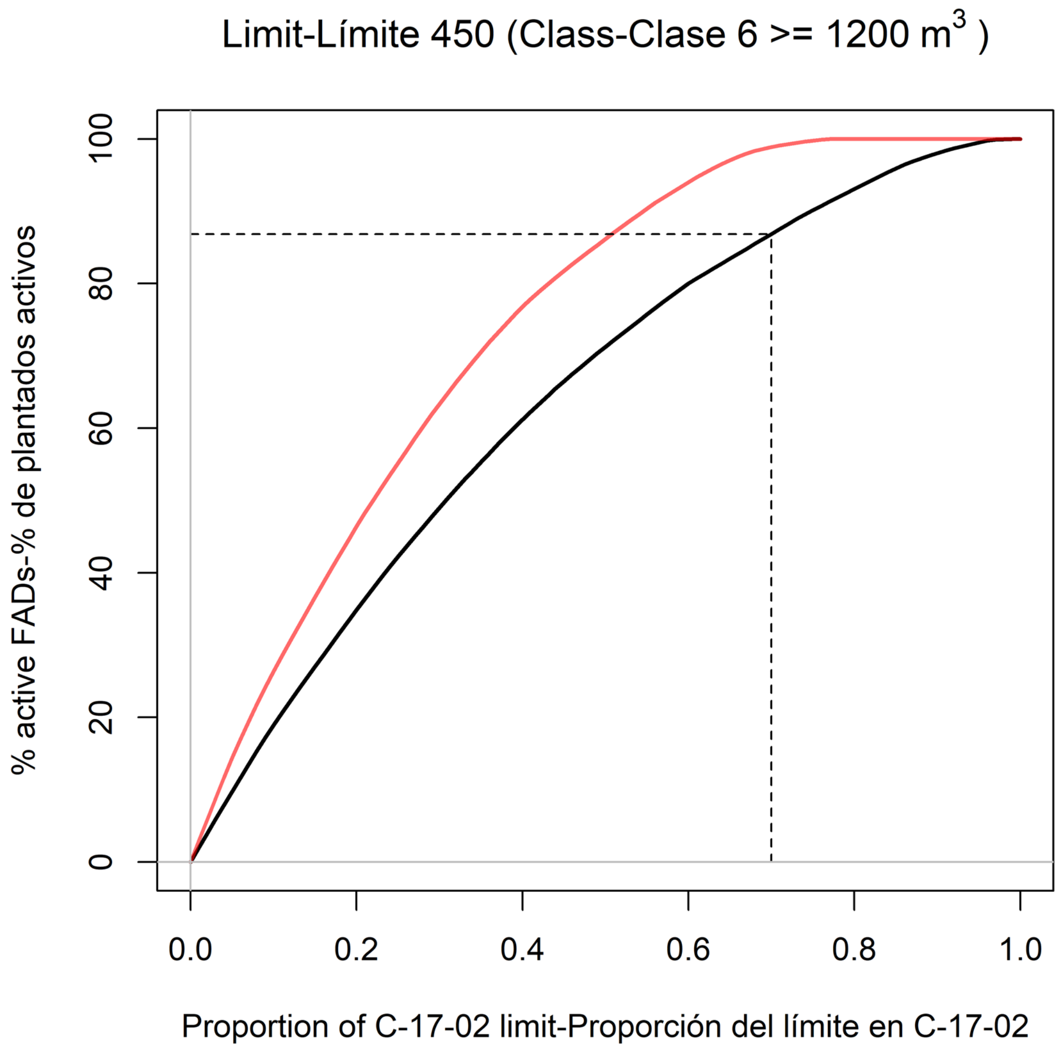

FIGURE 9. Impact of incrementally reducing the active FAD limit for large (≥ 1,200 m^3) Class-6 vessels in Resolution C-17-02 (450) (x-axis; reduction shown as a proportion of the limit) on the number of active FADs in use by such vessels in 2018 (y-axis; reduction shown as a percentage of the total active FADs reported), calculated using the maximum (black line) and average (red line) number of active FADs per vessel. The dashed lines represent the estimate of the new active FAD limit (x-axis; equal to 0.7 x 450, *i.e.*, a 30% reduction) that would achieve a 13% reduction in active FADs (y-axis).

FIGURA 10. Efecto de una reducción incremental del límite de plantados activos para buques de clase 6 grandes (≥ 1,200 m^3) en la resolución C-17-02 (450) (eje *x*; reducción indicada como proporción del límite) sobre el número de plantados activos en uso por dichos buques en 2018 (eje *y*; reducción indicada como porcentaje del total de plantados activos reportados), calculados usando el número máximo (línea negra) y promedio (línea roja) de plantados activos por buque.Las líneas de trazos representan la estimación del nuevo límite de plantados activos (eje *x*; igual a 0.7 x 450, una reducción de 30%) que lograría una reducción de 13% de los plantados activos (eje *y*)