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EVALUATION OF THE DECLINING CATCH PER SET IN THE PURSE-SEINE FISHERY ON FLOATING OBJECTS IN THE EASTERN PACIFIC OCEAN

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ABSTRACT

There is concern over the increasing effort in the purse-seine fishery on floating objects in the eastern Pacific Ocean (EPO) and its correlation with reduced catch per set (CPS) for all three major tropical tuna species, particularly bigeye tuna. There are many possible hypotheses that could explain the correlation between increased effort and declining CPS, but we focus on three that we consider most probable: (H1) declining abundance, (H2) declining number of tuna per FAD, and (H3) change of targeting practices. Given the currently available data, it is difficult to determine the cause of the decline in catch per set of bigeye in the EPO floating object purse-seine fishery. There does not appear to be any evidence supporting any one of the three hypotheses over the others. However, the reduction in CPS is unlikely to be due to changes in spatial distribution of the fleet, increase FAD webbing depth, or increased purse-seine net depth. The stock assessment does not estimate an impact of the increased number of FAD sets on the bigeye populations. Research and data collection are needed. The most important piece of data is a measure of the local FAD density at a given time. The reasons why the number of sets is increasing at a faster rate than the capacity of the fleet should also be investigated. The additional sets may have lower catch rates of bigeye.

1. INTRODUCTION

There is concern over the increasing effort in the purse-seine fishery on floating objects, particularly fish-aggregating devices (FADs), in the eastern Pacific Ocean (EPO) (Figures 1-3) and its correlation with reduced catch per set (CPS) for all three major tropical tuna species (bigeye, yellowfin, and skipjack), particularly bigeye (Figure 4). Effort is often assumed to be proportional to fishing mortality, and catch rates are used as indices of abundance in stock assessment models, therefore it would seem logical that increased fishing mortality due to increased effort would reduce abundance, as measured by the catch per unit of effort (CPUE). However, to make this inference, the relationship between fishing mortality and effort and between abundance and CPUE need to be validated. In addition, credible alternative hypotheses also need to be evaluated. Here we evaluate these relationships and the alternative hypotheses, focusing mainly on bigeye tuna.

2. HYPOTHESES

There are many possible hypotheses that could explain the correlation between increased effort and declining CPS, but we focus on three that we consider most probable.

H1: Declining abundance

H2: Declining number of tuna per FAD as the number of FADs increases, because the tuna disperse themselves among FADs

H3: Change of targeting practices (*e.g*. a shift to skipjack, avoiding bigeye)

2.1. H1: Declining abundance

Declining abundance of the tuna stocks is inferred from the catch per set (Figure 4). CPUE data are a standard measure of relative abundance used in fisheries stock assessment models; however, the use of CPUE as an index of abundance is notoriously problematic (Maunder *et al.* 2006). A variety of sophisticated approaches, often called standardization, are used in an attempt to make the CPUE proportional to abundance (Maunder and Punt 2004). These approaches take into account a number of factors, including the spatial and temporal distribution of effort and the different characteristics of vessels within the fishing fleet. In general, the CPUE is developed based on a measure of search time, since it is the amount of effort needed to find fish that should be related to abundance. Catch per purse-seine set is considered a poor measure of effort, because typically a set is made on a school of tunas that has already been identified, and therefore the effort needed to find that school is not taken into account. Catch per day fished (CPDF) is considered a more reliable measure of search time. However, since the sets are made on FADs, which are located by using electronic beacons, and a single set is often made in the morning (Hall and Roman 2016) when fish are more aggregated around the FAD, after monitoring several FADs and choosing the one with the most fish, CPDF is not a good measure of search time for FAD-associated purse-seine fishing for tunas. A high proportion of FADs also transmit information remotely about the quantity of fish around it, which further reduces the ability to get a good measure of search time. Arguably, if school size changes in proportion to abundance, and there is one school at a FAD (or the number of fish at a FAD changes in proportion to abundance), then catch per set could reflect relative abundance. However, it is likely that both number of schools and school size change with abundance, but there is little information available on this relationship for tunas associated with FADs. Therefore, it is unlikely that catch per set is proportional to abundance, although there may be a nonlinear relationship in which catch per set declines with abundance.

The second component of the declining abundance hypothesis is that the catches of the floating-object fishery are causing the decline in abundance. Given that a majority of bigeye and skipjack are caught in the floating-object fishery, it is conceivable that the increasing effort (number of sets) in that fishery has caused a decline in abundance. The yellowfin catch in the floating-object fishery is only a minor component of the total yellowfin catch, and it is therefore unlikely that the fishery is causing a decline in the abundance of that species. However, there may be local depletion of yellowfin of the sizes caught in the floating-object fishery in the areas of most intensive fishing on floating objects.

The total number of sets has been steadily increasing since at least 2000 (Figure 1), and the number of FADs deployed has also been increasing (Figure 2; see Hall and Roman 2016 for a comprehensive description of the FAD fishery). The number of vessels fishing has remained fairly constant, and well volume has increased slightly. However, these apply to the entire purse-seine fishery, not only vessels that focus mainly on floating objects. Obviously, switching purse-seine set type to those on floating objects would increase the effort on floating objects. There was a large decrease in the number of purse-seine sets on unassociated schools between 2006 and 2010, but since 2010 there is no declining trend in purse-seine sets on unassociated schools or dolphins that could explain the continued increase in sets on floating objects (Figure 5). The catch per set of bigeye and yellowfin has been declining for over a decade, with the declines being greater for bigeye. The catch per set for skipjack has been fairly stable since 2007.

To test the declining-abundance hypothesis, we compare the index of abundance based on catch per set with the estimates of relative abundance from the stock assessment. For consistency, we include only ages that are caught in the floating-object fisheries.

The catch per set of bigeye in the floating-object fishery corresponds well with the CPDF from that fishery (Figure 6). This might not be surprising, since the vessels generally make one set per day, in the morning when the fish are aggregated around the FAD. The catch per set is similar to the biomass estimated from the stock assessment until about 2012, when the catch per set continues to decline while the estimate of biomass from the stock assessment increases.

The catch per set of yellowfin in the floating-object fishery corresponds reasonably well with both the CPDF in that fishery and the biomass estimated by the stock assessment model (Figure 7). Given that yellowfin is not the target species in this fishery, it might be expected that the catch per set is more related to abundance, since the catch of yellowfin is not targeted and thus more random.

The catch per set of skipjack in the floating-object fishery corresponds well with the CPDF in the same fishery (Figure 8). However, the CPDF from the unassociated fishery and the biomass estimate from the simple stock assessment model show an increasing trend in abundance (Figure 8).

2.2. H2: Declining number of tunas per FAD

Another possible explanation for the declining catch per set is that the tuna are distributing themselves evenly among FADs (Hall and Roman 2016). Therefore, even though the abundance of the tuna remains constant, increasing the number of FADs reduces the amount of tuna at each FAD, and consequently the catch per set. There is no direct measurement of the total number of FADs in the EPO at any moment in time, only records of the number of FADs deployed and recovered, but not of those lost (sunk or drifted out of the EPO). However, the increases in the number of FADs deployed (Figure 2) and the number of FAD sets (Figure 1) indicate that the number of FADs in the EPO has been increasing. Hall and Roman (2016) found a decreasing correlation between the total catch of tuna (yellowfin, bigeye, and skipjack) per set and the number of FADs deployed.

2.3. H3: Change of targeting practices

The final hypothesis is based on changes in the fishery that result in a particular species (in this case, bigeye) being less vulnerable to the fishing gear, and thus reducing the catch of bigeye. An analysis of purse-seine data (SAC-07-07e) determined that spatial factors (latitude and longitude), environment, depth of the net webbing typically attached under FADs in order to attract fish, and purse-seine net depth all influenced the catches of bigeye. Exploration of the number of sets by area shows that there has been a general overall increase in sets (Figures 9 and 10). There has been no obvious spatial change in the number of sets except for a recent increase in the southern coastal area off Peru, but the catch per set of bigeye in those areas is low (Figures 11 and 12). The depth of FAD webbing deployed by size class 6[1] vessels increased in the 1990s, was stable until 2011, and then started increasing again (Figure 13). Increasing the depth of the webbing would be expected to increase the catch per set of bigeye initially, because they are more vulnerable, and possibly decrease it as the population was depleted. However, the catch per set of bigeye continued its steady decline despite the increased webbing depth. Also, the depth of the purse-seine nets used by Class-6 vessels increased in the 1990s and remained constant thereafter. Therefore, it is unlikely that net depth has influenced the catch per set.

Changes in the fishery aimed at reducing the catch of bigeye, perhaps due to management concerns because the depletion of bigeye is largely driving the closures of the purse-seine fishery, would reduce

[1] Purse-seine vessels with carrying capacity > 363 t

the catch per set of bigeye. However, there is no evidence that this is the case. Changes made to increase the catch of skipjack may also reduce the catch per set of bigeye, but there is no evidence of increases in the catch per set of skipjack. It is unlikely that changes in the fishery characteristics have reduced the catch per set of bigeye. The increased number of sets (Figure 1), despite the fairly constant number of vessels and capacity (Figure 3), suggests that more sets per day are being made, which might lead to floating-object sets later in the day. However, since the number of days fished has increased (Figure 15), the number of sets per day has not changed, (Figure 16), nor has the average time of day of a set (Figure 17, see also Hall and Roman 2016). It is also noted that there have not been any changes in the proportion of sets with no catch (Hall and Roman 2016). There may have been some changes in the fishery not described here that increased the number of sets on floating objects (*e.g*. making additional sets later in the day), which may have also reduced the catch per set of bigeye, but further research is needed.

3. DISCUSSION

Given the currently available data, it is difficult to determine the cause of the decline in catch per set of bigeye in the purse-seine fishery on floating objects in the EPO. There does not appear to be any evidence supporting any one of the three hypotheses over the others. However, the reduction in catch per set is unlikely to be due to changes in the spatial distribution of the fleet, increased FAD webbing depth, or increased purse-seine net depth.

The stock assessment does not estimate an impact of the increased number of FAD sets on the bigeye populations. Nor does it account for the increased number of sets, but it does take into account all the recorded catch taken by the floating-object fishery. The stock assessment estimates of biomass are consistent with the decline in catch per set, except since 2012. However, there was no change in the decreasing trend in catch per set in 2012. There are still issues with the stock assessment, so there is a possibility that the estimates from the assessment are incorrect and that the abundance is declining, as suggested by the catch per set data. However, catch per set is generally not considered proportional to abundance. Therefore, monitoring of the increased number of FAD sets and the reduction in catch per set should continue, because there is uncertainty in the stock assessment estimates.

Research and data collection are needed. The most important piece of data is a measure of the number of FADs that are deployed in a particular area at a given time. This will probably require an identification system for FADs so that they can be accounted for. The identification code would be recorded every time a FAD is deployed or recovered, and such a system would also allow tag-recapture type methods to be used to estimate the number of unidentified FADs deployed. Ocean current models may be needed to determine the location of FADs after deployment. However, access to satellite information on the location of FADs would greatly increase the accuracy of FAD location after deployment. The reasons why the number of sets is increasing at a faster rate than the capacity of the fleet should also be investigated. The additional sets may have lower catch rates of bigeye.

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Marlon Roman, Nick Vogel, and Cleridy Lennert-Cody provided data and figures.

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Maunder, M.N. and Punt, A.E. (2004) Standardizing Catch and Effort Data: A Review of Recent Approaches. Fisheries Research 70(2-3): 141-159.

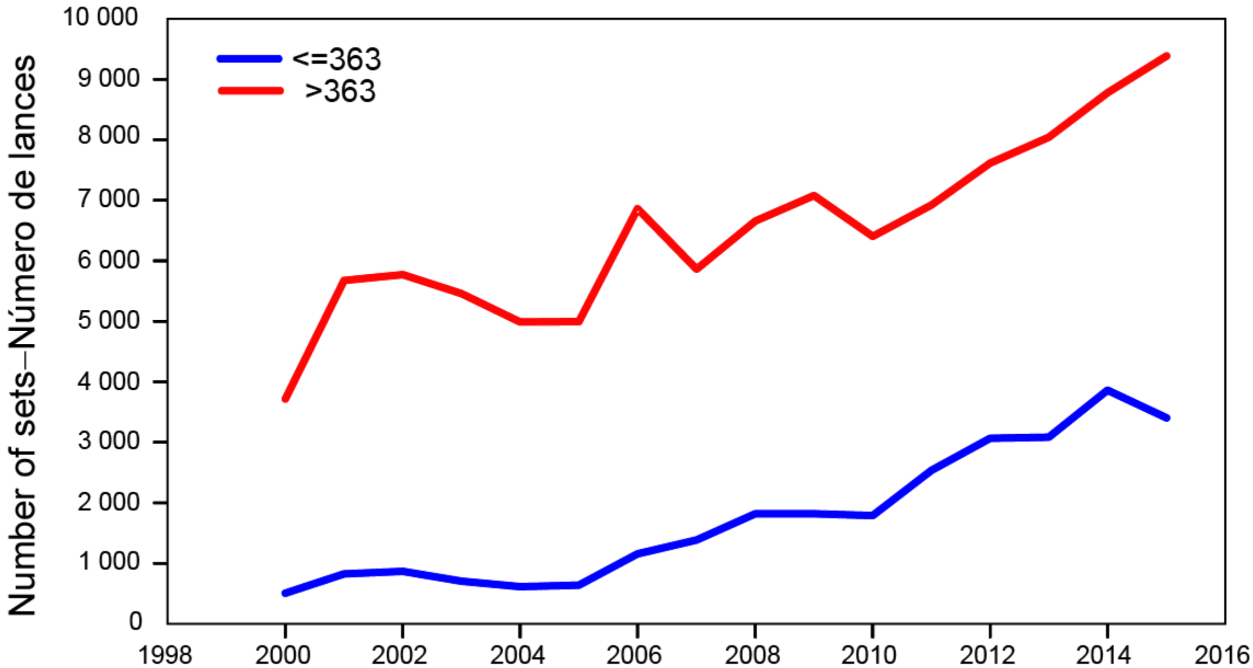

FIGURE 1. Number of purse-seine sets on floating objects by vessel size class (carrying capacity ≤363 t (Classes 1-5) and >363t (Class 6), 2000-2015.

FIGURA 1. Número de lances cerqueros sobre objetos flotantes, por clase de capacidad del buque (capacidad de acarreo ≤363 t (clases 1-5) y >363t (clase 6), 2000-2015.

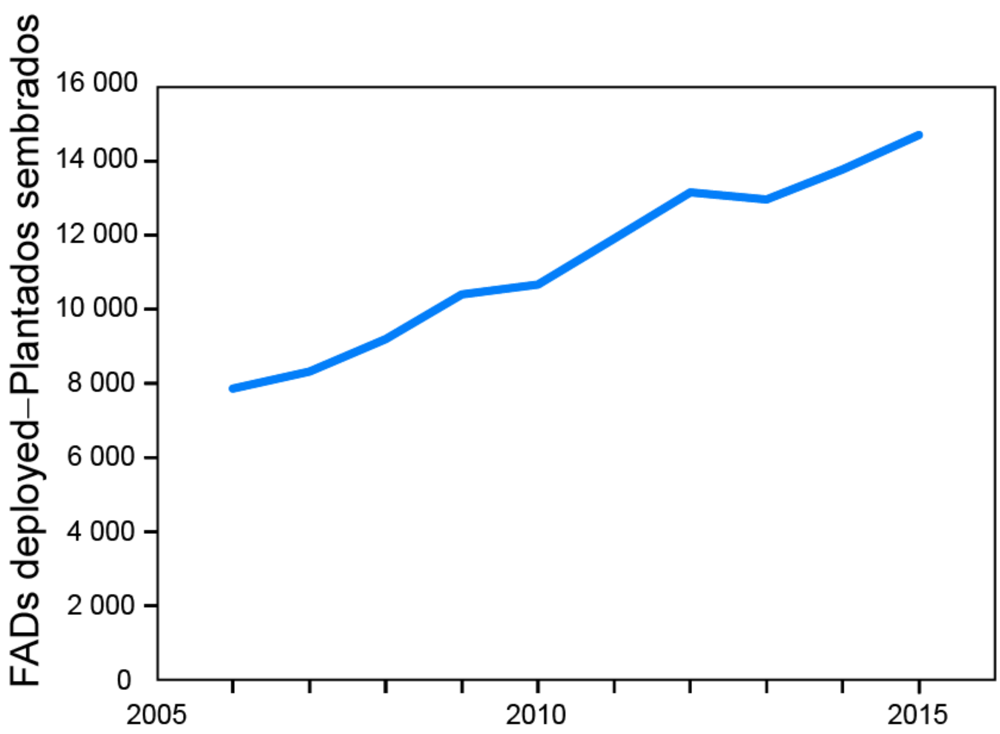

FIGURE 2. Number of FADs deployed, 2006-2015.

FIGURA 2. Número de plantados sembrados, 2006-2015.

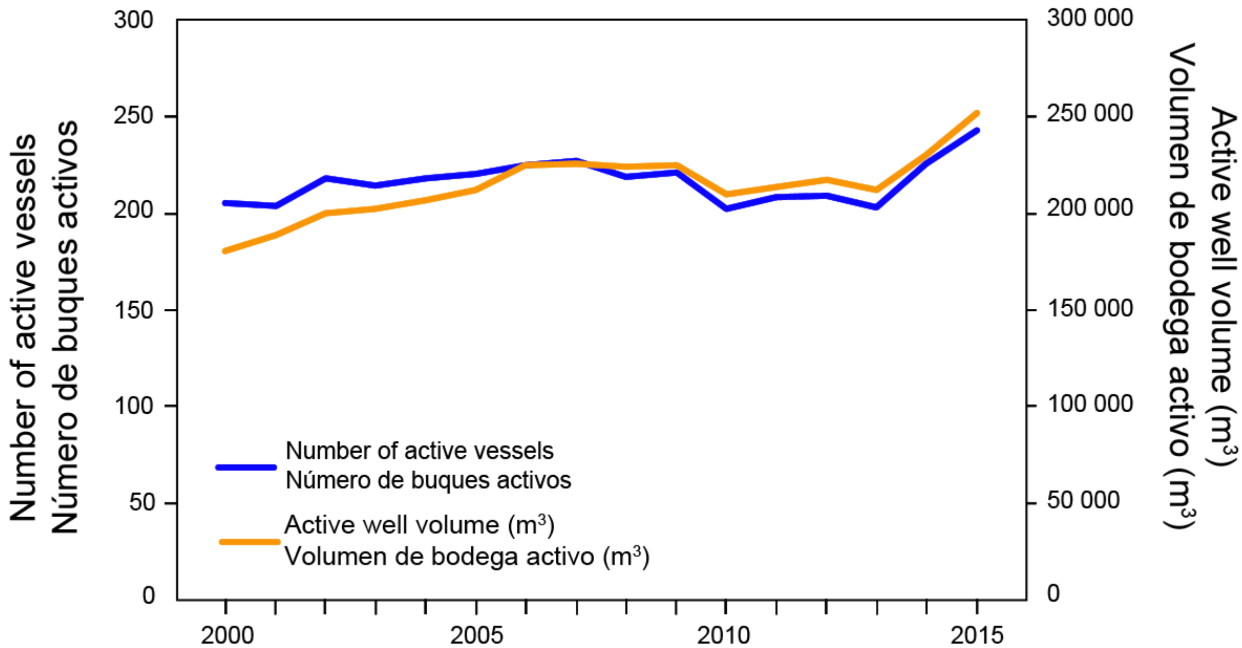

FIGURE 3. Number of active purse-seine vessels and active well volume (m^3) fishing in the EPO.
FIGURA 3. Número de buques cerqueros activos y volumen de bodega activo (m^3) que pescan en el OPO.

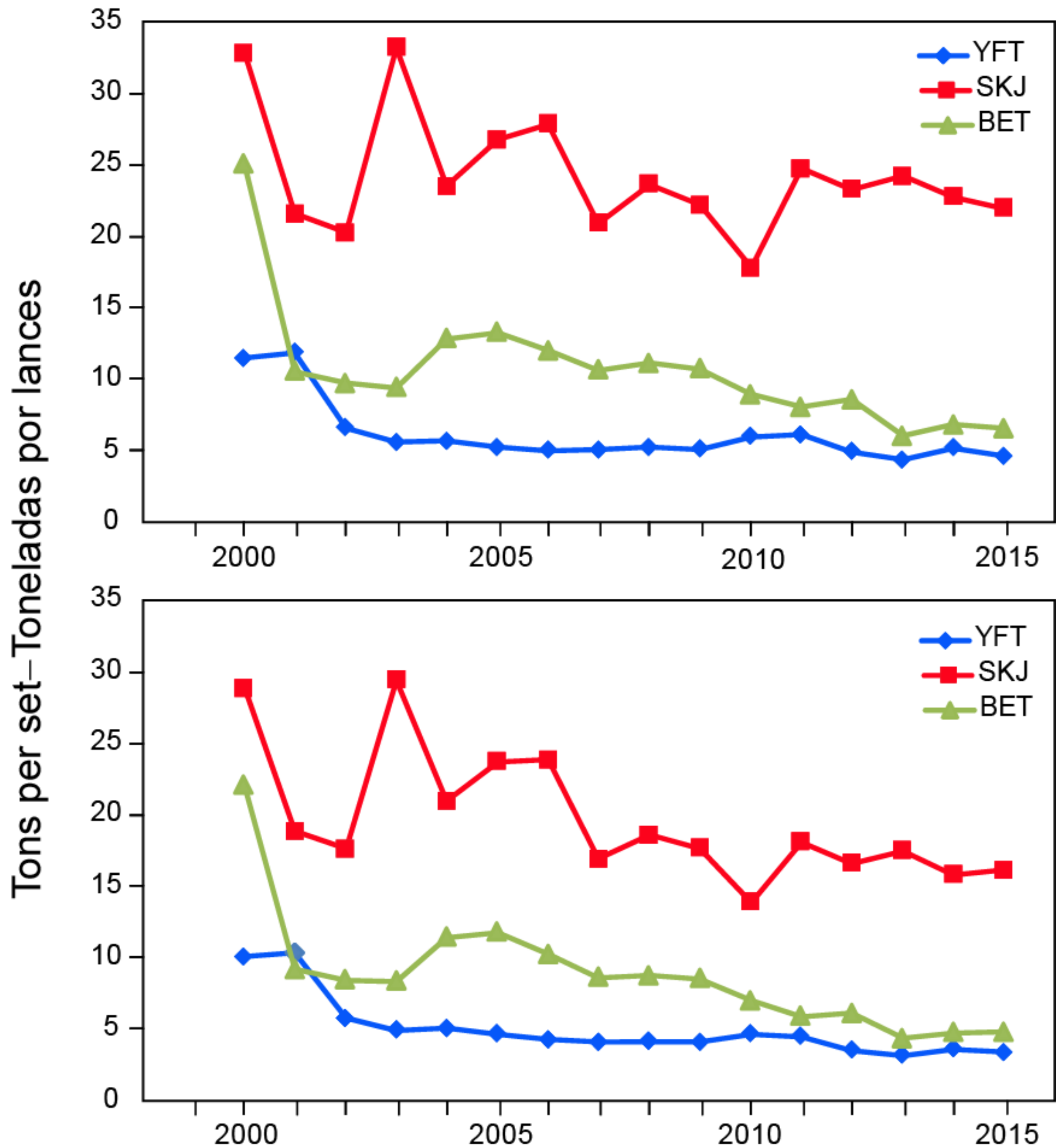

FIGURE 4. Catch per set, by species, using number of sets equal to those for Class-6 vessels (upper panel) and all vessels (lower panel), 2000-2015 YFT: yellowfin; SKJ: skipjack; BET: bigeye.

FIGURA 4. Captura por lance, por especie, usando un número de lances igual a aquel de los buques de clase 6 (recuadro superior) y de todos los buques (recuadro inferior), 2000-2015 YFT: aleta amarilla; SKJ: barrilete; BET: patudo.

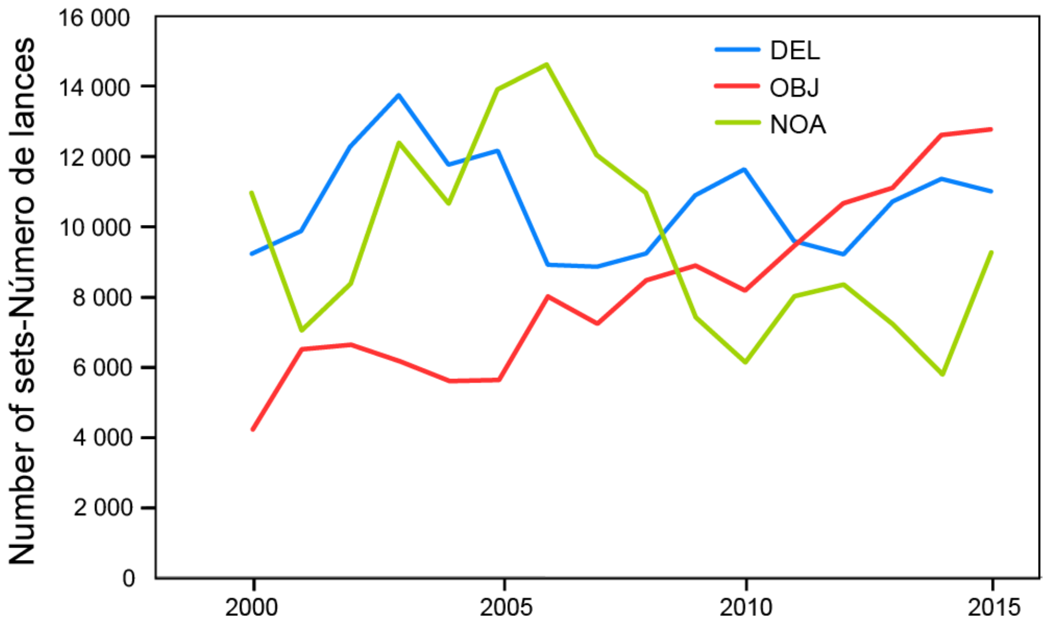

FIGURE 5. Number of sets, by set type, 2000-2015
FIGURA 5. Número de lances, por tipo, 2000-2015.

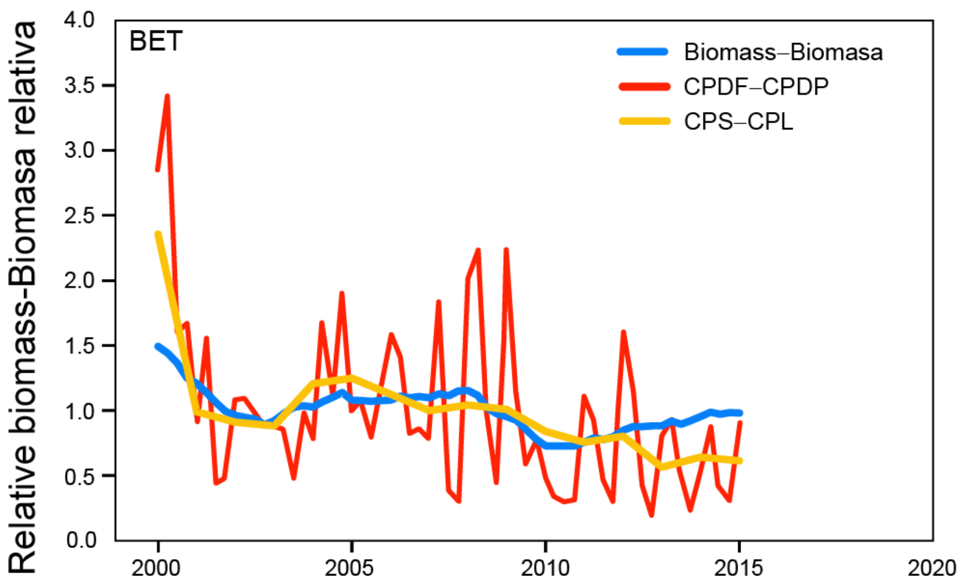

FIGURE 6. Comparison of catch per set (CPS) of bigeye on floating objects, by year, with catch per day's fishing (CPDF) in floating-object sets, by quarter, and the biomass estimated from the stock assessment model (Aires da Silva 2016; Document SAC-07-05a), by quarter, 2000-2015.
FIGURA 6. Comparación de la captura por lance (CPL) de patudo sobre objetos flotantes, por año, con la captura por día de pesca (CPDP) en lances sobre objetos flotantes, por trimestre, y la biomasa estimada del modelo de evaluación de poblaciones (Aires da Silva 2016; Documento SAC-07-05a), por trimestre, 2000-2015.

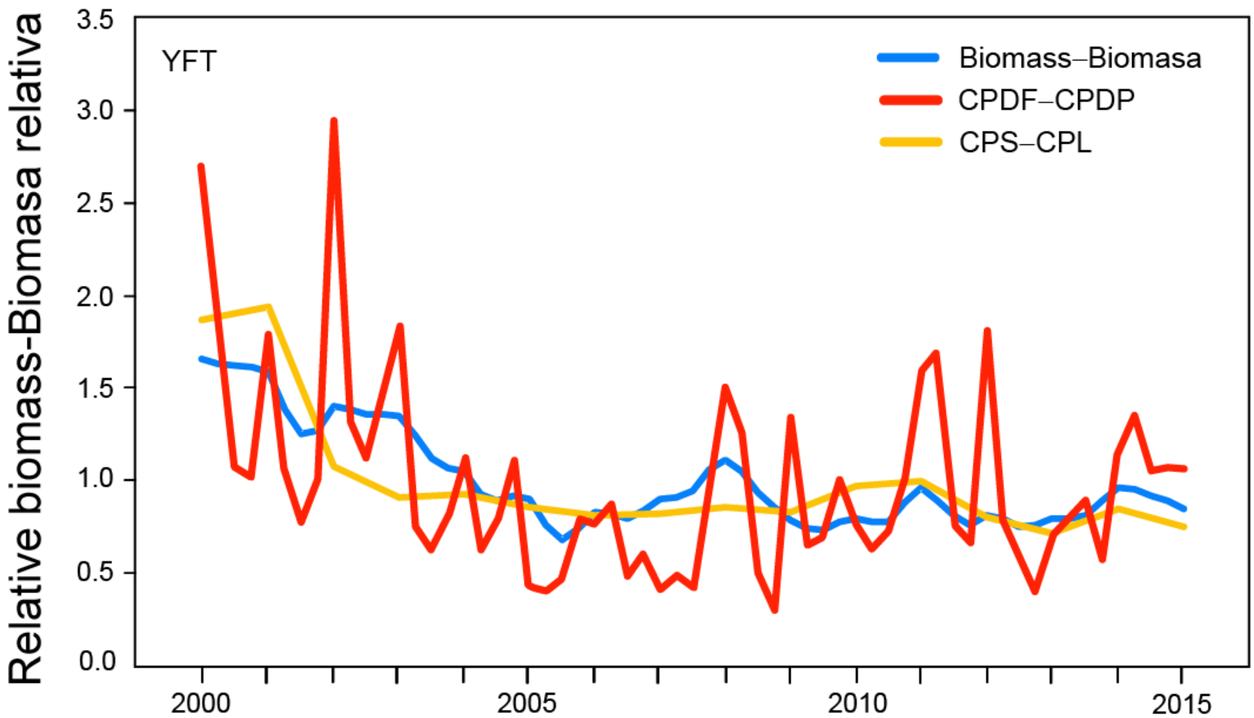

FIGURE 7. Comparison of catch per set (CPS) of yellowfin on floating objects, by year, with catch per day's fishing (CPDF) in floating-object sets, by quarter, and the biomass estimated from the stock assessment model (Minte-Vera 2016; Document SAC-07-05b), by quarter, 2000-2015.

FIGURA 7. Comparación de la captura por lance (CPL) de aleta amarilla sobre objetos flotantes, por año, con la captura por día de pesca (CPDP) en lances sobre objetos flotantes, por trimestre, y la biomasa estimada del modelo de evaluación de poblaciones (Minte-Vera 2016; Documento SAC-07-05b), por trimestre, 2000-2015.

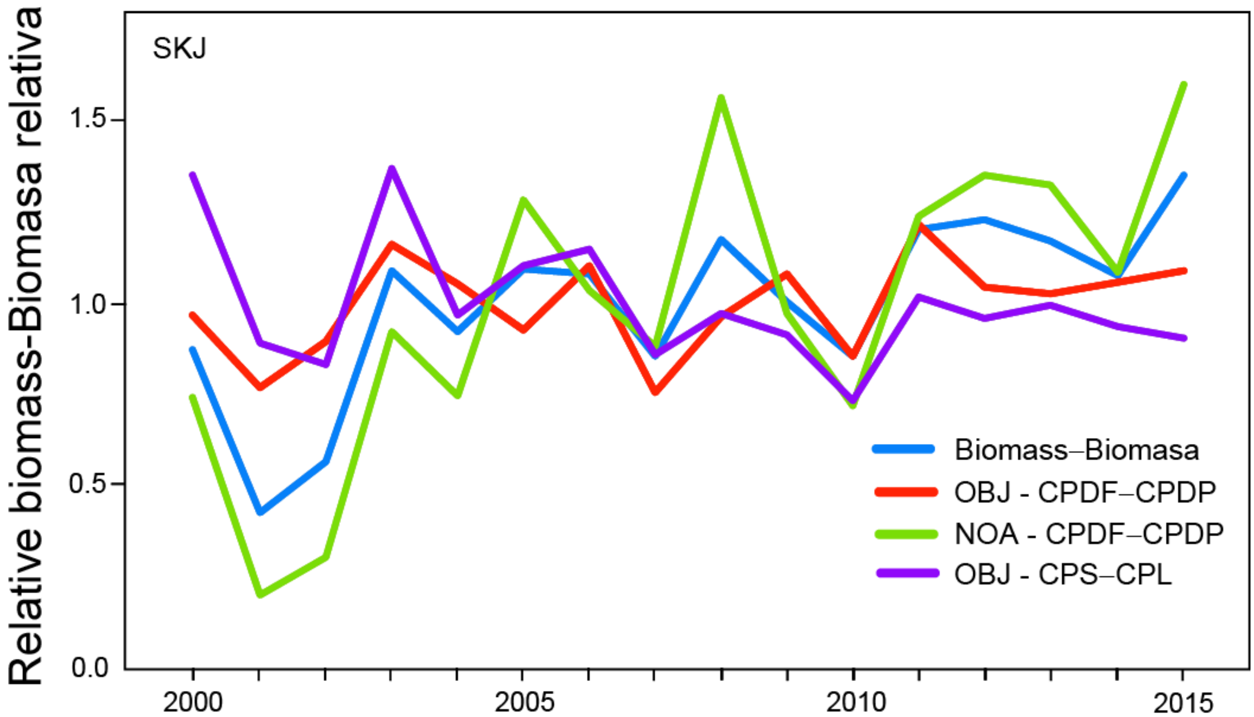

FIGURE 8. Comparison of catch per set (CPS) of skipjack on floating objects, by year, with catch per day's fishing (CPDF) in unassociated (NOA) and floating-object (OBJ) sets, and the biomass estimated from a simple stock assessment model, 2000-2015 (Maunder 2016; Document SAC-07-05c).

FIGURA 8. Comparación de la captura por lance (CPL) de barrilete sobre objetos flotantes, por año, con la captura por día de pesca (CPDP) en lances no asociados (NOA) y sobre objetos flotantes (OBJ), por trimestre, y la biomasa estimada del modelo de evaluación de poblaciones, 2000-2015 (Aires da Silva 2016; Documento SAC-07-05a), por trimestre.

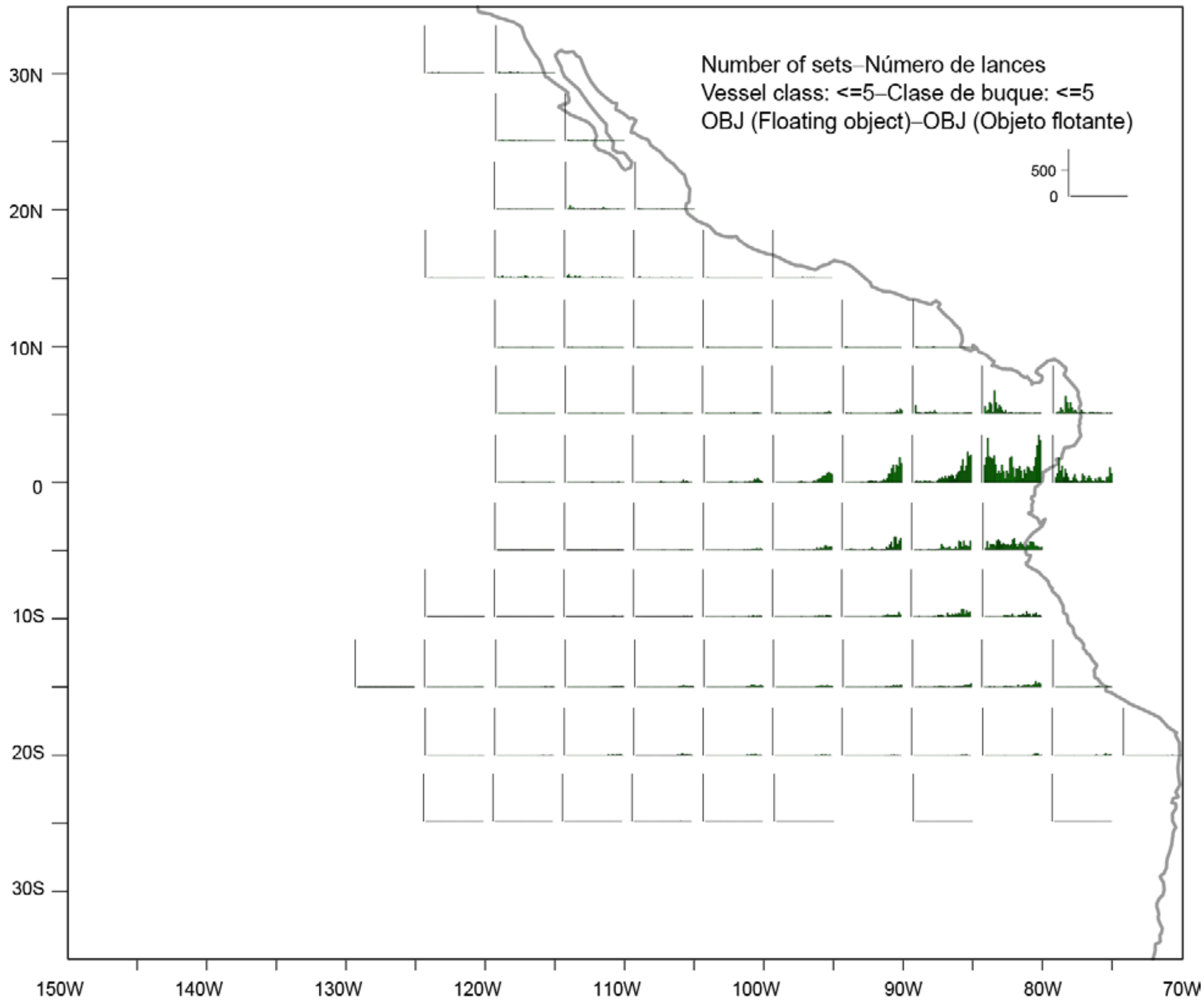

FIGURE 9. Number of floating-object sets by Class 1-5 purse-seine vessels (carrying capacity ≤363 t), by 5° area, 1980-2015.

FIGURA 9. Número de lances sobre objetos flotantes por buques cerqueros de clases 1-5 (capacidad de acarreo ≤363 t), por área de 5°, 1980-2015.

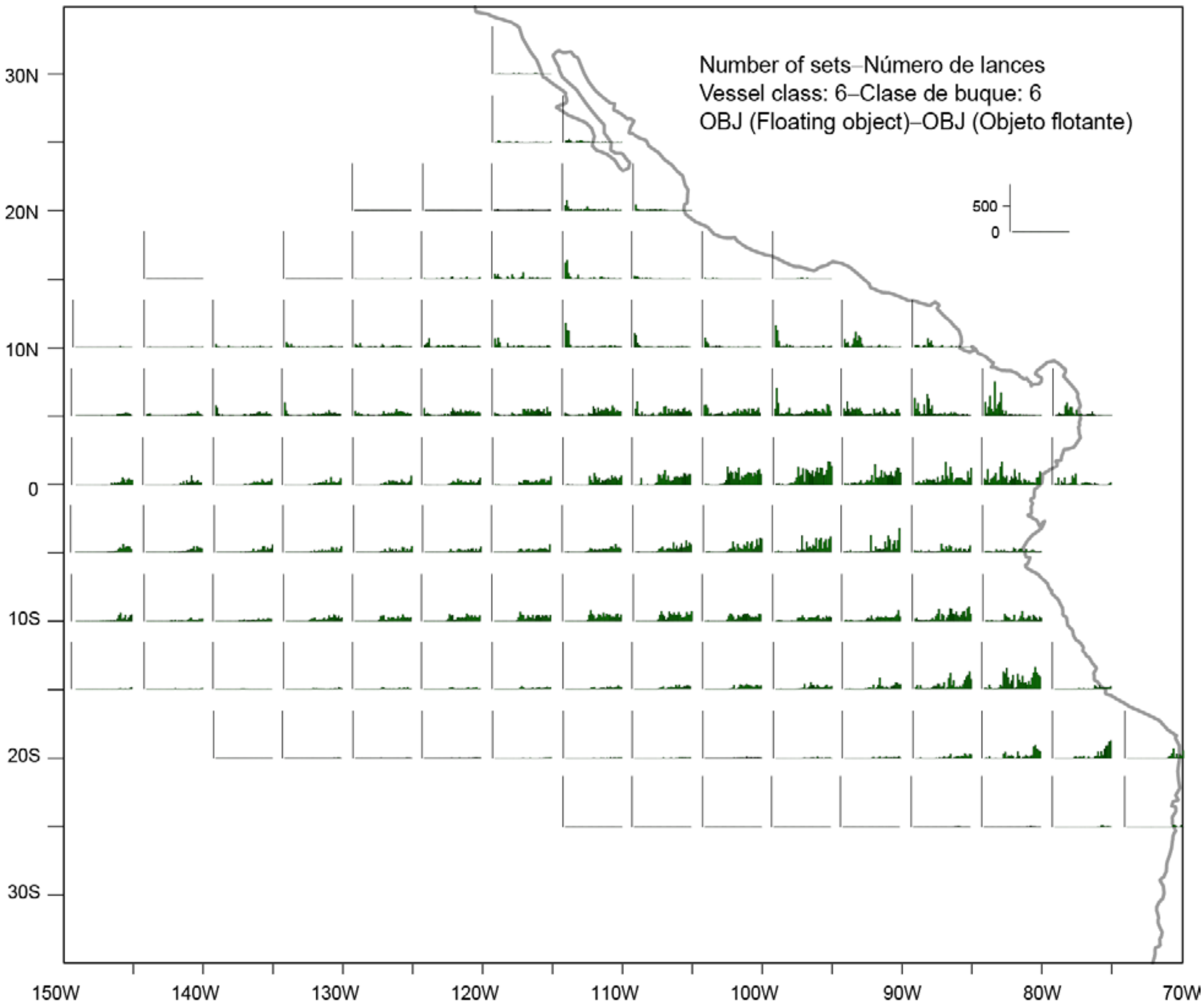

FIGURE 10. Number of floating-object sets by Class-6 purse-seine vessels (carrying capacity >363 t), by 5° area, 1980-2015.

FIGURA 10. Número de lances sobre objetos flotantes por buques cerqueros de clase 6 (capacidad de acarreo >363 t), por área de 5°, 1980-2015.

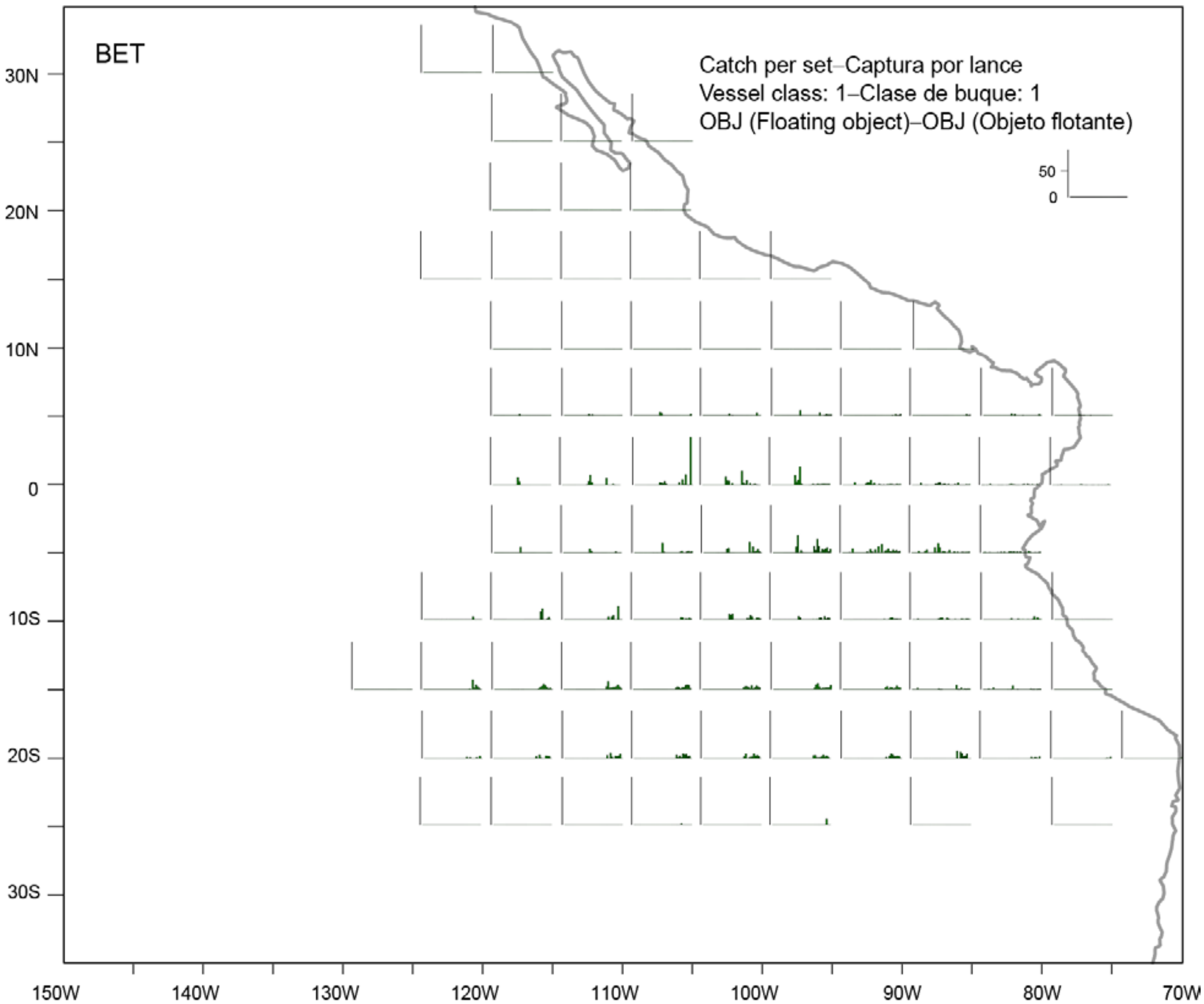

FIGURE 11. Catch per set of bigeye in floating-object sets by Class 1-5 purse-seine vessels (carrying capacity ≤363 t), by 5° area, 1980-2015.

FIGURA 11. Captura de patudo en lances sobre objetos flotantes por buques cerqueros de clases 1-5 (capacidad de acarreo ≤363 t), por área de 5°, 1980-2015.

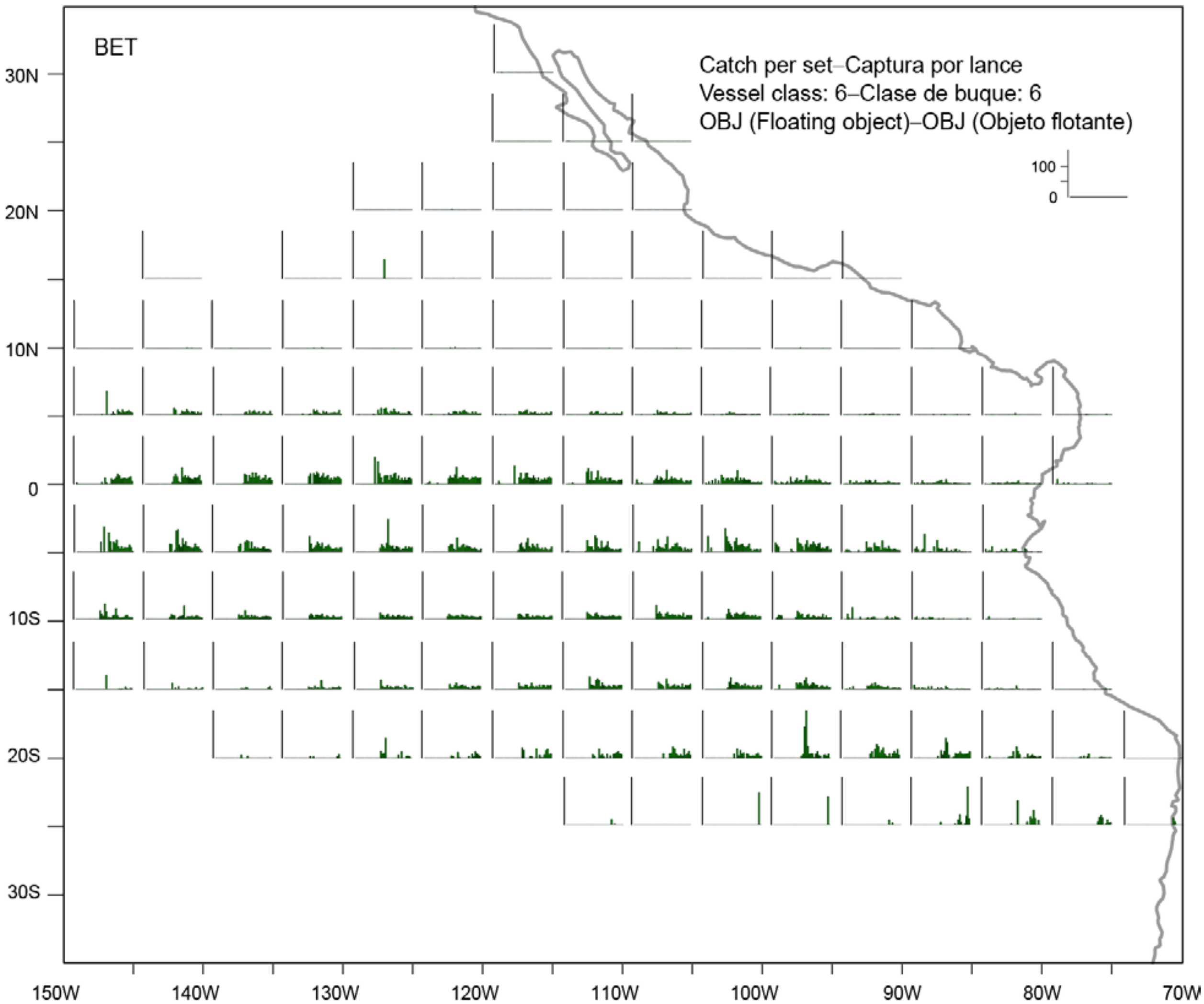

FIGURE 12. Catch per set of bigeye in floating-object sets by Class-6 purse-seine vessels (carrying capacity >363 t), by 5° area, 1980-2015.

FIGURA 11. Captura de patudo en lances sobre objetos flotantes por buques cerqueros de clase 6 (capacidad de acarreo >363 t), por área de 5°, 1980-2015.

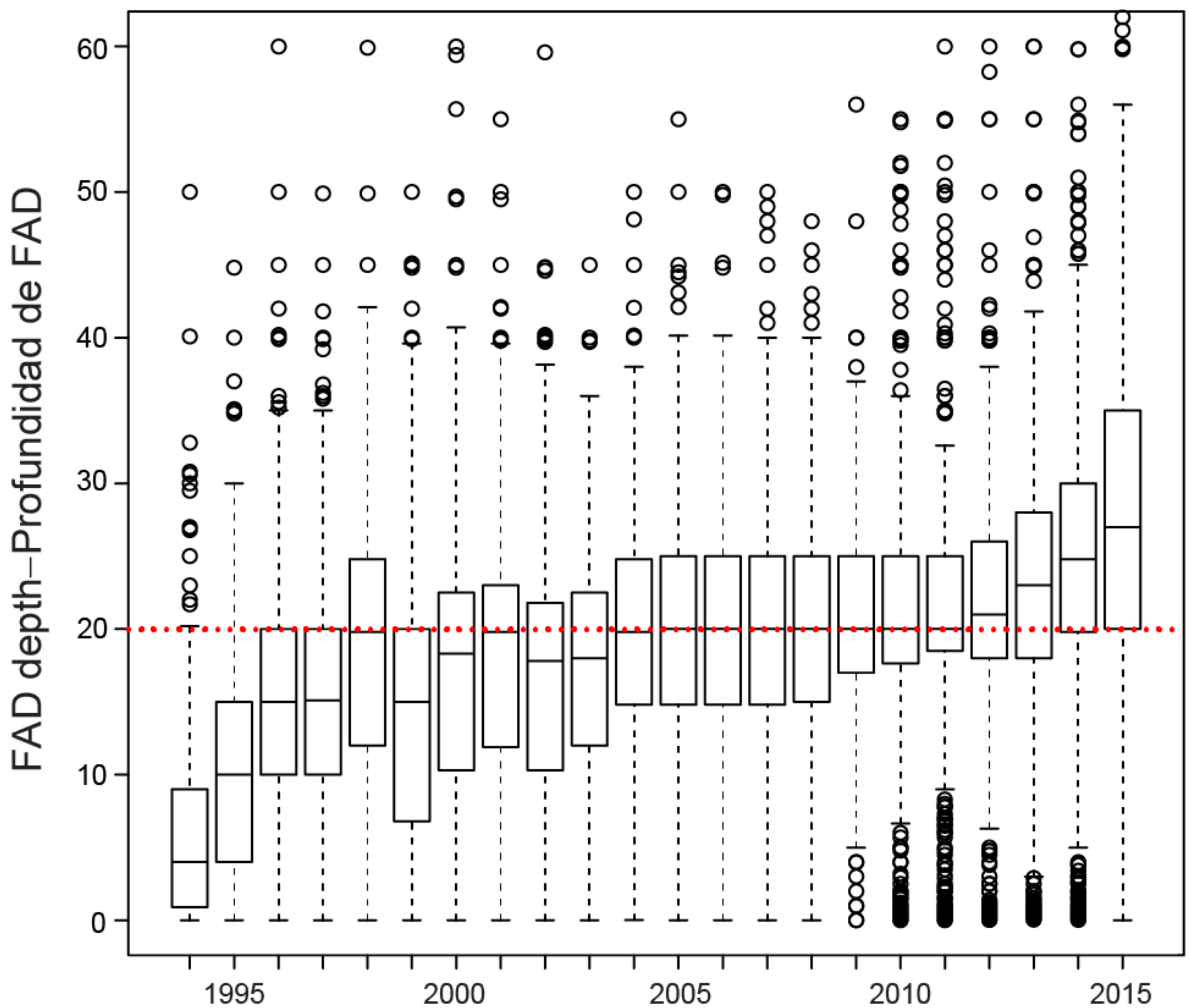

FIGURE 13. Depth of FADs deployed by Class-6 purse-seine vessels, 1994-2015.
FIGURA 13. Profundidad de plantados sembrados por buques de clase 6, 1994-2015.

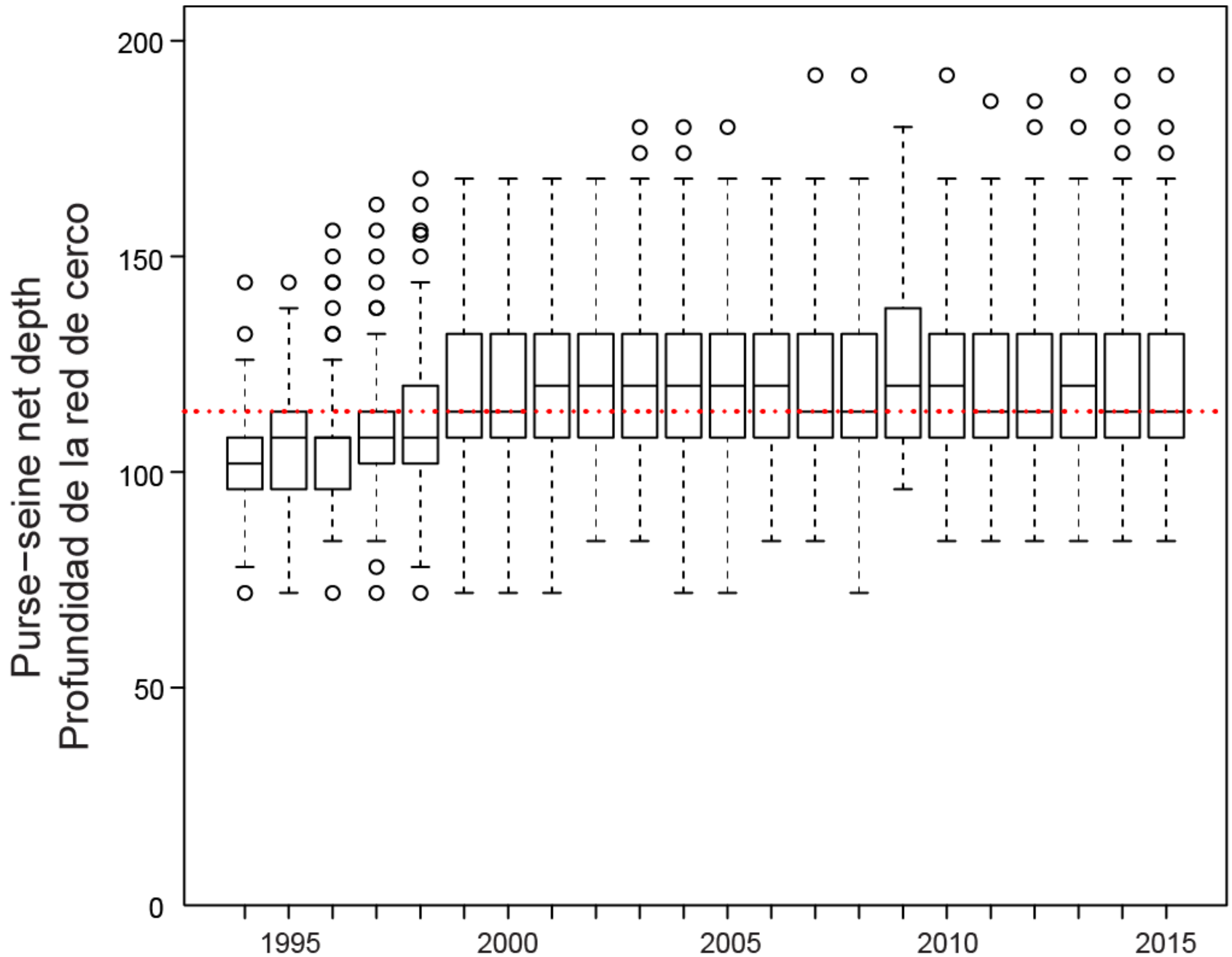

FIGURE 14. Depth of purse-seine net for Class-6 vessels, 1994-2015.
FIGURA 14. Profundidad de la red de cerco, buques de clase 6, 1994-2015.

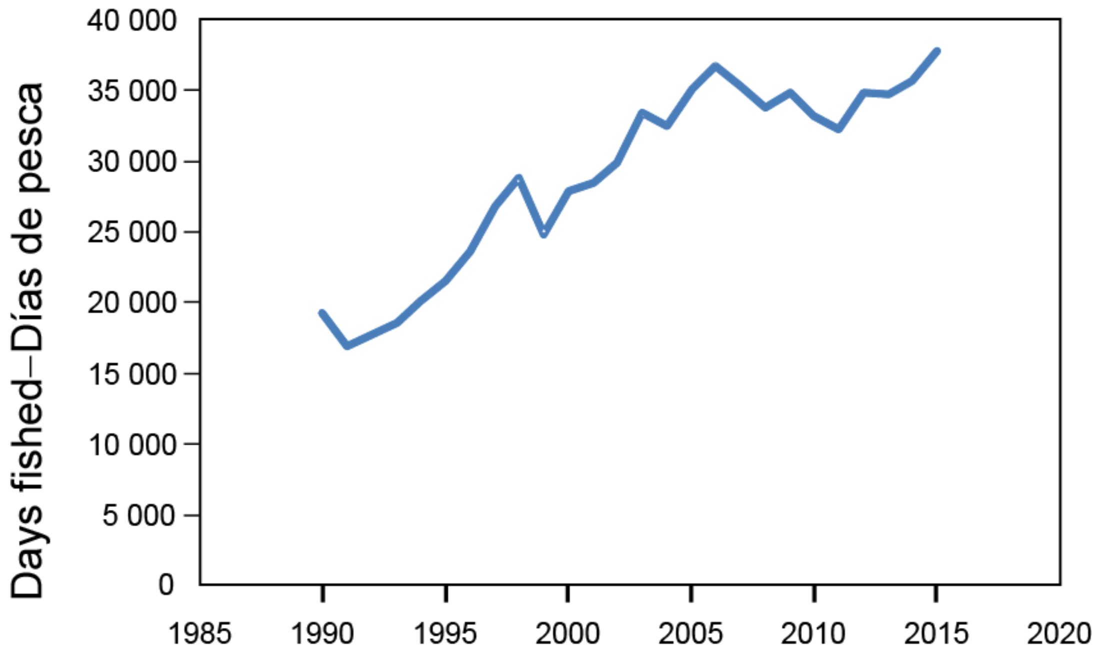

FIGURE 15. Number of days fished by purse-seine vessels in the EPO, 1990-2015.
FIGURA 15. Número de días de pesca por buques cerqueros en el OPO, 1990-2015.

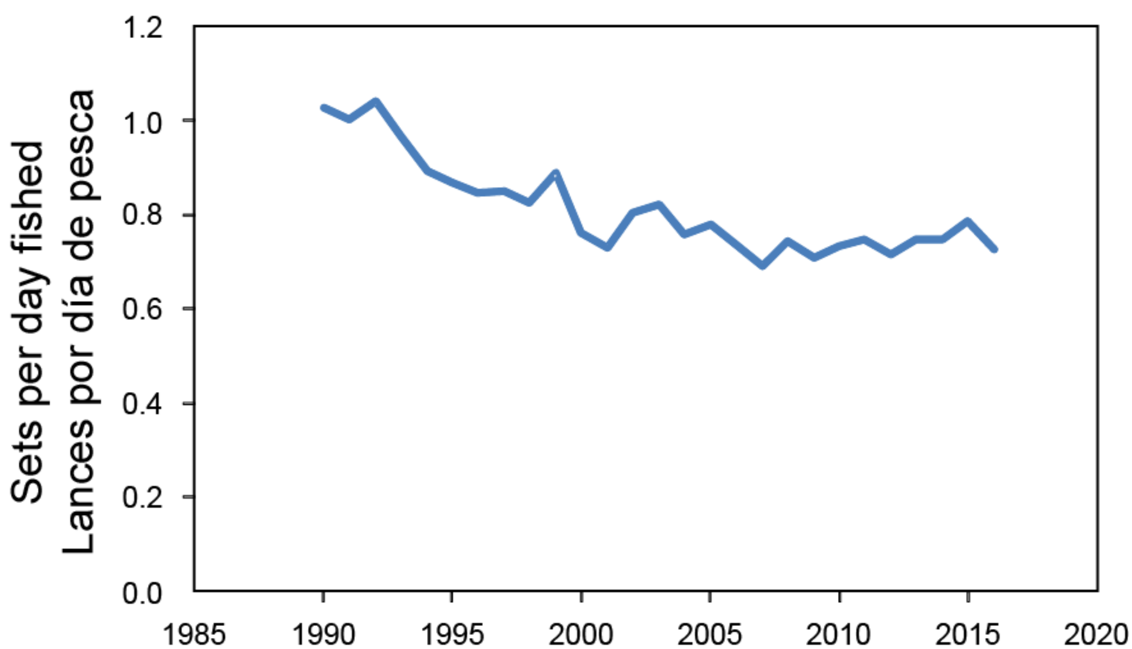

FIGURE 16. Number of purse-seine sets per day fished in the EPO.
FIGURA 16. Número de lances por día de pesca en el OPO, 1990-2015.

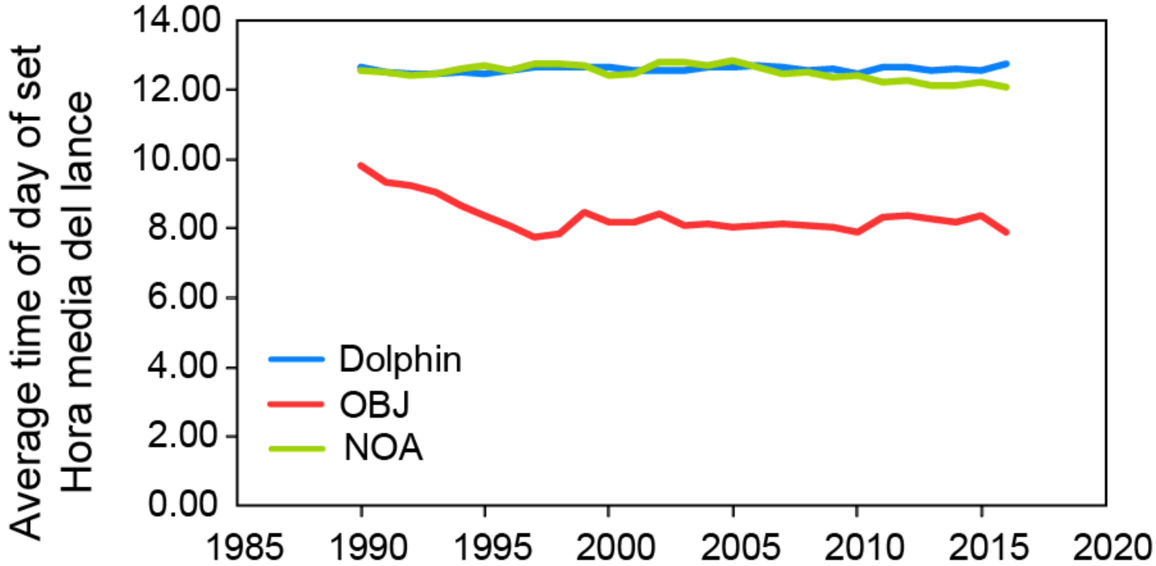

FIGURE 17. Average time of day of set in the EPO, 1990-2015, by set type (NOA: unassociated; DEL: associated with dolphins; OBJ: associated with floating object).

FIGURA 17. Hora media de los lances en el OPO, 1990-2015, por tipo de lance (NOA: no asociado; DEL: asociado a delfines; OBJ: asociado a objeto flotante.