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THE FISHERY ON FISH-AGGREGATING DEVICES (FADs) IN THE EASTERN PACIFIC OCEAN – UPDATE

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This document is an update and extension of Documents SAC-05-04a and SAC-07-03e and SAC-08-03e, presented at the meetings of the Scientific Advisory Committee in 2014 and 2016, respectively].

CONTENTS

As part of their data collection duties, observers aboard purse-seine vessels record the characteristics and use of fish-aggregating devices (FADs), both those fabricated and deployed for the sole purpose of attracting fish and those that are improvised at sea from flotsam to which the fishers attach a variety of materials that will make them more attractive to the fish. In recent years, the proportion of objects deployed has grown, and the proportion of sets on objects encountered at sea is very low.The information presented in this document is based on observer records; as such, it is predominantly from Class-6[1] purse-seine vessels, but also includes data from a small number of Class-5 vessels that have carried observers.

After increasing to a historic high last year, the total number of sets of all types has had a minor decline (Figure 1a). A decline in the number of school sets, prevailed over a small increase in the number of sets on floating objects. In the earlier years of the fishery, the majority of purse- seine catches in the region consisted of yellowfin tuna caught in association with dolphins; the rest were caught in sets on unassociated tunas or sets associated with drifting floating objects, mostly tree trunks or branches. The development of the fishery on fish-aggregating devices (FADs) greatly expanded the fishing area, growing to the west along the Equatorial region, and to the south along the Peruvian coast. Over the years, the proportion of sets on FADs grew from a small minority to the most common type of set (Figure 1b), due to the high productivity of this fishery, and to the closure of the US market to tuna caught in association

[1] Carrying capacity greater than 363 tons; Class-5 vessels are of carrying capacities between 273 and 363 tons

with dolphins, which motivated fishers to explore alternative ways of catching tunas

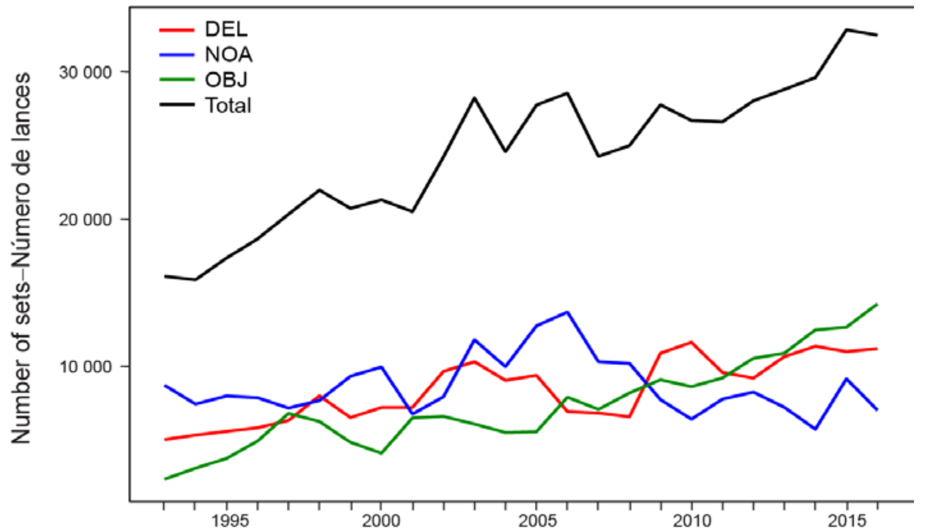


FIGURE 1a. Estimated number of sets, by type of class 1-6 vessels. 1993-2016

After an exploratory phase covering different areas and period, different FAD models and strategies, patterns began to emerge, but the fishery is still very dynamic, and we can't say that there is a simple description that applies to all years of the fishing cycles. Technological changes in detection and capture gear followed the needs of this new way of fishing. Improvements have been continuous. An example of that is the evolution in the use of acoustic buoys to provide information on the fish aggregations under FADs. The proportion of sets using this technology increased over time, but more importantly, the effectiveness of the system improved. In the early years, there were no differences in the catches per positive set on FADs with or without acoustic systems, but more recently, the technology is making a difference (Fig

1. FADS: CHARACTERISTICS AND DYNAMICS

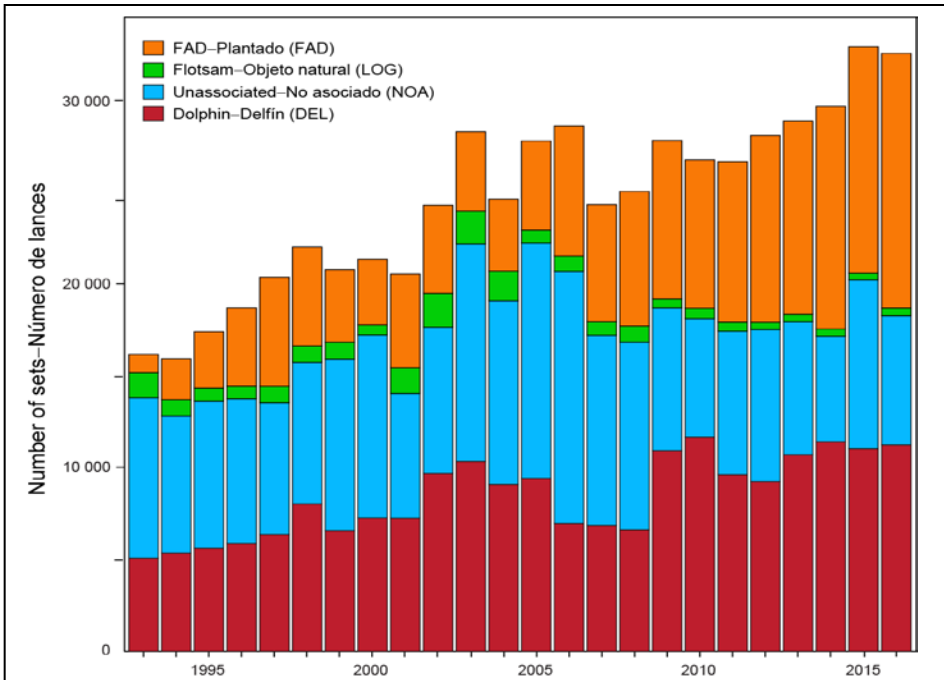


FIGURE 1b. Number of sets, by type, by all purse-seine vessels, 1993-2016**.** The proportion of FAD and LOG sets by Class-1-5 vessels were estimated based on the proportions of FAD and LOG sets by Class-6 vessels fishing in the Class-1-5 vessels' area of operation.

Currently, essentially all FADs are equipped with satellite tracking devices, and the vast majority are equipped with sonar buoys, which can be monitored via satellite from the vessel. These buoys, help reduce the time needed to identify FADs with good catches, and were expected to improve the efficiency of fishing operations by (a) reducing the proportion of null sets (sets with no capture) and (b) increasing catches from FAD sets, by allowing fishers to set on those FADs with the greatest potential catches. However, in general, the increased use of sonar buoys does not

seem to have reduced the proportion of null sets of any type (Figure 2). This is still the case by 2016. The average capture per positive set (CPS > 0) did not show differences due to the use of acoustic equipment before 2010, but since then the average captures in sets on FADs with sonar buoys have been higher than in sets without such buoys although the differences have been decreasing in the most recent years, and are much smaller in 2016 (Figure 3).

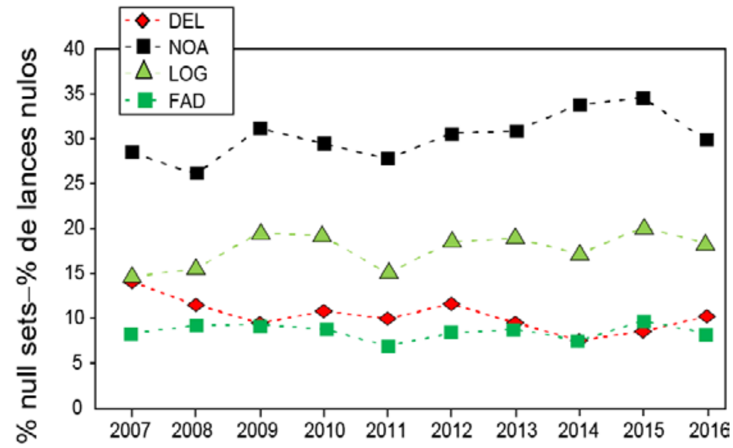


FIGURE 2. Percent of null sets by set type, 2007-2016

FAD deployments: Figure 4 shows the deployments and retrievals of FADs

recorded by observers during 2005-2013. The total number of FADs deployed per year has increased steadily, from about 4,000 in 2005 to close to 16,000 in 2016, a new record level. But the number of FADs recovered has declined significantly after 2012, and the difference (deployed minus recovered) has increased greatly. This may mean: a) more FADs are being lost, or b) more FADs are left for more time in the water to resume fishing on them, or c) both. It is important to determine the reason for this change. The numbers recovered seem to be levelling off.

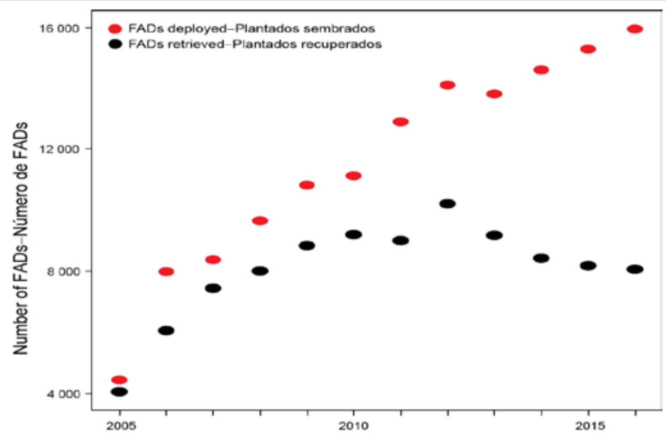


FIGURE 4. Number of FADs observed deployed and retrieved in the EPO by year, 2005-2016.

Many FADs are retrieved, although the percentage retrieved from the EPO was less in recent years than in previous years. The increasing difference may show that FADs are been left adrift for longer periods (even drifting to the Western Pacific where we won't continue the account of recoveries); those that are not recovered will continue to be monitored and used for fishing or are lost. The IATTC staff has been evaluating options for enhanced monitoring and data collection regarding use of FADs (see Document SAC-05-05), and the FAD Working Group is also involved in this development. The number of FADs deployed per vessel has increased as well. Figure 5 shows the number of FAD deployments per vessel in two years, separated by a decade (2006, 2016). In 2006 very few boats (4) deployed 300 or more FADs, while in 2016 the number of boats at 300 or more was 18. The average per boat has gone up by almost 50%.

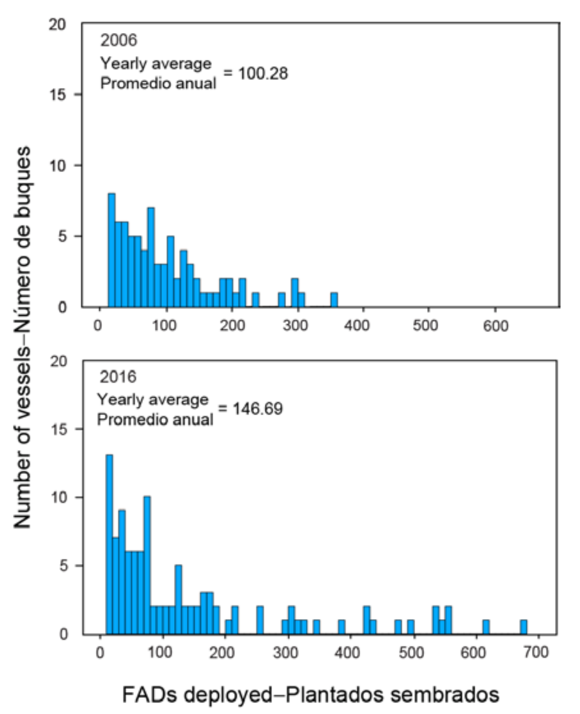


FIGURE 5. FAD deployments by vessels in two different years. Excludes vessels deploying less than 10 FADs in a year.

[Figure 6](#) shows boxplots for the most recent decade, 2006- 2016. Over the last three years the median values have remained quite stable, but over a period of 6-7 years there is a slow declining trend. The numbers and level of the outliers causes the changes in the averages.

2. PATTERNS OF FAD DISTRIBUTION IN THE EPO

The annual patterns of distribution of FAD deployments based on observer data is shown in a series of monthly maps comparing two periods (2010-2012 vs 2014-2016) to highlight changes in the distribution of deployments [Figure 7](#).

In FAD deployments in the more recent period show an increase in activity off Peru in the first months of the year, reaching as far south as 20 S. In the second quarter, the fleet leaves the Humboldt area and the deployments move towards the Equatorial area, just along the Equator. Even though there are deployments in the Galapagos region in this quarter, there are fewer now than in the earlier period. After June, the activity concentrates in the area west of Galapagos. Interestingly, a few trips to deploy FADs in the Humboldt system happen as early as August and September. The deployments off Peru show a major increase in the recent period going much farther to the south than previously, almost to 25 S. In November-December, the deployments in the Equatorial region decline, as many of the boats switch fishing to the Humboldt system.

Humboldt Current system: The deployments in this region (5°S - 25°S, mostly within 1,000 km of the coast, and outside the 200-mile boundary) continue to be seasonal, but they are increasing in numbers, and cover a longer period. This seasonality closely matches the oceanographic features of this region, with a warm-water tongue intruding from the north in the first quarter. Surface current speeds in this system are slow, and FADs do not move long distances. The increase in the activity in this region reported before continues to intensify.

Galapagos system: This system occupies the area west of 85°W and east of 100°W between 3°N and 5°S. FADs are deployed here year-round, with the largest numbers deployed in June-July and September-October. The current patterns around Galapagos are complex; during the second quarter there are flows even in an easterly direction, which are quite rare in the region.

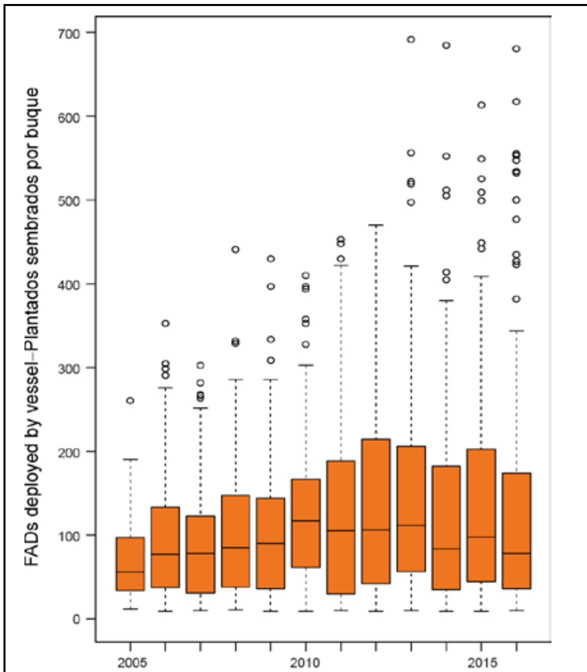


FIGURE 6. FAD deployments by vessels, 2005-2016. Excludes vessels deploying less than 10

Offshore Equatorial area: Deployments in this area, between about 100°W to the western boundary of the IATTC Convention Area at 150°W, occur along the Equator. Given the fast current speeds in this region, FADs are likely to move fast to the west. That, and the presence of eddies originating in the coasts of Mexico and Central America, and traveling northeast to southwest, probably scatter FADs faster than in other regions.

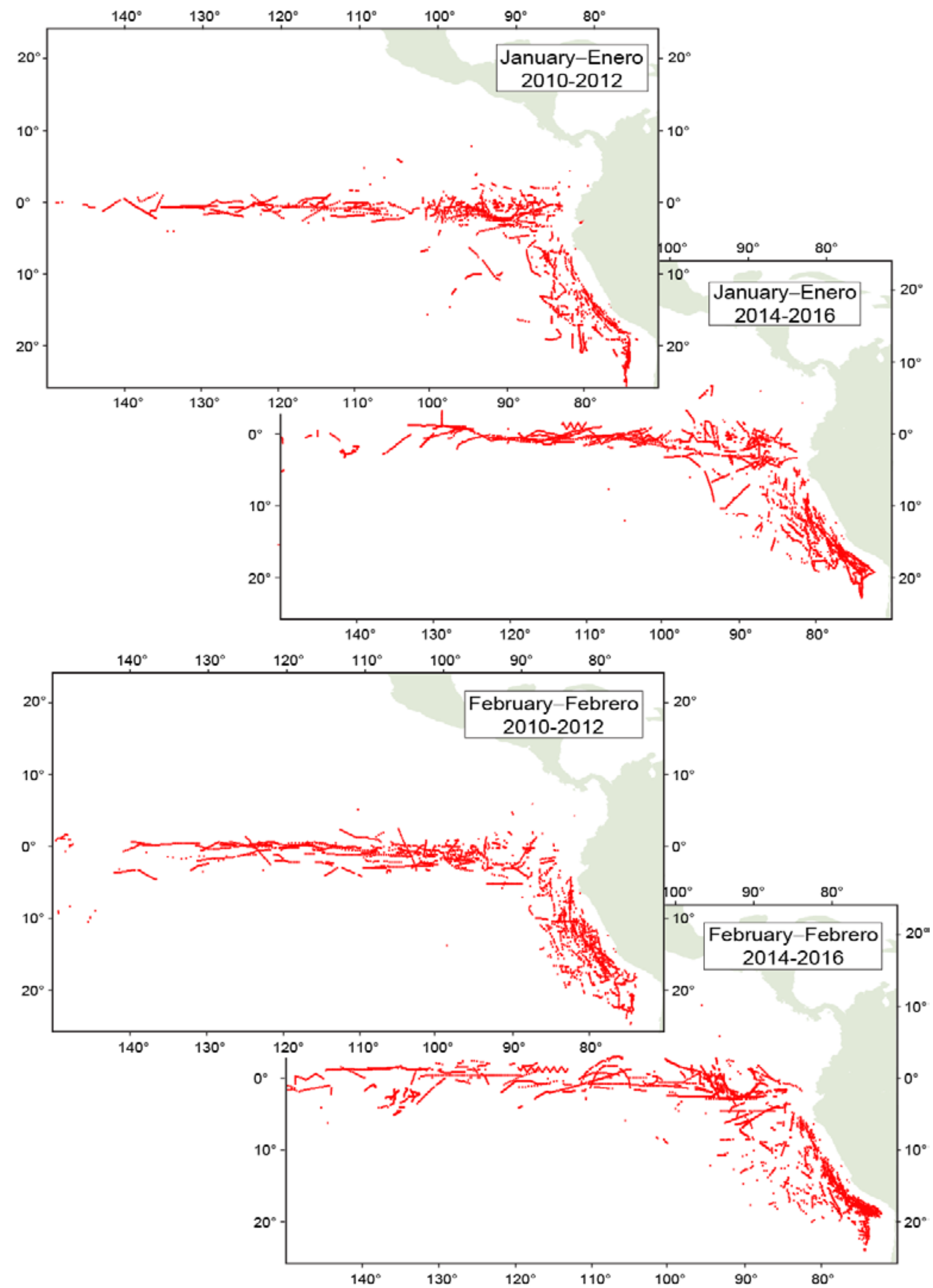


FIGURE 7. Distribution of FAD deployments, by month, 2010-2016

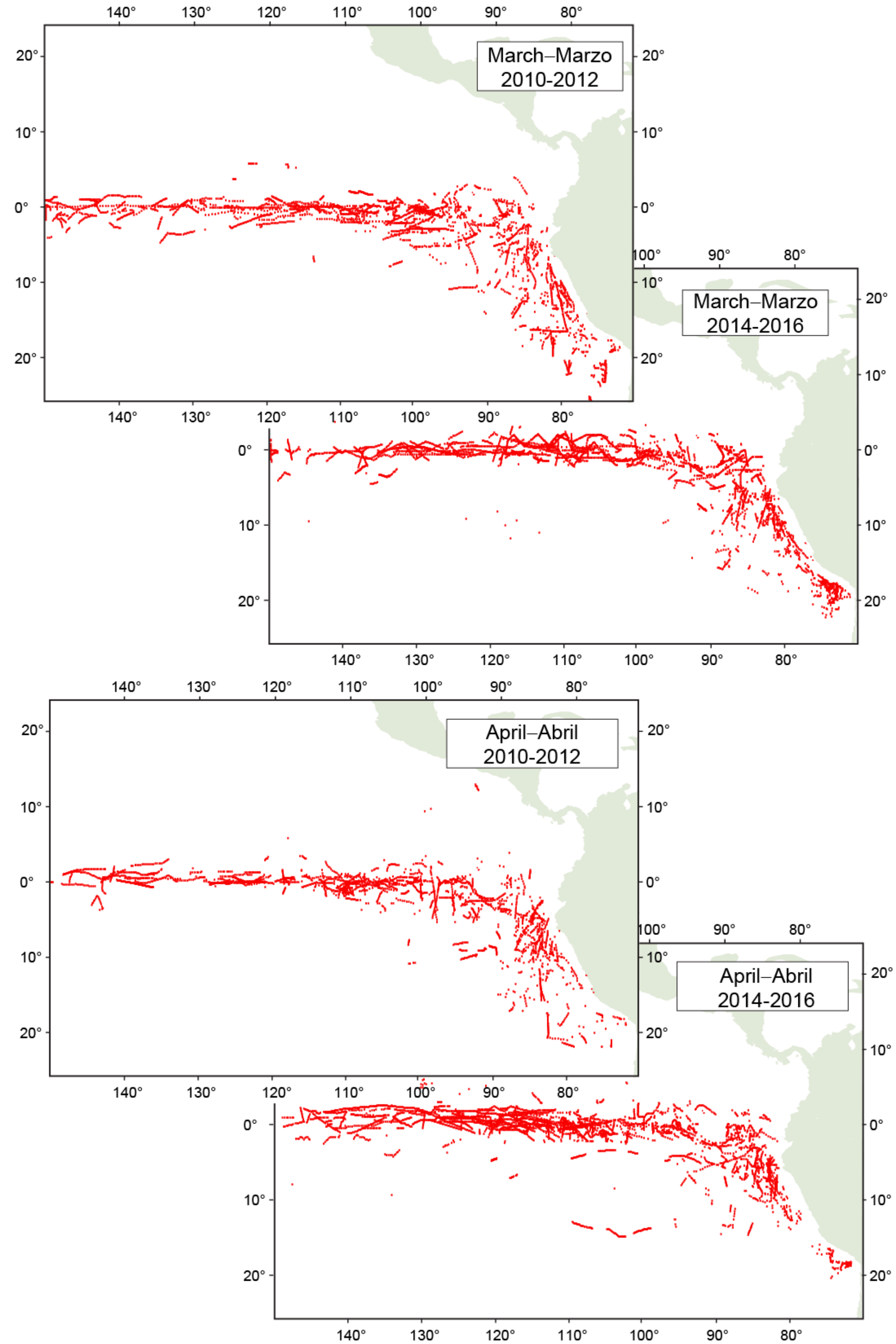


FIGURE 7 (cont.) Distribution of FAD deployments, by month, 2010-2016

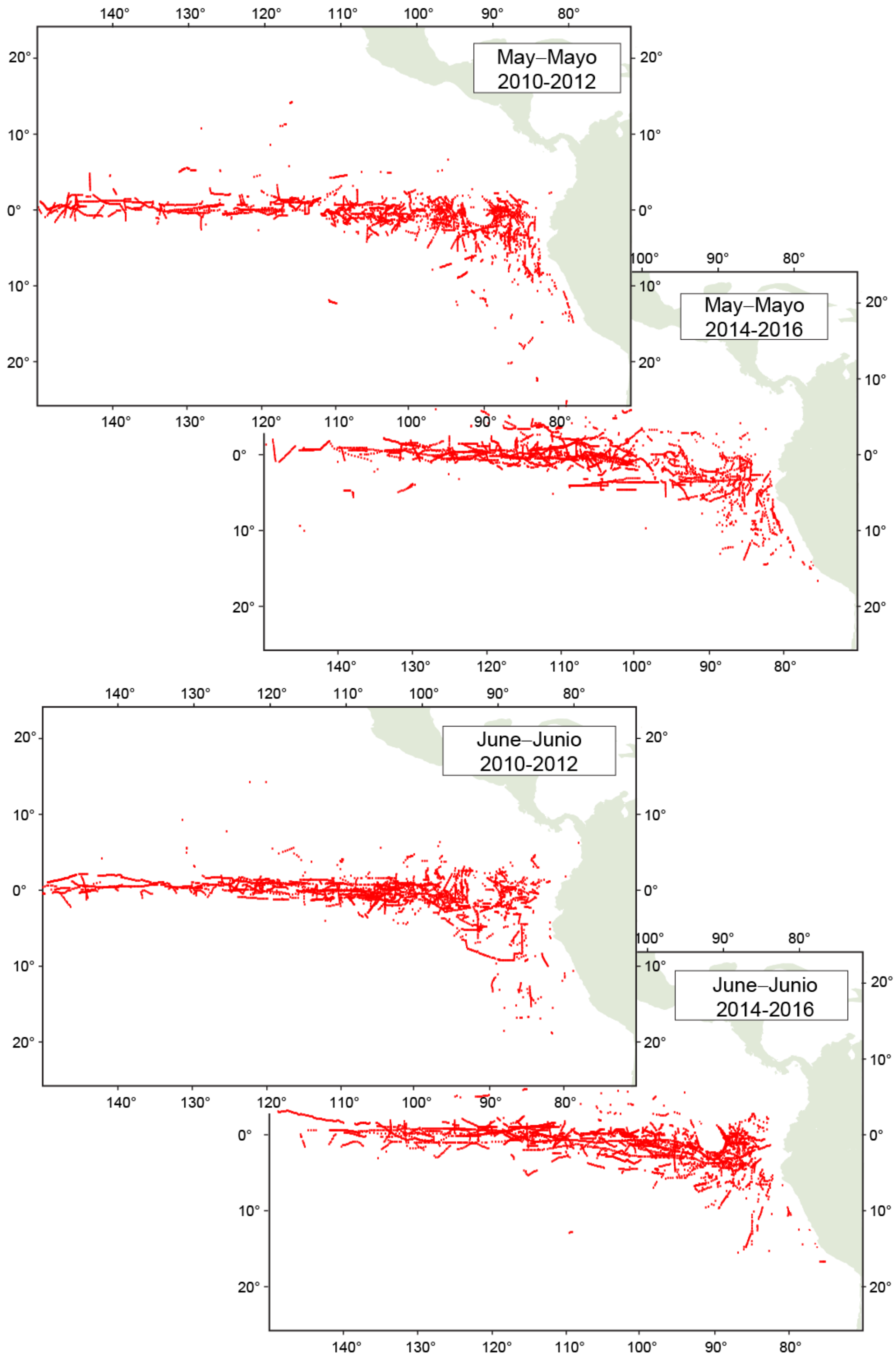


FIGURE 7 (cont.) Distribution of FAD deployments, by month, 2010-2016

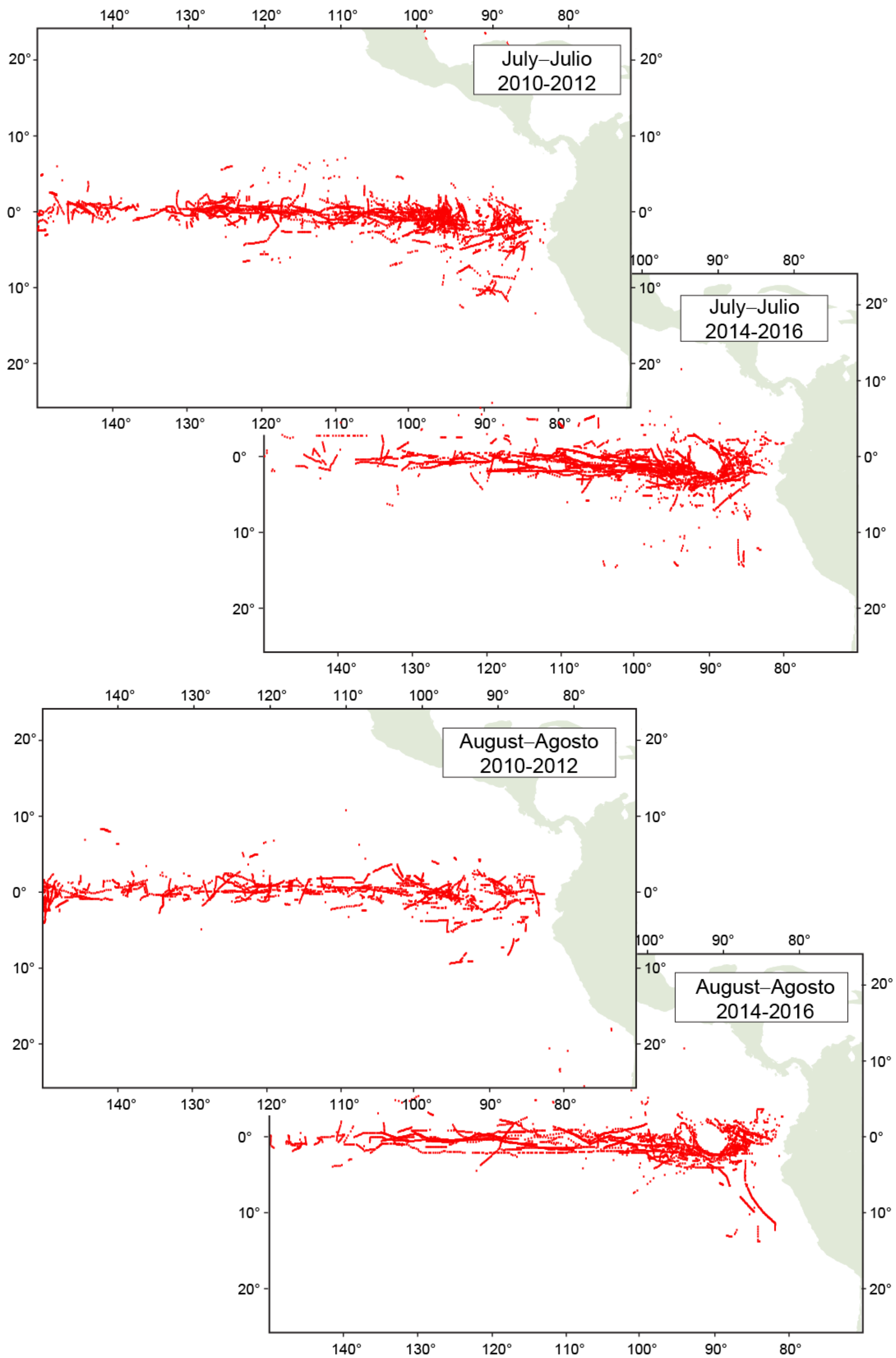
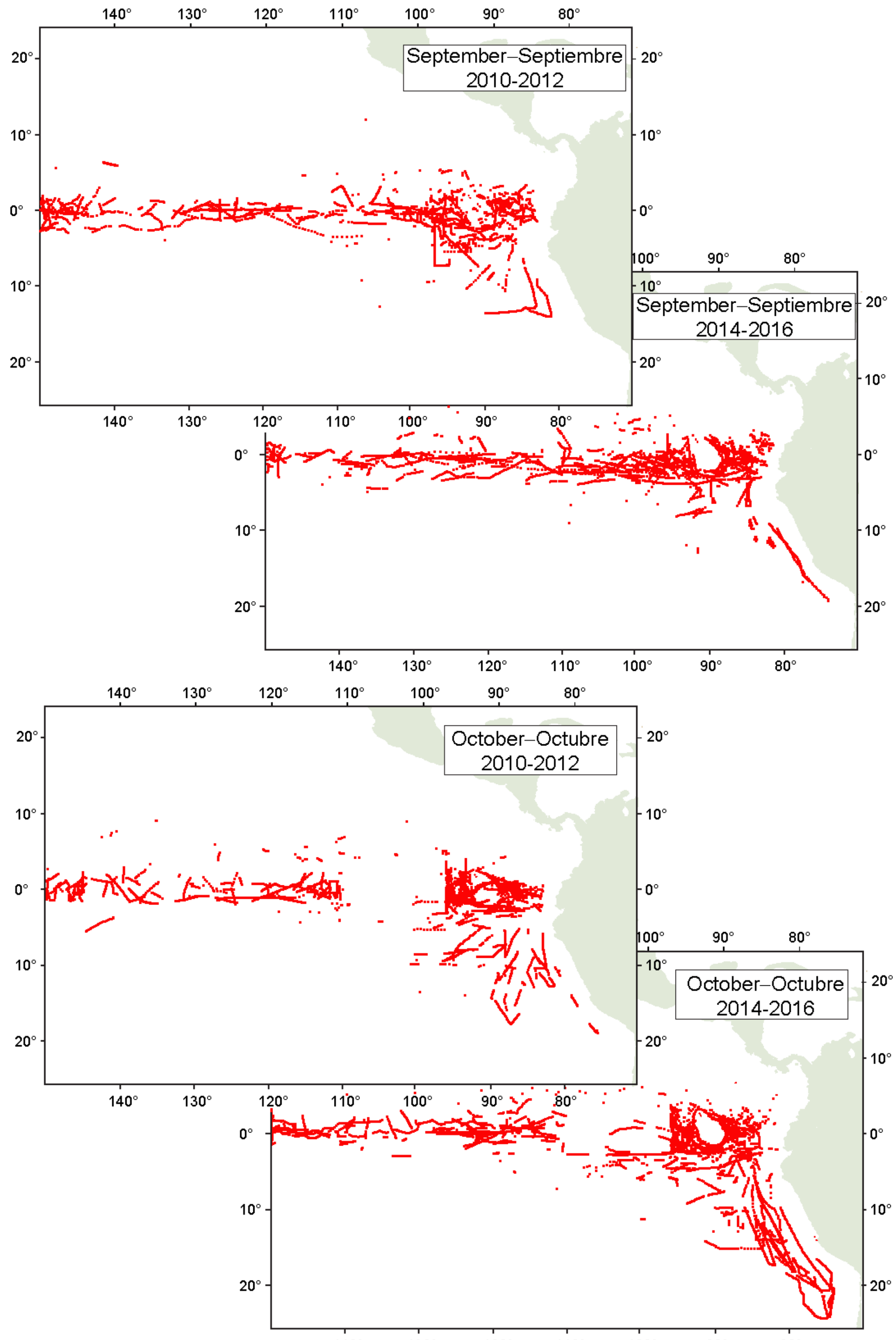


FIGURE 7 (cont.) Distribution of FAD deployments, by month, 2010-2016



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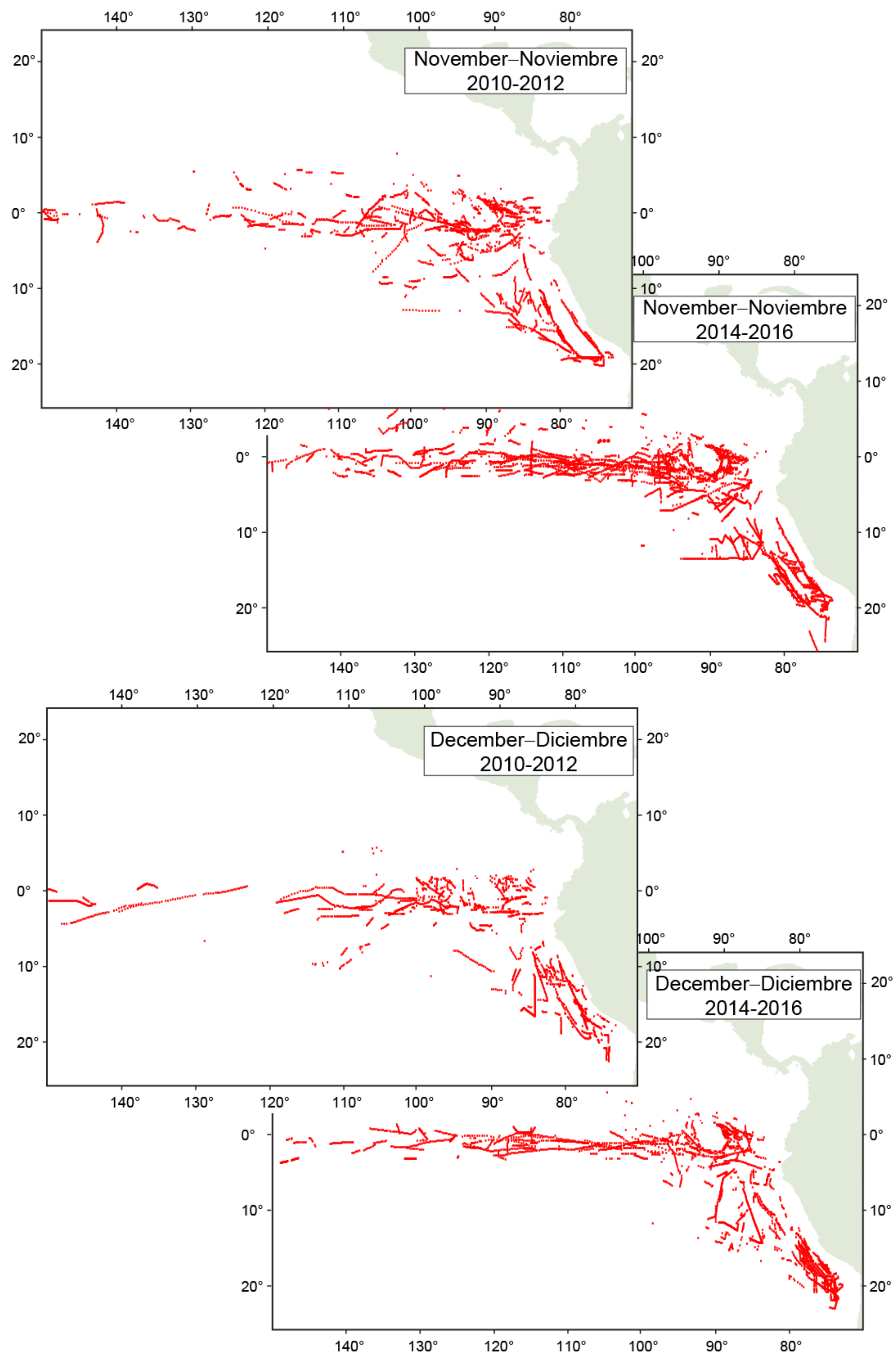

FIGURE 7 (cont.) Distribution of FAD deployments, by month, 2010-2016

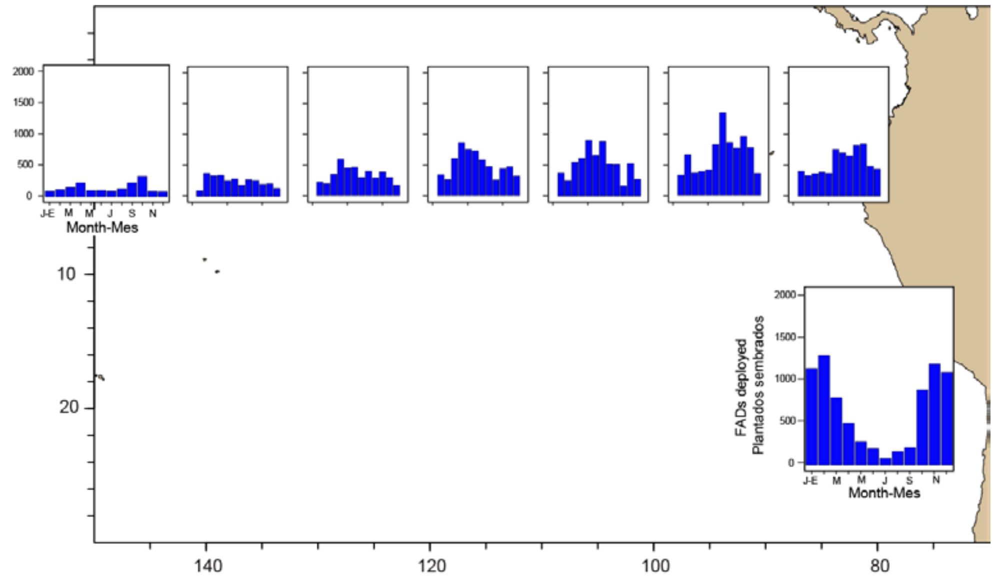

FIGURE 8. Number of FADs deployed, by month and area, 2013-2016

Deployment rates in this system peak in June and July. The impact of the closure of the "corralito" is clearly visible in the October map. The increase in deployments off Peru results in the reduction of deployments in this area at the end of the year.

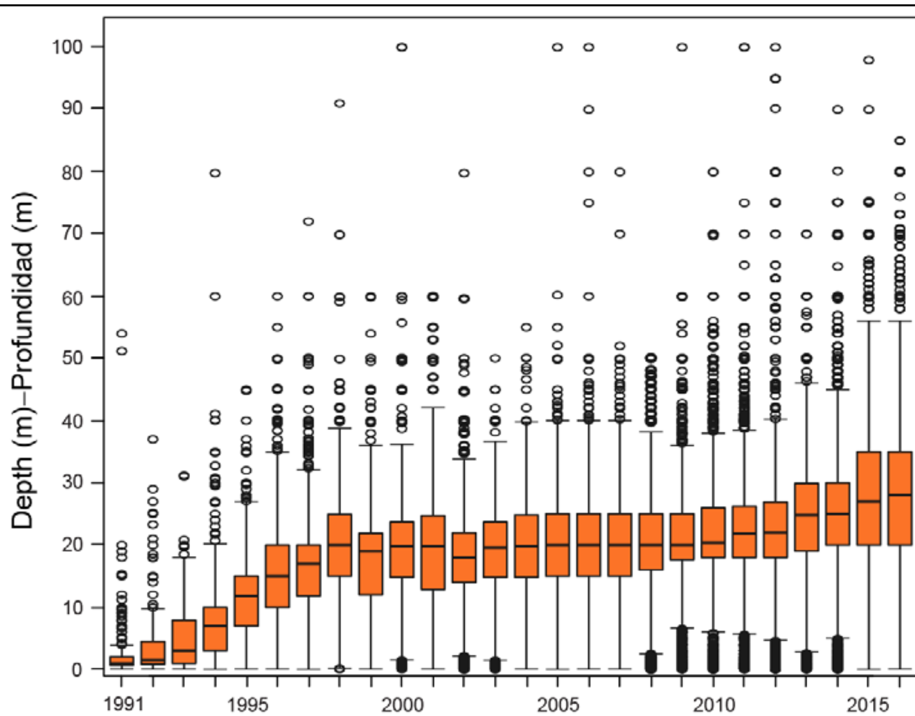

FIGURE 9. Box plots showing average depth of FAD net webbing, by year, 1991-2016.

[Figure 8](#) shows the number of FADs deployed, by month and region, during 2014-2016.

3. FAD DEPTH

After a period of relative stability, the median depth has increased after 2010. Boats fishing further to the west tend to have deeper nets because the thermoclines are deeper there.

Diel patterns: The pattern observed before continues to show. The vast majority of FAD sets are made very early in the day, within an hour of sunrise ([Figure 10](#)).

4. DEFINITIONS USED IN THE BYCATCH SECTION

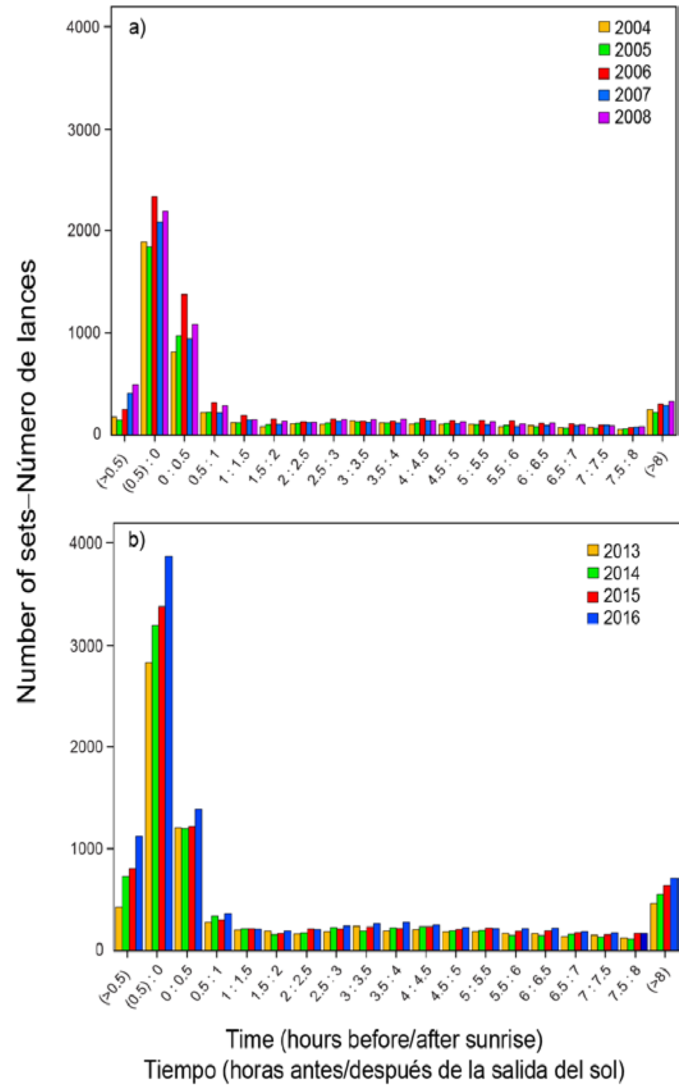

FIGURE 10. Timing of FAD sets relative to sunrise, 2004-08 and 2013-2016

TOTAL CAPTURE, or CAPTURE for short, is the product of the physical action of encircling in the net (for a purse seine), and the action itself. It can be intentional or incidental (*e.g.* a whale may swim into the seine). The total number of individuals or biomass encircled of any species (target or not) is the CAPTURE. [Spanish: CAPTURA TOTAL]

CATCH or RETAINED CATCH is the portion of the CAPTURE that is retained for utilization by the crew (*e.g.* for food or bait) or sale. The CATCH can be legal or illegal, depending on the permits the vessel has. The bycatch section definitions of CATCH do not imply any recognition by IATTC of the legality of the operation; it is simply a statement of fact identifying the fate of a portion of the CAPTURE. [Spanish: CAPTURA RETENIDA]

BYCATCH is the portion of the biomass or the numbers of individuals encircled in the net that is not retained, and is discarded dead, either from the net or from the deck. The BYCATCH of the major tuna species object of the fishery is synonymous with DISCARDS, and it has been used that way in IATTC tables.

It is presumed to be dead, even if it is returned to the sea, so it is considered among the impacts of the fishery. [Spanish: CAPTURA DESCARTADA o DESCARTE].

Individuals that are captured in the net intentionally or incidentally can be released alive. This fraction is called the RELEASE (*e.g.* almost all dolphins in dolphin sets) and they are not included in the BYCATCH because they are expected to survive their release. [Spanish: CAPTURA LIBERADA]

5. SPECIES COMPOSITIONS OF CAPTURES IN FAD SETS

Total tuna captures: Figure 11 shows aggregate FAD set captures in four regions, by size and species. These data are useful for management because they show that some species or sizes are absent or infrequent in some regions or periods, and it is possible to develop a spatial strategy to take advantage of that. The region off Peru shows a predominance of larger sizes of yellowfin and skipjack and not much small bigeye, with its catches concentrated in February and March. Most of the catches in both Equatorial regions are of skipjack or medium/large yellowfin, with bigeye catches of low magnitude and concentrated in October. Small skipjack constitute the bulk of the Equatorial offshore captures for most of the year. The increases in deployments off Peru, later in the year, do not result in captures in that period; the captures peak early in the year. In the Galapagos region, catches are quite similar for the last quarter of the year, and medium size skipjack is the predominant size. We should clarify that when the categories small, medium and large were established, they were based on the yellowfin tuna, but applied to all tunas, so the category medium skipjack represents most of the larger sizes of skipjack taken.

6. BYCATCHES

Tuna bycatches (Discards): Over the past two decades, the proportions of captured tunas subsequently discarded have declined in all set types. High prices, and a ban on discards have contributed to this. Typical reasons for discards of tuna include: the vessel is full; sizes of the tunas are too small to be marketable; the tunas are in bad condition and not fit for consumption

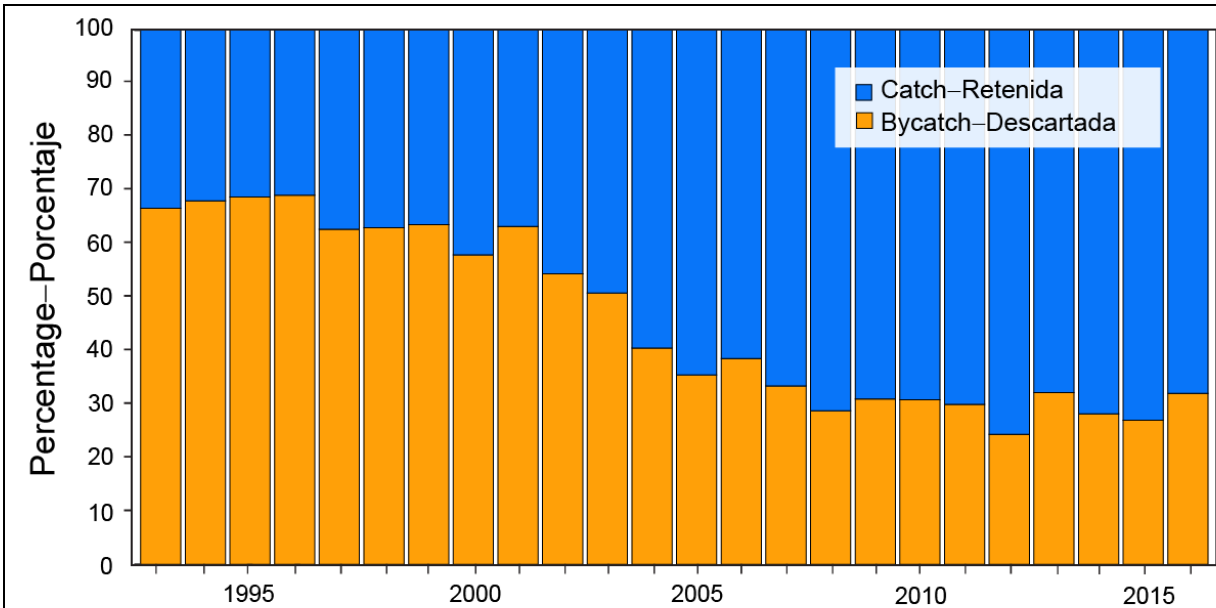

FIGURE 12. Utilization of non-tuna species captured in FAD sets, 1993-2016

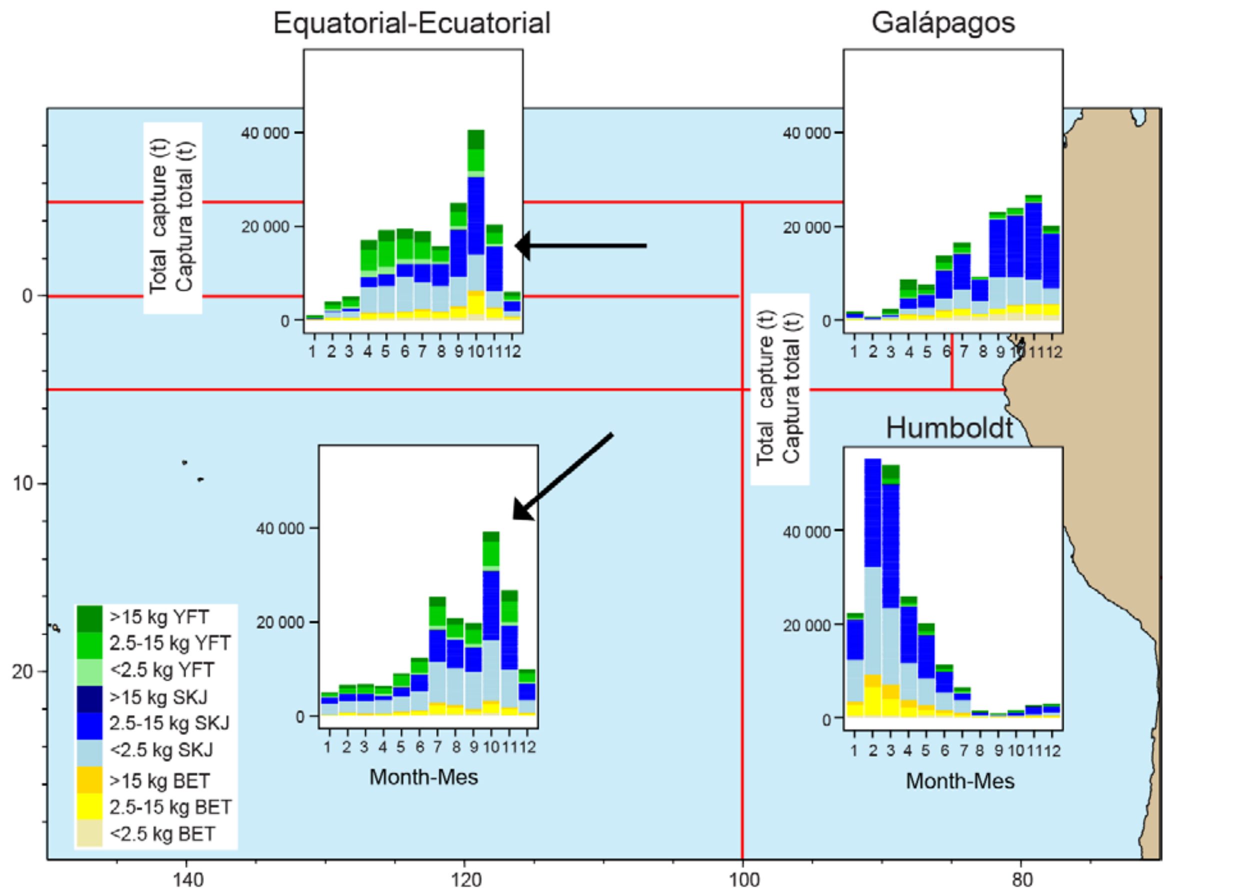

FIGURE 11. Total captures of tunas, by species and size, in sets on FADs, by month and area, 2010-2016

(usually after a very long set), *etc*. Consistently, sets on dolphins have produced the lowest level of tuna discards. Tuna discard rates in all types of sets have declined to 1% or less because of the high prices and the regulations banning discarding (Resolutions C-00-08, C-13-01).

Recent developments and current levels of bycatch: Table 1a shows observer data on total captures in numbers, average of 1993 – 2016, and Table 1b shows figures for 2016 for the main non-tuna groups (billfishes, sharks, mobulid rays, large pelagics). Table 2a shows the bycatches (dead discards) for the same time periods. This allows a comparison with the long term averages and the most recent figures. Dolphins are excluded from these tables. Sea turtle mortalities remained under 10 individuals in 2016, with no loggerheads, leatherbacks, or hawksbills, which are the species of conservation concern. These low numbers reflect the effectiveness of the release practices, since the total captures are over 1,100 individuals (including 3 leatherbacks, 49 loggerheads and 22 hawksbills). Large pelagic species such as the mahi-mahi, and wahoo, are now commonly utilized in a large proportion.

Billfishes: The sailfish continues to dominate dolphin and school sets, and they are quite rare in sets on floating objects, where blue and black marlin are the most abundant. There is also a high level of utilization of these species.

TABLE 1a. Capture per set and observed total captures in numbers 1993 – 2016 average

All years (1993-2016) **Size class 6 only**	Bycatch per set			Estimated total bycatch in the EPO			
Species	Dolphin	School	Log	Dolphin	School	Log	All
Sailfish	0.023	0.047	0.007	204.1	235.9	43.4	483.4
Blue marlin	0.000	0.002	0.021	4.9	11.2	125.1	141.3
Black marlin	0.001	0.003	0.019	12.8	16.8	116.2	145.8
Striped marlin	0.001	0.002	0.004	7.5	11.7	27.4	46.6
Other/Unid billfish	0.002	0.003	0.007	17.6	14.8	52.8	85.2
Silky shark	0.089	0.425	2.811	901.6	2,284.9	17,521.5	20,708.0
Oceanic whitetip shark	0.005	0.023	0.315	67.1	132.2	1,936.9	2,136.3
Scalloped hammerhead	0.001	0.010	0.044	7.5	49.5	269.4	326.4
Smooth hammerhead	0.001	0.006	0.046	5.8	25.9	265.8	297.5
Other/Unid HH shark	0.003	0.016	0.072	27.0	94.1	441.8	562.9
Other/Unid shark	0.048	0.091	0.363	479.0	438.4	2,317.2	3,234.6
Giant manta	0.002	0.026	0.001	16.5	111.4	4.2	132.1
Spinetail manta	0.010	0.020	0.003	81.5	87.9	19.4	188.8
Chilean devil ray	0.004	0.006	0.001	32.1	28.2	4.7	65.0
Smoothtail manta	0.007	0.062	0.002	63.2	274.1	13.3	350.6
Munk's devil ray	0.002	0.007	0.000	15.5	33.7	2.6	51.9
Unid Manta/devil rays	0.039	0.207	0.011	348.3	1,235.8	73.0	1,657.0
Pelagic stingray	0.024	0.071	0.019	225.0	618.8	111.2	955.1
Other/Unid rays	0.002	0.000	0.000	17.0	0.8	0.2	17.9
Mahi mahi	0.010	0.652	35.224	87.3	3,393.8	215,435.2	218,916.3
Wahoo	0.006	0.047	15.243	79.7	283.5	92,172.8	92,536.0
Rainbow runner	0.001	0.157	11.252	9.1	679.1	66,541.5	67,229.7
Yellowtail	0.018	1.233	2.995	246.1	6,406.4	21,839.1	28,491.6
Other large fish	0.007	0.762	0.736	65.1	6,248.4	4,424.5	10,738.0

TABLE 1B. BYCATCH PER SET AND OBSERVED TOTAL CAPTURES 2016 IN NUMBERS

Year: 2016 **Size class 6 only** **(except dolphins)**	Bycatch per set			Estimated total bycatch in the EPO			
Species	Dolphin	School	Log	Dolphin	School	Log	All Sets
Sailfish	177.044	111.840	2.052	177.0	111.8	2.1	290.9
Blue marlin	1.000	1.773	44.345	1.0	1.8	44.3	47.1
Black marlin	3.000	0.114	16.199	3.0	0.1	16.2	19.3
Striped marlin	2.292	0.000	0.000	2.3	0.0	0.0	2.3
Other/Unid billfish	26.253	9.044	50.408	26.3	9.0	50.4	85.7
Silky shark	287.149	376.175	22,220.588	287.1	376.2	22,220.6	22,883.9
Oceanic whitetip shark	2.000	13.022	164.075	2.0	13.0	164.1	179.1
Scalloped hammerhead	9.000	21.000	241.434	9.0	21.0	241.4	271.4
Smooth hammerhead	9.000	16.007	360.266	9.0	16.0	360.3	385.3
Other/Unid HH shark	5.000	19.000	253.614	5.0	19.0	253.6	277.6
Other/Unid shark	100.740	115.668	2,735.552	100.7	115.7	2,735.6	2,952.0
Giant manta	8.000	65.000	7.004	8.0	65.0	7.0	80.0
Spinetail manta	116.000	18.064	5.002	116.0	18.1	5.0	139.1
Chilean devil ray	25.000	16.945	13.005	25.0	16.9	13.0	54.9
Smoothtail manta	145.945	26.007	18.007	145.9	26.0	18.0	190.0
Munk's devil ray	63.000	236.000	2.312	63.0	236.0	2.3	301.3
Unid Manta/devil rays	228.113	203.571	50.975	228.1	203.6	51.0	482.7
Pelagic stingray	345.718	35.014	60.490	345.7	35.0	60.5	441.2
Other/Unid rays	2.000	0.000	2.001	2.0	0.0	2.0	4.0
Mahi mahi	2.000	125.114	49,921.672	2.0	125.1	49,921.7	50,048.8
Wahoo	3.000	14.081	15,975.708	3.0	14.1	15,975.7	15,992.8
Rainbow runner	37.000	0.000	21,654.928	37.0	0.0	21,654.9	21,691.9
Yellowtail	0.000	323.000	10,755.668	0.0	323.0	10,755.7	11,078.7
Other large fish	121.000	868.086	931.076	121.0	868.1	931.1	1,920.2

TABLE 2a. Total bycatches (Dead discards) Average 1993 – 2016 in numbers

All years (1993-2016) **Size class 6 only (except dolphins)**	Bycatch per set			Estimated total bycatch in the EPO			
Species	Dolphin	School	Log	Dolphin	School	Log	All
Sailfish	0.071	0.095	0.014	690.8	512.5	85.7	1289.0
Blue marlin	0.008	0.025	0.194	87.0	124.5	1149.4	1360.9
Black marlin	0.009	0.016	0.095	84.9	84.1	572.3	741.3
Striped marlin	0.009	0.022	0.023	100.7	116.5	144.9	362.1
Other/Unid billfish	0.007	0.010	0.024	67.9	49.6	157.8	275.3
Silky shark	0.202	0.663	3.992	2137.8	3580.9	25943.2	31661.9
Oceanic whitetip shark	0.008	0.027	0.351	93.3	158.3	2172.3	2423.9
Scalloped hammerhead	0.002	0.018	0.052	22.6	100.0	319.0	441.6
Smooth hammerhead	0.001	0.014	0.059	12.5	70.2	340.9	423.6
Other/Unid HH shark	0.006	0.027	0.091	62.6	170.5	563.6	796.8
Other/Unid shark	0.072	0.149	0.516	728.3	787.2	3362.2	4877.6
Giant manta	0.002	0.026	0.001	16.8	111.5	4.3	132.6
Spinetail manta	0.010	0.020	0.003	84.8	88.9	20.1	193.8
Chilean devil ray	0.004	0.007	0.001	34.5	28.6	4.8	68.0
Smoothtail manta	0.008	0.063	0.002	66.1	275.4	13.4	355.0
Munk's devil ray	0.002	0.007	0.000	16.4	34.0	2.6	53.0
Unid Manta/devil rays	0.044	0.213	0.012	388.5	1279.1	75.2	1742.8
Pelagic stingray	0.024	0.071	0.019	228.1	622.7	113.4	964.2
Other/Unid rays	0.002	0.000	0.000	17.0	1.0	0.2	18.2
Mahi mahi	0.038	1.543	71.544	343.0	8118.6	433921.6	442383.1
Wahoo	0.023	0.158	37.122	222.0	859.3	221413.9	222495.1
Rainbow runner	0.002	0.208	11.926	14.5	910.1	70579.0	71503.6
Yellowtail	0.031	3.357	4.202	362.3	17650.0	30121.2	48133.5
Other large fish	0.009	1.191	1.138	79.7	9920.1	6819.0	16818.7

Year: 2016 **Size class 6 only** **(except dolphins)**	Bycatch per set			Estimated total bycatch in the EPO			
Species	Dolphin	School	Log	Dolphin	School	Log	All Sets
Sailfish	0.113	0.105	0.004	1266.0	517.5	46.3	1829.8
Blue marlin	0.007	0.018	0.174	83.0	100.2	1802.7	1985.9
Black marlin	0.006	0.012	0.035	67.0	61.6	362.9	491.4
Striped marlin	0.009	0.008	0.007	104.0	37.5	78.0	219.5
Other/Unid billfish	0.026	0.026	0.079	289.0	138.2	823.4	1250.6
Silky shark	0.200	0.228	2.783	2249.0	1129.2	29017.3	32395.5
Oceanic whitetip shark	0.000	0.002	0.016	2.0	13.0	164.2	179.2
Scalloped hammerhead	0.001	0.005	0.024	9.0	25.0	248.4	282.4
Smooth hammerhead	0.001	0.003	0.037	11.0	16.0	383.3	410.3
Other/Unid HH shark	0.000	0.004	0.025	5.0	20.0	255.5	280.5
Other/Unid shark	0.027	0.047	0.276	301.0	233.7	2923.2	3457.8
Giant manta	0.001	0.013	0.001	8.0	66.0	7.0	81.0
Spinetail manta	0.010	0.004	0.000	117.0	19.1	5.0	141.1
Chilean devil ray	0.002	0.003	0.001	26.0	17.0	13.0	56.0
Smoothtail manta	0.013	0.006	0.002	150.0	31.0	18.0	199.0
Munk's devil ray	0.006	0.048	0.000	63.0	236.0	2.3	301.3
Unid Manta/devil rays	0.021	0.050	0.005	233.0	248.0	51.2	532.2
Pelagic stingray	0.031	0.008	0.006	346.0	37.0	60.5	443.5
Other/Unid rays	0.000	0.000	0.000	2.0	0.0	2.0	4.0
Mahi mahi	0.009	0.383	24.738	100.0	1888.5	255360.5	257349.0
Wahoo	0.003	0.191	15.043	34.0	943.0	155279.7	156256.7
Rainbow runner	0.003	0.127	2.631	37.0	628.0	27169.7	27834.7
Yellowtail	0.094	0.270	1.887	1059.0	1330.0	19487.5	21876.5
Other large fish	0.012	0.176	0.232	139.0	872.2	2409.9	3421.2