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

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CONTENTS

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

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. 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.

The total number of sets has increased to a historical maximum (Figure 1a). The increase in 2015 was led by school sets, while the other types remained at the 2014 levels. Until the 1990s, the majority of purse-seine catches in the eastern Pacific Ocean (EPO) 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. Fishers would add radio beacons to floating objects they encountered to enable them to be found again. Eventually, the concept of fish-aggregating devices (FADs) began to emerge as an alternative strategy, but the numbers and proportion of sets of this type were not significant. However, in the 1990s the fishery on FADs expanded rapidly (Figure 1b), due in part to the closure of the US market to tuna caught in association with dolphins, which motivated fishers to explore

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

alternative ways of catching tunas

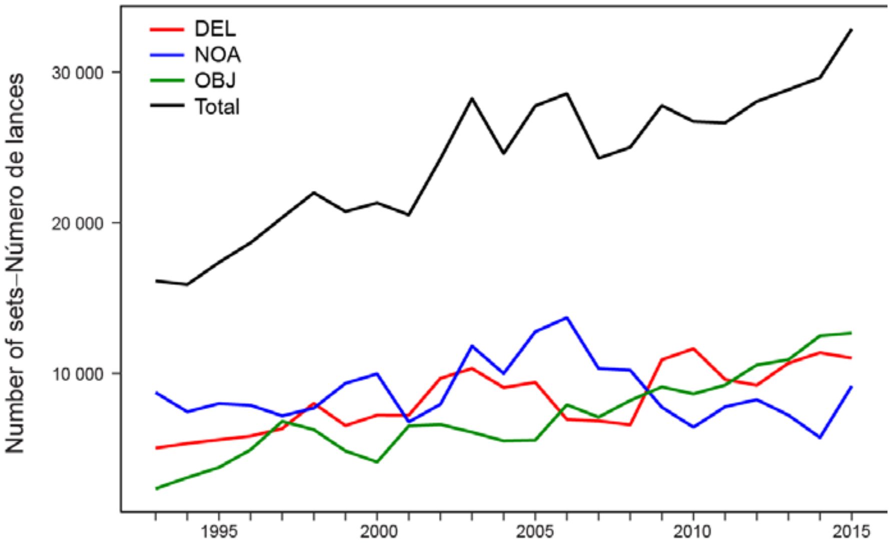


FIGURE 1a. Estimated number of sets, by type of class 1-6 vessels. 1993-

During the early years of the FAD fishery, fishers experimented with FAD construction, where and when to deploy FADs, how frequently to revisit them, technologies for monitoring and tracking FADs, *etc*. The development of spatial-temporal strategies, taking into account oceanographic factors, management restrictions, access to fishing areas, and other factors, was a key component. In parallel to these developments, the industries producing tracking and acoustic technologies developed products for this new market, and the changes have been fast and very significant.

The total number of sets has continued increasing, and 2015 is the highest record observed. There is a large increase in unassociated sets in 2015. FAD sets remained at the high level they had reached in 2014. Sets on logs (defined as floating objects that are not FADs) are a small proportion of the total, but are slightly higher in 2015. Also, the El Niño phenomenon that is affecting the area may affect the number and spatial distribution of the effort.

1. FADS: CHARACTERISTICS AND DYNAMICS

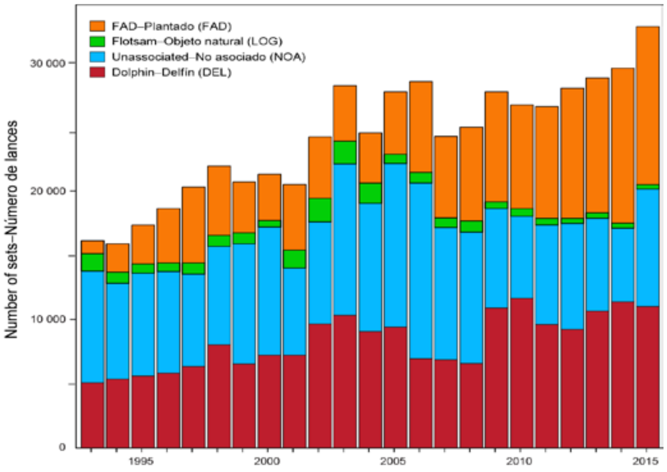


FIGURE 1b. Number of sets, by type, by all purse-seine vessels, 1993-2015**.** The proportion of FAD and LOG sets by Class-1-5 vessels were estimated based on the proportions of FAD and LOG sets by Class-6 vessels fishing in the Class-1-5 vessels' area of operation.

In the early days of the FAD fishery, fishers relied on visual cues, such as flags, to locate FADs, but soon these gave way to sophisticated electronic methods. Currently, essentially all FADs are equipped with satellite tracking devices, and close to 75% are also outfitted with sonar buoys, which can be monitored via satellite from the vessel. These buoys, which are used by fishers to determine remotely the biomass associated with a FAD, could potentially 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

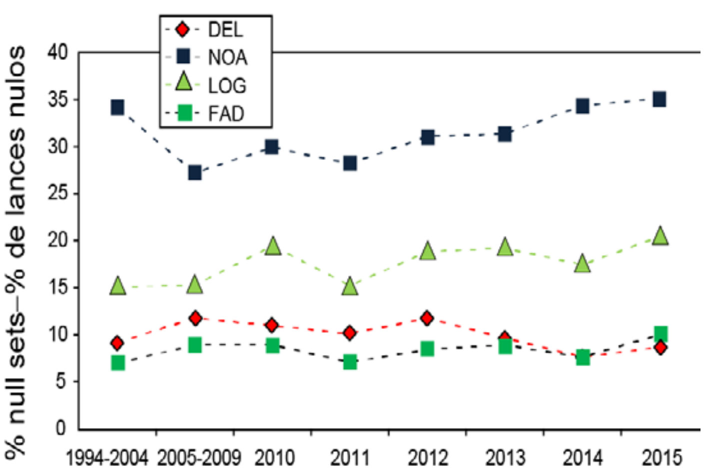


FIGURE 2. Percent of null sets by set type, 1994-2015

seem to have reduced the proportion of null sets of any type (Figure 2). This is still the case by 2015. 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 considerably higher than in sets without such buoys (Figure 3), possibly due to improvements in the technology and/or the skill of the fishers in interpreting the data transmitted by the buoys

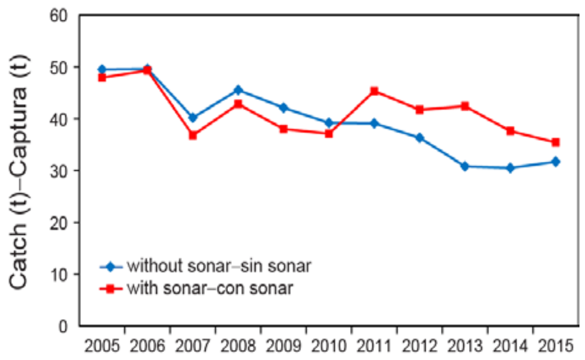


FIGURE 3. Total capture per set on FADs with and without sonar, 2004-2015.

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 almost 15,000 in 2015, the highest number on record, although there seems to be a reduction in the annual rates of increase (*e.g.* the curve is reaching an asymptote). But the number of FADs recovered has declined significantly, 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.

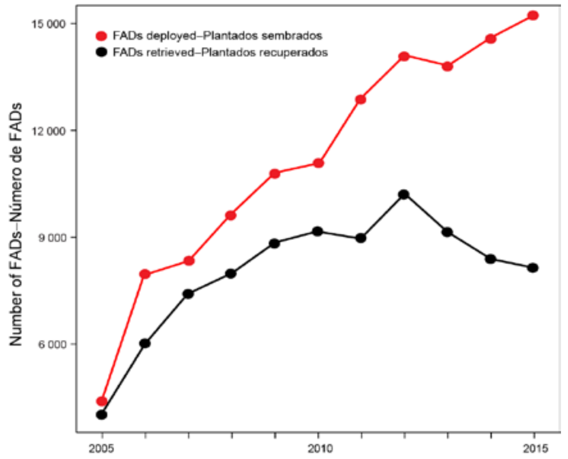


FIGURE 4. Number of FADs observed deployed and retrieved in the EPO by year, 2005-2015.

Most FADs are retrieved, although the percentage retrieved from the EPO was less in 2014 and 2015 than in previous years; those that are not either continue to be monitored and used for fishing (some, perhaps outside the EPO) or are lost. It should be noted that the recording process is interrupted when an observer leaves a vessel at the end of a trip, thus these data and the conclusions that might be drawn from them are limited because there is no continuity in the counting of FADs. With the aim of eventually overcoming the limitations of these data and pursuant to the direction provided by CPCs, the IATTC staff has been evaluating options for enhanced monitoring and data collection regarding use of FADs (see Document SAC-05-05).

The number of FADs deployed per vessel has increased as well. Figure 5 shows the number of FADs deployed per vessel in 2005, 2010, and 2015. In 2005, the average number of FADs deployed per vessel was 71; and the highest number of FADs deployed during the year was less than 300. By

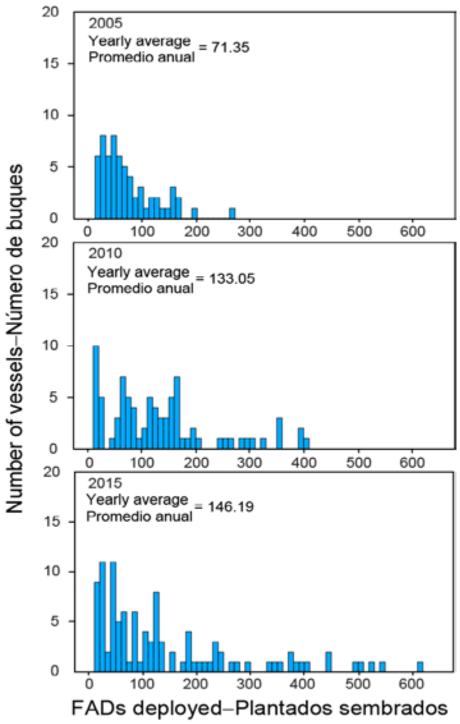


FIGURE 5. FAD deployments by vessels in three different years. Excludes vessels deploying less than 10 FADs in a year.

2010 the average number of FADs deployed per observed trip had increased to 133, with some vessels deploying nearly 500. In 2015, the average increased to 146, and the number of vessels deploying more than 300 FADs a year has also increased. Also, vessels belonging to the same company often share FADs, so a vessel may have many more FADs available than it deploys.

Figure 6 shows boxplots for the most recent decade, 2005-2015. The medians have not changed much in recent years, but a few very large values drive the average up.

2. PATTERNS OF FAD DISTRIBUTION IN THE EPO

The patterns of FAD deployments by month, based on observer data for the periods 2010-2012 and 2013-2015, are illustrated comparatively in Figure 7, which shows the month-by-month changes during those two periods. The lines are not tracks of deployed FADs, but the sequential FAD deployments that occur as a vessel follows a given course. The effects of the current strong El Niño may be reflected in the changes in deployment patterns observed in 2015, but the maps were prepared for multi-year periods to retain the comparability.

In summary, FAD deployments in the more recent period show an extension of the fishing season off Peru beginning much earlier than before, in October, retreating north and shifting to the area around the Galapagos during the second quarter, and then to the offshore equatorial region west of the Galapagos for the rest of the year.

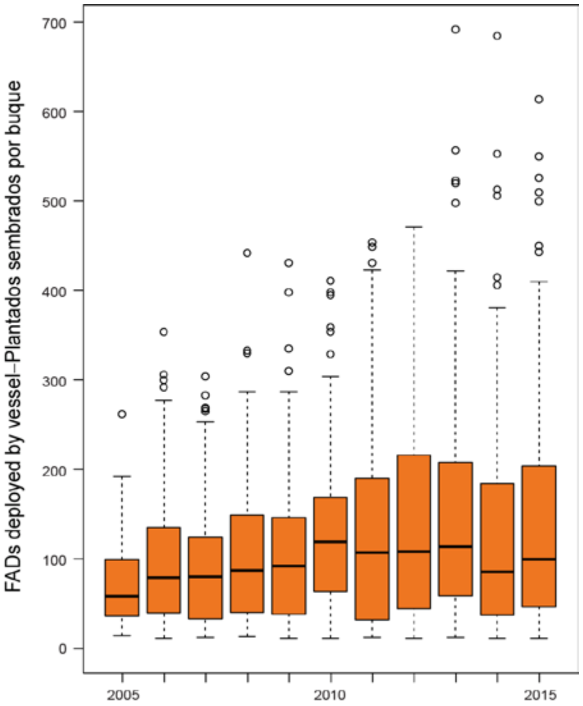
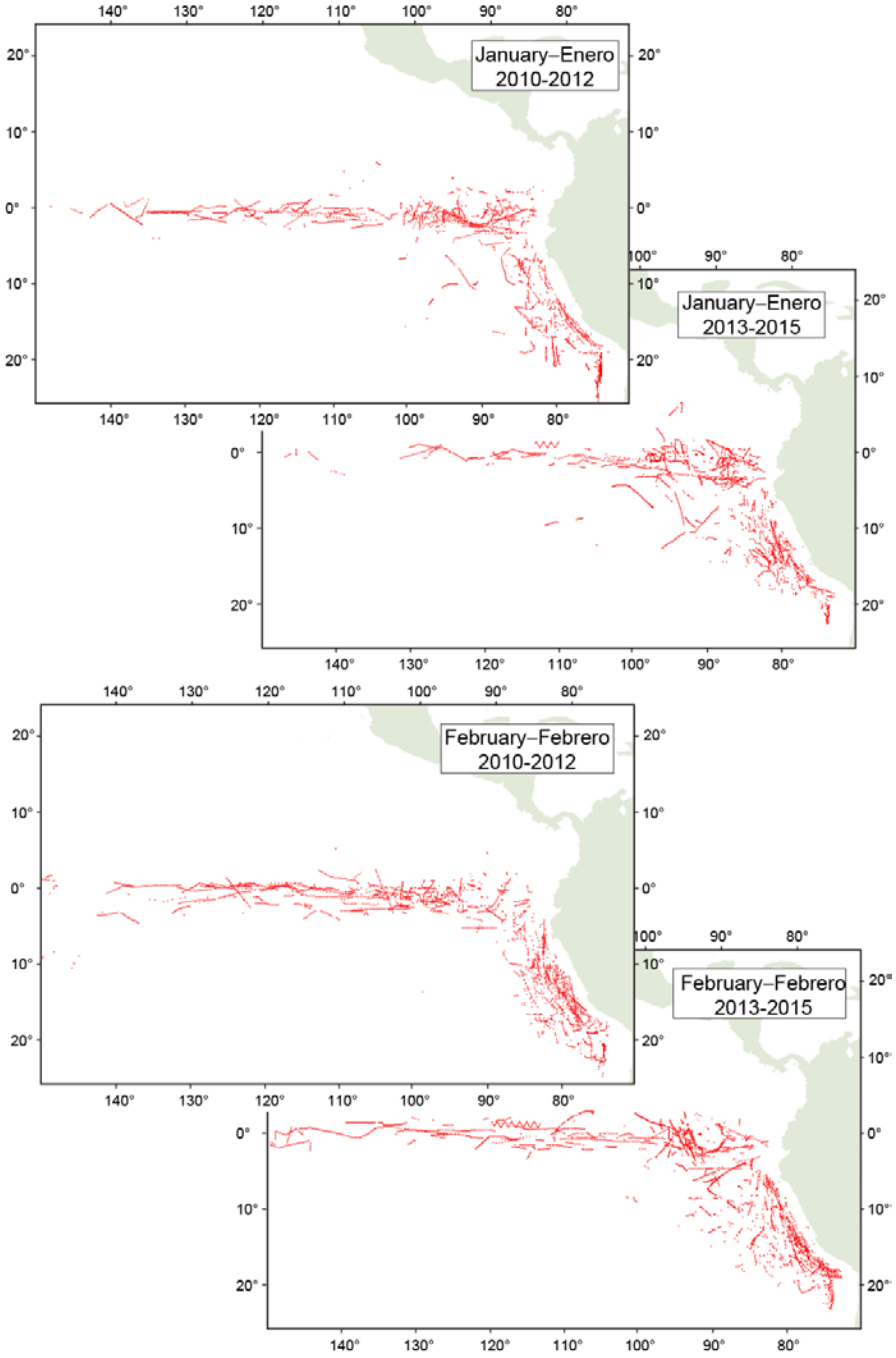


FIGURE 6. FAD deployments by vessels, 2005-2015. Excludes vessels deploying less than 10 FADs in a year.

Humboldt Current system: The deployments in this region (roughly between 5°S and 25°S within 1,000 km of the coast) are quite seasonal, coinciding with the presence of a "tongue" of warm water that spreads south from equatorial region to northern Chile. Most of the deployments occur from October to March, moving north in April as the warm water recedes. Surface current speeds in this system are slow, and FADs do not move long distances. The proportion of FADs planted in the Humboldt Current system area has increased considerably in recent years. The fishing season now goes from October to March.

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 yearround, 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.

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. The westward-flowing currents north and south of the Equator are the fastest in the Pacific Ocean, especially during the second quarter of the year,


January–Enero 2010-2012

January–Enero 2013-2015

February–Febrero 2010-2012

February–Febrero 2013-2015

FIGURE 7. Distribution of FAD deployments, by month, 2010-2015

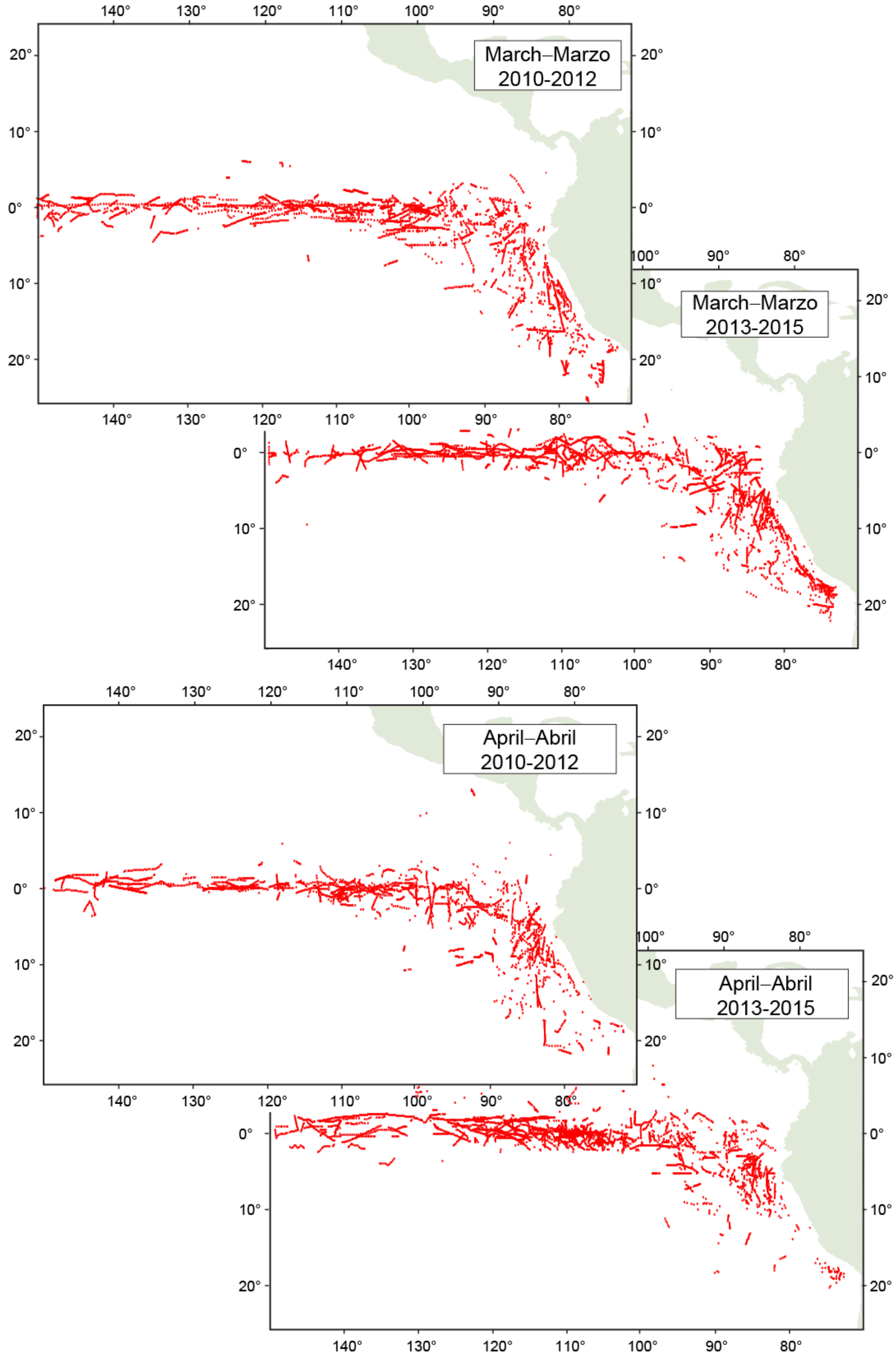


FIGURE 7 (cont.) Distribution of FAD deployments, by month, 2010-2015

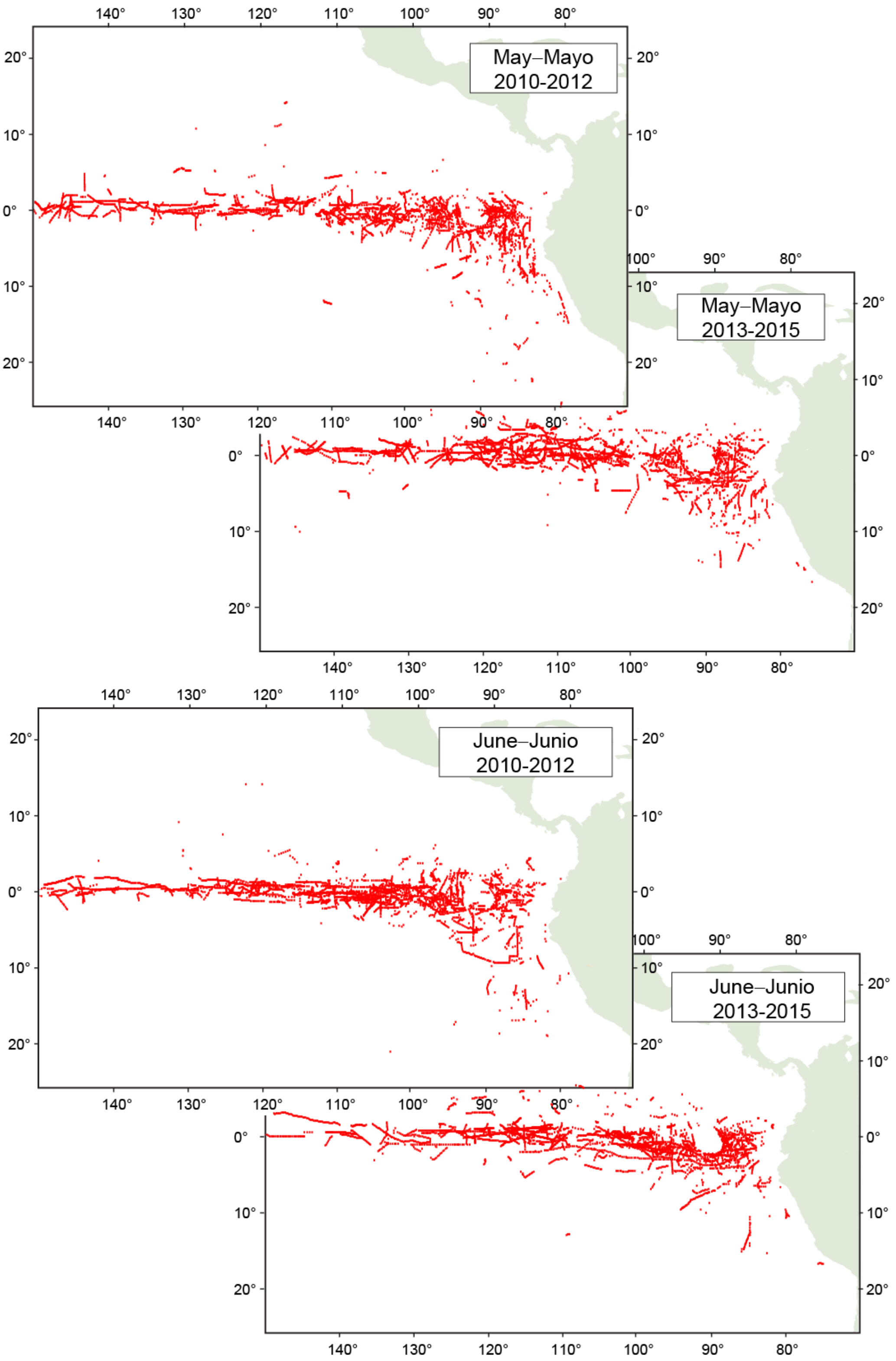


FIGURE 7 (cont.) Distribution of FAD deployments, by month, 2010-2015

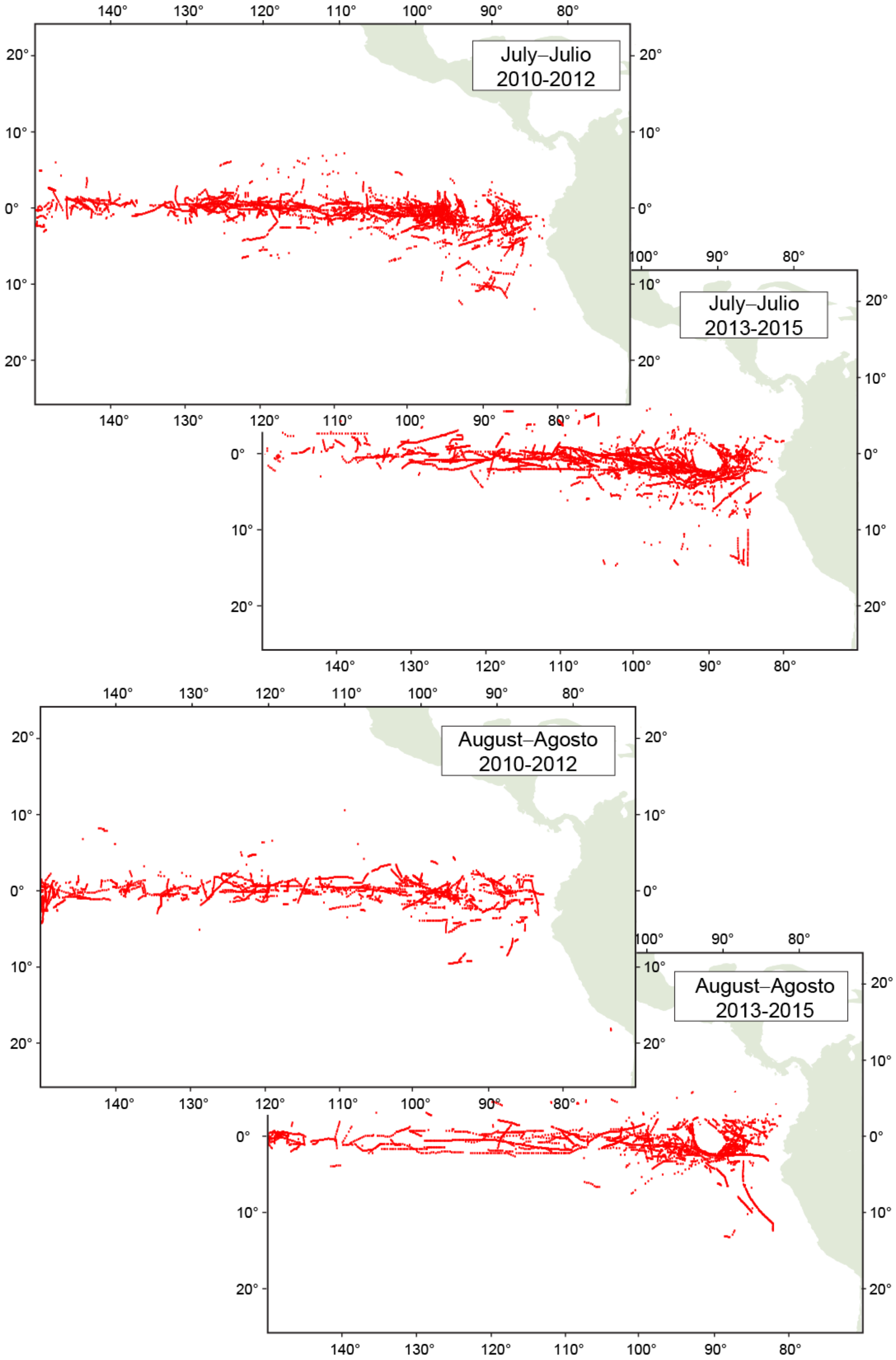


FIGURE 7 (cont.) Distribution of FAD deployments, by month, 2010-2015

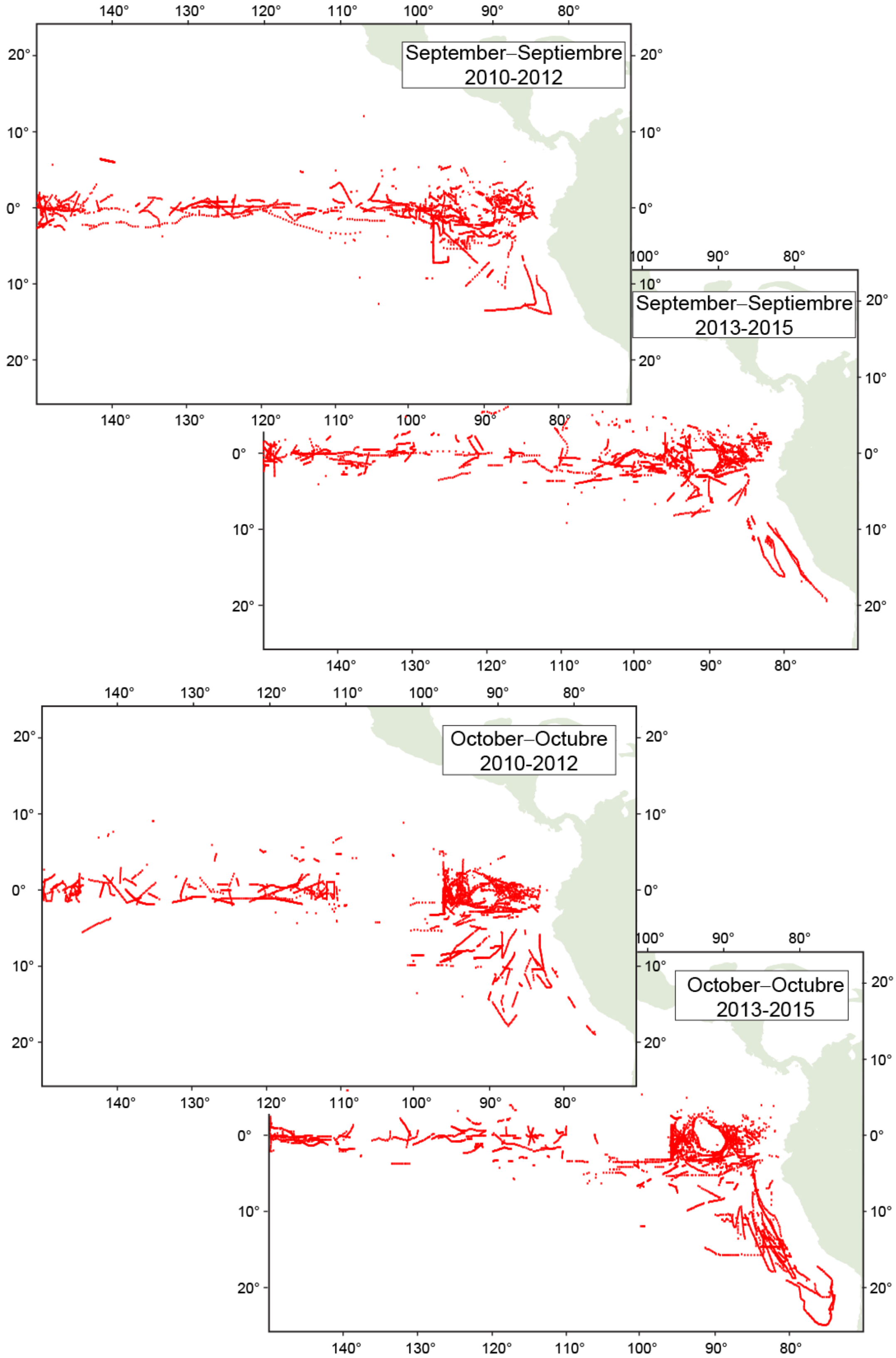


FIGURE 6 (cont.) Distribution of FAD deployments, by month, 2011-2015

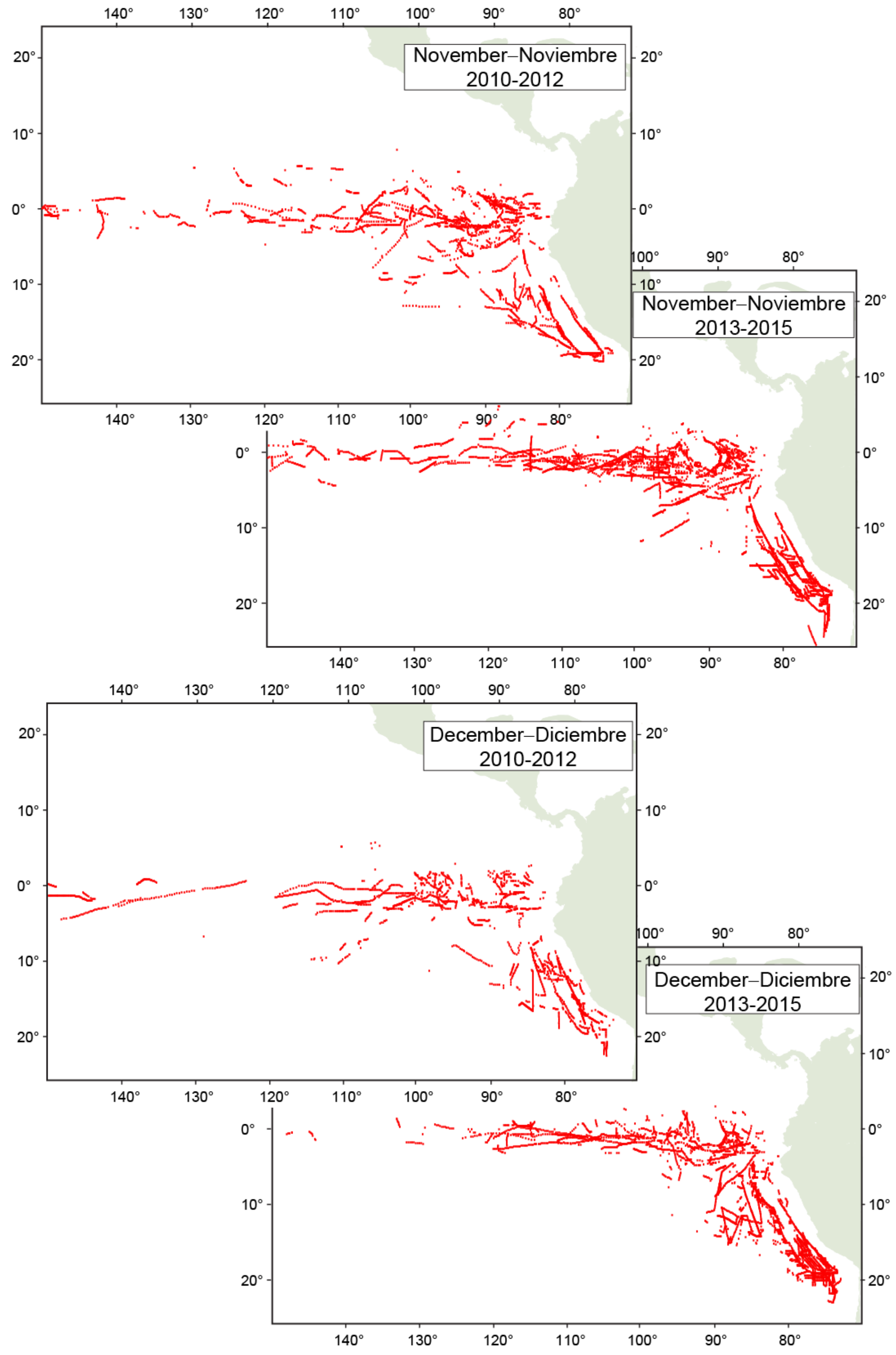


FIGURE 7 (cont.) Distribution of FAD deployments, by month, 2010-2015

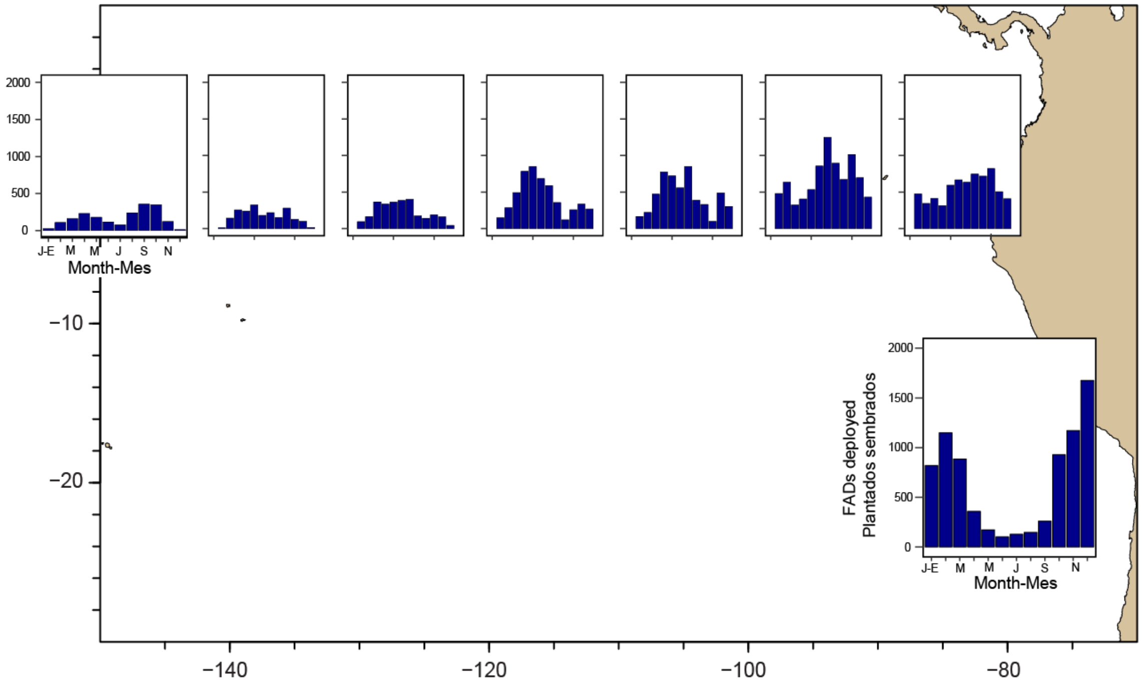


FIGURE 8. Number of FADs deployed, by month and area, 2013-2015

and the longitudinal movements of FADs are significantly greater than in other periods. Deployment rates in this system are lowest in November-December, because of the movement of vessels to the Humboldt region, then typically increase from January to a peak in June and July. Their distribution in this area in October is influenced by the closure of the area between 96° and 110°W from 4°N to 3°S ("*corralito*"). The reduction in deployments at the end of the year is even more marked in recent years.

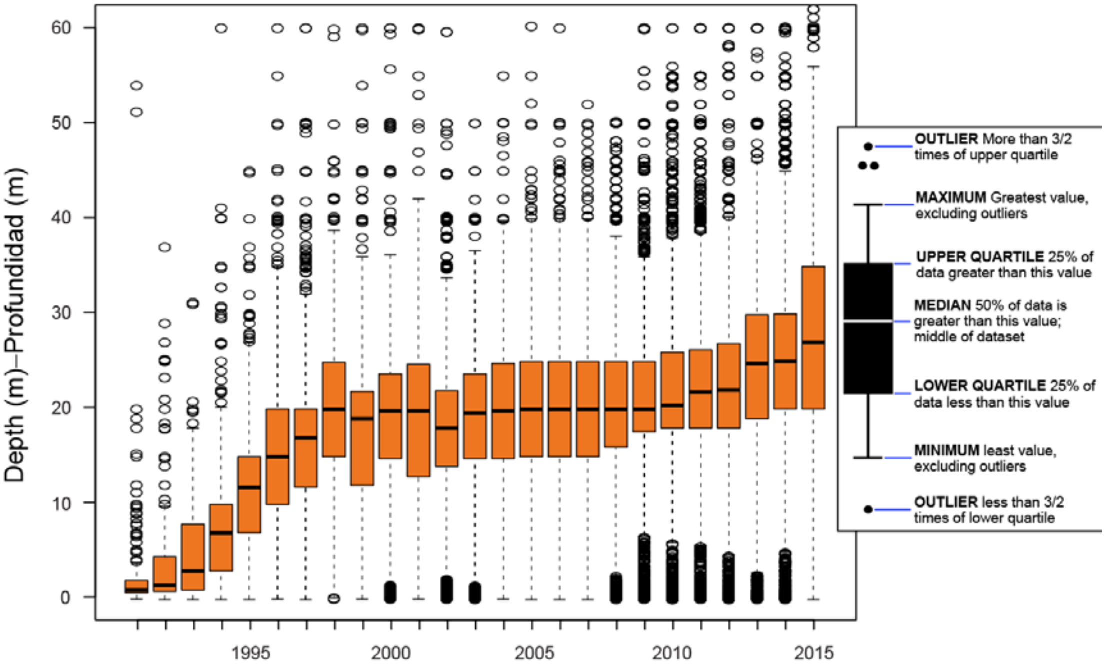


FIGURE 9. Box plots showing average depth of FAD net webbing, by year, 1991-2015.

Figure 8 shows the number of FADs deployed, by month and region, during 2013-2015.

3. FAD DEPTH

From the beginning of the FAD fishery, pieces of webbing, usually old netting materials, have been added under the FADs to increase their attractiveness to the fish. Figure 9 illustrates the changes in FAD construction over the years: a rapid increase in the depth of the materials hung from the FAD in the early years, followed by a stable period from the late 1990s, with a median depth around 25-30 m. More recently, the median depth appears to be increasing again, apparently following the practice in other oceans, with depths of 40 m becoming more common, and with some approaching 80 m. This trend towards deeper FADs is accentuated in the most recent years.

Diel patterns: In the EPO, the vast majority of FAD sets are made within an hour of sunrise. Researchers in other regions have suggested that some fleets were increasing the number of sets on FADs later in the day. However, no such increase is evident as of yet in the EPO (Figure 10).

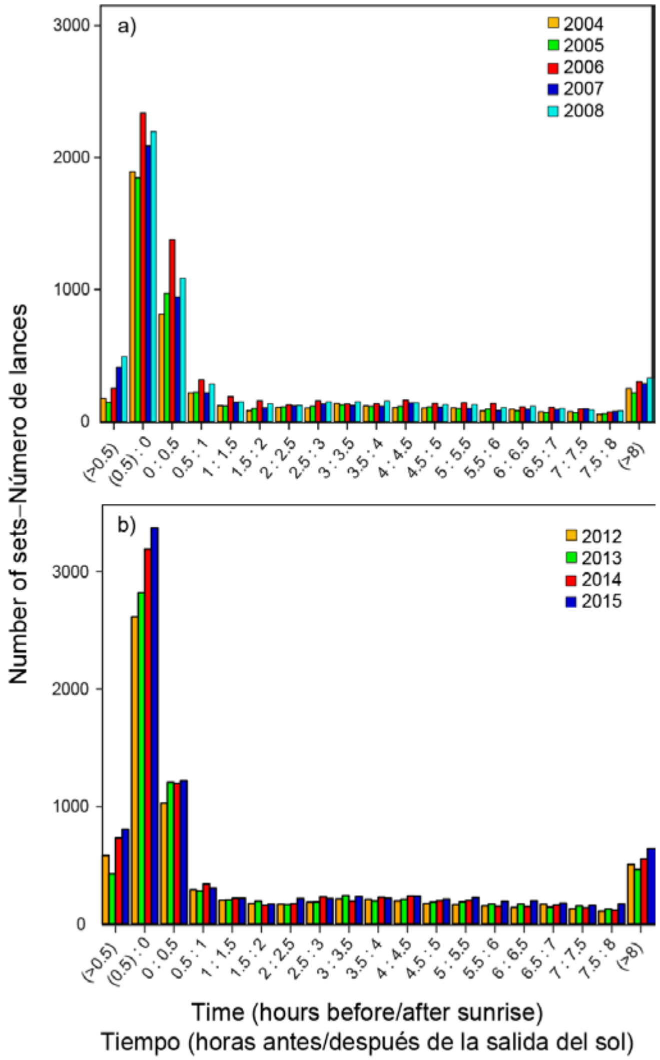


FIGURE 10. Timing of FAD sets relative to sunrise, 2004-08 and 2012-2015

4. DEFINITIONS USED IN THE BYCATCH SECTION

TOTAL CAPTURE, or CAPTURE for short, is the product of the physical action of encircling in the net (for a purse seine), and the 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. For example, the region off Peru shows a predominance of larger sizes of yellowfin and skipjack in proportion to the other sizes, when compared with the other locations, and the captures of 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. Around Galapagos, the bulk of the captures are taken close to the end of the year.

6. BYCATCHES

Tuna bycatches (Discards): Over the past two decades, the proportions of captured tunas subsequently discarded have declined in all set types. 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

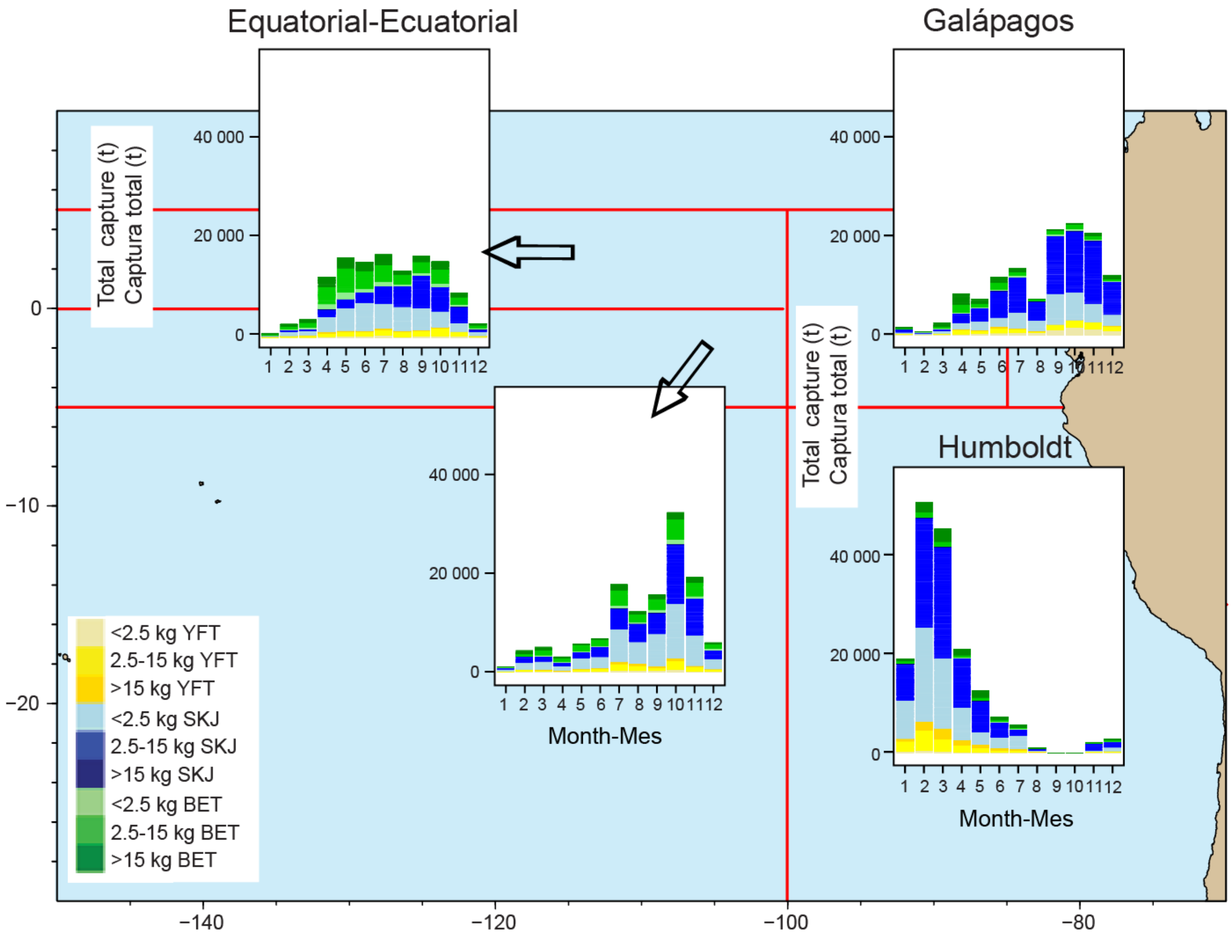


FIGURE 11. Total captures of tunas, by species and size, in sets on FADs, by month and area, 2010-2015

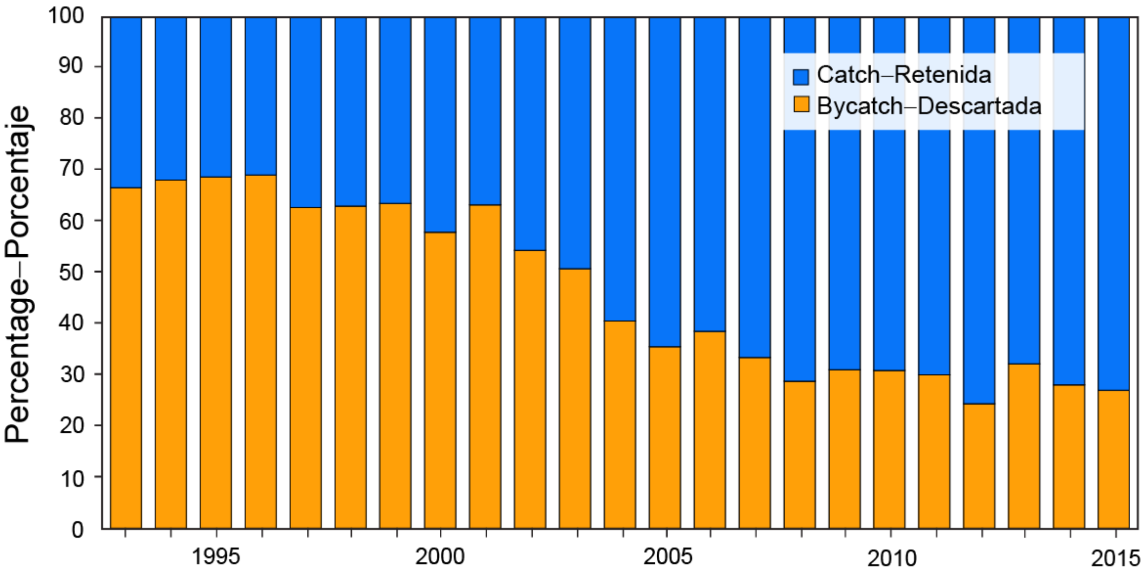


FIGURE 12. Utilization of non-tuna species captured in FAD sets, 1993-2015.

(usually after a very long set), *etc*. Historically, sets on dolphins have produced the lowest level of tuna bycatch, and sets on floating objects the highest. However, all tuna discard rates have declined: since the mid-1990s they have fallen from around 16% to 1% or less. The main reasons for this are probably the increased marketability of small tunas, and the full retention requirements established by the IATTC (see Resolutions C-00-08, C-13-01).

Recent developments and current levels of bycatch: Table 1a reflects observer data on total captures and bycatches, in numbers, in 2015. Table 1b shows captures and bycatches, in weight, per 1,000 t of tuna captured. Dolphins are excluded from these tables. Practically all species show lower bycatch rates in recent years than in the earlier years of the fishery.. These reductions may reflect changes in abundance, changes in fishing areas or methods, higher utilization rates, or some combination of factors. For example, based on what is known about the status of oceanic whitetip sharks, the increasing rarity of this species in EPO purse-seine sets likely tracks closely with its relative abundance. On the other hand, the reduced bycatch rates of some large pelagic species (billfishes, dorado, wahoo, *etc*.) is likely due, at least in part, to higher utilization rates due to expanded markets for these fish, as can be seen when looking at the differences between captures and bycatches..

The increasing utilization of individuals that would otherwise have been discarded dead does not add to the fishing mortality resulting from the harvest (Figure 12). To the extent that non-tuna species increasingly occupy well space on purse-seine vessels, this may be a positive step in the sense that it may result in a reduction in capacity for tuna species by taking up well space, and distributing the impact of the fishery among more components of the ecosystem, and thus more in line with an ecosystem-based approach to harvesting the oceans. Greater retention of non-tuna species also produces economic benefits from what was wasted before and may provide socio-economic benefits to coastal communities, without increasing the impacts on the ecosystem. Marlins, wahoo and dorado continue their high and increasing level of utilization. Sets on floating objects show the higher captures and bycatches.

In 2015 close to 75% of the captures of these species was discarded (Figure 12).

TABLE 1a. Estimated total bycatch (excluding marine mammals and sea turtles) and bycatch per 1000 t of tunas (yellowfin, skipjack, and bigeye) captured by Class-6 purse-seine vessels in the EPO, in metric tons (t), by set type and all sets combined, 2015

Species	Total bycatch (t)				Bycatch/1,000 t tuna capture			
	Dolphin	School	FAD/Log	All Sets	Dolphin	School	FAD/Log	All Sets
Sailfish	3.43	3.76	0.37	7.57	0.02	0.03	0.00	0.05
Blue marlin	0.03	5.27	5.55	10.85	0.00	0.02	0.02	0.04
Black marlin	0.28	4.65	8.59	13.52	0.00	0.02	0.03	0.05
Striped marlin	0.09	0.00	0.00	0.09	0.00	0.00	0.00	0.00
Other/Unid billfish	0.35	1.19	0.25	1.79	0.00	0.01	0.00	0.01
Silky shark	2.85	77.78	362.92	443.54	0.02	0.62	1.29	1.93
Oceanic whitetip shark	0.03	0.38	3.21	3.62	0.00	0.00	0.01	0.01
Scalloped hammerhead	0.18	0.64	8.85	9.67	0.00	0.01	0.03	0.04
Smooth hammerhead	0.15	2.36	32.92	35.44	0.00	0.02	0.12	0.14
Other/Unid HH shark	0.64	0.56	10.98	12.18	0.00	0.00	0.04	0.05
Other/Unid shark	2.81	10.78	35.15	48.75	0.02	0.09	0.13	0.23
Giant manta	0.58	10.50	0.63	11.71	0.00	0.08	0.00	0.08
Spinetail manta ray	20.95	1.36	2.64	24.94	0.13	0.01	0.01	0.15
Chilean devil ray	6.21	2.30	1.23	9.74	0.04	0.01	0.00	0.05
Smoothtail manta	3.15	1.53	0.50	5.18	0.02	0.01	0.00	0.03
Munk's devil ray	1.36	0.30	0.17	1.83	0.01	0.00	0.00	0.01
Unid Manta/devil rays	8.91	3.51	0.95	13.37	0.05	0.02	0.00	0.08
Pelagic stingray	0.42	0.18	0.22	0.82	0.00	0.00	0.00	0.00
Other/Unid rays	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dorado	0.00	0.22	168.96	169.18	0.00	0.00	0.61	0.61
Wahoo	0.00	0.02	41.30	41.33	0.00	0.00	0.15	0.15
Rainbow runner	0.00	0.00	7.73	7.74	0.00	0.00	0.03	0.03
Yellowtail	0.00	0.00	6.83	6.83	0.00	0.00	0.02	0.02
Other large fish	0.77	10.91	6.54	18.22	0.00	0.07	0.02	0.10

TABLE 1b. Estimated total bycatch (excluding marine mammals and sea turtles) and bycatch per 1000 t of tunas (yellowfin, skipjack, and bigeye) captured by Class-6 purse-seine vessels in the EPO, in number of individuals, by set type and all sets combined, 2015

Species	Total bycatch (t)				Bycatch (t)/1,000 t tuna capture (3 spp.)			
	Dolphin	School	Log	All Sets	Dolphin	School	Log	All Sets
Sailfish	114.58	117.89	12.79	245.26	0.69	0.94	0.05	1.67
Blue marlin	2.00	28.00	42.36	72.36	0.01	0.11	0.14	0.26
Black marlin	3.00	24.23	74.34	101.56	0.02	0.12	0.23	0.37
Striped marlin	1.00	0.00	0.00	1.00	0.01	0.00	0.00	0.01
Other/Unid billfish	4.00	7.84	5.46	17.30	0.02	0.06	0.02	0.11
Silky shark	108.83	2,101.49	21,055.67	23,265.99	0.65	16.53	75.34	92.51
Oceanic whitetip shark	1.00	9.64	108.35	118.99	0.01	0.06	0.39	0.46
Scalloped hammerhead	2.00	15.00	167.84	184.84	0.01	0.12	0.61	0.75
Smooth hammerhead	4.00	22.02	464.12	490.14	0.02	0.18	1.70	1.90
Other/Unid HH shark	6.00	8.00	152.00	166.00	0.04	0.06	0.56	0.65
Other/Unid shark	76.36	290.04	2,285.39	2,651.79	0.46	2.32	8.34	11.12
Giant manta	38.00	67.01	1.00	106.01	0.23	0.53	0.00	0.76
Spinetail manta ray	303.83	21.02	45.04	369.89	1.82	0.17	0.16	2.15
Chilean devil ray	90.00	25.00	11.00	126.00	0.54	0.14	0.04	0.72
Smoothtail manta	101.00	40.99	14.01	156.00	0.60	0.33	0.05	0.98
Munk's devil ray	72.00	11.01	6.00	89.01	0.43	0.09	0.02	0.54
Unid Manta/devil rays	160.01	57.04	27.62	244.67	0.96	0.41	0.10	1.46
Pelagic stingray	155.00	65.01	82.04	302.05	0.93	0.52	0.30	1.75
Other/Unid rays	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dorado	4.51	107.09	57,729.23	57,840.84	0.03	0.86	209.37	210.26
Wahoo	2.00	23.00	22,629.98	22,654.98	0.01	0.18	82.18	82.38
Rainbow runner	0.00	3.00	6,359.55	6,362.55	0.00	0.02	23.06	23.08
Yellowtail	0.00	0.00	8,818.15	8,818.15	0.00	0.00	32.20	32.20
Other large fish	6.00	4,093.06	784.50	4,883.57	0.04	17.56	2.72	20.31

A. ADDENDUM

As the fishery on FADs has developed in several ocean regions, according mostly to seasonalityThe regions are shown in Figure 11: a) the **Galapagos** system area, from 5°N to 5°S, and 85°W to 100°W; b) the **Equatorial** front area, from the western border of the Galapagos area to 150°W, divided into regions north and south of the Equator; and c) the **Humboldt** system area, from Peru to 100°W. . A more detailed look at some of the parameters in each of them will be useful for interpreting changes in catch rates, species composition, *etc*.

As the FAD fishery has expanded, the number of FADs deployed has grown, and this might affect the effectiveness and the productivity of the vessels. Two factors can be influenced by the number of FADs available to a vessel: a) more FADs may reduce the probability of a null sets, because there is a previous verification from the acoustic equipment of the existence and closeness of fish under a FAD; or b) the average catch per set in positive sets (captures $\geq$ 0.5 t), increases when more options are available to the vessel. The proportion of null sets, discussed above, has not changed much in FAD fishing.

The impacts of the current El Niño event may affect all these variables (*e.g.* changes in thermocline depth may increase the proportion of null sets), but the information needed to quantify them and to separate these impacts is not available.

7. CATCH PER POSITIVE SET

This is not a measure of catch per unit effort, but rather informs on the school sizes and the numbers of schools of the same or different species that are encountered associated with FADs or dolphins. The sum of the catches of all three major tropical tuna species (yellowfin, skipjack, and bigeye) was used to compute the catch per positive sets (CPPS) in each region of interest mentioned above. In general, FAD and log sets produce larger CPPS than unassociated sets, and all are higher than dolphin sets (Table 3). This, combined with the lower proportion of null sets, shows that FAD fishing is the most productive form of fishing in terms of total tonnage produced per set attempted.

Captures in unassociated sets show very little change, and the trends are not significant at the 0.05 level. Captures in dolphin sets also show relative stability. Captures in log sets in the Galapagos region show a significant decline, but the sample sizes are relatively low. The variability of CPPS in FAD sets is very high; after a peak in 1999-2000 in all regions, the values show declines in recent years (Table 3).

8. NUMBER OF FADS DEPLOYED BY REGION VERSUS CAPTURE PER POSITIVE SET (CPPS)

As the numbers of FADs deployed increased over time, it is interesting to explore the changes in CPPS with higher densities of FADs. Ideally, this type of study should be done with local densities of FADs, not aggregated over a large region, but with the data currently available, that would require either modelling the drift of the FADs deployed, or obtaining satellite data on FAD drifts.

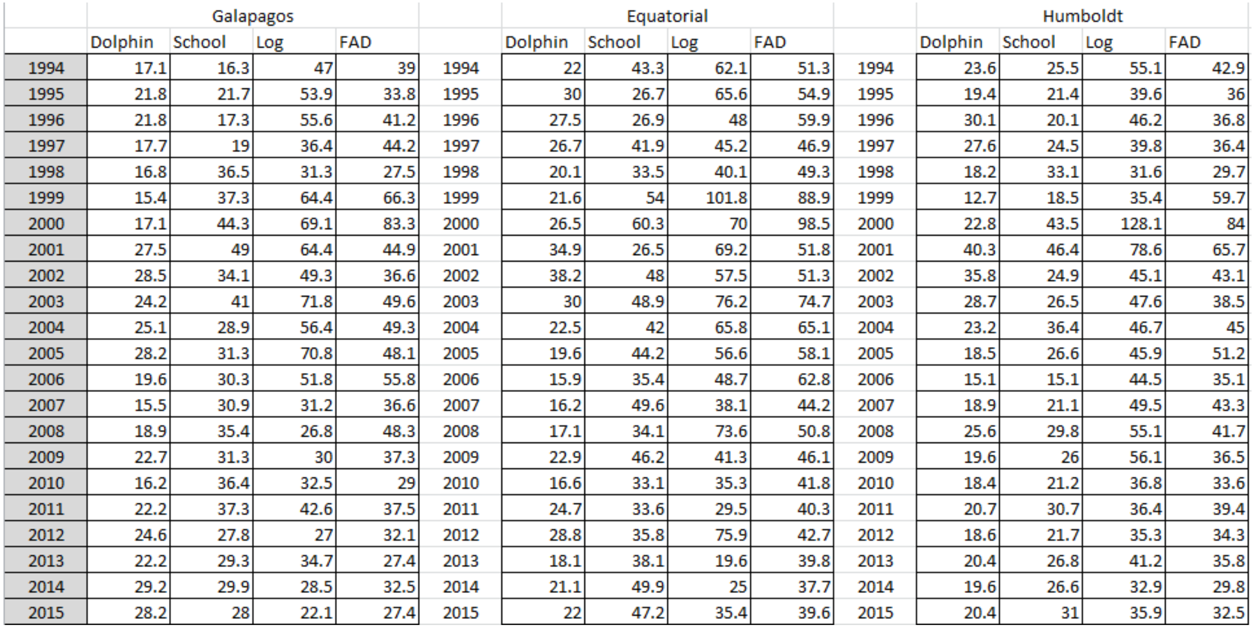
There are several possible alternatives for the impact on the fishery of a greater number of FADs in the water:

a. Vessels have more options, so they can pick FADs with more fish (in which case CPPS should increase), and avoid FADs with small schools or schools that are not closely associated with the FAD, based on acoustic data (in which case null sets should decrease).

b. With FADs “competing” with each other for the tuna schools, CPPS should decline. When there are few FADs in an area, an individual FAD may attract more than one school of tuna, and thus have a higher CPPS, whereas if there are many FADs, many of them will attract only one school, or none. This issue can be further explored by lookiexamining the length-frequency data from individual sets, since the variability should be reduced if only one school per FAD becomes the prevalent case.

c. As the number of FADs has been increasing for a decade or more, the increased productivity of the fishery may be reflected in the biomasses of the species captured. Declines in the abundance of tuna species may be reflected in a) declines in the number of schools, or b) declines in average school size, or c) both. The first alternative could be explored by examining the changes over time in the proportion of FADs without any tuna aggregated or in some measure of encounter rate, but this is not available in this dataset. The second alternative may affect the CPPS value.

TABLE 3. Capture per positive set, by set type and region.



	Galapagos					Equatorial					Humboldt			
	Dolphin	School	Log	FAD		Dolphin	School	Log	FAD		Dolphin	School	Log	FAD
1994	17.1	16.3	47	39	1994	22	43.3	62.1	51.3	1994	23.6	25.5	55.1	42.9
1995	21.8	21.7	53.9	33.8	1995	30	26.7	65.6	54.9	1995	19.4	21.4	39.6	36
1996	21.8	17.3	55.6	41.2	1996	27.5	26.9	48	59.9	1996	30.1	20.1	46.2	36.8
1997	17.7	19	36.4	44.2	1997	26.7	41.9	45.2	46.9	1997	27.6	24.5	39.8	36.4
1998	16.8	36.5	31.3	27.5	1998	20.1	33.5	40.1	49.3	1998	18.2	33.1	31.6	29.7
1999	15.4	37.3	64.4	66.3	1999	21.6	54	101.8	88.9	1999	12.7	18.5	35.4	59.7
2000	17.1	44.3	69.1	83.3	2000	26.5	60.3	70	98.5	2000	22.8	43.5	128.1	84
2001	27.5	49	64.4	44.9	2001	34.9	26.5	69.2	51.8	2001	40.3	46.4	78.6	65.7
2002	28.5	34.1	49.3	36.6	2002	38.2	48	57.5	51.3	2002	35.8	24.9	45.1	43.1
2003	24.2	41	71.8	49.6	2003	30	48.9	76.2	74.7	2003	28.7	26.5	47.6	38.5
2004	25.1	28.9	56.4	49.3	2004	22.5	42	65.8	65.1	2004	23.2	36.4	46.7	45
2005	28.2	31.3	70.8	48.1	2005	19.6	44.2	56.6	58.1	2005	18.5	26.6	45.9	51.2
2006	19.6	30.3	51.8	55.8	2006	15.9	35.4	48.7	62.8	2006	15.1	15.1	44.5	35.1
2007	15.5	30.9	31.2	36.6	2007	16.2	49.6	38.1	44.2	2007	18.9	21.1	49.5	43.3
2008	18.9	35.4	26.8	48.3	2008	17.1	34.1	73.6	50.8	2008	25.6	29.8	55.1	41.7
2009	22.7	31.3	30	37.3	2009	22.9	46.2	41.3	46.1	2009	19.6	26	56.1	36.5
2010	16.2	36.4	32.5	29	2010	16.6	33.1	35.3	41.8	2010	18.4	21.2	36.8	33.6
2011	22.2	37.3	42.6	37.5	2011	24.7	33.6	29.5	40.3	2011	20.7	30.7	36.4	39.4
2012	24.6	27.8	27	32.1	2012	28.8	35.8	75.9	42.7	2012	18.6	21.7	35.3	34.3
2013	22.2	29.3	34.7	27.4	2013	18.1	38.1	19.6	39.8	2013	20.4	26.8	41.2	35.8
2014	29.2	29.9	28.5	32.5	2014	21.1	49.9	25	37.7	2014	19.6	26.6	32.9	29.8
2015	28.2	28	22.1	27.4	2015	22	47.2	35.4	39.6	2015	20.4	31	35.9	32.5

As a preliminary measure, we computed the annual average CPPS in FAD sets for the three regions (Figure 13). We used calendar year data, which could be close enough in two of the regions, but, for instance, it would fail to reflect deployments in November and December that affect catches in the first months of the following year. This issue should be more important for the Humboldt region because the seasonality of the fishery includes parts of two years.

In all three regions, CPPS showed significant declining trends when plotted against the number of FADs deployed (Figure 13). As this number has increased over time, the variable is confounded with a possible temporal change in the abundance of tuna stocks or with some environmental factor that increased constantly over this period. However, the conclusion that deploying more FADs may result in lower CPPS may be useful for management, and deserves further investigation.

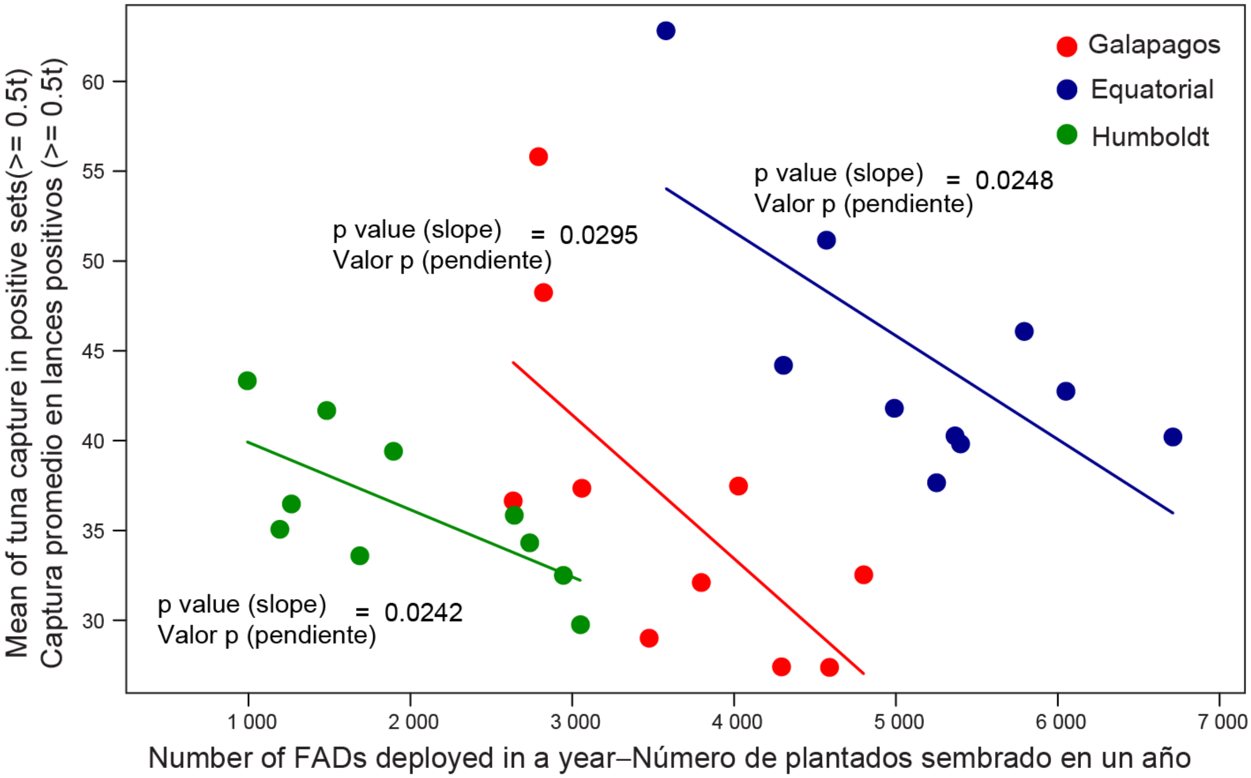


FIGURE 13. Average capture per positive set of all tunas (yellowfin, skipjack and bigeye) in FAD sets, by year and by region.