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

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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.

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 1), due in part to the closure of the US market to tuna caught in association with dolphins, which motivated fishers to explore alternative ways of catching tunas.

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

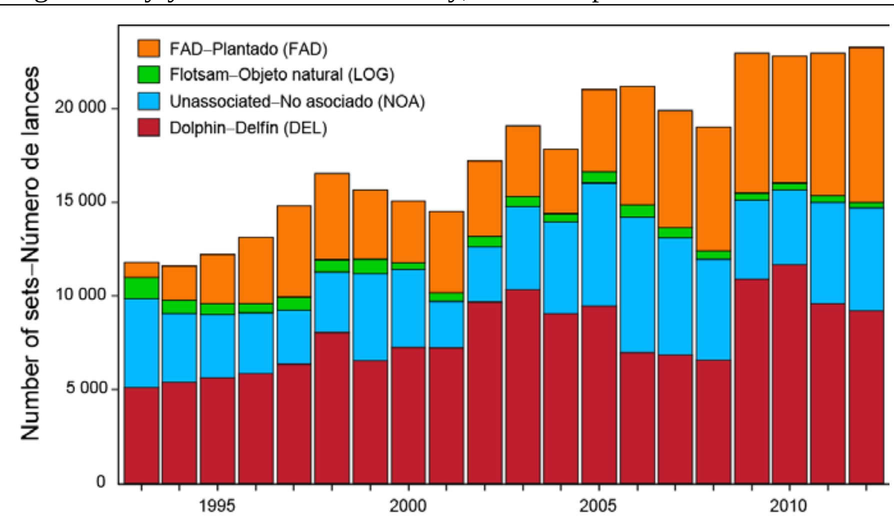

FIGURE 1. Number of sets by set type, 1993-2012**.**

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

industries producing tracking and acoustic technologies developed products for this new market, and the changes have been fast and very significant.

1. FADs: CHARACTERISTICS AND DYNAMICS

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 about a third 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 seem to have reduced the proportion of null sets of any type (Figure 2). The average capture per set did not show differences 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. These analyses are preliminary, and do not take into account potential differences in the spatial and temporal distributions of FADs with and without sonic buoys, differences in FAD construction, or differences in the characteristics of the purse-seine nets used.

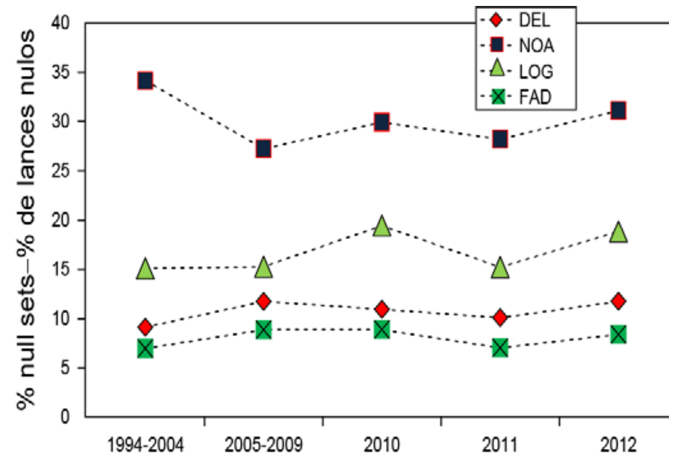

FIGURE 2. Percent of null sets by set type, 1994-2012

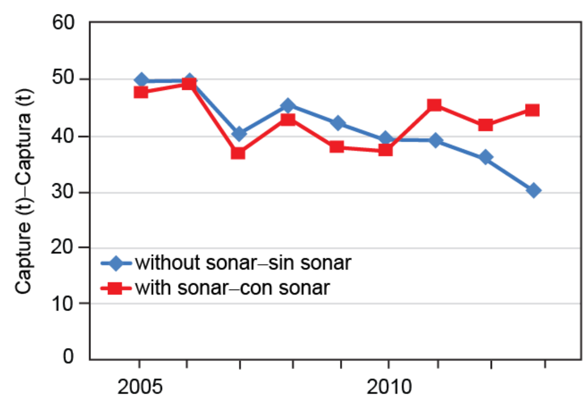

FIGURE 3. Total capture per set on FADs with and without sonar, 2004-2014.

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 over 14,000 in 2013. Most FADs are retrieved, although the percentage retrieved from the EPO was less in 2011-2013 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,

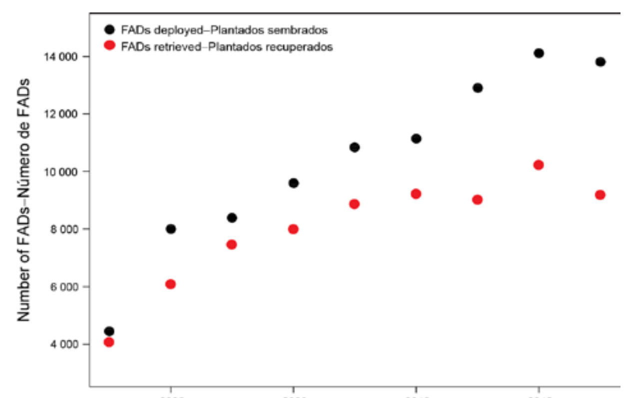

FIGURE 4. Number of FADs observed deployed and retrieved in the EPO by year, 2005-2013.

thus this 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 vessels annually. In 2005, the average number of FADs deployed per vessel was 71; and the highest number of FADs deployed during a single trip was about 250. By 2012 the average number of FADs deployed per observed trip had increased to 131, with some vessels deploying nearly 500. Fleets with several vessels often share FADs, so a vessel may have many more FADs available than it deploys.

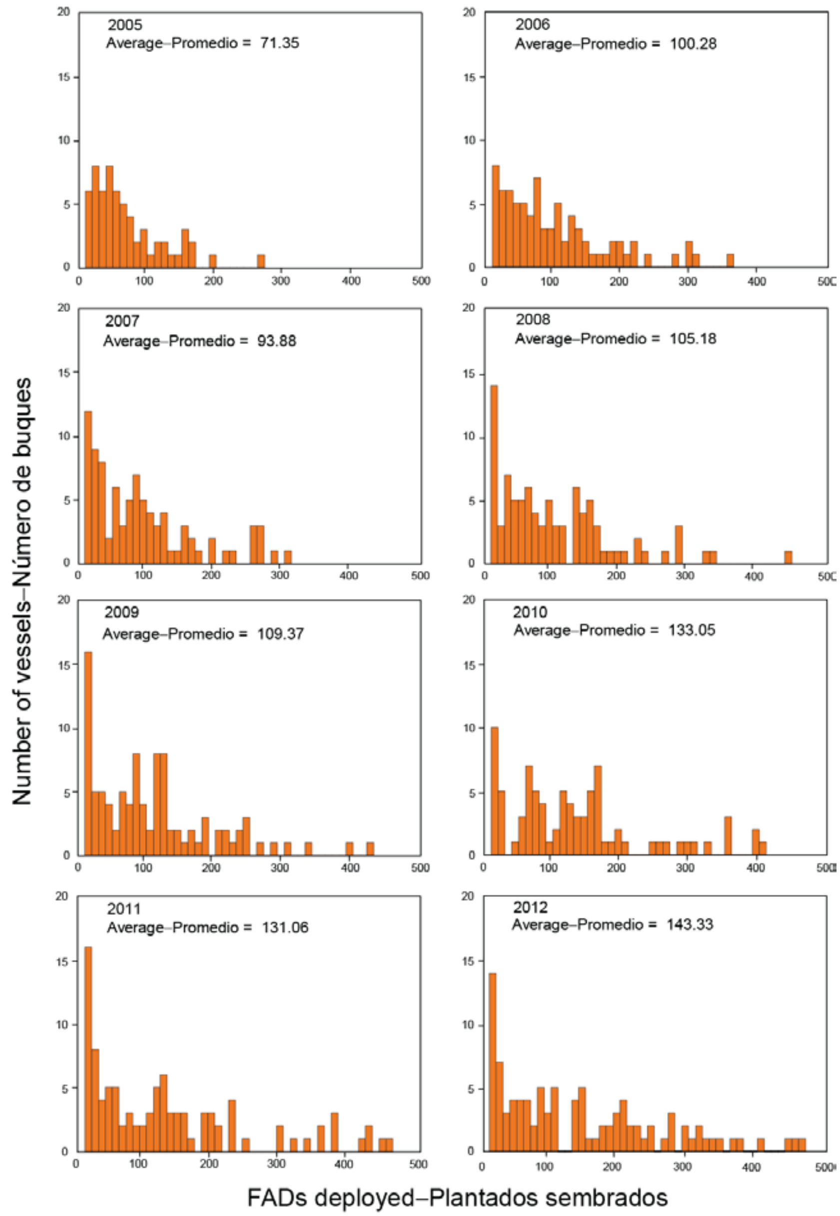

FIGURE 5. FAD deployments by vessels, 2005-2012. Excludes vessels deploying less than 10 FADs in a year.

2. PATTERNS OF FAD DISTRIBUTION IN THE EPO

The patterns of FAD deployments by month, based on observer data from 2010-2012, are illustrated in Figure 6 The lines are not tracks of deployed FADs, but rather the sequential FAD deployments that occur as a vessel follows a given course.

In summary, FAD deployments are concentrated in the Humboldt Current system off Peru during the 1st quarter, 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.

Humboldt Current system: The deployments in this region (roughly between 5°S and 25°S within 600 miles of the coast) are quite seasonal, coinciding with the presence of a "tongue" of warm water that spreads south from the equatorial region to northern Chile. Most of the deployments occur from November to February, moving north in March and April as the warm water recedes. Surface current speeds in this system are slow, and FADs do not move long distances.

Galapagos system: This system occupies the area west of 85°W and east of 100°W between 3°N and 5°S. FAD deployment occurs here year-round, peaking from May to 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, 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 96º and 110ºW from 4°N to 3°S ("*corralito*").

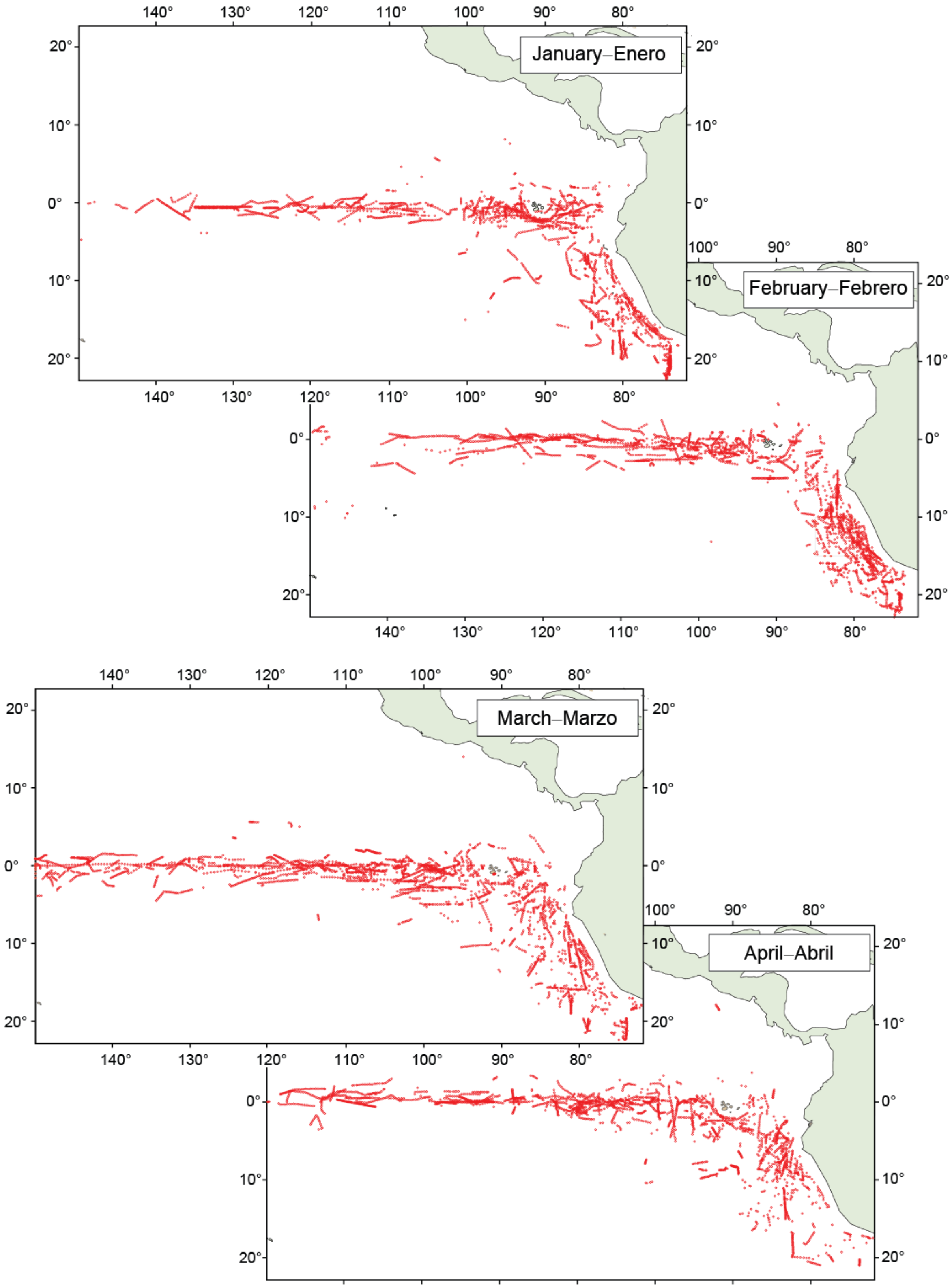

FIGURE 6. Distribution of FAD deployments, by month, 2010-2012

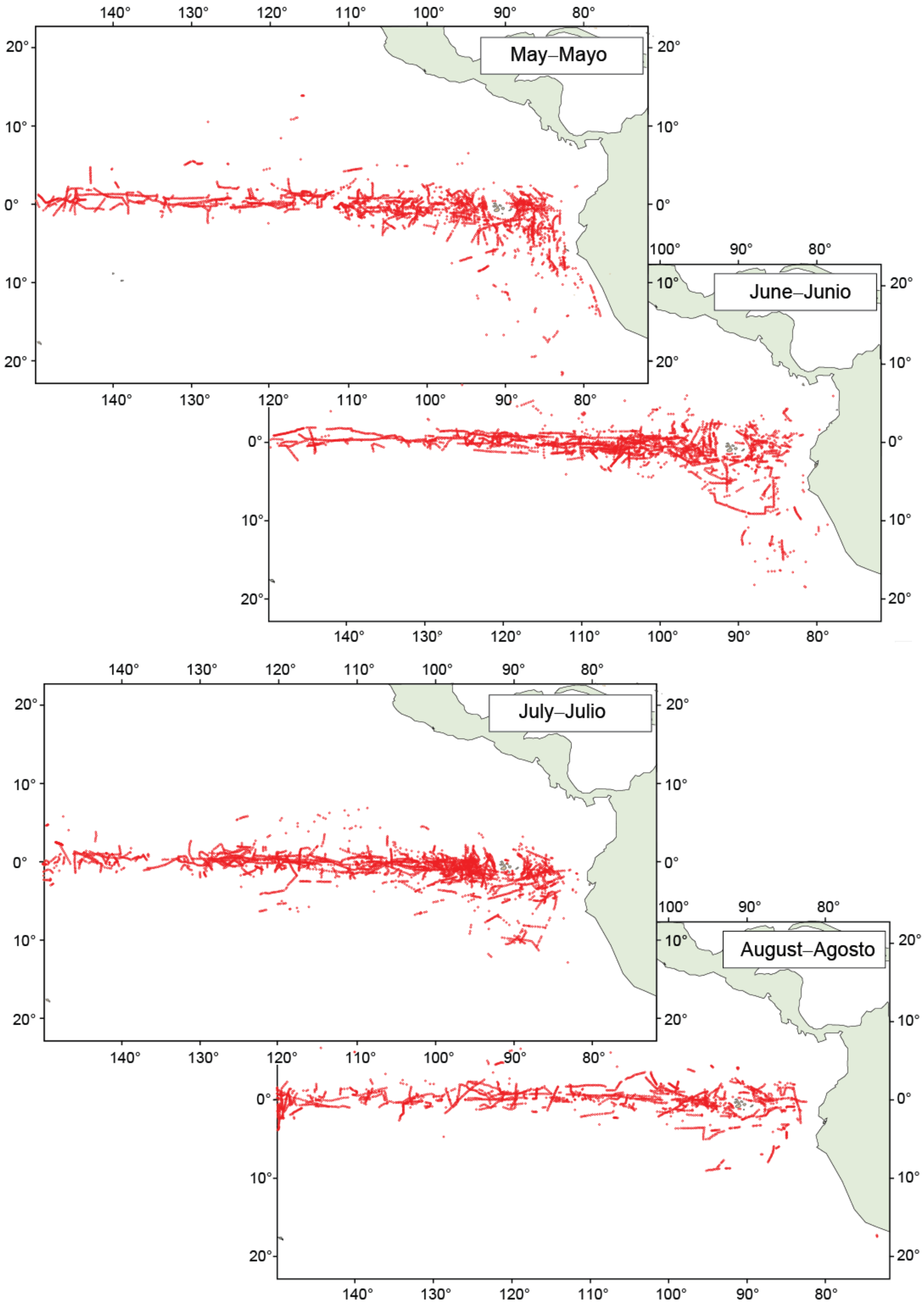

FIGURE 6. Cont. Distribution of FAD deployments, by month, 2010-2012

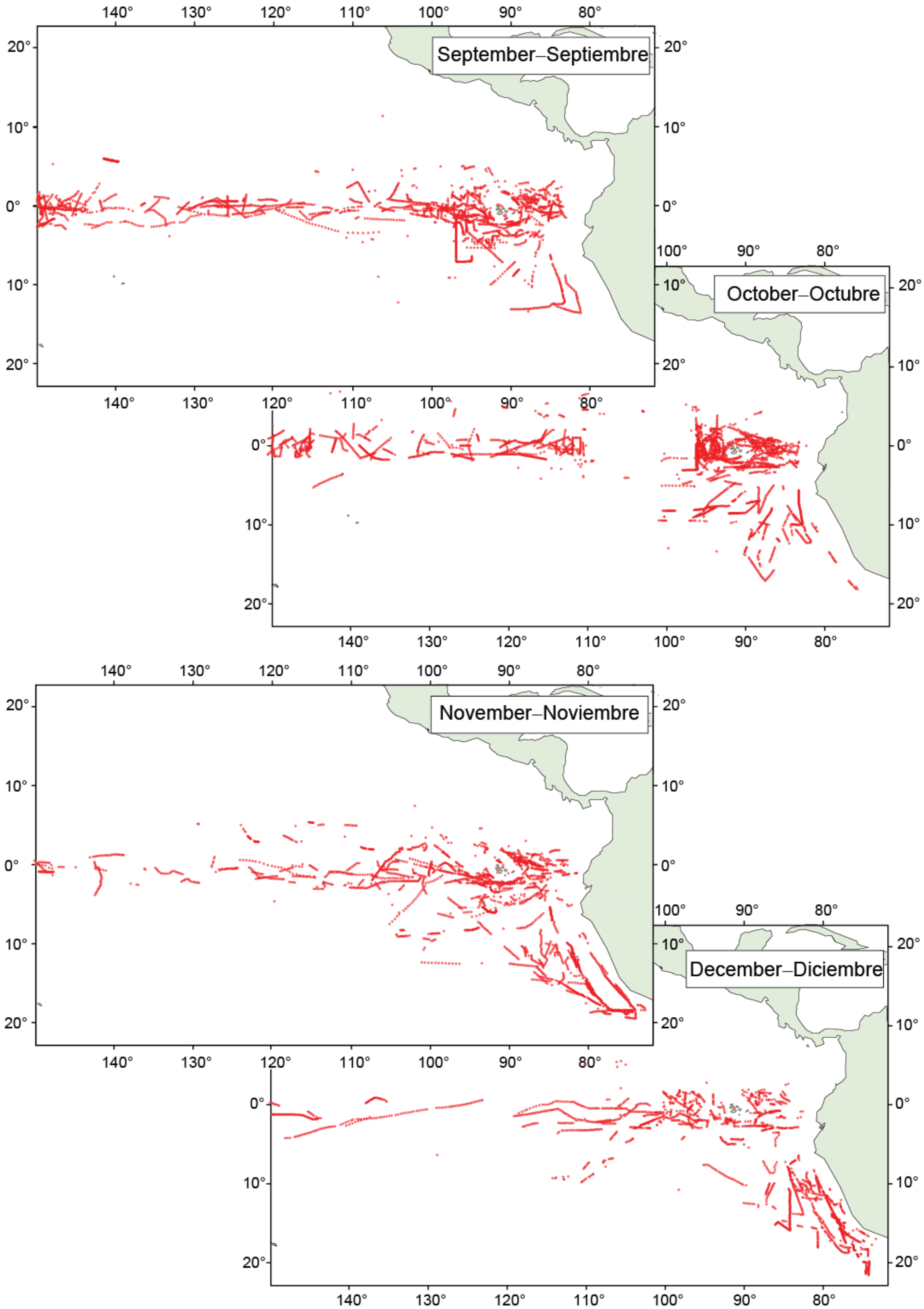

FIGURE 6. Cont. Distribution of FAD deployments, by month, 2010-2012

Figure 7 shows the number of FADs deployed per month by region. The largest numbers of FADs are deployed around Galapagos in June-July and September-October. The numbers decline further to the west.

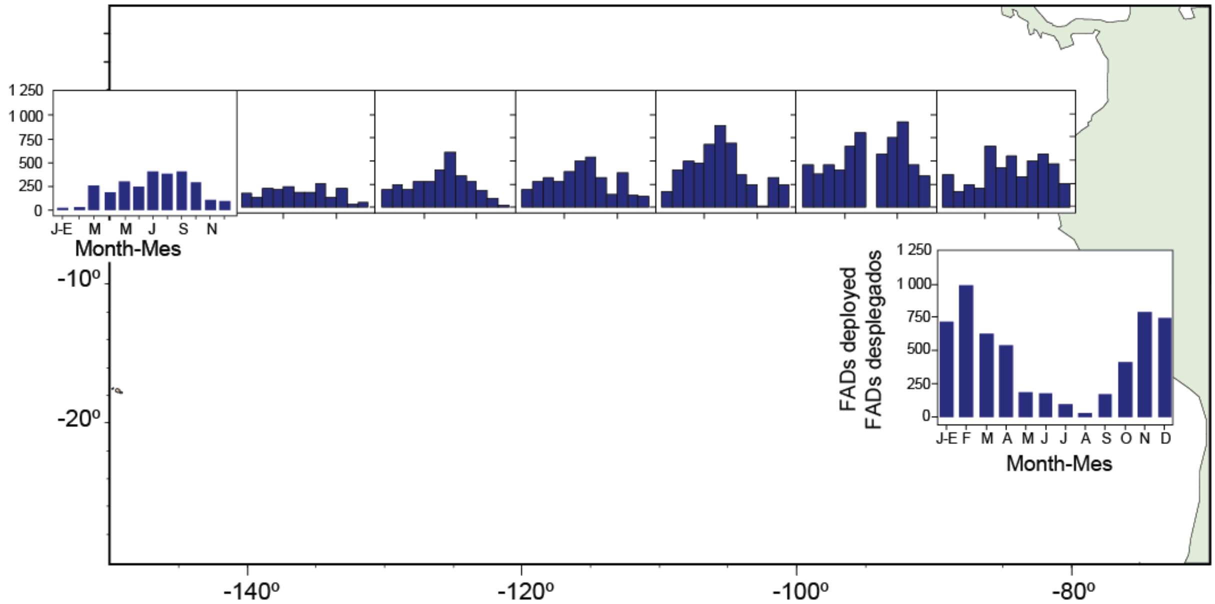

FIGURE 7. Number of FADs deployed by month and by area. Period 2010 – 2012

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 8 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.

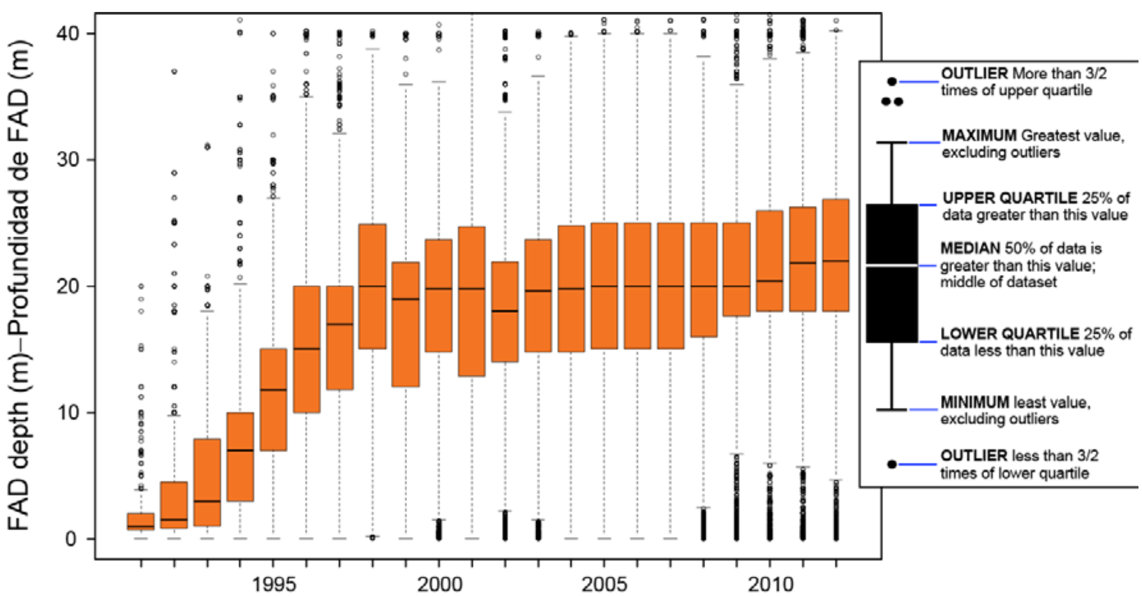

FIGURE 8. Box plots showing average depth of FAD net webbing, by year. Period 1991-2012.

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 does 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 of 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. [CAPTURA LIBERADA]

5. SPECIES COMPOSITIONS OF CAPTURES IN FAD SETS

Total tuna captures (Figure 9): shows aggregate FAD set catches in the three regions partitioned 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.

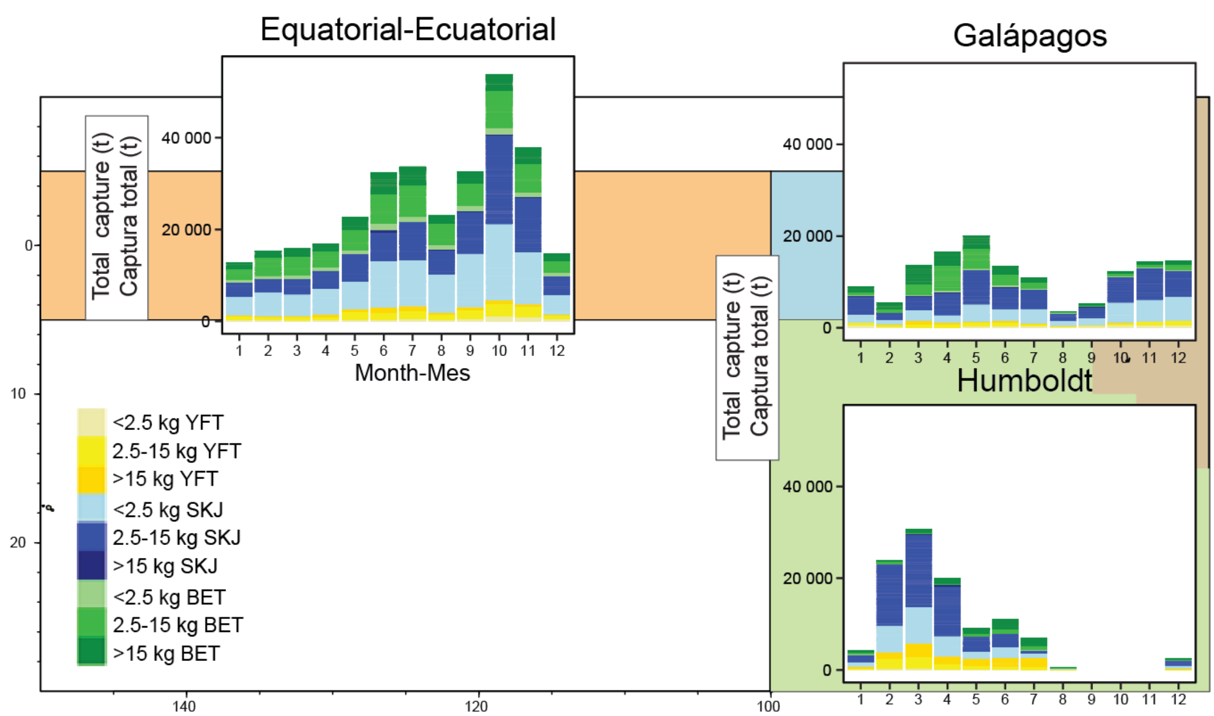

FIGURE 9. Total captures of tunas, by species and size, in sets on FADs, by month and area, 2010-2012.

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).

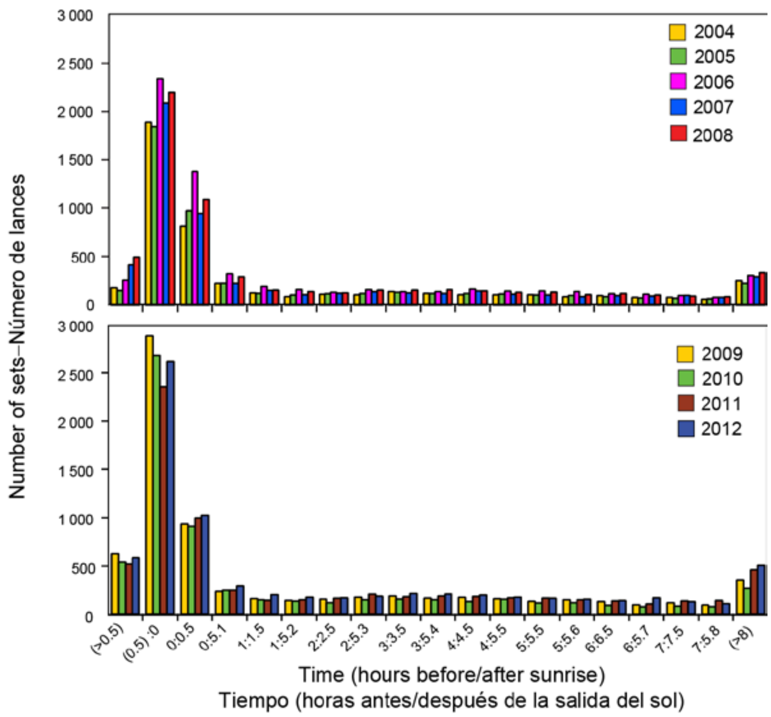

FIGURE 10. Timing of FAD sets relative to sunrise, 2004-2012.

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 (usually after a very long set), *etc.* Figure 11 show the average percentage of tuna capture discarded as bycatch, by year, for floating-object sets (inclusive of FAD sets), unassociated sets and dolphin sets, respectively. 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 to historical lows: since the mid-1990s they have fallen from around 16% to about 1-2% in floating-object sets, from 2% to close to 0.2% in unassociated sets, and from about 0.6% to essentially zero in dolphin sets. 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).

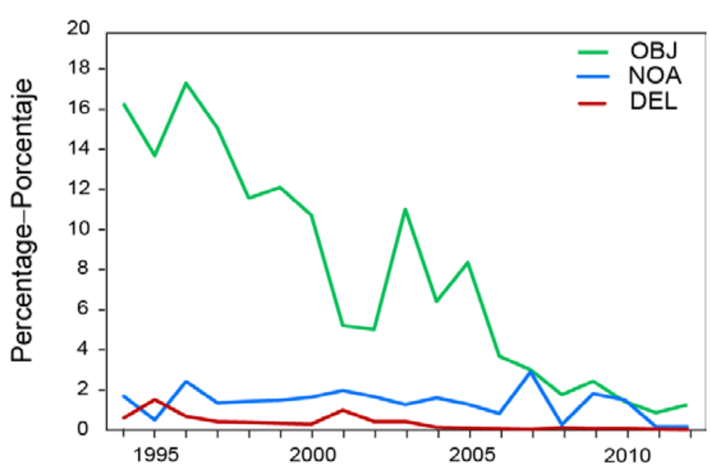

FIGURE 11. Percentage of tuna discards, by set type, 1994-2012.

Utilization of non-tuna species: Even though some non-target species have always been retained, the rates of retention of some species have increased considerably. The distinction between target and non-target species may change with economic or management actions. Billfishes, mahi-mahi, wahoo, and other large pelagic species are utilized in a variety of forms as small parallel industries to process them have developed. In order to improve retention of some of these species, several changes in the fishing operations have occurred: for example, divers harpoon individual specimens for high-quality markets, and some vessels dedicate wells to species other than tuna, where they are stored using methods other than the brine solution used to store tuna, while others store some species, such as mahi-mahi, in tuna wells, but later on wash away the salt and restore the appearance of the fish. Figure 12 shows the increasing utilization of species such as mahi-mahi and wahoo captured in FAD sets. However, not all species have found markets: rainbow runners and yellowtail captured in FAD sets are still typically discarded (Figure 13). Nonetheless, the overall retention of non-tuna species has increased from 30% in 1993 to 75% in 2012 (Figure 14).

Recent developments and current levels of bycatch: Table 1a. reflects observer data on total captures and bycatches for the year 2013. Table 1b. shows captures and bycatches but expressed per 1000 MT of tuna capture Errors may be introduced by misidentifications, unobserved mortalities, etc., but it is believed that most of the mortality is accurate and accounted for. Practically all species show lower bycatch rates in recent years than in previous years. Where reduced rates are observed, the possible sources of the reductions should be considered carefully. Such reductions may reflect changes in abundance, changed in fishing 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 their relative abundance. On the other hand, the reduced bycatch rates of some large pelagic species (billfishes, mahi-mahi, wahoo, *etc*.) is likely due, at least in part, to higher utilization rates due to expanded markets for these fish.

The increasing utilization of individuals that would have been discarded dead otherwise, does not add to the fishing mortality resulting from the harvest. To the extent that non-tuna species increasingly occupy well space on PS vessels, this may be a positive step in the sense that it may result in the distribution of 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.

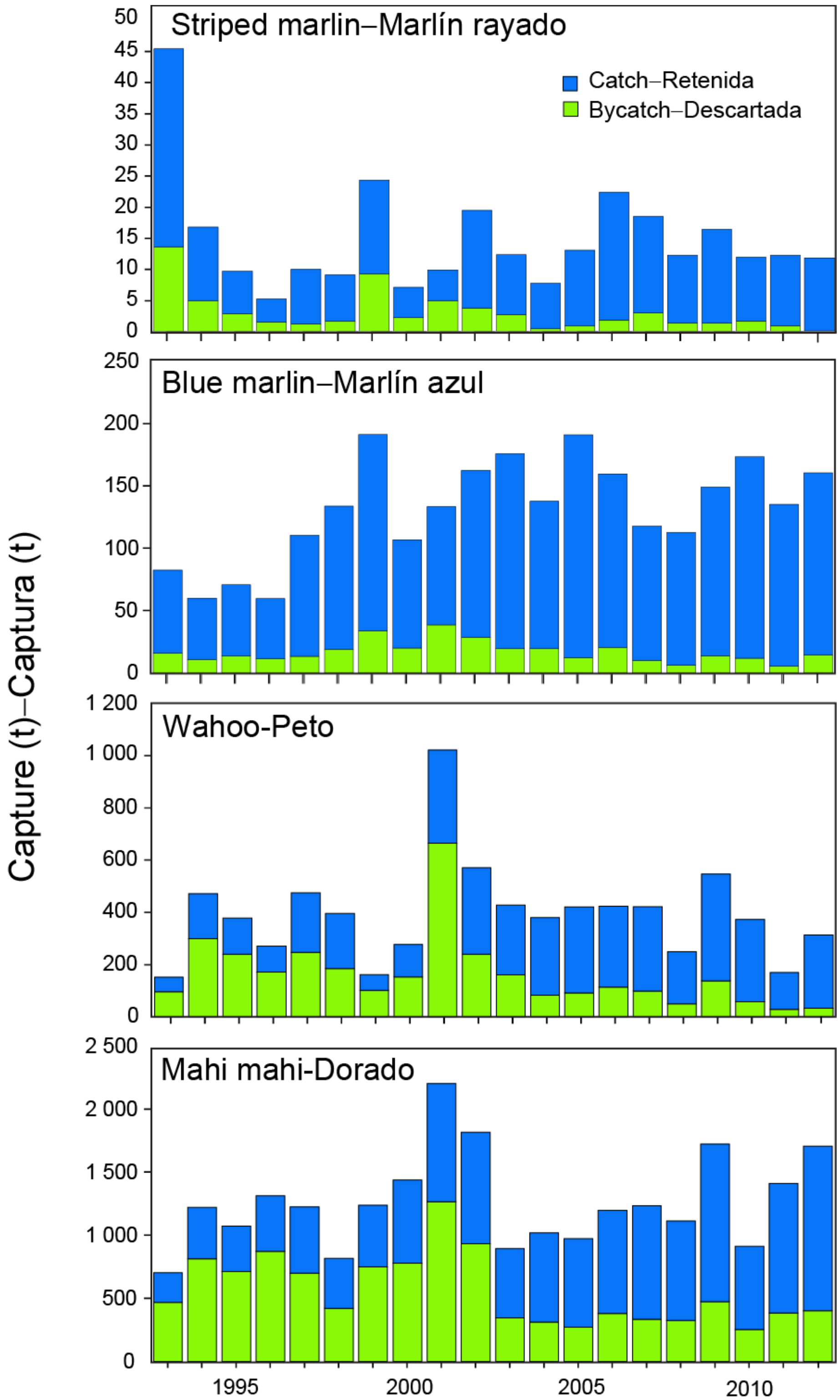

FIGURE 12. Utilization of striped marlin, blue marlin, wahoo, and mahi mahi captured in FAD sets, 1993-2012.

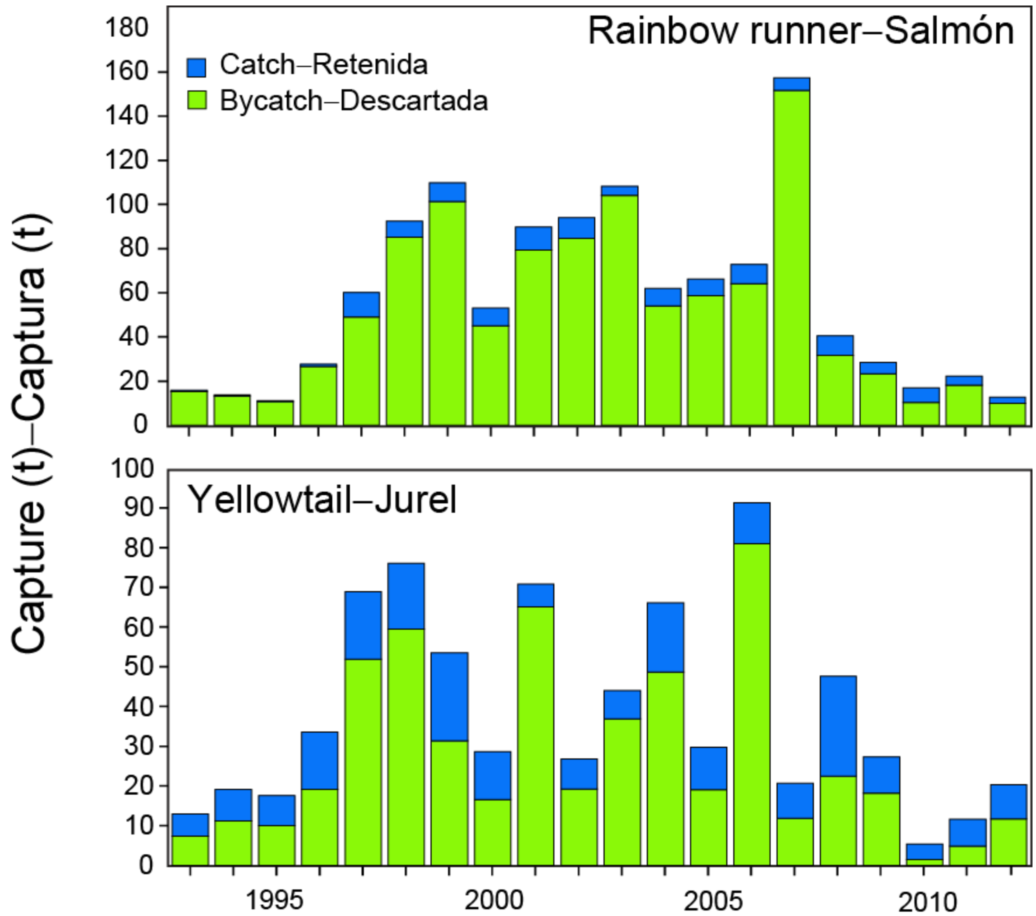

FIGURE 13. Discards of rainbow runner and yellowtail in FAD sets, 1993-2012.

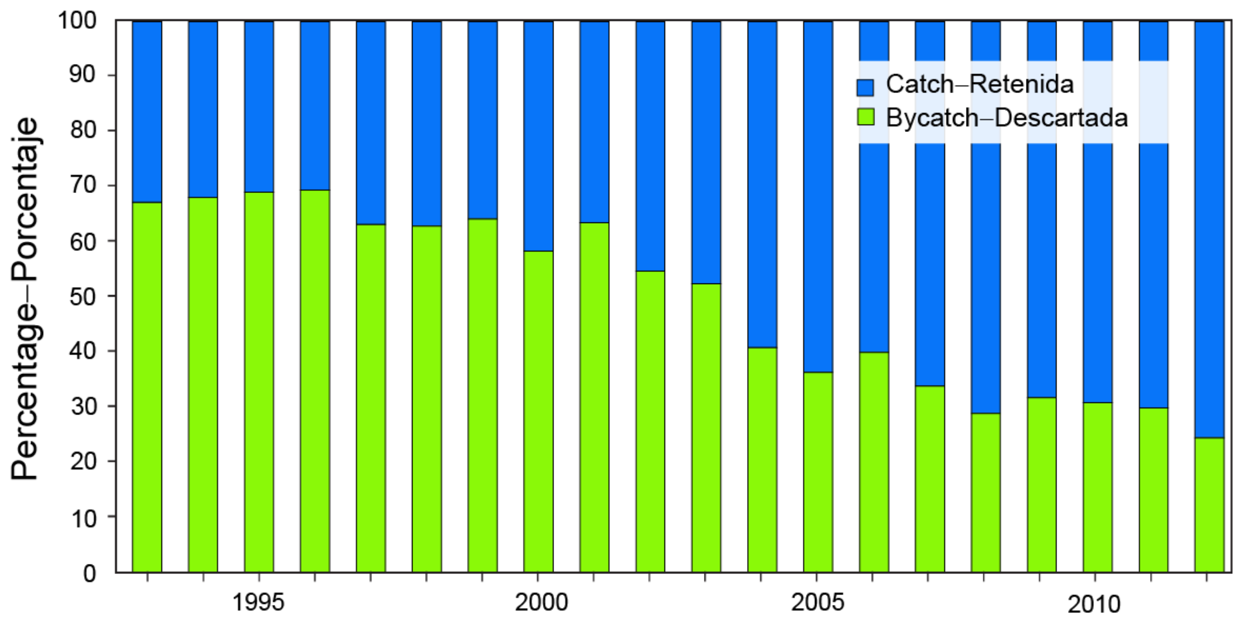

FIGURE 14. Utilization of non-tuna species captured in FAD sets, 1993-2012.

TABLE 1a.

Year: 2013

Class 6 Purse-Seine Vessels

(excluding marine mammals)

Estimated total capture and bycatch in MT in 2013 by set type and all sets combined

Species	Dolphin sets DEL Bycatch	DEL Capture	NOA Bycatch	NOA Capture	OBJ Bycatch	OBJ Capture	All Sets Bycatch	All Set Capture
Sailfish	1.24	14.92	0.45	1.74	0.01	0.72	1.71	17.38
Blue marlin	0.15	12.36	0.64	5.31	14.42	169.90	15.20	187.57
Black marlin	0.28	7.70	0.14	5.69	3.79	89.65	4.21	103.04
Striped marlin	0.20	6.43	0.00	3.57	0.47	12.13	0.67	22.13
Other/Unid billfish	0.00	1.50	0.20	2.13	2.54	17.73	2.74	21.36
Silky shark	0.83	38.14	4.71	54.72	124.61	212.29	130.15	305.15
Oceanic whitetip shark	0.00	0.00	0.01	0.01	0.68	0.89	0.68	0.90
Scalloped hammerhead	0.45	0.62	0.68	1.99	15.61	21.88	16.74	24.49
Smooth hammerhead	0.23	0.33	0.57	1.95	36.86	48.54	37.65	50.82
Other/Unid HH shark	0.18	0.22	0.50	1.59	7.84	9.05	8.51	10.86
Other/Unid shark	2.80	9.92	3.31	7.07	54.11	59.30	60.23	76.29
Giant manta	14.41	14.41	10.19	10.19	0.63	0.63	25.23	25.23
Spinetail manta	4.76	4.78	8.35	8.50	1.20	1.20	14.31	14.48
Chilean devil ray	1.03	1.07	3.42	3.42	0.73	0.86	5.18	5.35
Smoothtail manta	1.42	1.56	6.36	6.40	0.85	0.89	8.63	8.85
Munk's devil ray	0.17	0.17	1.37	1.37	0.12	0.12	1.66	1.66
Unid Manta/devil rays	5.92	6.17	5.42	5.52	1.24	1.25	12.58	12.94
Pelagic stingray	0.68	0.69	0.16	0.16	0.24	0.24	1.08	1.09
Other/Unid rays	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mahi mahi	0.00	0.46	1.60	6.87	489.14	1,457.79	490.74	1,465.12
Wahoo	0.00	0.07	0.03	1.47	86.04	518.90	86.07	520.44
Rainbow runner	0.00	0.00	0.00	0.33	10.02	18.77	10.02	19.10
Yellowtail	0.93	0.93	0.42	1.81	5.26	12.24	6.61	14.98
Other large fish	2.24	2.78	28.00	29.04	4.82	11.42	35.06	43.24
Olive ridley turtle	0.00	0.00	0.03	0.03	0.22	0.22	0.25	0.25
Loggerhead turtle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green/black turtle	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.02
Leatherback turtle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hawksbill turtle	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.04
Unid turtle	0.00	0.00	0.00	0.00	0.07	0.07	0.07	0.07

TABLE 1b.

Year: 2013

Class 6 Purse-Seine Vessels

(excluding marine mammals)

Bycatch and capture in MT per 1000 MT of tunas captured in 2013 by set type and all sets combined

Species	DEL Bycatch	DEL Capture	NOA Bycatch	NOA Capture	OBJ Bycatch	OBJ Capture	All Sets Bycatch	All Set Capture
Sailfish	0.01	0.09	0.01	0.02	0.00	0.00	0.01	0.11
Blue marlin	0.00	0.08	0.01	0.07	0.06	0.73	0.07	0.88
Black marlin	0.00	0.05	0.00	0.08	0.02	0.39	0.02	0.52
Striped marlin	0.00	0.04	0.00	0.05	0.00	0.05	0.00	0.14
Other/Unid billfish	0.00	0.01	0.00	0.03	0.01	0.08	0.01	0.12
Silky shark	0.01	0.23	0.06	0.73	0.53	0.91	0.60	1.87
Oceanic whitetip shark	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scalloped hammerhead	0.00	0.00	0.01	0.03	0.07	0.09	0.08	0.12
Smooth hammerhead	0.00	0.00	0.01	0.03	0.16	0.21	0.17	0.24
Other/Unid HH shark	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.06
Other/Unid shark	0.02	0.06	0.04	0.09	0.23	0.26	0.29	0.41
Giant manta	0.09	0.09	0.14	0.14	0.00	0.00	0.23	0.23
Spinetail manta	0.03	0.03	0.11	0.11	0.01	0.01	0.15	0.15
Chilean devil ray	0.01	0.01	0.05	0.05	0.00	0.00	0.06	0.06
Smoothtail manta	0.01	0.01	0.09	0.09	0.00	0.00	0.10	0.10
Munk's devil ray	0.00	0.00	0.02	0.02	0.00	0.00	0.02	0.02
Unid Manta/devil rays	0.04	0.04	0.07	0.07	0.01	0.01	0.11	0.12
Pelagic stingray	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Other/Unid rays	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mahi mahi	0.00	0.00	0.02	0.09	2.05	6.24	2.07	6.33
Wahoo	0.00	0.00	0.00	0.02	0.36	2.23	0.36	2.25
Rainbow runner	0.00	0.00	0.00	0.00	0.04	0.08	0.04	0.08
Yellowtail	0.01	0.01	0.01	0.02	0.02	0.05	0.03	0.08
Other large fish	0.01	0.02	0.38	0.39	0.02	0.05	0.41	0.46
Olive ridley turtle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Loggerhead turtle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green/black turtle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leatherback turtle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hawksbill turtle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unid turtle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00