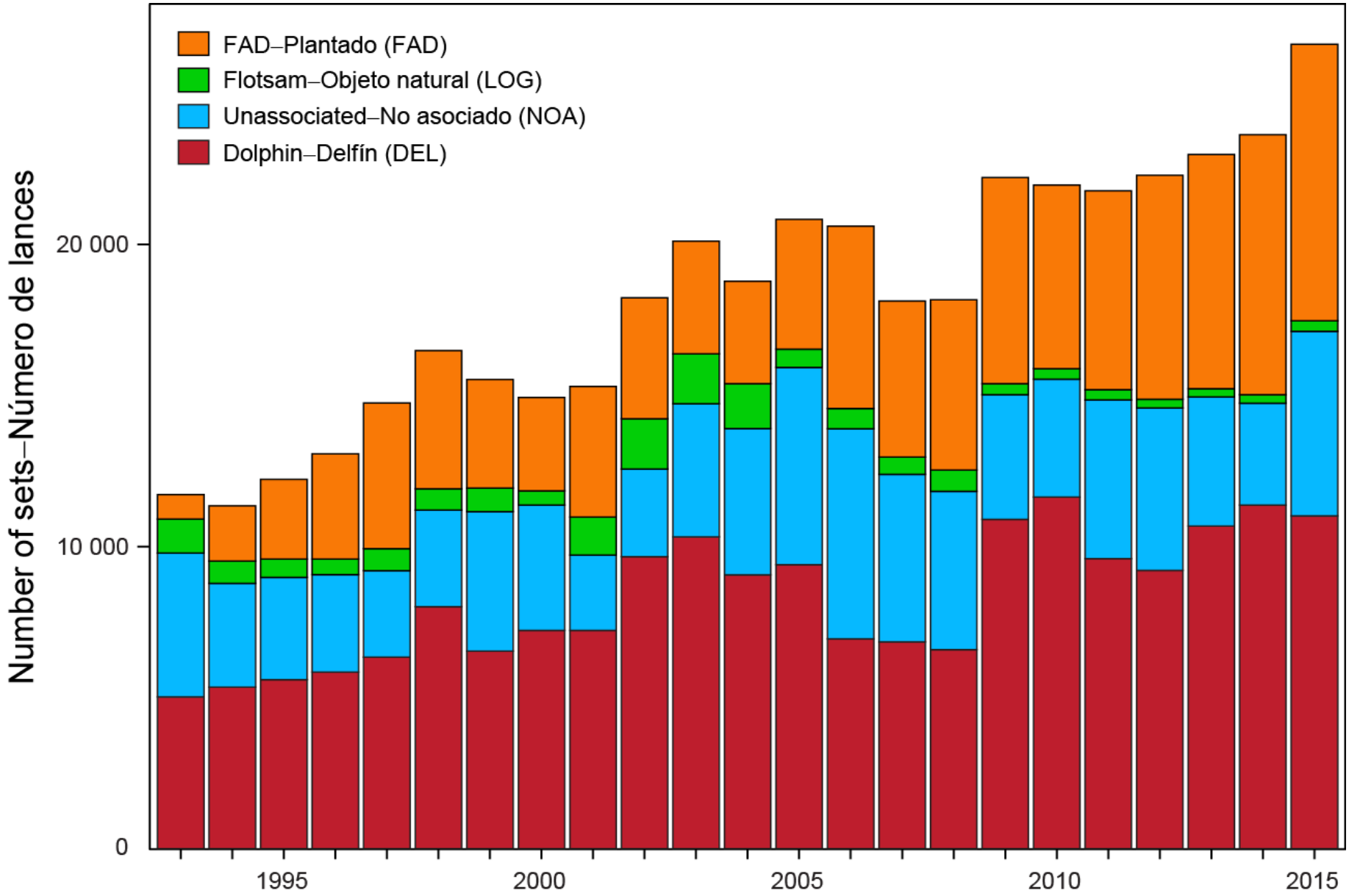
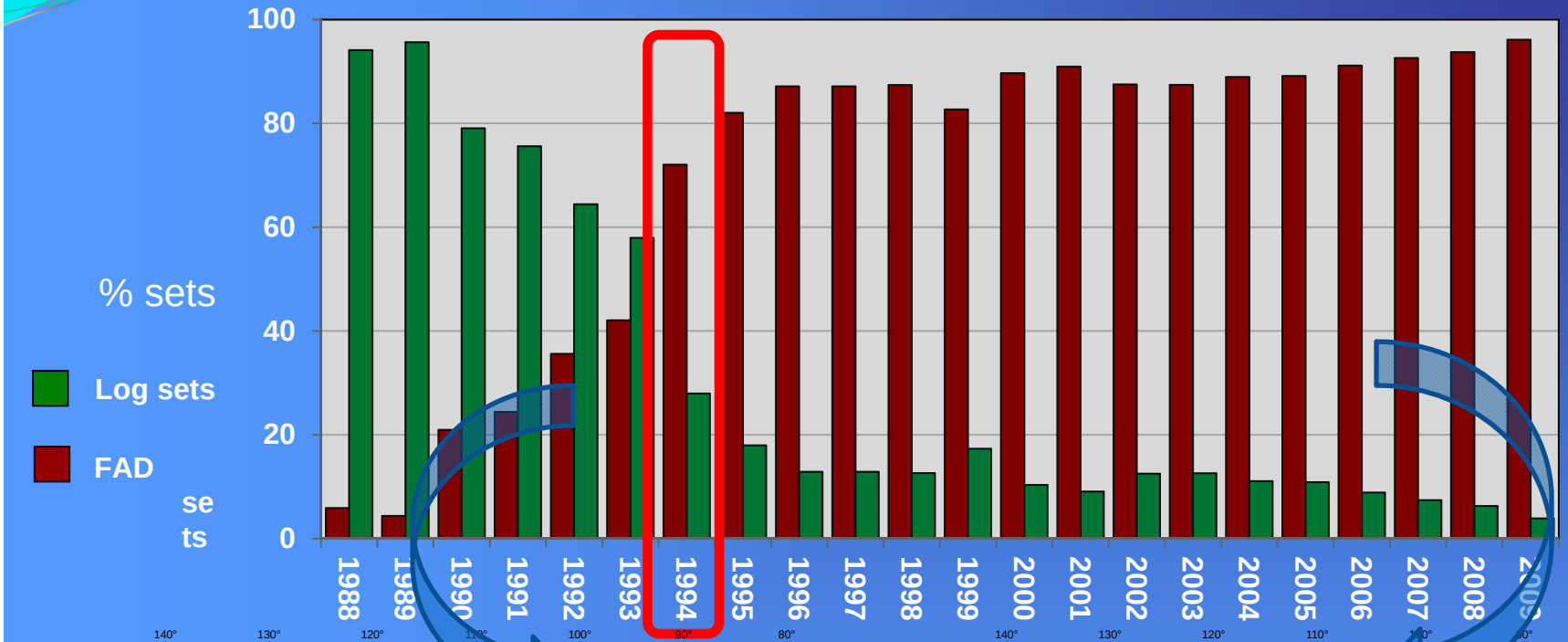
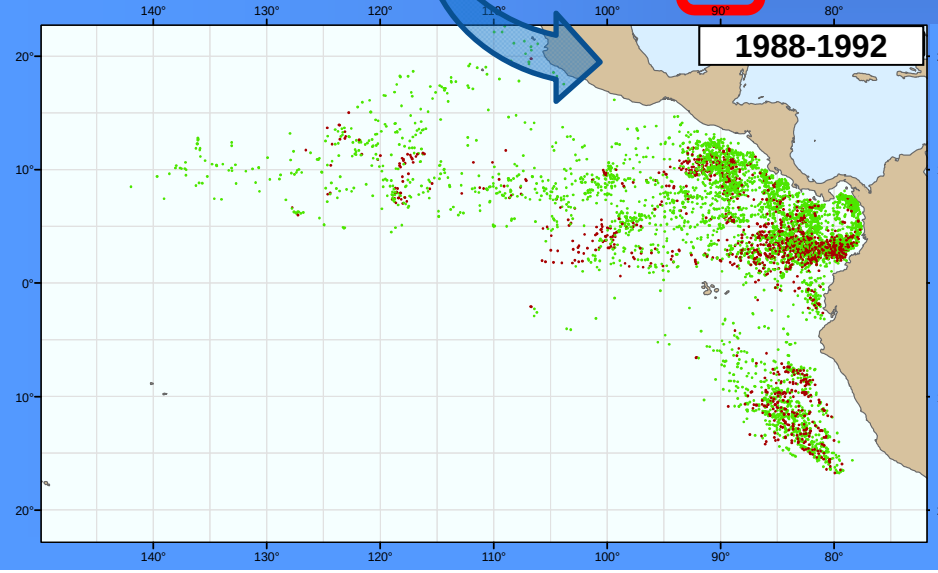
The evolution of the FAD fishery in the eastern Pacific

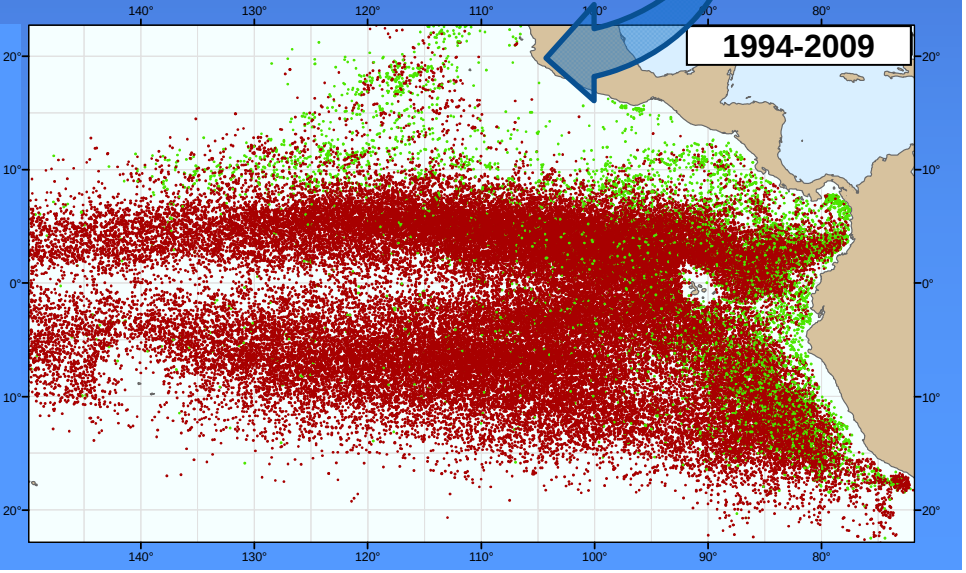
M. Hall and M. Roman


FAD–Plantado (FAD)
Flotsam–Objeto natural (LOG)
Unassociated–No asociado (NOA)
Dolphin–Delfín (DEL)
Number of sets–Número de lances
0
10 000
20 000
1995
2000
2005
2010
2015

FAD sets vs. Log sets





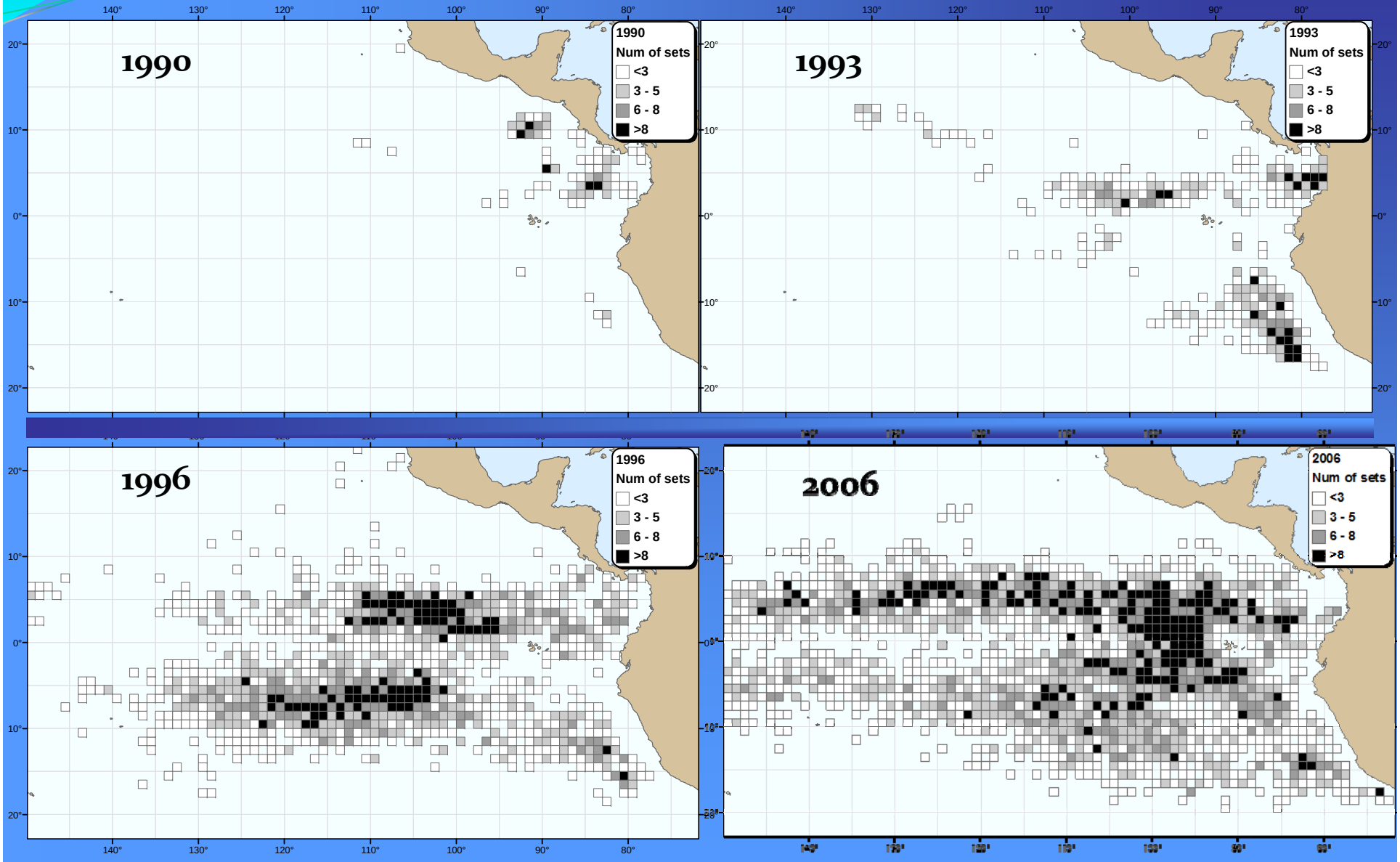


- Area 1 set (net diam. 600 m)
- 3.14x300x300 = 283,000 sq m = 0.11 sq mile

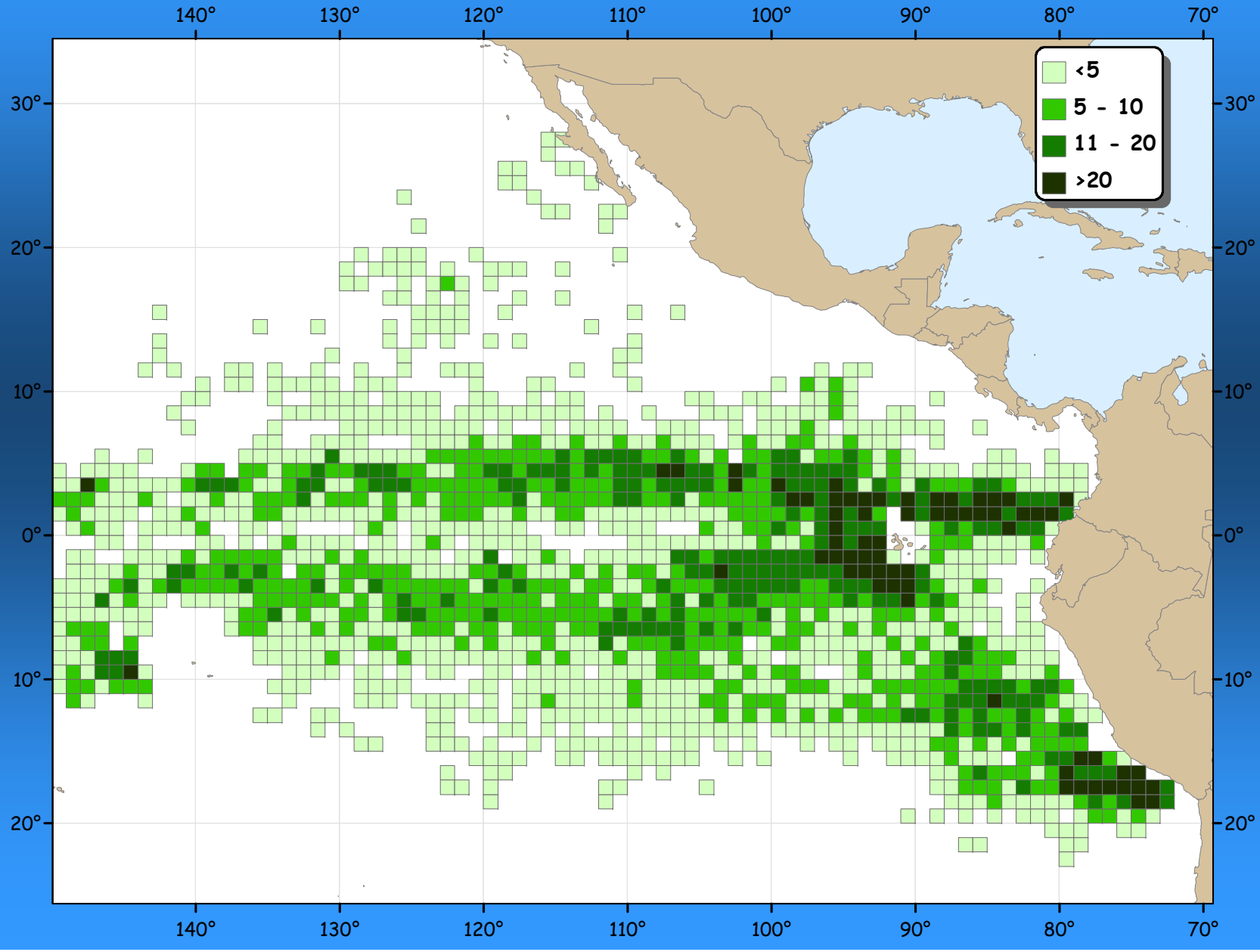
- 30,000 sets = 3,300 sq miles
- 1 degree square 68 miles x 68 miles = 4,624 sq miles

- All fishing effort in one year fits in one degree square with 30% of the square left to spare

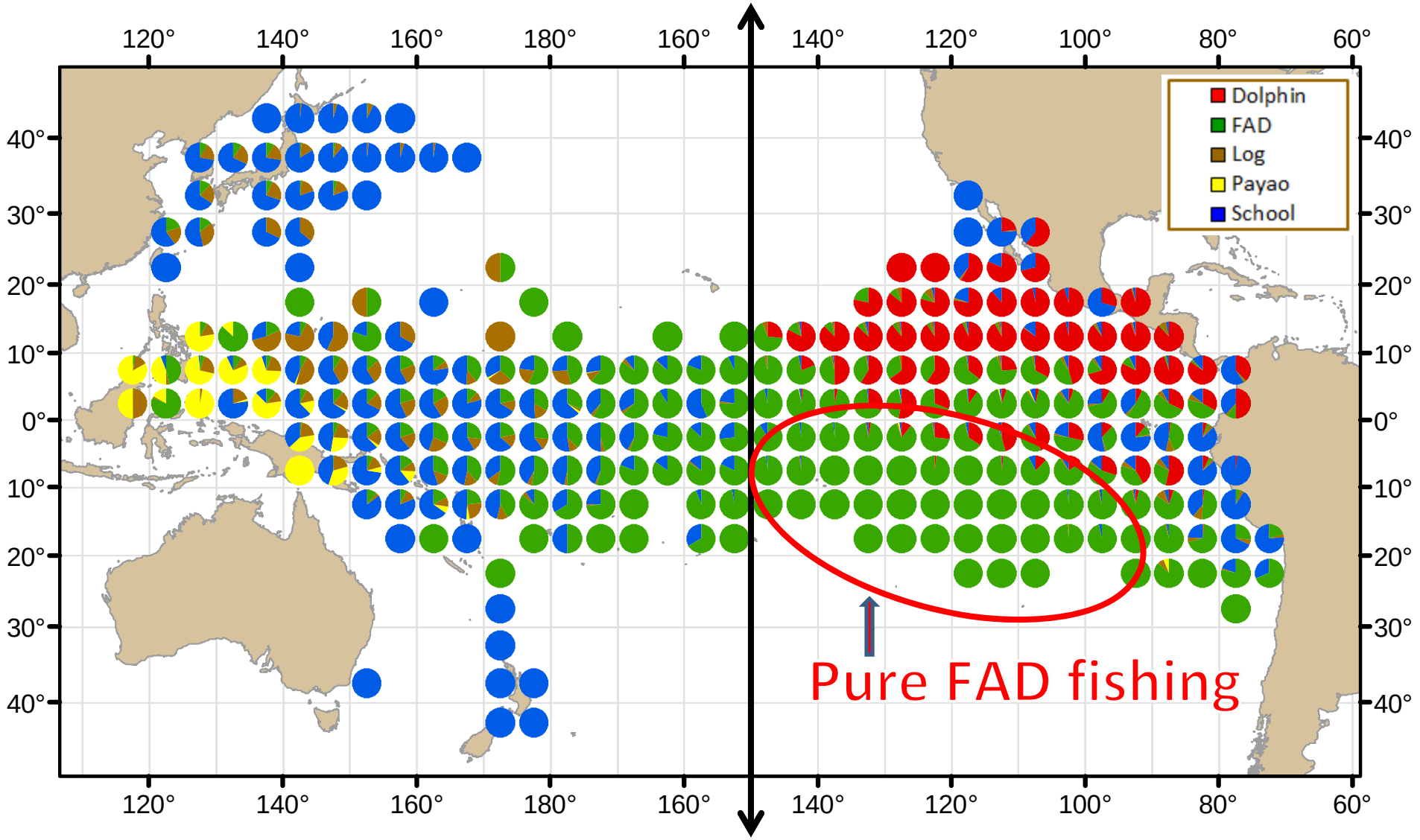
Spatial distribution of sets on FADs



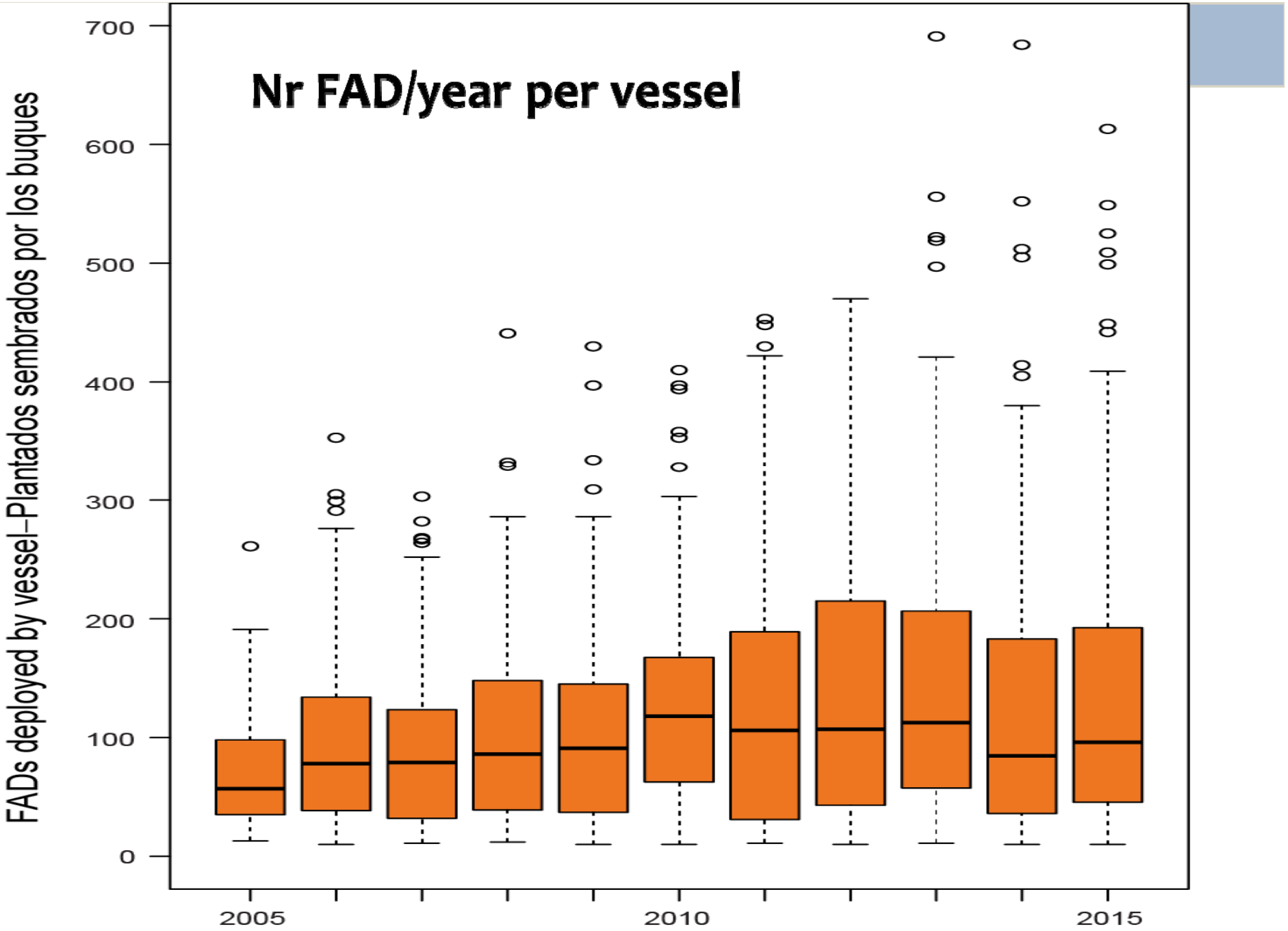
Nr Floating object sets 2015



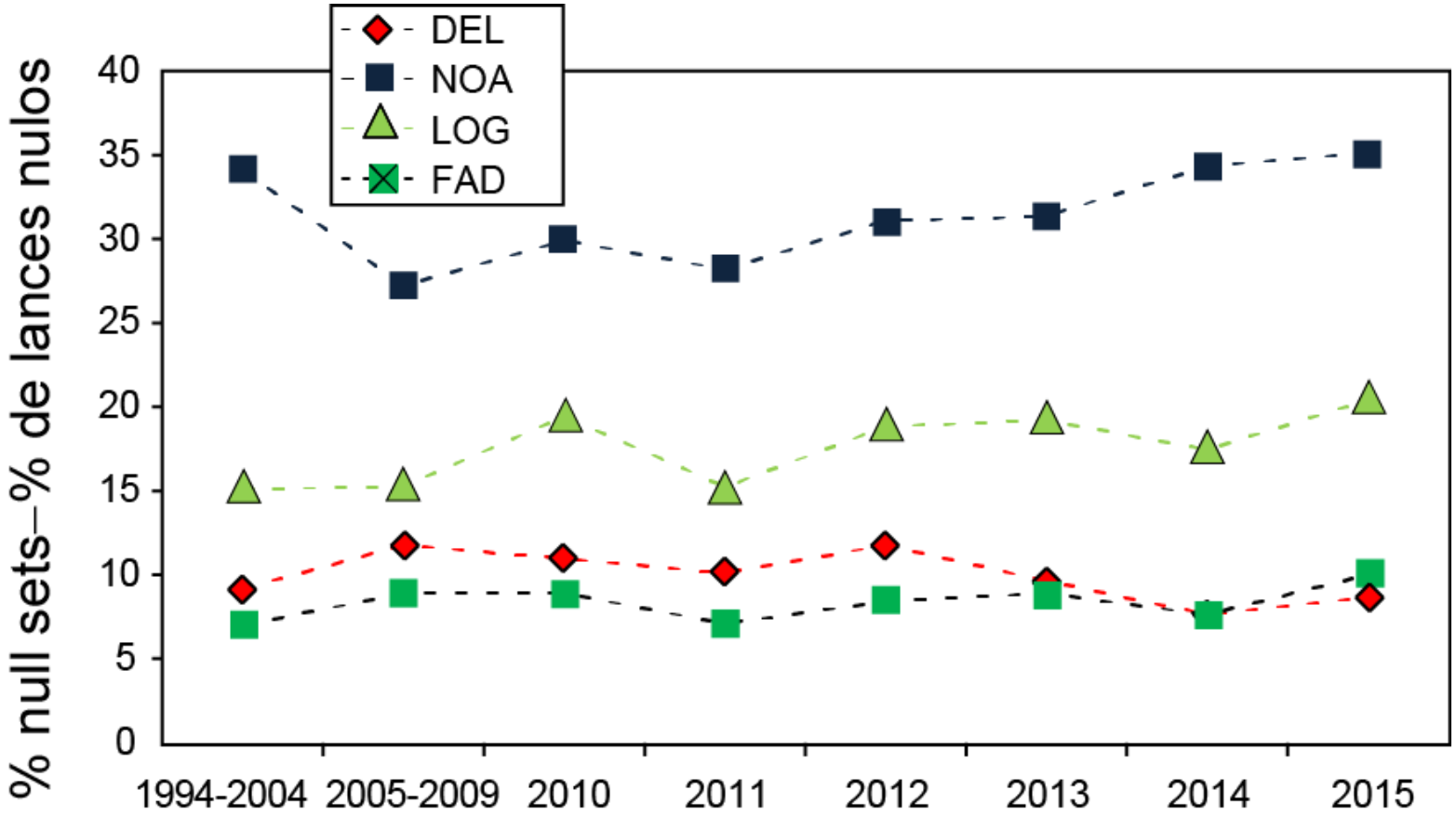
Distribution of sets by all type
2005 - 2011

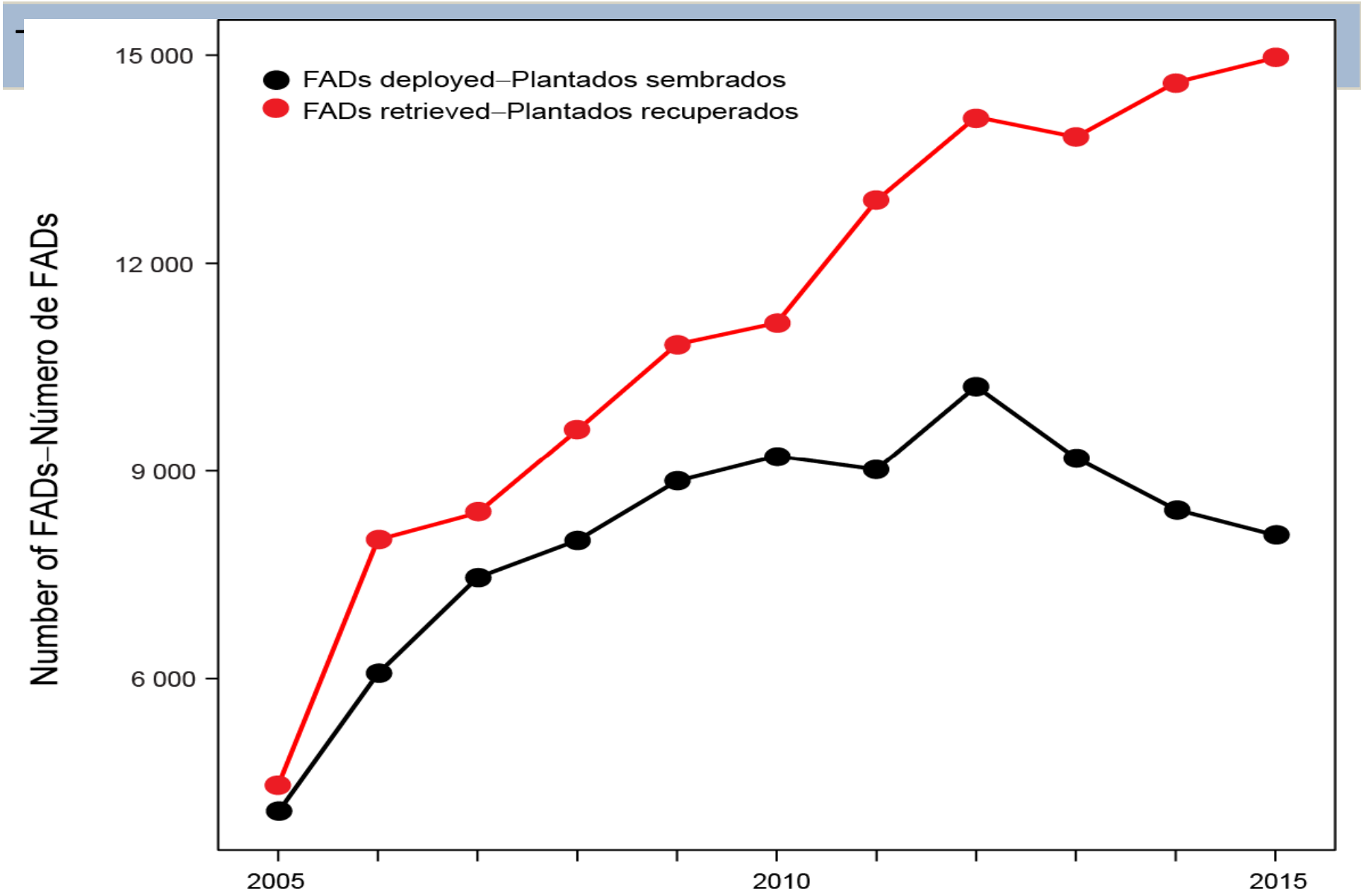


T

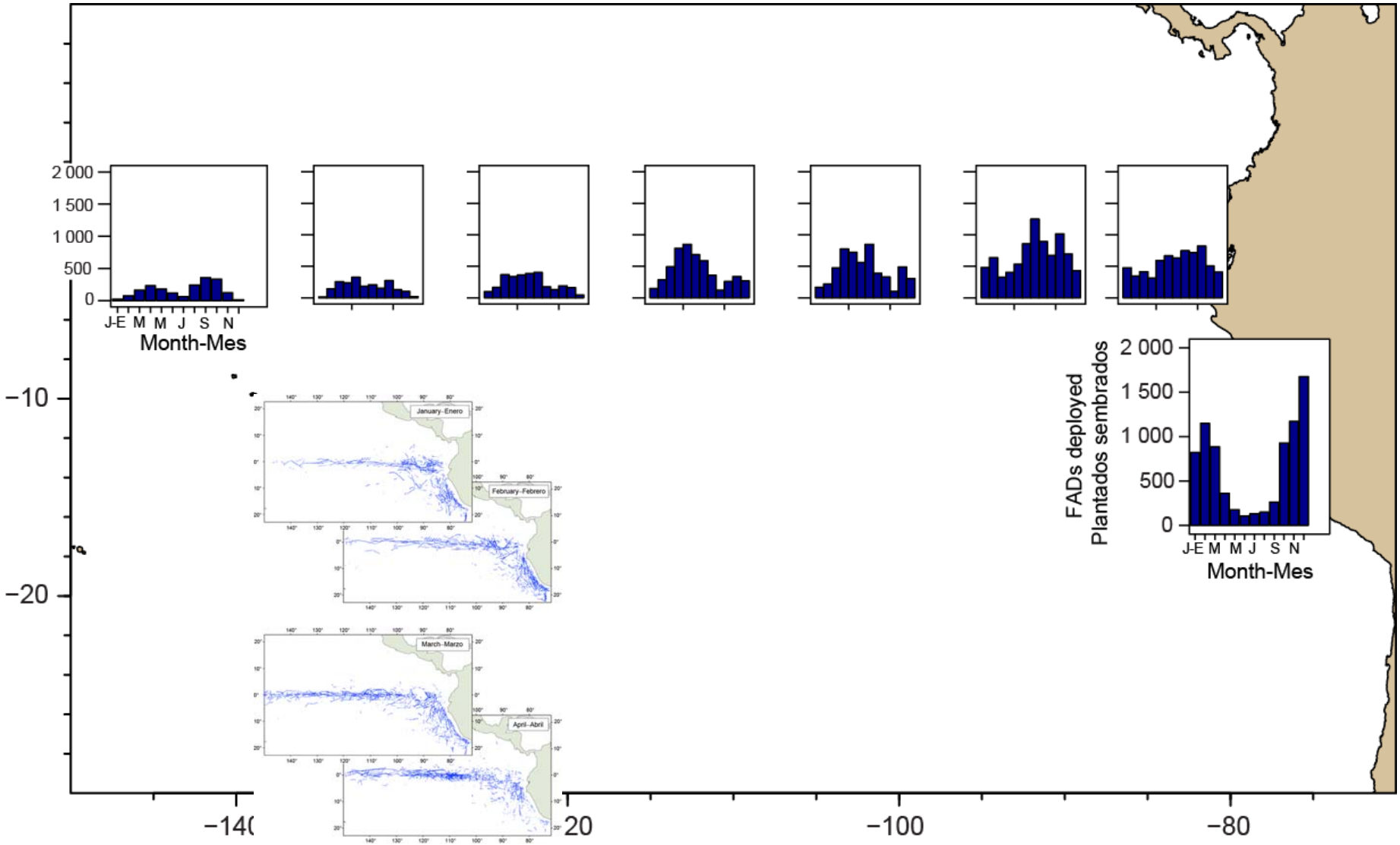

Nr FAD/year per vessel
FADs deployed by vessel–Plantados sembrados por los buques
0
100
200
300
400
500
600
700
2005
2010
2015

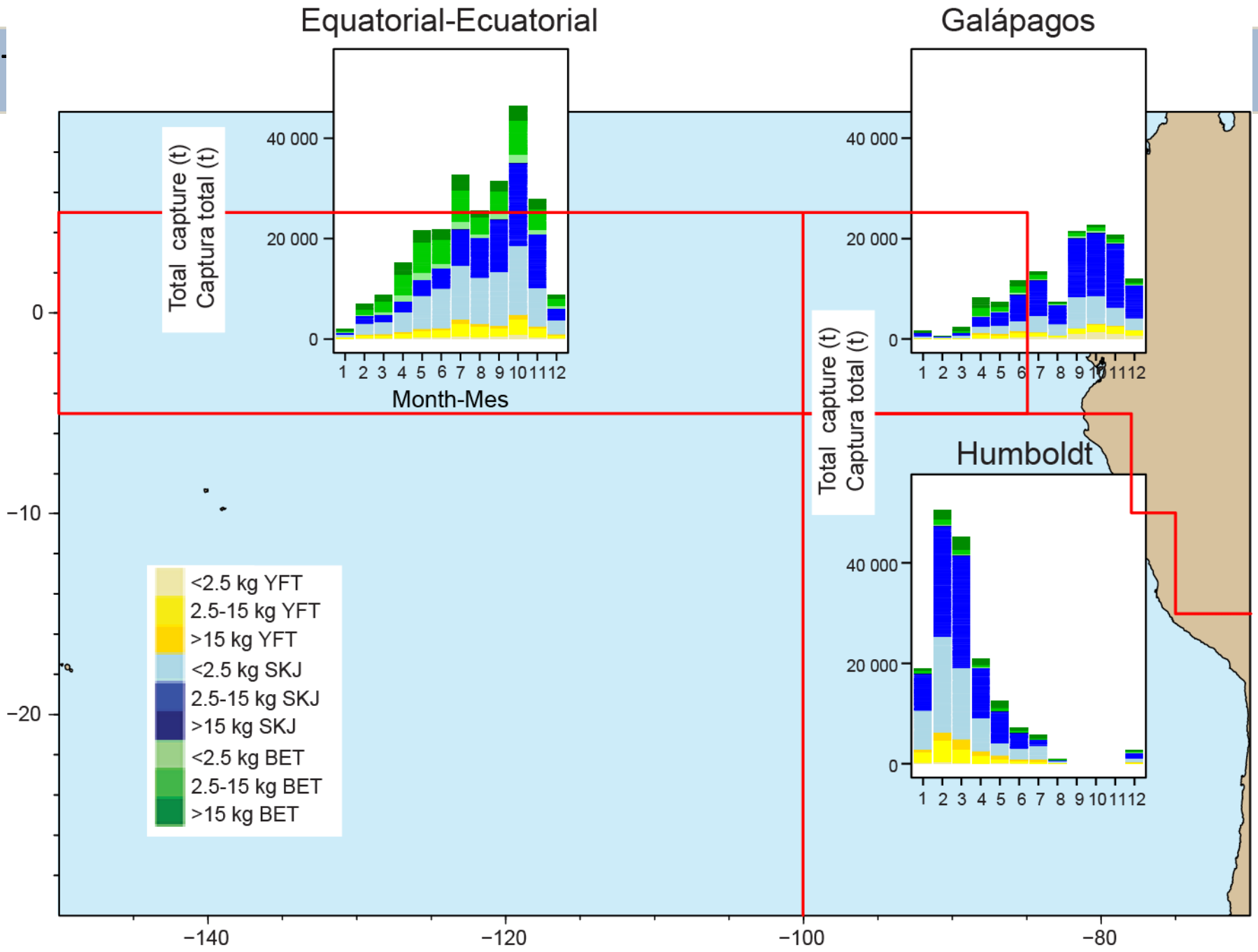
% NULL ("skunk") SETS




FADs deployed–Plantados sembrados
FADs retrieved–Plantados recuperados
Number of FADs–Número de FADs
15 000
12 000
9 000
6 000
2005
2010
2015

Seasonality of FAD deployment: still changing

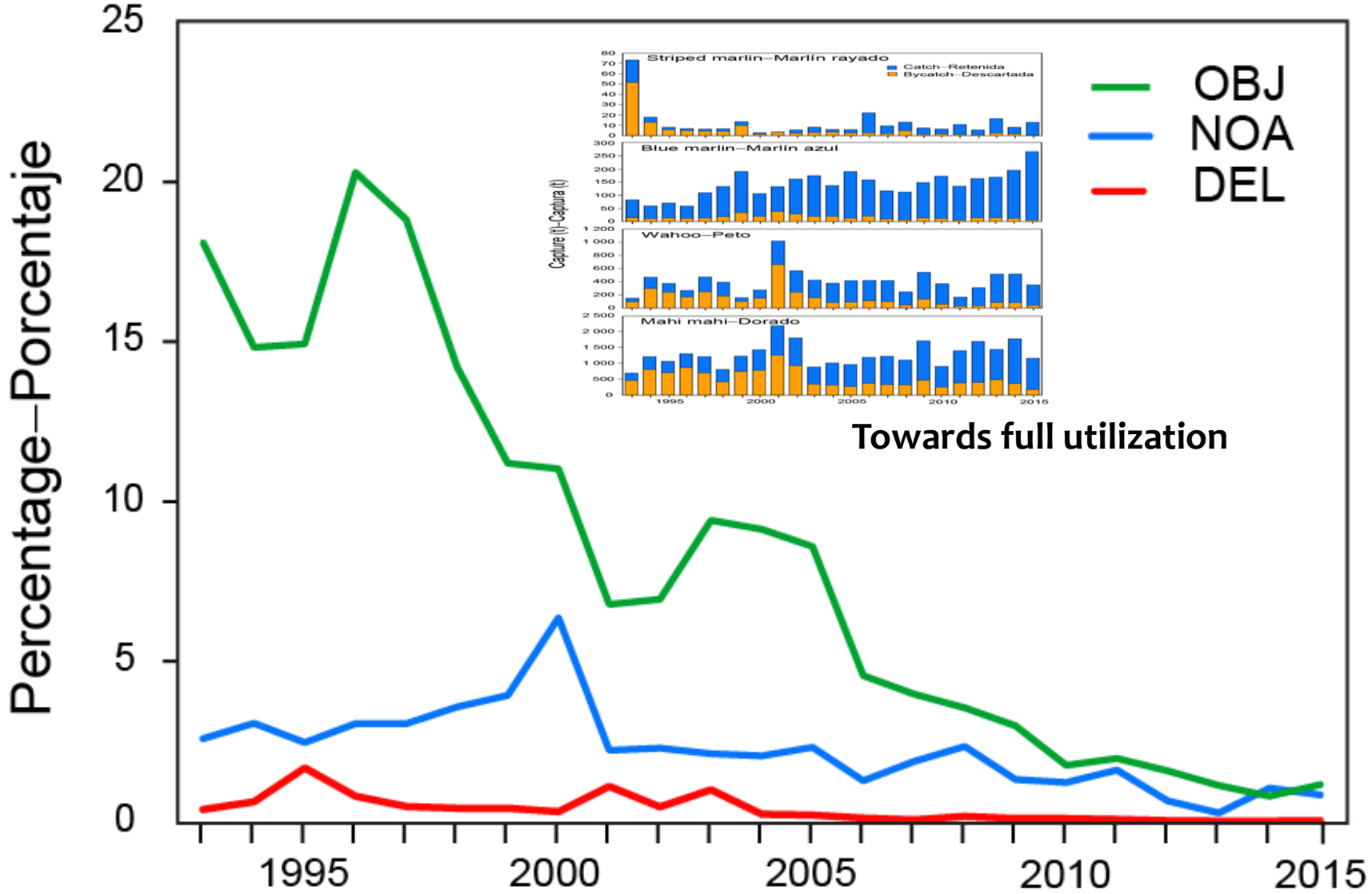



Equatorial-Ecuatorial
Galápagos
Humboldt
Total capture (t)
Captura total (t)
40 000
20 000
0
1 2 3 4 5 6 7 8 9 10 11 12
Month-Mes
<2.5 kg YFT
2.5-15 kg YFT
>15 kg YFT
<2.5 kg SKJ
2.5-15 kg SKJ
>15 kg SKJ
<2.5 kg BET
2.5-15 kg BET
>15 kg BET
0
−10
−20
−140
−120
−100
−80

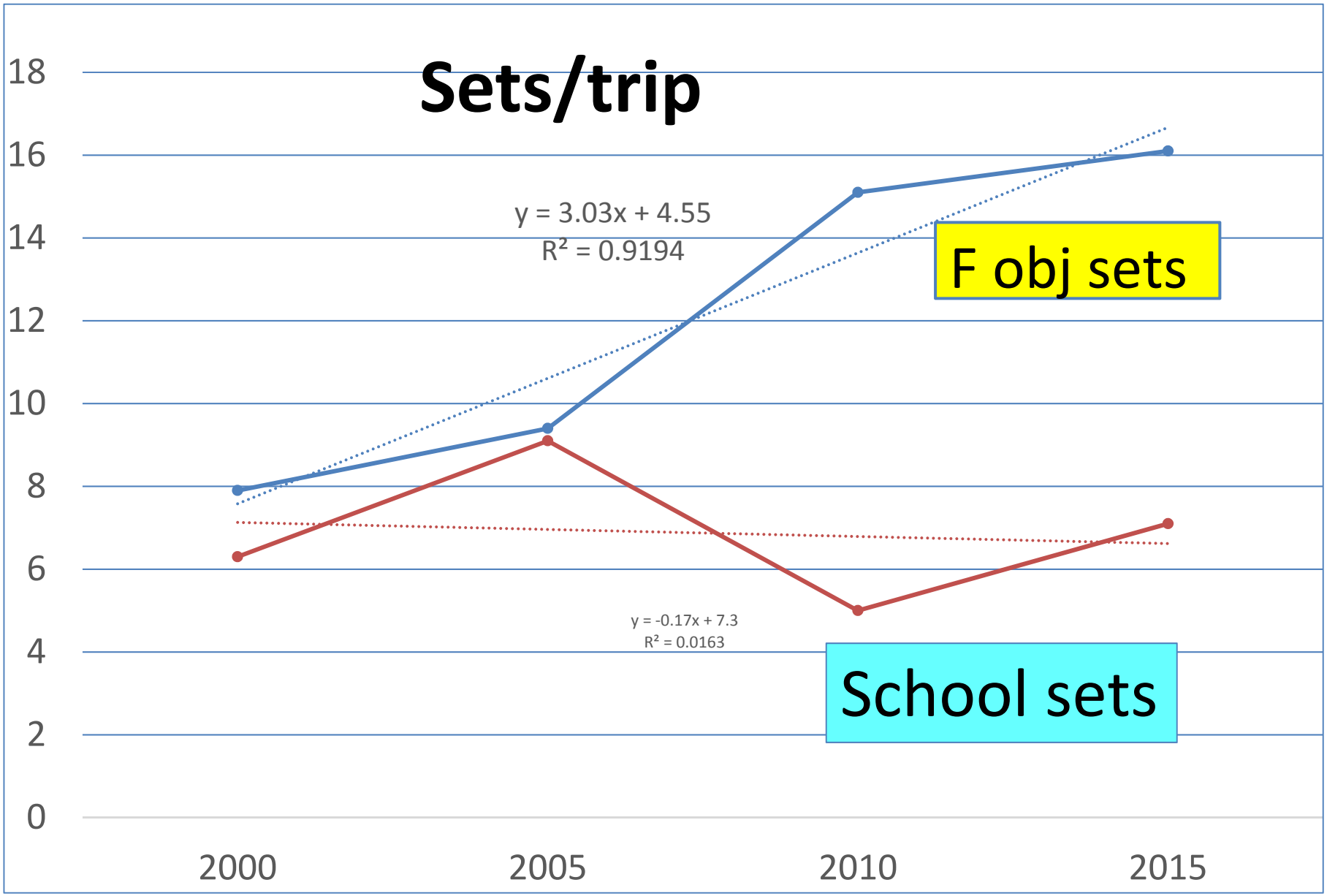
Area	Small YFT	Med YFT	Lrg YFT	Small SKJ	Med SKJ	Lrg SKJ	Small BET	Med BET	Lrg BET	Tot capt
Galapagos	6304	8692	1506	28864	65688	813	2102	8064	7528	129560
Equatorial N	2927	8966	1954	34548	29271	248	6509	25666	14135	124224
Equatorial S	1898	7259	2870	45443	39548	526	3905	19627	6940	128015
Humboldt	1478	12347	7103	56170	74842	870	504	4670	9063	167047

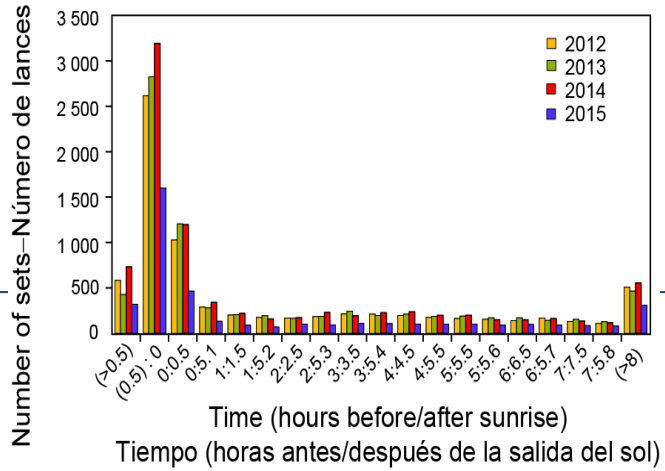
Catch per positive set (any species) and per all sets

Area	Tot capt	N FAD +	CPPS	All FAD sets	CPS
Galapagos	129560	4654	27.8	5113	25.3
Equatorial N	124224	3551	35.0	3703	33.5
Equatorial S	128015	3000	42.7	3127	40.9
Humboldt	167047	5389	31.0	5867	28.5

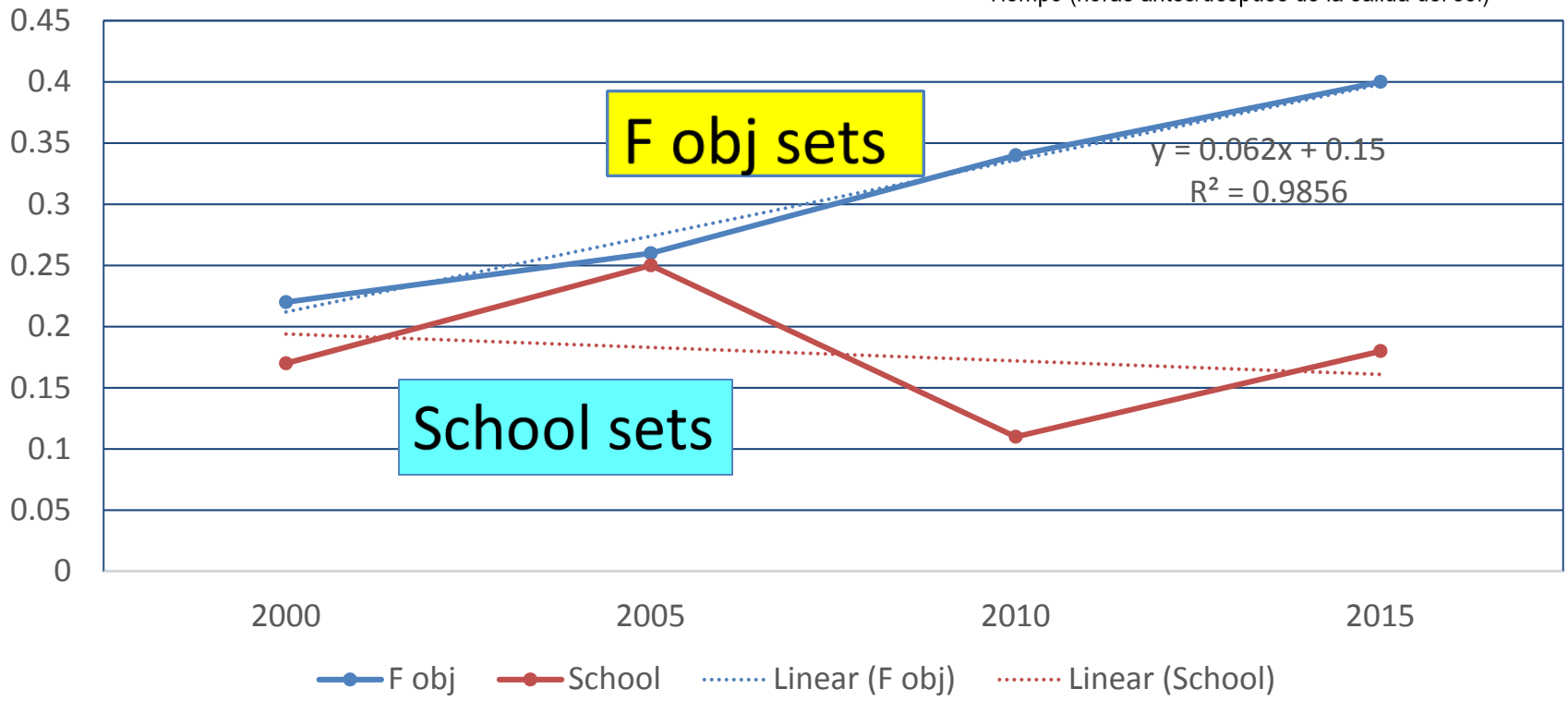


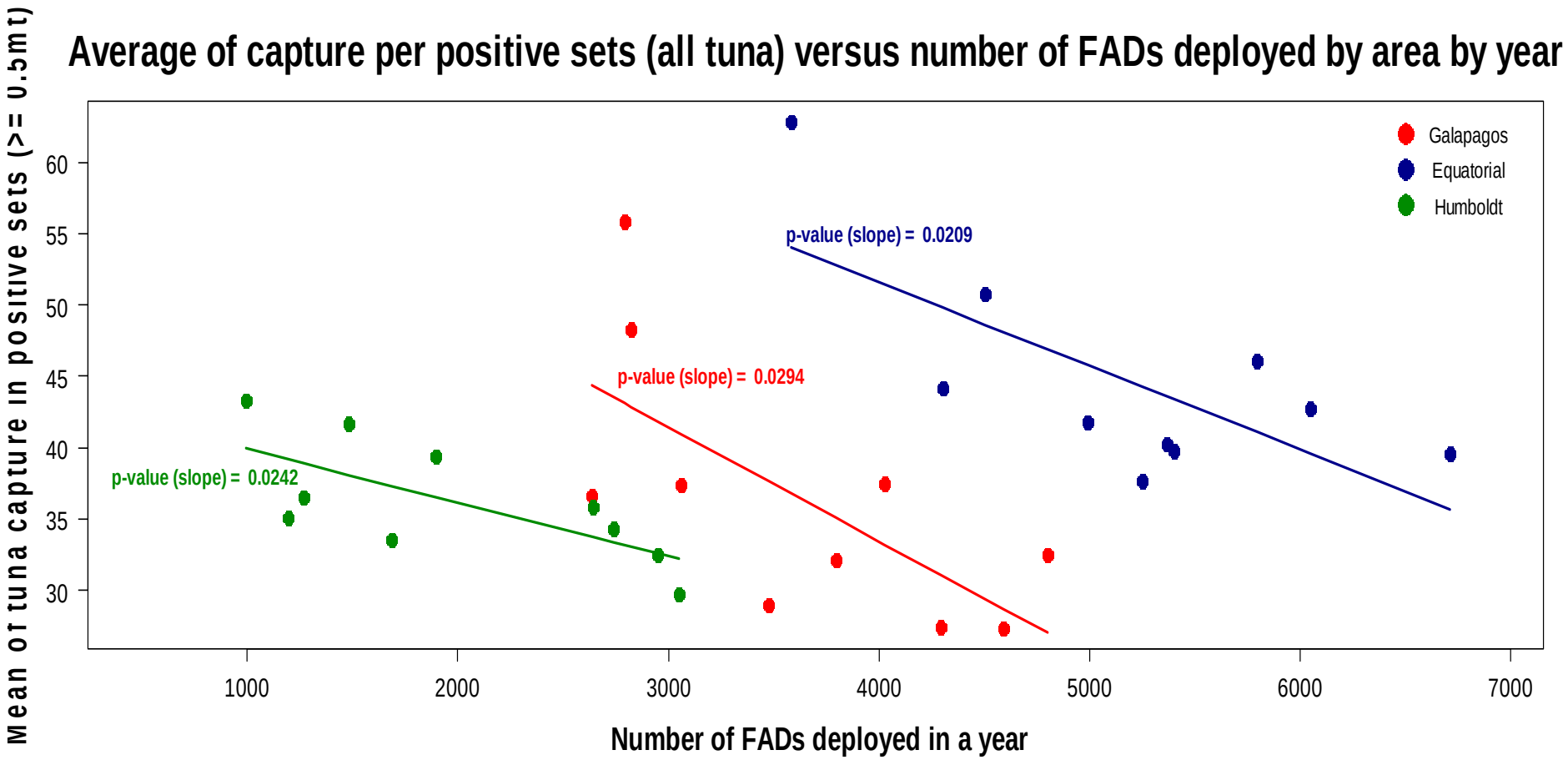
PERCENT TUNA DISCARDS


Sets/trip
18
16
14
12
10
8
6
4
2
0
2000
2005
2010
2015
y = 3.03x + 4.55
R² = 0.9194
y = -0.17x + 7.3
R² = 0.0163
F obj sets
School sets


Number of sets–Número de lances
3 500
3 000
2 500
2 000
1 500
1 000
500
0
2012
2013
2014
2015
(>0.5)
(0.5) : 0
0:0.5
0.5:1
1:1.5
1.5:2
2:2.5
2.5:3
3:3.5
3.5:4
4:4.5
4.5:5
5:5.5
5.5:6
6:6.5
6.5:7
7:7.5
7.5:8
(>8)
Time (hours before/after sunrise)
Tiempo (horas antes/después de la salida del sol)

Sets/day


0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
F obj sets
y = 0.062x + 0.15
R² = 0.9856
School sets
2000
2005
2010
2015
F obj
School
Linear (F obj)
Linear (School)


Average of capture per positive sets (all tuna) versus number of FADs deployed by area by year
Mean of tuna capture in positive sets (>= 0.5mt)
Number of FADs deployed in a year
Galapagos
Equatorial
Humboldt
p-value (slope) = 0.0209
p-value (slope) = 0.0294
p-value (slope) = 0.0242
30
35
40
45
50
55
60
1000
2000
3000
4000
5000
6000
7000

Hypotheses for the decline in CPPS

CPPS is **NOT** an index of abundance, but….
It could be an "ecological index" related to prey abundance, productivity, etc., or it could be a measure of the "encounter rate" between tuna schools and FADs, and in this case it may be related to the density of schools in an area or to the density of FADs in the area.

a) Too many attractors
b) Schools are smaller because of ecological or environmental changes (e.g. prey abundance or aggregation)
c) FADs are set on sooner than in the past
d) Smaller CPPS may reflect lower abundance of one or more species

When tuna biomass changes (e.g. a decrease), do we expect to see fewer schools, smaller schools, a bit of each?

Assumption

Most of the school is caught in the set

Uncertainties:

Are there many pure schools that only merge under the FADs?

Or

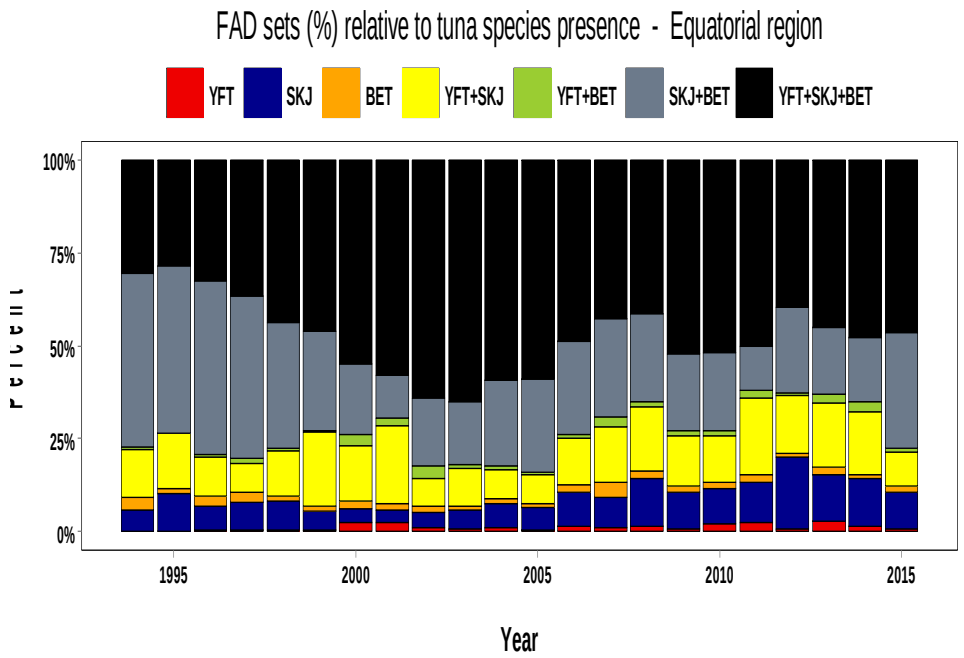
Are there many mixed schools that join the FAD as a group?

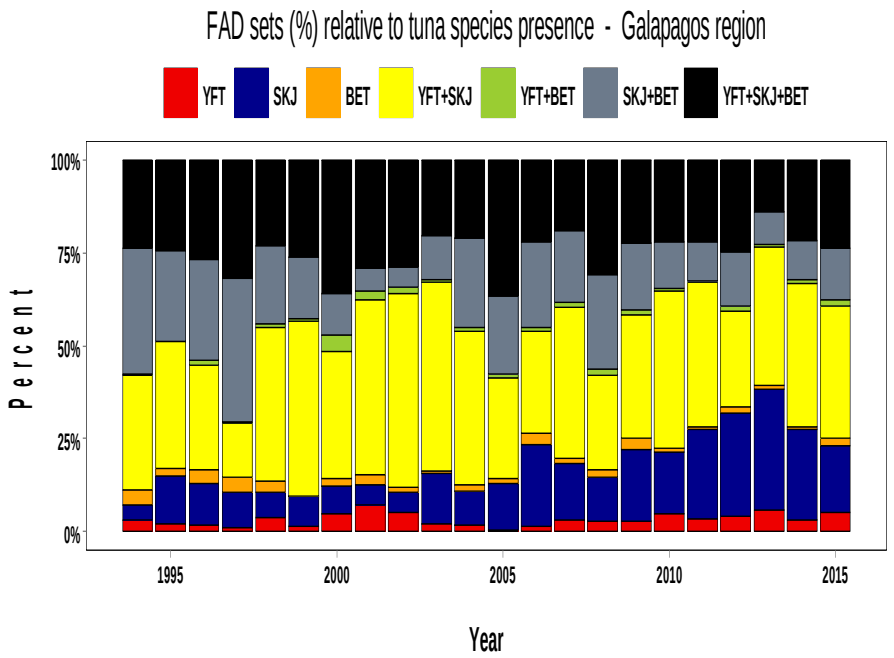
Or

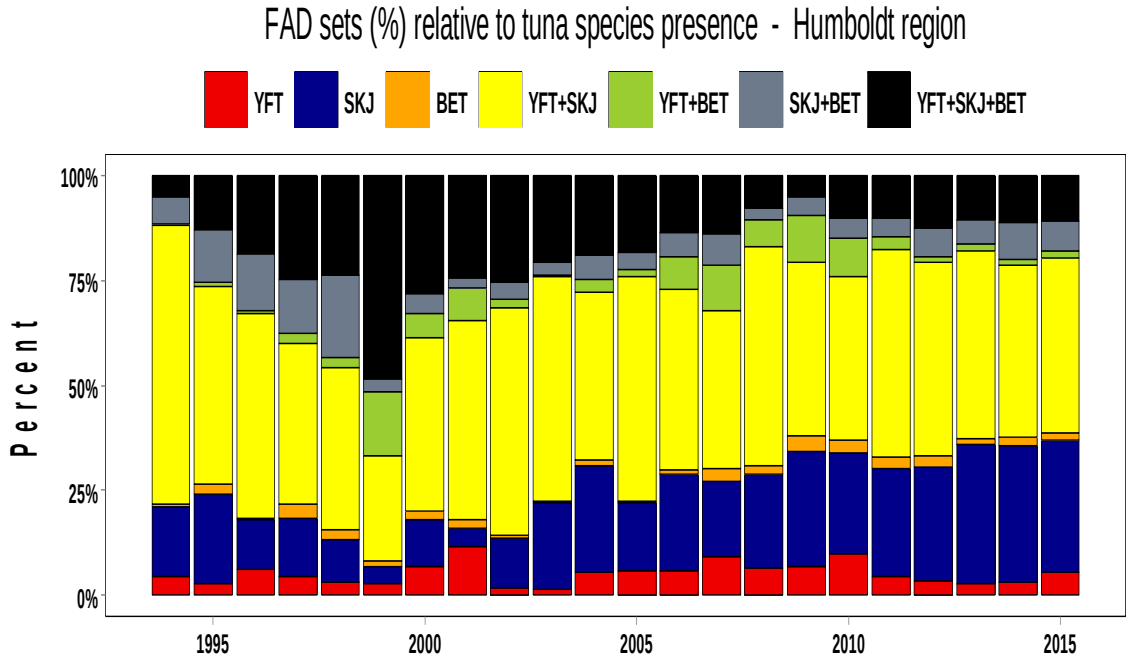
Which is the balance of the previous two options?

* **Exploring a) the increase in the number of FADs results in lower CPPS**

* **If there are fewer schools under the FADs, the schools captured may have fewer species and/or fewer size classes present.**

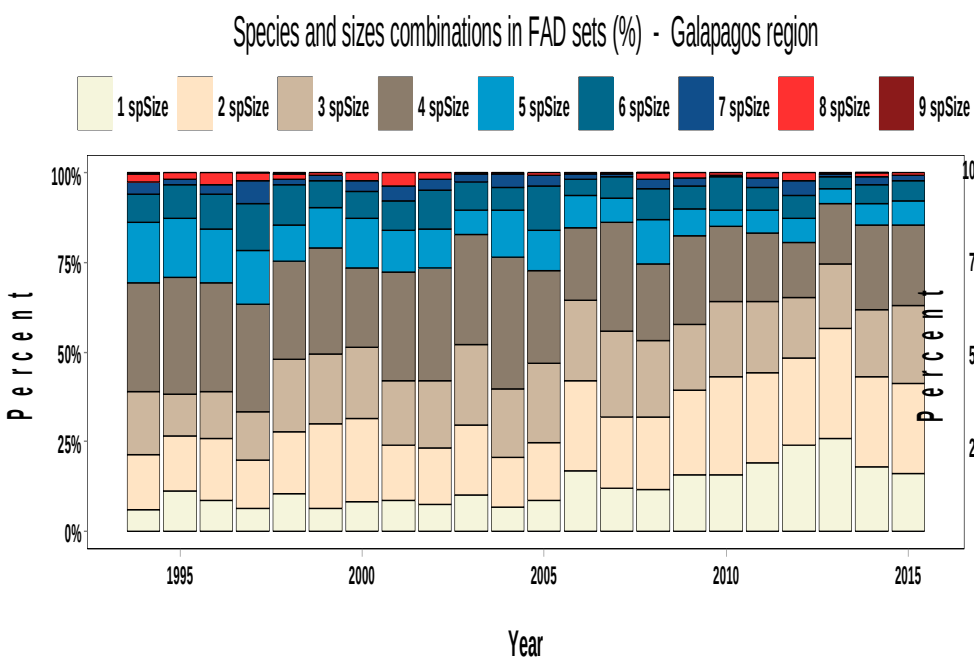

FAD sets (%) relative to tuna species presence - Equatorial region
YFT
SKJ
BET
YFT+SKJ
YFT+BET
SKJ+BET
YFT+SKJ+BET
100%
75%
50%
25%
0%
1995
2000
2005
2010
2015
Year

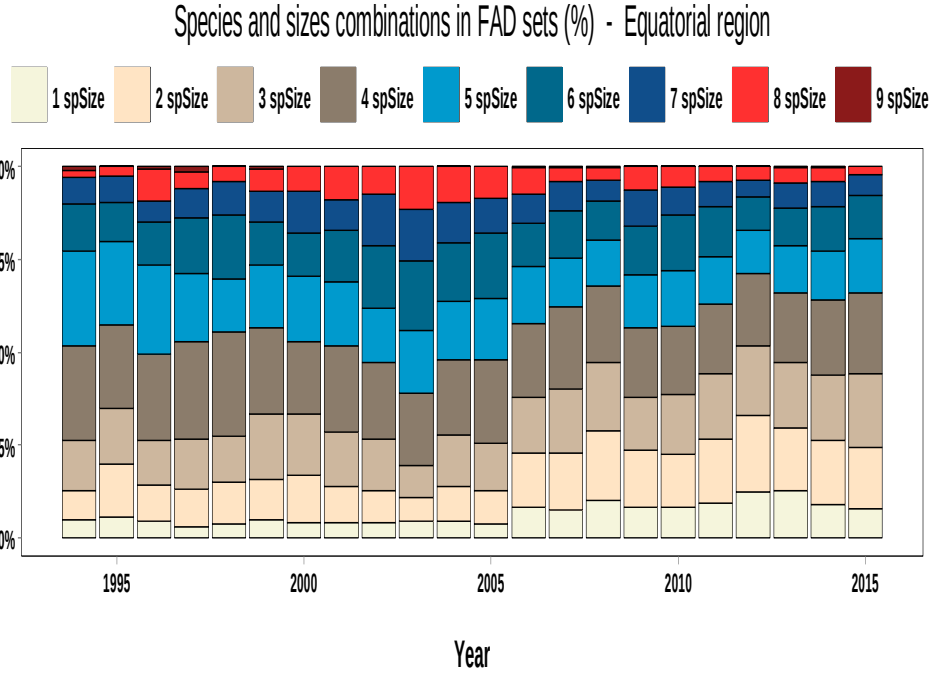

FAD sets (%) relative to tuna species presence - Galapagos region
YFT
SKJ
BET
YFT+SKJ
YFT+BET
SKJ+BET
YFT+SKJ+BET
Percent
100%
75%
50%
25%
0%
1995
2000
2005
2010
2015
Year

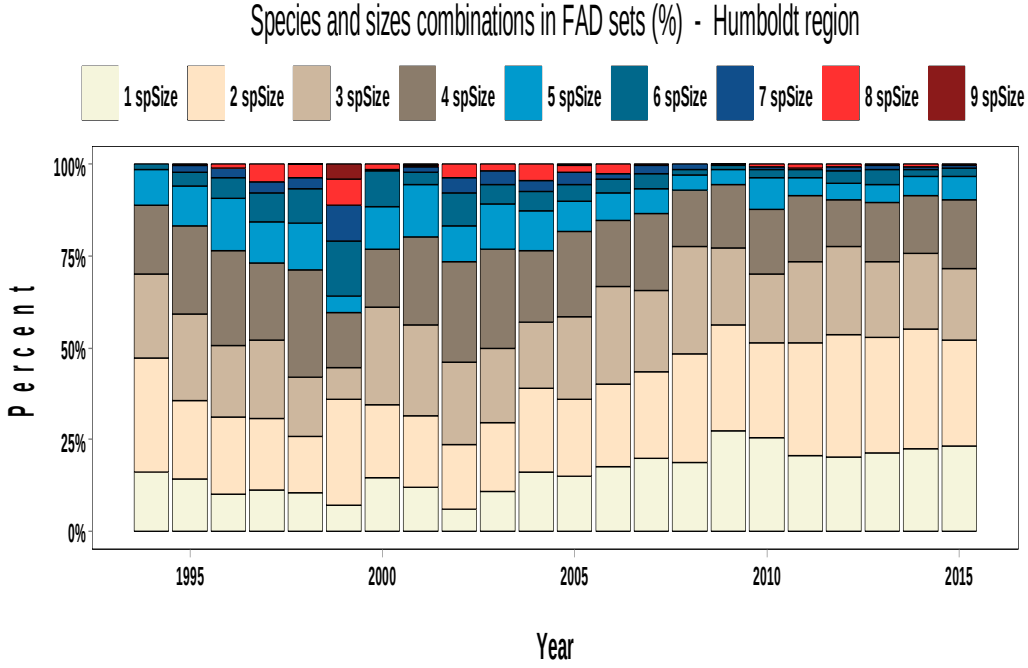

FAD sets (%) relative to tuna species presence - Humboldt region
YFT
SKJ
BET
YFT+SKJ
YFT+BET
SKJ+BET
YFT+SKJ+BET
Percent
100%
75%
50%
25%
0%
1995
2000
2005
2010
2015

If there are fewer schools, there may be fewer combinations of species and sizes in the sets:

We have 3 species and 3 size categories (not great for SJ), so a set may yield from 1 to 9 classes (speciesxsize)

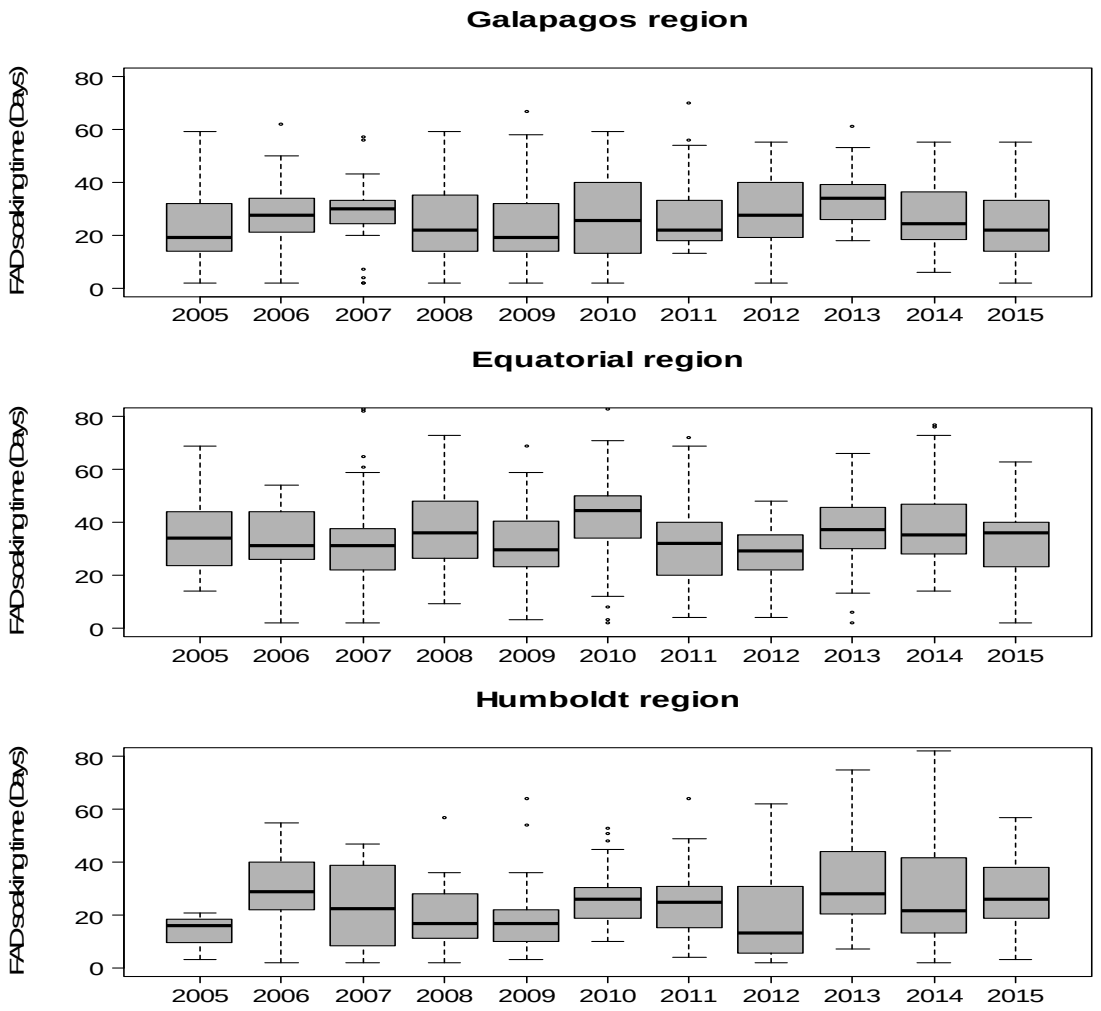

Species and sizes combinations in FAD sets (%) - Galapagos region
1 spSize
2 spSize
3 spSize
4 spSize
5 spSize
6 spSize
7 spSize
8 spSize
9 spSize
Percent
100%
75%
50%
25%
0%
1995
2000
2005
2010
2015
Year


Species and sizes combinations in FAD sets (%) - Equatorial region
1 spSize
2 spSize
3 spSize
4 spSize
5 spSize
6 spSize
7 spSize
8 spSize
9 spSize
Percent
100%
75%
50%
25%
0%
1995
2000
2005
2010
2015
Year


Species and sizes combinations in FAD sets (%) - Humboldt region
1 spSize
2 spSize
3 spSize
4 spSize
5 spSize
6 spSize
7 spSize
8 spSize
9 spSize
Percent
100%
75%
50%
25%
0%
1995
2000
2005
2010
2015
Year

FAD soaking time (days) by year

>=2 soak days



Hypotheses for the decline in CPPS:

Not conclusive evidence for any of them; a comprehensive model is needed

a) High density of FADs competing for schools

Some supporting evidence of school "simplification" but there are alternative explanations (e.g. one species declining, etc.)

b) Schools are smaller because of ecological or environmental changes (e.g. prey abundance, thermocline depth, etc.)

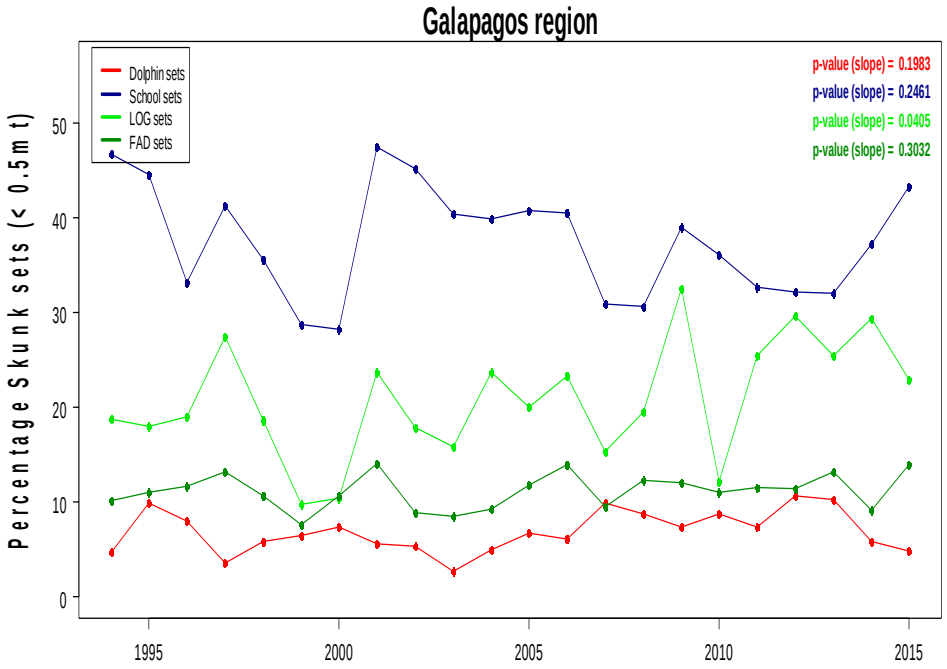
Not explored yet

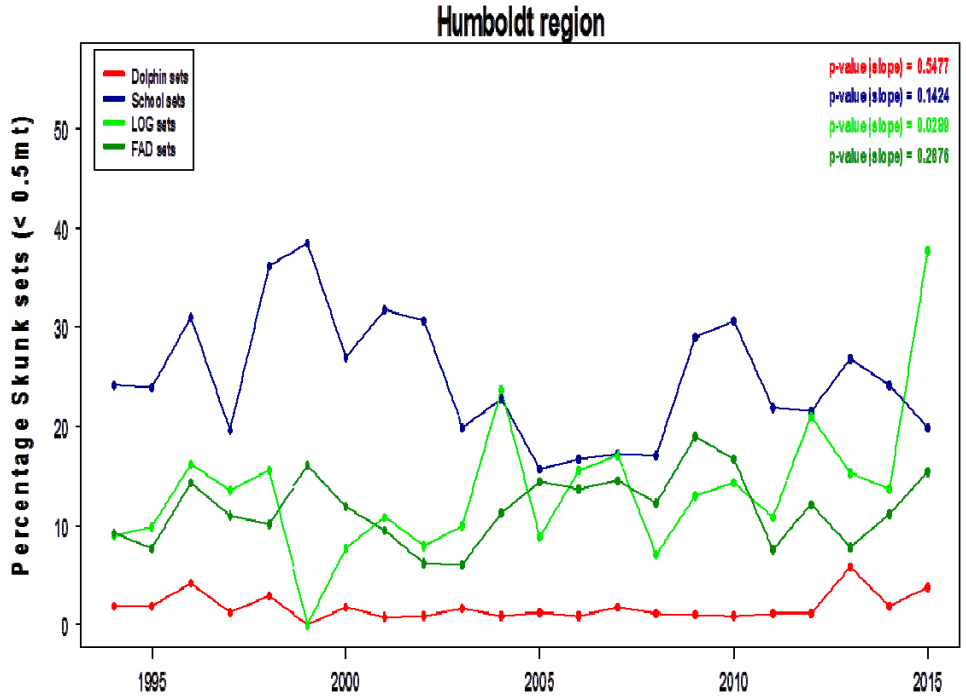
c) FADs are set on sooner after planting than in the past, so schools don't have time to accumulate.

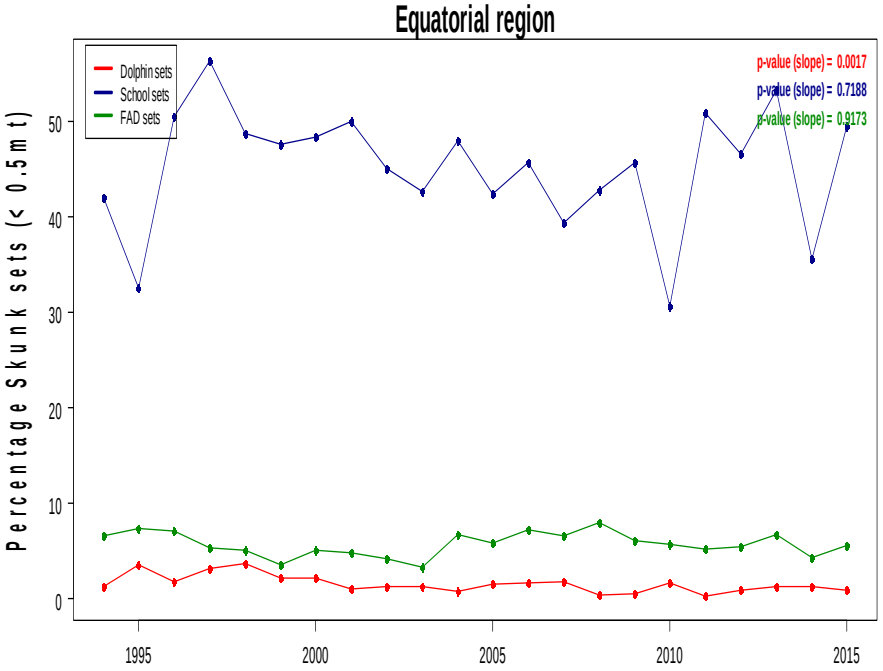
Some support with regional differences

d) Smaller schools reflect lower abundance of one or more species

Simplification of schools, and lower CPPS could be the result of abundance changes.

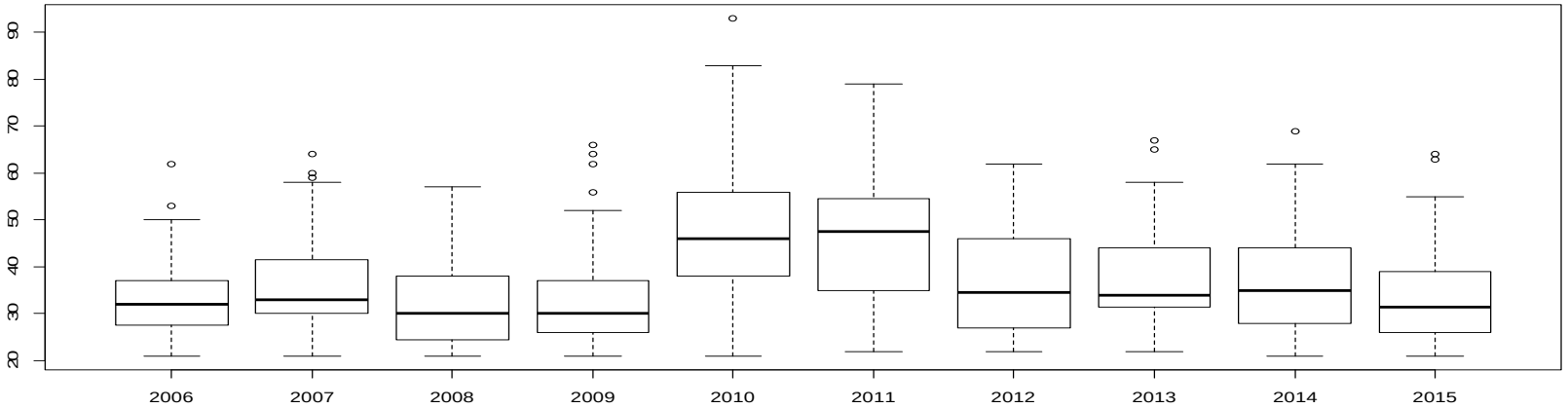




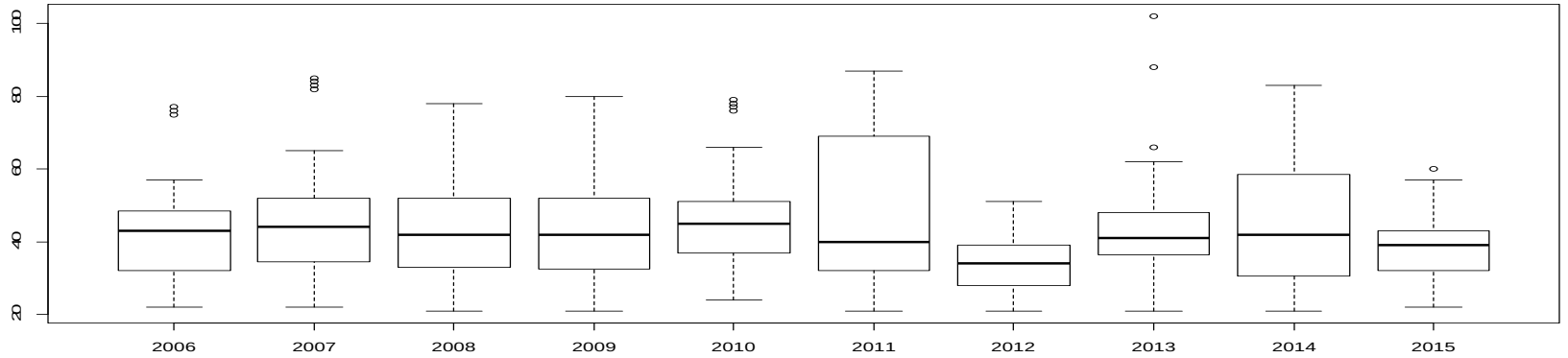


No clear trends in the % of skunk sets but there are regional differences

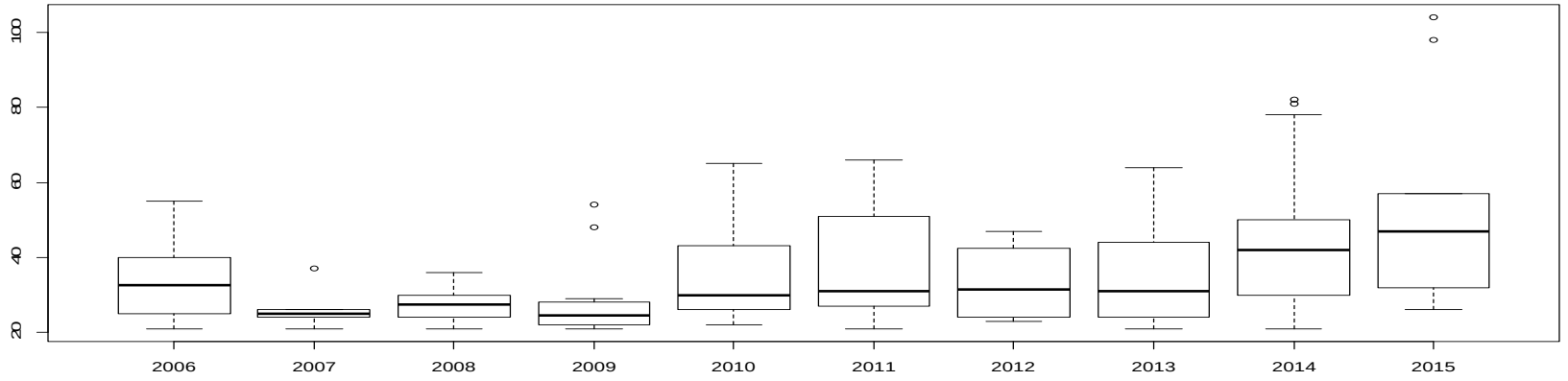
FAD soaking time before the first set - Galapagos



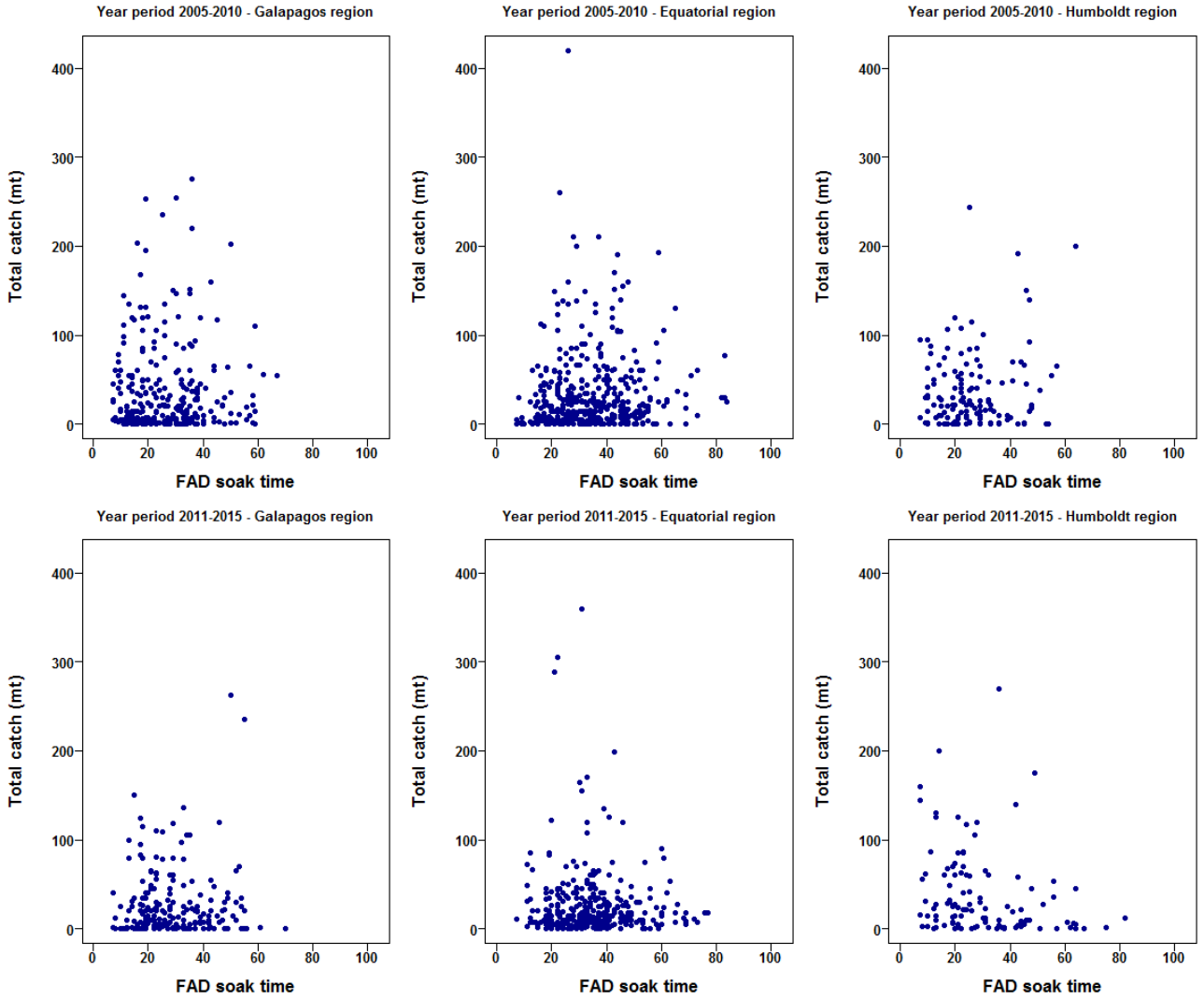
FAD soaking time before the first set - Equatorial

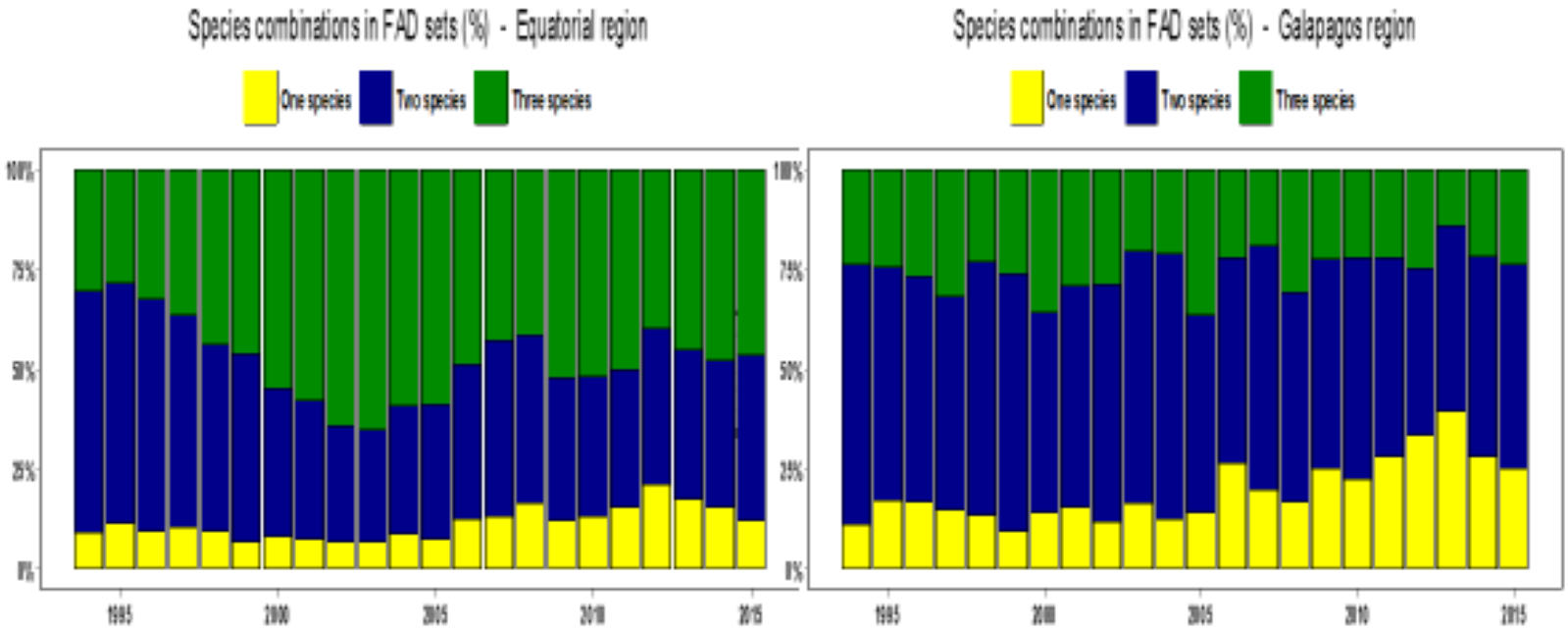


FAD soaking time before the first set - Humboldt

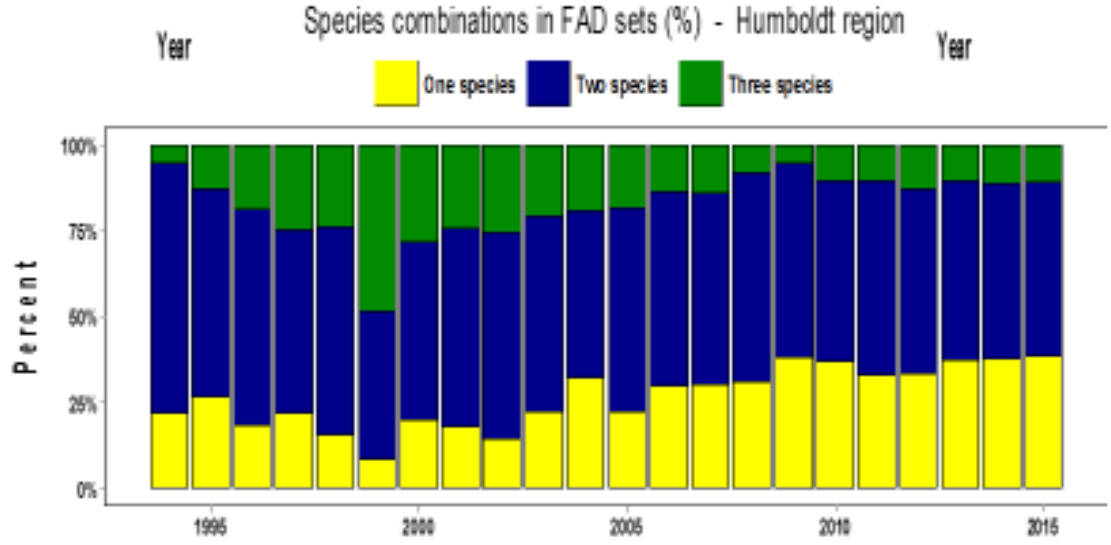


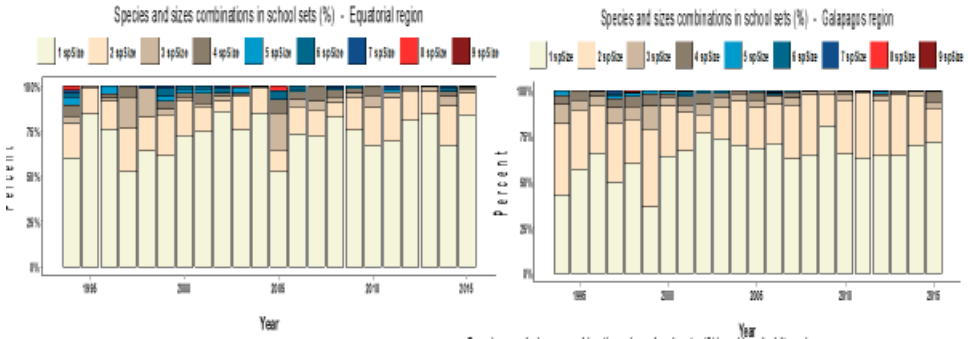
Tuna catch (YFT+SKJ+BET) vs FAD soaking time



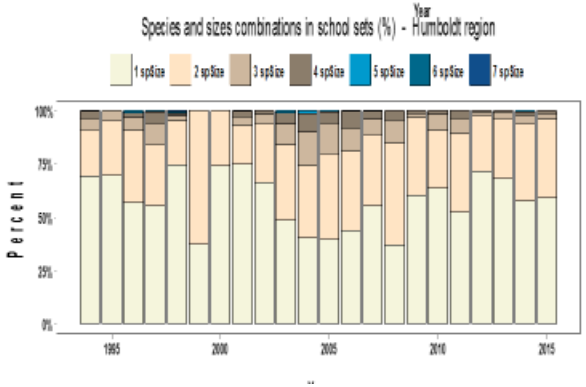

Species combinations in FAD sets (%) - Equatorial region
One species
Two species
Three species
100%
75%
50%
25%
0%
1995
2000
2005
2010
2015
Year

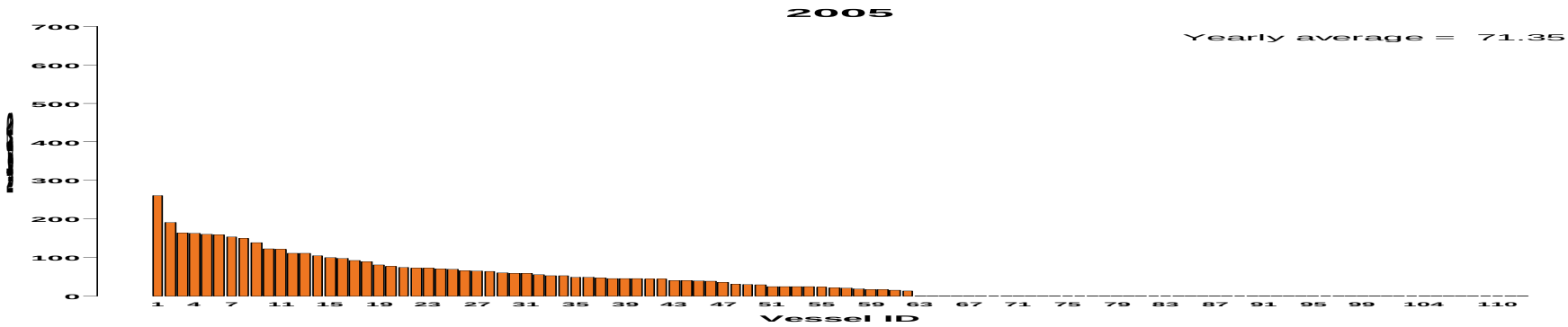
Species combinations in FAD sets (%) - Galapagos region
One species
Two species
Three species
100%
75%
50%
25%
0%
1995
2000
2005
2010
2015
Year

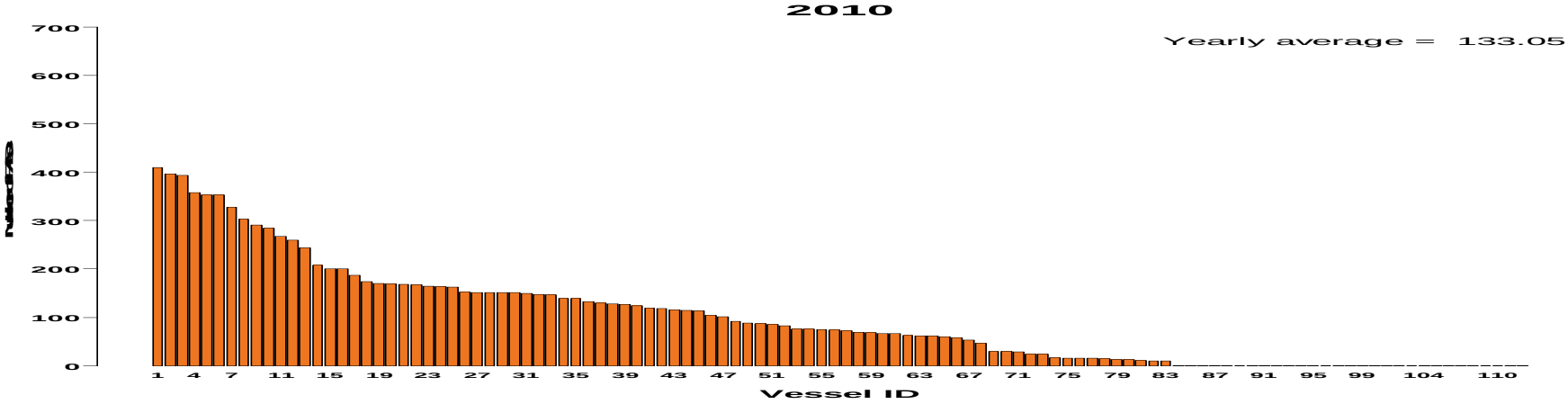

Species combinations in FAD sets (%) - Humboldt region
One species
Two species
Three species
Percent
100%
75%
50%
25%
0%
1995
2000
2005
2010
2015

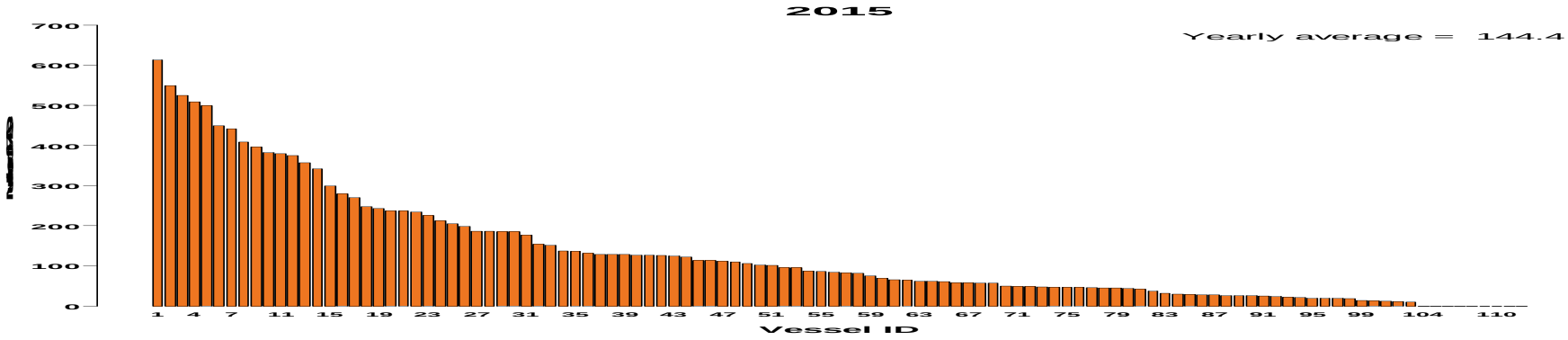


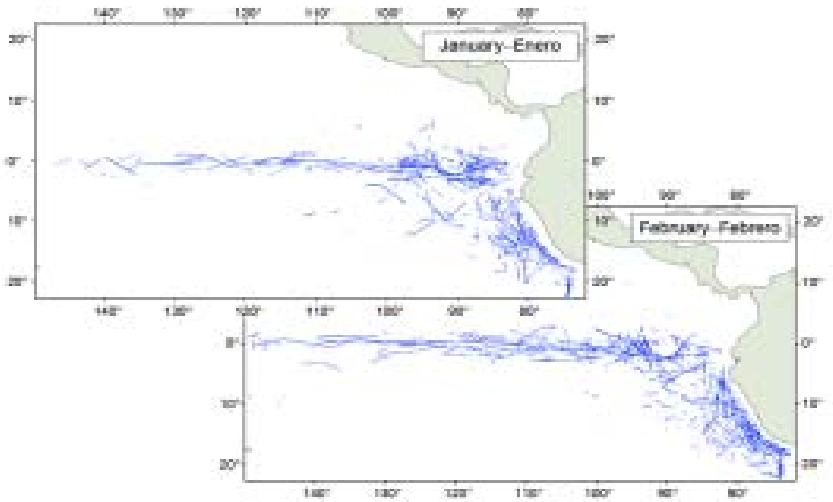
Simplification of schools

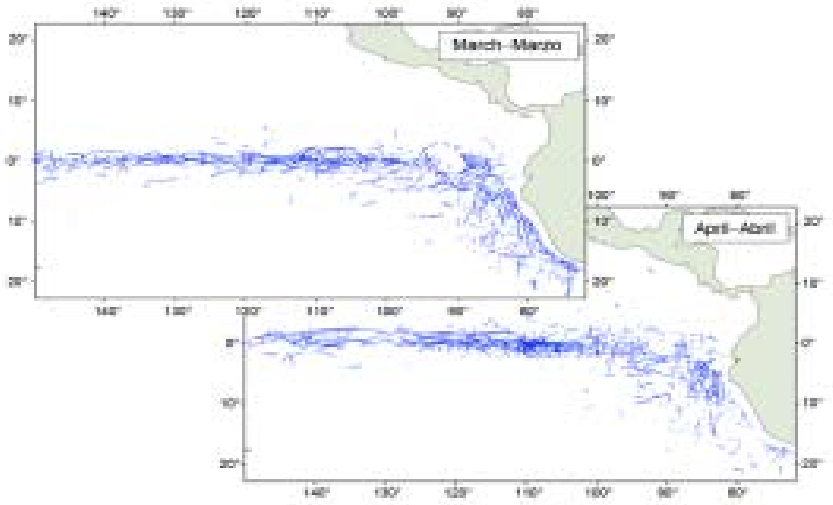


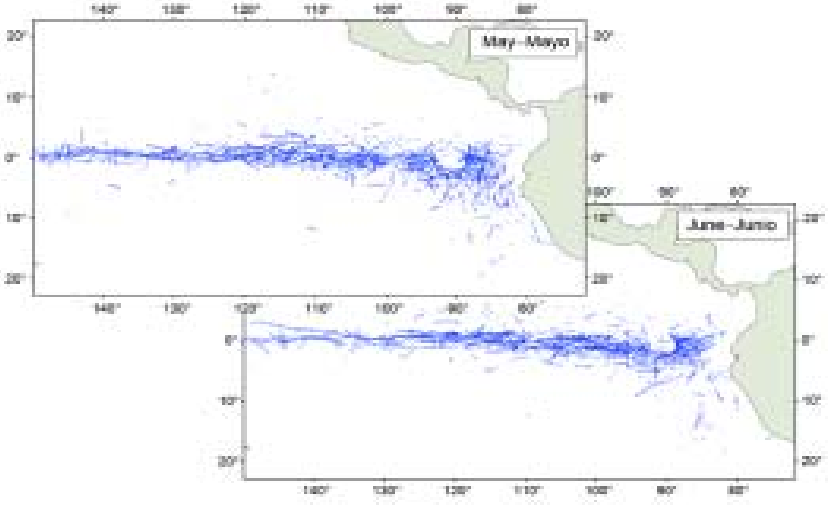

2005
Yearly average = 71.35
Vessel ID

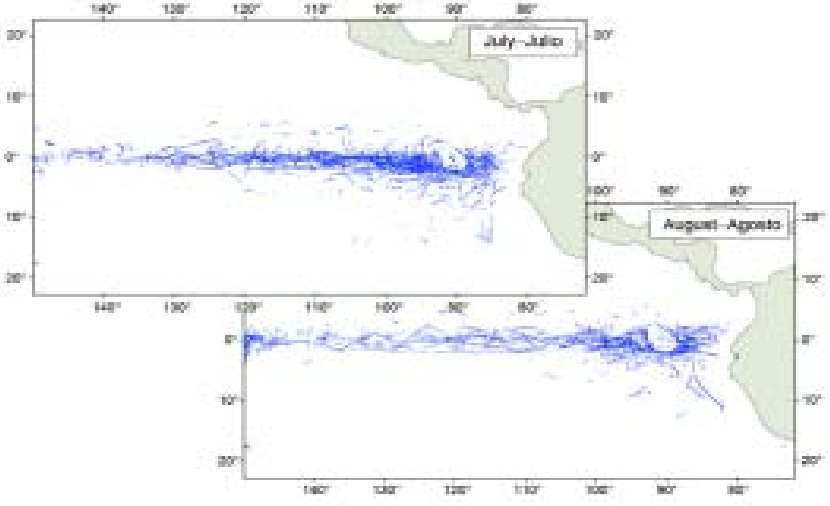

2010
Yearly average = 133.05
Vessel ID


2015
Yearly average = 144.4
Vessel ID

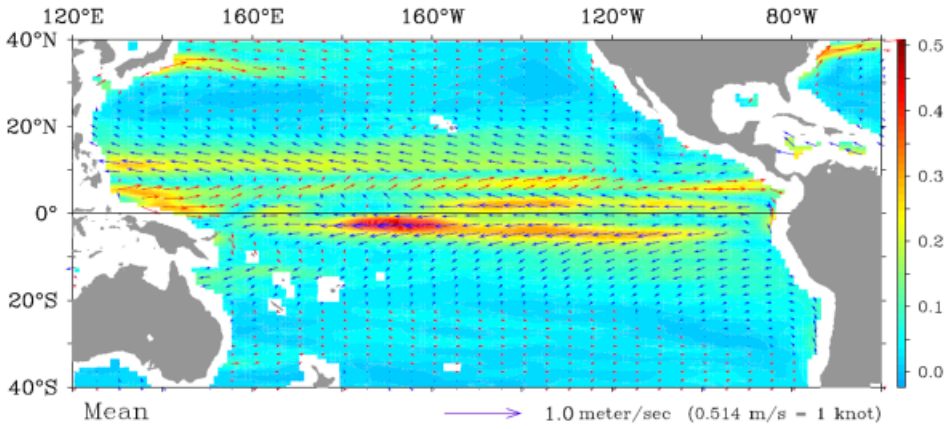

January–Enero
February–Febrero

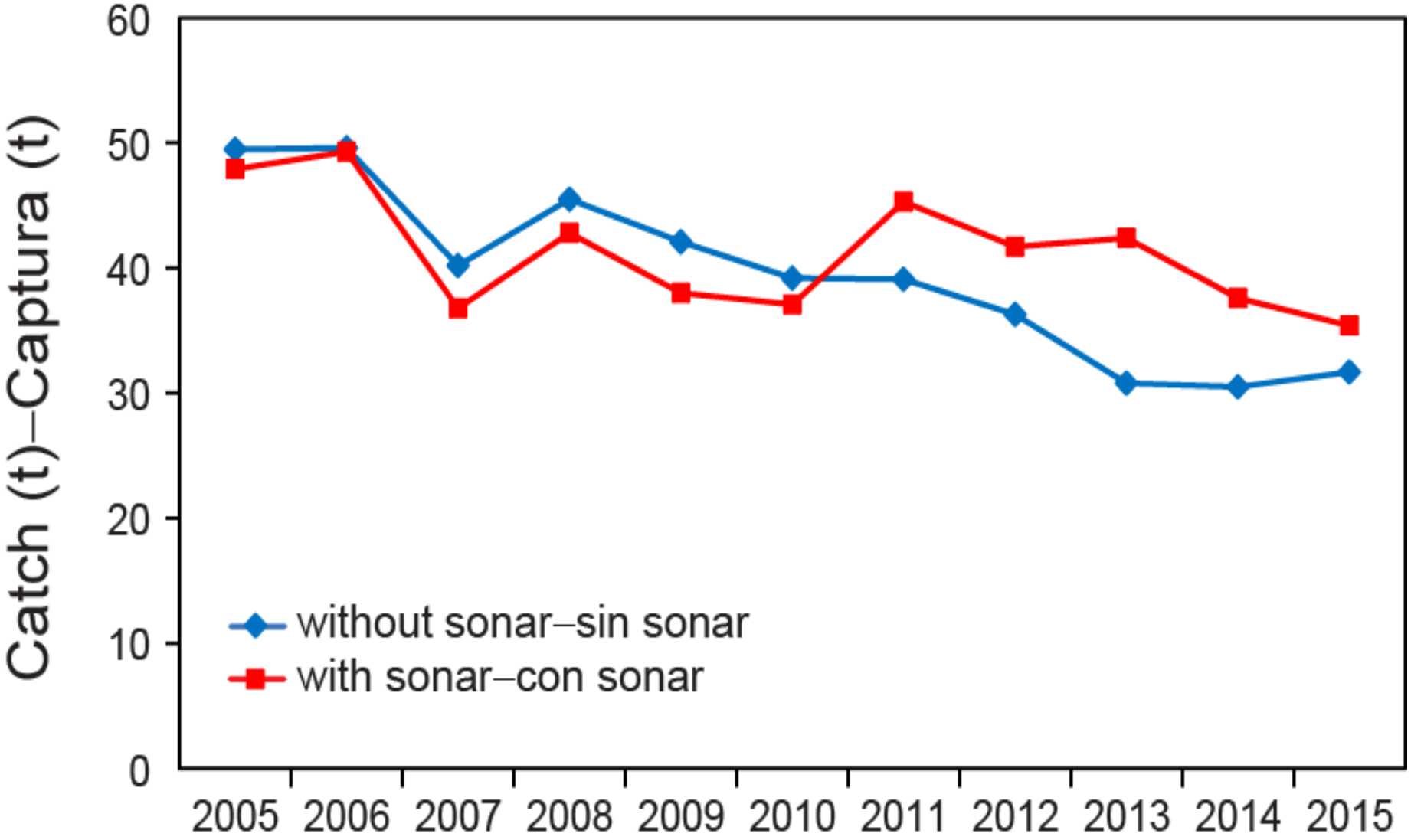

March–Marzo
April–Abril


May–Mayo
June–Junio


July–Julio
August–Agosto

19-year Mean ocean Surface Currents (meter/sec)
1993 - 2011




Catch (t)–Captura (t)
60
50
40
30
20
10
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
without sonar–sin sonar
with sonar–con sonar