# INTERACTIONS BETWEEN WHALE SHARKS, MARINE MAMMALS AND THE EUROPEAN TROPICAL TUNA PURSE SEINE FISHERY IN THE INDIAN AND ATLANTIC OCEANS


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# Introduction

- Tuna fishery:
  - Ecosystem approach to fisheries (FAO)
  - Tuna purse seine fishery (PSF) in the Atlantic and Indian Oceans (62%) (FAO, 2008)
    - European: 70 vessels and 10% global fisheries (Pianet *et al.*, 2011)
    - French & Spanish: 42 vessels followed by IRD, AZTI & IEO since 1980.

- Search of tuna:
  - Fish aggregating devices (FADs)
    - Natural wood log
    - Artificial: bamboo raft, anchored buoy

- Marine macroorganisms
  - Whale sharks (WHS)
  - Marine mammals (MAM)

- Catch of macroorganisms (Hall et al., 2000)
- Restrictions in IO and AO (EU, 2007)

- Objective:
  - Distribution of the frequency of co-occurrence of tuna's PSF with whale sharks and marine mammals in IO and AO.

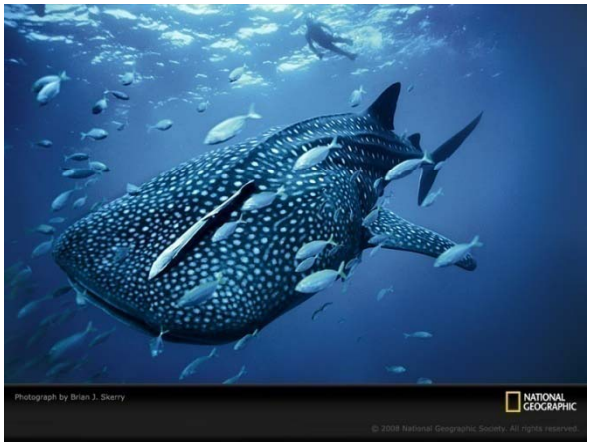
- Study:
  - The spatial and temporal distribution
  - The impact on the mortality

# Materials & Methods

- **Purse seine logbooks [1980-2011, 31 years]**
  - high coverage (almost 100 %)
  - one observation by set or by day
  - declarative data and information only by species groups

- **Purse seine scientific observer program [1995-2011, 16 years]**
  - low coverage (less than 10% of trips)
  - one observation for any change of activity during daytime or by hour
  - independant scientific observers (species identification, size ...)

- **Whale sharks (*Rhincodon typus*, Smith 1828):**
  - Coastal and oceanic tropical waters (Roward & Brooks, 2012)
  - Vulnerable (2000, IUCN)
  - Selection of habitat and migration little known



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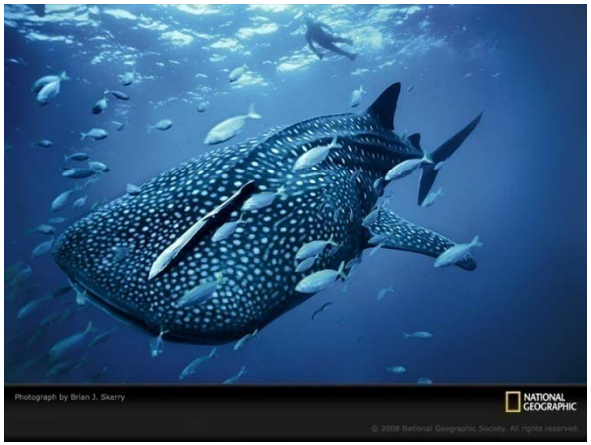
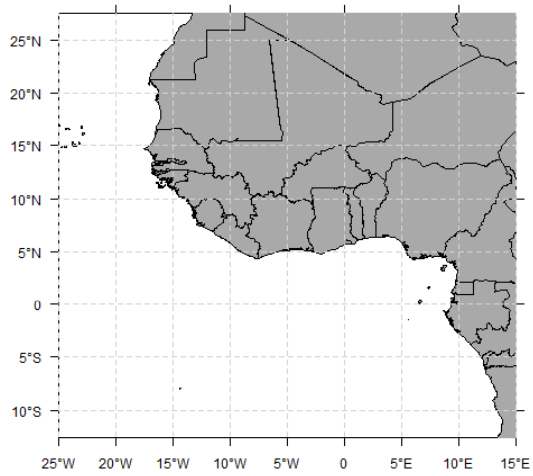


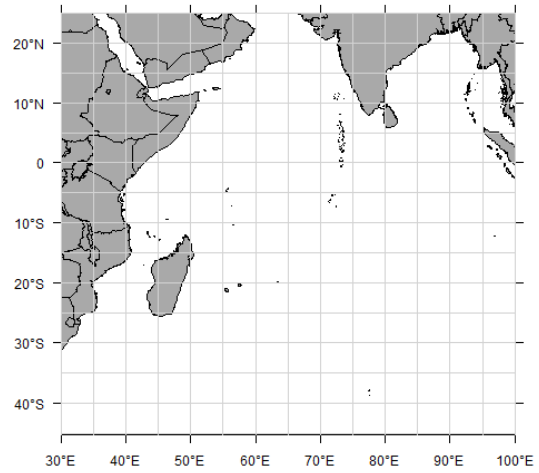

- **Marine Mammals:**
  - Tropical and temperate waters (Schipper et al., 2008)
  - Various statutes
  - Whale, small toothed whales and big toothed whales

- **Distribution maps & statistical analyses:**

  - **SPUE:** Sightings Per Unit Effort (sightings/activities)

    **Activities:** daily position during fishing activity (set) or travelling




  - **Year and season effects**
    - AO: trimester
    - IO: monsoon and intermonsoon

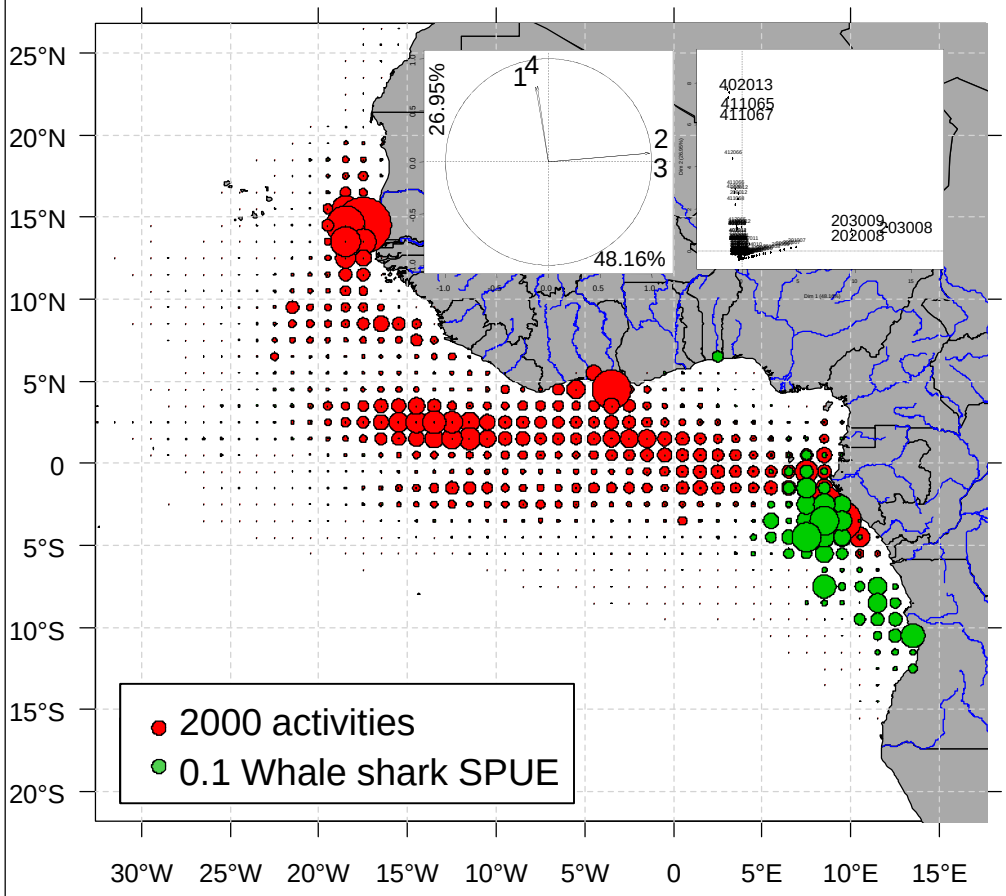
  - **Principal Component Analyses to investigate spatio-temporal patterns.**

# Results

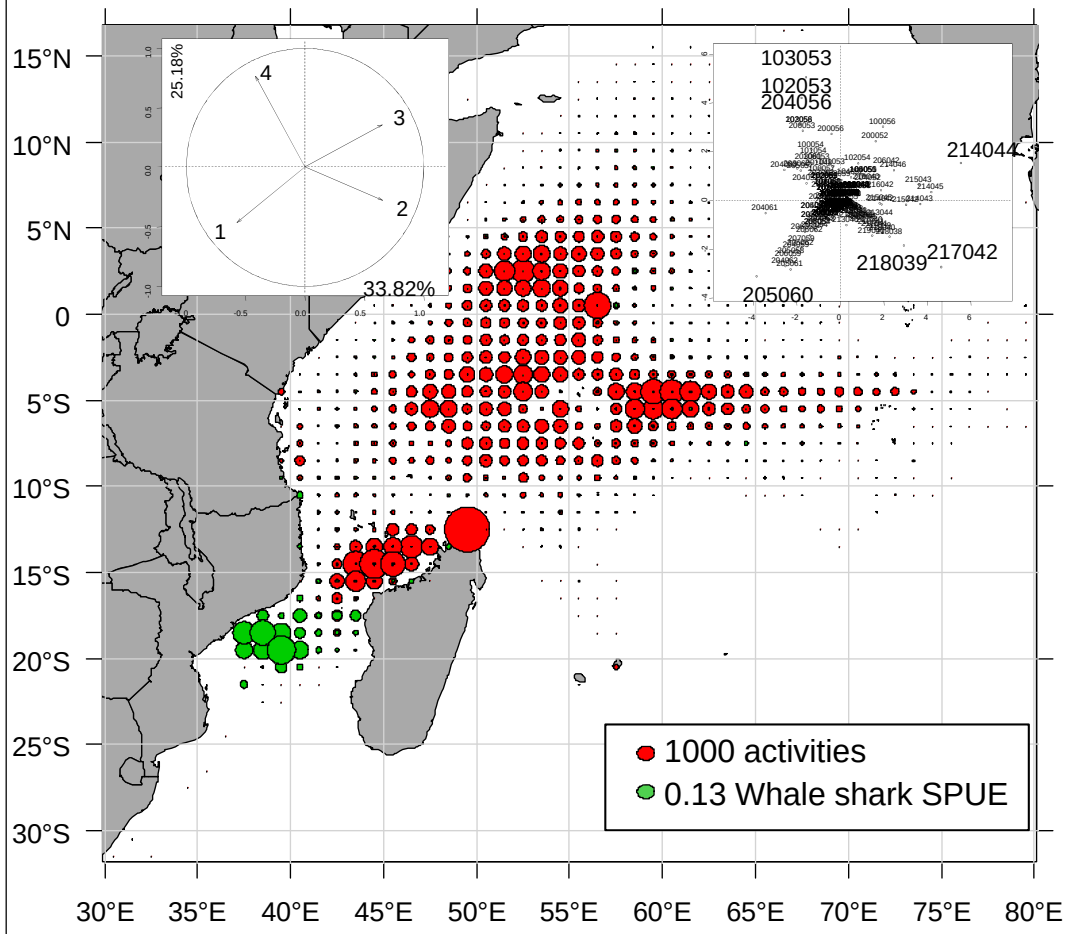
- Logbook data (IO and AO):
  - **775 606 activities** with **1% of WHS** and **2.3% of MAM** sightings.
  - 55% of set among activities

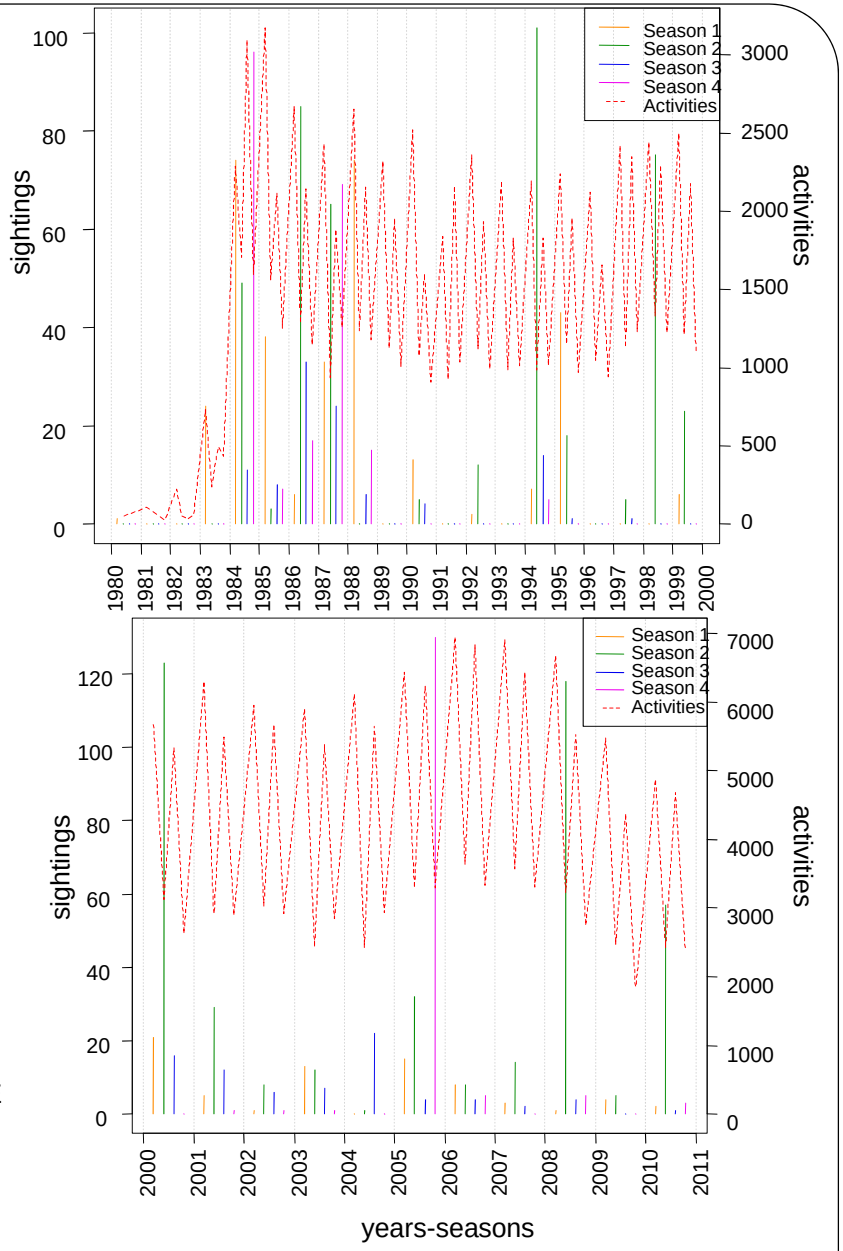
- Scientific observer data (IO and AO):
  - **284 127 activities** with **0.1% of WHS** and **1.3% of MAM** sightings.
  - **MAM:** 93.3% of whales (WHA), 0.2% of big toothed whales (BTW) and 6.5% of small toothed whales (STW).
  - 6% of set among activities

# Whale shark distribution and annual, seasonal variation of whale shark sightings and activities



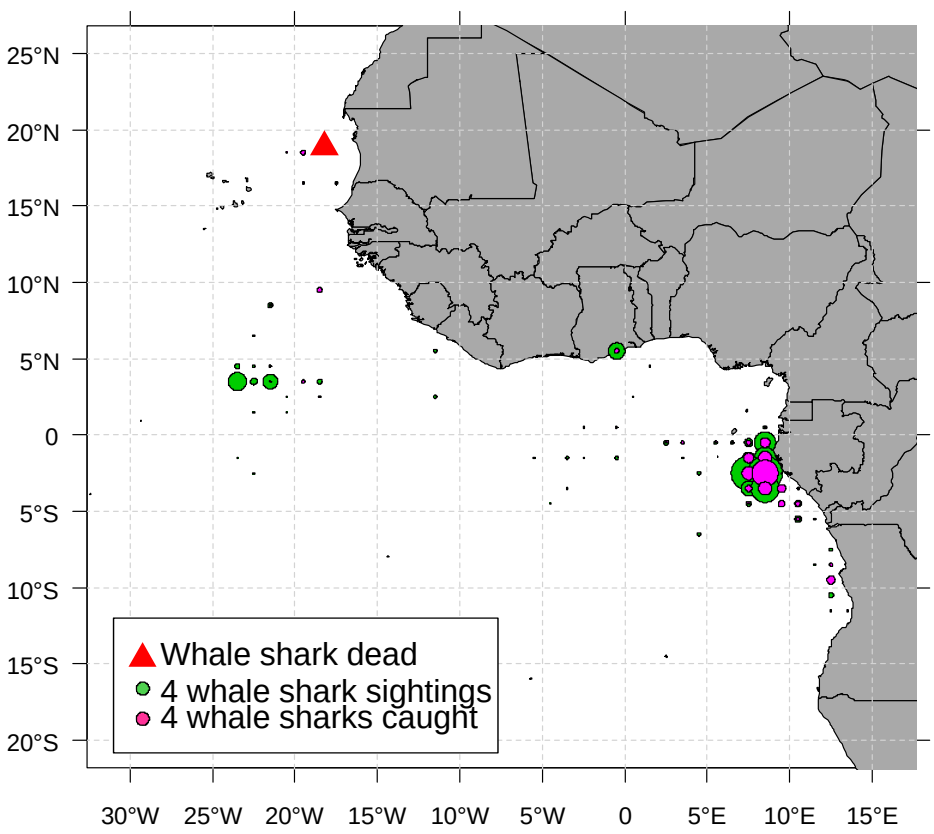
- Coastal zone of Gabon (77%)
- Preponderance of April to September (~6000 sightings)

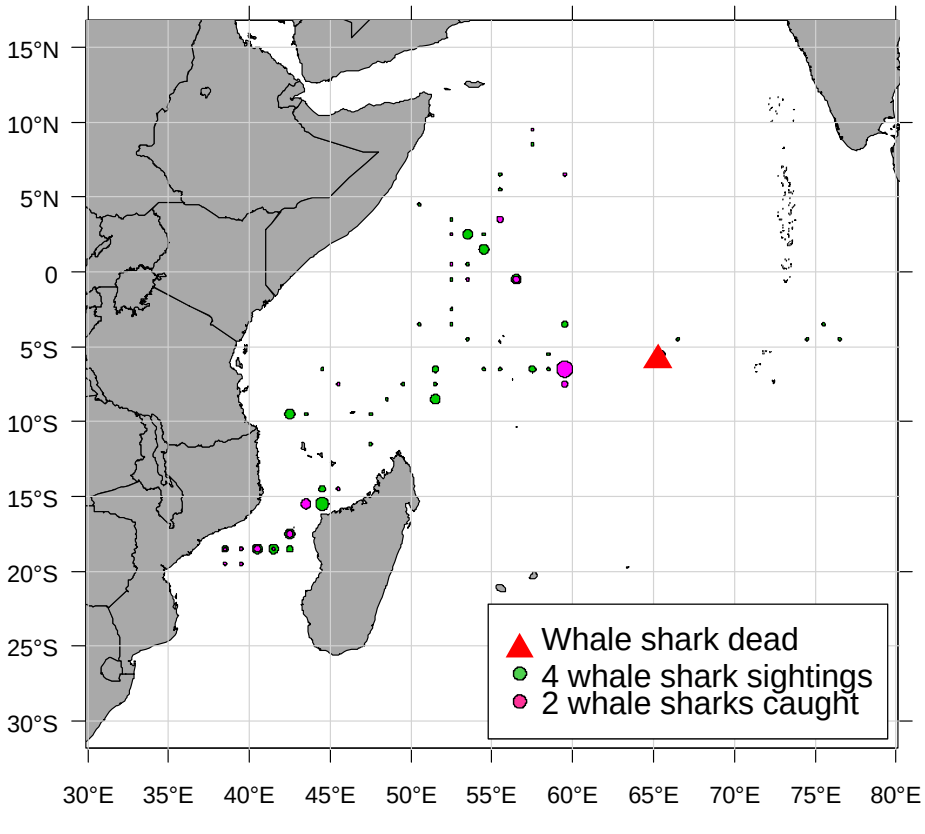



- Predominance on the Mozambique Channel
- Preponderance of April-May (~ 800 sightings)

# Distribution of observations, catches and mortality of whale sharks (Scientific observers data)

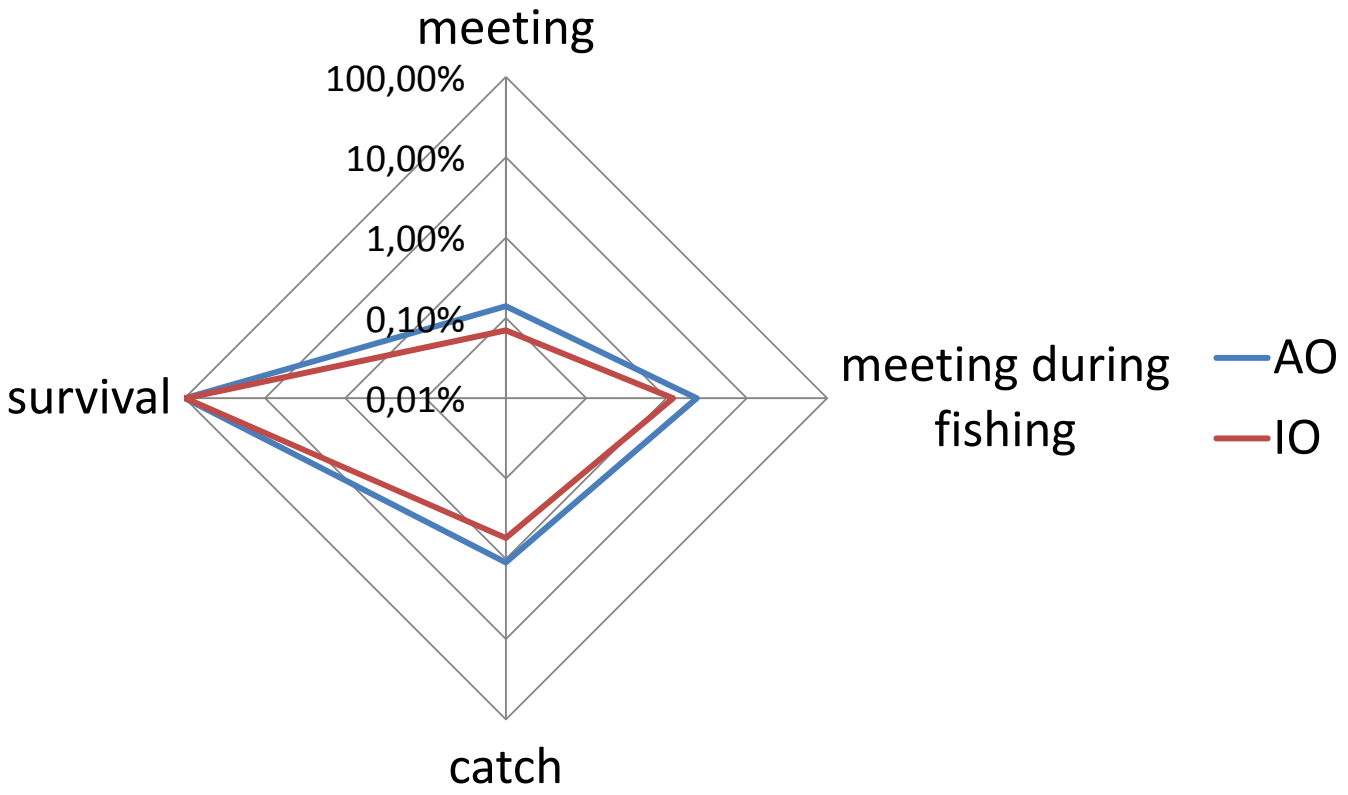



AO: Littoral zone of Gabon. 1 mortality case (North) on 110.

IO: Mozambic Channel and near to the Seychelles.
1 mortality case (East) on 39.

# Indices of interactions between PSF and WHS




**Spider graph (logarithmic scale)**

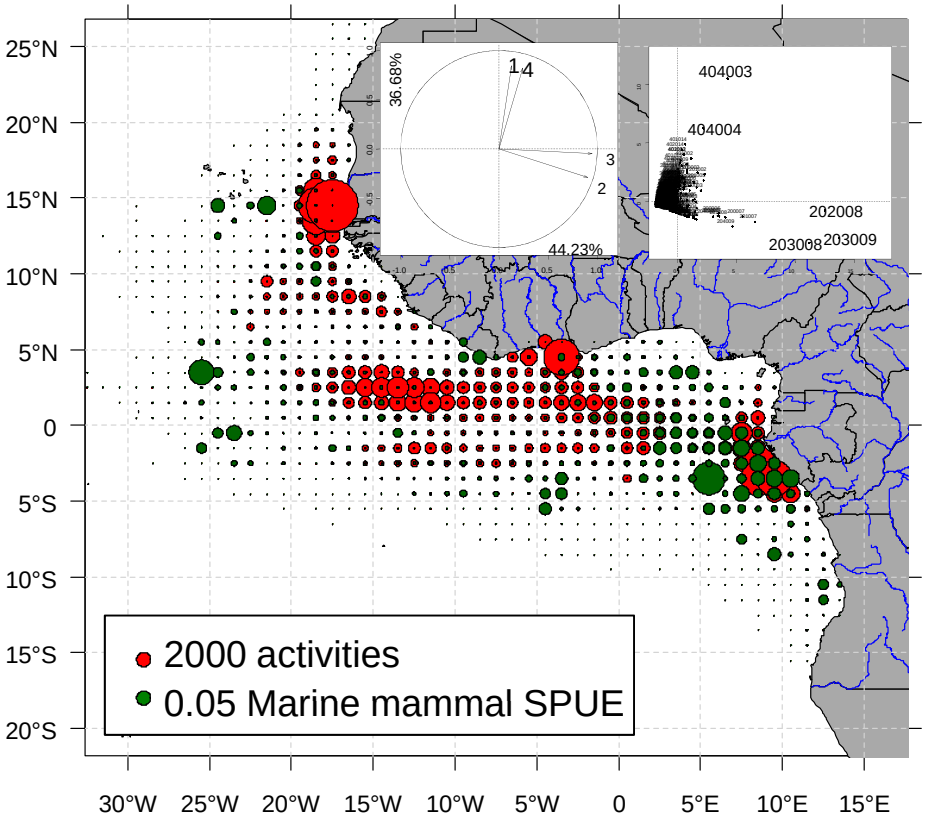
Meeting= 0.11%

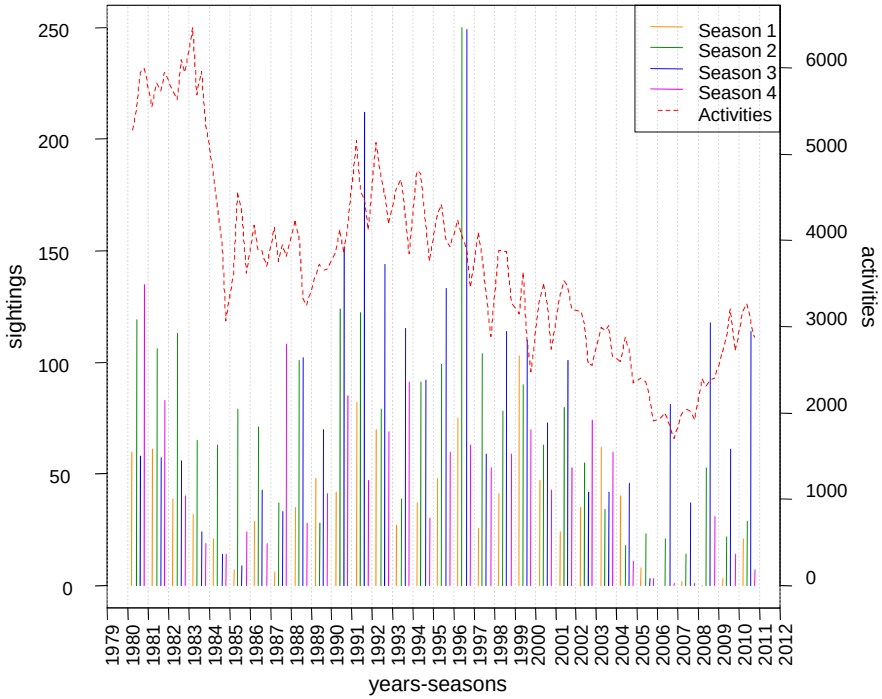
Meeting during fishing= 2%

Catch= 0.9%

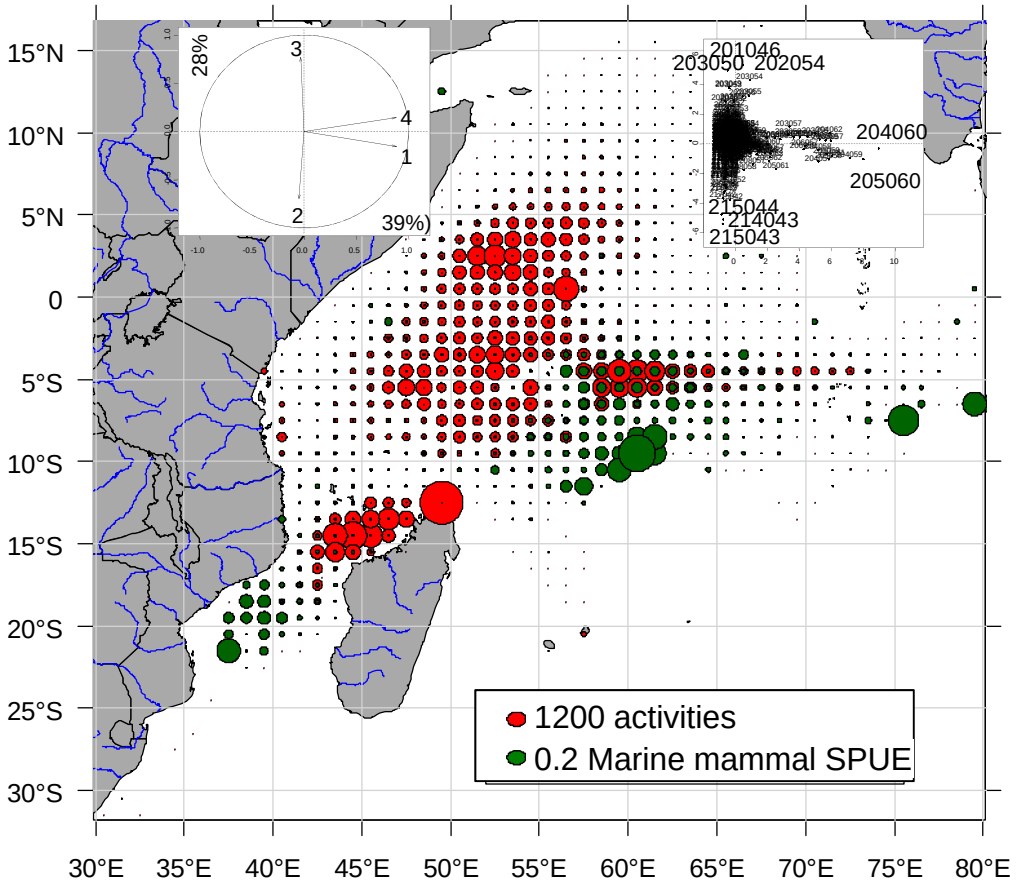
Survival= 98.5%

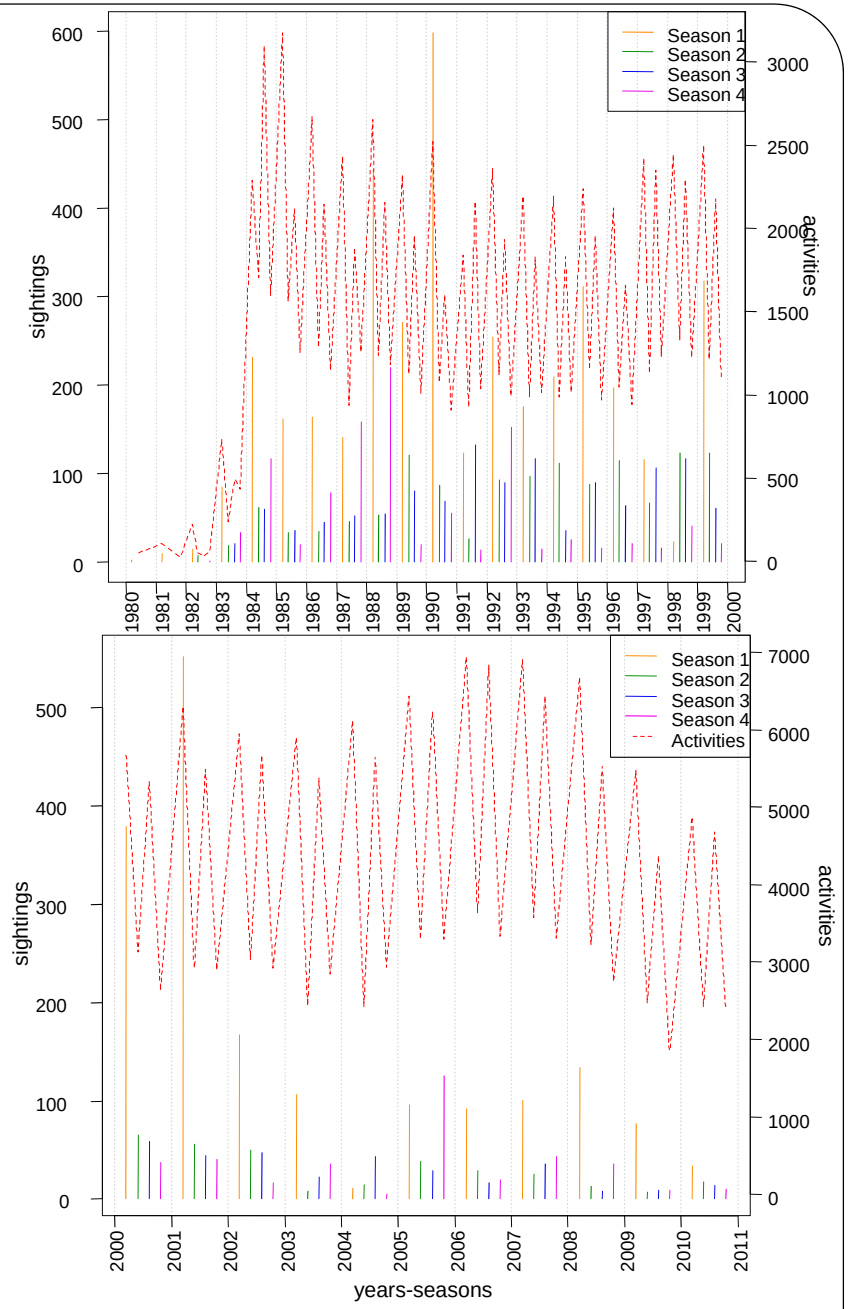
# Marine mammal distribution and annual, seasonal variations of marine mammals sightings and activities



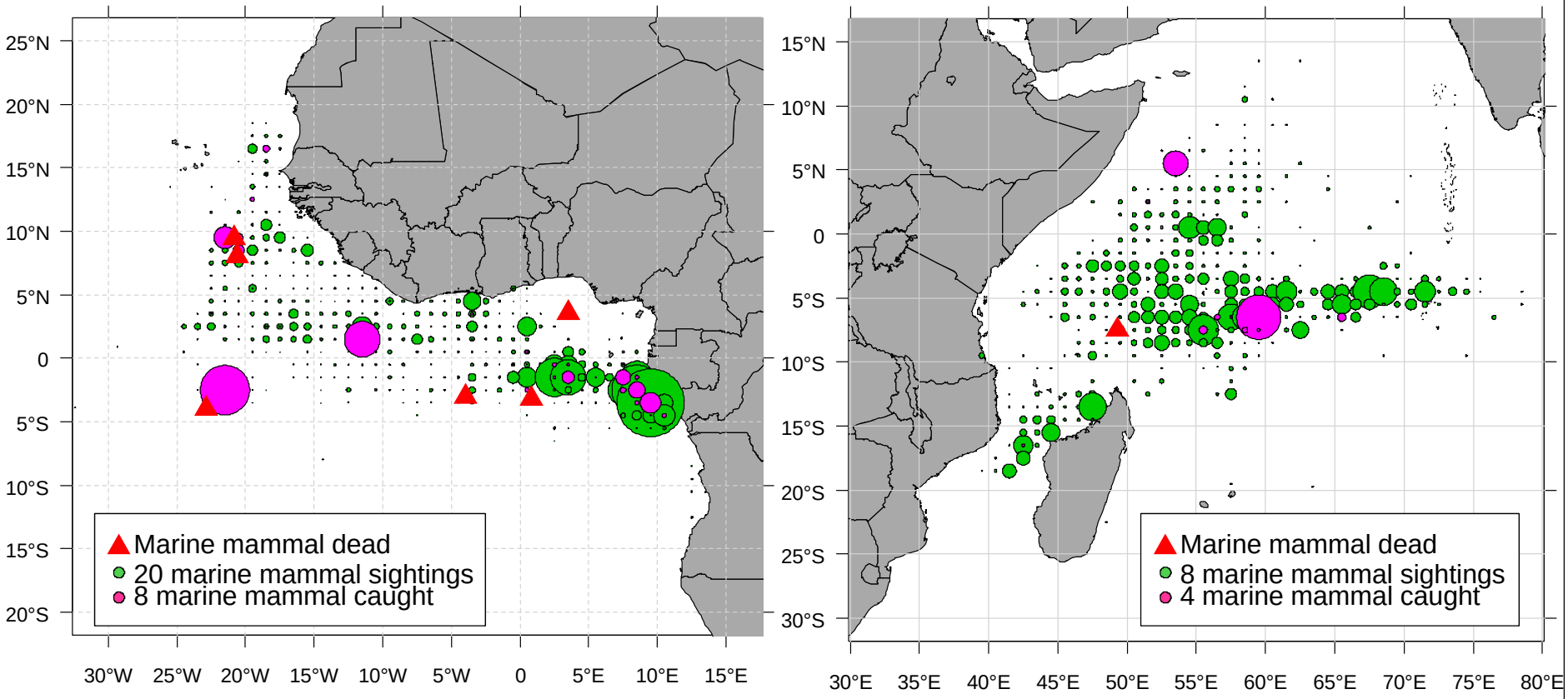

- Wider distribution in comparison to WHS
- Coastal zone of Gabon (WHA) from April to September




- Seychelles (MAM) and Mozambique Channel (WHA)
- Preponderance of December to March and April-May

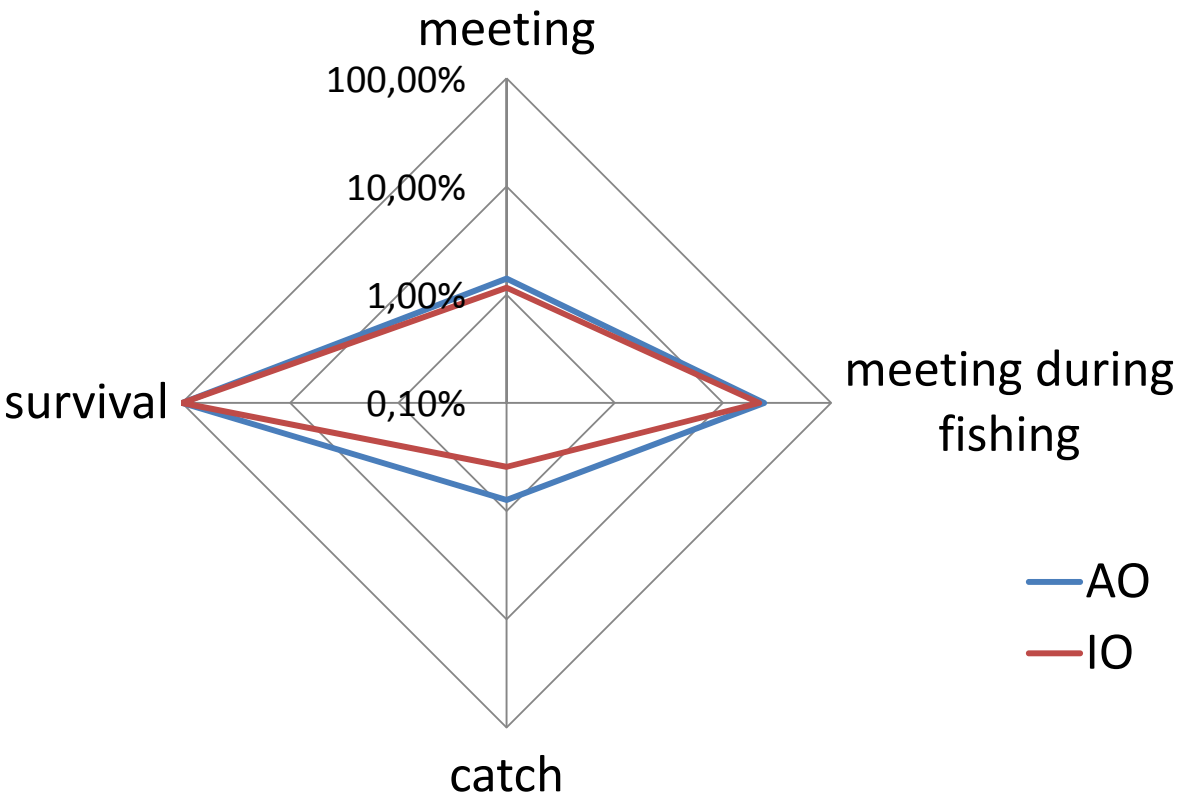
# Distribution of observations, catches and mortality of marine mammals (Scientific observer data)




AO: Littoral zone of Gabon. 14 mortality cases on 193 (8 STW and 5 WHA)

IO: Mozambic Channel and near to the Seychelles. One mortality case on 41 (WHA).

# Indices of interactions between PSF and MAM




**Spider graph (logarithmic scale)**

Meeting= 1.3%

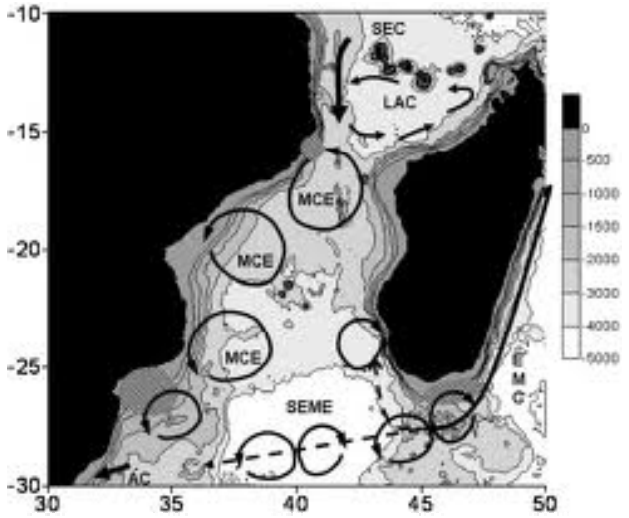
Meeting during fishing= 23%

Catch= 0.6%

Survival= 99.7%

# Discussion

- Environmental conditions that influence the distribution of co-occurrence of activities and observations
  (Sequeira et al., 2012; Saetre & Da Silva, 1984).



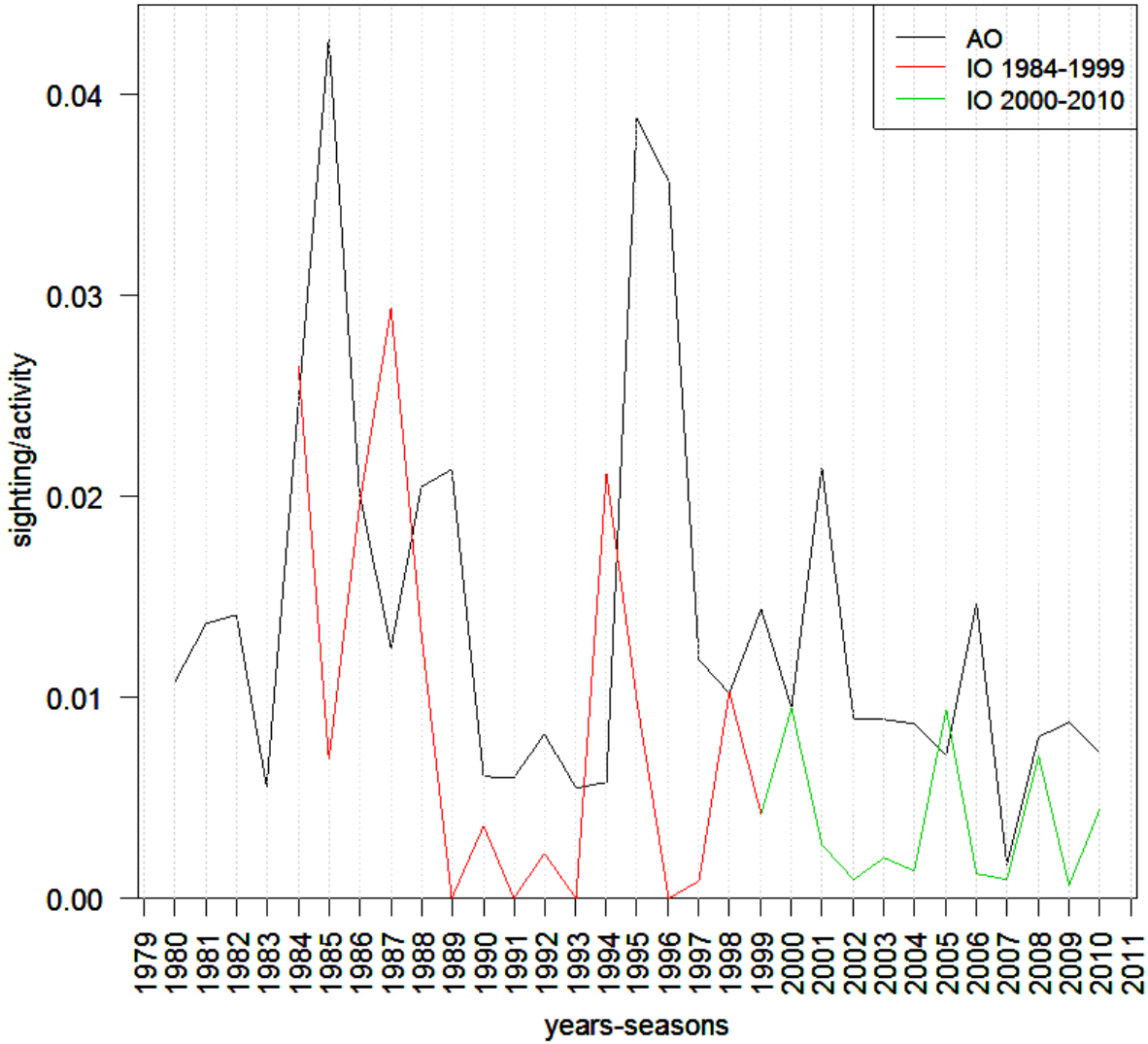

- Apparent low impact in the studied oceans (different from the Pacific, Hall, 1998)

# Conclusions and perspectives

- Frequency distribution of co-occurrence of activities and observations influenced by seasons and years
- Hotspots of interactions: coastal zone of Gabon, Mozambique channel (WHS and MAM) and Seychelles (MAM)

- Form to the attention of shipmasters
- Need to increase the percentage of coverage of scientific observers
- Descriptive models for the study of environmental factors
- Tagging experiment (ISSF)

# Annexes


AO
IO 1984-1999
IO 2000-2010
sighting/activity
0.00
0.01
0.02
0.03
0.04
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
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2001
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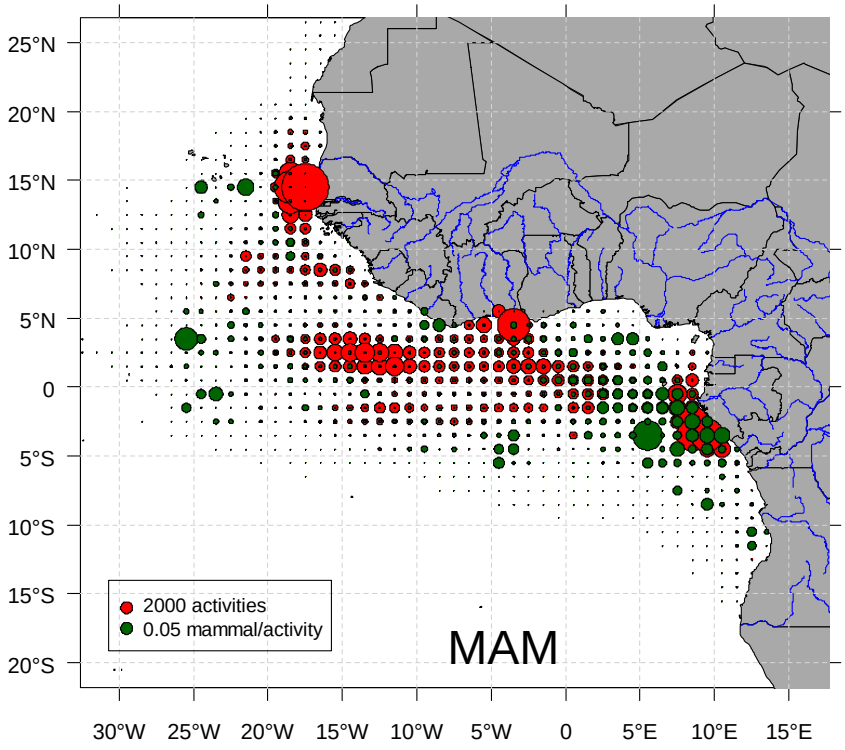
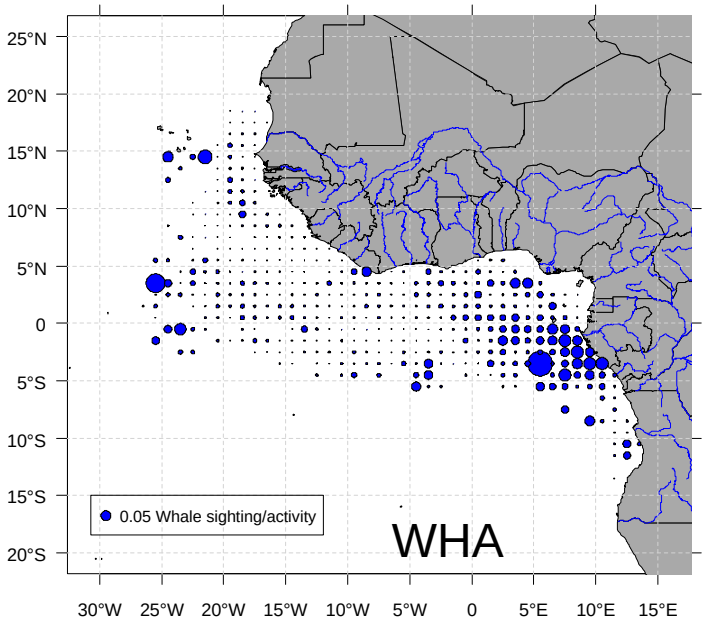
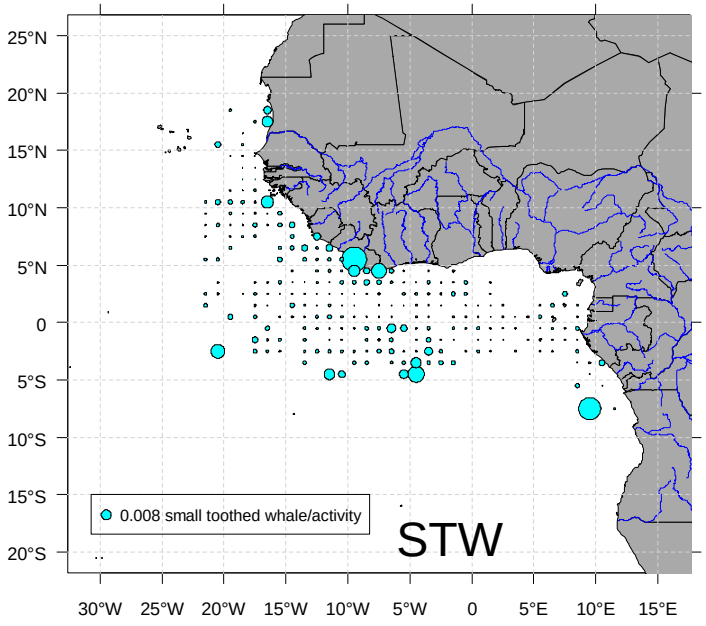
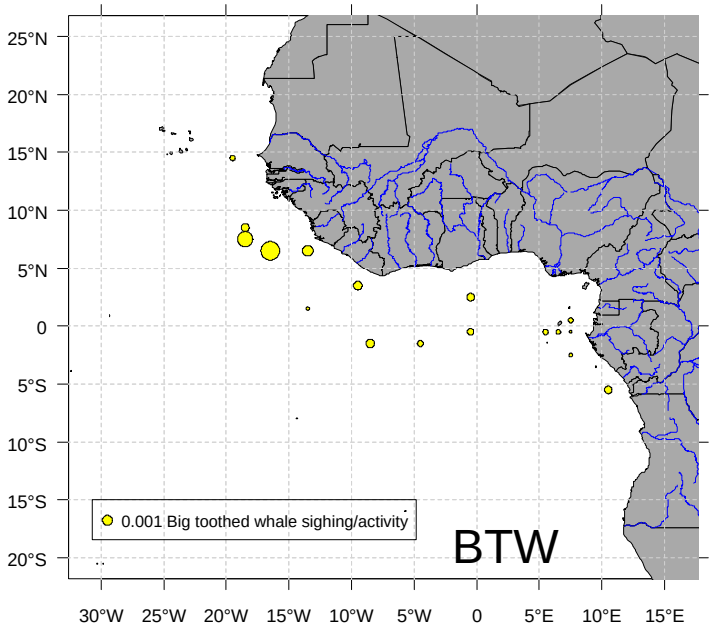
2003
2004
2005
2006
2007
2008
2009
2010
2011
years-seasons

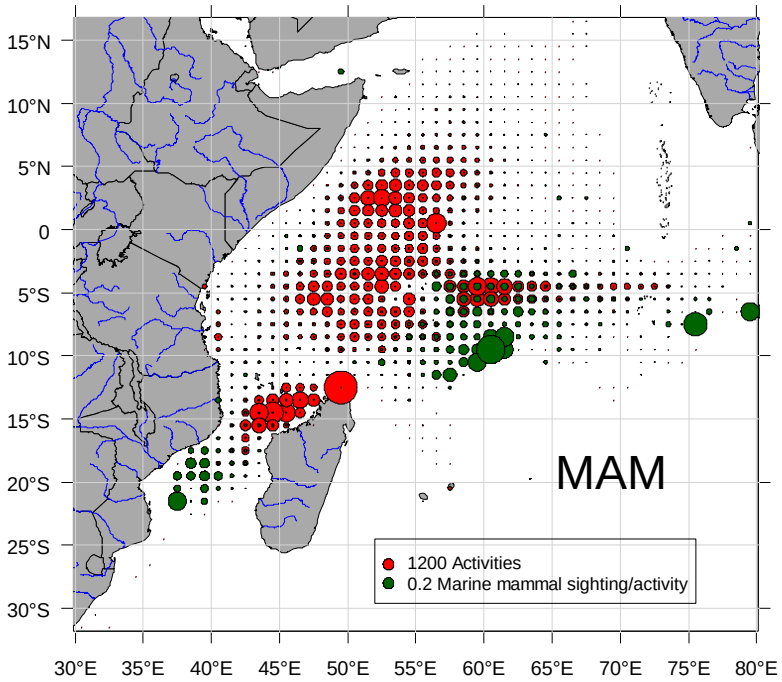
# Marine mammals

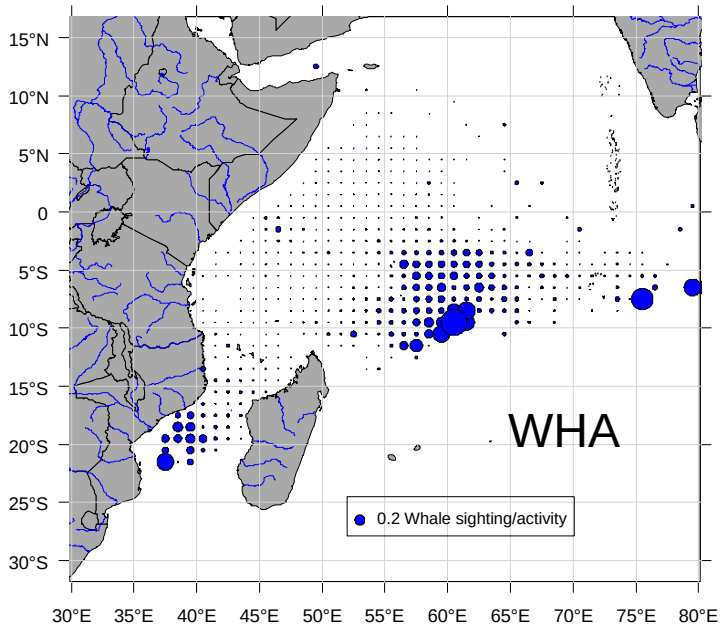


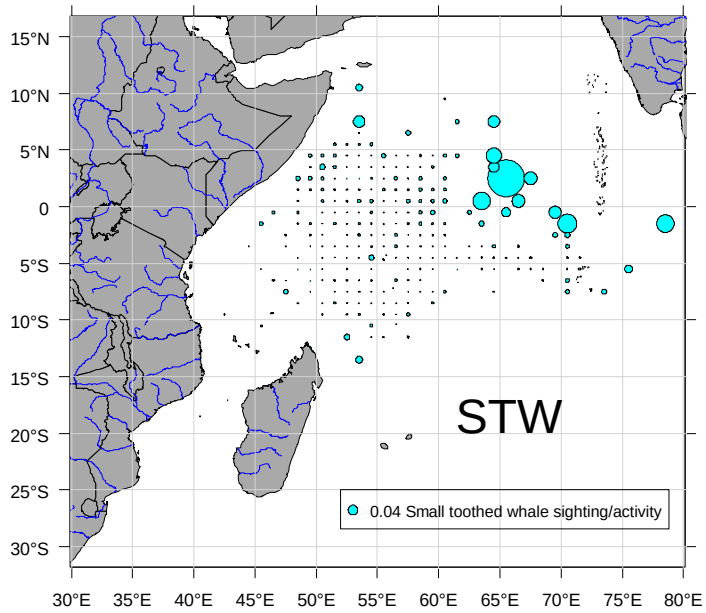



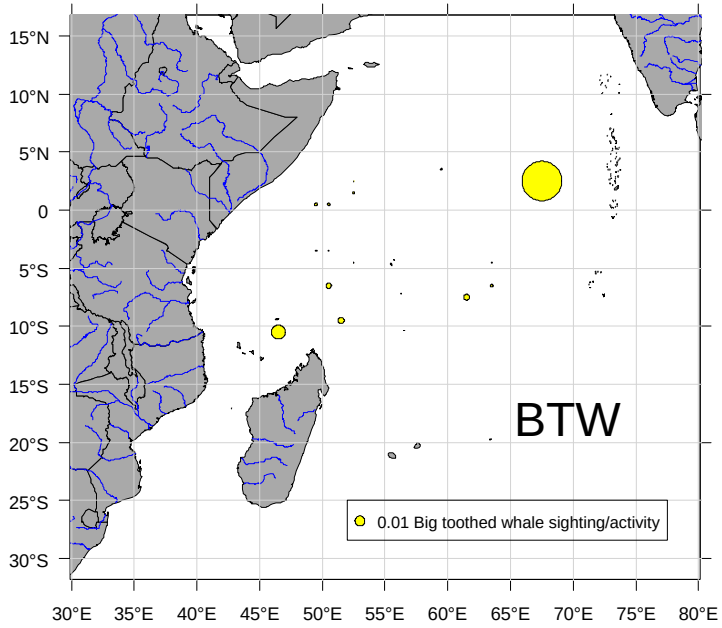



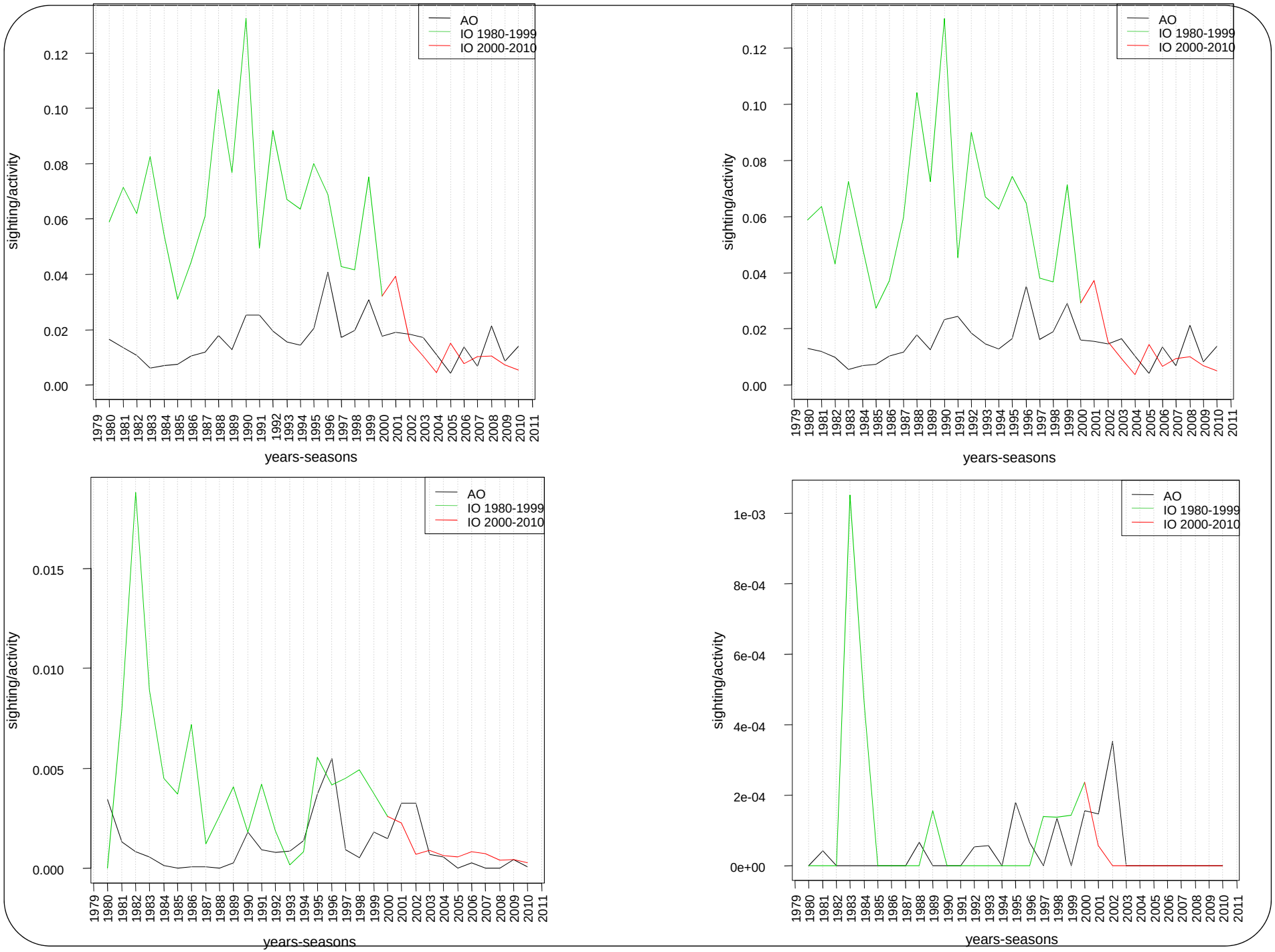




MAM
1200 Activities
0.2 Marine mammal sighting/activity
15°N
10°N
5°N
0
5°S
10°S
15°S
20°S
25°S
30°S
30°E
35°E
40°E
45°E
50°E
55°E
60°E
65°E
70°E
75°E
80°E


WHA
0.2 Whale sighting/activity
15°N
10°N
5°N
0
5°S
10°S
15°S
20°S
25°S
30°S
30°E
35°E
40°E
45°E
50°E
55°E
60°E
65°E
70°E
75°E
80°E


STW
0.04 Small toothed whale sighting/activity
15°N
10°N
5°N
0
5°S
10°S
15°S
20°S
25°S
30°S
30°E
35°E
40°E
45°E
50°E
55°E
60°E
65°E
70°E
75°E
80°E


BTW
0.01 Big toothed whale sighting/activity
15°N
10°N
5°N
0
5°S
10°S
15°S
20°S
25°S
30°S
30°E
35°E
40°E
45°E
50°E
55°E
60°E
65°E
70°E
75°E
80°E


AO
IO 1980-1999
IO 2000-2010
sighting/activity
years-seasons
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.000
0.005
0.010
0.015
0e+00
2e-04
4e-04
6e-04
8e-04
1e-03
1979
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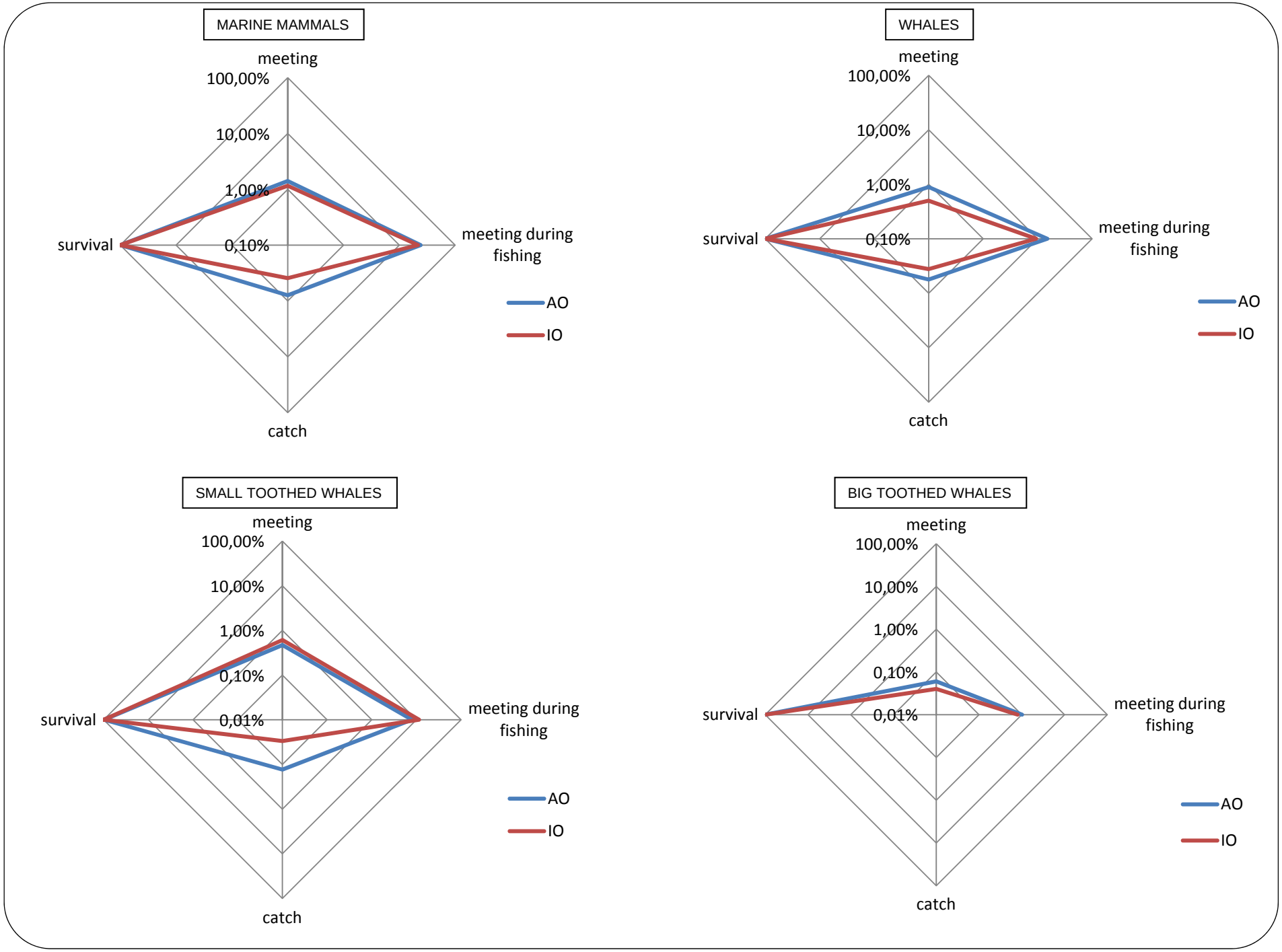
2011

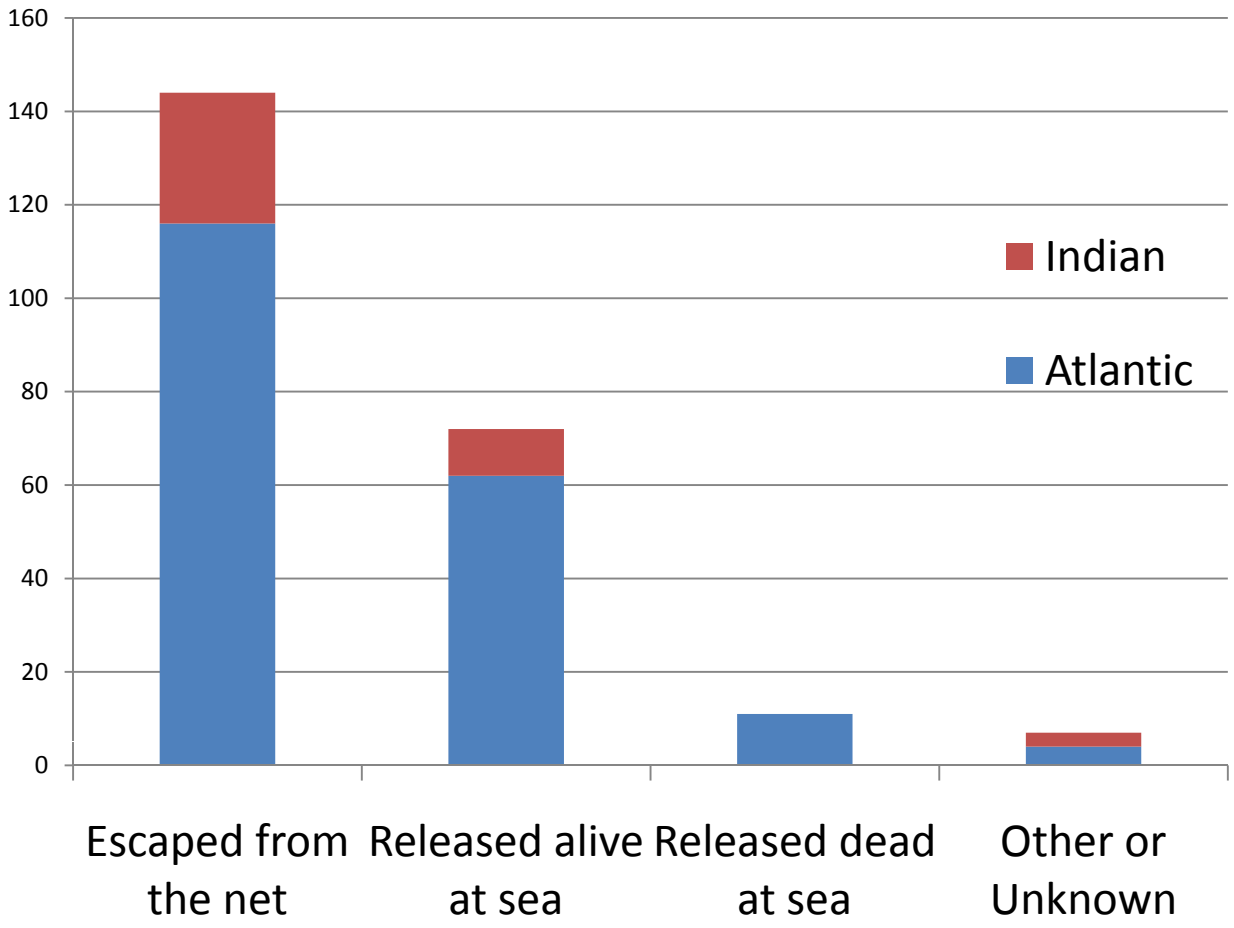

MARINE MAMMALS
meeting
100,00%
10,00%
1,00%
0,10%
survival
meeting during fishing
catch
AO
IO
WHALES
meeting
100,00%
10,00%
1,00%
0,10%
survival
meeting during fishing
catch
AO
IO
SMALL TOOTHED WHALES
meeting
100,00%
10,00%
1,00%
0,10%
0,01%
survival
meeting during fishing
catch
AO
IO
BIG TOOTHED WHALES
meeting
100,00%
10,00%
1,00%
0,10%
0,01%
survival
meeting during fishing
catch
AO
IO

# Species and fate (source observers)

**Table :**Species and numbers of marine mammals encircled and their fate in observers data on purse seine fishery in the Atlantic and Indian Ocean from 1995 to 2011

| Species/groups | Common name | Escaped from the net | | | Released alive at sea | | | Released dead at sea | | | Other or Unknown | | | Total | | | Max on a catch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AO | IO | Total | AO | IO | Total | AO | IO | Total | AO | IO | Total | AO | IO | Total | |
| Unidentified cetacean | | 11 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 11 | 1 |
| Unidentified baleen whale | | 32 | 13 | 45 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 34 | 14 | 48 | 6 |
| *Megaptera novaeangliae* | (Humpback whale) | 5 | 0 | 5 | 1 | 0 | 1 | 3 | 0 | 3 | 1 | 0 | 1 | 10 | 0 | 10 | 3 |
| *Balaenoptera physalus* | (Fin whale) | 13 | 9 | 22 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 9 | 25 | 4 |
| *Balaenoptera edeni* | (Bryde's whale) | 14 | 5 | 19 | 4 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 5 | 23 | 3 |
| *Balaenoptera borealis* | (Sei whale) | 5 | 1 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 5 | 3 | 8 | 2 |
| Unidentified toothed whale | | 0 | 0 | 0 | 13 | 0 | 13 | 0 | 0 | 0 | 2 | 0 | 2 | 15 | 0 | 15 | 5 |
| *Tursiops truncatus* | (Common bottlenose dolphin) | 0 | 0 | 0 | 4 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 4 | 4 |
| *Stenella attenuata* | (Pantropical spotted dolphin) | 0 | 0 | 0 | 9 | 0 | 9 | 8 | 0 | 8 | 0 | 0 | 0 | 17 | 0 | 17 | 6 |
| *Peponocephala electra* | (Melon-headed whale) | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| *Steno bredanensis* | (Rough-toothed dolphin) | 6 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 6 | 6 |
| *Pseudorca crassidens* | (False killer whale) | 0 | 0 | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 9 |
| *Globicephala melas* | (Long-finned pilot whale) | 0 | 0 | 0 | 26 | 0 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 0 | 26 | 26 |
| *Globicephala macrorhynchus* | *(Short-finned pilot whale)* | 30 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 30 | 30 |
| Total general | | 116 | 28 | 144 | 62 | 10 | 72 | 11 | 0 | 11 | 4 | 3 | 7 | 193 | 41 | 234 | |
| % | | 60% | 68% | 62% | 32% | 24% | 31% | 6% | 0% | 5% | 2% | 7% | 3% | 100% | 100% | 100% | |

# Fate of marine mammals after being encircled by PSF (source observer data)



| | AVDTH dataset 1980-2011 | | | | ObServe dataset 1995 - 2011 | | |
|---|---|---|---|---|---|---|---|
| | OA 1980-2011 | OI 1980-1999 | OI 2000-2011 | Total | OA 1995-2011 | OI 1995-2011 | Total |
| ACTIVITIES | 467 814 | 110 575 | 197 217 | 775 606 | 169 546 | 114 581 | 284 127 |
| WSH | 6 673 | 1 073 | 706 | 8 452 | 237 | 74 | 311 |
| % WSH by activities | 1.43 | 0.97 | 0.36 | 1.09 | 0.14% | 0.07% | 0.11% |
| SETS | 237 918 | 59 940 | 120 924 | 418 782 | 9 969 | 6 129 | 16 098 |
| % SETS among activities | 50.86% | 54.21% | 61.32% | 53.99% | 5.88% | 5.35% | 5.67% |
| WHS associated to a set | 6613 | 1003 | 675 | 8291 | 94 | 24 | 118 |
| % WHS with sets | 99.10% | 93.48% | 95.61% | 98.10% | 39.66% | 32.43% | 37.94% |
| % SETS with whs | 2.78% | 1.67% | 0.56% | 1.98% | 0.94% | 0.39% | 0.73% |
| CATCHES occurancy of whs | - | | - | - | 111 | 34 | 145 |
| Nb WHS caught | - | | - | - | 115 | 39 | 154 |
| % WHS by catch occurancy | - | | - | - | 46.84% | 45.33% | 46.47% |
| WHS fate known | - | | - | - | 110 | 39 | 149 |
| % survie | | | | | 99.09% | 97.44% | 98.66% |

| | AVDTH dataset 1980-2011 | | | | ObServe dataset 1995 - 2011 | | |
|---|---|---|---|---|---|---|---|
| | OA | OI | | Total | OA | OI | Total |
| | | 1980-1999 | 2000-2010 | | | | |
| ACTIVITIES | 467 814 | 110 575 | 197 217 | 775 606 | 169546 | 114581 | 284127 |
| MAMMALS | 7 454 | 7405 | 2 836 | 17 695 | 2 395 | 1 326 | 3 721 |
| BALEINES | 6875 | 6989 | 2 648 | 16 512 | 1504 | 575 | 2079 |
| GRAND ODONTOCETES | 18 | 10 | 5 | 33 | 101 | 49 | 150 |
| PETITS ODONTOCETES | 561 | 406 | 183 | 1 150 | 790 | 702 | 1492 |
| %MAMMALS by activity | 1.59% | 6.70% | 1.44% | 2.28% | 1.41% | 1.16% | 1.31% |
| %WHALES by activity | 1.47% | 6.32% | 1.34% | 2.13% | 0.89% | 0.50% | 0.73% |
| %BIG TOOTHED by activity | 0.00% | 0.01% | 0.00% | 0.00% | 0.06% | 0.04% | 0.05% |
| %SMALL TOOTHED by activity | 0.12% | 0.37% | 0.09% | 0.15% | 0.47% | 0.61% | 0.53% |
| SETS | 237 918 | 59 940 | 120 924 | 418 782 | 9969 | 6129 | 16098 |
| % SETS among activities | 50.86% | 54.21% | 61.32% | 53.99% | 5.88% | 5.35% | 5.67% |
| MAMMALS associated to a set | 5819 | 5405 | 2634 | 13858 | 287 | 106 | 393 |
| WHALES | 1257 | 1241 | 361 | 2859 | 255 | 95 | 350 |
| BIG TOOTHED | 12 | 82 | 4 | 98 | 7 | 3 | 10 |
| SMALL TOOTHED | 393 | 365 | 155 | 913 | 25 | 8 | 33 |
| % MAM with sets | 77.70% | 78.30% | 81.74% | 85.61% | 11.98% | 7.99% | 10.56% |
| %whales | 81.72% | 99.82% | 86.37% | 82.69% | 16.95% | 16.52% | 16.84% |
| %BIG TOOTHED | 33.33% | 20.00% | 20.00% | 27.27% | 6.93% | 6.12% | 6.67% |
| %SMALL TOOTHED | 29.95% | 10.10% | 19.67% | 21.30% | 3.16% | 1.14% | 2.21% |
| % SET with MAM | 3.13% | 12.35% | 2.35% | 4.23% | 2.88% | 1.73% | 2.44% |
| %set with whales | 2.89% | 11.66% | 2.19% | 3.94% | 2.56% | 1.55% | 2.17% |
| %set with big | 0.01% | 0.02% | 0.00% | 0.01% | 0.07% | 0.05% | 0.06% |
| %set with small | 0.24% | 0.68% | 0.15% | 0.27% | 0.25% | 0.13% | 0.20% |
| CATCHES occurancy of mam | | | | | 79 | 24 | 103 |
| CATCHES occurancy of whales | | | | | 56 | 22 | 78 |
| CATCHES occurancy of big | | | | | 0 | 0 | 0 |
| CATCHES occurancy of small | | | | | 13 | 2 | 15 |
| Nb MAM caught | | | | | 193 | 41 | 234 |
| Nb WHALES caught | | | | | 84 | 31 | 115 |
| Nb BIG caught | | | | | 0 | 0 | 0 |
| Nb SMALL caught | | | | | 99 | 10 | 109 |
| % MAM by catch occurancy | | | | | 3.30% | 1.81% | 2.77% |
| %whales | | | | | 3.72% | 3.83% | 3.75% |
| %big | | | | | 0.00% | 0.00% | 0.00% |
| %small | | | | | 1.65% | 0.28% | 1.01% |
| MAM dead | | | | | 12 | 1 | 13 |
| whale dead | | | | | 3 | 1 | 4 |
| ptit dead | | | | | 9 | 0 | 9 |