EU PURSE SEINE FISHERY INTERACTION WITH MARINE TURTLES IN THE ATLANTIC AND INDIAN OCEANS: A 15 YEARS ANALYSES

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Abstract

Bycatch of marine turtles, vulnerable or endangered species, is a growing issue of all fisheries, including Oceanic purse-seine fishery. The present paper seeks to assess marine turtle bycatch at a spatial and temporal level in the European purse seine fishery operating in the Atlantic and Indian Oceans. The study was based on data collected through French and Spanish observer programs from 1995 to 2011, a period where more than 230 000 fishing sets were realized by the UE fleets in both Oceans. A total of 15 913 fishing sets were observed, including 6 515 on drifting Fish Aggregate Devices (FAD) and 9 398 on Free Swimming Schools (FSC). Over the study period, 597 turtles were caught, 86% being released alive at sea. At the same time, from 2003 to 2011, 14 124 specific observations were carried out on floating objects whether they ended in a set or not. 354 marine turtles were observed upon which 80% were already free or entangled alive and therefore released alive. At the temporal and spatial level, data were organized and analysed by Ocean, fishing mode (FAD vs. FSC) as well as by year, quarter and statistical square of 1°. In order to evaluate the impact if this fishery in both Oceans, bycatch distribution was compared to the total fishing effort of the UE fleet, as well as to the known marine turtle post nesting migration routes, nesting population abundances and known feeding areas. The species composition, the size and sex structure of bycatch are also discussed here. At last, an attempt to raise the data to the total fishing effort was carried out. Based on observation of marine turtle by-catches on sets, we estimated that, globally, 3500 marine turtles were accidentally captured by the EU-PS fleet in the Atlantic Ocean from 1995 to 2010, and around 2000 in the Indian Ocean from 2003 to 2010, with a corresponding annual bycatch rate of 218 (SD=150) and 250 (SD=157), with 91 and 77% being released alive, respectively in the Atlantic and Indian Ocean. However, because of important uncertainties mainly due to the low observation coverage and the scarcity of marine turtle bycatch events, it was impossible to produce solid and reliable global estimates of marine turtle bycatch and mortality due to PS activity.

Key words: European tuna fishery, purse seine, marine turtle, bycatch, Atlantic and Indian Oceans

1. Introduction

The environmental and economic concerns about the impacts of the fisheries on marine populations are growing. Fisheries can alter habitats, and disturb the community structure by increasing mortality and modifying the population composition and consequently, the whole ecosystem can be affected (Jennings & Kaiser, 1998; Hall et al., 2000; Jackson et al., 2001; Garcia & Cochrane, 2005; Pauly et al., 2005). So acts bycatch, *i.e.* the incidental takes of undesirable size or age classes of the target species (*e.g*. juveniles), or the incidental take of other non-target species (Lewison et al., 2004). This issue is essential since it has been identified as one of the first causes of marine megafauna population declines (Lewison et al., 2004). Large marine vertebrates, such as marine turtles, marine mammals and seabirds, have little or no commercial value, but become entangled or hooked accidentally by fishing gear that is intended for valuable target species, and no fishery is spared by this statement (Hall et al., 2000).

Marine turtles are highly vulnerable reptiles that have been subjected to direct exploitation for centuries, resulting in severely depleted populations in many cases. Marine turtle species are listed as vulnerable endangered, and critically endangered on the IUCN Red List (www.iucnredlist.org; accessed 30 July 2012). Five species are present in the Indian Ocean: the green turtle (*Chelonia mydas*), the hawksbill turtle (*Eretmochelys imbricata*), the loggerhead turtle (*Caretta caretta*), the olive ridley (*Lepidochelys olivacea*) and the leatherback turtle (*Dermochelys coriaca*). The Atlantic Ocean hosts one additional species: the Kemp's turtle (*Lepidochelys Kempii*). As the awareness of their plight and threatened status grew, so too has the advent of their protection in many regions of the world. Whist this protection has been successful in many cases, the threat to marine turtles remains high because of inadequate compliance with regulations and especially indirect mortality posed by fisheries (Bourjea, 2012).

Even if locally marine turtle behaviour, feeding and reproduction are well understood, the lack of a global vision and understanding of the movement between the successive habitats and their interactions with regional fisheries does not lead to appropriate conservation measures at the regional level. Marine turtle is known to spend the first years of life, commonly called "the lost years", drifting with currents in the open Ocean surface foraging zone (Carr, 1987). After 5 to 20 years in this habitat, the turtle is known to move to costal shallow water feeding zones and stay there until its sexual maturity. On reaching adulthood, reproductive females typically make long distance migrations between feeding sites and their natal breeding beaches (*e.g*. for green turtle see Limpus et al., 1992; annexe 1b). Marine turtle shows great fidelity to both nesting (Meylan 1982) and feeding grounds (Limpus et al., 1992), even though these may be separated by thousands of kilometres (Mortimer & Carr 1987). Annexe 1a-f presents nesting sites for marine turtle species found in the Atlantic and in the Indian Oceans. Attempts have been made to identify feeding areas using flipper tagging (*e.g*. Le Gall & Hughes 1987) as well as via satellite telemetry (see review in Godley et al., 2007), but the links between nesting sites and feeding areas are still not well known.

Oceanic purse seine (PS) fishery is responsible for 40% of the total tuna catches in the Atlantic and Indian Oceans (ICCAT, 2011; IOTC, 2011). The fishery represents around 500 000 tons of tuna per year and is largely dominated in the Atlantic and Indian Oceans by the European Union (EU) fleets composed by Spanish and French vessels. EU – PS fishery caught in 2010 196 000 and 100 000 tons of tunas (yellowfin (*Thunnus albacores*), skipjack (*Katsuwonus pelamis*) and bigeye (*Thunnus obesus*) tuna) respectively in the Atlantic and Indian Oceans (see ICCAT, 2011 and IOTC 2011). PS's technique consists in surrounding the tuna school with a net. The fishing activity can take place on a free swimming school or on a school aggregated under a floating object, called a Fish Aggregated Device (FAD). FAD can be natural objects, such as logs or palm branches, or man-made objects with a buoy incorporate which indicates their position. EU has developed fishing under FAD since 1993 (Chanrachkij & Loog-on, 2003), and nowadays it represents about 50% of the EU French and Spanish PS sets (IOTC – ICCAT databases 2011).

Purse seining operations can take place in turtles' habitats. Encounters between turtles and purse seiners or FAD can occur in coastal habitats near nesting beaches and feeding zones and across migration roads in open sea area (Chanrachkij & Loog-on, 2003; Luschi et al., 2003; Seminoff et al., 2008). Many reports and grey literature have already emphasized that PS fishery has a low bycatch level. Hall (2012) provided a review of available data on PS marine turtle bycatch in the 3 Oceans. He noted that marine turtle bycatch is usually less than 1% of the sets, with captures numbering generally one individual, and in the vast majority of the sets, the turtle is released alive. Most of the bycatch occurs when the purse seiners encircle the tuna schools. Marine turtles are most of the time entangled in the net and free alive when the net is pulled up from the water towards the power block. Marine turtles are also attracted by floating devices such as FAD that usually have piece of nets hanging below them. Turtle may become entangled for a long time and mortality may occur by drowning. An unknown percentage of drifting FAD gets lost due to currents, it creates what it is called ghost fishing phenomena by drifting FAD (*e.g.* Chanrachkij & Loog-on 2003).

The present paper focuses on the description of interactions between marine turtles and the EU PS fishery in the Atlantic and Indian Oceans (respectively call in this paper AO and IO) using 15 years of data from at-sea Spanish and French observer programs. Data collected from 1995 to 2011 were used (1) to assess, at a spatial and temporal level, marine turtle bycatch in the EU-PS fishery in the AO and IO, (2) to estimate whenever it was possible interaction at the species level, and finally (3) to provide an order of magnitude of the total marine turtle bycatch in the EU-PS fleets over the study period.

2. Materiel and methods

2.1. Data collection

As bycatch is poorly reported in fishery log-books, research is usually carried out using observer programs data (Rochet & Trenkel, 2005). The International Commission for the Conservation of Atlantic Tunas (ICCAT) and the Indian Ocean Tuna Commission (IOTC), the two Regional Fisheries Management Organisations (RFMO) that respectively manage large pelagic fishes in the AO and IO, recommended to signatory countries to implement observer programs in order to cover at least 5% of the effort by fleet and by Ocean (IOTC Resolution 10/02; ICCAT Resolution 10-10). Under the EU Data Collection Regulations (EC-DCR) No 1543/2000, 1639/2001 and 1581/2004, the European Union established a mandatory sampling program to estimate the amount of bycatch and discards in the EU fisheries. The French and Spanish scientific institutes (Institut de Recherche pour le Développement (IRD), AZTI-Tecnalia (AZTI) and Instituto Español de Oceanografía (IEO)) implemented a common framework for collecting and analysing the data from observer programs conducted on the tropical tuna PS fisheries operating in the AO and IO. The institutes also developed a common database (Observe), from which the data presented in this paper were extracted. The French and Spanish institutes started their programs respectively in 2005 and in 2003. In 2009, Terres Australes et Antartiques Françaises (TAAF) joined IRD observer program and database and deployed observers on UE PS in activity in the EEZ of the Eparses Islands. Data collection from French and Spanish PS observer DCR program is detailed in Amandè et al. (2008a; 2012). Results from other past observer programs implemented by each institute were also included in the database and analysed here: Faune associée (1995 – 1996), Patudo (1997-1999) and Moratoire (1997-2005) – see table 1. It is worthwhile noting that the integration of the data from Moratoire is still in process, and the information from this program is not validated yet.

2.2. Data processing

Data from two types of observations were used in this study: on sets and on drifting objects. On the one hand, observations on sets give us information on by-caught turtles during a set on Free Swimming School (FSC) or Fish Aggregated Device (FAD). A sample of these observed turtles was measured and their sex was identified whenever possible. Data from observed sets range from 1995 to 2011. On the other hand, observations on objects may take place even if the object is not fished (*i.e.* not set associated). The object can be deployed, removed, fished or just visited. As drifting objects are not individually identified and as their position can change, one object can be observed several times. The observer takes note of the presence or the entanglement of turtles or not. Object observations only cover the 2003-2011 period.

Before analysing the dataset, data were globally checked in order to avoid outliers due to mistakes in the capture of data into the database, and removed from the dataset if the correction was not obvious: incorrect statistical squares of 1°, isolated typos, and identically repeated data. Furthermore, marine turtle related data (*i.e.* location, size, weight, sex…) were checked one by one and compared to the literature (Table 2). Outliers were corrected whenever it was possible or removed from the analysis. Moreover, the Kemp's turtle being only present in the AO (Annexe 1f), turtles identified as Kemp's turtles in the IO were changed to olive ridley turtles as both species are often confused.

2.3. Analysis and extrapolation

Noting that observation protocols could be considered as similar between the different programs over the years as they were implemented by the same institutes following the same protocols, data from these different programs were aggregated. Furthermore, as fishing techniques and strategy for French and Spanish fleets were not available for this paper, we estimated that there may be no significant differences between both fleet activities. At last, as both countries share the same observer programs since their implementation, we supposed that there may be no significant differences in the observed data from both fleet. French and Spanish data were then gathered for the analyses.

Data were categorized using two fishing modes (FAD or FSC) that are known to result in the major source of variability for bycatch in PS (Delgado et al., 2000; Romanov, 2002; Sánchez et al., 2007, Amandè et al., 2010). However, because of (1) marine turtle identified Regional Management Units (Wallace et al., 2011), (2) main nesting sites (Annexe 1a-f), (3) the few current links that do exist between marine turtle stocks in the AO and IO (*e.g.* for green turtle, see Bourjea et al., 2007b) and (4) the spatial distribution of catch and effort from EU-PS, analyses were performed by Ocean. Finally, in order to assess a seasonal and spatial effect on marine turtle bycatch, observed data were stratified per 1° statistical square and yearly or by quarter. Whenever it was possible, analyses per species composition, sex and size were also temporarily and spatially investigated.

In order to avoid a bias from the observation effort, we raised the data to the observation effort. To obtain the number of observed turtles per observed set or per object observation per year, we divided the total number of observed turtles by the total observed sets or object observations per year. The annual mean of observed turtles per observed set or object and respective standard deviation were then calculated per Ocean and per fishing mode. The annual mean by 1° statistical square was also determined using the same calculation.

To observe if there is a spatial segregation between species accidentally caught, the latitudinal and longitudinal barycentres of by-caught or observed turtles were calculated for each species in both Oceans. For the turtles caught by fishing sets, no difference was made between fishing modes, since there were not enough data by species for sets on FSC in the IO. Moreover, GPS positions of by-catches were used to estimate the Utilisation Distribution (UD) of interaction with the kernels method. The kernel method has been recommended by many authors for the estimation of the utilization distribution (*e.g.* Worton, 1989, 1995). The Utilization Distribution (UD) is the bivariate function giving the probability density that an animal is found at a point according to its geographical coordinates. Using this model, one can define the home range as the minimum area in which an animal has some specified probability of being located. The functions used here correspond to the approach described in Worton (1995). Kernels were implemented using R (R Development Core Team. 2010; adehabitat and maps packages)

Marine turtle bycatch are rare events and because these resources (1) do not follow the assumptions most commonly used that discards are proportional to catch or to effort, and (2) are both environmental conditions and fishing methods dependent (Rochet & Trenkel, 2005), reliable estimations of bycatch remain ambitious in all fisheries without dedicated studies. Such environmental dependence is particularly noticeable in the case of marine turtles and PS fishery because of (1) the Oceanic range of PS fishing operation, (2) the complex life cycle of marine turtle (Figure 1, Miller, 1997), (3) their great migratory capability (Limpus et al., 1992), and (4) the lack of knowledge about the pelagic phases of these species (*e.g*. "the open Ocean surface foraging zone", figure 1). In PS fishery, marine turtle bycatch are only reported by on board observers, but this activity is also characterized by low observer coverage worldwide. Such a low coverage contributes to the difficulty in producing solid estimates of marine turtle bycatch and mortality due to PS activity (Sanchez et al., 2007). At last, Amandè et al., (2012) clearly stated that the low observation coverage in the case of EU-PS fishery in the IO resulted in large uncertainties in bycatch estimates (up to 50% of mean square error). Having said that, we carried out a tentative elevation of the observed bycatch data to the total fishing effort per year and Ocean in order to have an order of magnitude of the total number of marine turtles accidentally caught by the PS fishery in the AO and IO. We used information from French and Spanish fishing statistics from logbooks to determine a raising factor based on the effort of the fleets (number of sets on FSC and FAD per 1° square, per year and per quarter). In this way, we established an estimation of the total marine turtle bycatch based on information during observed fishing sets. Since there is no available information on the total number of deployed FAD by EU-PS fishery, it was not possible to raise the data and to estimate the real impact of ghost fishing by drifting FAD.

3. <u>Results</u>

Initially, the dataset related to observation on set or object extracted from the database "Observe" contained 17 869 data. After revisions, 503 mistakes were identified, 162 of which were modified and 341 were removed because of discrepancies with field reality or uncorrectable mistakes. The final dataset was therefore composed of 17 366 data.

The study was based on data collected through French and Spanish observer programs from 1995 to 2011, a period where more than 230 000 fishing sets were realized by the UE fleets in both Oceans (Table 3).

3.1. Data coverage

3.1.1. Observed fishing sets

The effort data of 2011 being still in process, the coverage was calculated from 1995 to 2010, even if we analysed turtle related data over the 1995 – 2011 period. The coverage of fishing set observation varied a lot since 1995 to 2010 ([0.5 – 33.6] in the AO and [0– 35.0] % in the IO; table 3). With a total number of observed sets of 15 931, 6 068 on FAD and 8 863 on FSC (Table 4), the overall coverage for the 1995-2010 period is quite important for such fishery, with respectively for the AO and IO, 10.3% and 5.1% (Table 3). Since 2007, the programs have reached in both Oceans at least the 5% coverage recommended by ICCAT and IOTC (Table 3). However, it is worthwhile noting that in 2010, there is still disequilibrium in sampling coverage between Oceans, the AO coverage (11.4%) being higher than the one in IO (8.3%). This disequilibrium is also noteworthy between fishing modes, with sets on FSC being more observed than sets on FAD (Table 4). Besides, the level of total fishing sets on FSC is almost the same in both Oceans (around 51 000 sets over the study period; table 5), but twice more observations were carried out on FSC in the AO. UE-PS used to fish twice more on FAD in the IO (61 734 sets) than in the AO (35 727 sets), which is not reflected in the observation effort, as the same number of observations were carried out on FAD in both Oceans (around 3000, see table 5). The coverage by quarter is given in annexe 2ab.

Figures 2ab and 3ab show the spatial distribution of the total fishing effort by fishing mode (in number of sets per 1°square) in both Oceans from 1995 to 2011, as well as the set observation effort (by quarter, see annexes 3a-d and 4a-d for FAD and annexes 5a-d and 6a-d for FSC). As the quality of the spatial and temporal distribution of the total fishing sets against total number of observed sets was already discussed in Amandè et al. (2008b; 2012), we only provide here the global pictures of these distributions. The spatial coverage of the observer programs in term of sets on FSC seems to contribute to a good coverage of the whole fishing area and effort (Figure 3ab). The coverage for FAD is well distributed in the AO, but in the IO, the Mozambique Channel is over represented compared to the North-Western IO (Figure 2ab). Per quarter, the observation coverage seems also to not detect any significant discrepancies with the fishing area and effort in both Oceans (Annexes 3a-d to 6a-d). However, some key spatio-temporal pattern must be highlighted here. In the IO, the fishing effort is concentred in the Mozambique Channel during the end of the first and all the second quarters of the year, before moving to the North Western in the third, fourth and beginning of the first quarters. In the AO, the fishing effort does not display a strong spatial pattern, but sets up a northwest to southeast movement along the year reaching more coastal water along the West African coast (Annexes 3a-d and 5a-d).

3.1.2. Object observations

More than 14 000 drifting objects were observed in both Oceans from 2003 to 2011, 66% of which in the IO, 34% in the AO (Table 6). The object component of the observer program started in 2003 (452 observations) and was largely improved to reach 2062 observations in 2011.

Figure 4 shows the spatial distribution of the observations in both Oceans (see data per quarter in annexe 7a-d). It is worthwhile noting that there is currently no available data on the number of deployed FAD per fleet and per Oceans. Nevertheless, by comparing the fishing effort on FAD to the observation of object coverage (*i.e.* Figure 2a), the object observation effort seems to cover well the total fishing effort on FAD even if the Mozambique Channel remains over observed.

3.2. Global EU-PS marine turtle bycatch

3.2.1. Bycatch during observed sets

On the 15 913 observed sets, 597 marine turtles were caught from 1995 to 2011, 415 and 182 respectively in the AO and IO (Table 7).

Figure 5 gives the number of by-caught turtles per observed set per year according to the fishing mode in both Oceans. In the AO, this number is similar between the two fishing modes (0.046 (SD=0.029) and 0.037 (SD=0.017) respectively on FAD and FSC). However, in the IO, more turtles were caught on FAD than on FSC (respectively 0.052 (SD=0.035) and 0.010 (SD=0.013)). The mean number of by-caught turtles per observed set on FAD per year is similar in the both Oceans (AO-FAD: 0.046, SD=0.029; IO-FAD: 0.052, SD=0.035); whereas for FSC, this number seems higher in the AO than in the IO (AO-FSC: 0.037, SD=0.017; IO-FSC: 0.010 SD=0.013). However, these results must be compared to the annual fishing effort in both Oceans and therefore, interpretations need to be taken with care.

More than 76% of the turtles were identified and 93% were associated to a fate (Table 8). With 172 observations, *Lepidochelys sp*. (2 species) are the most observed species in both Oceans. Loggerhead and leatherback turtles are the second most captured turtles in the AO (respectively 73 and 67), while in the IO, it is the hawksbill and green turtles (respectively 37 and 32). Only two leatherback turtles were caught during observed sets from 1995 to 2011 in the IO. Upon the 597 by-caught turtles, 91% and 77% were released alive respectively in the AO and IO, which represents only 21 dead turtle in the AO and 20 in the IO. In both Oceans, the percentage of marine turtles released alive is very similar between FAD and FSC (respectively 92% and 89.3% in the AO, and 76.4% and 79.4% in IO) as well as death occurrence.

The sex, size and the life stage were determined for 352 of these by-caught turtles. In the AO, 68% of the measured turtles were estimated to be adults at the contrary of the IO where most by-caught turtles were juvenile (74%, see table 9). Even if the sex of 72 marine turtles was also identified, it is difficult to describe a particular sex structure because of the small number of data as well as the important bias due to the difficulty in sex determination in marine turtle (Table 10).

3.2.2. Interaction between marine turtles and floating objects

From 2003 to 2011, 354 marine turtles were observed around 14 124 observed floating objects, 116 of which were in the AO, and 238 in the IO (Table 11).

The mean number of observed turtles per object observation per year is very similar in the AO and IO: 0.019 (SD=0.015) and 0.022 (SD=0.016) respectively (Figure 6). It is lower than the mean number of by-caught turtles per observed set and year (≅around 0.050 (SD≅0.030), see figure 5).

Upon the observed turtles, 74% were identified (Table 12). In the IO, the species composition is very similar to the one observed on fishing sets: the dominant species is *Lepidochelys olivacea* present in this Ocean (74 observed individuals), followed by the hawksbill (40) and the green turtle (37). As for fishing sets, leatherback turtle was also captured, but the occurrence is rare (6). In the AO, the most observed turtles are again the two species of *Lepidochelys* (41 olive ridley and 12 Kemp's turtles). No difference is observed between the 4 other species (around 6 according to the species). Most of the turtles observed around a floating device were entangled alive or already free. Hence, 93% and 73% of the individuals were released alive respectively in the AO and IO, which is a similar rate as the one found on fishing sets for both Oceans (See table 12 and 8).

As information, annexe 8 shows the different types of FAD observed in both Oceans. However, as no information is available on the amount of released or fished FAD, it remained impossible to assess the real impact of each type of FAD.

3.3. Annual and seasonal evolution of the European marine turtle bycatch

For each Ocean, we compared the annual evolution of the mean number of by-caught turtles per observed set on FAD and on FSC (Figure 7ab; see annexe 9ab for data per quarter). The same approach was used to compare the annual evolution of the mean number of observed turtles per object observation in the AO and IO (Figure 8; see annexe 10 for data per quarter). Each year presents high value of Standard Deviation (at least two times the mean value) and therefore interpretations should be made with caution. First because the figures should again be linked to the total fishing effort and second because the sampling per statistical square is too low and highly fluctuating. Therefore, a small variation in the observation effort may result in a strong variation in the observed turtle sample but that is not representative of the reality.

3.4. Spatial evolution of the European marine turtle bycatch

3.4.1. Bycatch during observed sets

Over the study period and in both Oceans, the areas with by-caught turtles cover the whole fishing zones (Figure 9ab; see annexes 11a-d and 12a-d for data per quarter), and are illustrated by the distribution estimations of observed by-catches using a kernel (Figure 10). The kernel also seems to indicate that the level of bycatch is higher in the North Indian Ocean and North Western of the Mozambique Channel. To analyse the number of by-caught turtles, the map should be confronted to the spatial repartition of the observation effort (see figures 2b and 3b). This analysis is only possible with bycatch of marine turtle per unit of observation effort (see figure 11ab below).

The by-catches of marine turtles per unit of observation effort (*i.e.* observed sets) from 1995 to 2011 are shown in figure 11ab (see annexes 13a-d and 14a-d for the same maps per quarter). The mean number of by-caught turtles per observed set, where a capture occurred, is 1.14 (SD=0.46) in the AO and 1.11 (SD=0.31) in the IO, meaning that most of the time, captures per set rarely account to more than a single individual. The highest capture rates on FAD and FSC happen in the North Western IO around India but are low in the Mozambique Channel even with a higher observation effort. In the AO, captures occur more or less in all the fishing area with an interesting high level of bycatch off the French Guinea coast.

In order to assess a spatial pattern per species, we plotted the barycentres of the by-caught turtles for each species in both Oceans (Figure 12). In the AO, the distribution seems to not show a strong spatial pattern, and olive (N=76) and Kemp's (N=37) turtles are the species caught in the eastern area of the fishing zone while leatherback (N=67) is found in the western area. In the IO, the olive ridley is clearly found more in the northern area (N=58) while hawksbill (N=37) and green (N=32) turtles are found in all the area. These two species are also the only one by-caught in the Mozambique Channel. The loggerhead (N=19) turtle has an intermediate position but is not found in the Mozambique Channel. Such observations are highlighted when looking at distribution estimations using the Kernel approach in both Oceans (Figure 13ab).

3.4.2. Interaction between marine turtles and floating objects

As for observation on sets, marine turtles interacted with floating objects in the whole AO and IO fishing area observed since 2003 (Figure 14ab and figure 15; see annexes 15a-d and 16a-d for data by quarter).

Similarly to the number of by-caught turtles, the number of observed turtles per object observation is mostly one individual (1.15 (SD=0.32) in the AO and 1.12 (SD=0.37) in the IO). In the IO, we observe the same pattern as for set observations: the highest turtle observation rates are located in the North Western zone and occur during the third and fourth quarters (Figure 16; for data by quarter, see annexe 17a-d). In the AO, the turtle observation occurrence on objects shows no specific spatial pattern.

We also plotted barycentres of the observed turtles for each species in both Oceans (Figure 17). The results confirm the same pattern observed in figure 12: the distributions almost completely overlap for every species in the AO with the olive (N=41) and Kemp's (N=12) turtles being observed in the eastern area. However, the hawksbill distribution (N=6) is located in the northern fishing area and seems to be less dispersed than the other ones (CCC=7, CMM=6, DCC=8, LKE=12 and LOL=41). In the IO and as for set observations, hawksbill (N=40) and green (N=37) turtles are observed more often in the southern area even if interaction with EU-PS occurs in all the fishing area while the olive ridley (N=74) observations on object are clearly located more in the Northern IO. Loggerhead (N=18) and leatherback (N=6) turtles have a middle position. Such observations are highlighted when looking at distribution estimation using the Kernel approach in the IO (Figure 18). Same approach where not possible because of the too low number of data for the AO.

3.5. Total EU bycatch estimation

Using the number of by-caught marine turtles per observed sets by year according to the fishing mode in both Oceans and the total fishing effort in number of sets available for the EU-PS in both the AO (Table 13a) and IO (Table 13b), we produced an order of magnitude of the total marine turtle bycatch. Over the period 1995-2010, we estimated the total incidental capture of marine turtles to 3491 in the AO and 2001 over the 2003-2010 period in the IO. Knowing that 91% and 77% of the observed by-caught turtles were released alive respectively in the AO and IO (Table 8), we estimated 314 and 461 dead marine turtles respectively in the AO and IO. In average, we found that the annual UE-PS bycatch rate for marine turtle is 218 (SD=150) and 250 (SD=157) with a 91 and 77%, respectively, being released alive respectively in the AO and IO). Even with large Standard Deviation due to the low observation rate, we can roughly consider that this fishery kills less than 20 and 60 individuals per year respectively in the AO and IO.

4. Discussion

4.1. Global marine turtle bycatch assessment in purse seine fishery

Bycatch of megafauna such as marine mammals, seabirds, marine turtles, or sharks which are long-lived and have low reproductive rates is one of the most significant issues affecting fishery management today (Hall 2000). A recent FAO report estimates bycatch to be approximately 23% of global marine landings, though these levels can be much higher for specific fishing gear (Kelleher 2005; FAO 2009) and mortality rates associated with bycatch can be very high. For commercially exploited species, it is often argued that economic extinction of exploited populations will occur before biological extinction, but this is not the case for non-target species caught incidentally in fisheries (Dulvy et al., 2003). Based on data from observer programs over the 1995-2011 period, this study presents an attempt to evaluate the global bycatch of the European Union oceanic Purse Seine fishery operating in the Atlantic and Indian Ocean on marine turtles. Observations were carried out on more than 15 000 sets (Table 4), which represents an overall observation coverage of 10.3% and 5.1% respectively in the AO and IO (Table 3). It is quite important for such an industrial fishery even if it is still below the optimal level necessary for an accurate estimation of the total bycatch. Amandè et al. (2008b; 2012) showed that the current sampling coverage in the observer programs of the PS tropical tuna fishery resulted in large uncertainties in precision and accuracy in bycatch estimates by species. As marine turtle bycatch was reported to be rare events (Sims et al., 2008; Amandè et al., 2012), the coverage rate should even be higher to allow a good estimate of the impact on these endangered species. For instance, in the case of whales, the required observer coverage is 100% for the Atlantic shark gillnet fishery, during times of the year when whales are calving (NMFS 2002). In the Pacific Ocean, PS observer programs have covered 20 to 100% of the fishing effort (Lennert-Cody et al., 2004; Amandè et al., 2012). The coverage levels of at least 50% of total effort for rare species would give reasonably good estimates of total by-catches of rare species (see review in Babcock et al., 2003). These observation conditions are idealistic to have a good estimate of bycatch levels, but are costly given, in most of the case, the availability of resources, economic or logistic constraints that allow only low sampling of the activity (Hall 1999), and therefore, are really difficult to implement.

From 1995-2011, 15913 observed sets allowed establishing that 415 and 182 marine turtles were by-caught respectively in the AO and IO (Table 7). Despite uncertainties due to insufficient sampling, we estimated that less than 3500 marine turtles were captured accidentally in the AO from 1995 to 2010, and around 2000 in the IO from 2003 to 2010, with respectively an estimated mean number per year of 218 (SD=150) and 250 (SD=157) (Table 13ab). Even if standard deviations are high due to the rarity of highly variable events (1 to 5 turtles/set) and low sampling rates, level of bycatch from EU-PS remains very low in comparison to other fishery gears (see review for the IO in Bourjea et al., 2008, 2012) such as long-lines fishery that results in substantial level of marine turtle bycatch (see review in Read, 2007; *e.g*. Petersen et al., 2009; Casale, 2011), gillnet (Casale, 2011) or bottom trawl fishery (*e.g*. Fenessy et al., 2008; Casale, 2011). As a matter of fact, Lewison et al. (2004) estimated that 200 000 loggerhead and 50 000 leatherback turtles were by-caught in the pelagic long-line fisheries worldwide only in 2000. As another example, before implementation of voluntary and/or compulsory mitigating measures such as Turtle Excluding Devices (TED) in the trawl net fisheries, 5295 turtles were estimated to be by-caught annually (SD=1231) by the Queensland East Coast Otter Trawl Fishery (Robins, 1995), and 39 000 captures per year were estimated to occur in the entire bottom trawl fleet in the Mediterranean (Casale, 2011). Gillnets are also known to be a major threat to marine turtles. Casale (2011) estimated the bycatch of the entire set net fleet in the Mediterranean around 23 000 marine turtles by-caught annually. Besides, as the survival rates are significant in the PS-fishery (for set observations: 91% in the AO and 77% in the IO, see table 8; for object observations: 93% in the AO and 73% in the IO, see table 12), mortality from this fishery was roughly estimated here at less than 20 and 60 individuals per year respectively in the AO and IO, resulting in a very low impact of EU-PS on marine turtle populations in comparison to the three industrial fisheries mentioned above. As for comparisons, according to Casale (2011), the turtle mortality rate in the entire Mediterranean fleet were estimated at 20%, 30%, 40% and 60% respectively for the bottom trawl, pelagic long-line, demersal long-line and set net fisheries leading to an estimated annual total mortality of 44 000 turtles.

Set observation coverage in the AO and IO fluctuated considerably from 1995 to 2011 (Table 5ab). Apart from 1995 and 1998, no observations were carried out in the IO until the beginning of the DCR program. Hence, it is difficult to compare the global bycatch between both Oceans. Moreover, many factors have an influence on bycatch rates, as fishing strategies, design of observer programs or seasonal variations, and can be very different between Oceans. However, we can still notice that the orders of magnitude of bycatch are similar between the AO (3.9 (SD=2.01) occurrences per 100 sets) and the IO (2.7 (SD=1.48) occurrences per 100 sets; see table 13ab). In the Pacific Ocean, Hall (2012) showed less accidental catches in the Pacific PS, with less than one encounter per 100 sets occurring annually, but with a similar survival rate to the one of the present study (around 90%).

4.2. Comparative impact of FAD versus FSC

Previous Working Documents from RFMOs and dedicated studies have suggested that interactions between PS and tuna associated species is mainly due to the use of FAD (Fonteneau et al., 2000; Sánchez et al., 2007; Amandè et al., 2008; Amandè et al., 2010) that may act, like for tunas, as protection from predators, source of food (Gooding & Magnuson 1967), or meeting location (Dagorn et al., 1995; Fréon & Dagorn, 2000). The results from the present study do not go in the direction that FAD is by far the main source of incidental captures of marine turtles. Our finding for the AO shows the same observation made by Hall (2012) in the Pacific Ocean, being that the mean number of by-caught turtles per observed set is very similar between fishing modes (Figure 5). However, in the IO, more turtles are observed on FAD than FSC. It seems difficult to explain such differences but we also observed that catches of juveniles are surprisingly much higher in the IO (74%; N=87) while by-catches are largely dominated by adults in the AO (68%; N=159). Witherington et al. (2012) showed that several species of young marine turtles were used to aggregate to *Sargassum*-dominated drift communities and that their diet was composed principally of *Sargassum*-community associates. His statement however is clearly species-depend. These observations lead us to hypothesize that juvenile marine turtles in their drifting pelagic phase, may be more attracted by FAD looking for protection or food rather than just drifting. The differences observed between the AO and IO may only be the consequence of the abundance of open sea juvenile marine turtles in the fishing area. Models of drifting trajectories of immature marine turtles have been already developed in the AO (Blumenthal et al., 2009; Monzón-Argüello et al., 2010; Lohmann et al., 2012; Proietti et al., 2012). On the one hand, juveniles born along the west African coast appear to be carried away towards America, and on the other hand, young marine turtles born on American beaches seem to remain in the western AO or at least in the northern hemisphere. In consequence, it seems reasonable to assume that the low number of observed juveniles by-caught by the EU-PS in the AO could be attributed to a low abundance of this stage of life. Contrary to the AO, recent dispersal modeling of juvenile marine turtles from the most important nesting sites in the western IO showed that they are found overall the western IO (IFREMER, CLS, Kélonia, unpublished data).

It is worthwhile noting that, observations on sets do not take into account the ghost fishing phenomenon occurring on floating devices (part of them being lost by owners) that do not end up in a fishing set. Pieces of net, hung below the FAD, are believed to be the cause of marine turtle mortality by entanglement and subsequent drowning. Mesh size of these net fragments used by such FAD appear to be a key contributing factor (Amandè et al., 2008). This mortality is difficult to observe by on-board observers, and may explain why the mean number of observed turtles per object observation (Figure 6) is lower than the one obtained with observations of sets occurring on FAD (Figure 5).

4.3. Lessons from the observed bycatch per species

The highest bycatch rates are not necessarily observed where the fishing effort is the most significant (See figures 2a and 3a versus figure 11). An analysis at the species level is therefore needed to understand the species pattern observed according to the by-catches location.

Dermochelys coriaca

The leatherback turtle is listed as critically endangered (World Conservation Union (IUCN) Red List, Seminoff 2004). In the IO, only 2 individuals of this species were caught during observed sets over the 1995-2011 period and 6 were observed around objects from 2003 to 2011 (Tables 8 and 12). These numbers are very low in comparison to the other observed species (at least 30 individuals for each species, see tables 8 and 12). In the West IO, the most important nesting site is located in KwaZulu-Natal (South Africa; Hughes, 2010), with annually, only a couple of hundred nesting females (Ronel Nel, Comm. Pers.). This species feeds over an extended large pelagic area in the south of the African continent (from Mozambique to Namibia; Luschi et al., 2006), targeting macro-planktons and staying in low latitude areas. Knowing that the abundance of that species is low and that its distribution overlaps only a little with PS fishing area in the IO (Figures 2a and 3a), the impact of the EU-PS activity is expected to be limited. However, in the AO, the leatherback turtle is one of the most by-caught turtles by EU-PS (N= 67, 70% of adults; see tables 5 and 9). Such a result is not astonishing as there are two large nesting colonies in the eastern part of the AO: in the French Guinea (between 5 000 and 63 000 estimated nests were laid annually from 1967 to 2002) and in the Gabon (~5 800-20 000 females nesting annually) (see review in Eckert et al., 2012). Interestingly the two main hotspots of by-caught leatherbacks are observed off the coast of those nesting sites (Figure 13a, species DCC).

Eretmochelys imbricata

The critically endangered hawksbill (IUCN Red List) is, with the green turtle, the most widely distributed and abundant marine turtle species in the tropical IO (Bourjea, 2012). In our study, it is also the most observed species after the olive ridley (Tables 8 and 12). Over previous decades, the IO represents one of just five nations in the world with more than 1 000 females nesting annually (Meylan & Donnelly, 1999), mainly nesting in the Seychelles and the British and French oversea territories (*e.g.* Allen et al., 2010; Lauret-Stepler et al., 2010), whereas the AO hosts a highly endangered population near the Congo (Marquèz, 1990). Such statement may explain the differences observed between both Oceans: contrary to the IO, the bycatch level of this species in the AO is very low (Tables 8 and 12) but with a greater impact as the Congo population is highly threatened. In the IO, only juveniles were by-caught during observed sets (Table 9). The hawksbill turtle is a coastal and not long distance migrant species (Gaos et al., 2012); therefore, individuals observed in pelagic habitats are usually juveniles. Individuals observed in the IO were mostly found away from the nesting sites (Figures 13b and18, species EIM), which can explain why they all were juveniles. In the AO, observations of hawksbill turtles occurred closer to the coast (Figure 13a), and even if we observed few individuals, mostly adults were by-caught (Table 9).

Chelonia mydas

The endangered green turtle (IUCN Red List) is one of the most widely distributed and abundant in both Oceans (Wallace et al., 2011). In our study, it is the second most observed species with the hawksbill turtle after the olive ridley in the IO, but one of the least observed in the AO (Tables 8 and 12). Moreover, 78% (N=18) and 81% (N=18) of by-caught individuals were juveniles respectively in the AO and the IO (Table 9). Individuals are observed overall the fishing areas (Figure 13 species CMM), and not especially near major nesting sites (Eparses Islands (Lauret-Stepler et al., 2007), Mayotte (Bourjea et al., 2007a), Madagascar (Bourjea et al., 2006) Seychelles (Mortimer et al., 2001a,b) in the IO; Ascension Island (Mortimer & Carr, 1987), Congo and Guinea Bisseau in the AO; see Halpin et al., 2009). One hypothesis that may explain such a pattern is that, as for hawksbill, the green turtle is a coastal species (Márquez, 1990). Adults use pelagic habitats only for breeding migration (Limpus et al., 1992) with a very determined behaviour while travelling fast and without feeding to and from breeding sites (Luschi et al., 2007; Benhamou et al., 2011), decreasing the chances of interaction with PS activities. On the opposite, juveniles use the pelagic habitats for a long period, drifting within the dominant currents (*e.g.* Hamanna et al., 2011; Proietti et al., 2012), removing them from the main fishing area in the AO or increasing their chances to interact with the PS activity in the IO. Such open sea behaviour have been recently shown using satellite tracked juvenile green and hawksbill turtles by-caught by purse seiner in the western IO (Bourjea, Com. Pers.)

Caretta caretta

In the AO, the loggerhead turtle is one of the most by-caught turtles with the leatherback after *Lepidochelys sp.* (Table 8), and most are adults (Table 9). Cape Verde hosts the only major nesting site of the eastern AO (Monzón-Argüello et al., 2007; Lino et al., 2010), in front of which many individuals were by-caught (Figure 13a, species CCC). Based on satellite tracked turtles, Hawkes et al. (2006) indicated that feeding grounds may be located along the southern coast of West Africa, explaining why some adult loggerheads are by-caught in this area (Figure 13a) while few juveniles are observed (see also paragraph 4.2). It is fundamental to remember that the Cape Verde site is also one of the most threatened nesting sites in the world. As most of the captures are adults, the impact of the EU-PS may have important consequences on this population already at risk. However, it is worthwhile noting that the mortality rate (4%) of loggerhead is particularly very low over the study period. A specific genetic study focusing on the origin of adult loggerheads should be of great importance to assess whether or not PS affects this threatening nesting site. Contrary to the AO, in the IO, the loggerhead is one of the least by-caught species (Table 8) and observed around an object (Table 12). There are two main nesting sites in the West IO. The first one is in KwaZulu-Natal in South African waters (Hughes, 2010, Ronel Nel, unpublished data) but by far less abundant than the Oman loggerhead healthy nesting hotspot hosting 20 000 to

40000 turtles nesting annually (Baldwin et al., 2003). Most of the captures occurred in the North of the PS fishing area and most are juveniles (Table 9), which follow the pattern observed in long-line by-catches operating in the West Tropical IO (Ciccione & Bourjea 2010). Moreover, according to Rees et al. (2010), adult loggerhead turtles from Oman remain in this area to feed, where the PS fishing effort is almost null. However our findings are opposite to what was found in the South African waters where it is hypothesized that long-lines catch more loggerhead adults near their nesting sites (Petersen et al., 2009). In fact, nesters from South Africa are used to migrate to feeding grounds following coastal routes (Papi et al., 1997; Ronel Nel, unpublished data) not used by PS for fishing while juvenile turtles occupy open sea areas including, in the north, the PS fishing area (Ciccione & Bourjea, 2010; IFREMER/Kélonia unpublished data).

Lepidochelys sp. (L. olivacea and L. Kempii)

Lepidochelys sp. is the most observed marine turtle by-caught in both Oceans (Tables 8 and 12) and no specific pattern related to their maturity stages can be drawn from our data (Table 9). The Kemp's turtle is listed as critically endangered (IUCN Red List), and is only present in the AO. If we compare its known global distribution (Annexe 1f) to the spatial location of by-caught and observed Kemp's turtles (Figure 9a and 14a), we notice no overlap. It is worthwhile noting that identified Kemp's turtle data used in this study could be the result from misidentifications with olive ridley turtle as these two species are very difficult to differentiate. At the same time, this statement also does not indicate that all identifications are definitively wrong and such a result is an opportunity to review the global distribution of the Kemp's turtle in the AO. However such a review is not possible without being sure of the species identifications. In any case, to avoid confusions between the two species and without an at sea observer special training, identifications should stop at the genus level (*Lepidochelys sp.*) instead of the species level. The possible misidentification at the species level does not allow us to discuss the impact of EU-PS bycatch on these species in the AO.

The olive ridley turtle is the most observed marine turtles by observer programs in the IO (Tables 8 and 12) and captures occurred in the northern part of the EU-PS fishing area (Figures 12 and 17or figures 13b and 18) with only rare records in the southern hemisphere (Figures 9b and 14b). The level of bycatch seems to increase while the PS fleet goes north (Annexes 3 and 5). Few records of nesting have occurred in the East African coast, South Africa and Madagascar (Frazier 1975), and the major and closest nesting sites of *L. olivacea* are in the northern hemisphere, in India (Shanker et al., 2003; Halpin et al., 2009). It is therefore highly likely that by-caught olive ridley turtles are from the Indian stock, even if a genetic analysis is needed to confirm such hypothesis. Indian populations are being highly threatened (Wallace et al., 2011) and, thus, even a low interaction showed here with PS activity may have a great impact in the population. But the olive ridley is a vagrant species and because of the low number of nesting and in-water sightings, nothing is really known on the migration behaviour of this species in the SWIO, neither if specific feeding grounds exist in the region (Bourjea, 2012).

5. Conclusion

Before raising any conclusions from the present study focusing on the impact of EU-PS fishery on marine turtles in the AO and IO, it is important to remind that because of the low level of bycatch occurrences, the large spatial distribution of the fishing activity, and the complex behaviour of all marine turtle life stages, the present dataset does not allow an accurate and reliable bycatch estimates. In order to improve the sample collection, it is highly recommended that higher observation coverage should be achieved and species identification improved. With less than an estimated hundred marine turtles killed per year in both Oceans, our study shows that the observed impact of the large scale industrial EU-PS tropical fishery on this threatened species remains globally low in comparison to other industrial fisheries worldwide.

It is also interesting to note that, despite what was expected, the mean number of by-caught turtles per observed set is very similar between FAD and FSC fishing modes in the AO (Figure 5) even if in the IO, more turtles are observed on FAD than FSC. Except time closure on specific areas determined on the baseline of migratory corridors or drifting paths of juveniles, few mitigation measures can be proposed to limit the bycatch when a set occurs on FSC. However, it is also important to note that based on our observer data most of the turtles either caught in FSC or FAD sets or entangled in the FAD are released alive (93 % on sets and 79 % on objects). In this sense, some developments and/or modifications of the FAD design can be made to mitigate the entanglement of turtles on FAD. If we consider the potential high number of FAD deployed and the cryptic mortality they are believed to cause by entanglement and subsequent drowning (not evaluated here), it is recommended to develop FAD without the piece of nets hanging below the FAD or alternative models without nets as the mesh size of these net fragments used by such FAD appeared to be a key contributing factor (Amandè et al., 2008). The IOCT Working Party on Ecosystems and bycatch has already recommended to design FAD and use biodegradable materials (IOTC Resolution 12/04).

At last, it is useful to compare the impact of the EU-PS fishery on marine turtles in the overall context and to highlight that other fisheries, such as the artisanal fishery, may have a greater impact on marine turtles than industrial fisheries. A recent study showed for example that the annual turtle catch in the south-western province of Tulear (Madagascar) alone is between 10 000 and 16 000 (Humber et al., 2010). Another recent study estimated that 5900 turtles were captured annually in Peru only by the national small-scale long-line, bottom set nets fisheries (Alfaro-Shigueto et al., 2011). It is also important to note that currently is estimated that 30 % of the tropical tuna catches in the Indian Ocean are done by gillnets, which is also thought to have a high level of bycatch. Therefore, it is necessary to investigate and implement pilot observer programs on those fisheries, for which a complete lack of data exist, in order to globally evaluate different fishery interaction with turtle populations and associated turtle mortality. At last, we must keep in mind the impacts of fisheries in the light of other land-based or coastal threats. It is also clear that, despite strong legislation prohibiting the direct take of turtles throughout, it is still regarded as the most important threat (See review for the IO in Bourjea, 2012).

6. Acknowledgments

The authors are grateful to the observers involved in data collection. They thank the fishing masters and their fishing companies for their close collaboration with the observers and IRD/IEO/AZTI scientists. These observer programs are co-financed by IRD/IEO/AZTI and the European Data Collection Framework (Reg EC 1543/2000 and 199/2008). We also thank L. Floch, P. Cauquil and A. Damiano (IRD) for database development and management. We wish to M. Roppert and L. Maurel for their helpful advice on GIS and M. Dalleau for R implementation.

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Tables

Programs	France	Spain
Faune associée	1995-1996	IEO : 1995
Patudo	1998-1999	IEO : 1997-1999
Moratoire	1997-2005	Data not integrated yet
DCR	IRD : 2005-today TAAF : 2011-today	AZTI and IEO : 2003-today
TAAF (Eparse Islands)	2009-2010	-

Table 1: Period where French and Spanish observer programs were active and integrated in the database “Observe”

Species	Code 31	Maximal CCL (cm)	Maximal weight (kg)	Minimal CCL for sex identification (cm)
Caretta caretta	CCC	110	150	70
Chelonia mydas	CMM	120	250	70
Dermochelys coriacea	DCC	220	900	110
Eretmochelys imbricata	EIM	100	120	60
Lepidochelys kempii	LKE	75	50	50
Lepidochelys olivacea	LOL	75	80	50

Table 2: Maximal Curved Carapace Length (CCL, in cm) and maximal weight (in kg) for each marine turtle species; minimal CCL (in cm) presented here were used in this study to allow sex determination (Márquez 1990, Marine Turtles Identification Cards from the IOTC). Code31 are the one used by observer programs and used in this paper.

Year	Atlantic			Indian		
	Total sets	Observed sets	% coverage	Total sets	Observed sets	%coverage
1995	8600	320	3,7	4522	430	9,5
1996	7834	40	0,5	3951		0
1997	6238	1033	16,6	3611		0
1998	6850	2300	33,6	3330	1166	35,0
1999	5595	1141	20,4	3239		0
2000	6026	341	5,7	8934		0
2001	5944	548	9,2	8735		0
2002	4828	356	7,4	8318		0
2003	6115	555	9,1	8168	172	2,1
2004	4574	417	9,1	8503	240	2,8
2005	3433	198	5,8	10254	464	4,5
2006	2748	97	3,5	10979	542	4,9
2007	2976	189	6,4	9793	875	8,9
2008	4101	394	9,6	8995	698	7,8
2009	5706	424	7,4	6933	650	9,4
2010	6626	758	11,4	7000	583	8,3
2011	Still in process	657	-	Still in process	325	-
Total 1995-2010	88 194	9 111	10,3	115 265	5820	5,1

Table 3: Number of observed sets in the Spanish and French observer programs by year and Ocean, and percentage coverage of the total fishing effort

Year	Fishing mode	Number of observed sets/quarter Atlantic				Total	Number of observed sets/quarter Indian				Total	Total
		1	**2**	**3**	**4**		**1**	**2**	**3**	**4**		
	FAD	18	14	6	33	71	12	9		44	65	136
1995	FSC	66	51	69	63	249	105	126	24	110	365	614
	Total	**84**	**65**	**75**	**96**	**320**	**117**	**135**	**24**	**154**	**430**	**750**
	FAD	1				1						1
1996	FSC	39				39						39
	Total	**40**				**40**						**40**
	FAD		60	110	89	259						259
1997	FSC		67	125	582	774						774
	Total		**127**	**235**	**671**	**1033**						**1033**
	FAD	118	116	219	262	715				486	486	1201
1998	FSC	344	291	202	748	1585				680	680	2265
	Total	**462**	**407**	**421**	**1010**	**2300**				**1166**	**1166**	**3466**
	FAD	72	9		323	404						404
1999	FSC	204	56		477	737						737
	Total	**276**	**65**		**800**	**1141**						**1141**
	FAD	20			84	104						104
2000	FSC	50			187	237						237
	Total	**70**			**271**	**341**						**341**
	FAD	13			138	151						151
2001	FSC	75			322	397						397
	Total	**88**			**460**	**548**						**548**
	FAD	43			93	136						136
2002	FSC	33			187	220						220
	Total	**76**			**280**	**356**						**356**
	FAD	53	3	15	127	198		26	23	59	108	306
2003	FSC	72	51	34	200	357		34	1	29	64	421
	Total	**125**	**54**	**49**	**327**	**555**		**60**	**24**	**88**	**172**	**727**
	FAD	55	4	13	112	184		40	105	1	146	330
2004	FSC	26	19	23	165	233		24	35	35	94	327
	Total	**81**	**23**	**36**	**277**	**417**		**64**	**140**	**36**	**240**	**657**
	FAD	47	9		30	86	2	31	73	60	166	252
2005	FSC	77	19		16	112	11	127	27	133	298	410
	Total	**124**	**28**		**46**	**198**	**13**	**158**	**100**	**193**	**464**	**662**
	FAD		7		24	31	10	56	54	174	294	325
2006	FSC		39		27	66	90	76	9	73	248	314
	Total		**46**		**51**	**97**	**100**	**132**	**63**	**247**	**542**	**639**
	FAD		34	20	28	82	23	80	136	172	411	493
2007	FSC		73	27	7	107	56	143	74	191	464	571
	Total		**107**	**47**	**35**	**189**	**79**	**223**	**210**	**363**	**875**	**1064**
	FAD	20	67	38	52	177	63	70	155	154	442	619
2008	FSC	54	88	45	30	217	82	99	16	59	256	473
	Total	**74**	**155**	**83**	**82**	**394**	**145**	**169**	**171**	**213**	**698**	**1092**
	FAD	17	20	54	72	163	300	161			461	624
2009	FSC	53	41	85	82	261	145	44			189	450
	Total	**70**	**61**	**139**	**154**	**424**	**445**	**205**			**650**	**1074**
	FAD	76	32	71	147	326	103	298			401	727
2010	FSC	162	105	108	57	432	70	112			182	614
	Total	**238**	**137**	**179**	**204**	**758**	**173**	**410**			**583**	**1341**
	FAD	35	86	77	97	295	52	31	60	9	152	447
2011	FSC	141	129	68	24	362	39	89	11	34	173	535
	Total	**176**	**215**	**145**	**121**	**657**	**91**	**120**	**71**	**43**	**325**	**982**
	FAD	588	461	623	1711	3383	565	802	606	1159	3132	6515
Total	FSC	1396	1029	786	3174	6385	598	874	197	1344	3013	9398
	Total	**1984**	**1490**	**1409**	**4885**	**9768**	**1163**	**1676**	**803**	**2503**	**6145**	**15913**

Table 4: Number of observed sets in the Spanish and French observer programs by year, quarter and fishing mode in both Oceans (FAD: Fish Aggregate Device and FSC: Free Swimming School)

Year	FAD			FSC			Indeterminate	
	Total sets	Observed sets	Coverage (%)	Total sets	Observed sets	Coverage (%)	Total sets	Observed sets
1995	3690	71	1.9	4754	249	5.2	156	0
1996	3466	1	0	4330	39	0.9	38	0
1997	2412	259	10.7	3717	774	20.8	109	0
1998	2153	715	33.2	4371	1585	36.3	326	0
1999	1782	404	22.7	3576	737	20.6	237	0
2000	2144	104	4.9	3686	237	6.4	196	0
2001	2055	151	7.3	3698	397	10.7	191	0
2002	1643	136	8.3	3103	220	7.1	82	0
2003	1910	198	10.4	4148	357	8.6	57	0
2004	1921	184	9.6	2562	233	9.1	91	0
2005	1429	86	6	1976	112	5.7	28	0
2006	1231	31	2.5	1505	66	4.4	12	0
2007	1449	82	5.7	1519	107	7	8	0
2008	2030	177	8.7	2063	217	10.5	8	0
2009	2710	163	6	2994	261	8.7	2	0
2010	3702	326	8.8	2912	432	14.8	12	0
2011	In process	295	-	In process	362	-		
Total 1995-2010	35727	3088	8.6	50914	6023	11.8	1553	0

Table 5a

Year	FAD			FSC			Indeterminate	
	Total sets	Observed sets	Coverage (%)	Total sets	Observed sets	Coverage (%)	Total sets	Observed sets
1995	2275	65	2.9	2247	365	16.2		
1996	1998		0	1953		0		
1997	2247		0	1364		0		
1998	1998	486	24.3	1332	680	51.1		
1999	1617		0	1622		0		
2000	5076		0	3669		0	189	0
2001	4281		0	4278		0	176	0
2002	5103		0	3107		0	108	0
2003	3883	108	2.8	4136	64	1.5	149	0
2004	3449	146	4.2	4927	94	1.9	127	0
2005	4443	166	3.7	5635	298	5.3	176	0
2006	5295	294	5.6	5635	248	4.4	49	0
2007	5114	411	8	4676	464	9.9	3	0
2008	4748	442	9.3	4236	256	6	11	0
2009	4940	461	9.3	1989	189	9.5	4	0
2010	5267	401	7.6	1725	182	10.6	8	0
2011	In process	152	-	In process	173	-		
Total 1995-2010	61734	2980	4.8	52531	2840	5.4	1000	0

Table 5b

Table 5: Number of observed sets in the Spanish and French observer programs by year and fishing mode, and percentage coverage of the total fishing effort in the (a) Atlantic Ocean and (b) Indian Ocean

Year	Number of object observations/quarter				Total	Number of object observations/quarter				Total	Total
	Atlantic					Indian					
	1	2	3	4		1	2	3	4		
2003		31	90		121		106	44	181	331	452
2004			93	28	121	4	75	733	52	864	985
2005	72	38		52	162	11	93	278	214	596	758
2006	45	30	15	78	168	54	68	226	442	790	958
2007	45	111	68	117	341	142	373	692	615	1822	2163
2008	75	277	68	84	504	170	370	442	452	1434	1938
2009	84	96	182	221	583	901	806	25		1732	2315
2010	189	274	478	480	1421	136	935			1071	2492
2011	293	345	308	408	1354	73	399	206	30	708	2062
Total	803	1202	1302	1468	4775	1491	3225	2646	1986	9348	14123

Table 6: Number of object observations by year and quarter in the Atlantic and Indian oceans

		FAD	FSC	Total
Atlantic	By caught-turtles	**201**	**214**	**415**
	Observed sets	3383	6385	9768
Indian	By caught-turtles	**148**	**34**	**182**
	Observed sets	3132	3013	6145
Total	By caught-turtles	**349**	**248**	**597**
	Observed sets	6515	9398	15913

Table 7: Total number of by-caught marine turtles and total number of observed sets by fishing mode and ocean over the study period 1995-2011

Species	Atlantic			Atlantic	Indian			Indian	Total
	Alive	Dead	Unknown		Alive	Dead	Unknown		
Caretta caretta	67	3	3	73	13	3	3	19	92
Chelonia mydas	36		4	40	24	2	6	32	72
Dermochelys coriacea	60	4	3	67	2			2	69
Eretmochelys imbricata	12	2		14	32	2	3	37	51
Lepidochelys kempii	35	2	1	38					38
Lepidochelys olivacea	73	1	2	76	47	4	7	58	134
Unidentified turtles	93	9	5	107	22	9	3	34	141
Total	**376** (91%)	**21** (5%)	**18** (4%)	**415**	**140** (77%)	**20** (11%)	**22** (12%)	**182**	**597**
FAD	185 (92%)	7 (3.5%)	9 (4.5%)	201 (48.4%)	113 (76.4%)	16 (10.8%)	19 (12.8%)	148 (81.3%)	
FSC	191 (89.3%)	14 (6.5%)	9 (4.2%)	214 (51.6%)	27 (79.4%)	4 (11.8%)	3 (8.8%)	34 (18.7%)	

Table 8: Total number of by-caught marine turtles by species and fate and percentage of alive and dead turtles released by fishing mode in the Atlantic and Indian Oceans.

Species	Atlantic			Atlantic	Indian			Indian	Total
	Adult	Juvenile	Unknown		Adult	Juvenile	Unknown		
Caretta caretta	21	7		28	1	9	2	12	40
Chelonia mydas	5	18		23	3	18	1	22	45
Dermochelys coriacea	47	16		63					63
Eretmochelys imbricata	2	6		8		31		31	39
Lepidochelys kempii	34	9		43					43
Lepidochelys olivacea	48	16		64	17	27		44	108
Unidentified turtle	2	2	2	6		2	6	8	14
Total	**159** 68%	**74** 31%	**2** 1%	**235**	**21** 18%	**87** 74%	**9** 8%	**117**	**352**

Table 9: Total number of sampled by-caught marine turtles by species and life stage, and percentage of identified adult and juvenile turtles in the Atlantic and Indian oceans

Species	Atlantic			Atlantic	Indian			Indian	Total
	Male	Female	Unknown		Male	Female	Unknown		
Caretta caretta	2	5	14	21			1	1	22
Chelonia mydas	2		3	5	1		2	3	8
Dermochelys coriacea	4	5	38	47					47
Eretmochelys imbricata		2		2					2
Lepidochelys kempii	4	1	29	34					32
Lepidochelys olivacea	15	22	11	48	1	8	8	17	65
Unidentified turtle			2	2					2
Total	**27** 17%	**35** 22%	**97** 61%	**159**	**2** 9.5%	**8** 38%	**11** 52.4%	**21**	**180**

Table 10: Total number of sampled by-caught marine turtles by species and sex, and the percentage of male and female turtles in the Atlantic and Indian oceans

Ocean	Observed turtles	Observed objects
Atlantic	116	4775
Indian	238	9349
Total	354	14124

Table 11: Total number of observed marine turtles around a floating object and total number of object observations over the study period 2003-2011 by Ocean

Species	Atlantic			Atlantic	Indian			Indian	Total
	Entangled alive	Entangled dead	Free		Entangled alive	Entangled dead	Free		
Caretta caretta	6		1	7	10	6	2	18	25
Chelonia mydas	2		4	6	12	10	15	37	43
Dermochelys coriacea	4		4	8	2		4	6	14
Eretmochelys imbricata	4		2	6	17	10	13	40	46
Lepidochelys kempii	2		10	12					12
Lepidochelys olivacea	26	1	14	41	34	21	19	74	115
Unidentified turtle	14	7	15	36	34	18	11	63	95
Total	**58** 50%	**8** 7%	**50** 43%	**116**	**109** 46%	**65** 27%	**64** 27%	**238**	**354**

Table 12: Total number of observed marine turtles around a floating object by species and fate in the Atlantic and Indian oceans

Year	Number of by-caught turtles per observed set		Total number of fishing sets		Total estimation of by-caught turtles	Number of turtles per 100 sets
	FAD	FSC	FAD	FSC		
1995	0,070	0,060	3690	4754	546	6,47
1996	0	0,026	3466	4330	111	1,42
1997	0,054	0,036	2412	3717	265	4,32
1998	0,076	0,027	2153	4371	281	4,31
1999	0,064	0,024	1782	3576	202	3,77
2000	0,010	0,038	2144	3686	161	2,75
2001	0,007	0,010	2055	3698	51	0,88
2002	0,015	0,014	1643	3103	66	1,40
2003	0,066	0,045	1910	4148	311	5,14
2004	0,016	0,013	1921	2562	64	1,43
2005	0,058	0,036	1429	1976	154	4,51
2006	0,032	0,061	1231	1505	131	4,79
2007	0,049	0,065	1449	1519	170	5,73
2008	0,040	0,041	2030	2063	166	4,05
2009	0,049	0,046	2710	2994	271	4,75
2010	0,104	0,053	3702	2912	541	8,18
				Sum	3491	
				Mean	218	3,99
				SD	150	2,01

Table 13a

Year	Number of by-caught turtles per observed set		Total number of fishing sets		Total estimation of by-caught turtles	Number of turtles per 100 sets
	FAD	FSC	FAD	FSC		
1995	0,123	0,044	2275	2247		
1996			1998	1953		
1997			2247	1364		
1998	0,049	0,006	1998	1332		
1999			1617	1622		
2000			5076	3669		
2001			4281	4278		
2002			5103	3107		
2003	0,056	0,016	3883	4136	280	3,50
2004	0,055	0	3449	4927	189	2,26
2005	0,030	0,010	4443	5635	191	1,89
2006	0,071	0	5295	5635	378	3,46
2007	0,100	0,011	5114	4676	561	5,73
2008	0,041	0,004	4748	4236	210	2,34
2009	0,013	0	4940	1989	64	0,93
2010	0,022	0,005	5267	1725	128	1,83
			Sum 2003-2010		2001	
			Mean 2003-2010		250	2,74
			SD 2003-2010		157	1,48

Table 13b

Table 13: Estimation of the total marine turtle bycatch and of the number of by-caught turtles per 100 sets by EU-PS fishery by year in the (a) Atlantic and (b) Indian Oceans

Figures

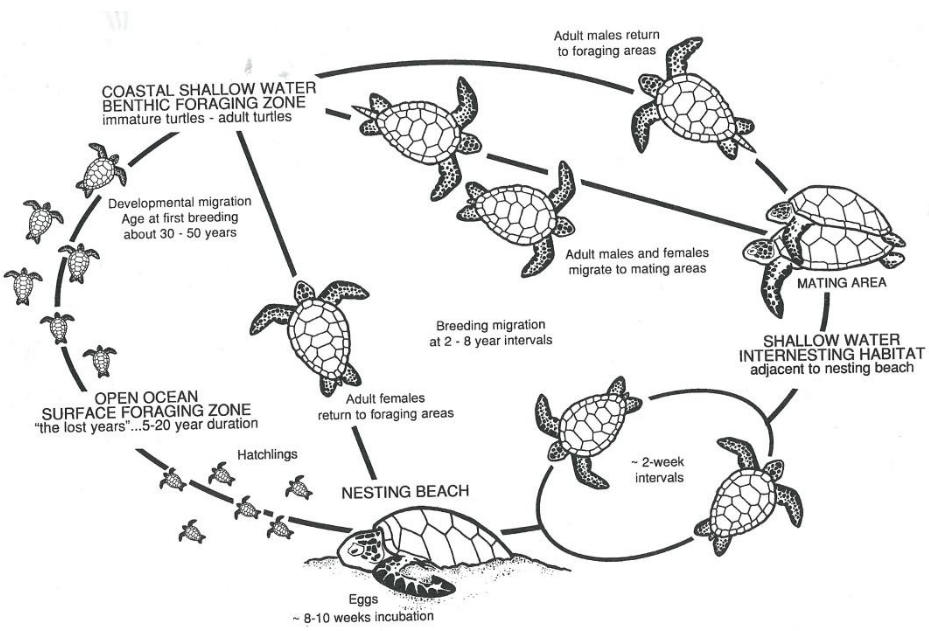


Figure 1: Global life cycle of marine turtle (from Miller, 1997)

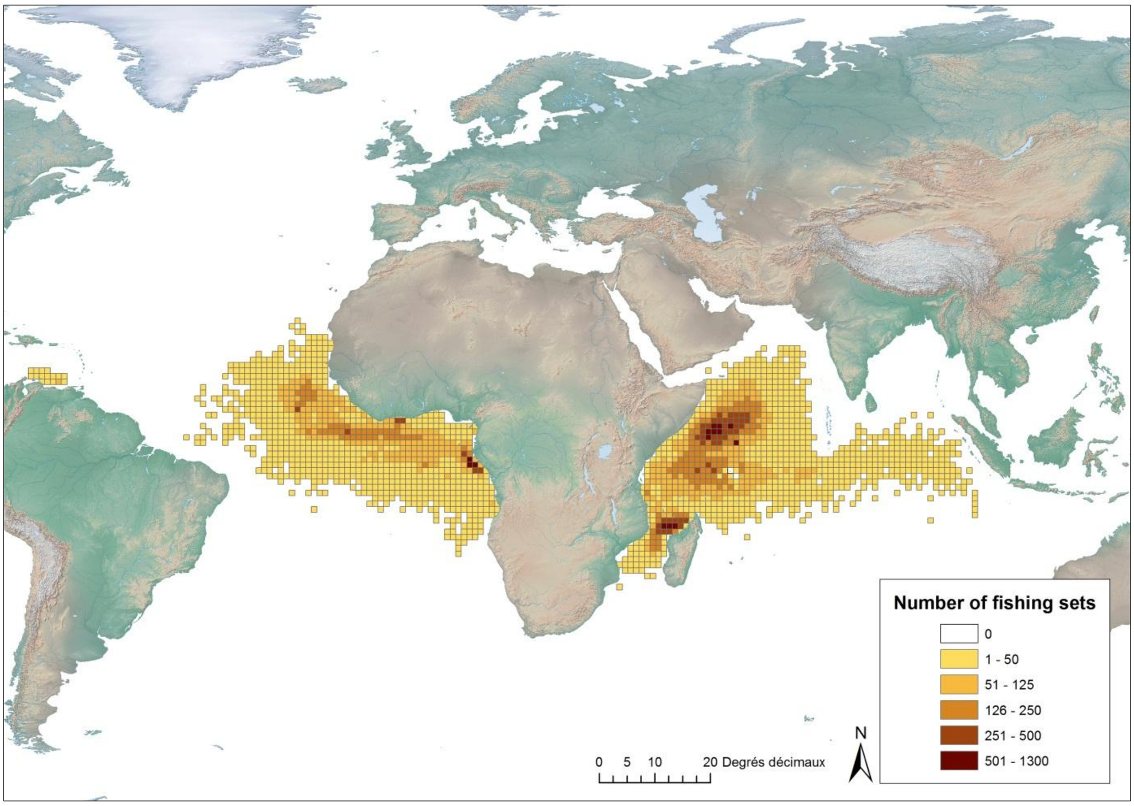


Figure 2a

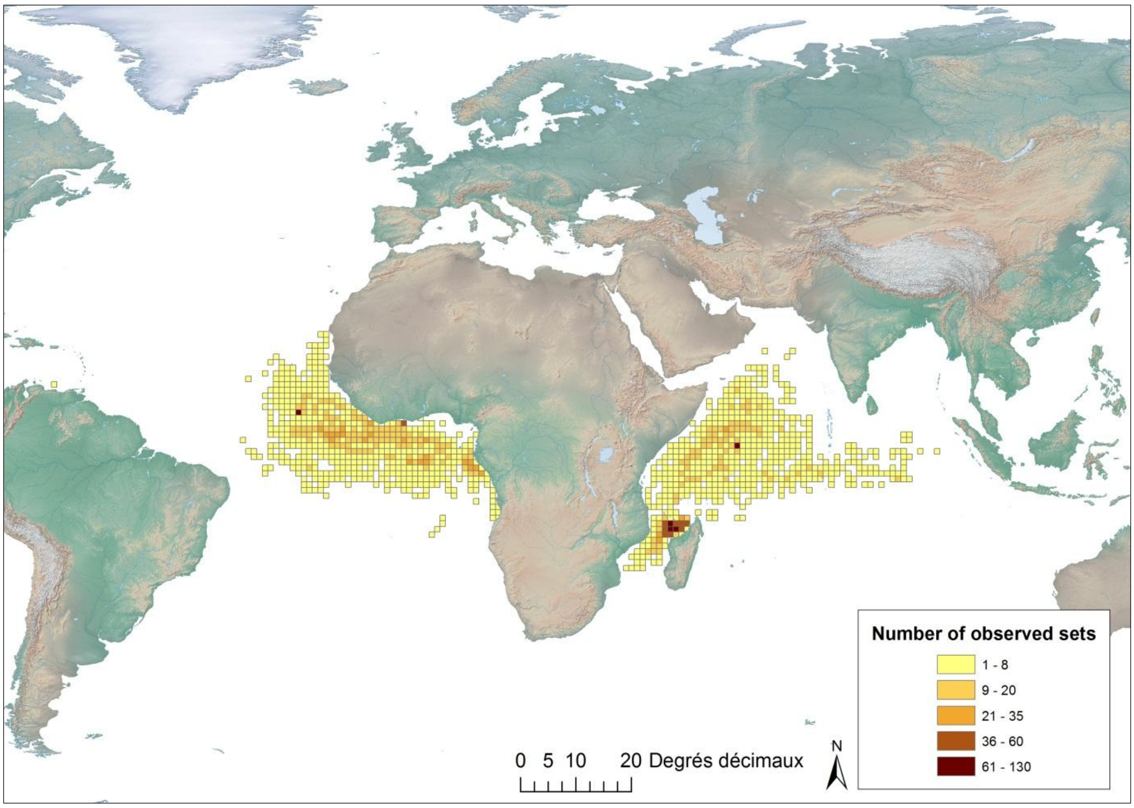


Figure 2b

Figure 2: (a) Total fishing effort and (b) total observation effort (in fishing sets) on FADs per statistical square of 1° of French and Spanish fleets from 1995-2011 in the Atlantic and Indian Oceans

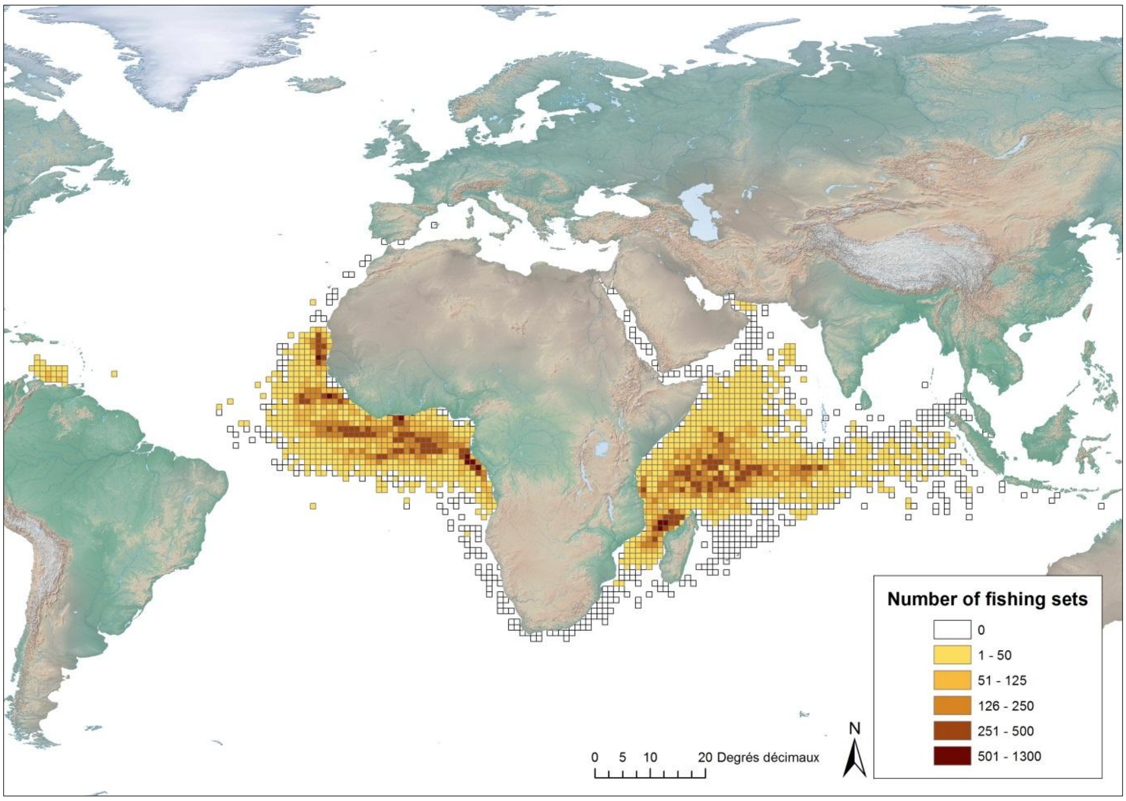


Figure 3a

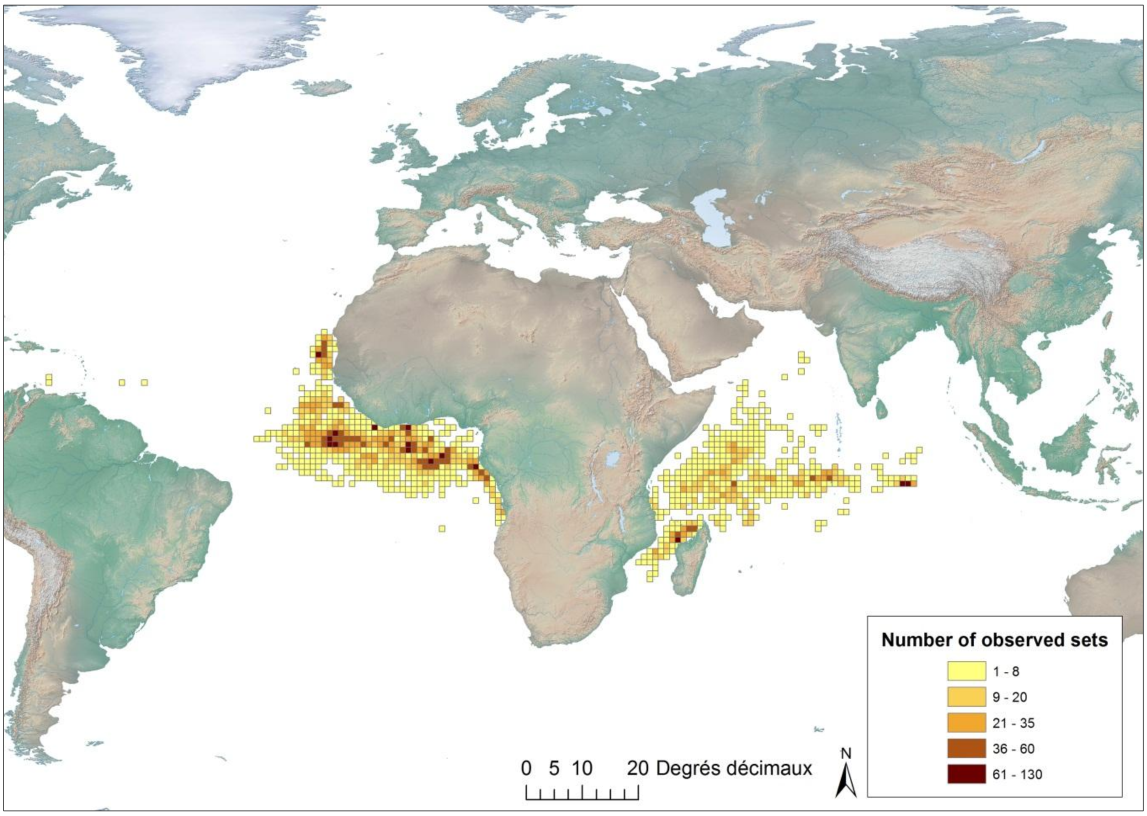


Figure 3b

Figure 3: (a) Total fishing effort and (b) total set observed (in fishing sets) on FSCs per statistical square of 1° of French and Spanish fleets from 1995-2011 in the Atlantic and Indian Oceans

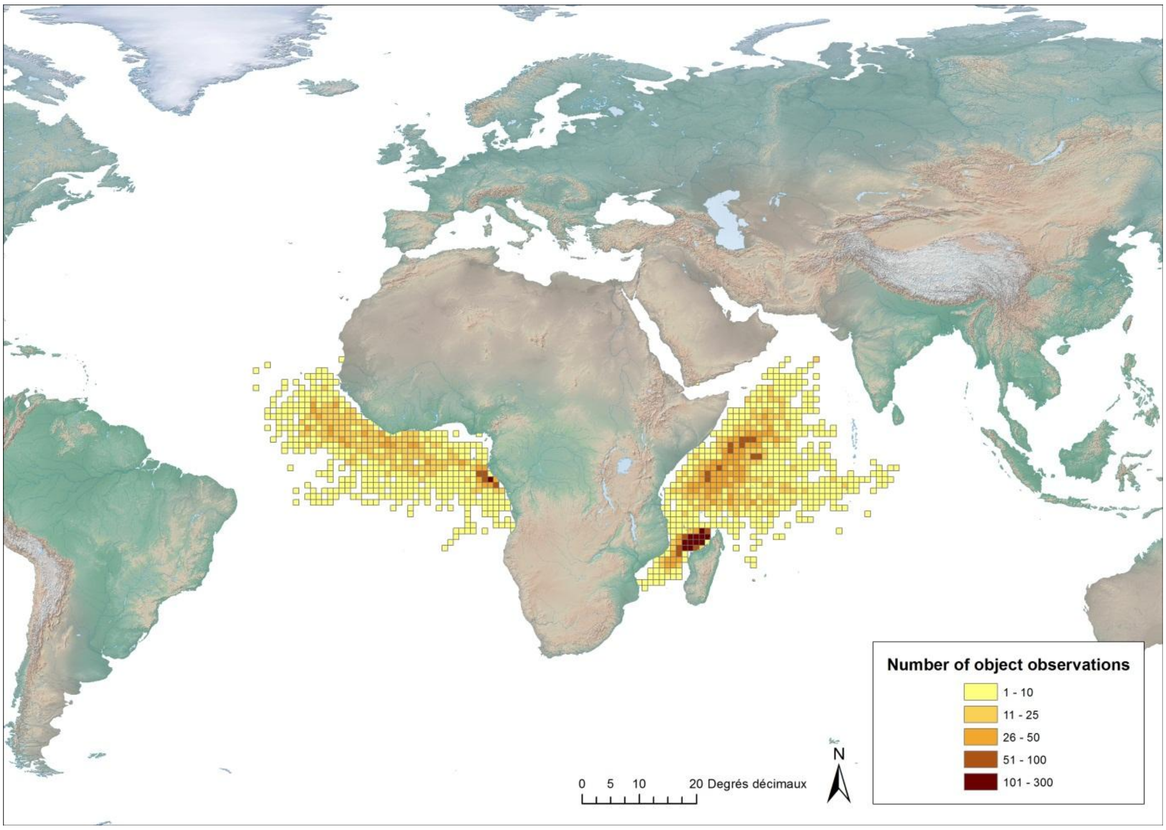


Figure 4: Total object observation effort (in number of observations) per statistical square of 1° of French and Spanish observer programs from 2003-2011 in the Atlantic and Indian Oceans

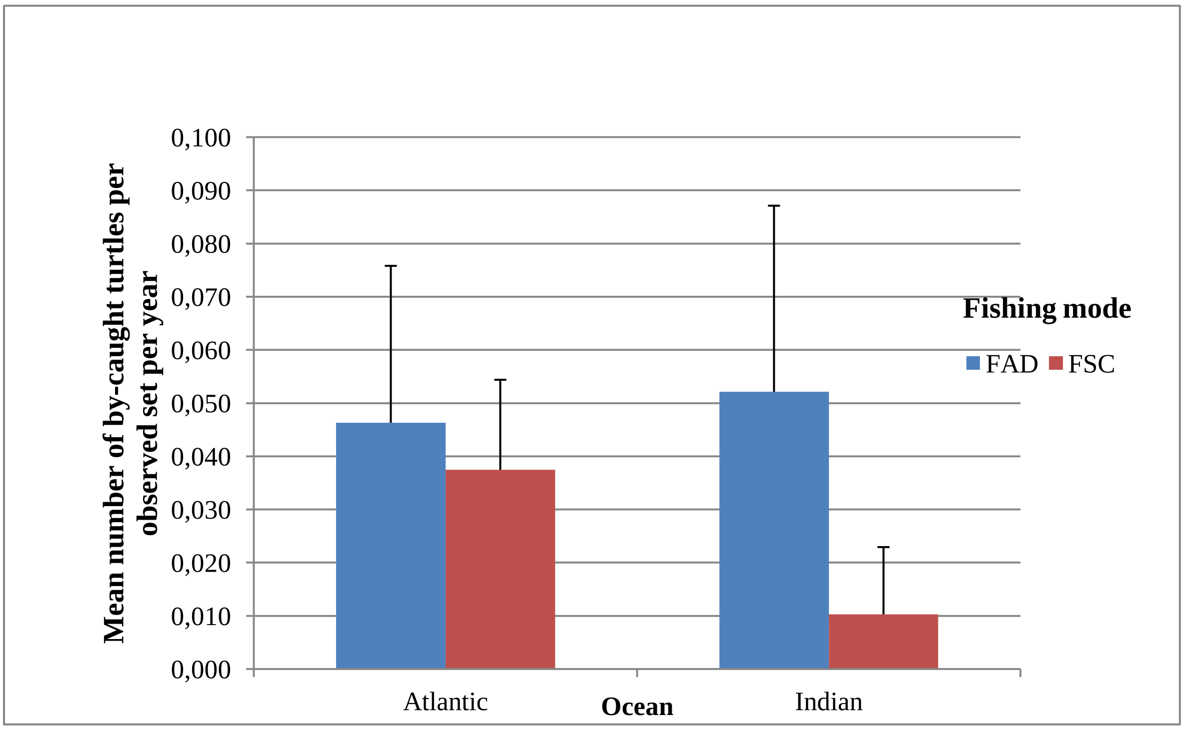


Figure 5: Mean number and standard deviation of by-caught marine turtles per observed set per year according to the fishing mode (FAD or FSC) in the Atlantic and Indian Oceans over the study period 1995-2011

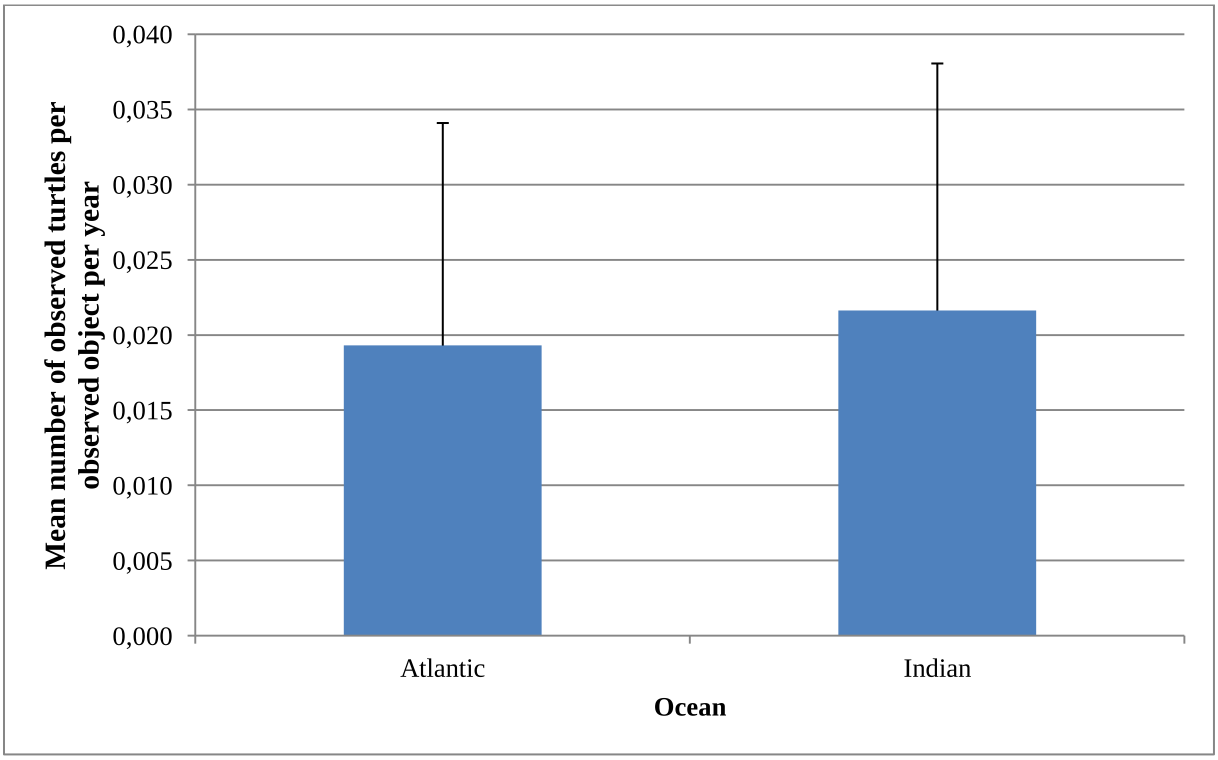


Figure 6: Mean number and standard deviation of observed turtles per object observation per year in the Atlantic and Indian Oceans over the study period 2003-2011

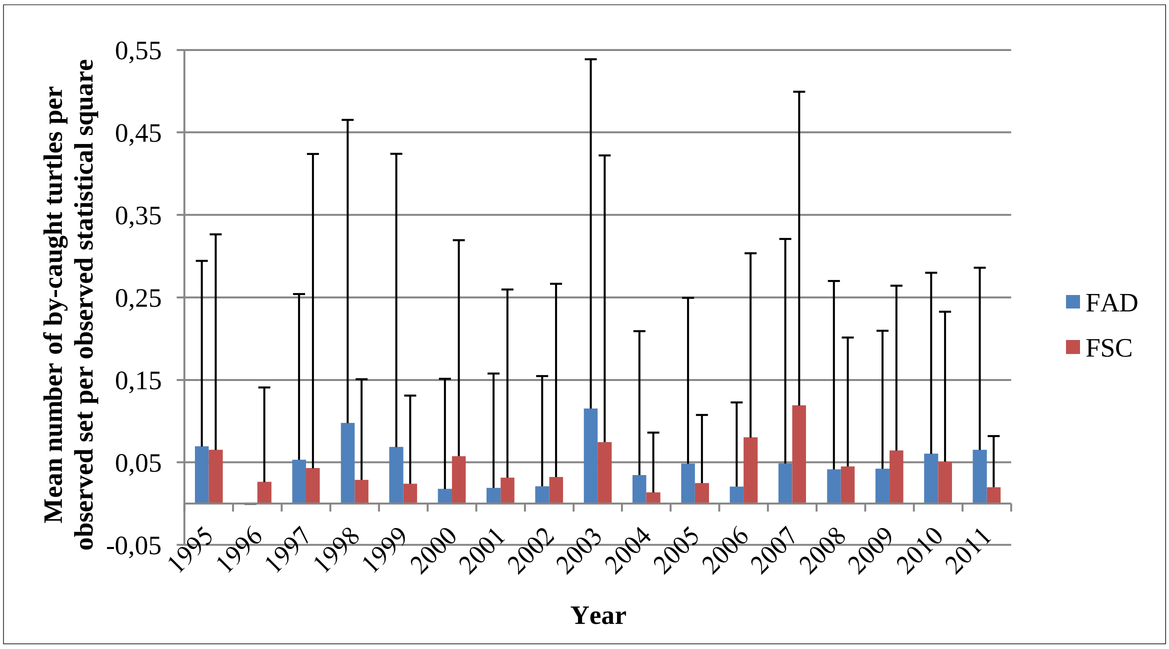


Figure 7a

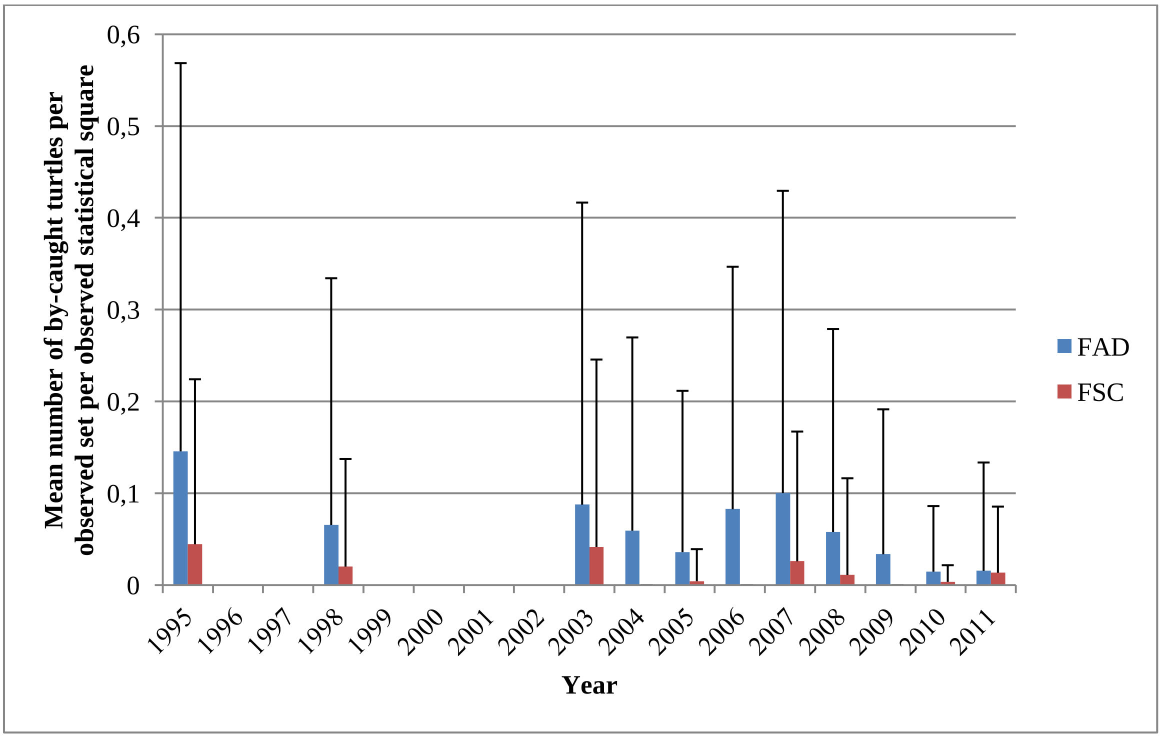


Figure 7b

Figure 7: Mean number of by-caught marine turtles per observed set and per observed statistical square according to the fishing mode in the (a) Atlantic and (b) Indian Oceans over the 1995-2011 period.

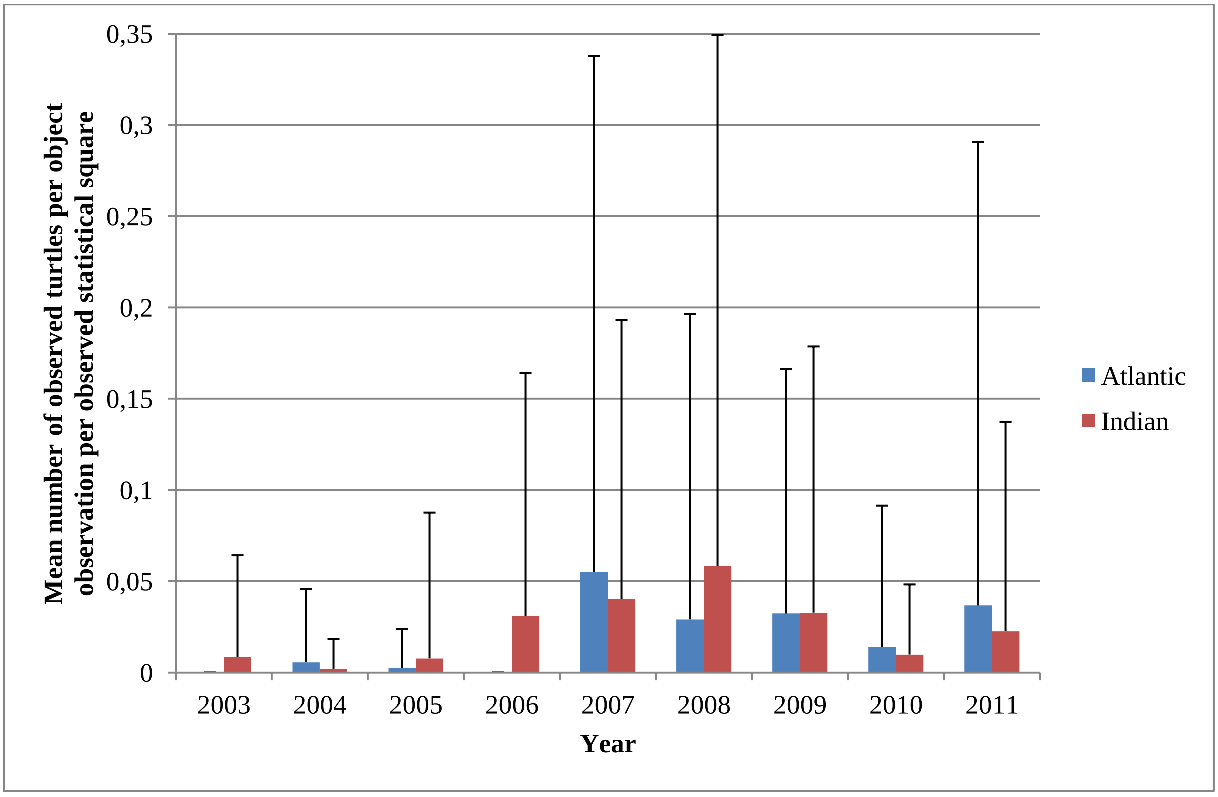


Figure 8: Mean number of observed marine turtles per object observation per observed statistical square over the 2003-2011 period in the Atlantic and Indian Oceans

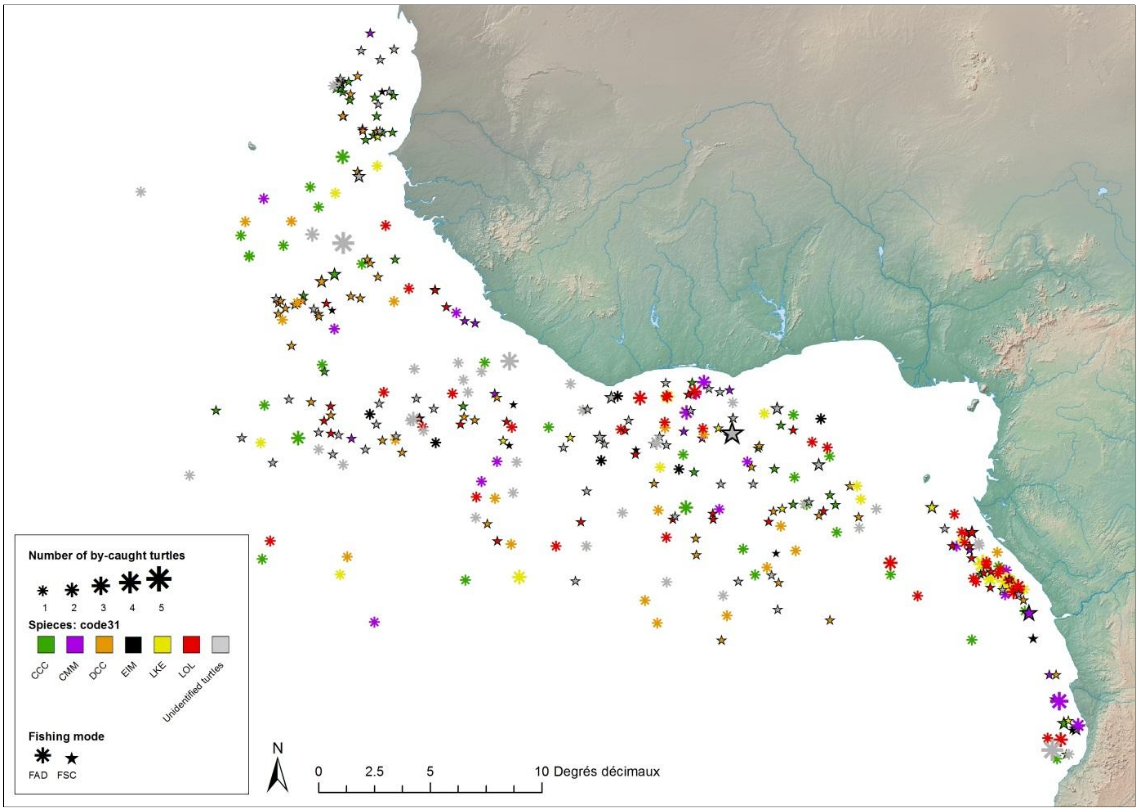


Figure 9a

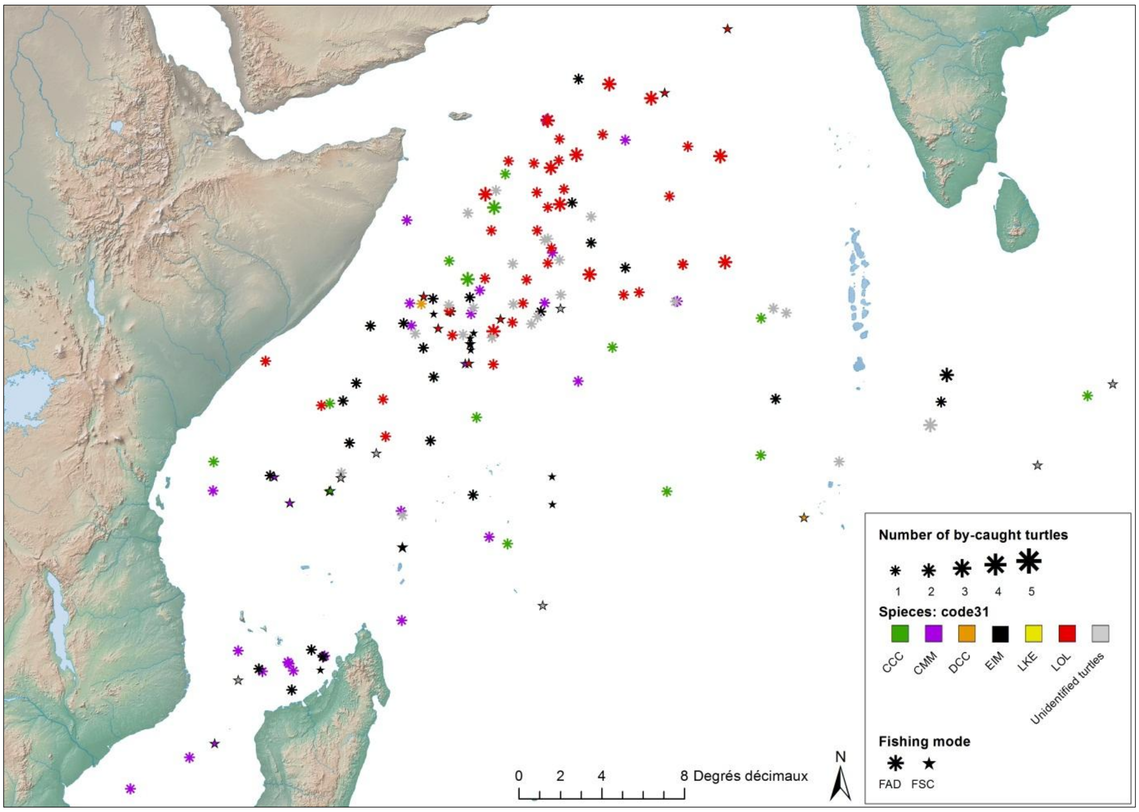


Figure 9b

Figure 9: Number of observed marine turtles by species caught by French and Spanish PS during observed sets on FADs and FSCs for the period 1995-2011 in the (a) Atlantic and (b)

Indian Oceans (CCC=*Caretta caretta*, CMM=*Chelonia mydas*, DCC=*Dermochelys coriacea*, EIM=*Eretmochelys imbricata*, LKE=*Lepidochely Kempii* and LOL=*Lepidochely olivacea*).

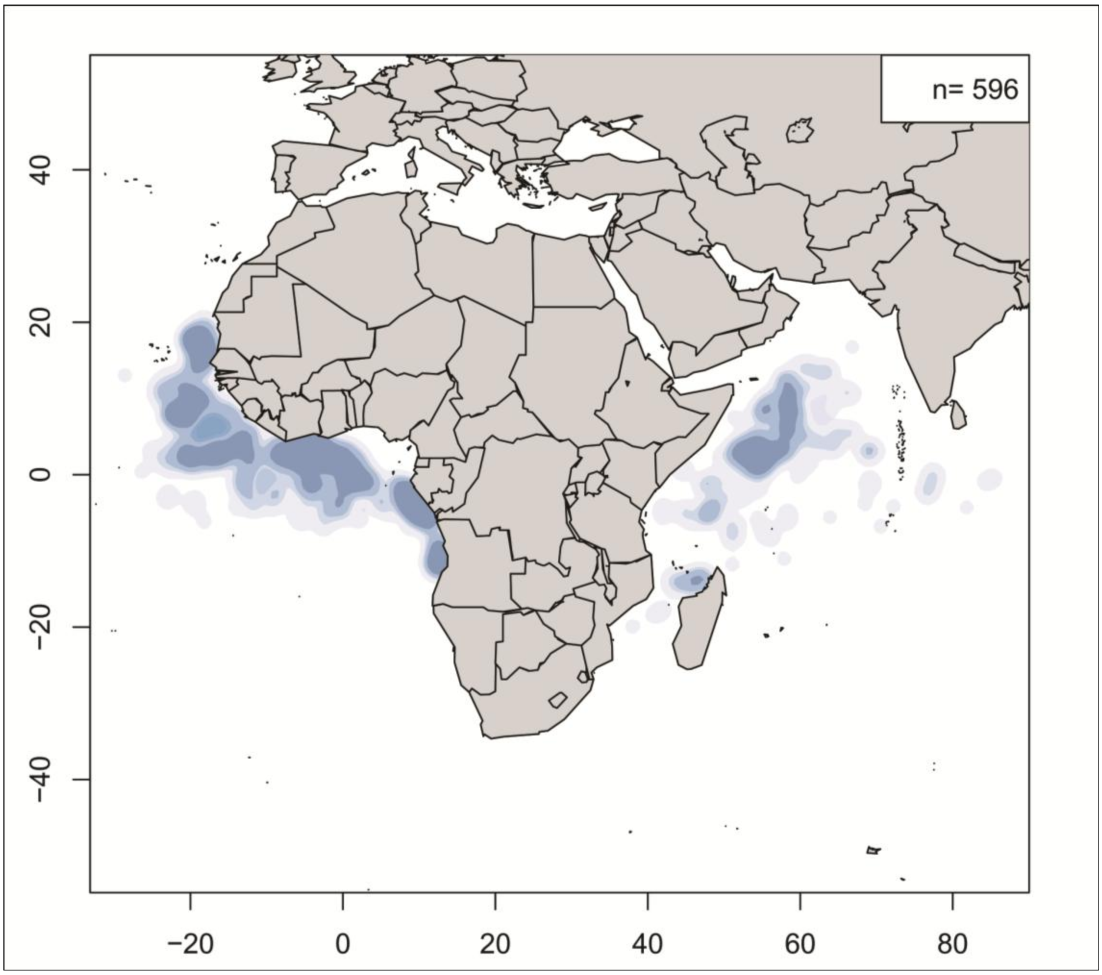


Figure 10: Estimated Utilisation Distributions of marine turtle-PS interactions with the kernel methods, based on set observations by observer programs from 1995 to 2011 (all species taken together).

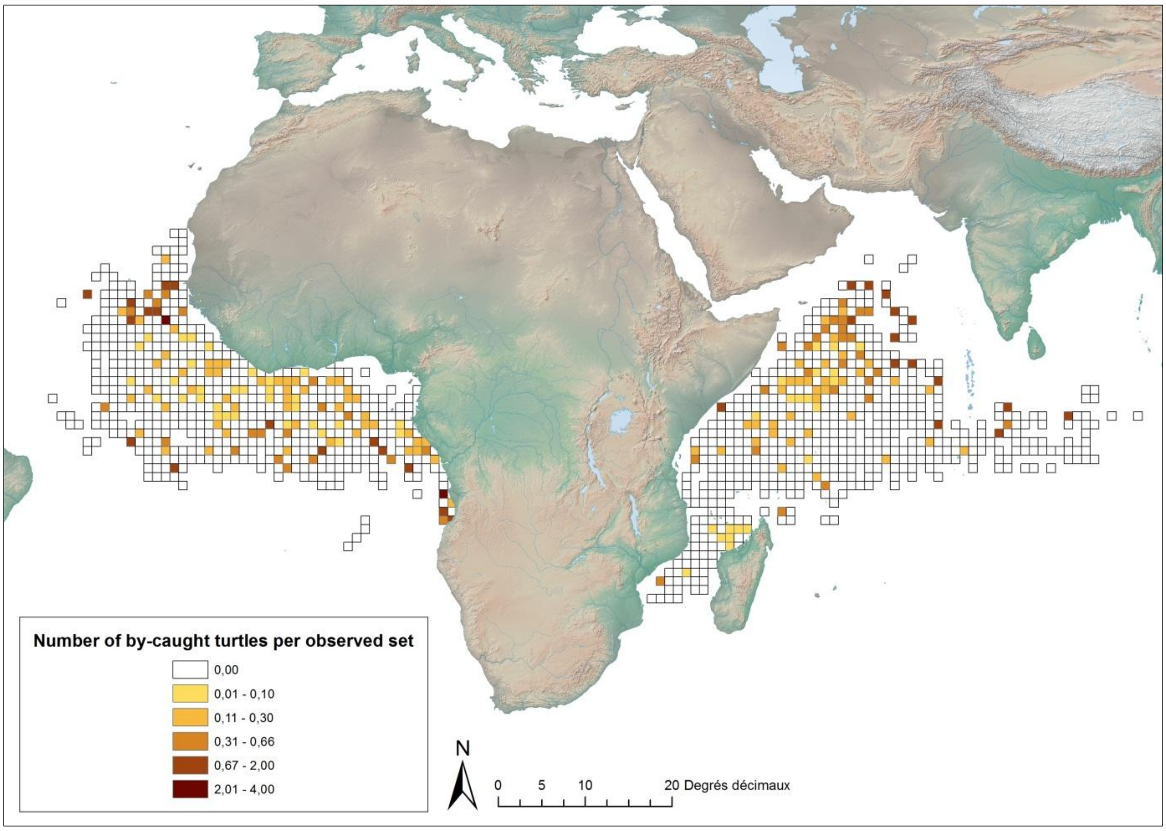


Figure 11a

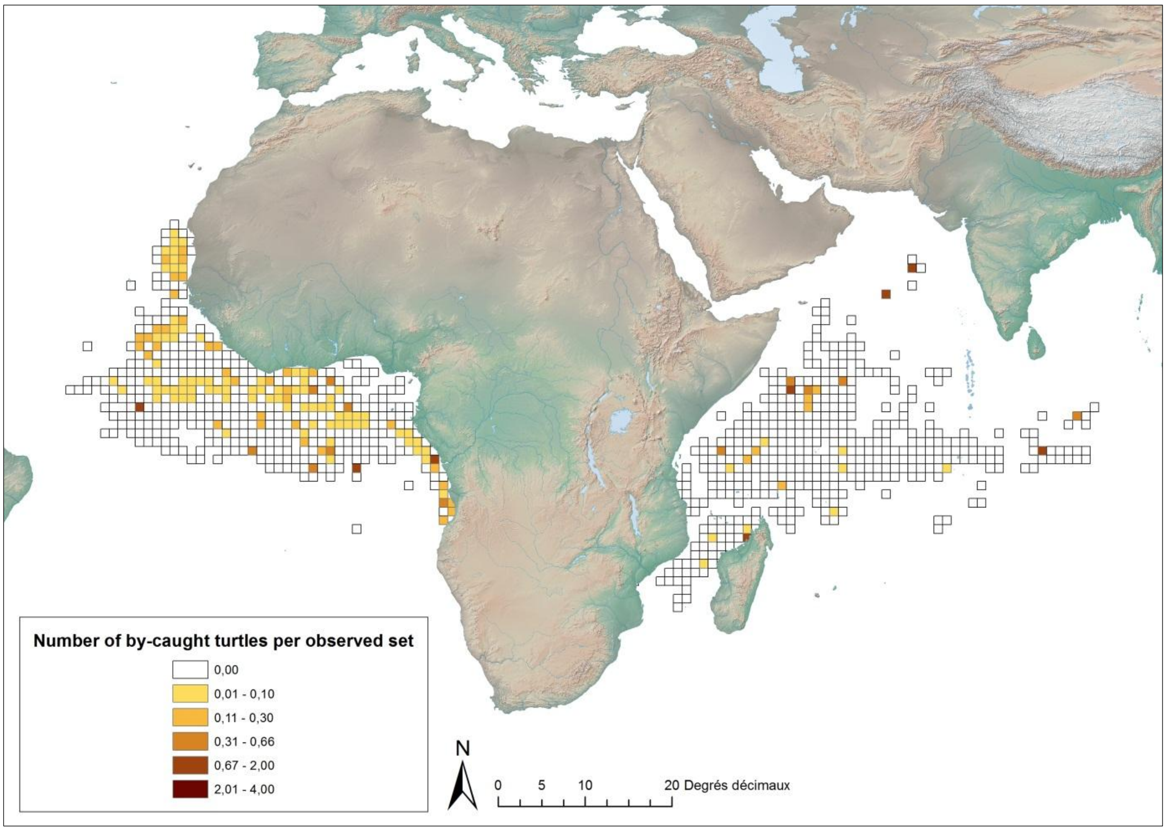


Figure 11b

Figure 11: Number of by-caught marine turtles per observed set on (a) FADs and (b) FSCs per statistical square of 1° from 1995 to 2011 in the Atlantic and Indian oceans.

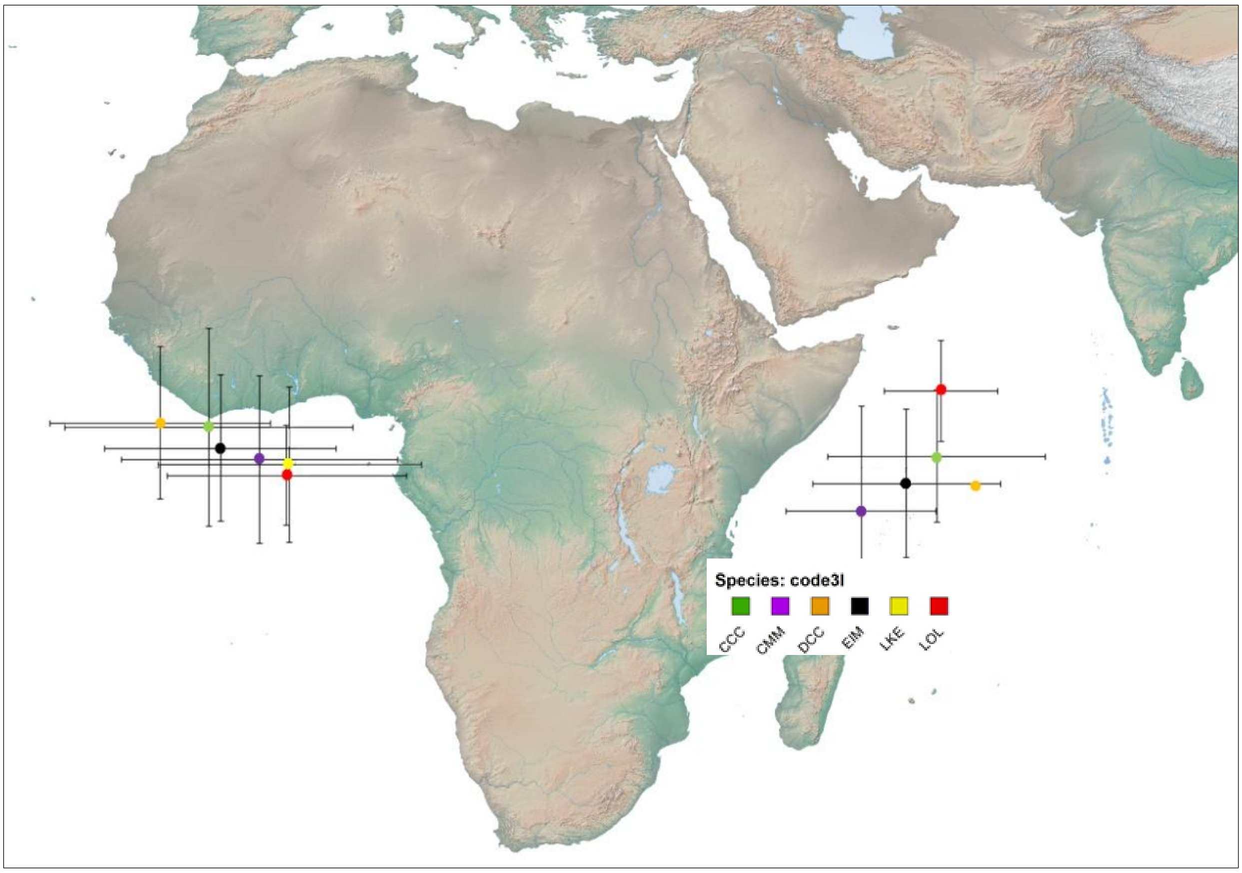
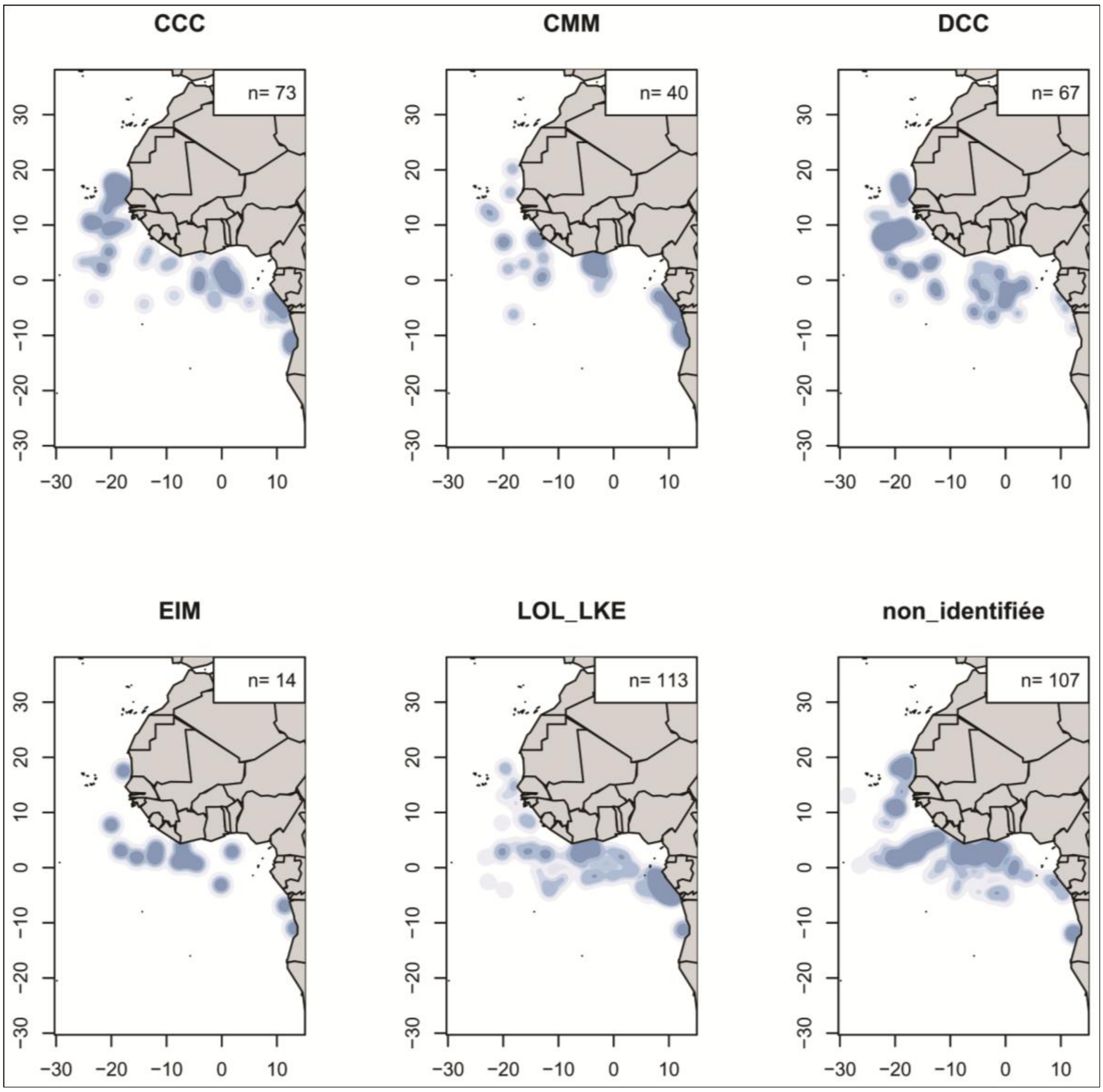


Figure 12: Latitudinal and longitudinal barycentres and standard deviations of each species caught by EU-PS during observed sets in the Atlantic and Indian Oceans from 1995 to 2011 (no standard deviation for DCC in the Indian Ocean, because of too small samples) (CCC=*Caretta caretta* (N_{OA}=73; $N_{OI=}$19), CMM=*Chelonia mydas* (N_{OA}=40; $N_{OI=}$32), DCC=*Dermochelys coriacea* (N_{OA}=67; $N_{OI=}$2), EIM=*Eretmochelys imbricata* (N_{OA}=14; $N_{OI=}$37), LKE=*Lepidochely Kempii* (N_{OA}=37) and LOL=*Lepidochely olivacea* (N_{OA}=76; $N_{OI=}$58))



CCC
n= 73
CMM
n= 40
DCC
n= 67
EIM
n= 14
LOL_LKE
n= 113
non_identifiée
n= 107

Figure 13a

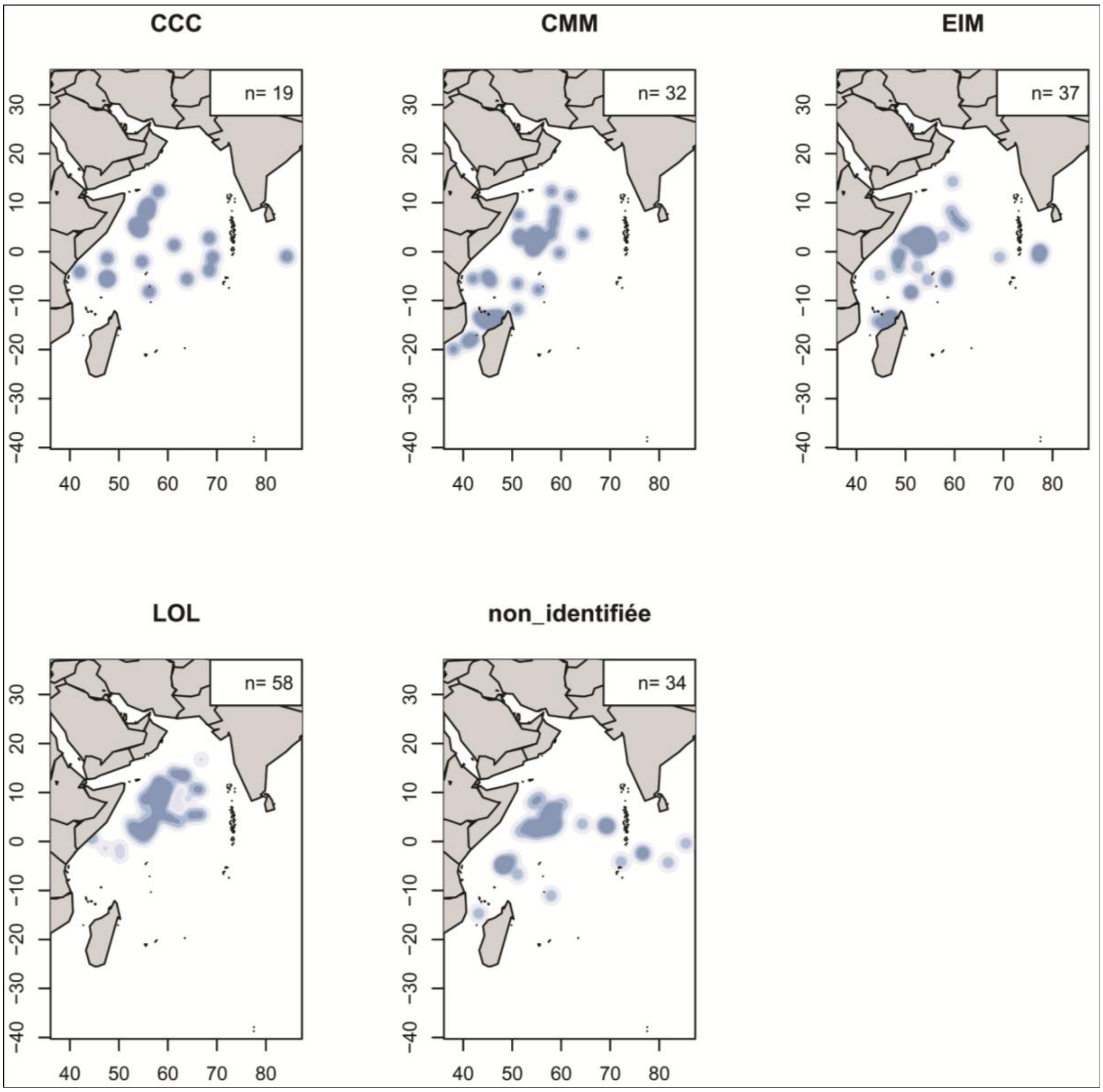


Figure 13b

Figure 13: Estimated Utilisation Distributions of marine turtle-PS interactions by species with the kernel methods, based on set observations by observer programs from 1995 to 2011 in the (a) AO and (b) IO (CCC=*Caretta caretta*, CMM=*Chelonia mydas*, DCC=*Dermochelys coriacea*, EIM=*Eretmochelys imbricata*, LKE=*Lepidochely Kempii* and LOL=*Lepidochely olivacea*).

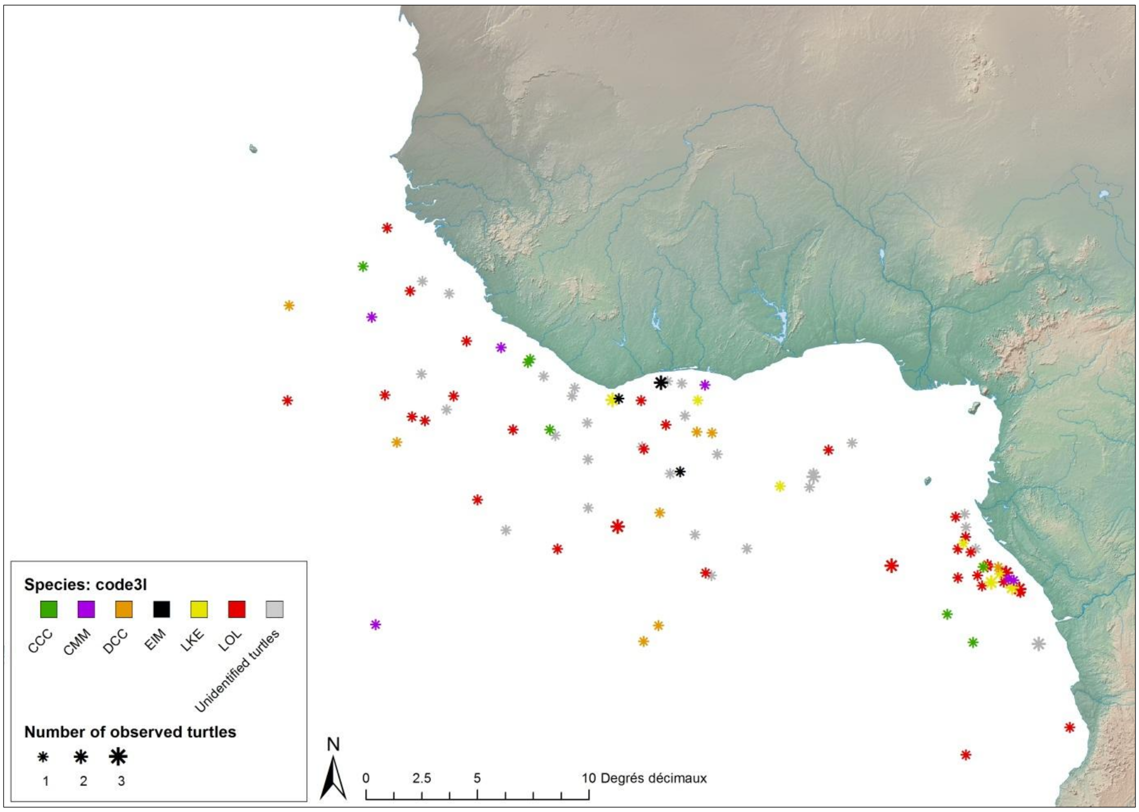


Figure 14a

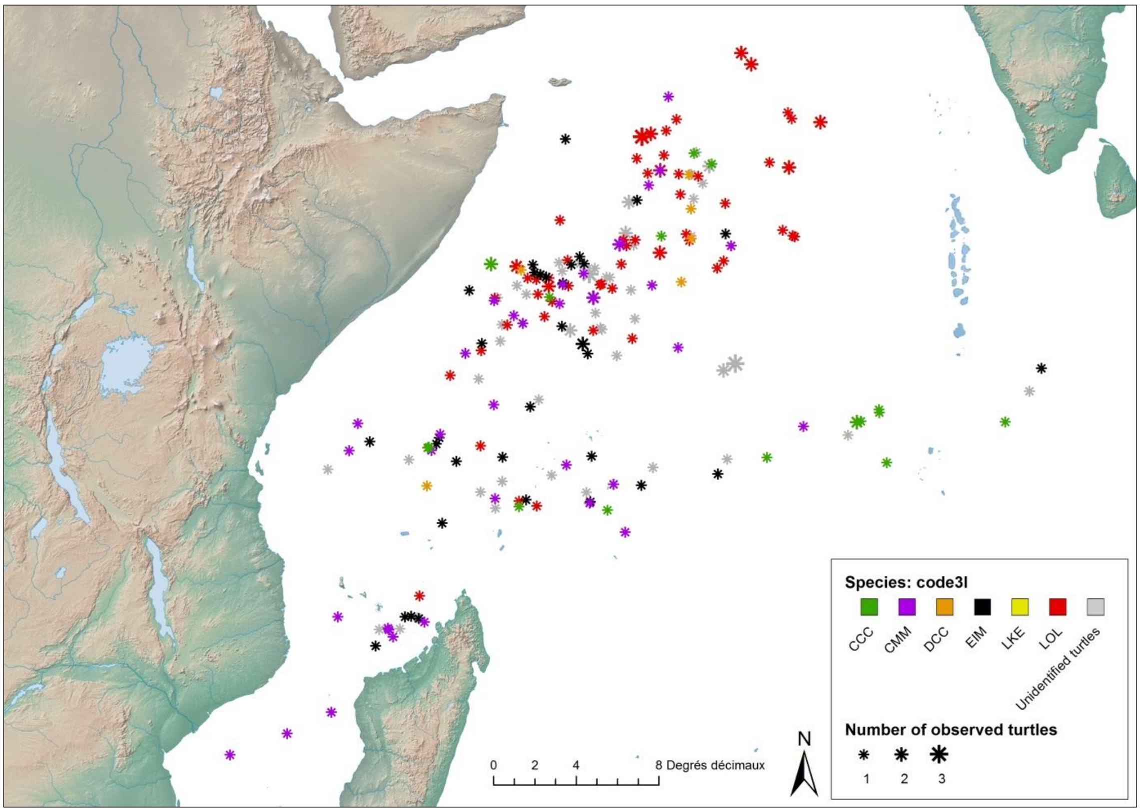


Figure 14b

Figure 14: Number of marine turtles by species observed around a floating device during the study period 2003-2011 in the (a) Atlantic and (b) Indian Oceans (CCC=*Caretta caretta*,

CMM=*Chelonia mydas*, DCC=*Dermochelys coriacea*, EIM=*Eretmochelys imbricata*, LKE=*Lepidochely Kempii* and LOL=*Lepidochely olivacea*)

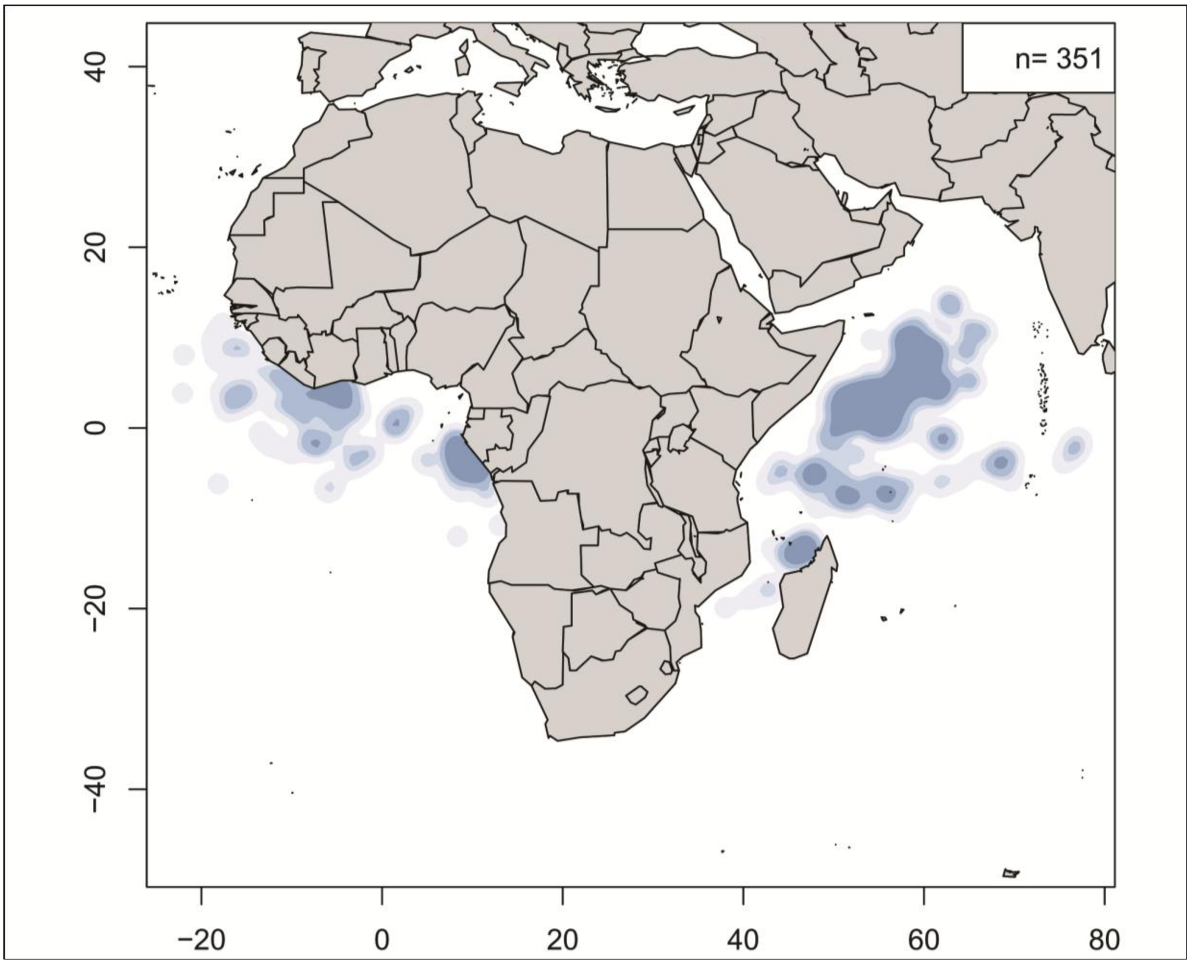


Figure 15: Estimated Utilisation Distributions of marine turtle-PS interactions with the kernel methods, based on object observations by observer programs from 2003 to 2011 (all species taken together).

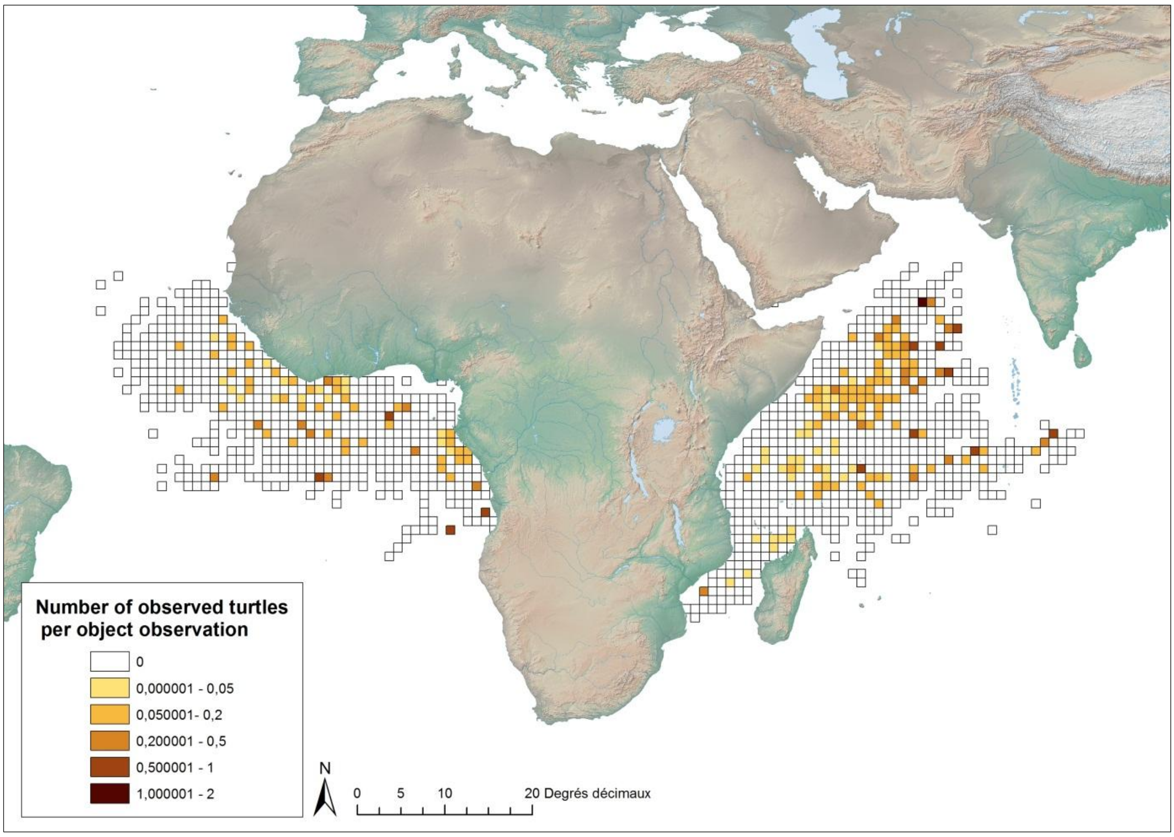


Figure 16: Number of observed marine turtles per object observation set and per statistical square of 1° over the study period 2003-2011 in the Atlantic and Indian oceans

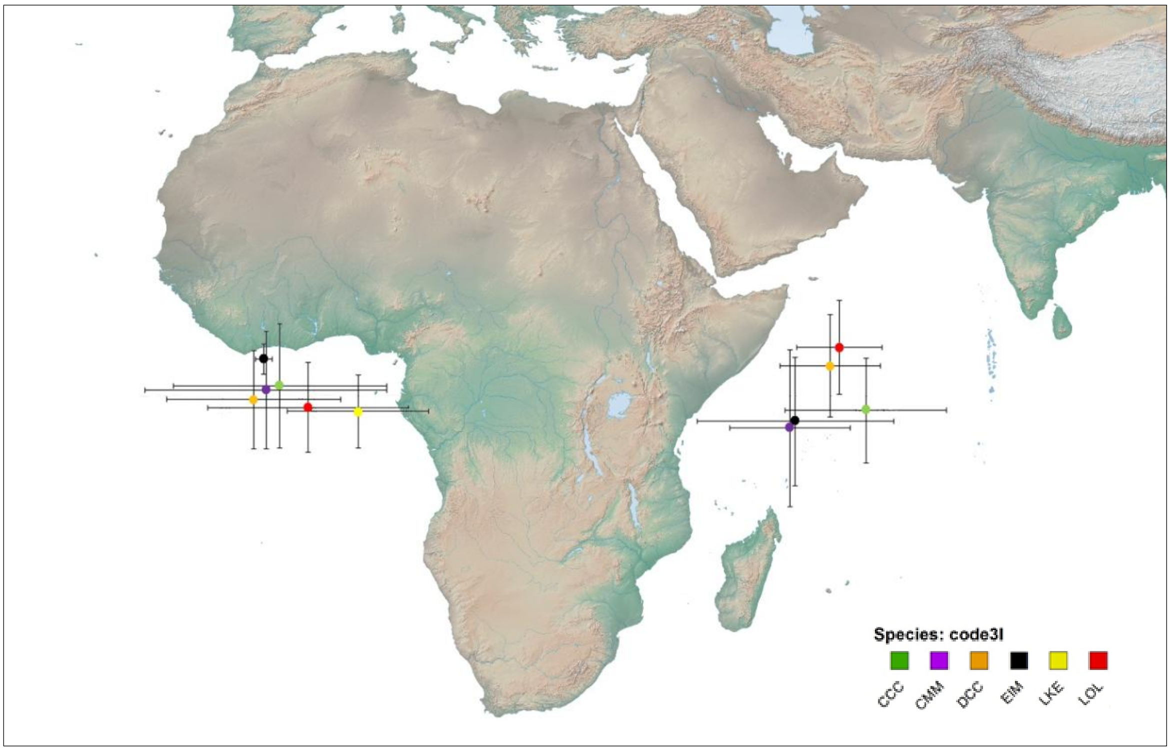


Figure 17: Latitudinal and longitudinal barycentres and standard deviations of each marine turtle species observed by observers around a floating device in the Atlantic and Indian

Oceans from 2003 to 2011 (CCC=*Caretta caretta* (N_{OA}=7; $N_{OI=}$18), CMM=*Chelonia mydas* (N_{OA}=6; $N_{OI=}$37), DCC=*Dermochelys coriacea* (N_{OA}=8; $N_{OI=}$6), EIM=*Eretmochelys imbricata* (N_{OA}=6; $N_{OI=}$40), LKE=*Lepidochely Kempii* (N_{OA}=10) and LOL=*Lepidochely olivacea* (N_{OA}=41; $N_{OI=}$74)).

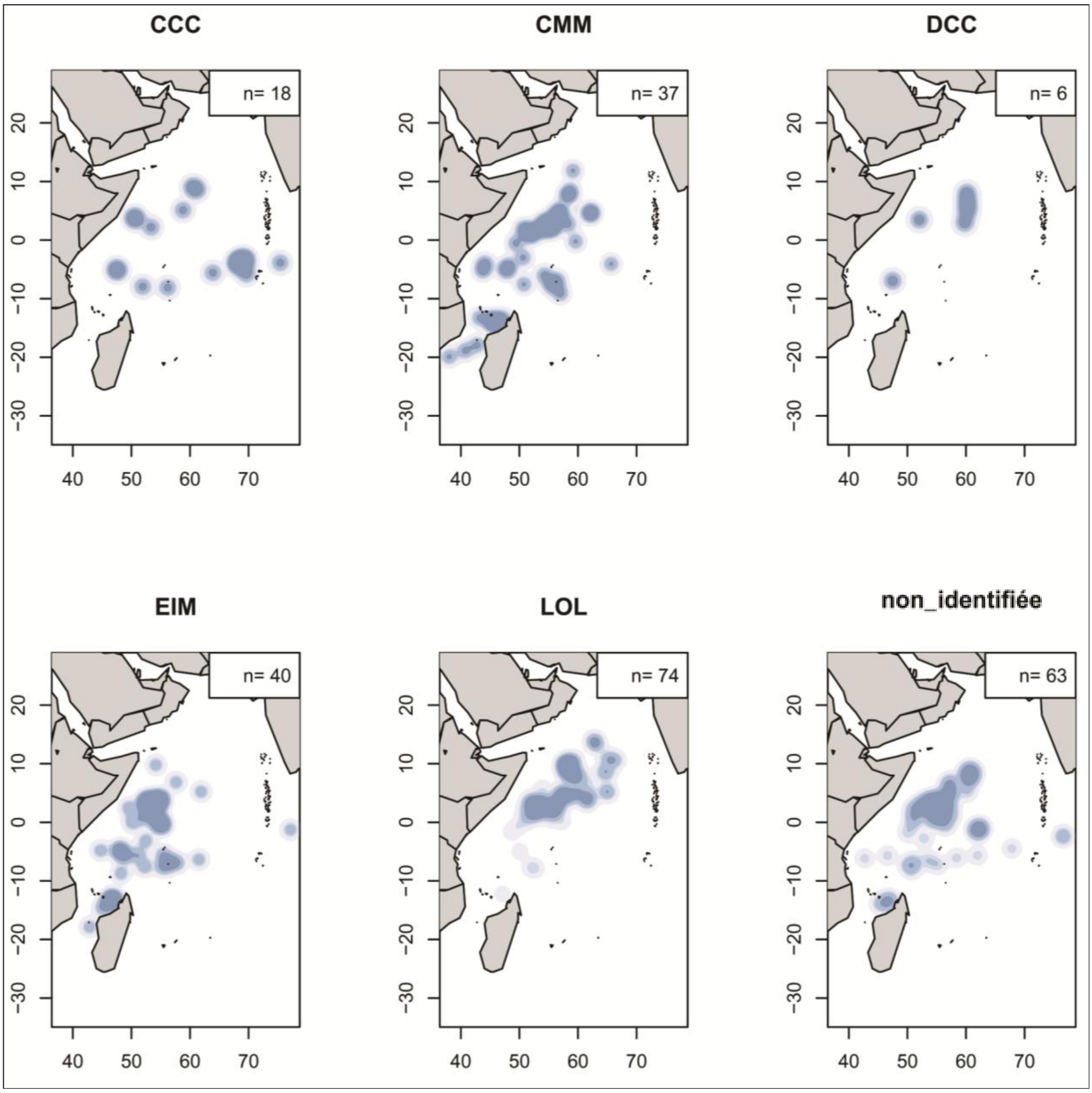
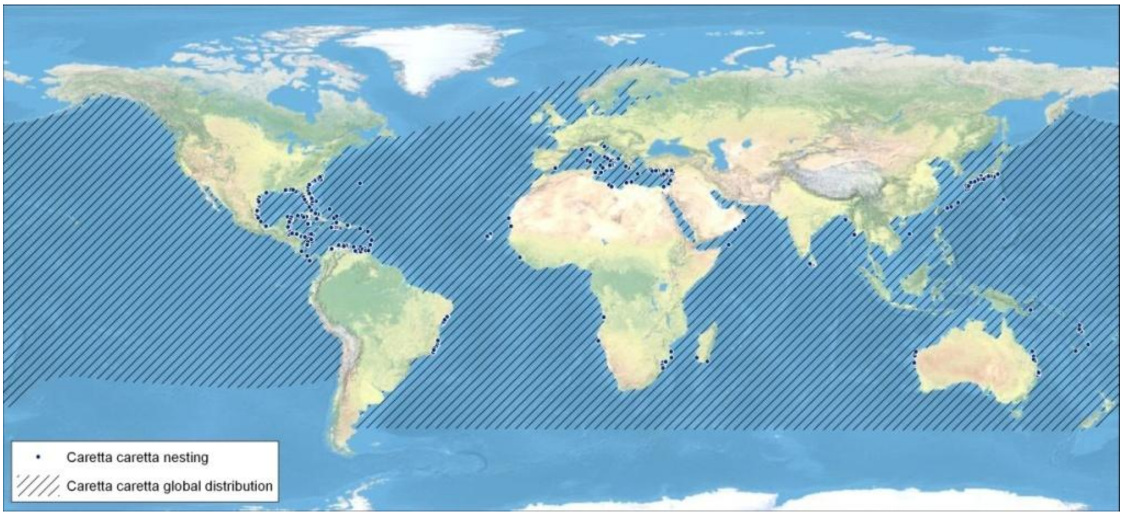
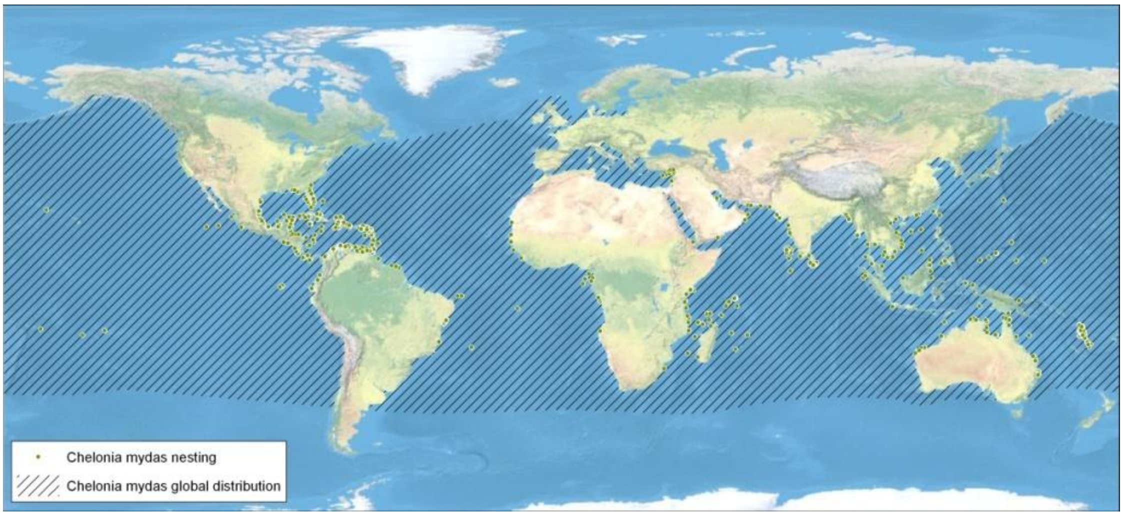


Figure 18: Estimated Utilisation Distributions of marine turtle-PS interactions by species with the kernel methods, based on object observations by observer programs from 2003 to 2011 in the IO (CCC=*Caretta caretta*, CMM=*Chelonia mydas*, DCC=*Dermochelys coriacea*, EIM=*Eretmochelys imbricata*, and LOL=*Lepidochely olivacea*). Same approach where not possible because of the too low number of data for the AO.

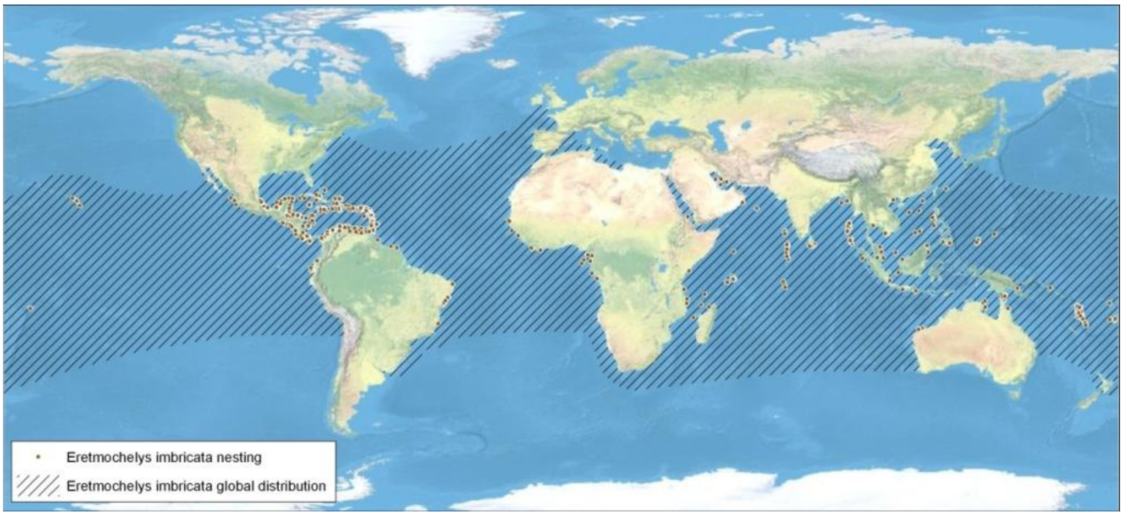
Annexes



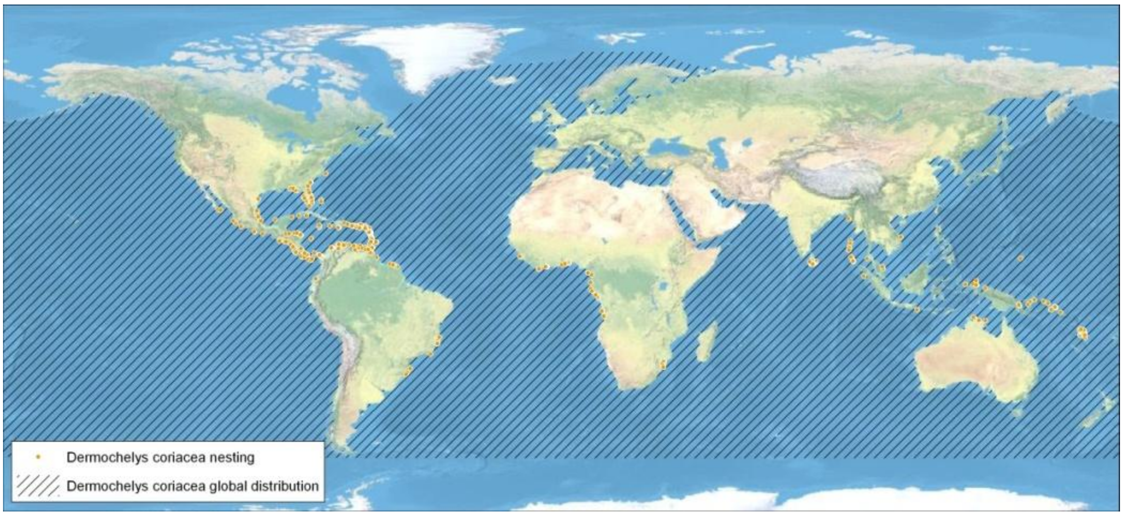
Annexe 1a



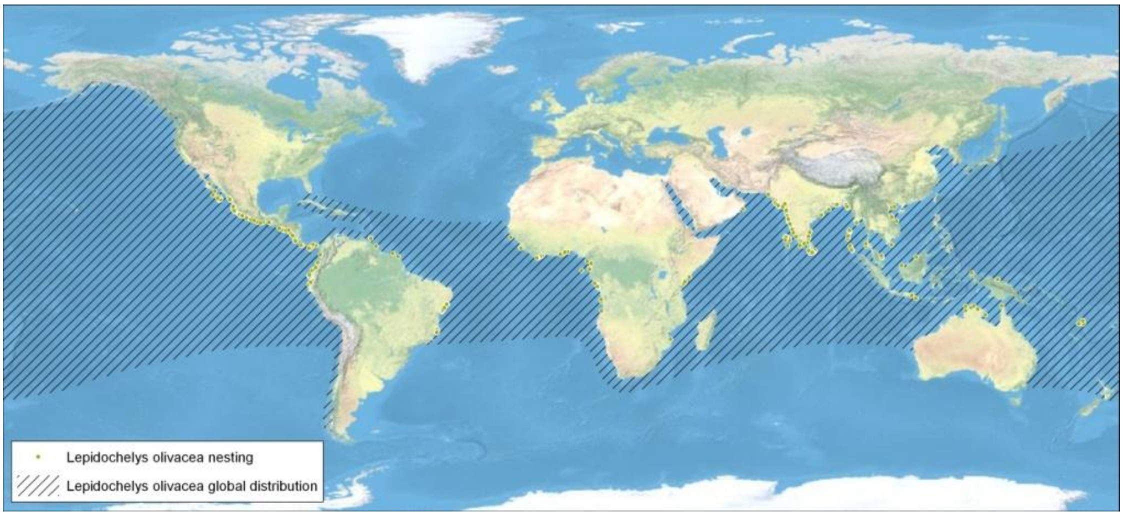
Annexe 1b



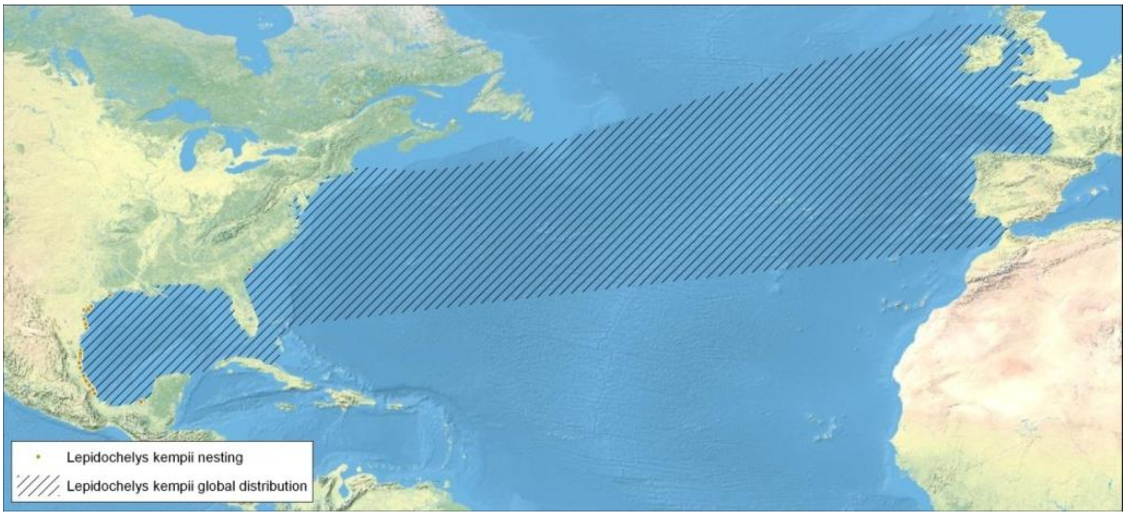
Annexe 1c



Annexe 1d



Annexe 1e



Annexe 1f

Annexe 1: Nesting sites and main global distribution of marine turtles in the Atlantic, Pacific and Indian Ocean (from Wallace et al., 2010): (a) the loggerhead turtle (*Caretta caretta*), (b) the green turtle (*Chelonia mydas*), (c) the hawksbill turtle (*Eretmochelys imbricata*), (d) the leatherback turtle (*Dermochelys coriaca*), (e) the olive ridley (*Lepidochely olivacea*) and (f) the Kemp's turtle (*Lepidochely Kempii*).

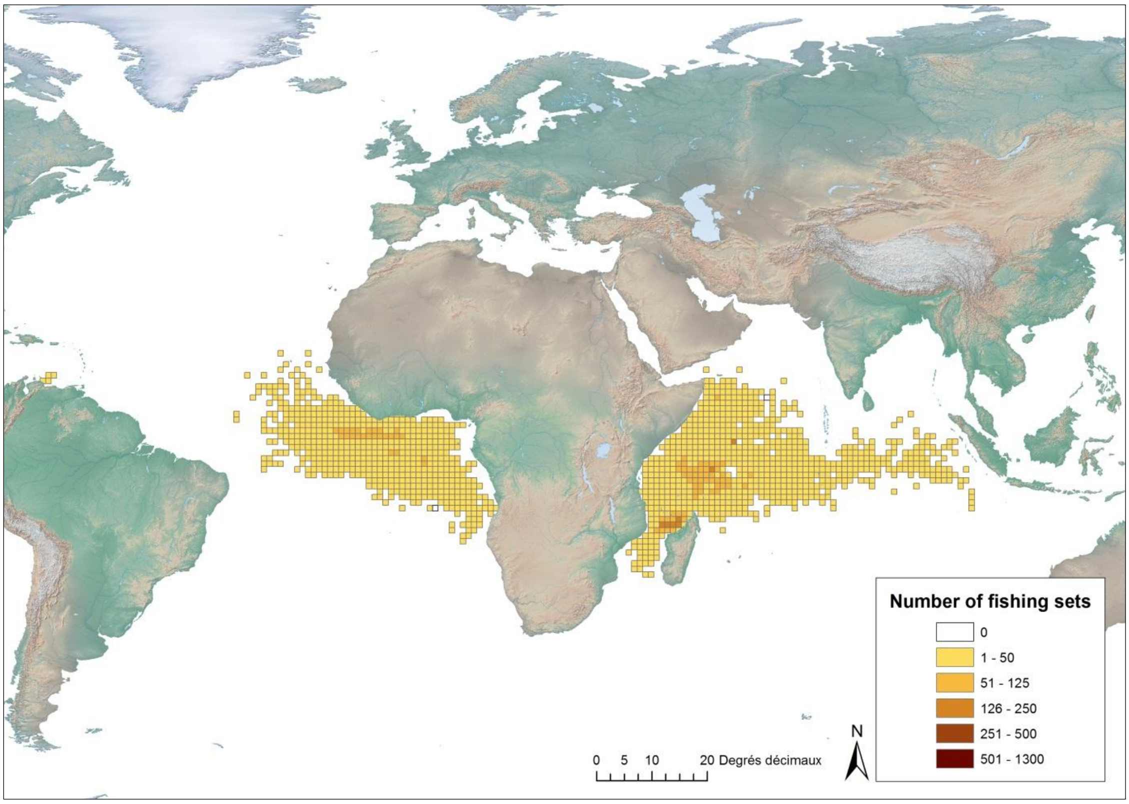
Quarter	Atlantic			Indian		
	Total sets	Observed sets	Coverage (%)	Total sets	Observed sets	Coverage (%)
1	7496	553	7,4	12418	513	4,1
2	9347	375	4,0	13003	771	5,9
3	8377	546	6,5	19346	546	2,8
4	10507	1614	15,4	16967	1150	6,8
Total	35727	3088	8,6	61734	2980	4,8

Annexe 2a

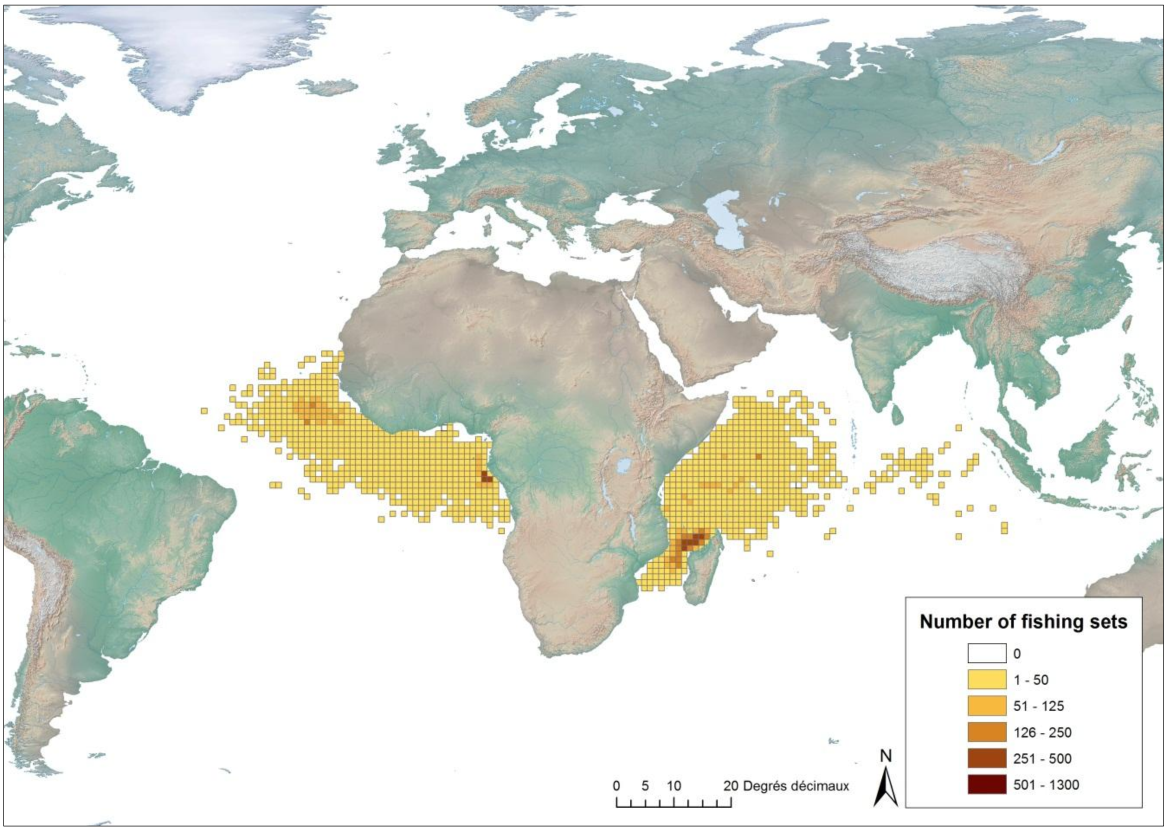
Quarter	Atlantic			Indian		
	Total sets	Observed sets	Coverage (%)	Total sets	Observed sets	Coverage (%)
1	16449	1255	7,6	19874	559	2,8
2	14591	900	6,2	16056	785	4,9
3	13022	718	5,5	5578	186	3,3
4	6852	3150	46,0	11023	1310	11,9
Total	50914	6023	11,8	52531	2840	5,4

Annexe 2b

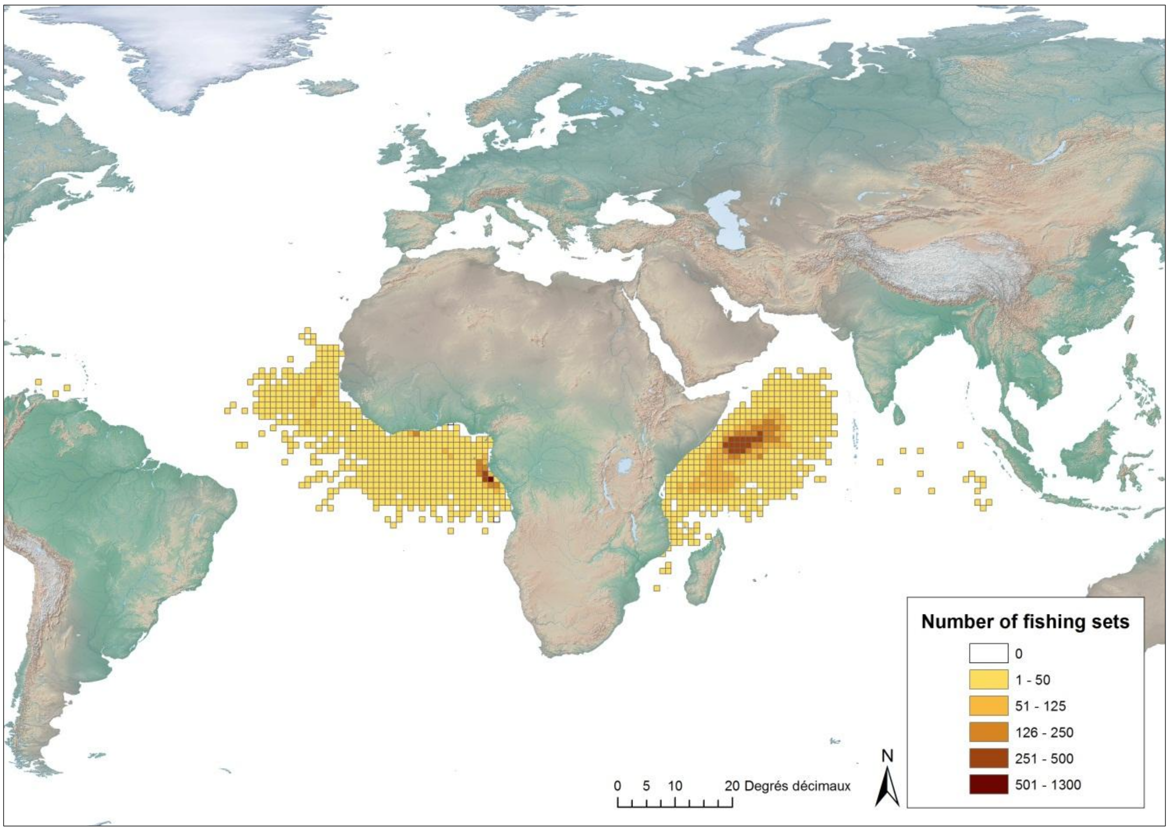
Annexe 2: Number of observed sets on (a) FADs and (b) FSCs in the Spanish and French observer programs by quarter and ocean, and percentage coverage of the total fishing effort for the study period 1995-2010



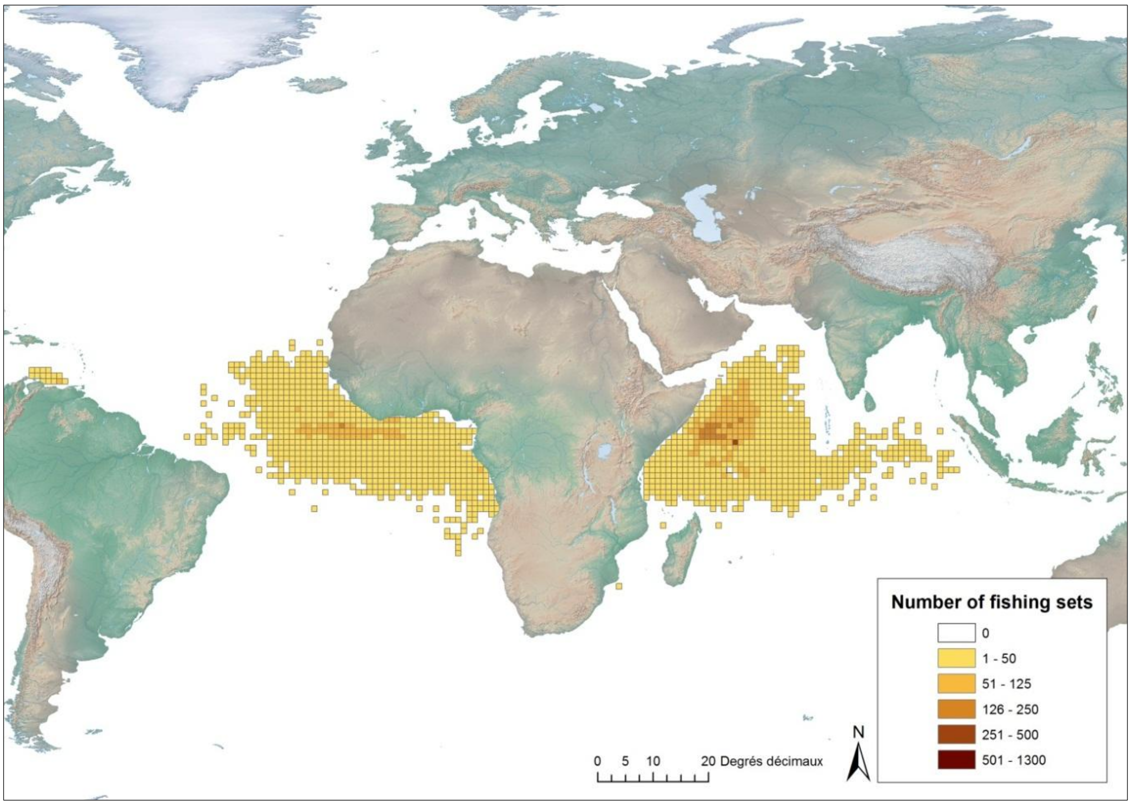
Annexe 3a



Annexe 3b

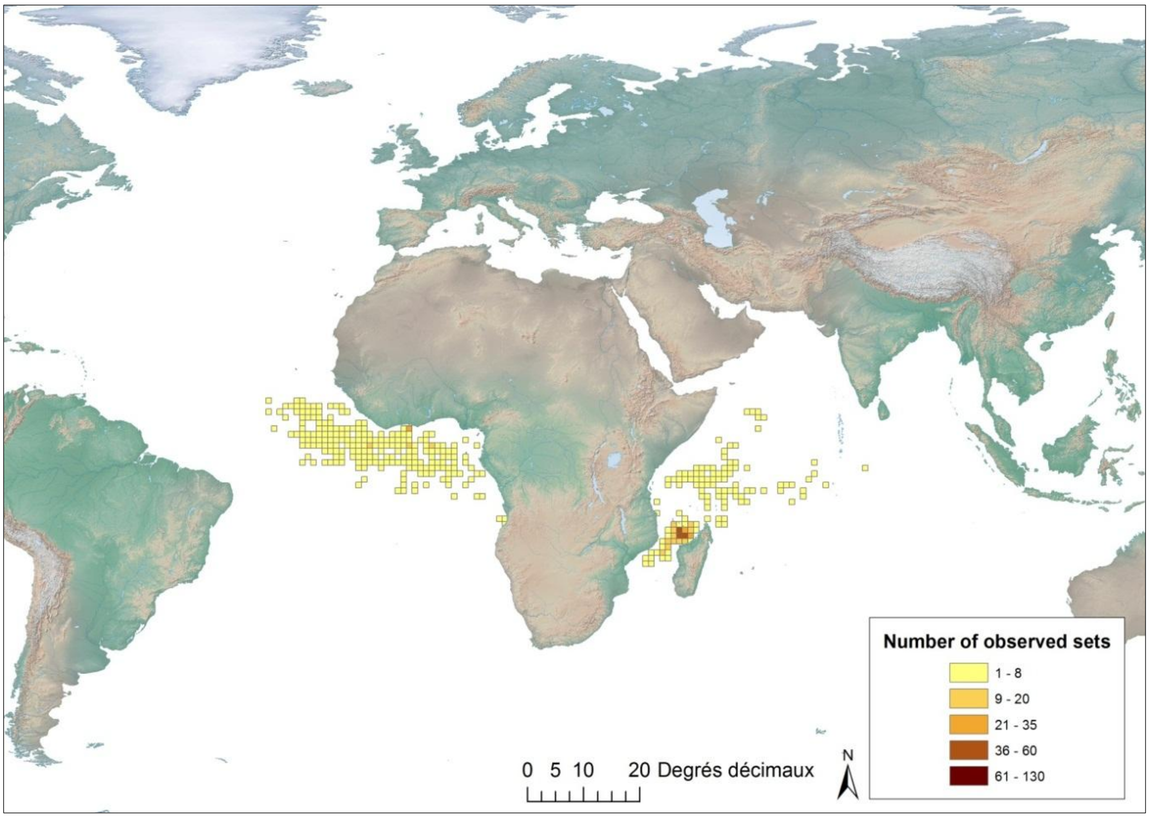


Annexe3c

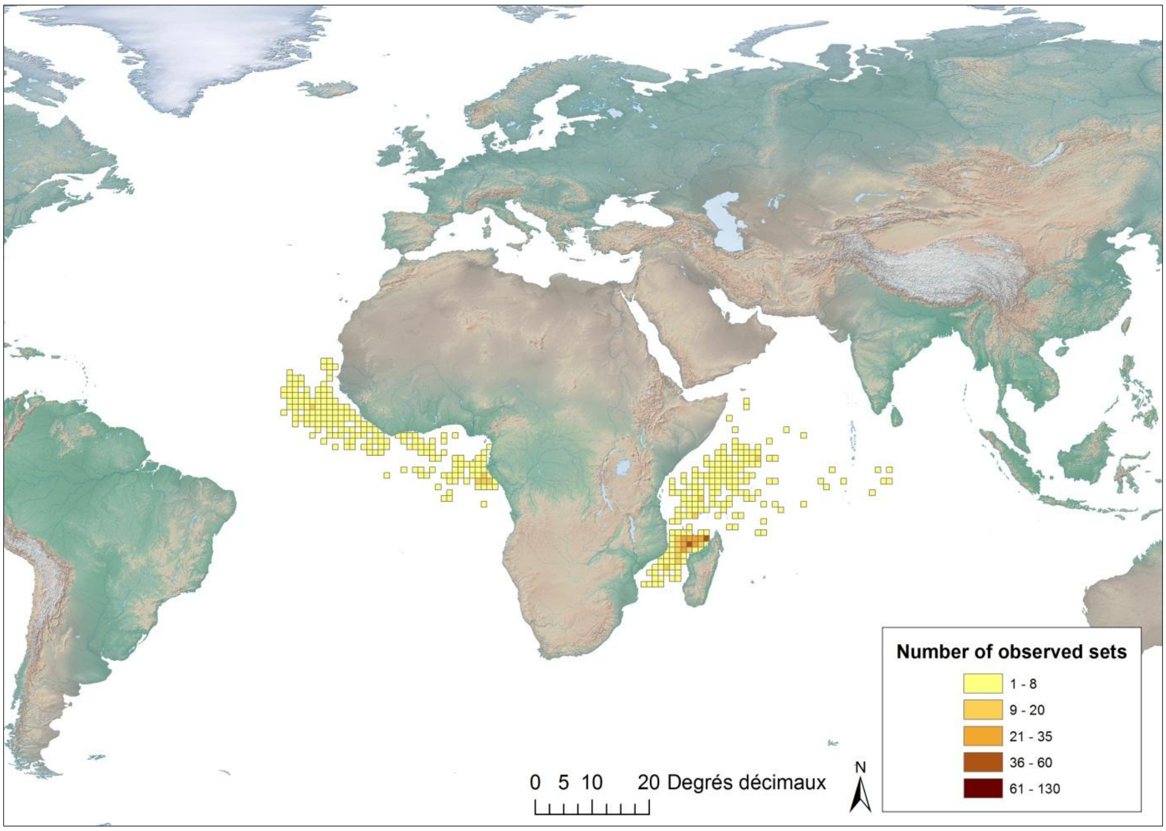


Annexe 3d

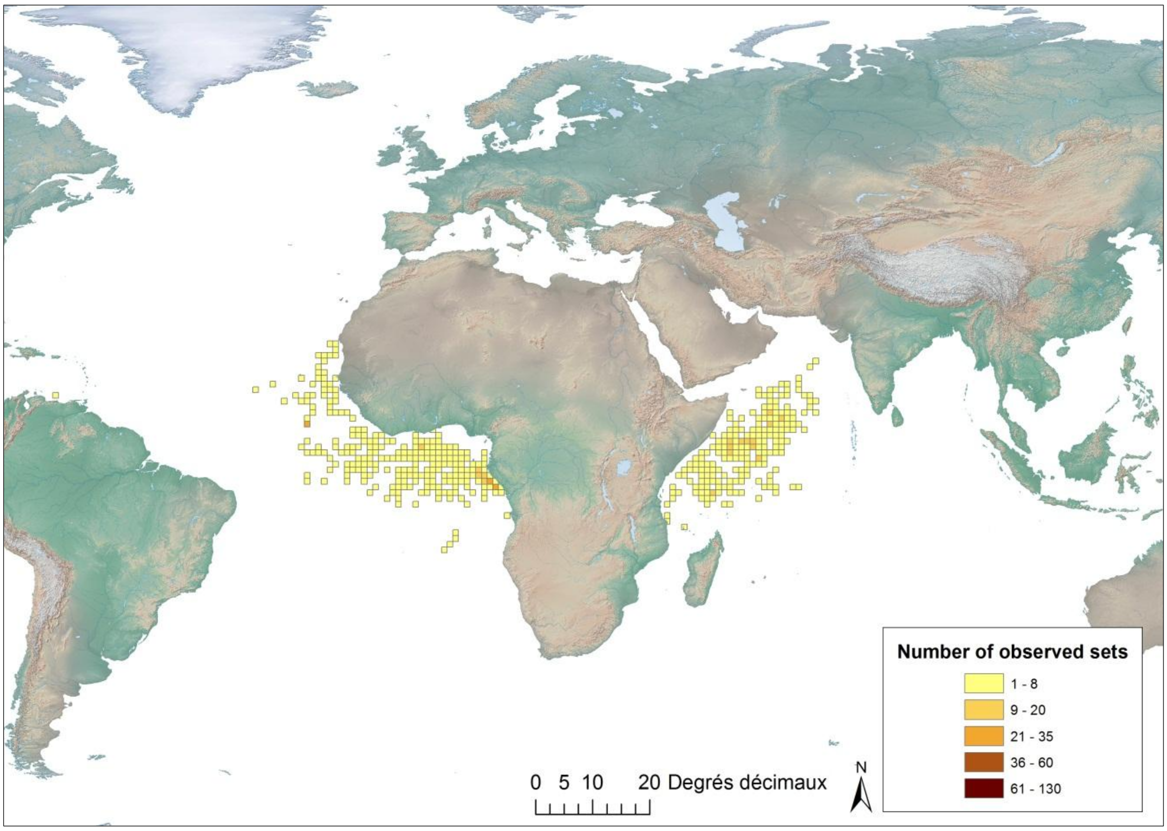
Annexe 3: Total fishing effort (in number of fishing sets) on FADs by quarter (from the 1st to the 4th quarter: from annexe 3a to annexe 3d) and per statistical square of 1°of the EU PS fishery over the study period 1995-2011



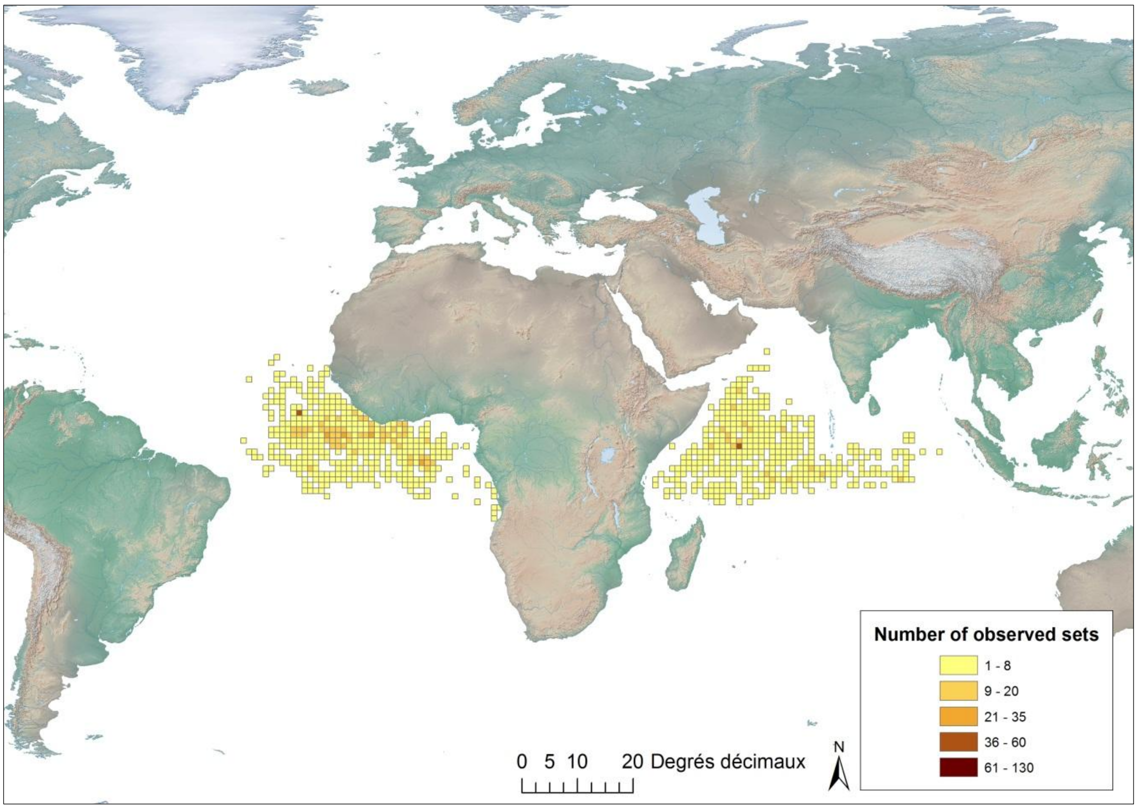
Annexe 4a



Annexe 4b

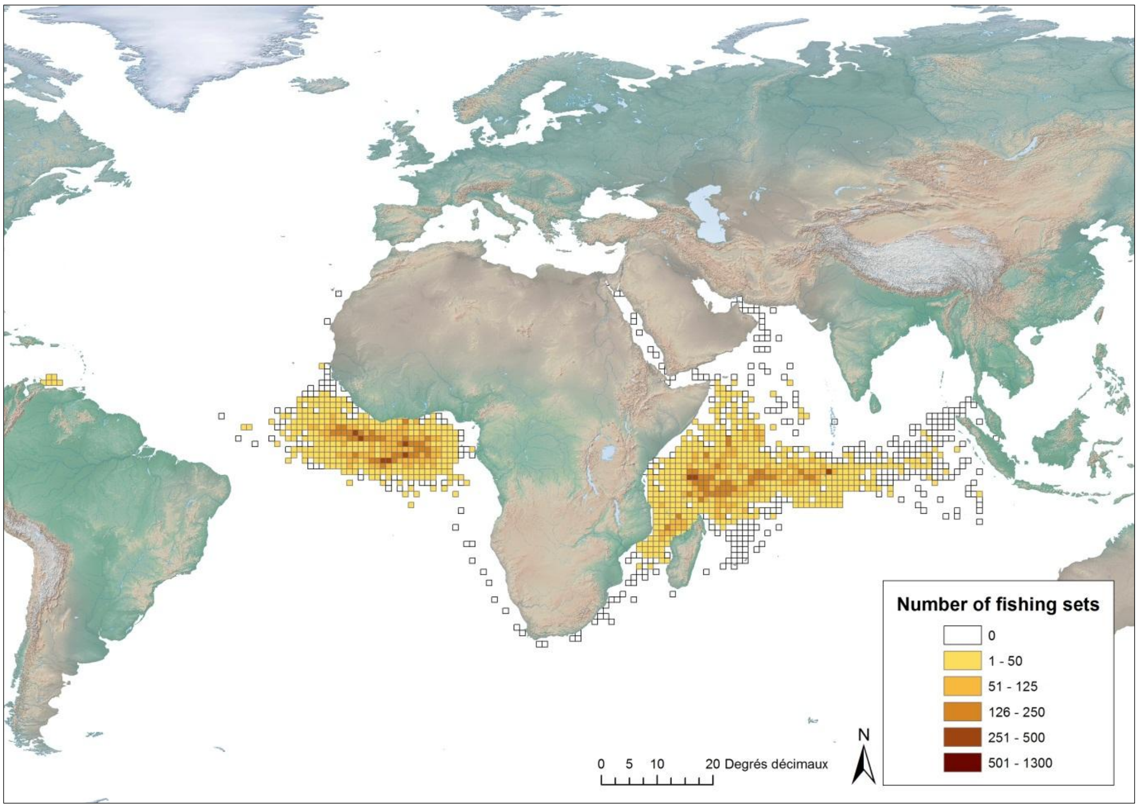


Annexe 4c

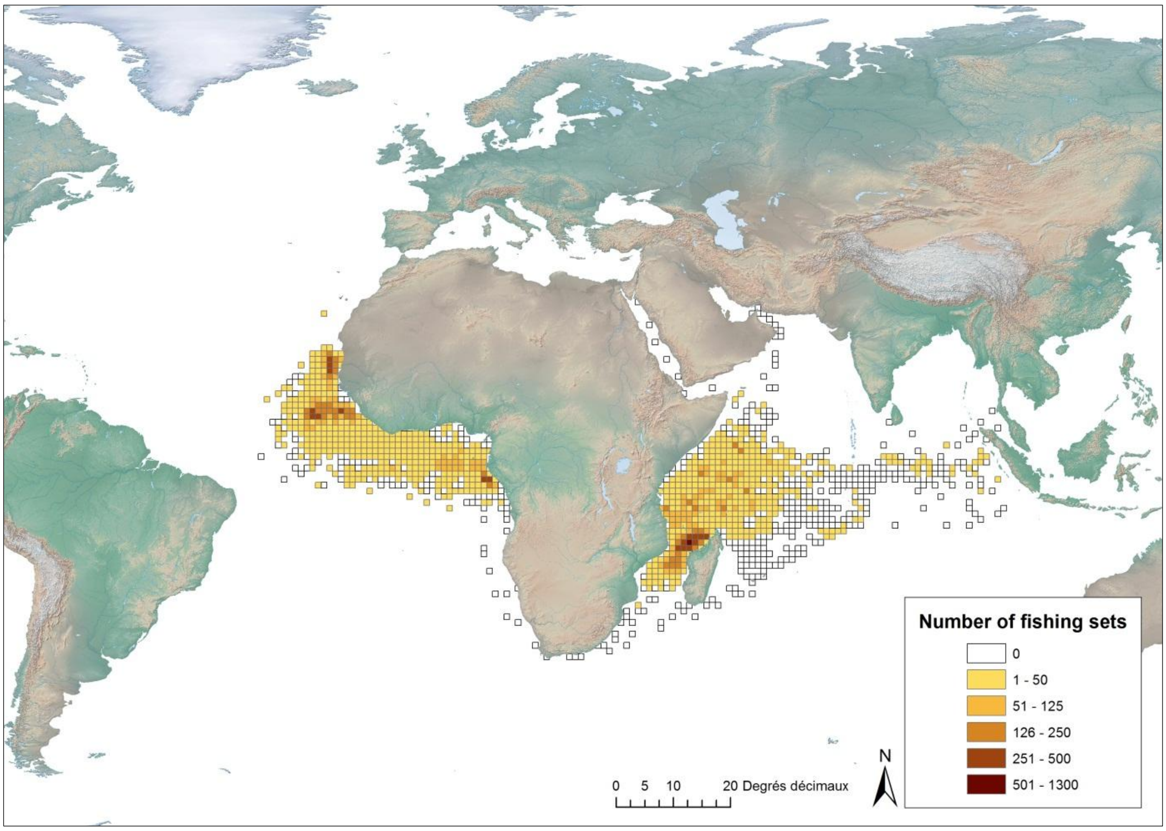


Annexe 4d

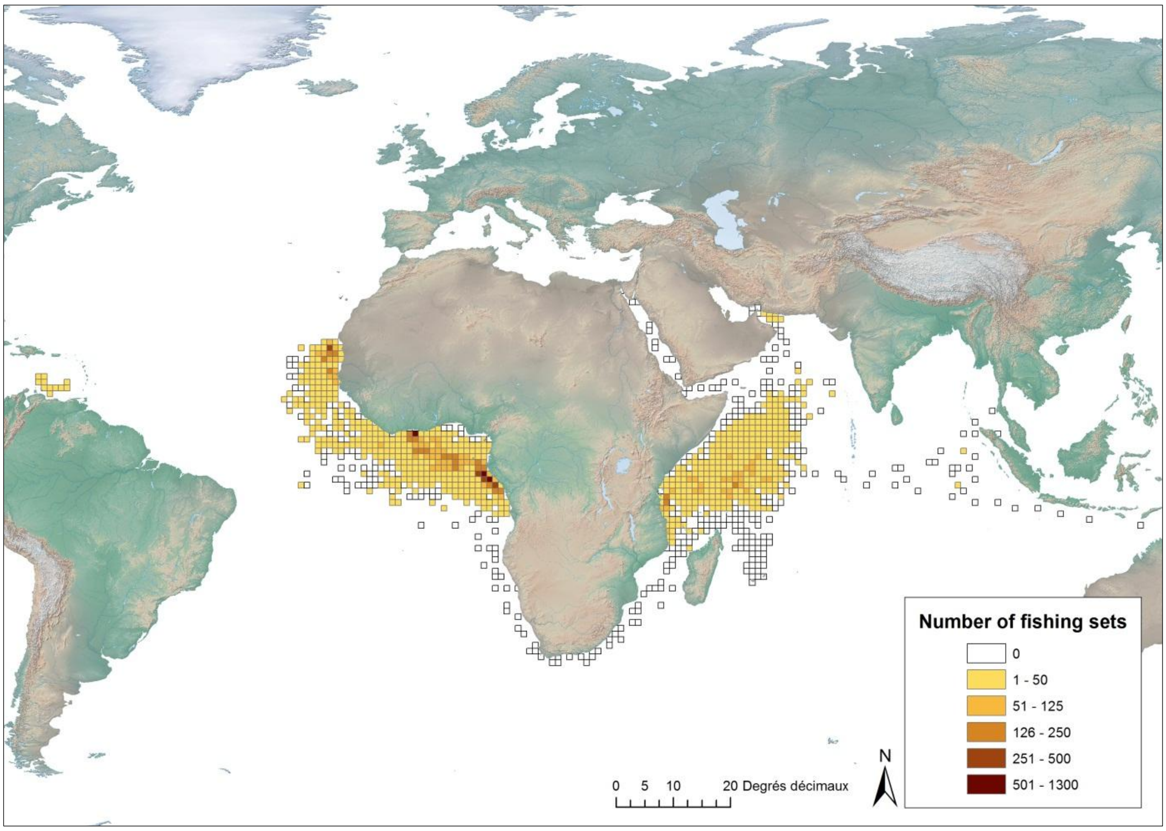
Annexe 4: Total set observation effort (in number of observed sets) on FADs by quarter (from the first to the fourth quarter: from annexe 4a to annexe 4d) and per statistical square of 1°of the EU PS fishery over the study period 1995-2011



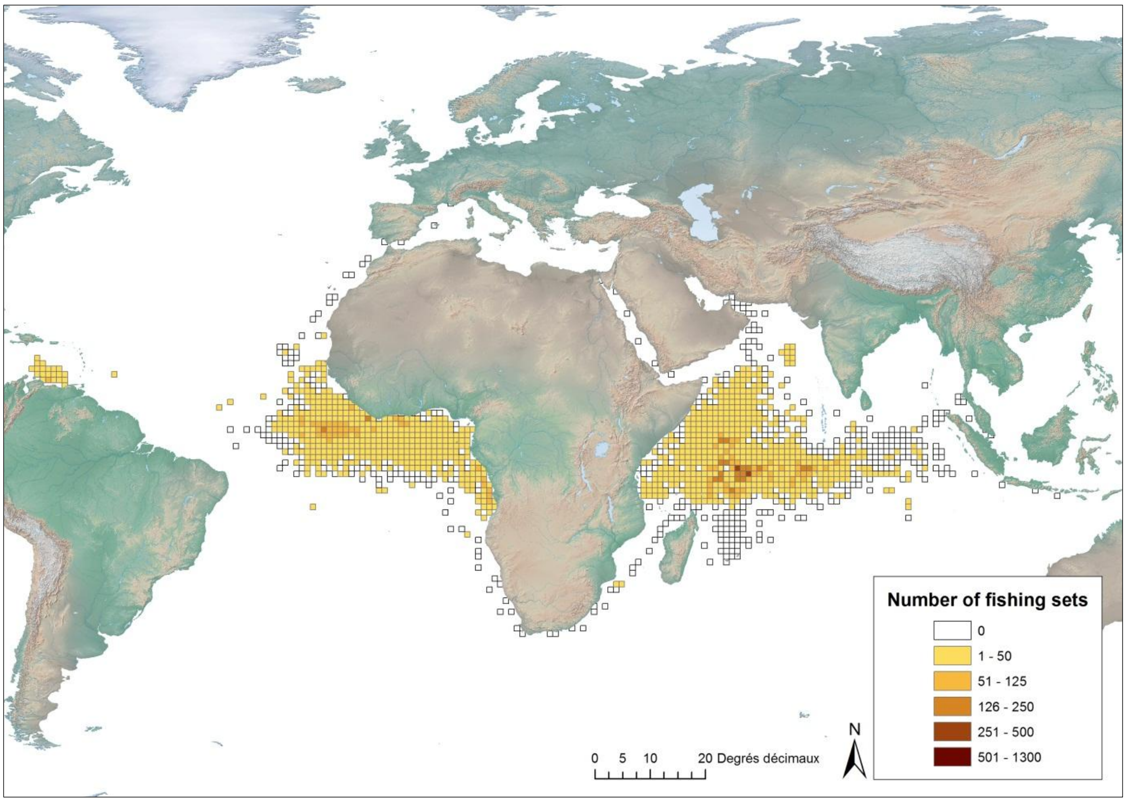
Annexe 5a



Annexe 5b

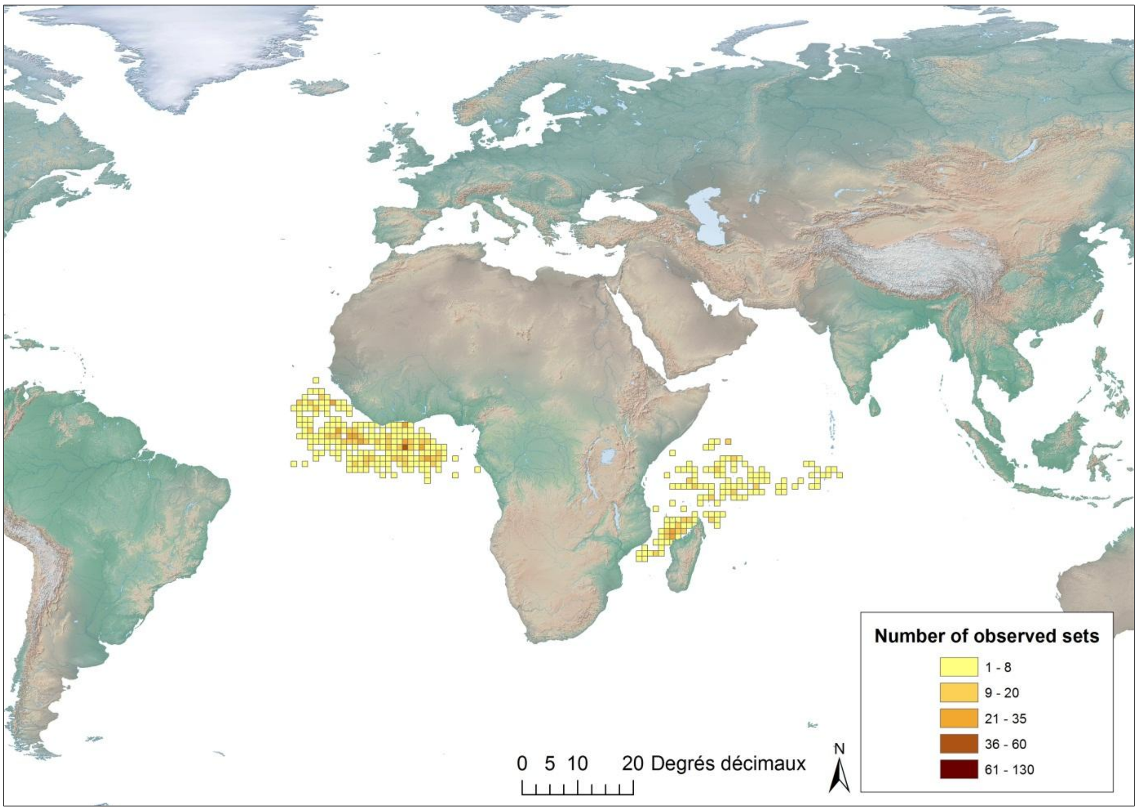


Annexe 5c

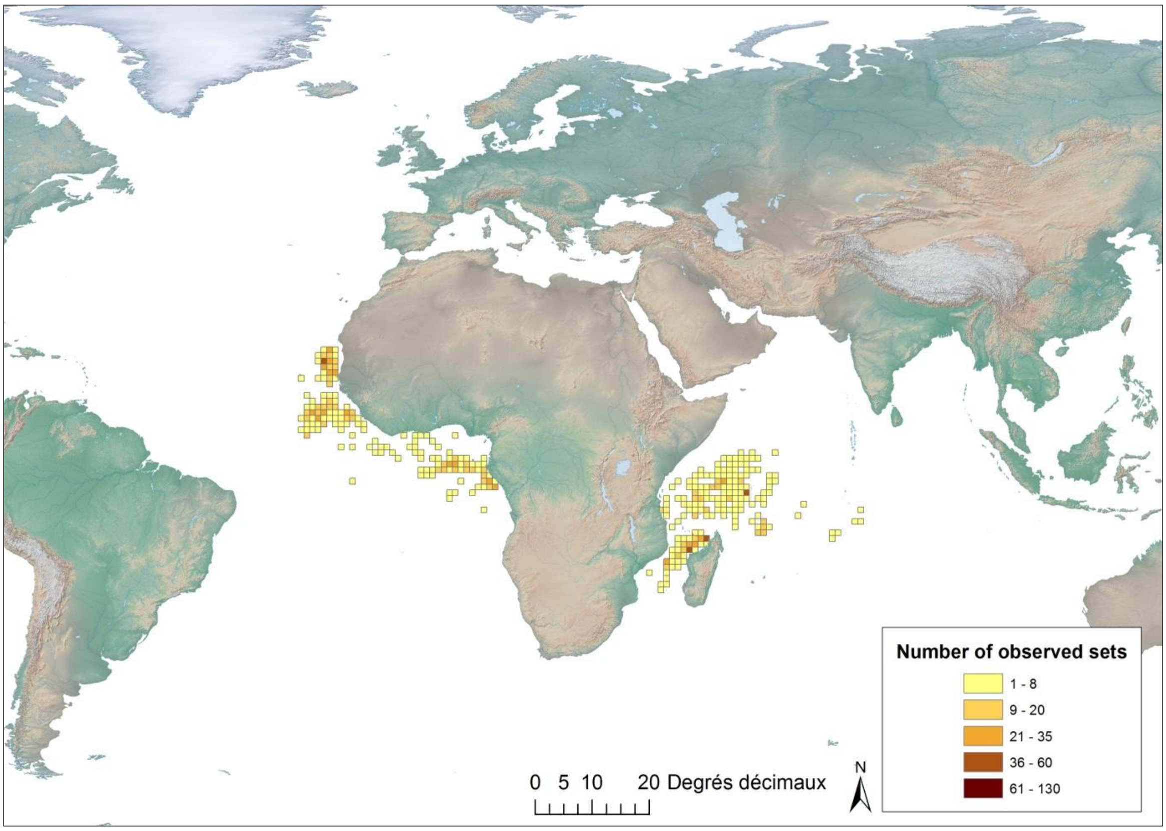


Annexe 5d

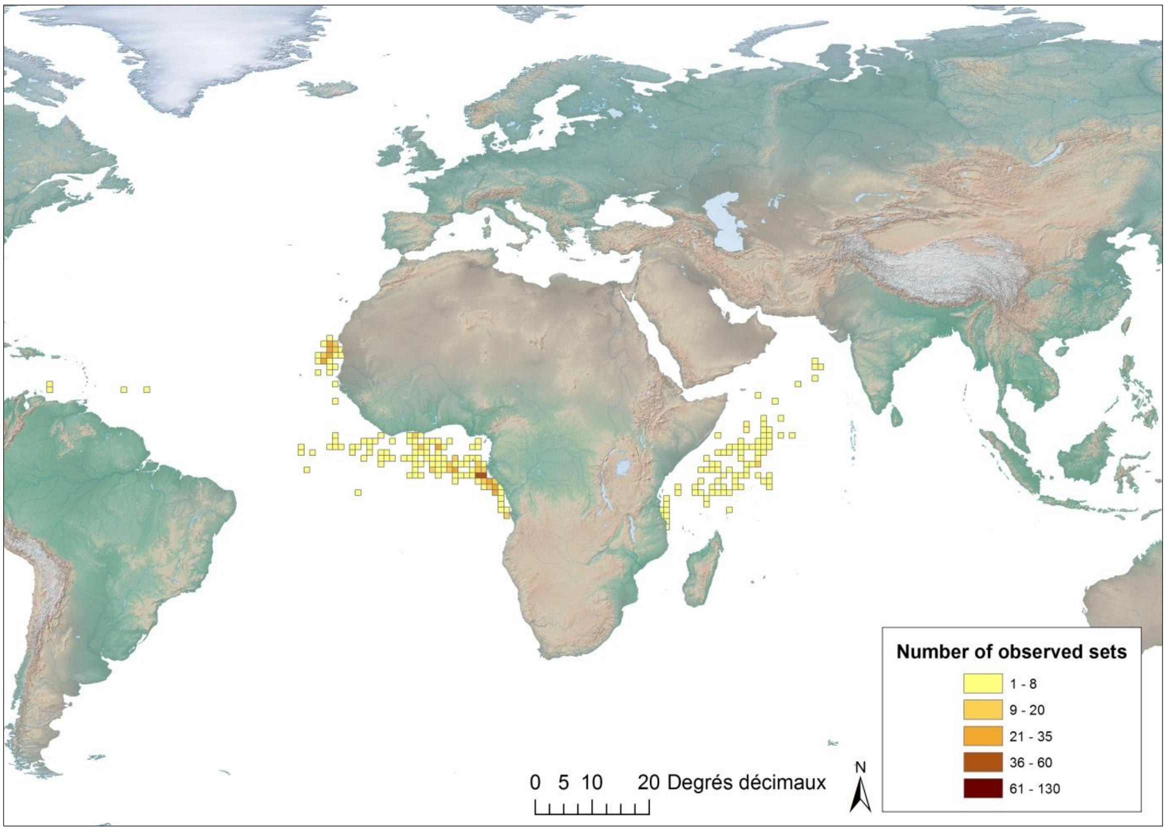
Annexe 5: Total fishing effort (in number of fishing sets) on FSCs by quarter (from the 1st to the 4th quarter: from annexe 5a to annexe 5d) and per statistical square of 1°of the EU PS fishery over the study period 1995-2011



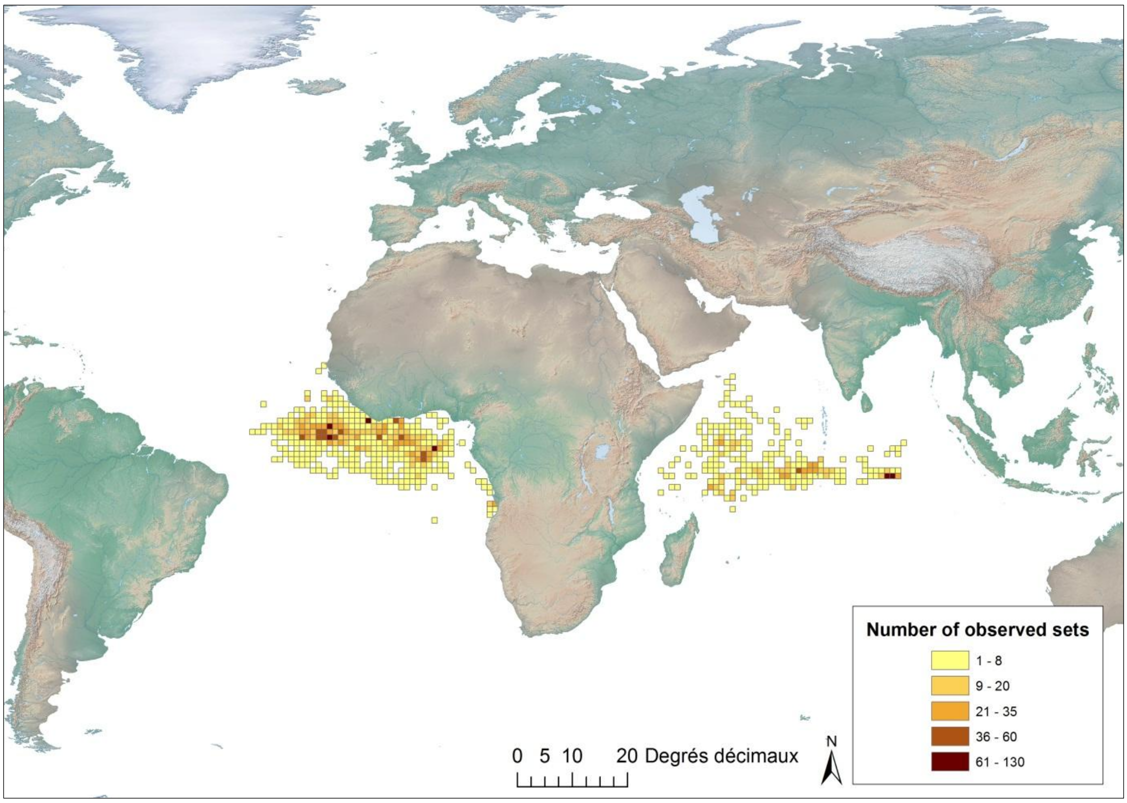
Annexe 6a



Annexe 6b

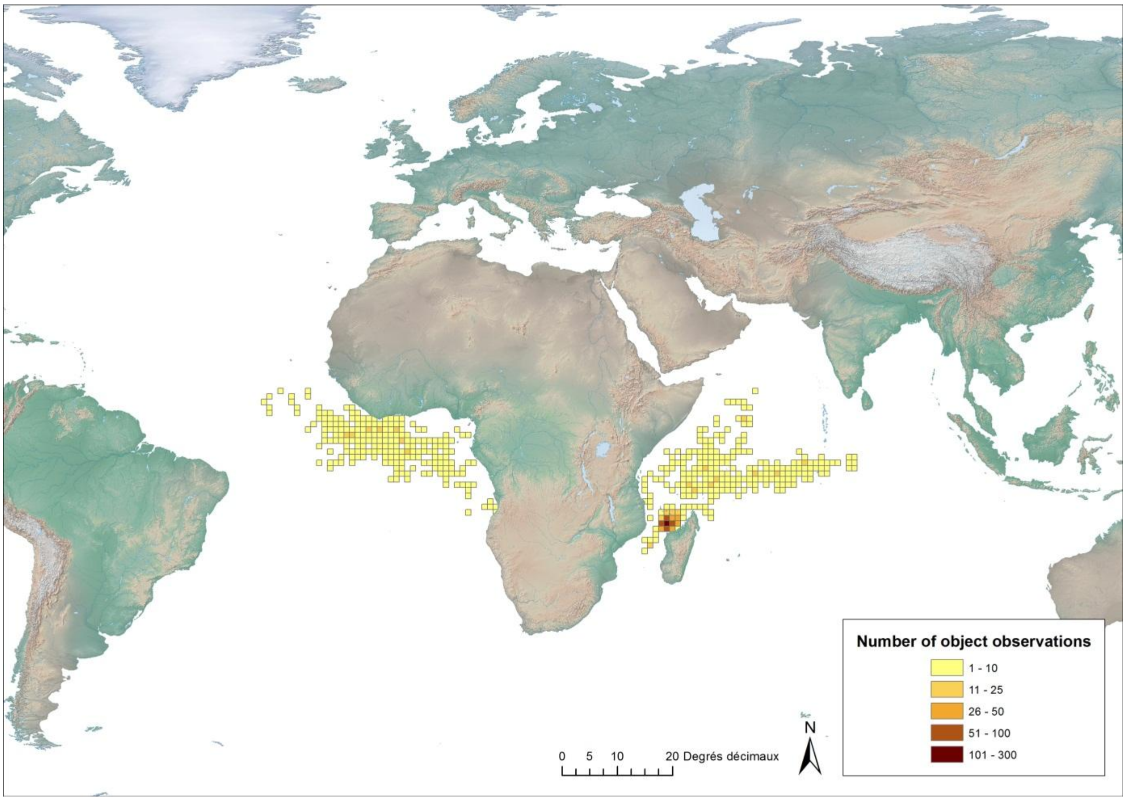


Annexe 6c

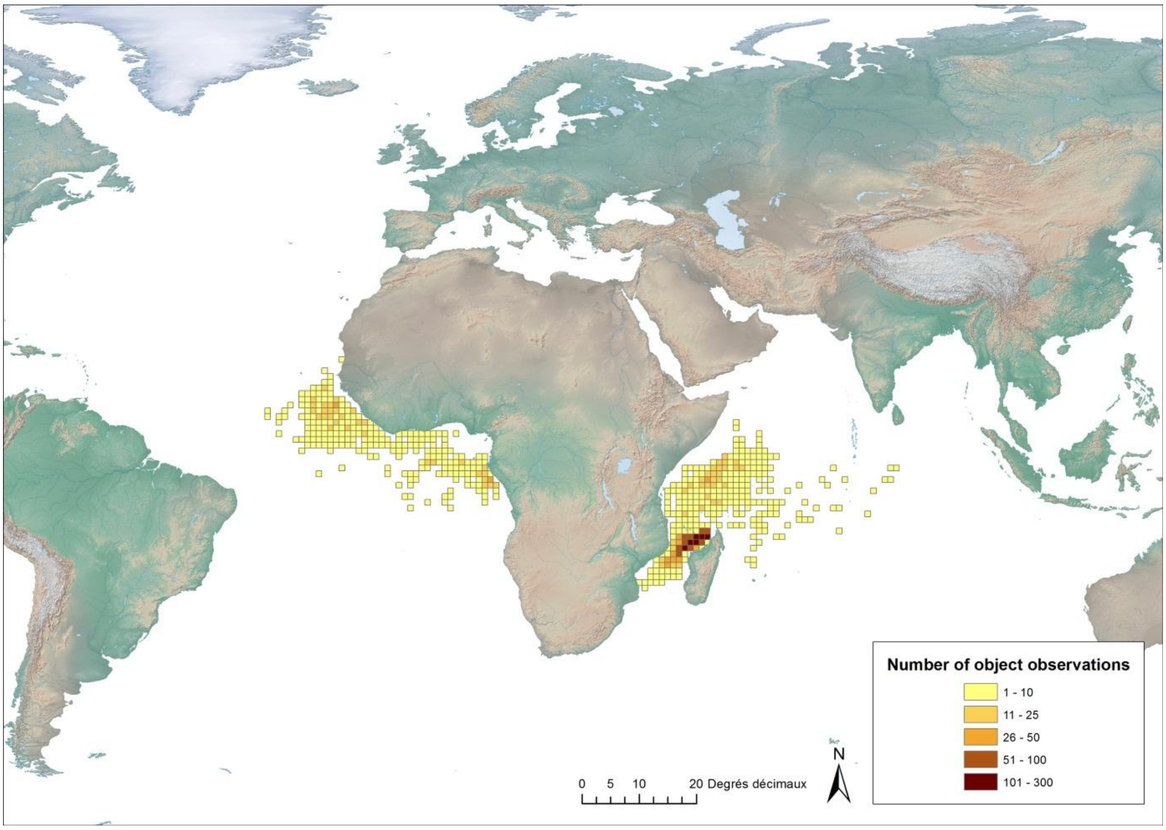


Annexe 6d

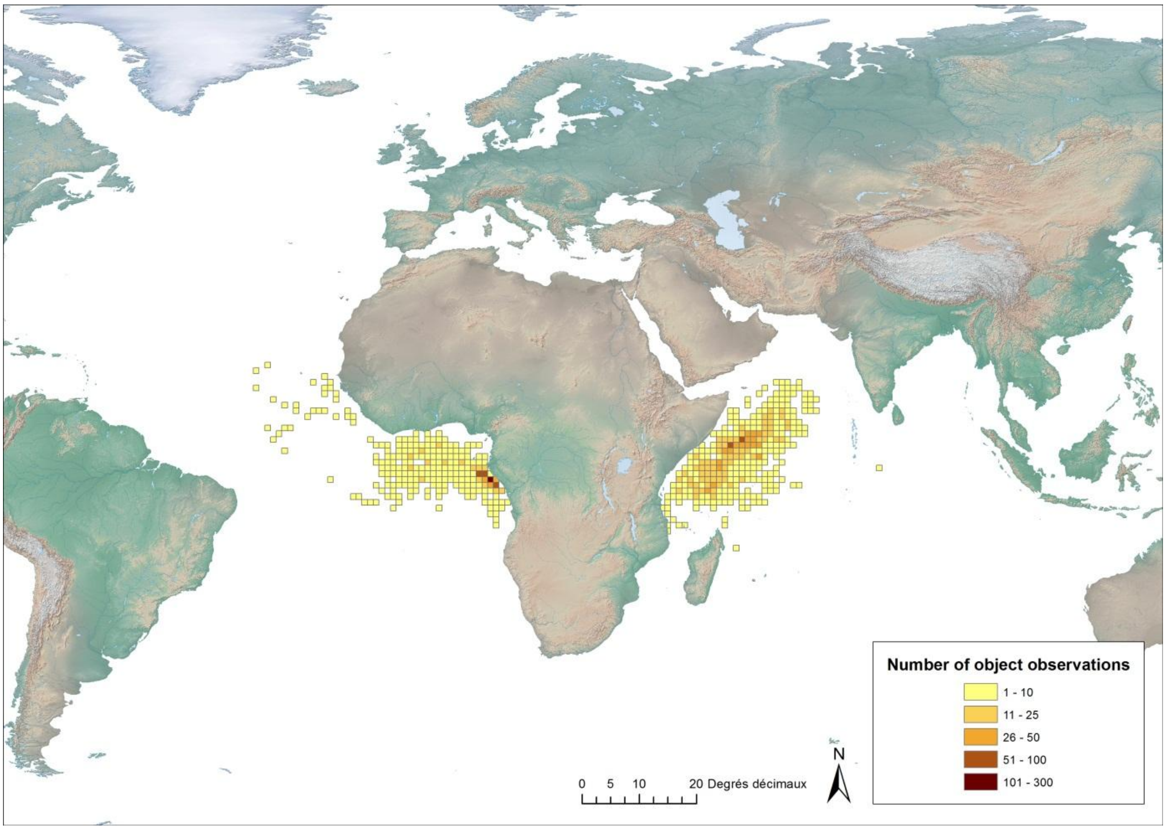
Annexe 6: Total observed sets (in number of observed sets) on FSCs by quarter (from the first to the fourth quarter: from annexe 6a to annexe 6d) and per statistical square of 1°of the EU PS fishery over the study period 1995-2011



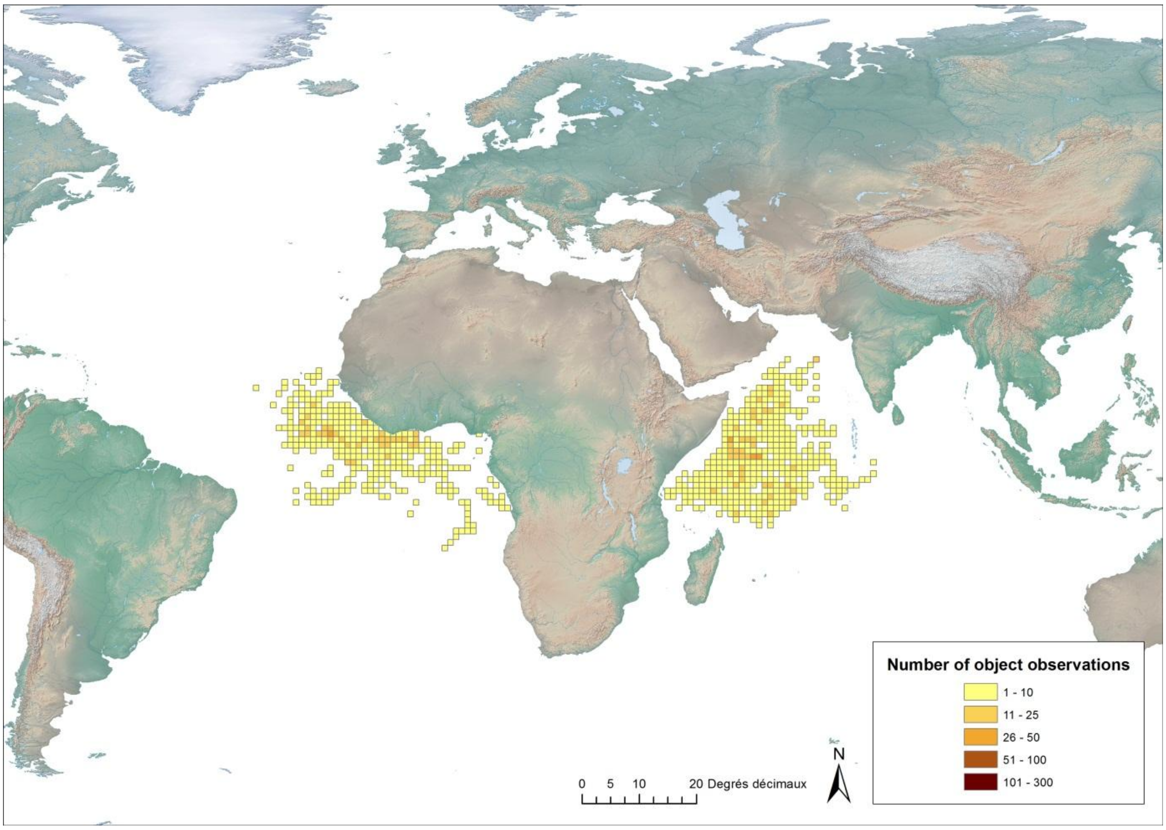
Annexe 7a



Annexe 7b



Annexe 7c

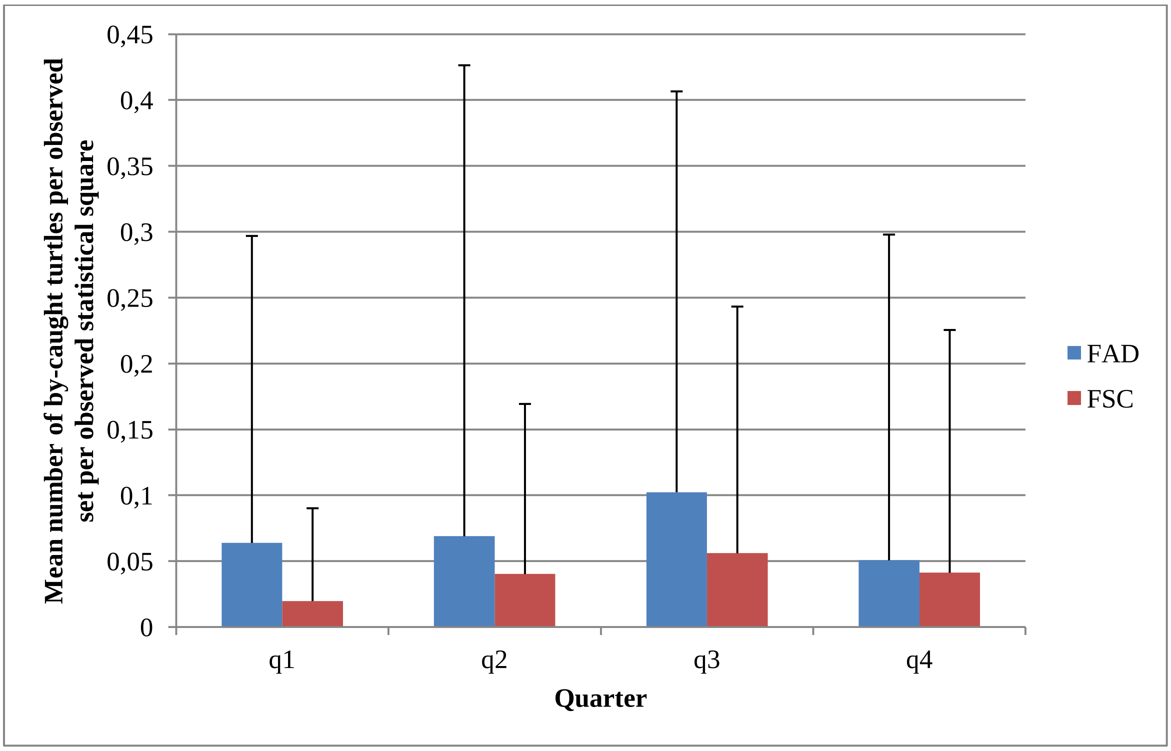


Annexe 7d

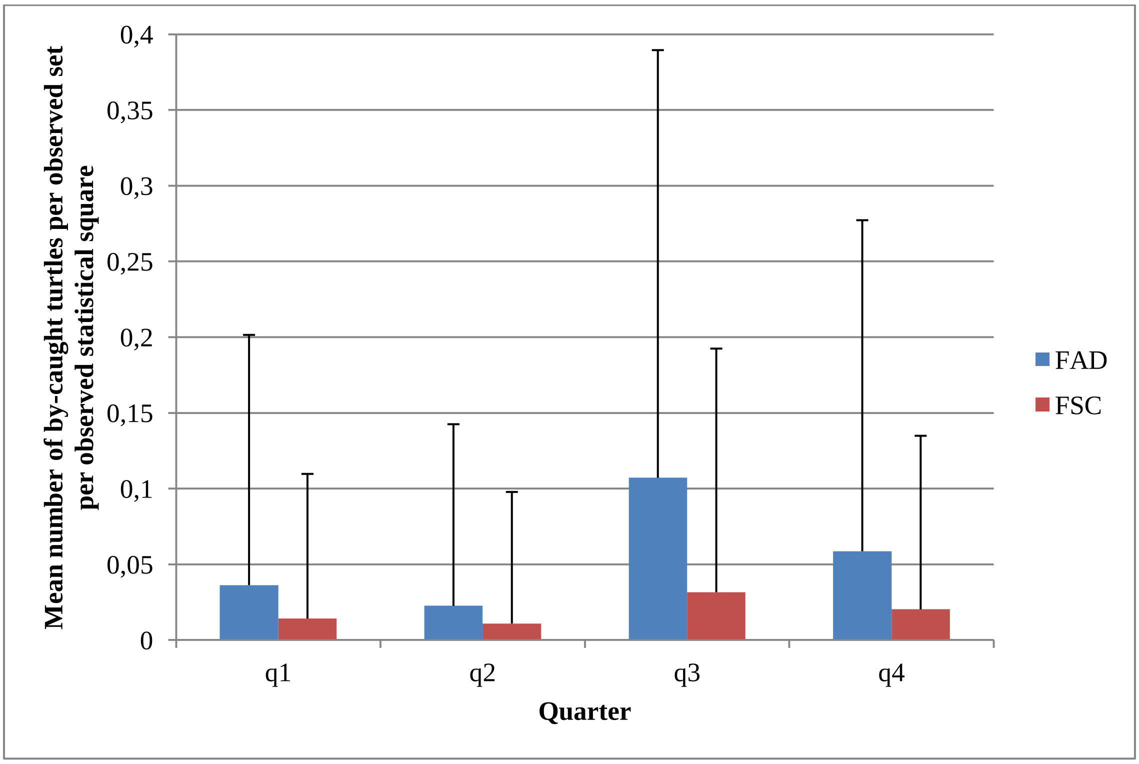
Annexe 7: Total object observation effort (in number of observations) by quarter (from the first to the fourth quarter: from annexe 7a to annexe 7d) and per statistical square of 1°of the EU PS fishery over the study period 2003-2011

	Number of observed turtles		
Type of FADs	Atlantic	Indian	Total
Raft with buoy (bamboo or net)	19	85	104
Raft with buoy (fishing line or net)	49	119	168
Net or piece of net	19		19
Straw pile	13		13
Tree (or branch)	2	11	13
Box or big branch	7	4	11
Other	2	6	8
Rope	2	3	5
Palm leaves	1	2	3
Plastic object	2	1	3
Raft		3	3
Supply		2	2
Carrion		1	1
Experimental object		1	1
Total	116	238	354

Annexe 8: Total number of observed turtles according to the type of FAD in the Atlantic and Indian Oceans

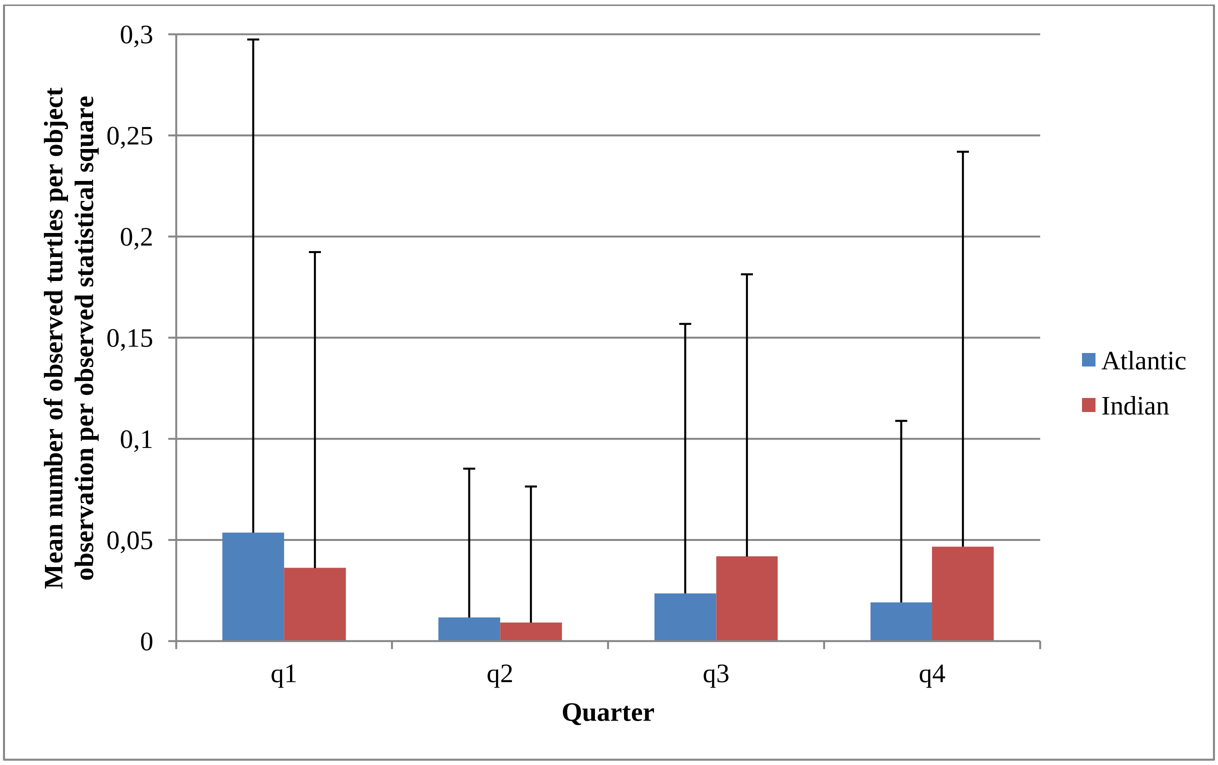


Annexe 9a

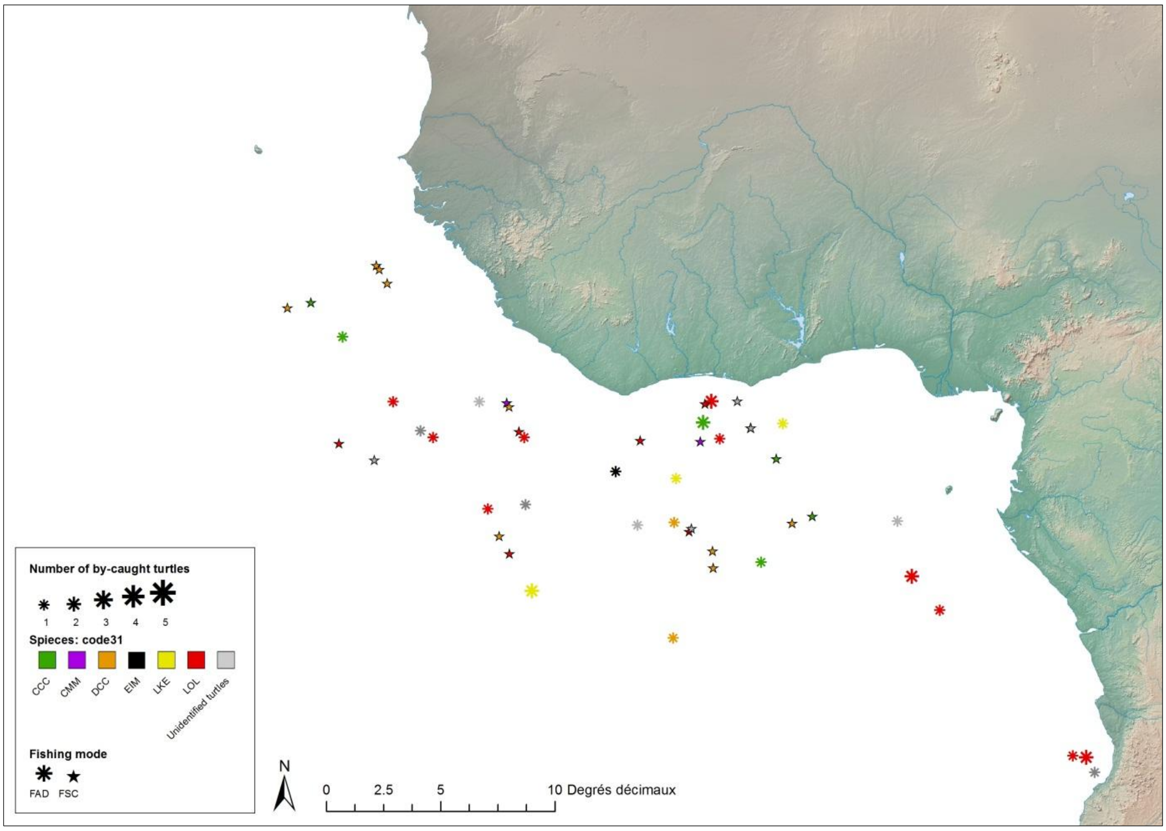


Annexe 9b

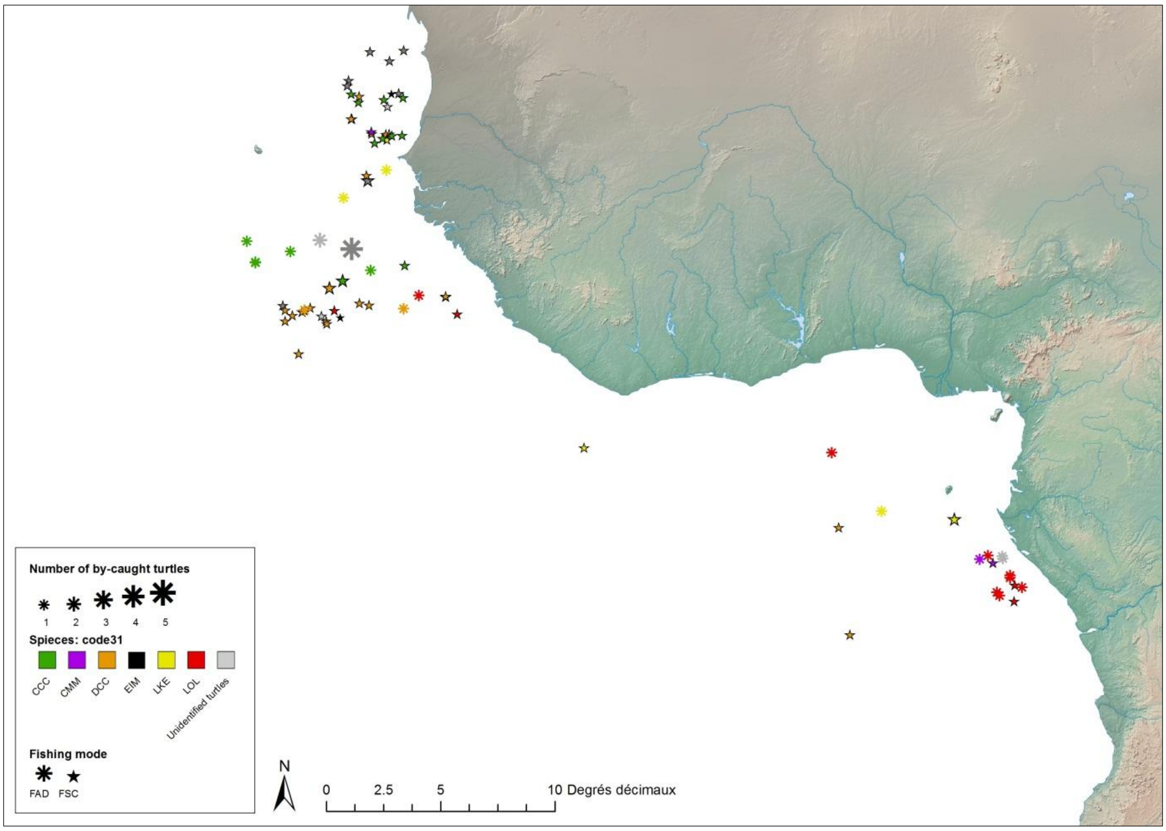
Annexe 9: Mean number of by-caught marine turtles per observed set and per statistical square by quarter and fishing mode in the (a) Atlantic and (b) Indian Oceans over the 1995-2011 period



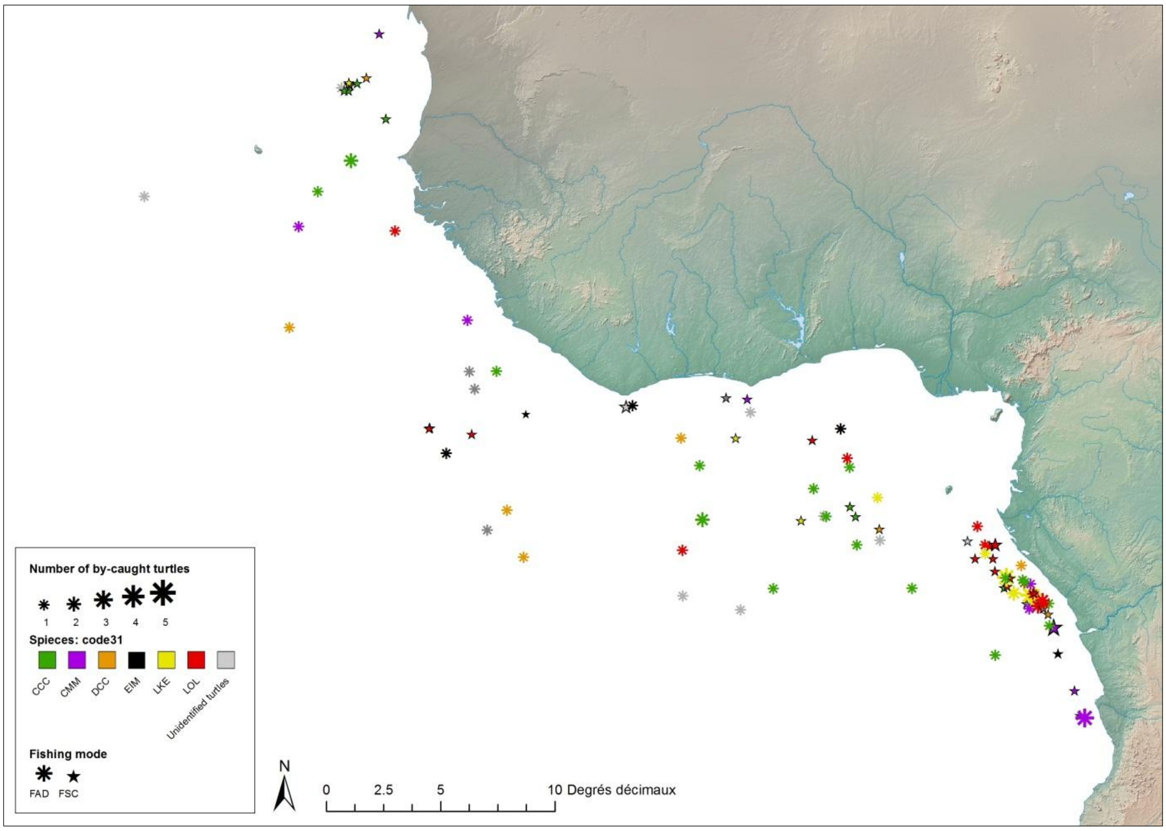
Annexe 10: Mean number of observed marine turtles per object observation per observed statistical square by quarter in the Atlantic and Indian oceans



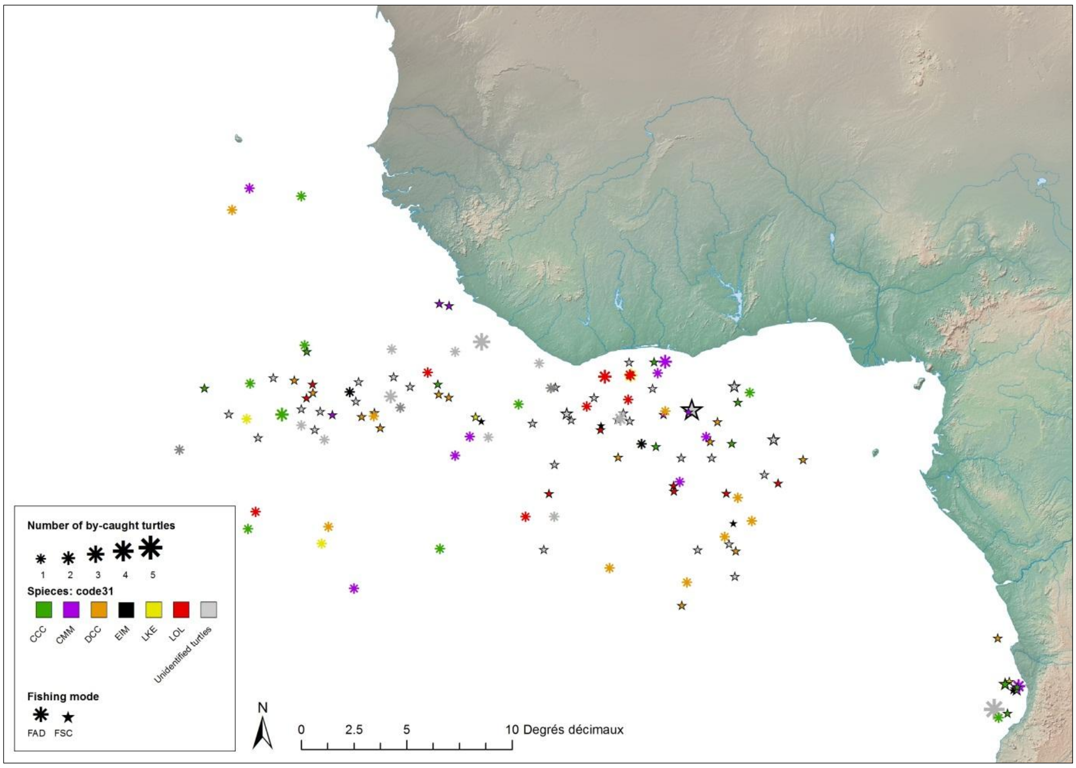
Annexe 11a



Annexe 11b

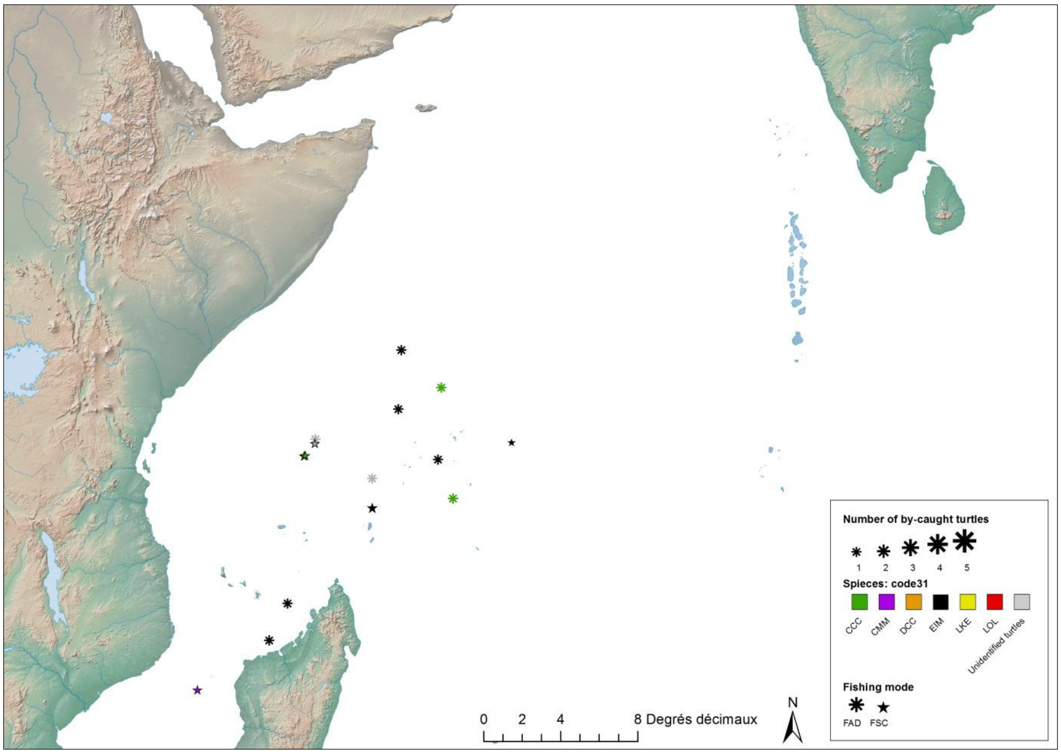


Annexe 11c

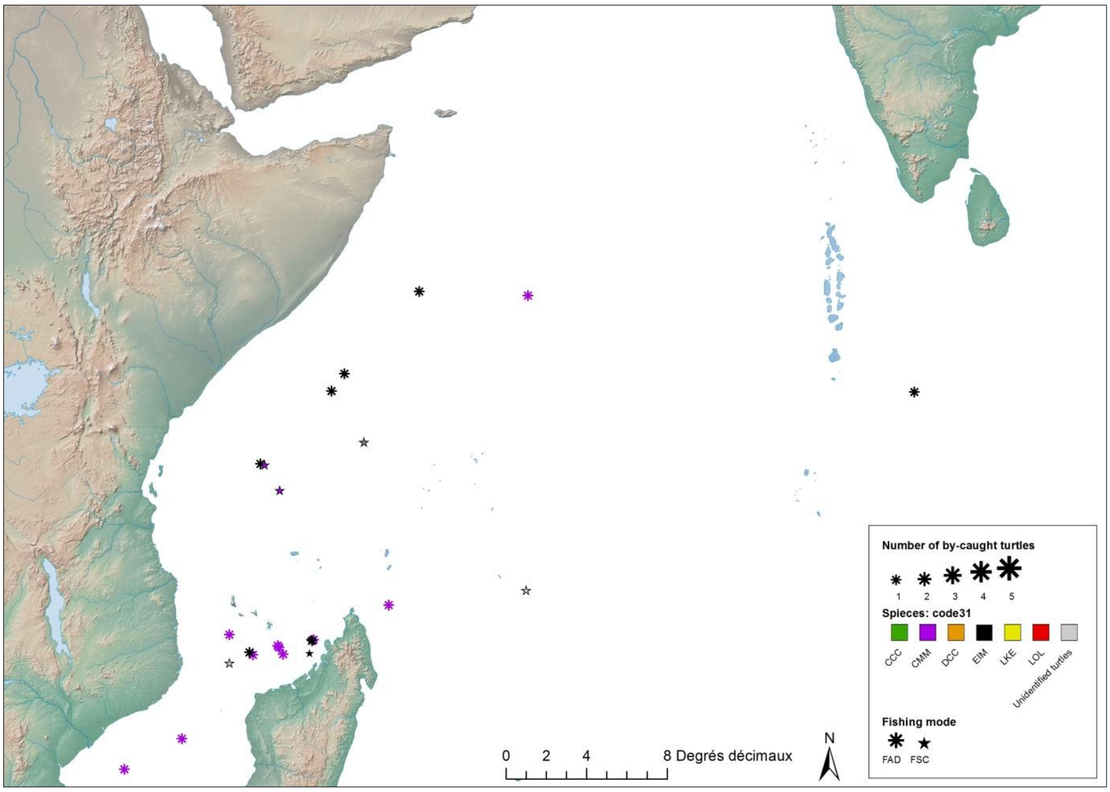


Annexe 11d

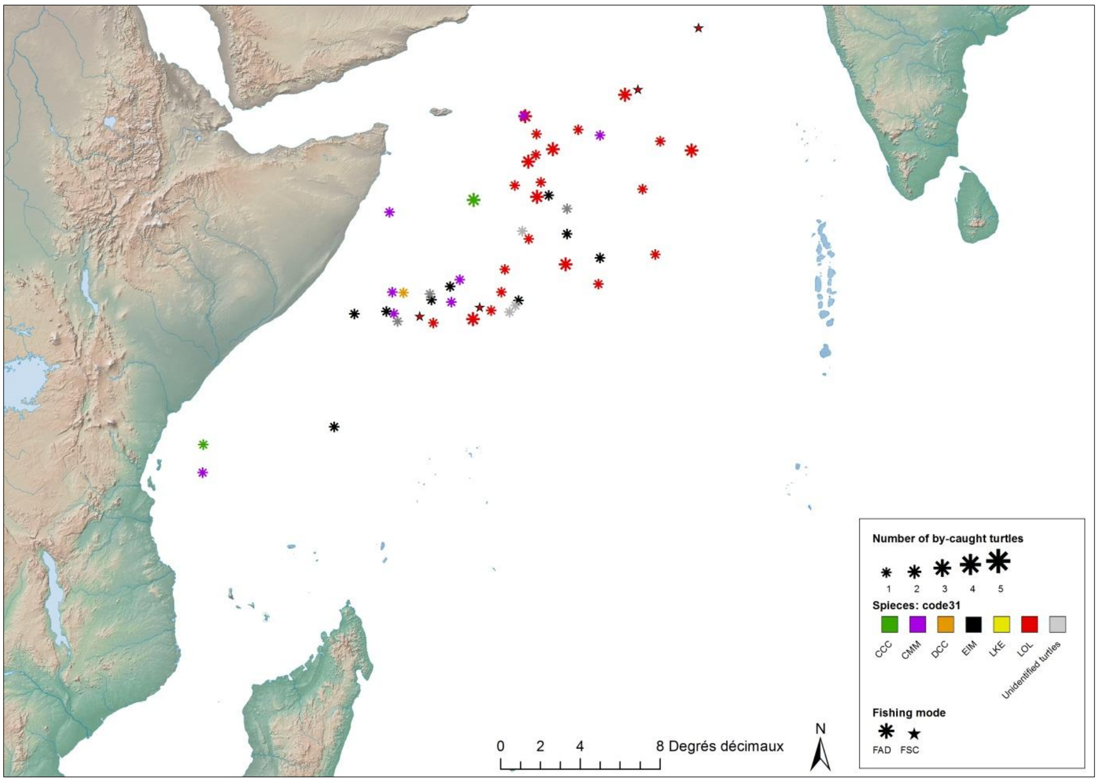
Annexe 11: Number of marine turtles by species by-caught in the Atlantic Oceans during observed sets on FADs and FSCs over the study period 1995-2011 during the (a) 1st , (b) 2nd , (c) 3rd and (d) 4th quarter (CCC=*Caretta caretta*, CMM=*Chelonia mydas*, DCC=*Dermochelys coriacea*, EIM=*Eretmochelys imbricata*, LKE=*Lepidochely Kempii* and LOL=*Lepidochely olivacea*)



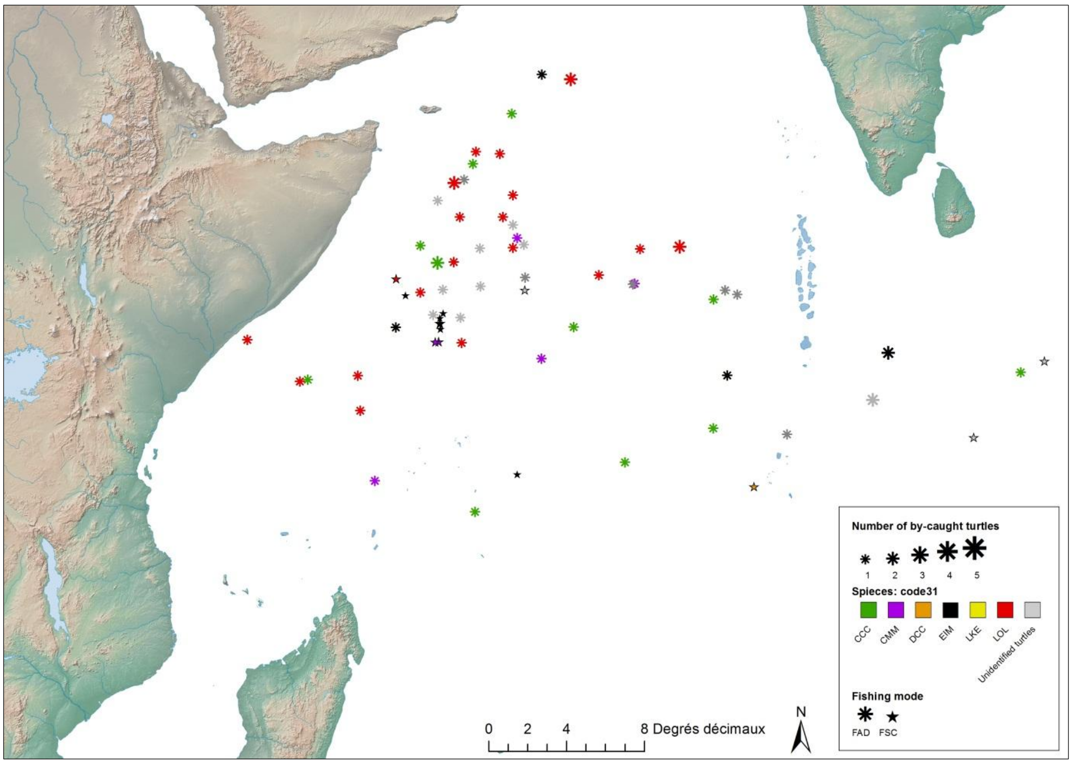
Annexe 12a



Annexe 12b

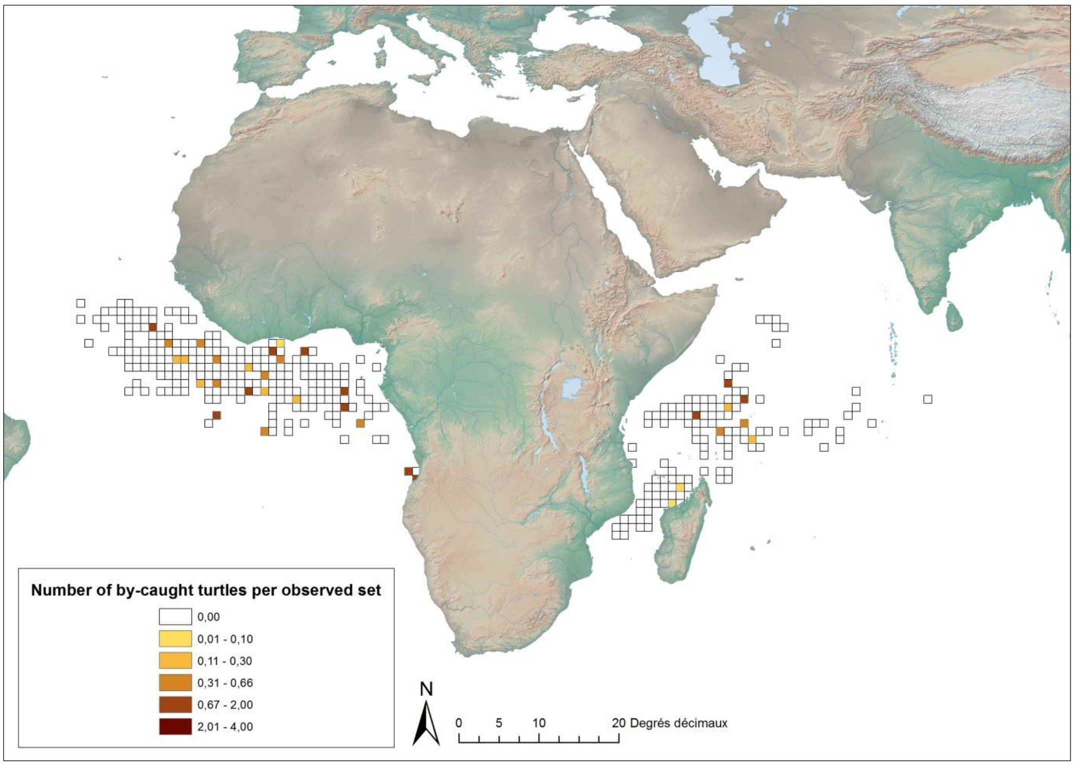


Annexe 12c

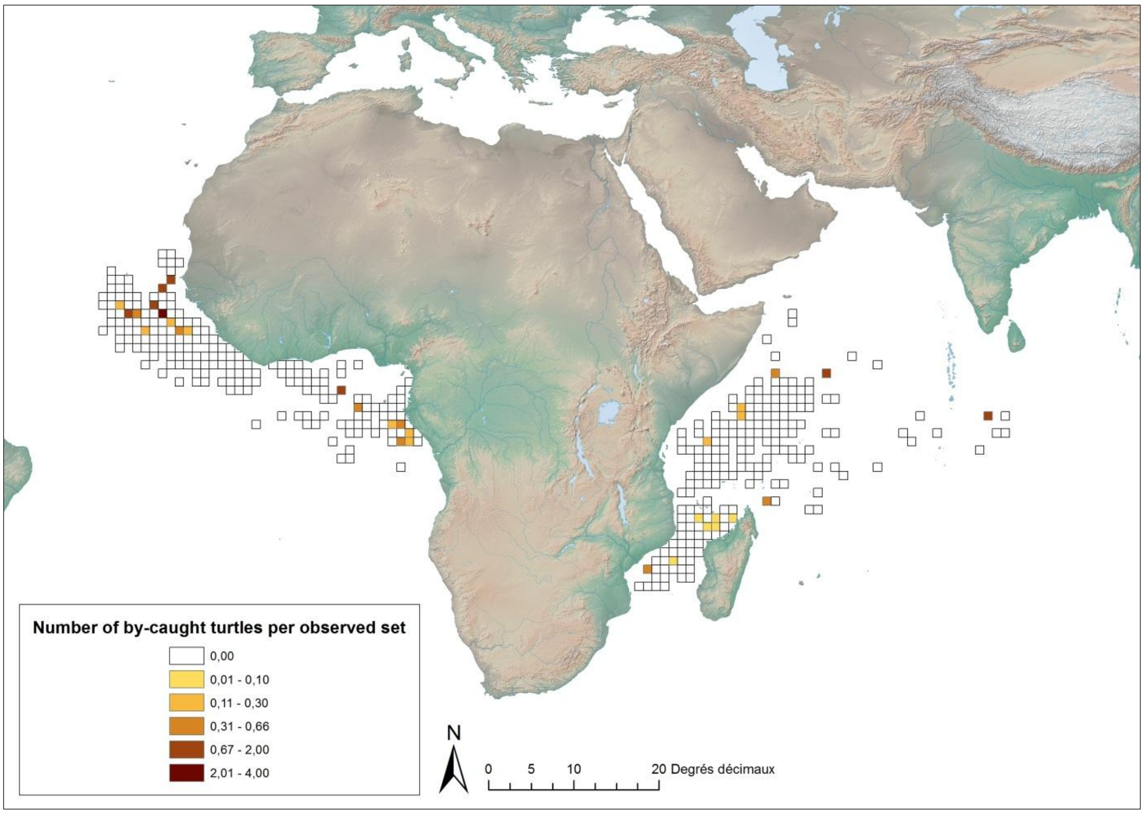


Annexe 12d

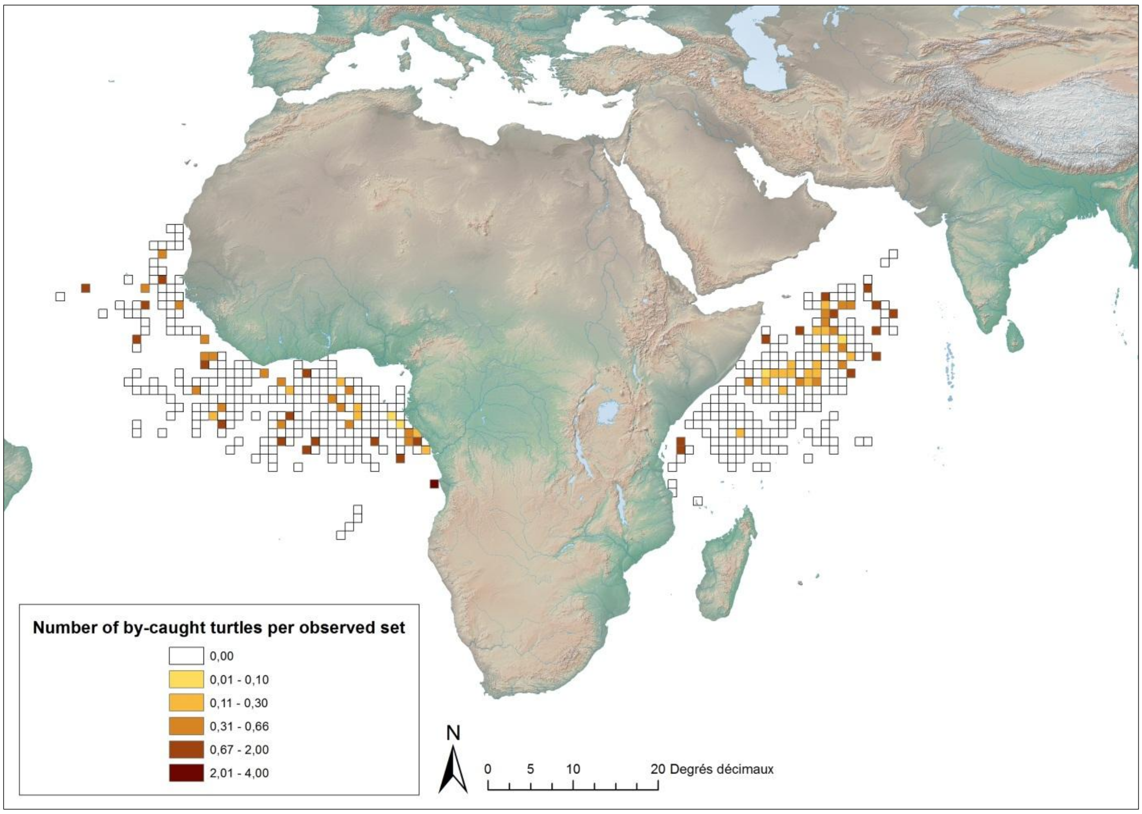
Annexe 12: Number of marine turtles by species by-caught in the Indian Ocean during observed sets on FADs and FSCs over the study period 1995-2011 during the (a) 1st , (b) 2nd , (c) 3rd and (d) 4th quarter (CCC=*Caretta caretta*, CMM=*Chelonia mydas*, DCC=*Dermochelys coriacea*, EIM=*Eretmochelys imbricata*, LKE=*Lepidochely Kempii* and LOL=*Lepidochely olivacea*)



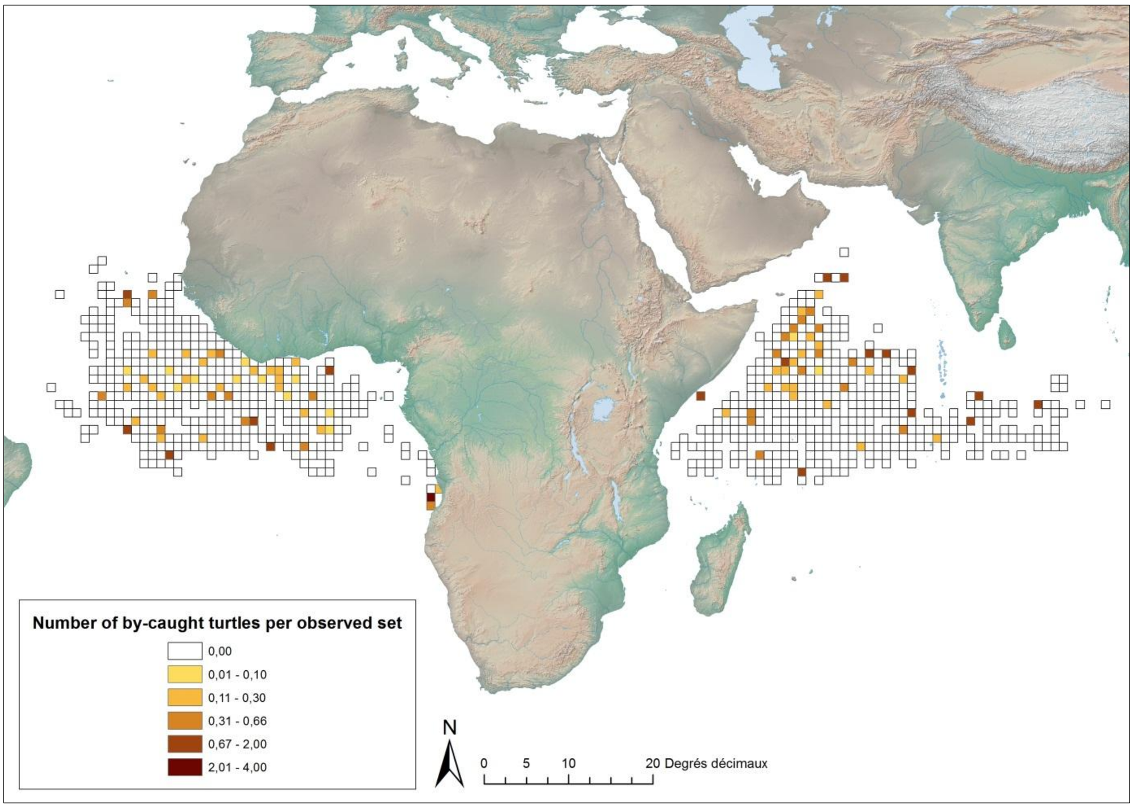
Annexe 13a



Annexe 13b

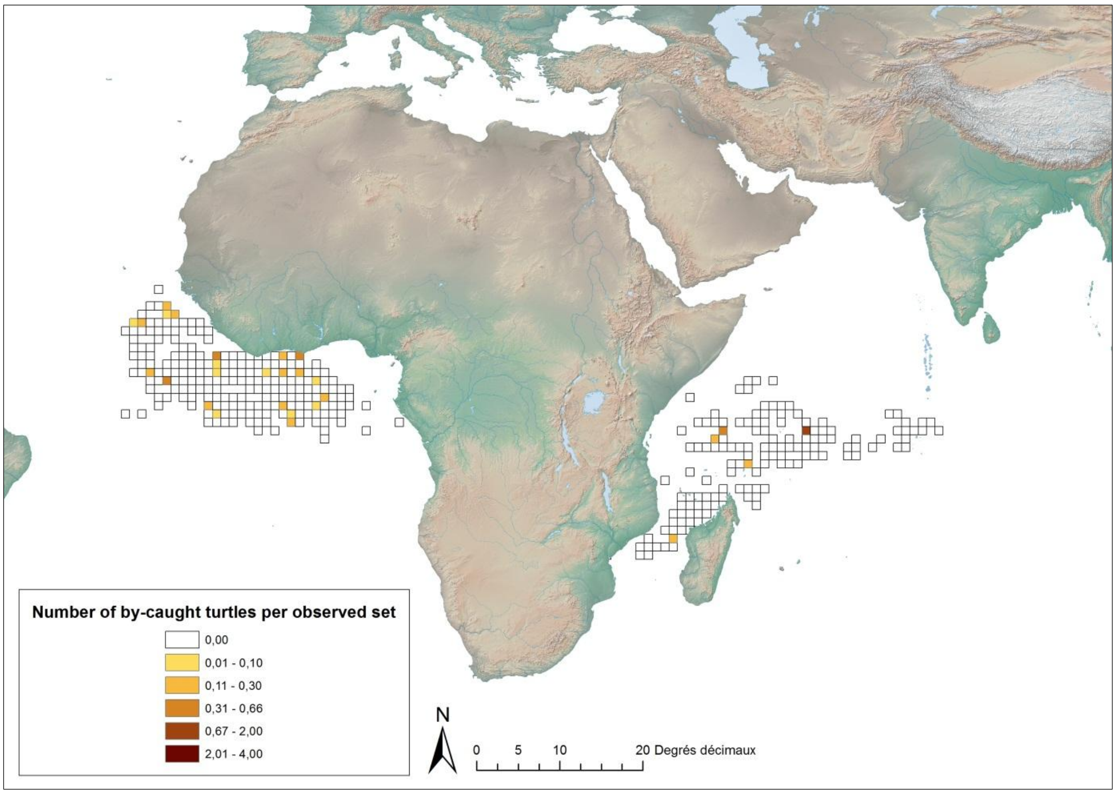


Annexe 13c

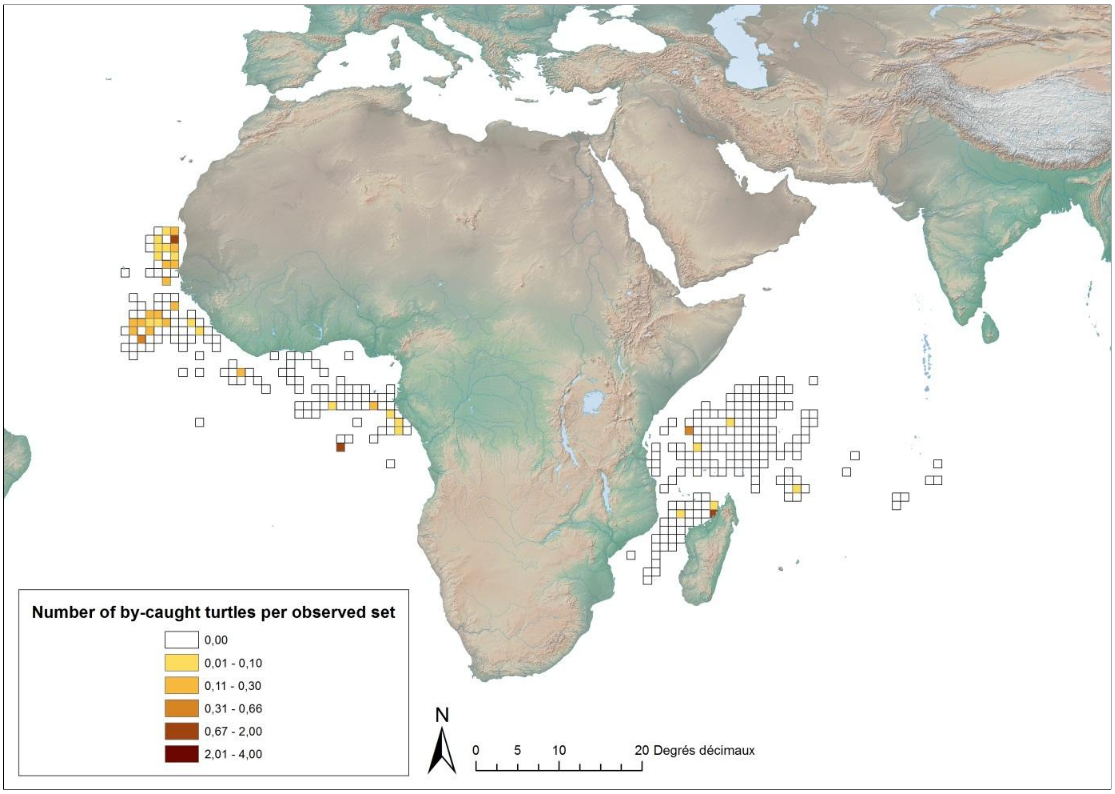


Annexe 13d

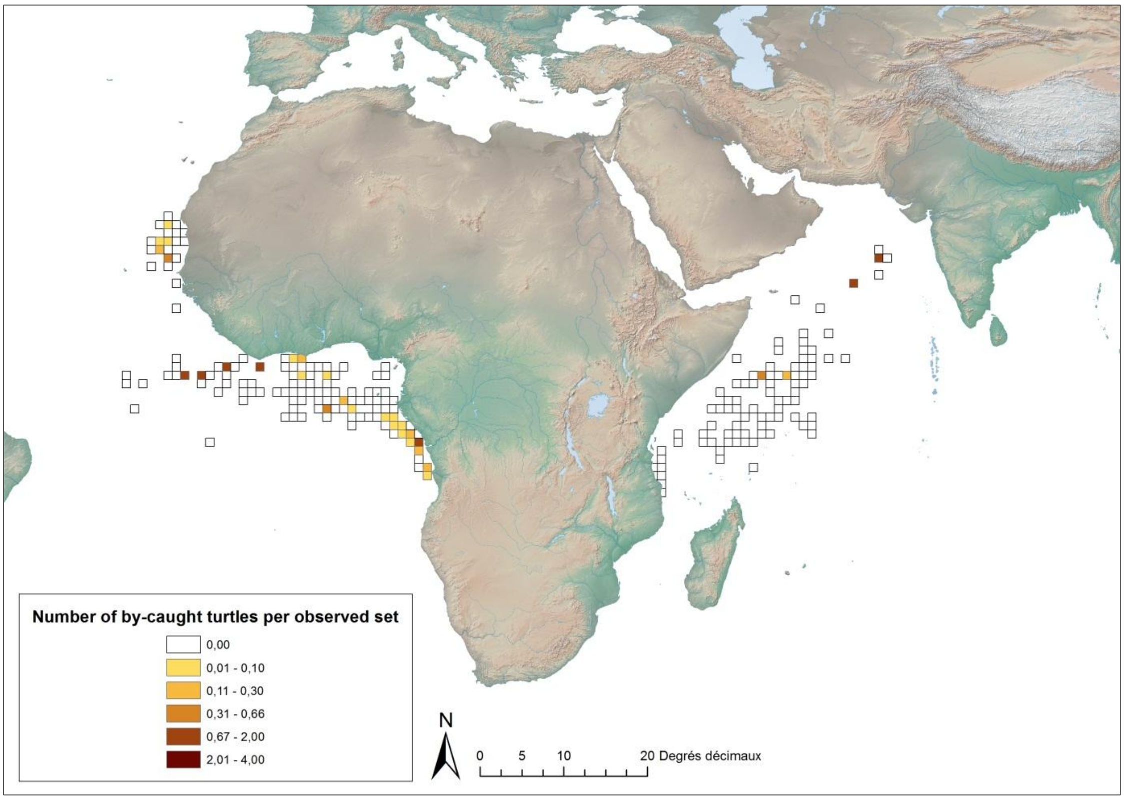
Annexe 13: Number of by-caught marine turtles per observed set on FADs per statistical square of 1° from 1995 to 2011 in the Atlantic and Indian oceans during the (a) 1st, (b) 2nd, (c) 3rd and (d) 4th quarter



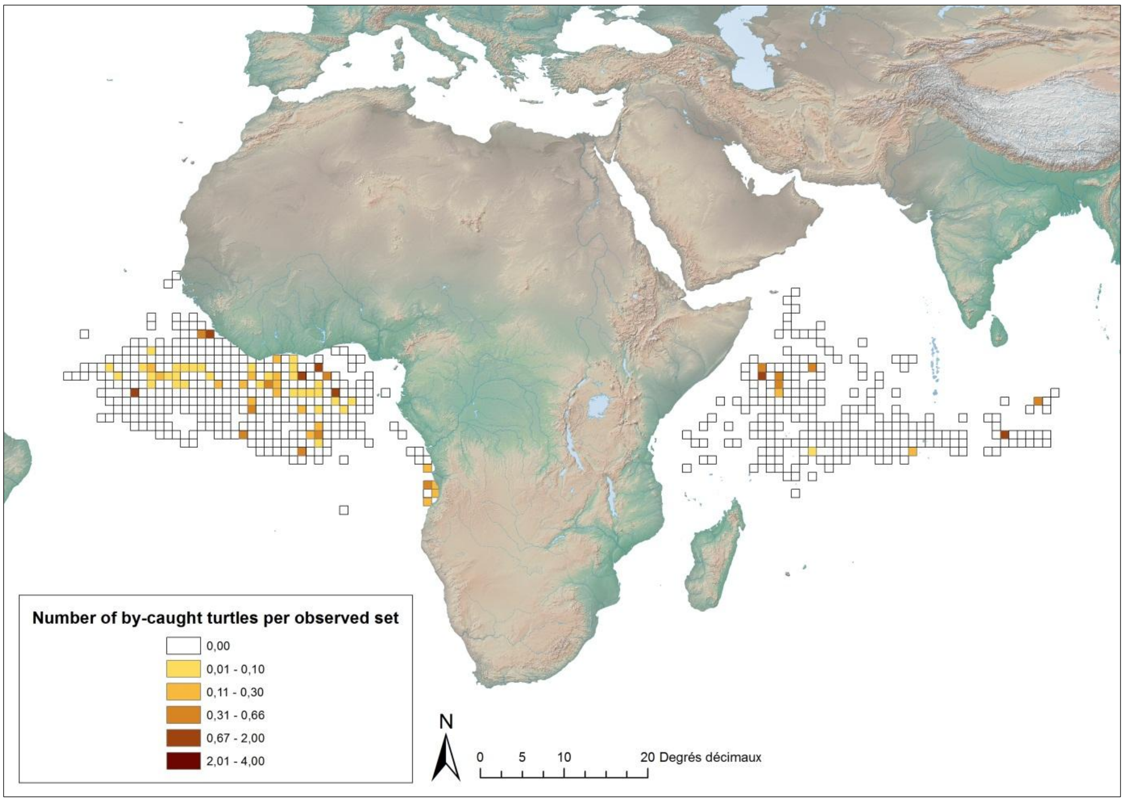
Annexe 14a



Annexe 14b

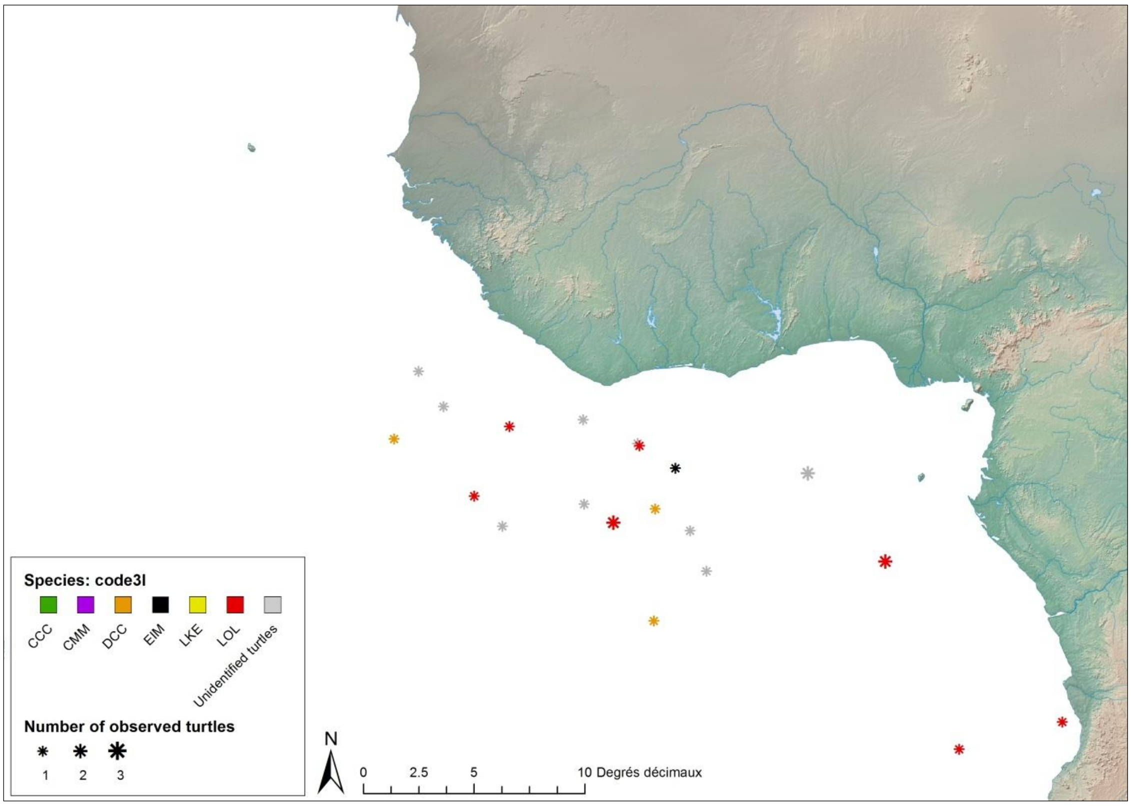


Annexe 14c

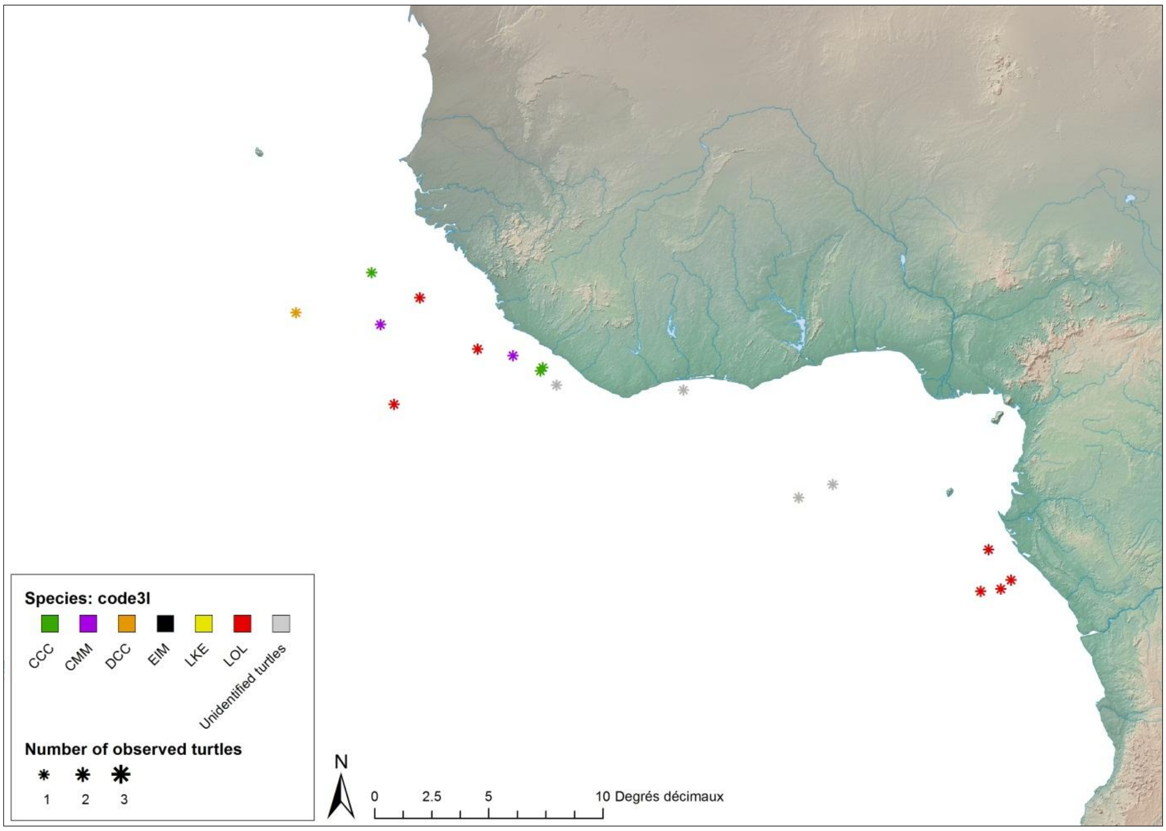


Annexe 14d

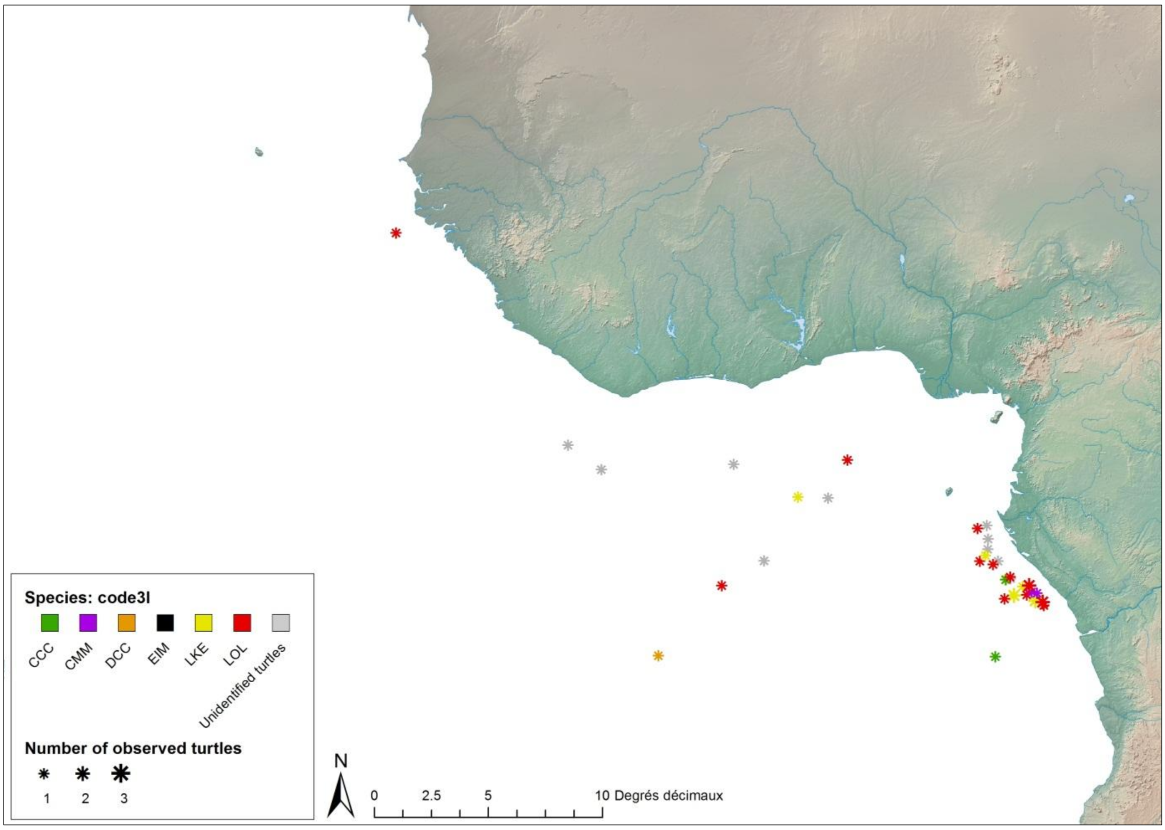
Annexe 14: Number of by-caught marine turtles per observed set on FSCs per statistical square of 1° from 1995 to 2011 in the Atlantic and Indian oceans during the (a) 1st, (b) 2nd, (c) 3rd and (d) 4th quarter



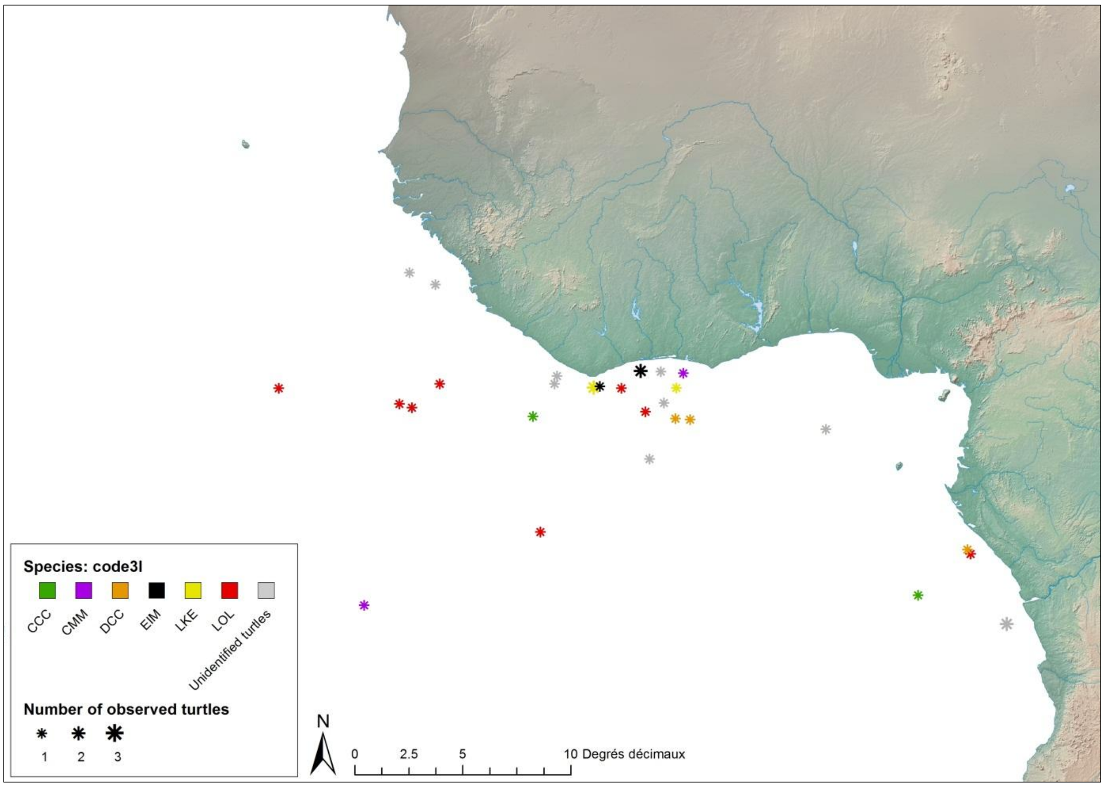
Annexe 15a



Annexe 15b

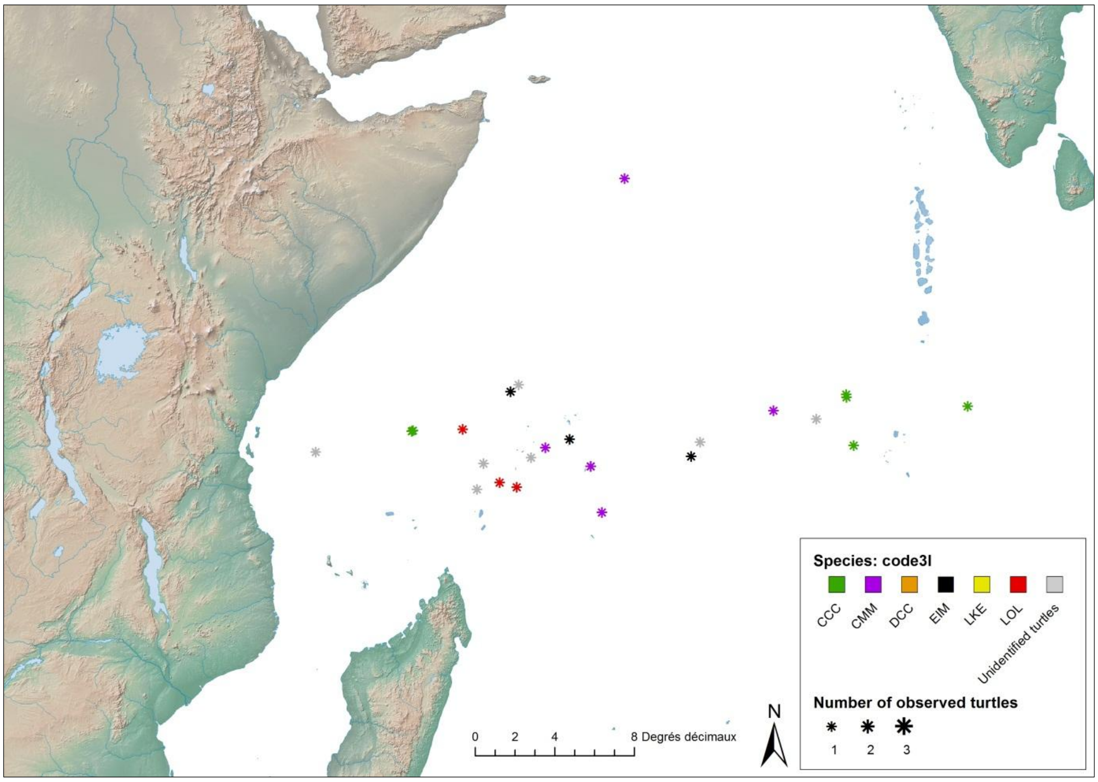


Annexe 15c

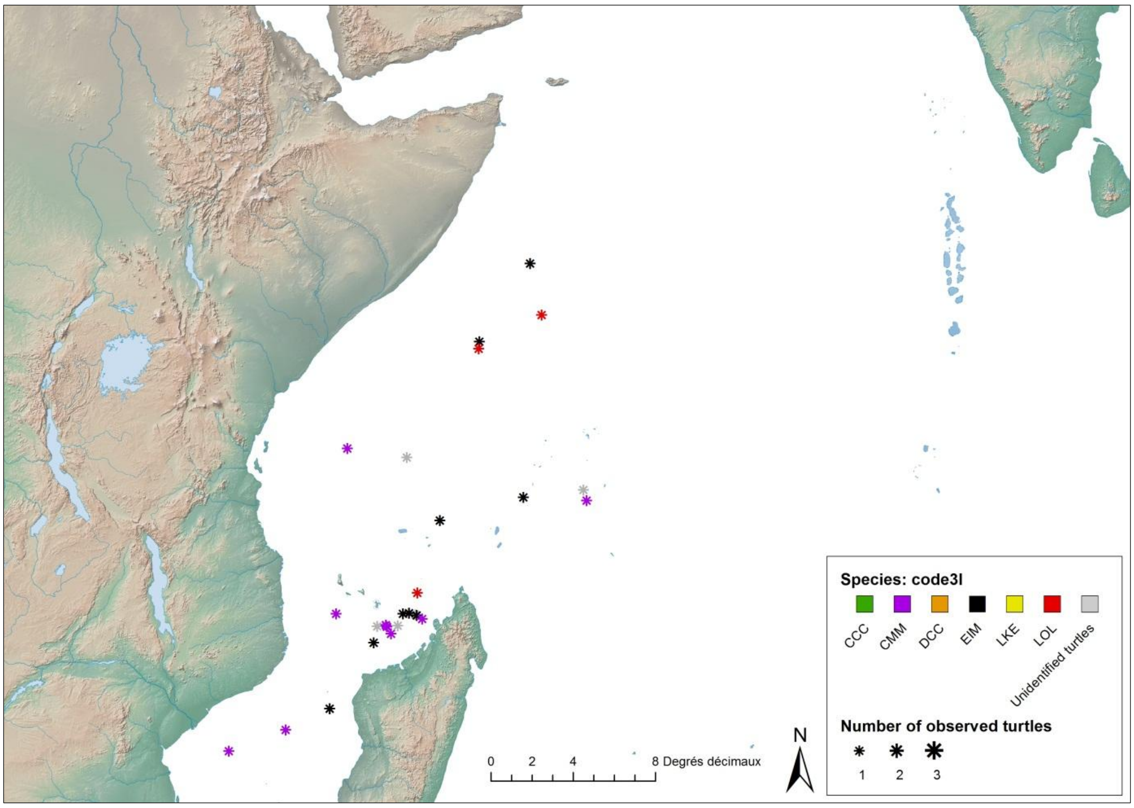


Annexe 15d

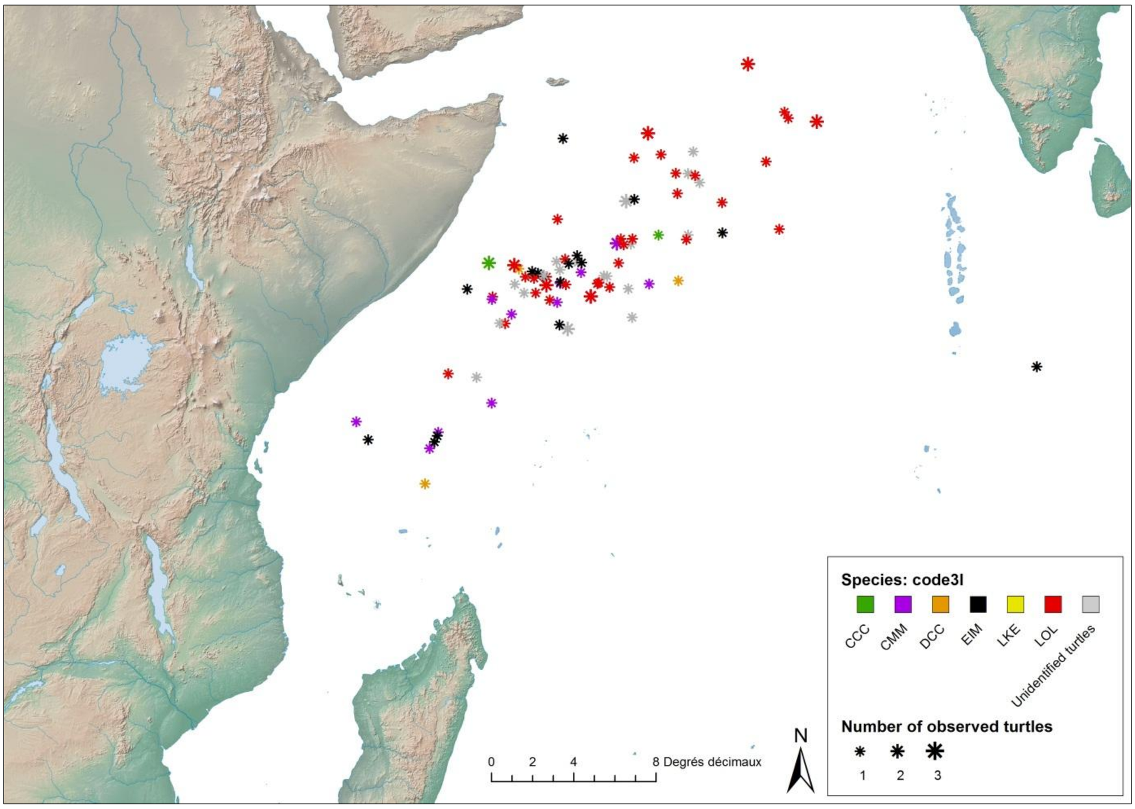
Annexe 15: Number of marine turtles by species observed around a floating device in the Atlantic Ocean over the study period 2003-2011 during the (a) 1st , (b) 2nd , (c) 3rd and (d) 4th quarter (CCC=*Caretta caretta*, CMM=*Chelonia mydas*, DCC=*Dermochelys coriacea*, EIM=*Eretmochelys imbricata*, LKE=*Lepidochely Kempii* and LOL=*Lepidochely olivacea*)



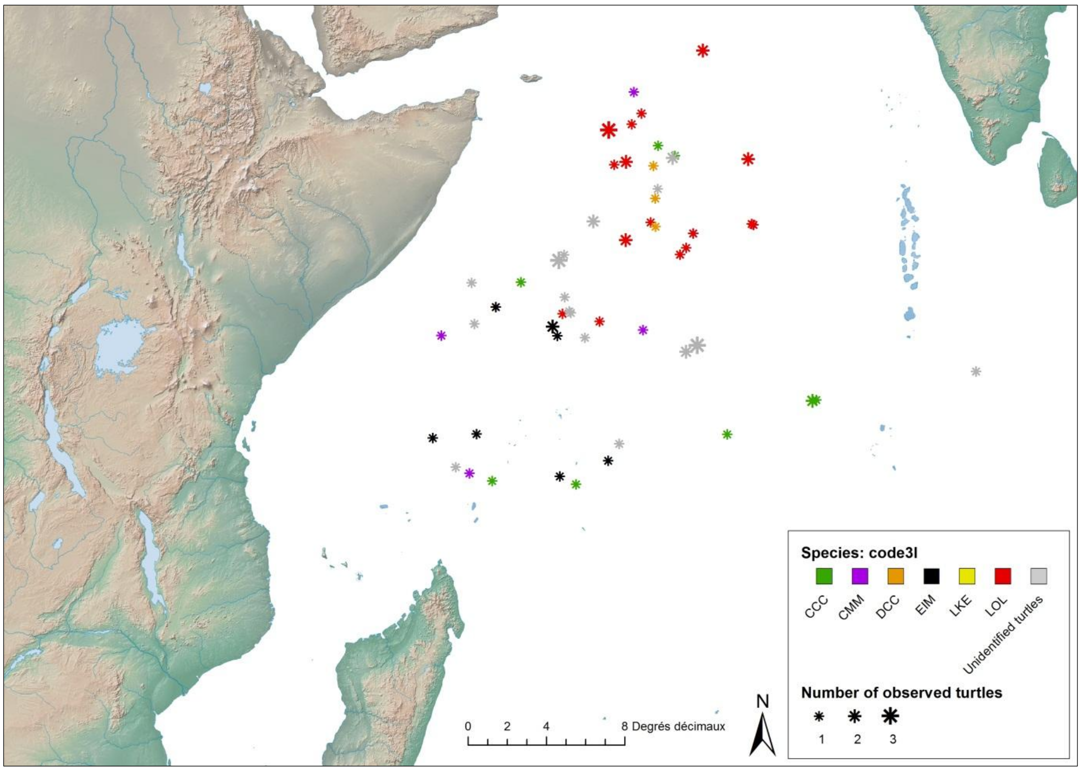
Annexe 16a



Annexe 16b

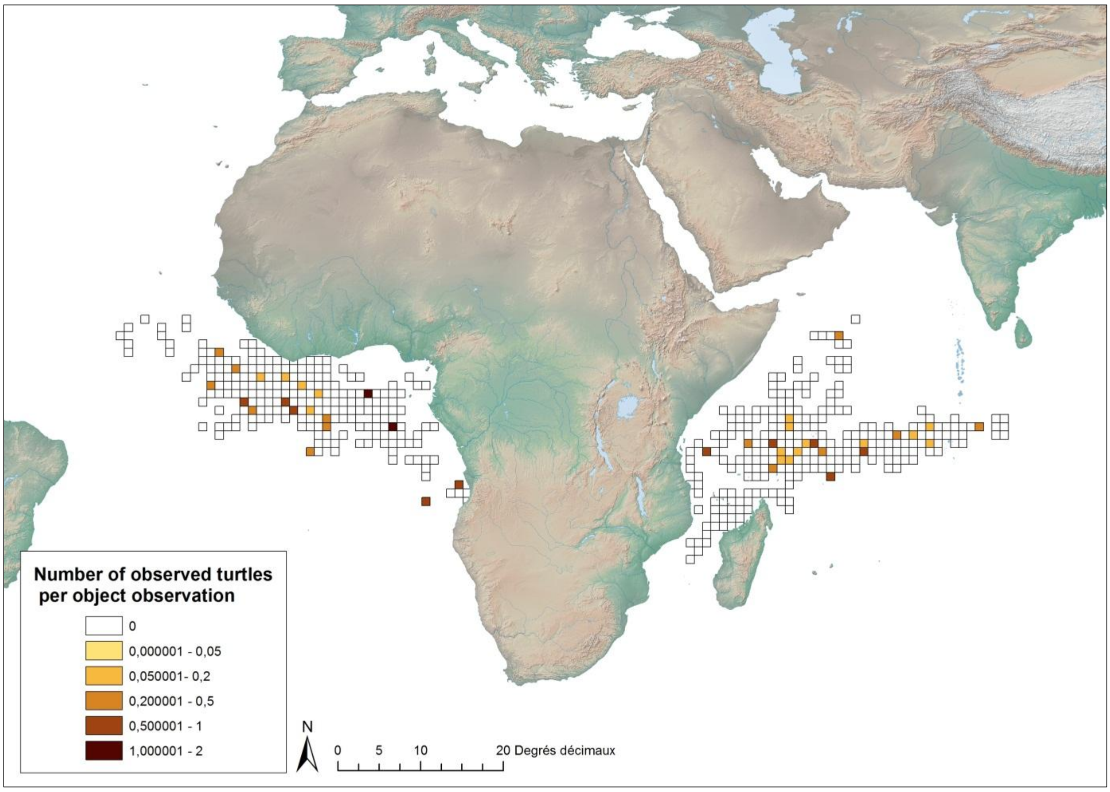


Annexe 16c

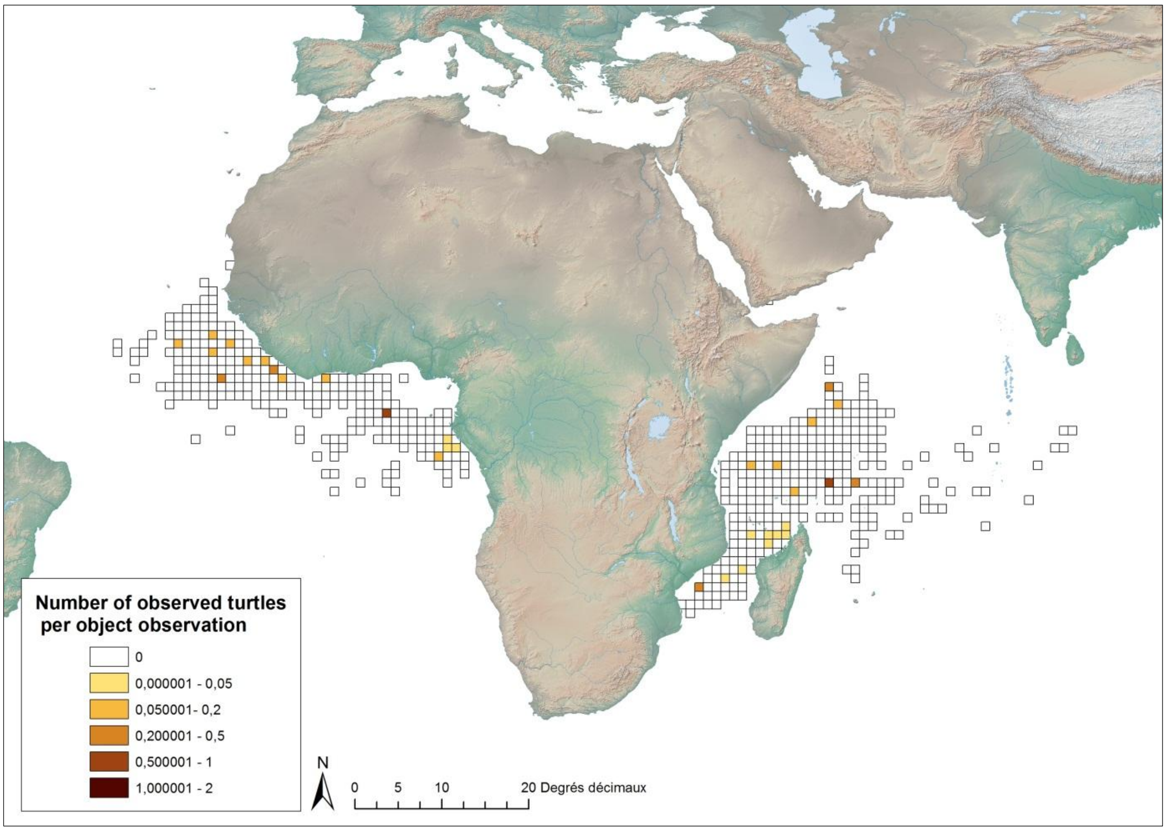


Annexe 16d

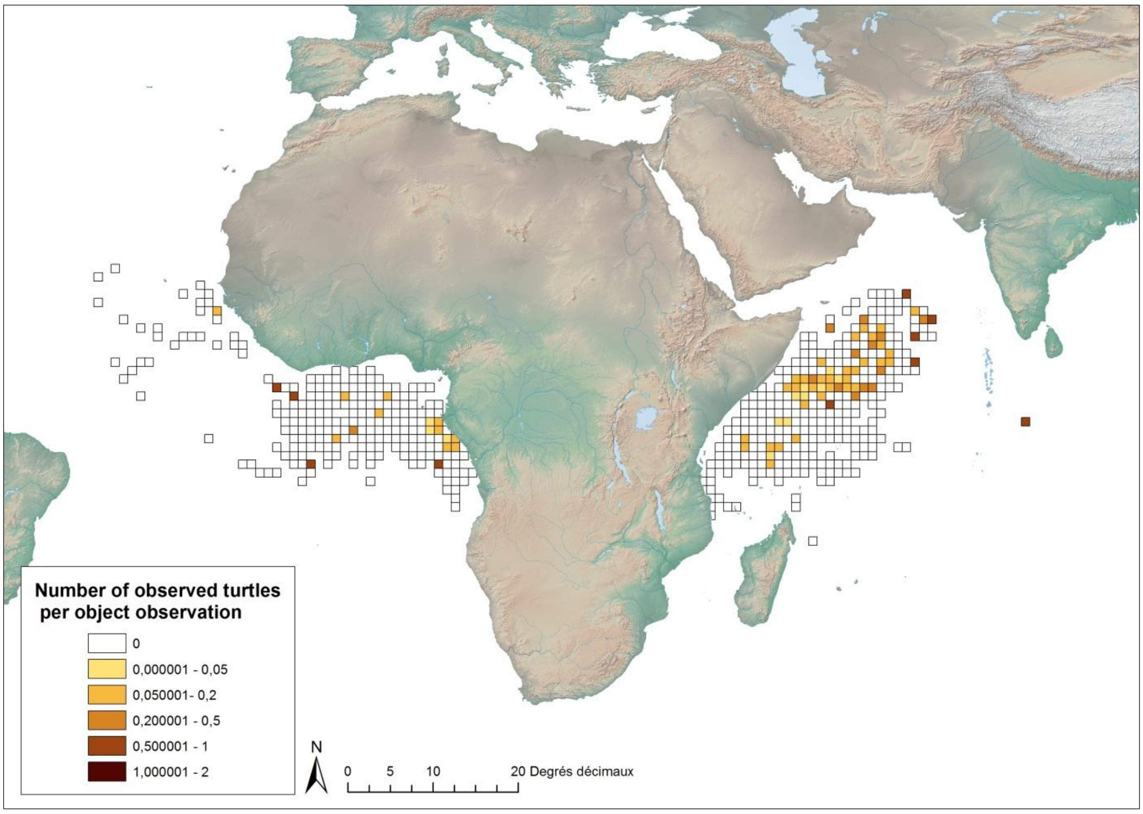
Annexe 16: Number of marine turtles by species observed around a floating device in the Indian Ocean over the study period 2003-2011 during the (a) 1st , (b) 2nd , (c) 3rd and (d) 4th quarter (CCC=*Caretta caretta*, CMM=*Chelonia mydas*, DCC=*Dermochelys coriacea*, EIM=*Eretmochelys imbricata*, LKE=*Lepidochely Kempii* and LOL=*Lepidochely olivacea*)



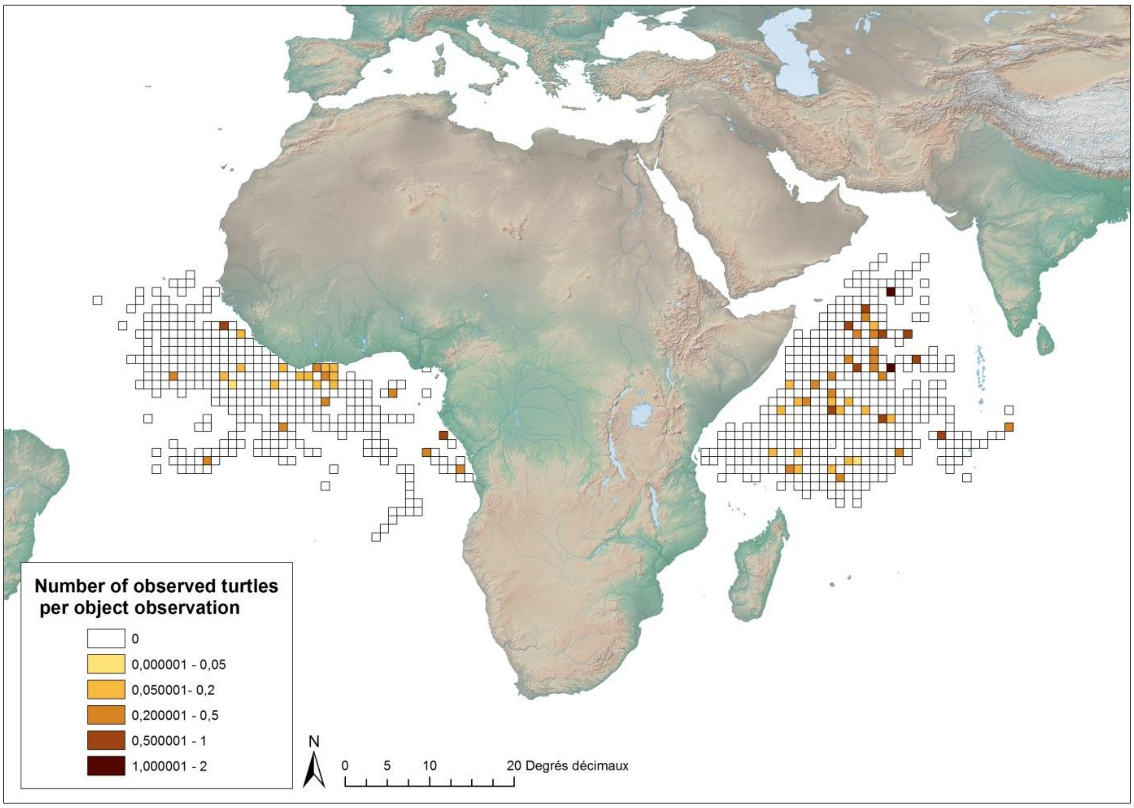
Annexe 17a



Annexe 17b



Annexe 17c



Annexe 17d

Annexe 17: Number of observed marine turtles per object observation per statistical square of 1° from 2003 to 2011 in the Atlantic and Indian Oceans during the (a) 1st, (b) 2nd, (c) 3rd and (d) 4th quarter