Analysis of the validity of potential frontiers between hypothetical sub stocks at the periphery of the purse seine fishing zones

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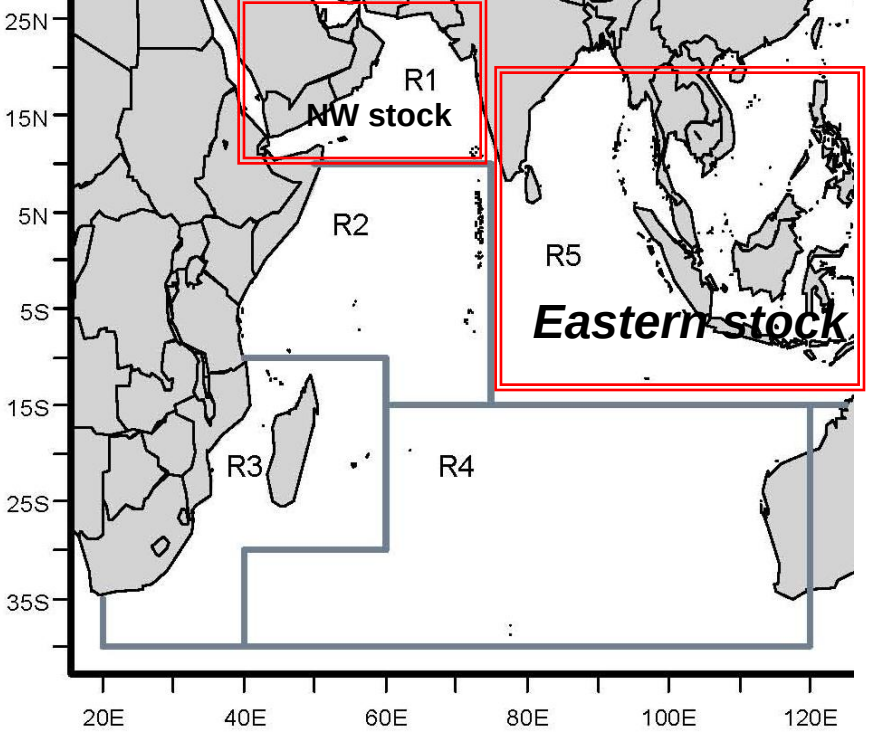
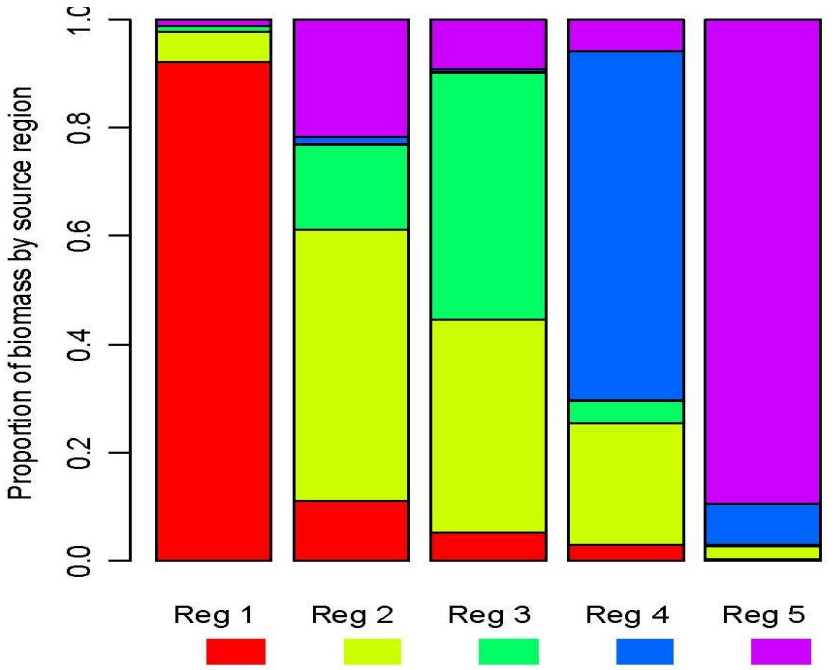
Introduction: why this study?

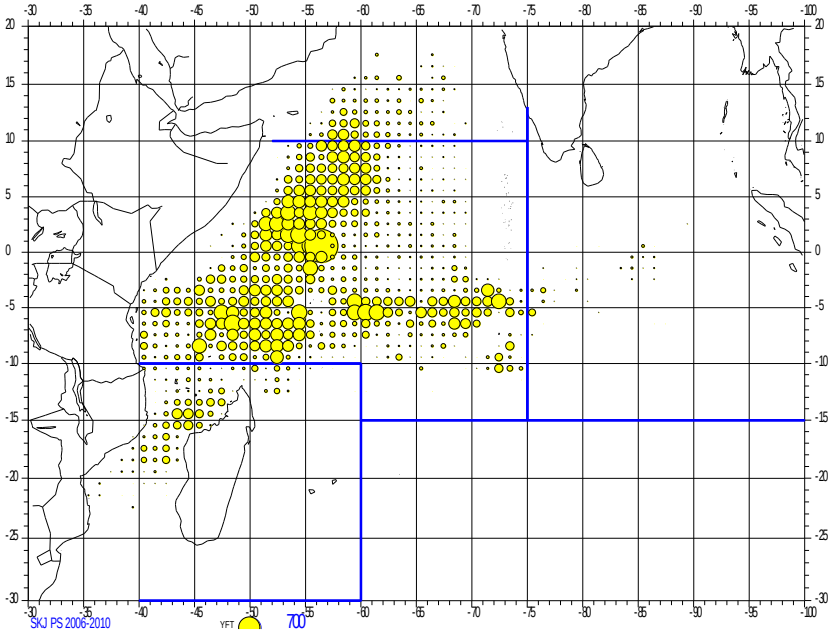
- Its goal was to examine the validity of the surprisingly low migration rates between areas that have been repeatedly estimated by the stock assessment MFCL model for the yellowfin Indian Ocean stock since 2008
- This work is based on a simple ad hoc analysis of catch and recoveries by EU purse seine fishery at the periphery of its fishing zone: a fishery with very good statistics & very high reporting rates of tag recoveries
- The method developed is primarily done comparing the ratio of numbers of tagged & of total numbers of fish caught in selected adjacent areas close to given selected potential geographical frontiers.
- These potential frontiers are selected at the periphery of the EU purse seiners fishing zones in the Western Indian Ocean: Northern, eastern and southern areas, at limits that are similar or identical to the MFCL yellowfin frontiers between areas.
- This work will be done in parallel for the 3 species tagged, yellowfin, skipjack and bigeye, as the pending questions on the stock structure of these 3 species are more or less the same…..

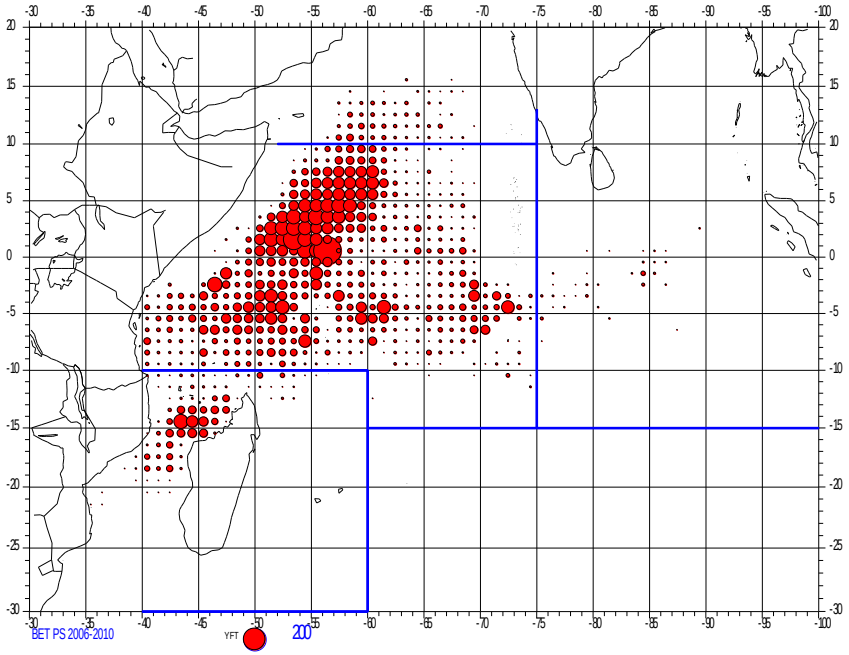
Back to the 2011 MFCL results: surprising results have been repeatedly obtained by the MFCL model on the Indian Ocean yellowfin stock:

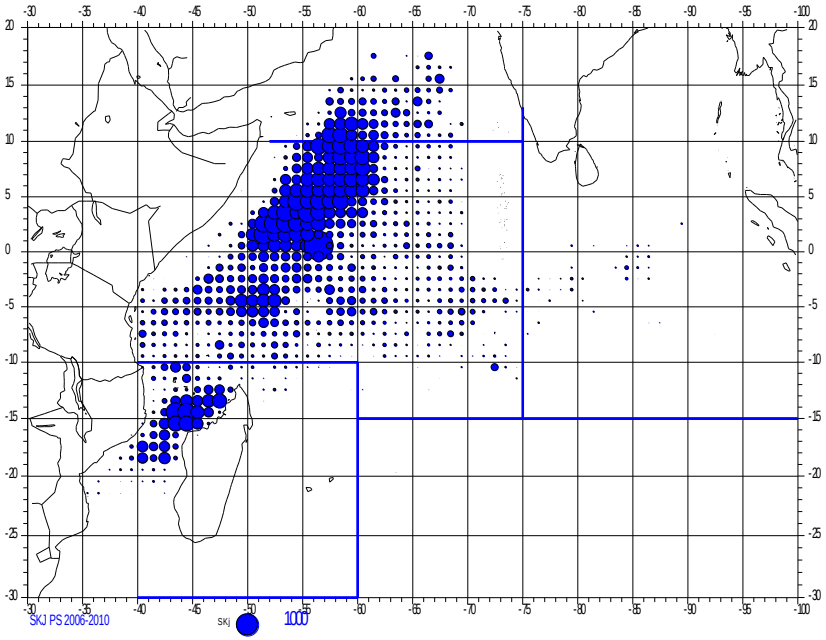
- Biomass of yellowfin are estimated to be nearly isolated in the NW area and Eastern Indian Ocean: only 10% of external biomass at the end of the YFT life in these areas.
- Surprising results « producing » 3 nearly independent yellowfin stocks in the NW, SW and Eastern Indian Ocean (no fishes born in the Western IO moving to the Eastern IO).
- The main goal of this work is to study how much these results are realistic or artificial ones, created by the model..
- For instance being due to the low catches by PS and subsequently to the very low numbers of tags declared/recovered outside the main fished zone of PS (area 2 and N-W component of area 3, Mozambique Channel). & to the very low reporting rates outside the area 2



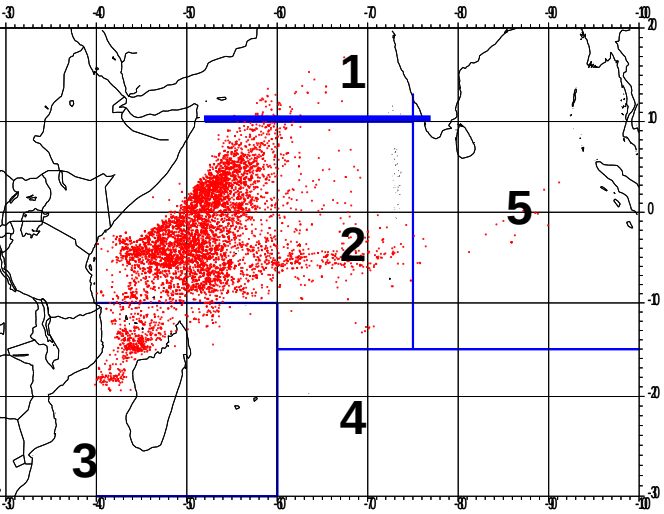




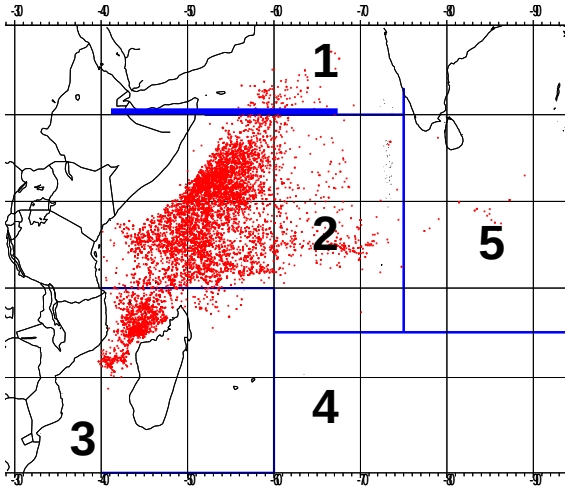




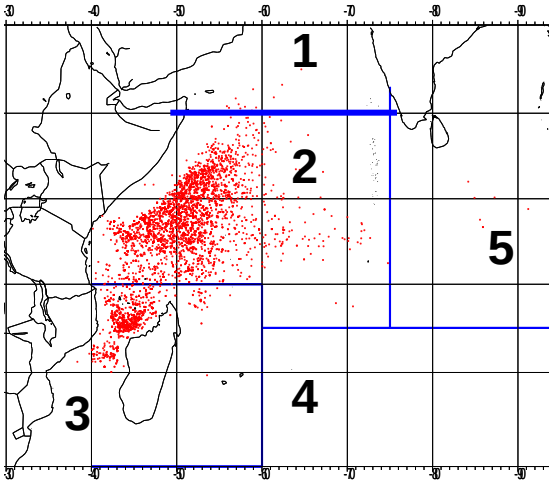
Average catches / 1° squares and by species by the EU PS fleet during the average period 2006-2010, and areas used for the IOTC YFT stock assessment (untill 2011).



YFT



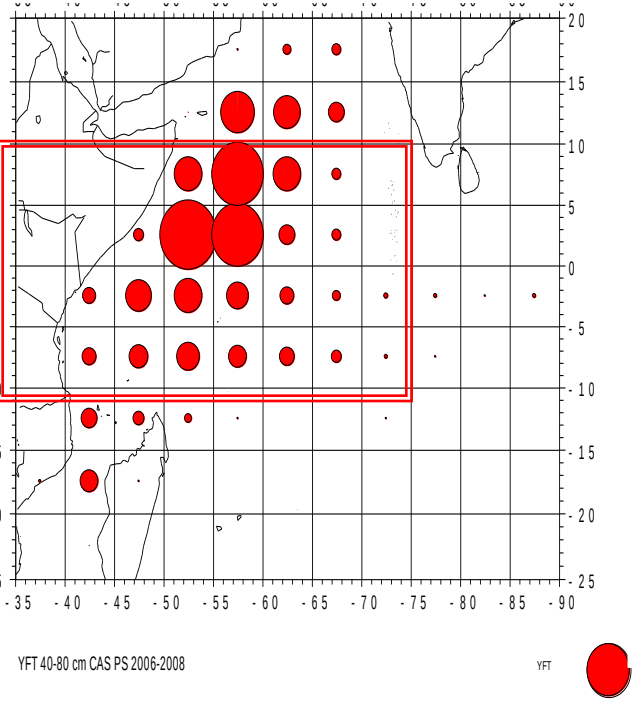
SKJ



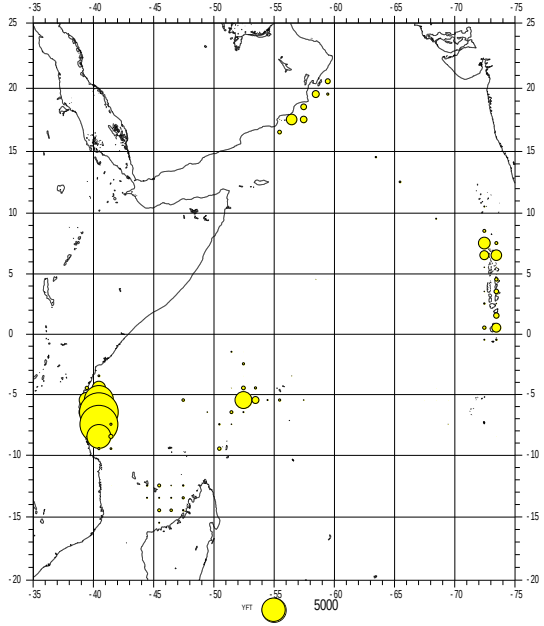
BET

Stock assessment areas used for YFT stock and positions of recoveries by Purse seiners (only PS!) of YFT, SKJ and BET

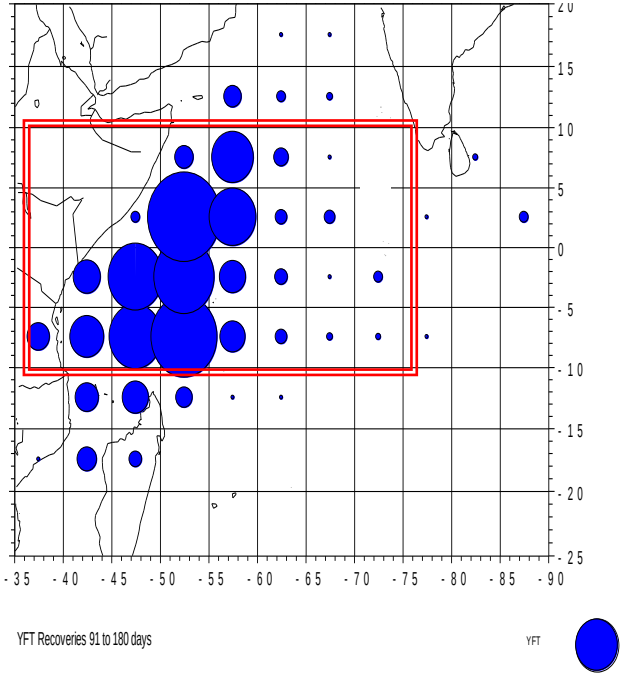
- No recoveries in area 4, outside PS fishing zones
- Areas 5 & 1: Very few recoveries by PS observed in these 2 areas, situated outside area 2, the core of PS fishing zones
- Large numbers of recoveries (for the 3 species) in the NW component of area 3, in the Mozambique channel: a major fishing zone for PS, but highly seasonal
- Very similar geographical patterns of the recoveries observed for the 3 species
- A study limited to the analysis of data from the EU purse seine fleet: because of its unique & good statistical & recovery data available, and also because of their high and well estimated reporting rates



Small YFT caught /PS 2006-2008 period



YFT tagging locations



Small YFT recovered /PS 2006-2008 during the 2nd quarter at liberty

Basically:

- A **very fast average mixing of tagged YFT at the scale of the MFCL areas**,
- Small YFT recovered in the entire fished zone 3 within **after 1 quarter, more or less in the proportion of tagged sizes catches**
- But an apparent **lower rate of tags caught at the periphery** of the fished zone,

But how much?

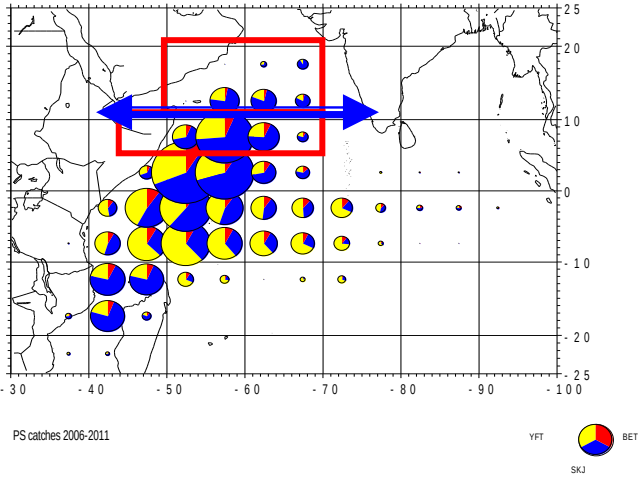
Method used

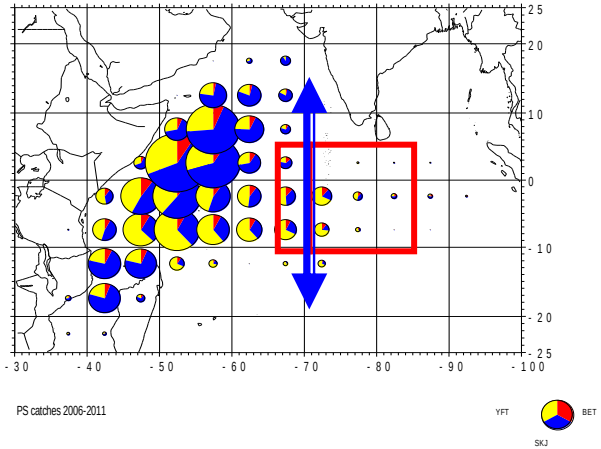
1) Choice of 3 potential geographical limits at the periphery of the PS fishing zone
2) Choice of 2 fishing zones (1 or several 5° squares, the basic statistical unit) on the 2 sides of this limit, and then:

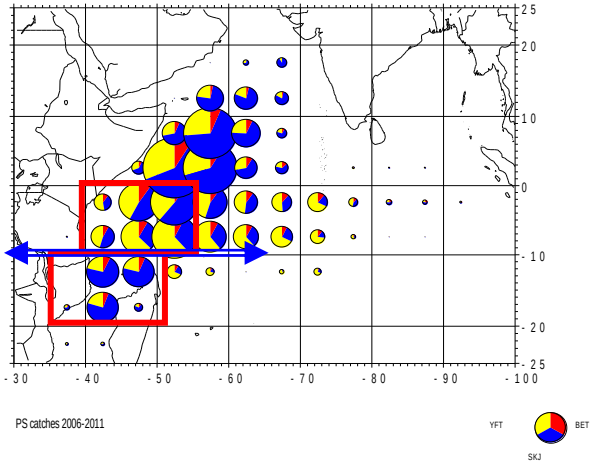
- The numbers of tunas caught during each quarter in each of these 2 areas adjacent to the potential frontier are calculated by species, and for 2 size categories (small & big), simply adding the monthly catch at size data of the EU PS fleet in the 5° squares of these areas.
- **Sizes used are mobile**, following the growth of recovered tunas
- These data are simply taken from the Catch at size by 5° squares and month data that have been submitted to the IOTC yearly by EU & Seychelles scientists
- Numbers of tagged tunas recovered each month in the same 2 areas are calculated by species and for the same size categories, simply based on the recoveries of tagged tunas declared by the EU PS fleet.
- This calculation is done on the subset of recoveries by purse seiners for which there is a known fishing date and known geographical position available
- The study has been done during the 2006-2010 period.

Potential frontiers and sub areas studied

- **3 potential frontiers** have been presently selected & studied at the North, East and South of the PS fishing zones, based on the choice of 6 selected fishing zones, adjacent to these 3 frontiers. The choice of these geographical limits was also conditioned to be consistent with the present MFCL yellowfin areas.





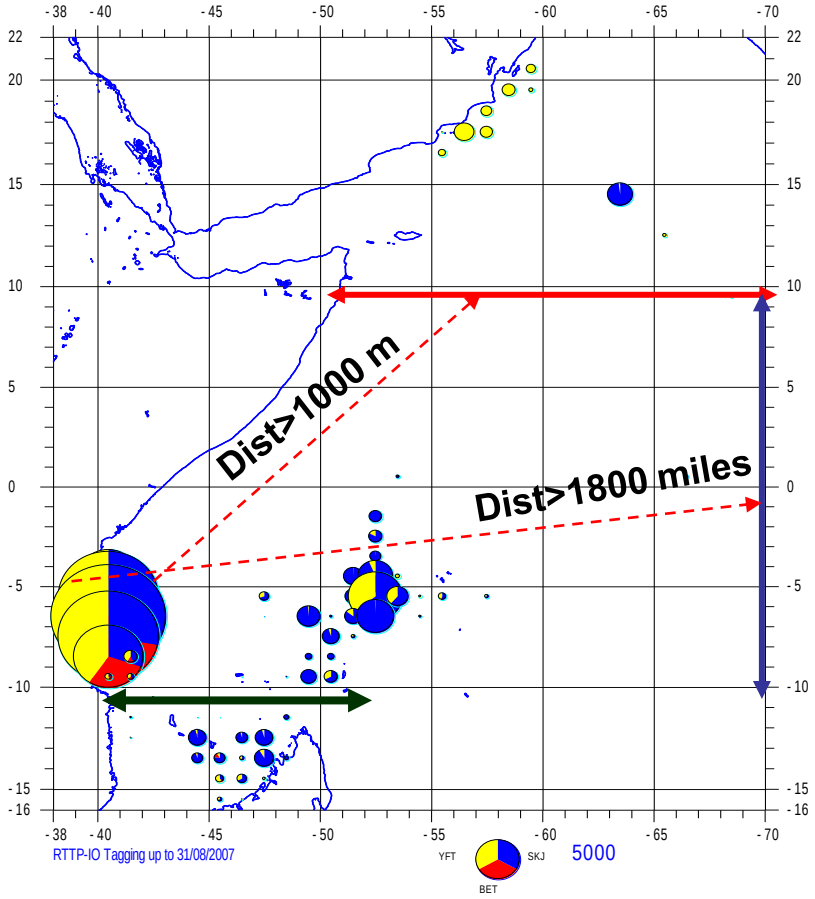


(1) Northern frontier at 10°N (idem MFCL)

(2) Eastern frontier at 70°E (MFCL frontier at 75°E)

(3) Southern frontier at 10°S (idem MFCL)

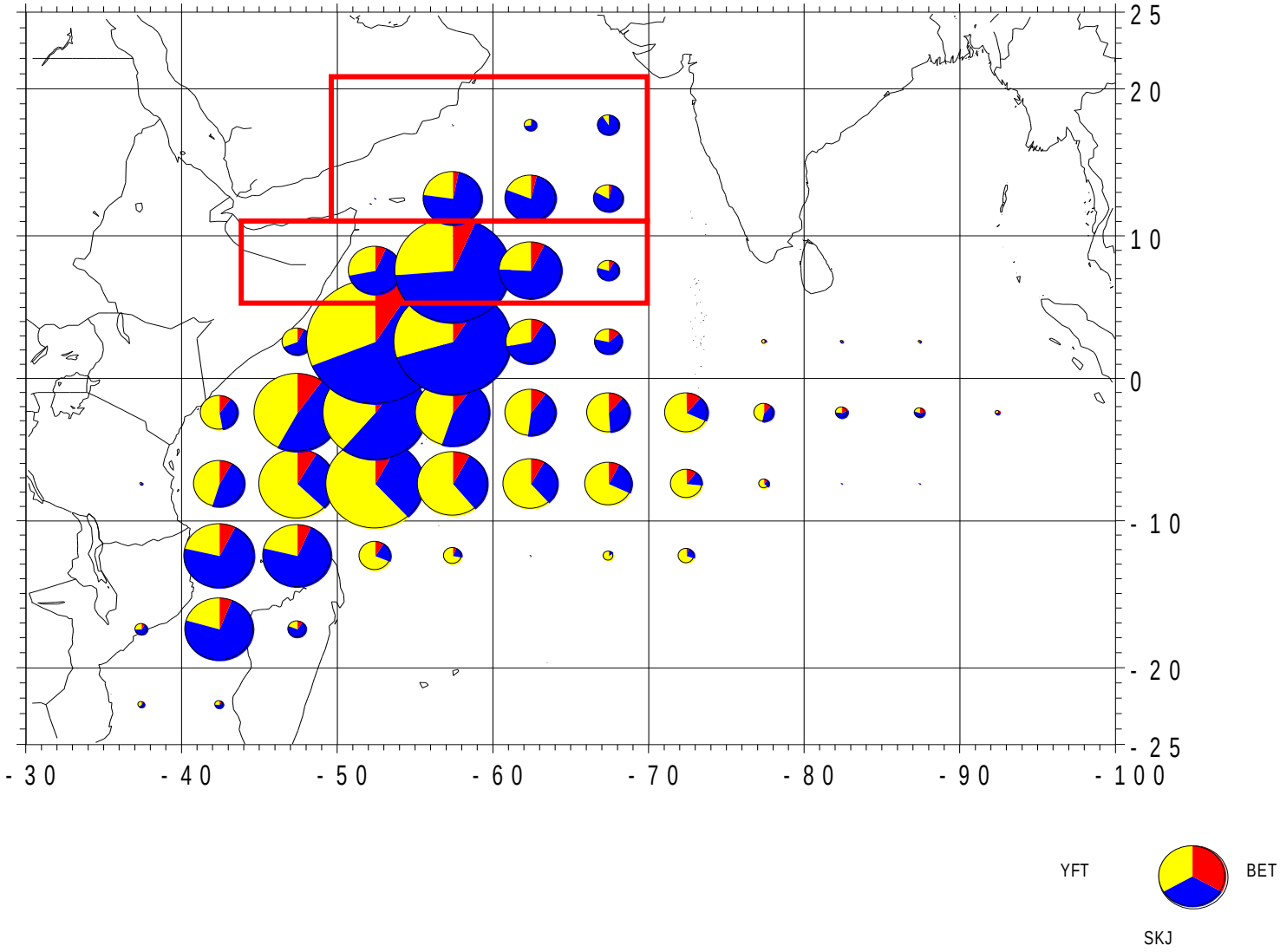
An overview of tagging areas of yellowfin, skipjack and bigeye, by size categories



Tagging areas and distances to the presently studied geographical limits

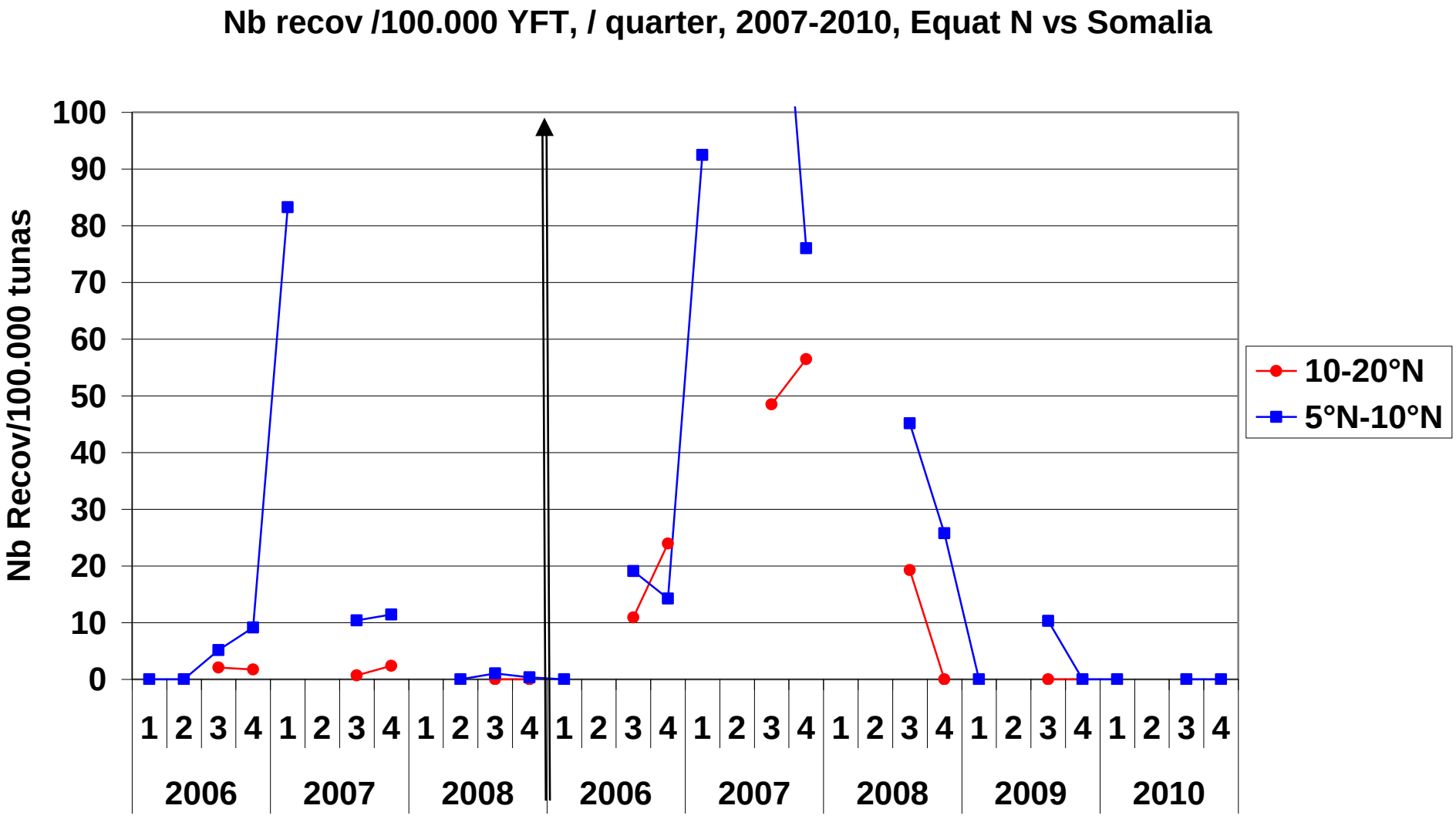
It is of fundamental importance to keep in mind the relative positions of the tagging and fishing zones in the analysis of recovery rates, as the probability to catch tagged fishes tend to be decreasing at increasing distances

(1) Northern frontier at 10°N



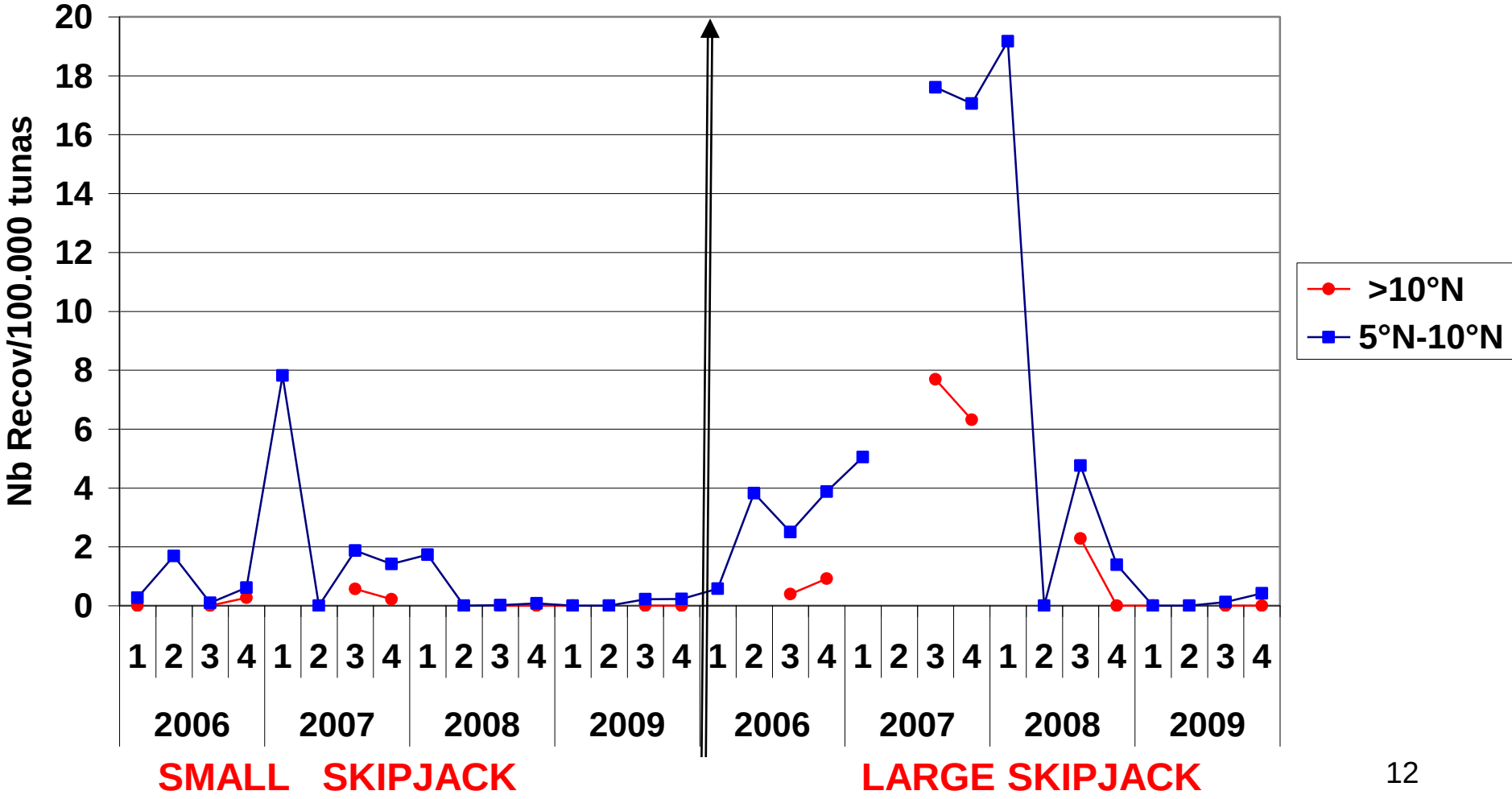
Average catches of purse seiners by species during the 2006-2010 period and the 2 sub areas selected to analyze recovery rates of tags in the northern area N & S of 10°N

LTRR of small and large **yellowfin** N & S of the 10°N latitude

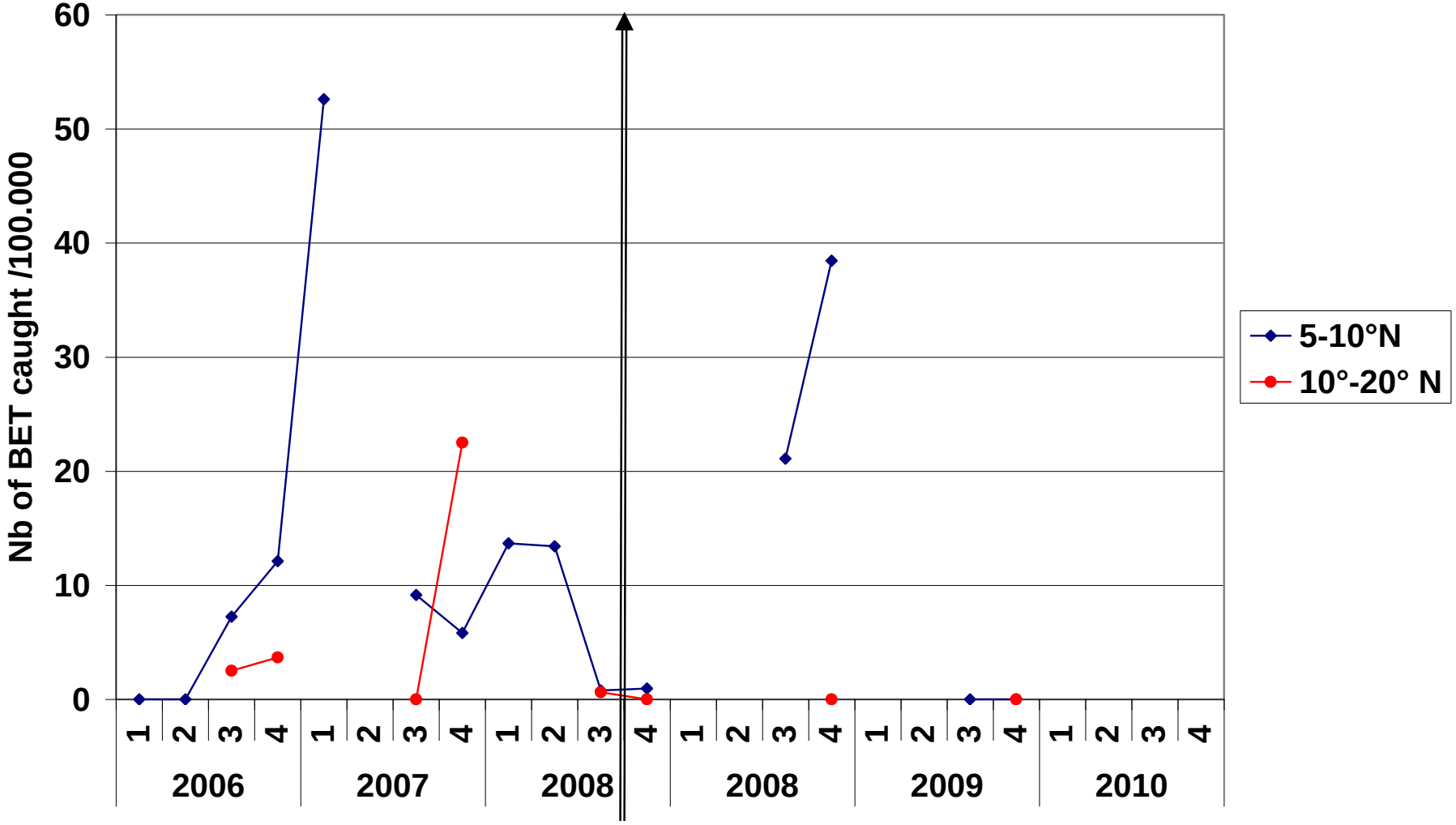


SMALL Yellowfin **LARGE Yellowfin**

LTRR **(Local Tag Recovery Rates)** of small and large **skipjack**, N & S of the 10°N latitude



LTRR of small and large **bigeye** N & S of the 10°N latitude

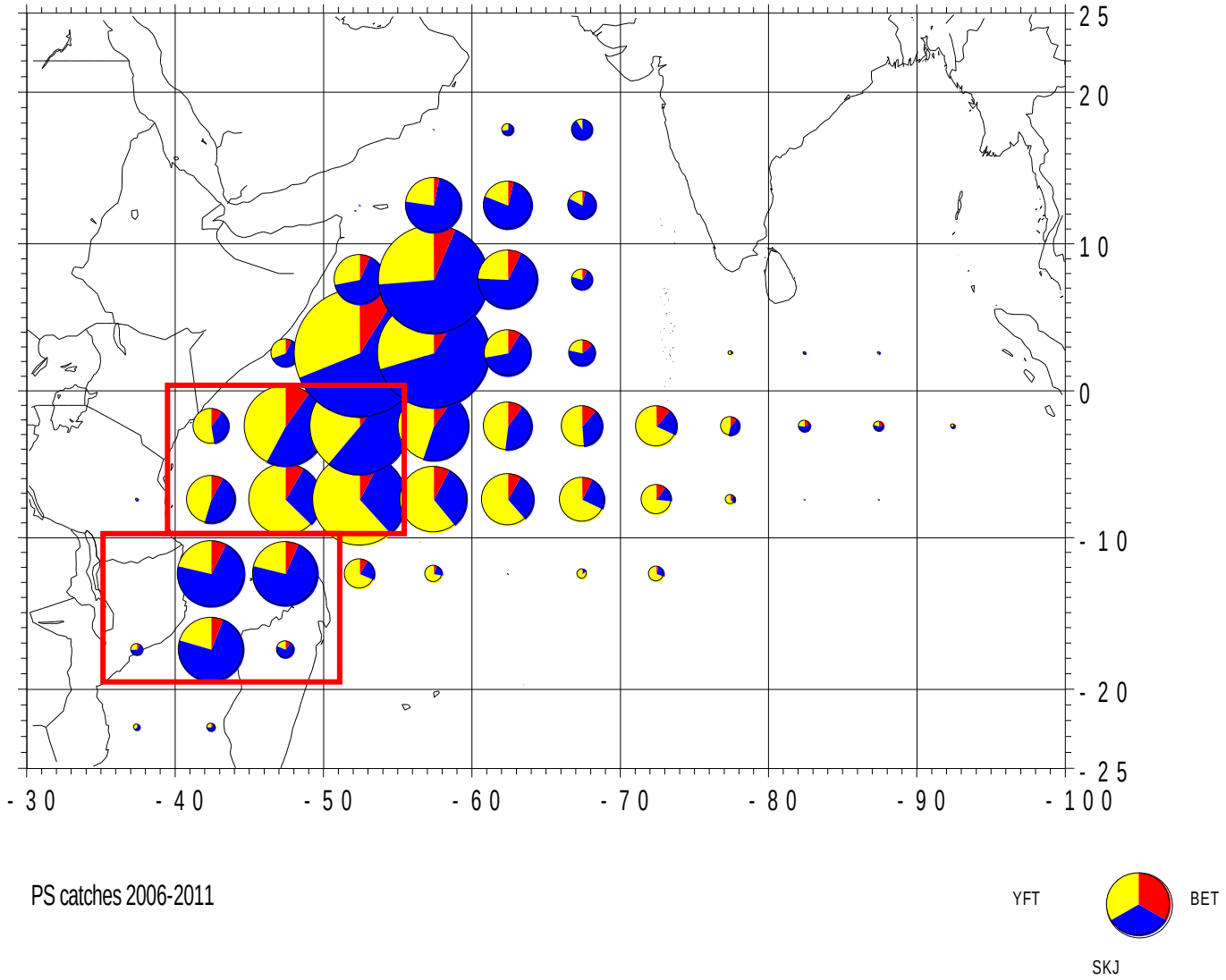


SMALL bigeye **LARGE bigeye**

Conclusion on the 10°N potential frontier

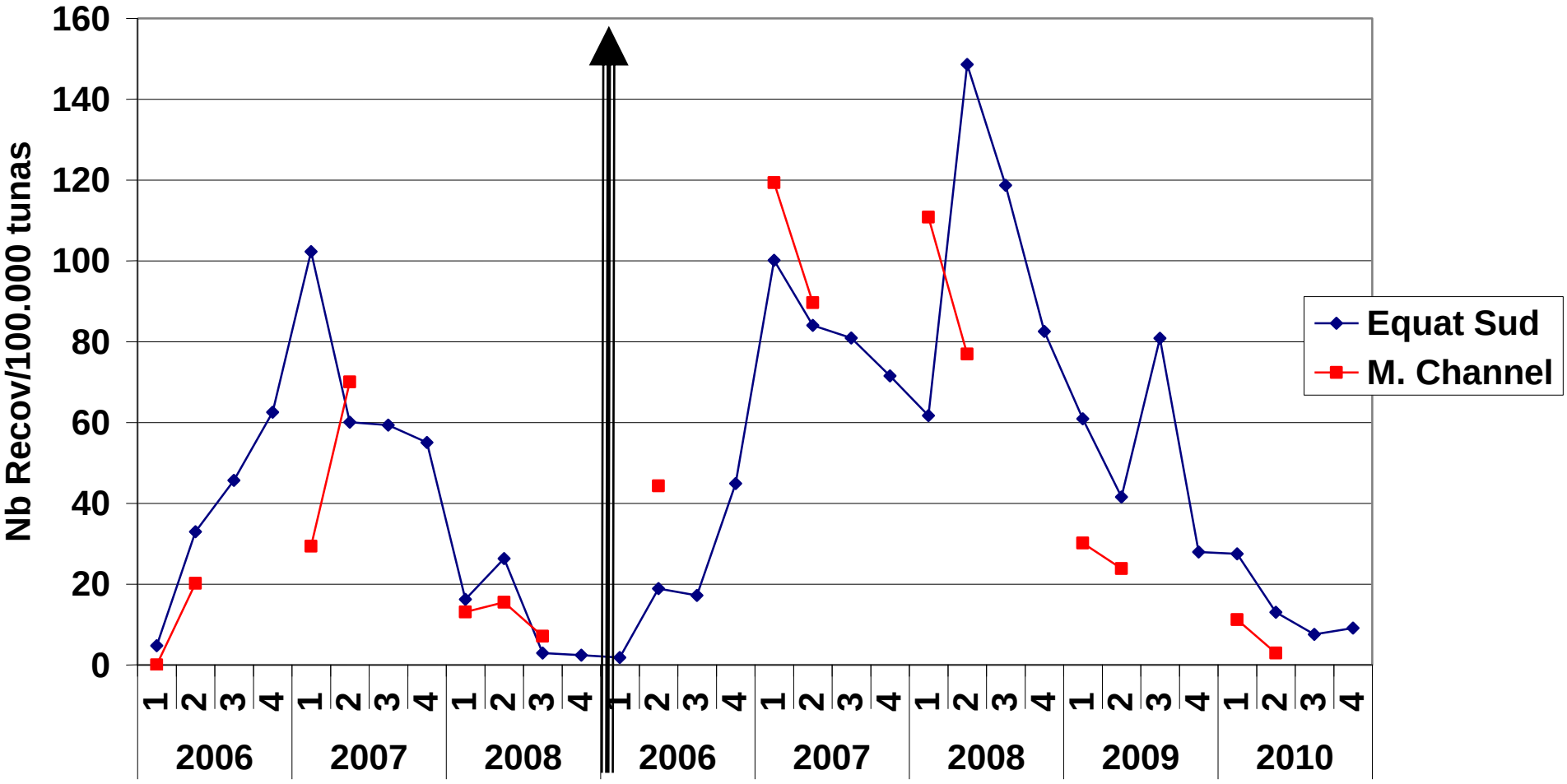
1) Somalian frontier: a highly seasonal fishing area N & S of 10°N, always dominated by SKJ and FAD fishing,
2) A frontier **very far from the main tagging areas: more than 1000 miles** between Tanzanian tagging zone and 10°N.
3) Catches by PS are **very low North of 10°N**, but significant between 5° and 10°N: an average percentage of Northern vs southern catches of 51% for YFT, 45% for SKJ, and only 21% for BET catches (BET being always rare in the PS catches north of 10°N, as well as in the LL catches).
4) Recovery rates of the 3 species are often observed N & S of the 10°N frontier, but **always at lower rates in the Northern area**: this result is logical taking into account the fact that most of the tagging have been done off Tanzania at a distance of about 1000 miles.
5) This result may widely be due to the **low catches** in the area and to the subsequently **low probability to catch tagged fishes** .
6) This result may also be indicative that this **10°N latitude is porous at least from south to north, for YFT and SKJ**
7) Keeping in mind that bigeye is nearly absent at all sizes north of 10°N.

(2) Southern frontier at 10° South



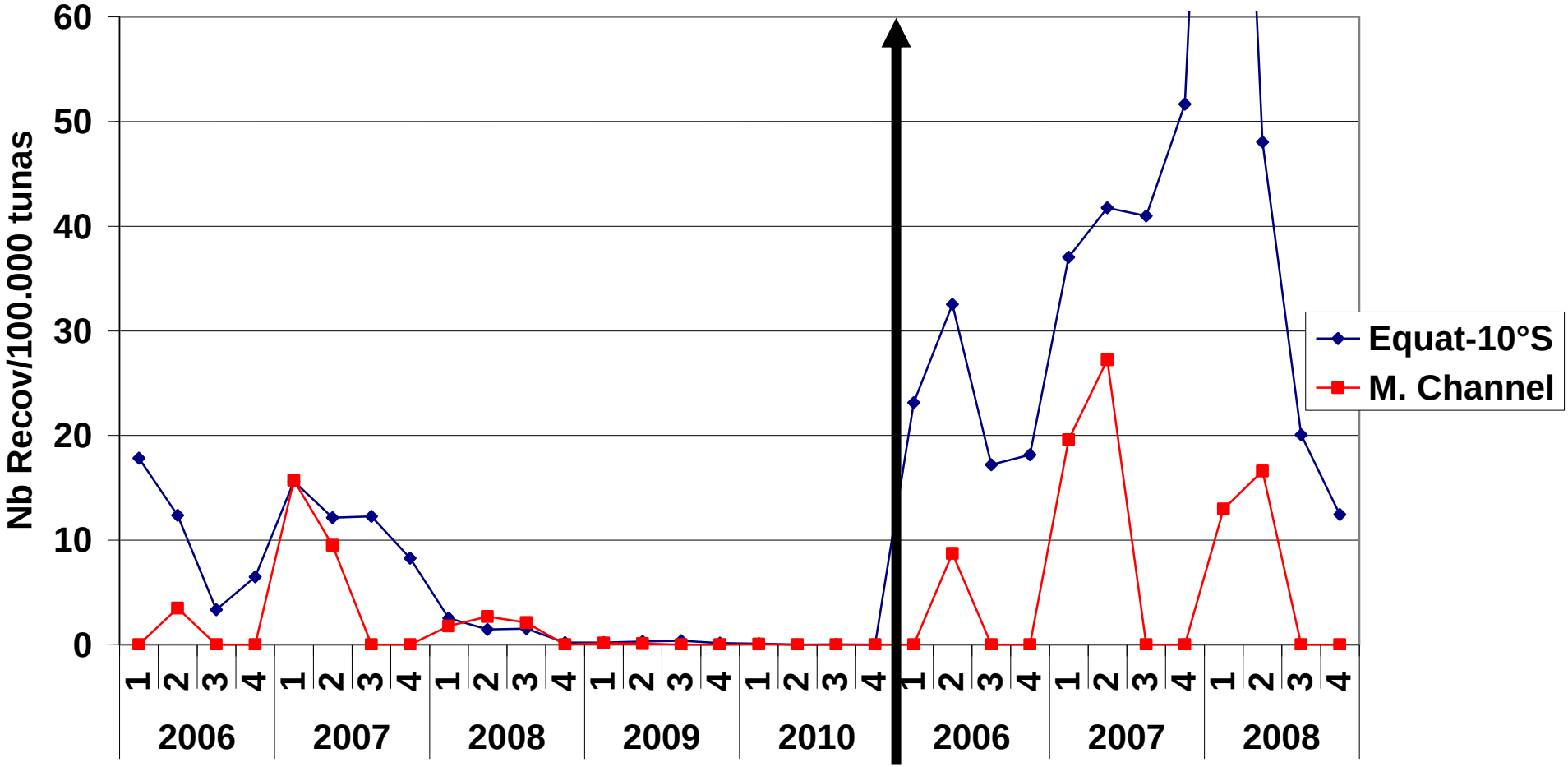
Average catches of purse seiners by species during the 2006-2010 period, and the 2 sub areas selected to analyze recovery rates of tags in the south western areas, N & S of 10°S.

LTRR of small and large **yellowfin** N & S of the 10°S latitude



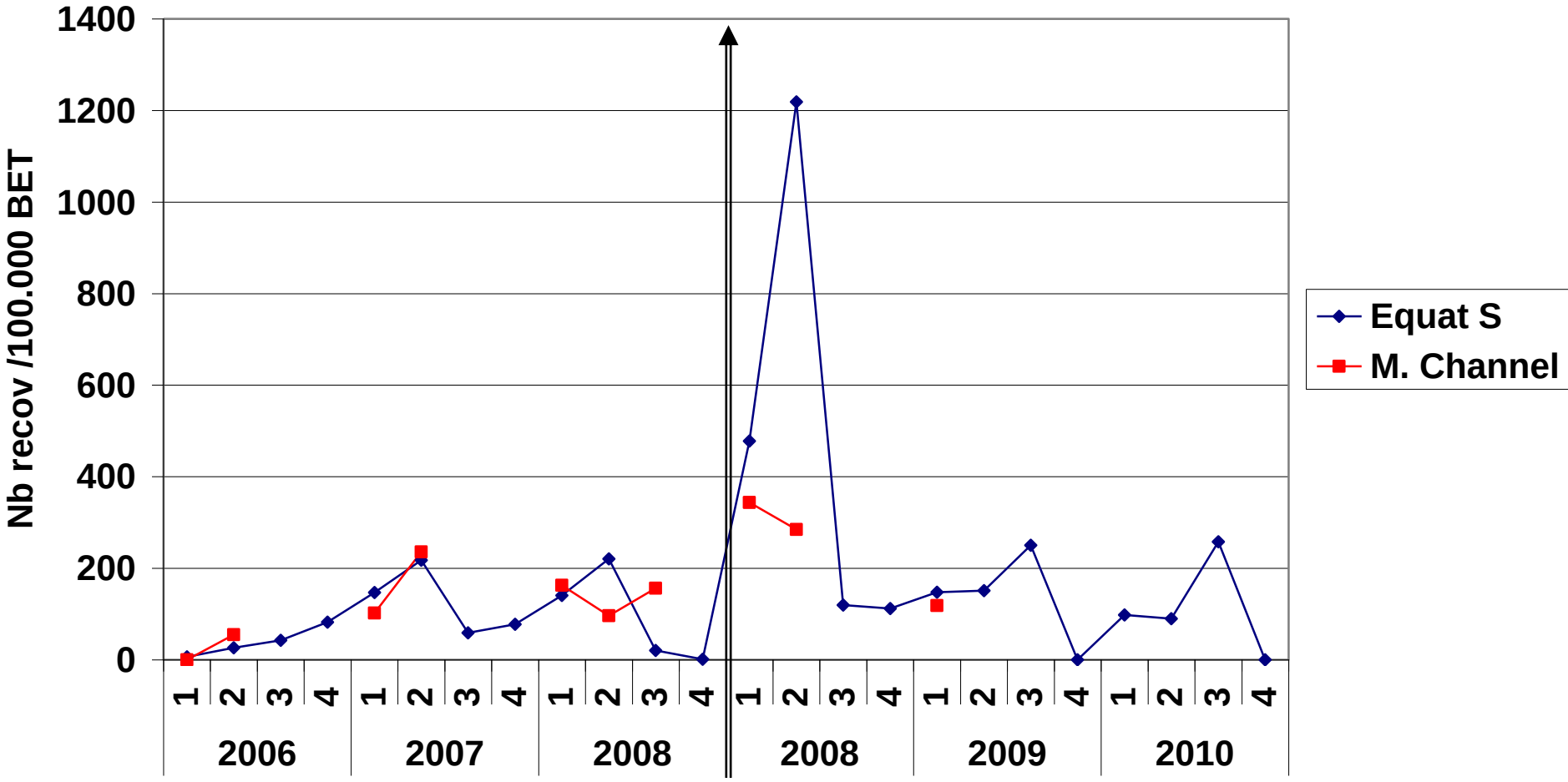
SMALL Yellowfin **LARGE Yellowfin**

LTRR of small and large **skipjack** N & S of the 10°S latitude



SMALL SKIPJACK **LARGE SKIPJACK**

LTRR of small and large **bigeye** N & S of the 10°S latitude

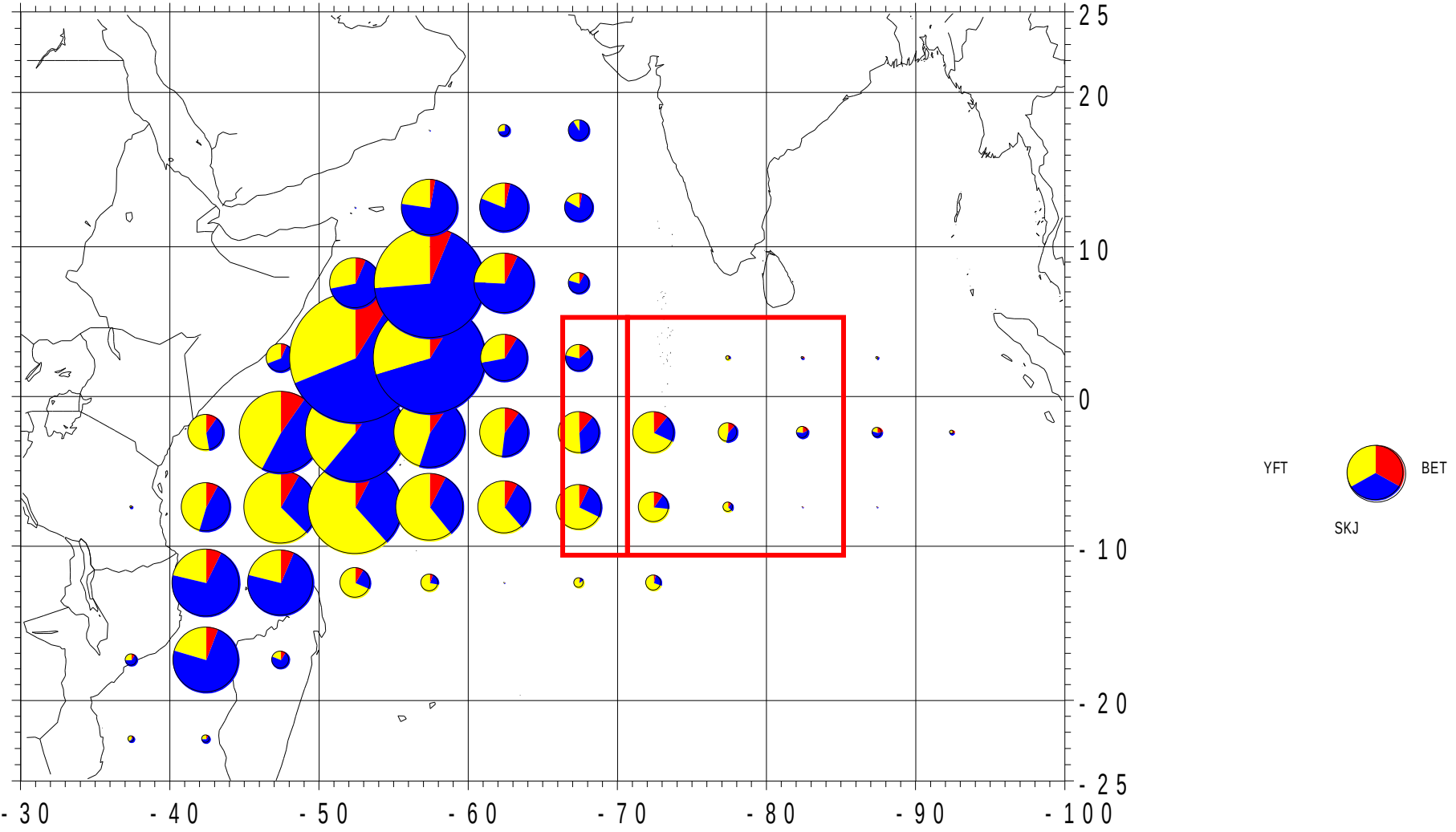


SMALL bigeye **LARGE bigeye**

Conclusion on the 10°S Mozambique Channel potential frontier

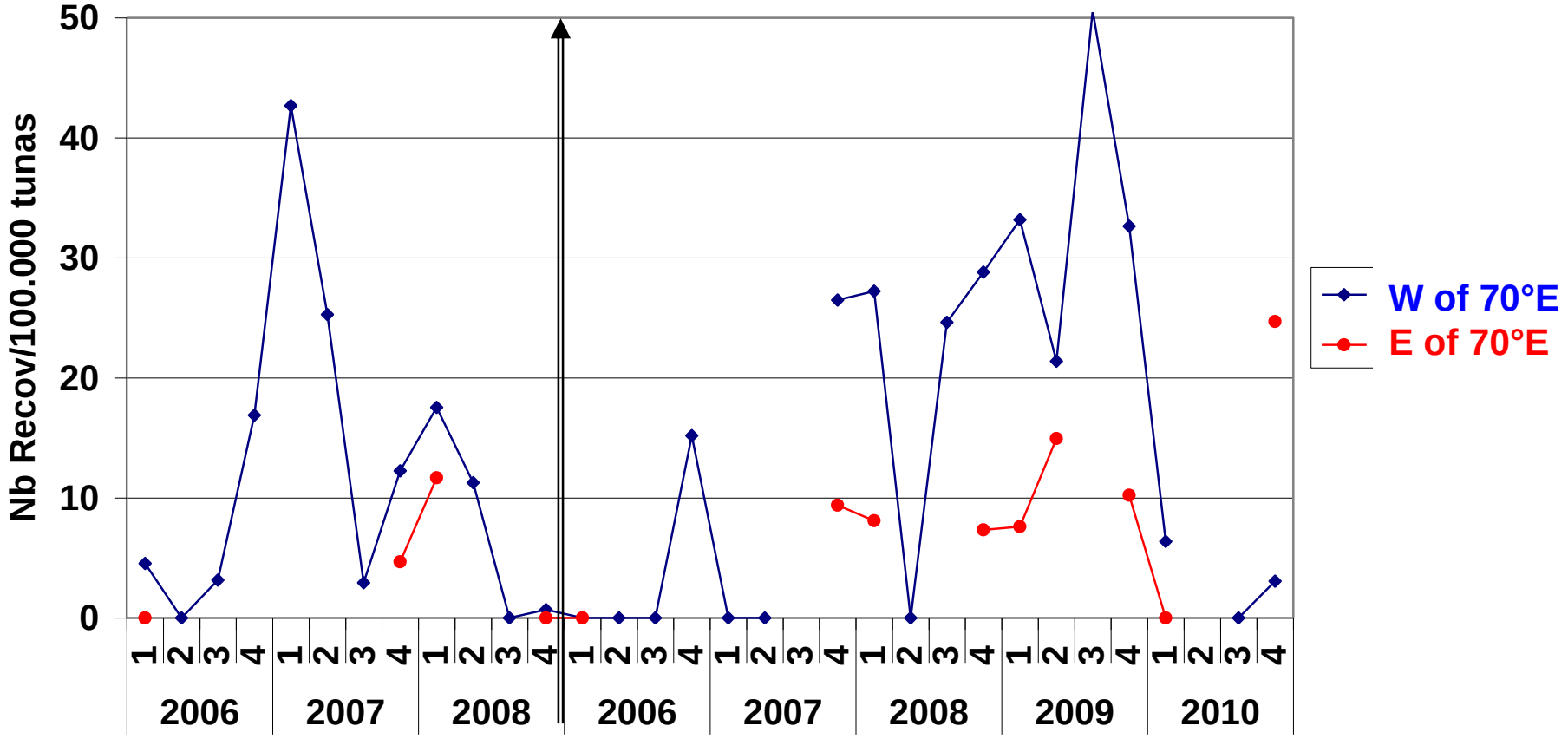
- Mozambique Channel 10°S frontier: a highly seasonal fishing area, **very close to the main tagging areas off Tanzania.**
- Recoveries of tagged tunas showing for yellowfin and bigeye, at all sizes, **quite, similar recovery rates of tagged tunas**.
- But the **rates of SKJ recoveries appear to be much lower south of 10°S**, and especially large individuals, possibly indicating an heterogeneity of the sub population of SKJ fished in the Canal and also corresponding to increased distances covered by larger SKJ.
- As a conclusion: the fractions of tuna stocks fished in the Mozambique Channel appear to be **heavily linked with the core** equatorial areas.
- The same conclusion would be more or less **valid for the 3 species**: yellowfin, skipjack and bigeye tunas

(3) Western Frontier at 70°E



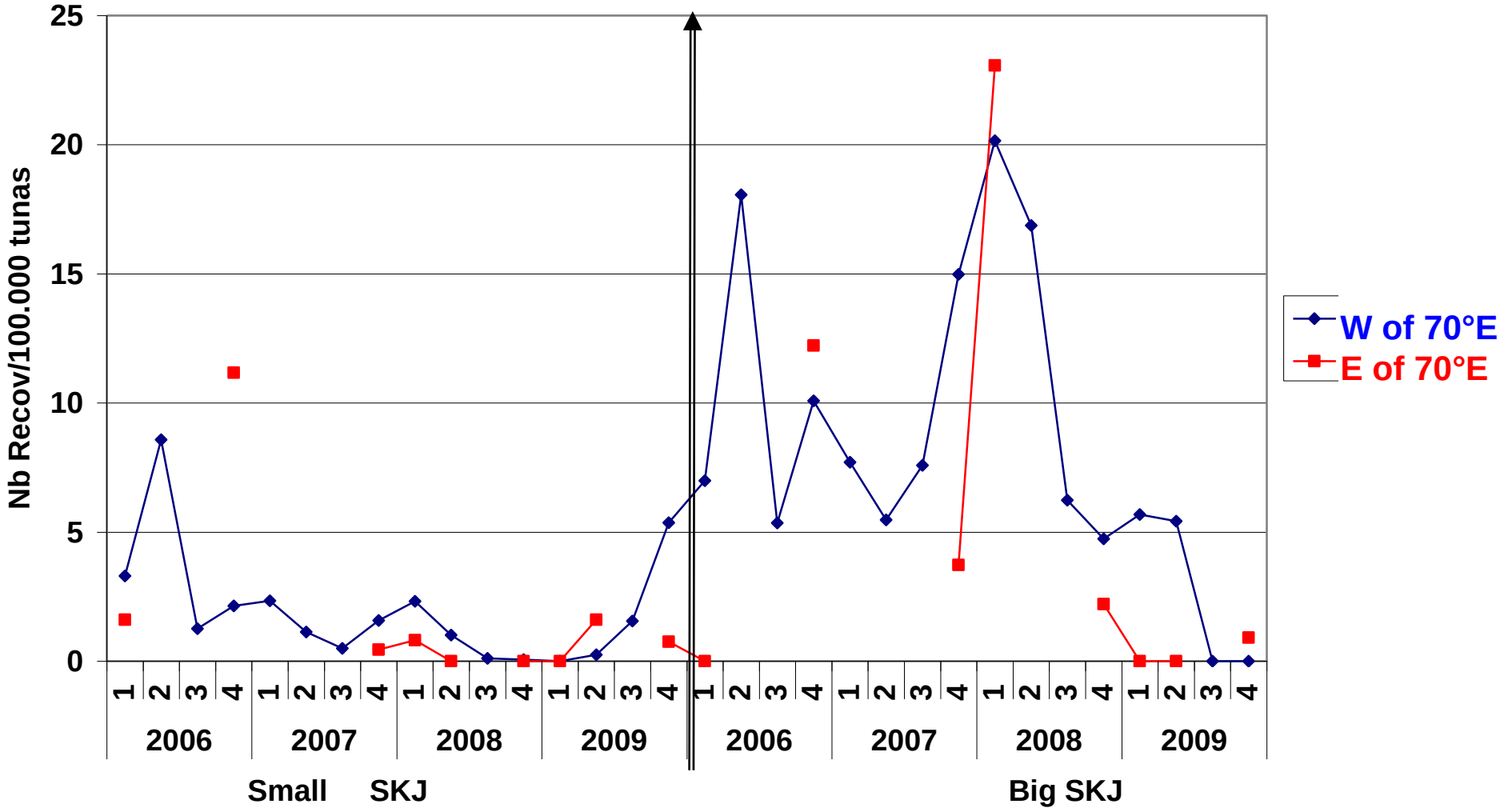
Average catches of purse seiners by species during the 2006-2010 period and the 2 sub areas selected to analyze recovery rates of tags in the Eastern area W & E of 70° East.

LTRR of small and large **yellowfin** E & W of the 70°E longitude



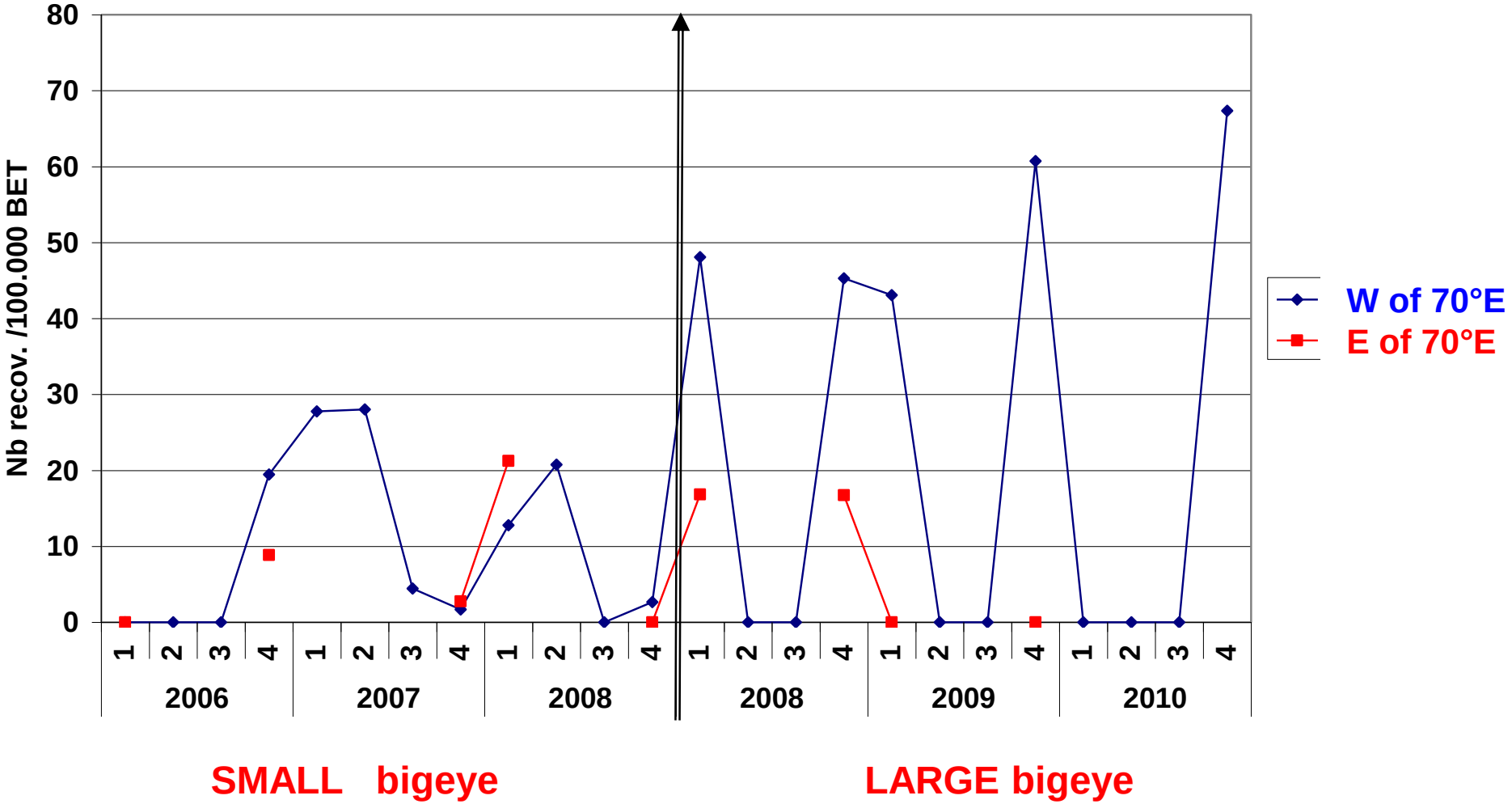
SMALL Yellowfin **LARGE Yellowfin**

LTRR of small and large **skipjack** E & W of the 70°E longitude



SMALL SKIPJACK **LARGE SKIPJACK**

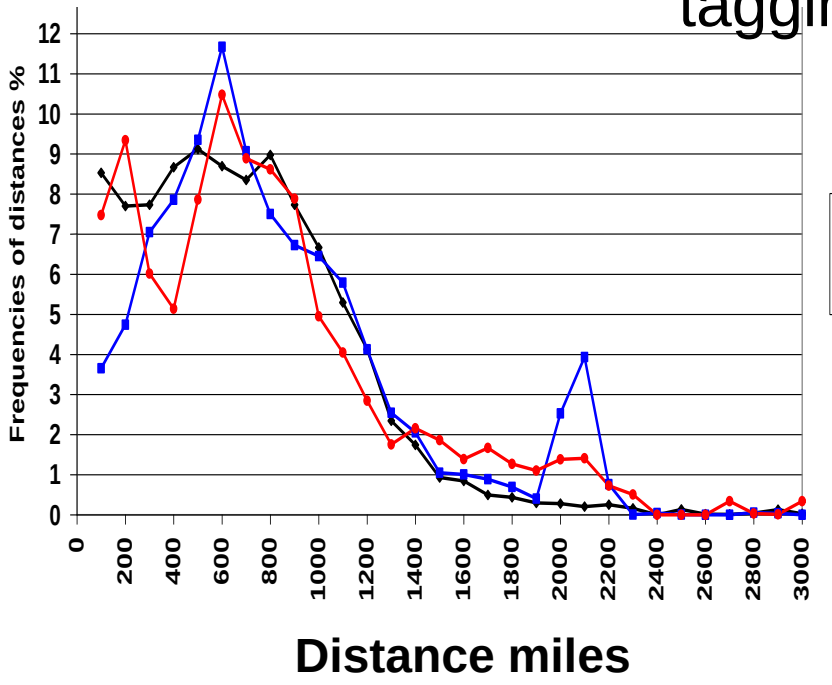
LTRR of small and large **bigeye** E & W of the 70°E longitude



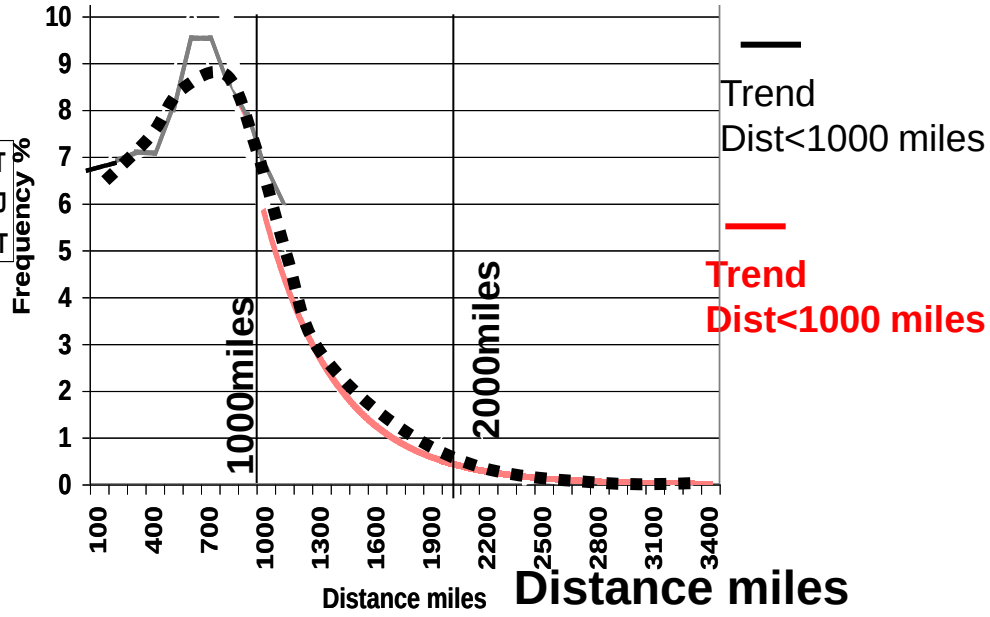
Conclusion on the 70°E potential frontier

1) Central IO frontier: a highly seasonal fishing area dominated by YFT,
2) A longitude very far from the main tagging areas: about 1800 miles, a distance seldom observed for recoveries of tagged tunas
3) Catches by PS are similar and very low east of 65°E and 70°E,
4) Recovery rates of the 3 species are most often (but not always!) lower east of the 70°E frontier, but they are frequently observed, despite the low catches and great distances from the tagging areas
5) this result is logical taking into account the fact that most of the tagging have been done off Tanzania at a great distance of about 1800 miles.
6) This result is probably indicative that this 70° longitude, close to the middle of Indian Ocean, is not a real frontier for any of the 3 stocks studied.

A final overview of linear distances travelled between tagging & recovery



Frequency of distances: by species



Probability of multispecies distances

-The recovery file & the estimates of recovery rates by gear allow to estimate the frequencies of apparent distances travelled by each species

-These 2 figures show that:

- distances between 0 & 1000 miles have been frequently & quickly observed and in a similar way for the 3 species

- Probability of distances **over 1000 miles**, numbers of recoveries are **declining exponentially**, for the 3 species, reaching maximum distance of 3000 miles (but very few recoveries).

Conclusion

- Recovery rates are **always lower in the external zones,** outside the studied frontiers.
- This result is widely due to their **great distances from the main tagging areas**: >1800 miles for the 70°E frontier and about 1000 miles for the 10° N frontier
- A result also widely due to the frequently **lower catches** outside these frontiers:

These semi quantitative results do not allow to estimate movement rates across the studied geographical limits, but they would tend to **strongly indicate the absence of any real frontier between the areas fished by purse seiners at the periphery of the fished zones.**

Our conclusion is that there is no visible frontier, but an **exponentially decreasing probability of movements at increasing distance over 1000 miles:** tuna living in the far East (Australia, Indonesia, etc..) are not isolated by a frontier with western tunas, but their probability of moving to the African coast is simply widely decreasing because of the great distances (4000 miles).

This basic & logical concept of **stock viscosity** should be applied in the models instead of the frontier/area concept.