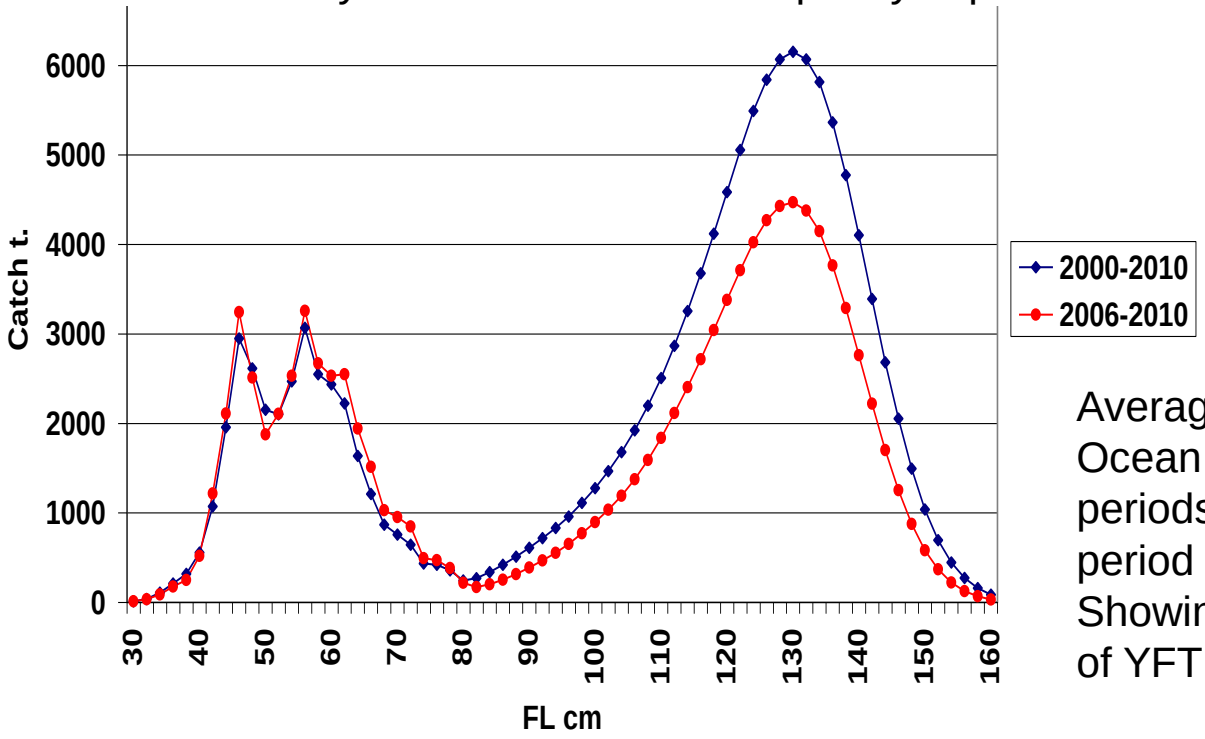
Why recoveries of yellowfin tuna should help to understand the 2 modes observed in the purse seine catches?

By Alain Fonteneau

A basic surprising fact in the Indian Ocean YFT PS fisheries:

Catches at size caught by purse seiners in the Indian Ocean have been always showing a marked bimodal structure, and very few yellowfin caught by PS at intermediate sizes in the 65-95 cm size range.

Until now, this marked decline of catches of medium sizes yellowfin has been seldom studied by scientists & it remains poorly explained



Average catch at size of YFT by Indian Ocean purse seiners during 2 recent periods (2000-2010 & 2006-2010, the period of major recoveries),
Showing the marked bimodal structure of YFT catches caught by PS in the IO

Why this bimodal permanent structure of YFT CAS?

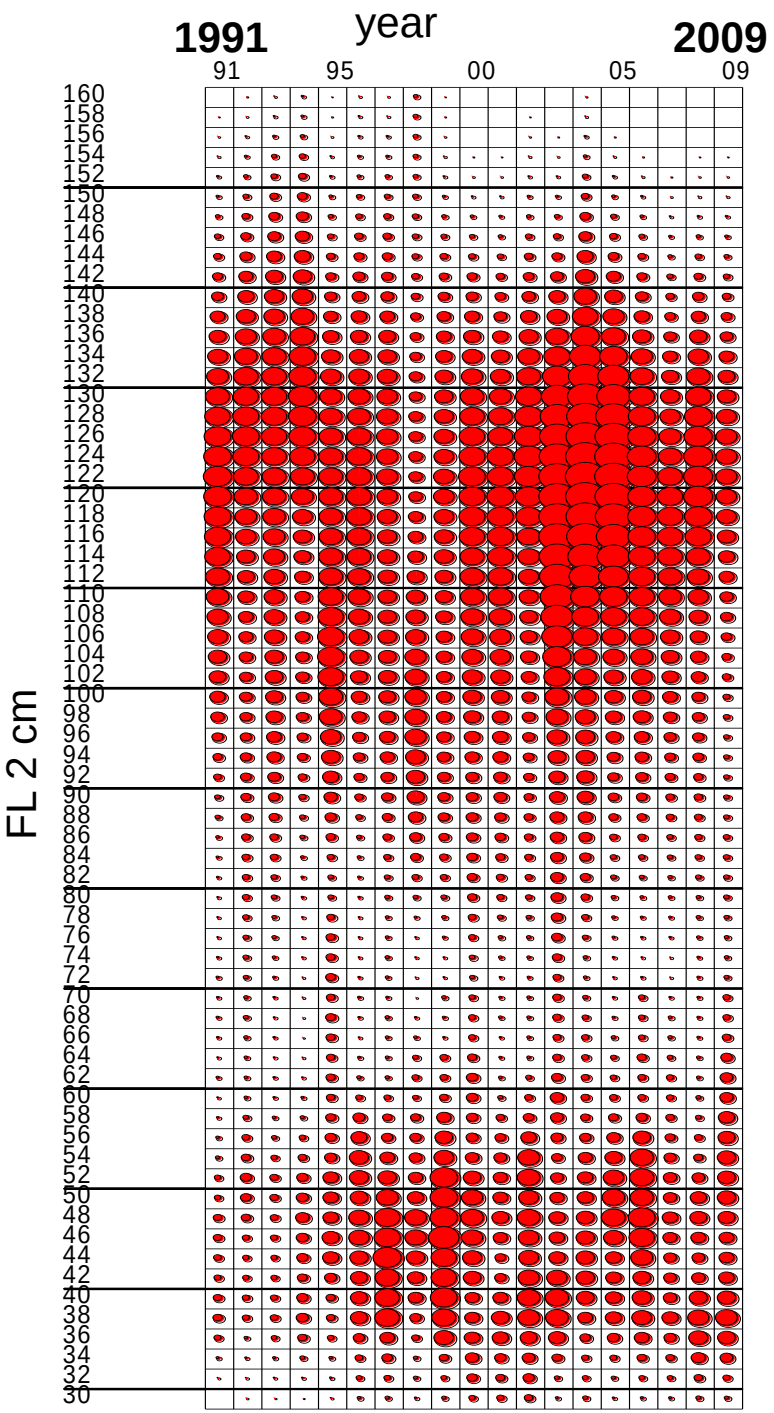
It could be due to a combination of at least 3 independent or additive causes such as:

1) **Accelerated growth at sizes between 65 & 95 cm**: reducing the numbers of swimming YFT in this size range, simply because of their fast growth rates
2) **Geographical mobility**: YFT moving at 65 cm towards fishing zones located outside the main fishing zones, reducing the catchability of these YFT.
3) **Change in tuna behaviour**: YFT at these intermediate pre adult sizes being more mobile, more scattered, less associated to FADs or deeper, this behavioural change producing a decline of their catchability (even in the same area).

The massive input of data obtained by the tagging programme on YFT recovered by PS, 9261 fishes recovered , 8117 of them being well measured, 4880 with good position and sizes, & covering all sizes caught by PS, offers now a good potential to better understand and explain this marked & rather strange bimodal structure.

Work done:

1) **Simulated size structure** of a cohort under various growth hypothesis: VB or multi stanza
2) **Size VPAs of YFT**: estimating total F at size and partial F exerted by purse seiners under various growth curves: VB or multistanza
3) YFT sizes at tagging & at recovery, compared to observed catch at size and to estimated Fishing mortality at size estimated for YFT caught by purse seine in the Indian Ocean
4) Simulating the **numbers of tagged YFT** during the 2006-2011 period
5) Discussion trying to explain the bimodal structure of PS Catch at size: evaluating the impact of growth, tuna behavior as a function of sizes, PS selectivity, geographical dispersion & availability of YFT to PS.

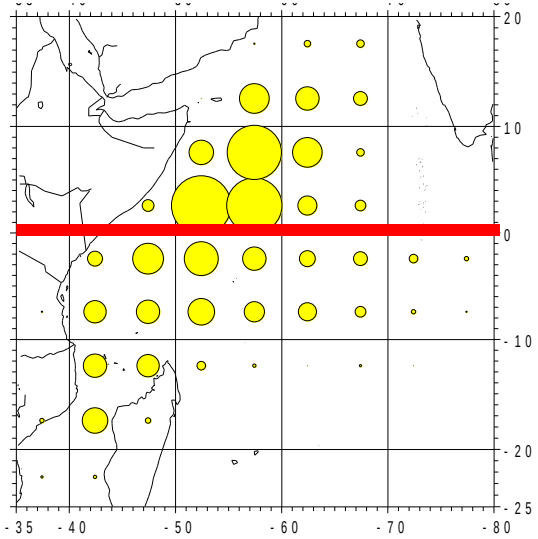


Yearly catch at size of YFT by Indian Ocean Purse seiners during the 1991-2009 period

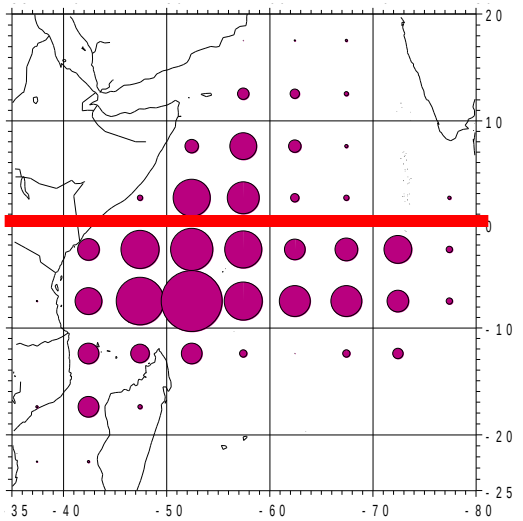
Showing each year the typical bimodal size structure of PS catches observed in the Indian Ocean,

But WHY?

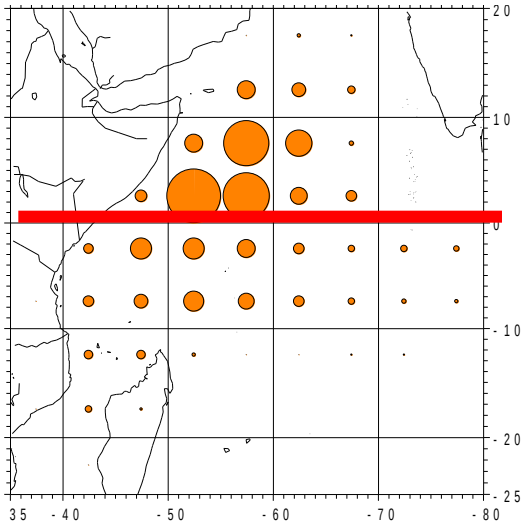
Yellowfin catches by areas for the 3 YFT size categories (period 2006-2010)



Small YFT catches <65cm



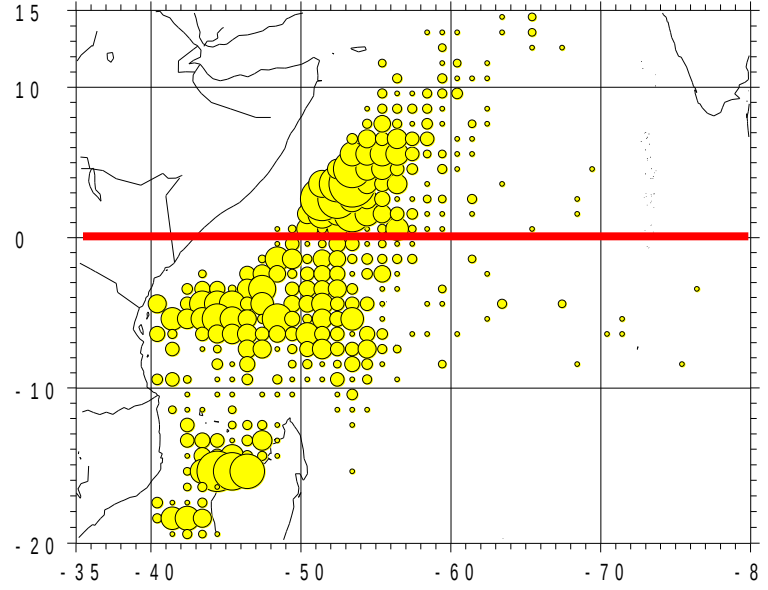
Large YFT catches >90cm



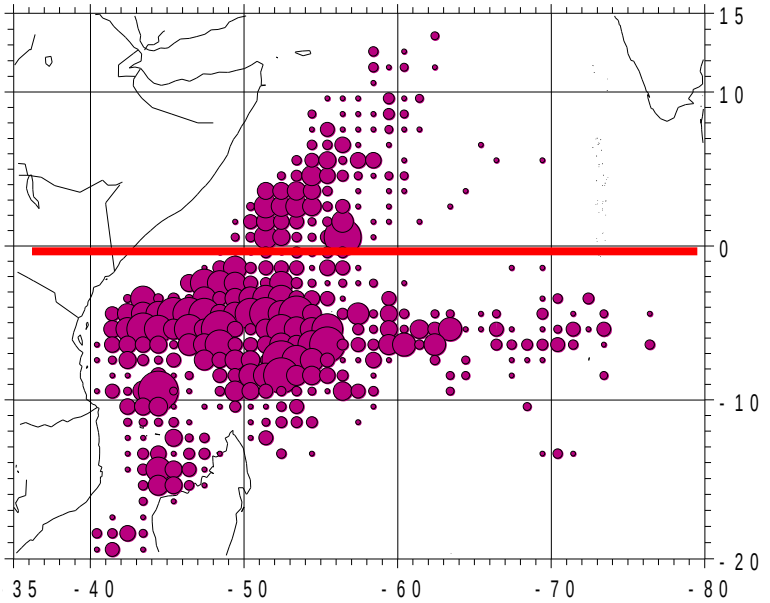
Medium YFT catches 65-90 cm

The 3 size categories of YFT (small, medium & large) have been caught by PS during recent years + or – in the same fishing zones between 15°N & 20°S,

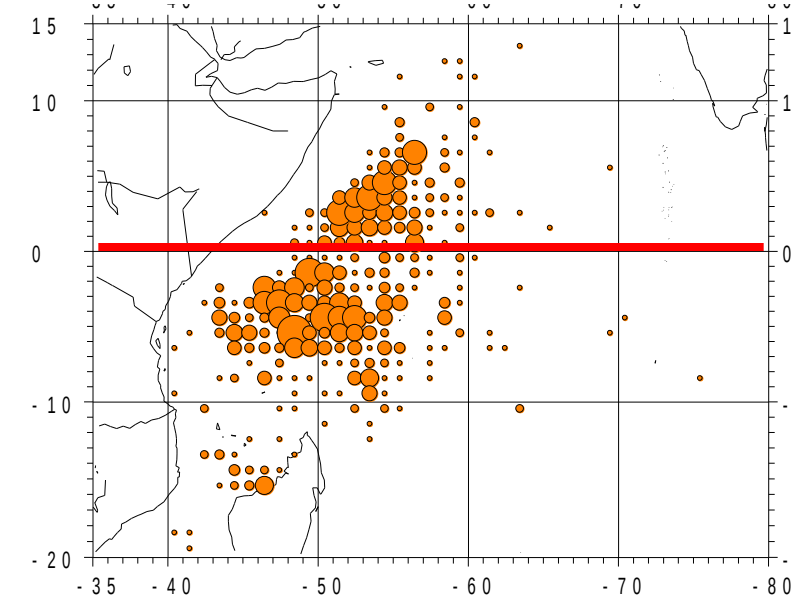
- But catches of both medium YFT are widely dominant in the Northern equatorial areas, between Equator & 10°N (probably their feeding zones)
- Large YFT are predominantly caught **south of the Equator** & north of 10°S.



YFT recoveries <65 cm



YFT recoveries >90 cm



YFT recoveries 65>90 cm

YFT RECOVERIES by SIZES

The 3 size categories of YFT (small, medium & large) have been recovered + or – in the same fishing zones, but at variable rates:

- areas of medium YFT recoveries are geographically smaller & equally distributed N & S of the equator, then showing relatively much higher rates of recoveries in the south (quite close from the main tagging areas) than in the North
- Large YFT have been predominantly recovered south of the Equator, in good relationship with their main fishing zones

Simulating the size structure of a cohort from birth to death under various geowth model: what biomass at size?

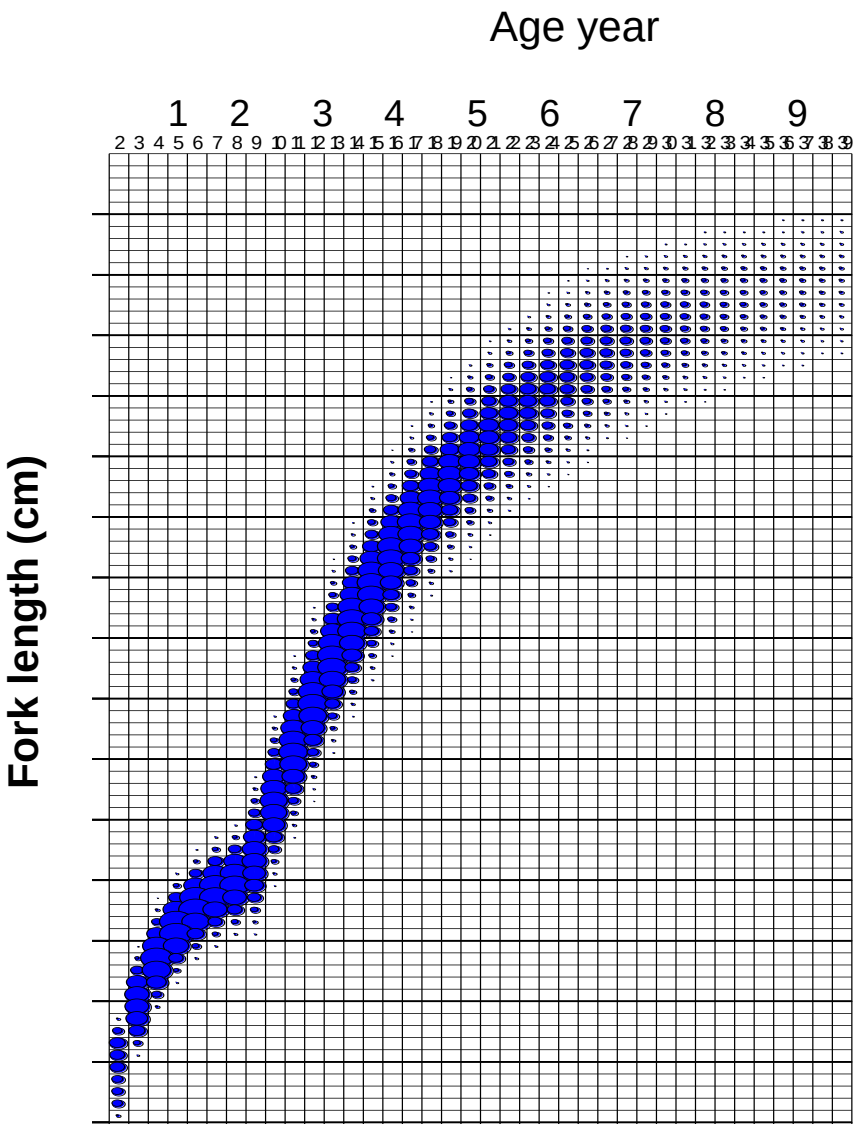
- Simulation method using the simple pre-historical method proposed by Fonteneau 1974: following the sizes and life of a cohort; 100000 fishes, assuming an hypothetical normal variability of t_0, k and L_∞ in the growth of each individual.
- Assuming 2 alternate growth models: (1) a single VB model or (2) a cohort following a cascade of 2 VB models for juvenile and for adult, and an inflexion point between the 2 models at 62 cm (and 2 years)

The assumed growth parameters were derived from typical growth pattern used in recent and in today IOTC YFT stock assessments. The standard deviations assumed for each of the growth parameters were selected in order to allow realistic variability of the sizes in the simulated cohort. A constant total yearly mortality Z was assumed at a level of 0.8 .

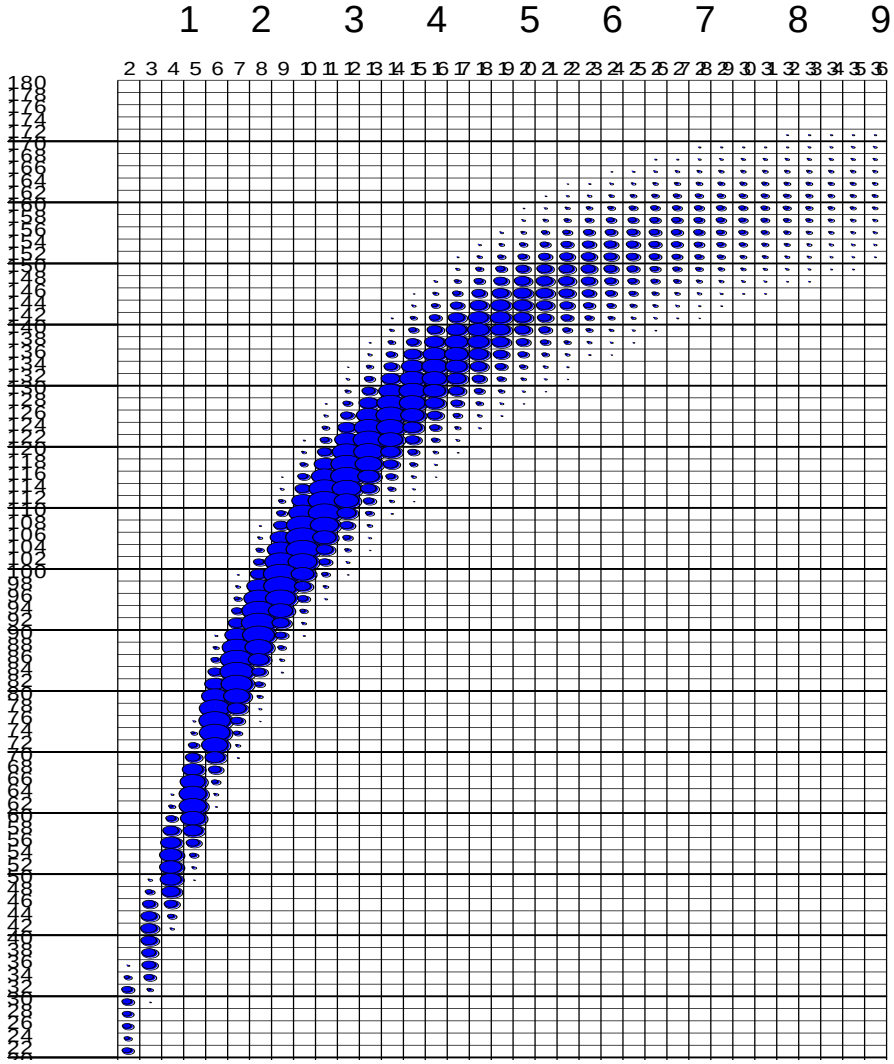
The average growth parameters are given in the following table

	Juvenile VB growth		Basic VB model	
Parameter	Average	Standard deviation	Average	Standard deviation
K	1.50	0.010	0.40	0.020
L inf	65.	3.	165.	5.
T 0	-0.033	0.010	-0.033	0.010
M	.8		.8	

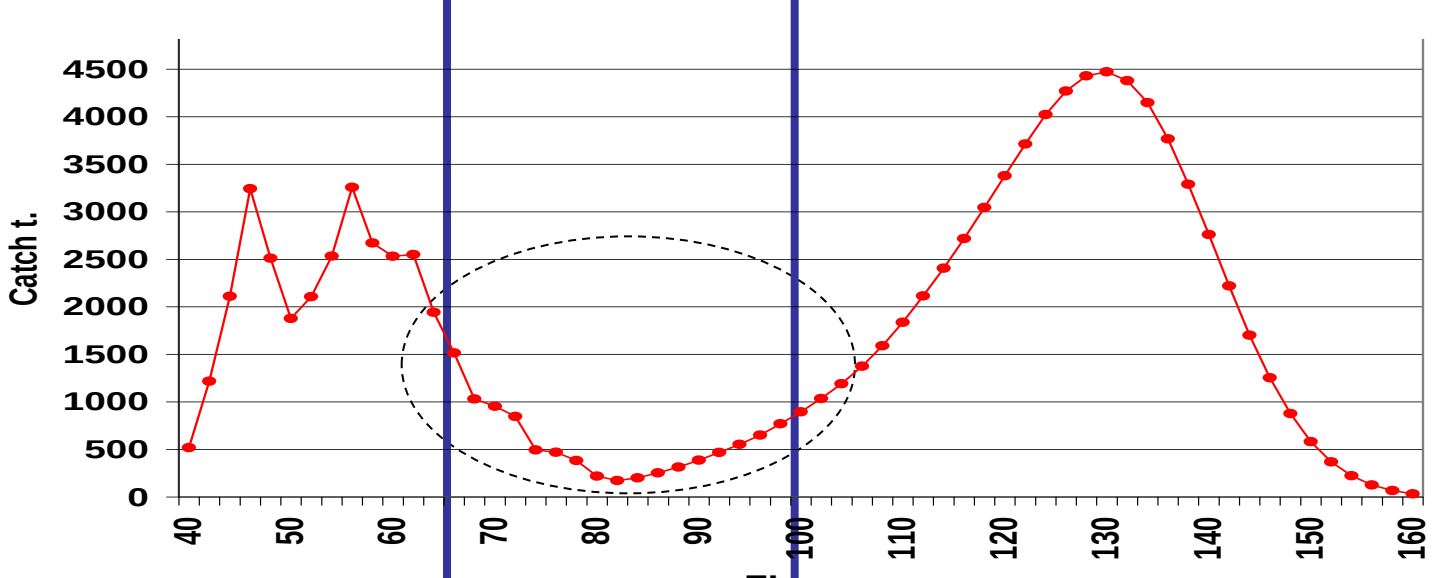
The subsequent yearly size distributions of these 2 simulated cohorts are shown by the 2 following figures 6 and 7:



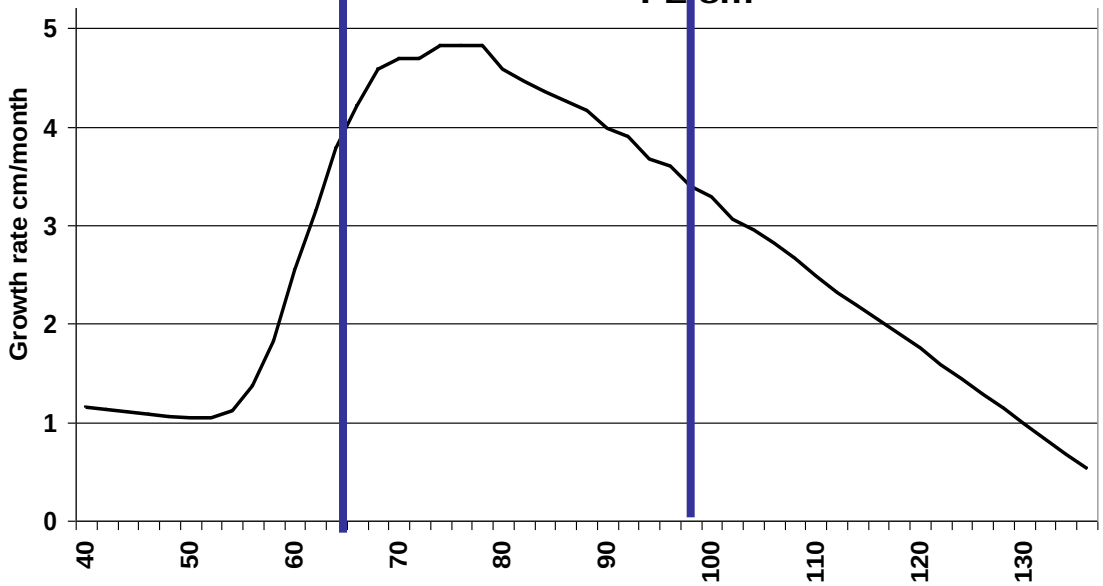
Quarterly population size in weight in the 2 stanza growth curve



Population size in weight in the basic Von Bertalanffy growth curve



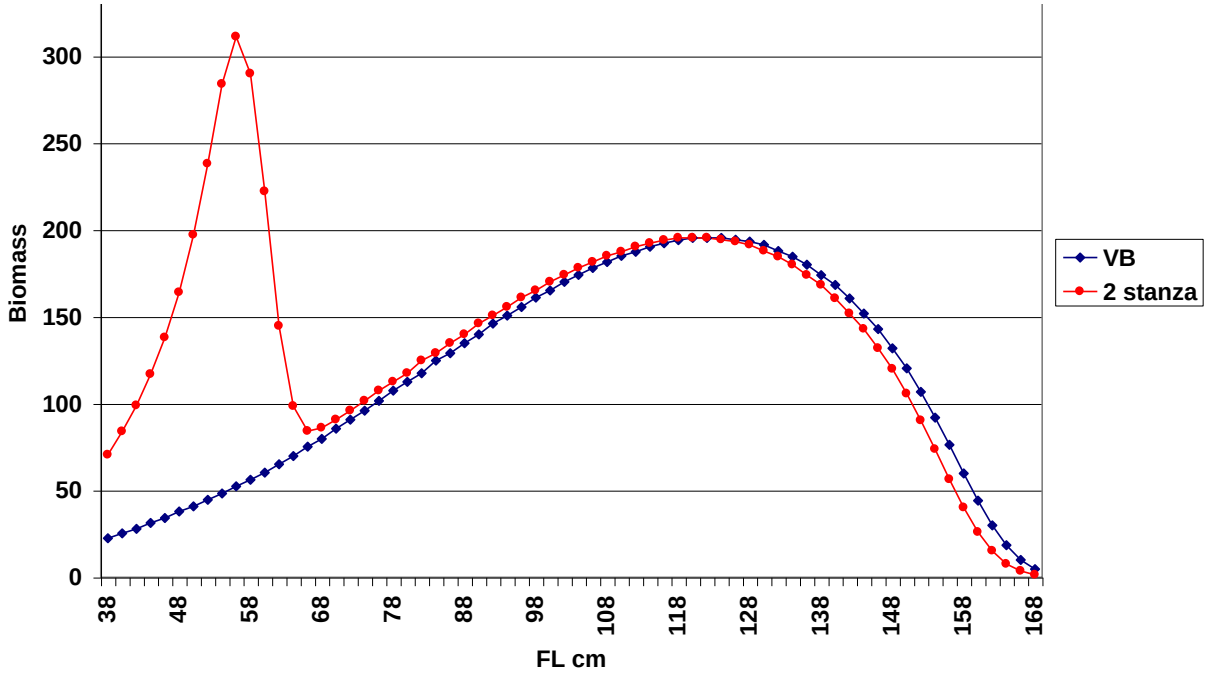
Sizes caught



Growth rates at size

- The decline of small YFT catches starts at 60 cm, i.e. at the beginning of the period of accelerated growth, a result in agreement with previously simulated growth
- Very low catches at intermediate sizes correspond to the plateau of maximal growth rates
- When the mode of adult YFT correspond to spawners and the exploitation of spawning concentrations

The numbers at time of these 2 cohorts are transformed as a pseudocohort, allowing to calculate & to show the weight of the pseudocohort as a function of fish sizes.
-The blue curve, a single VB model, shows a typical curve of a maximum biomass of the exploited cohort at adult size at about 120 cm. This basic result is typical of « traditional » yield per recruit analysis using the Von Bertalanffy model
-The red curve, corresponding to the simulated 2 stanza growth pattern, shows a bimodal structure of the biomass at size, a pattern seldom seen in fisheries: its first mode is simply due to the accumulated biomass of juvenile tuna close to their 1st juvenile asymptotic size.



Biomass of the simulated 2 cohorts following a VB growth (blue) and the assumed 2 stanza growth curve (and the hypothetical growth variability assumed in these 2 simulations)

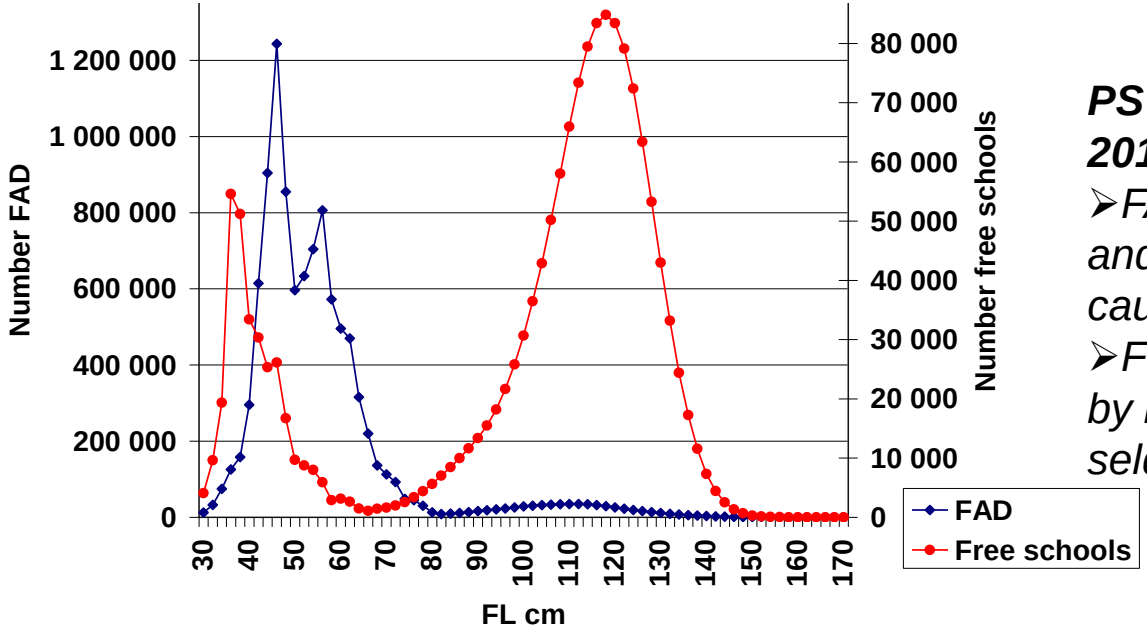
The present stochastic simulation of 2 tuna cohorts following a VB or a typical 2 stanza model would allow to conclude that a multistanza growth would be a logical reason explaining the observed bimodal structure of YFT catches.

This multistanza growth pattern is one of the new & very strong results obtained by the IOTC tagging program.

However, this result should be compared with the recovery rates at sizes observed in the YFT catches by purse seiners

Small YFT associated to FADs, large YFT in free schools: medium size YFT abandoning FADs, but not yet in typical free schools?

- All testimonies from PS fishermen would indicate that **medium size YFT are showing a peculiar behaviour**: being more scattered and more mobile that small YFT (easily caught in mixed schools under FADs) and that large YFT (easily caught in free schools in feeding and on spawning concentrations). These medium size YFT being called by French fishermen “Chicaneurs” or “quibblers”
- This behavioral characteristics is difficult to prove, but it should simply decrease the catchability, catches and fishing mortality of these medium YFT.
- However, such behavioral impact should also reduce the probability to recover tagged YFT during this period of low catchability

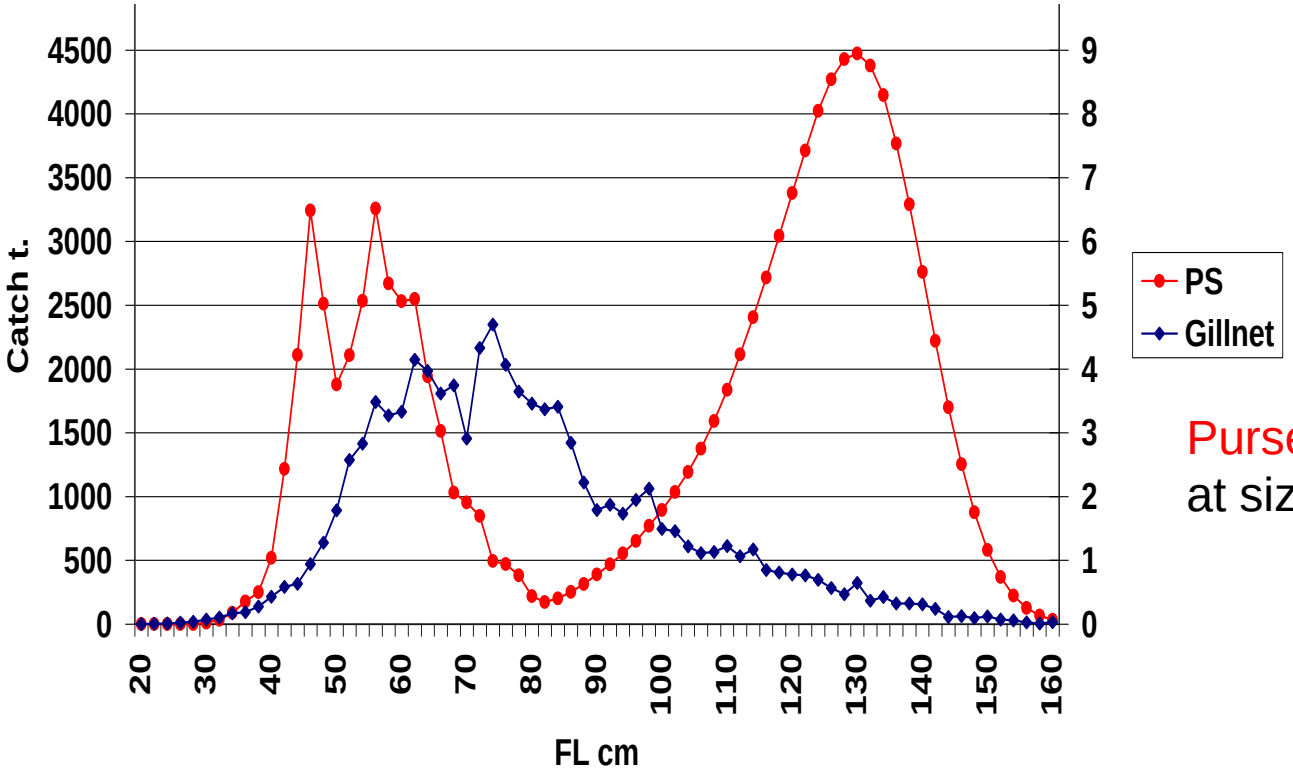


PS average YFT Catch at size, 2006-2010, in numbers:

➢*FAD catches dominated by small YFT, and mid size YFT are very seldom caught on FADs*

➢*Free schools YFT catches dominated by large fishes, mid size YFT are very seldom caught on free schools*

A northern dispersion/migration of 65 cm yellowfin towards the Arabian Sea?

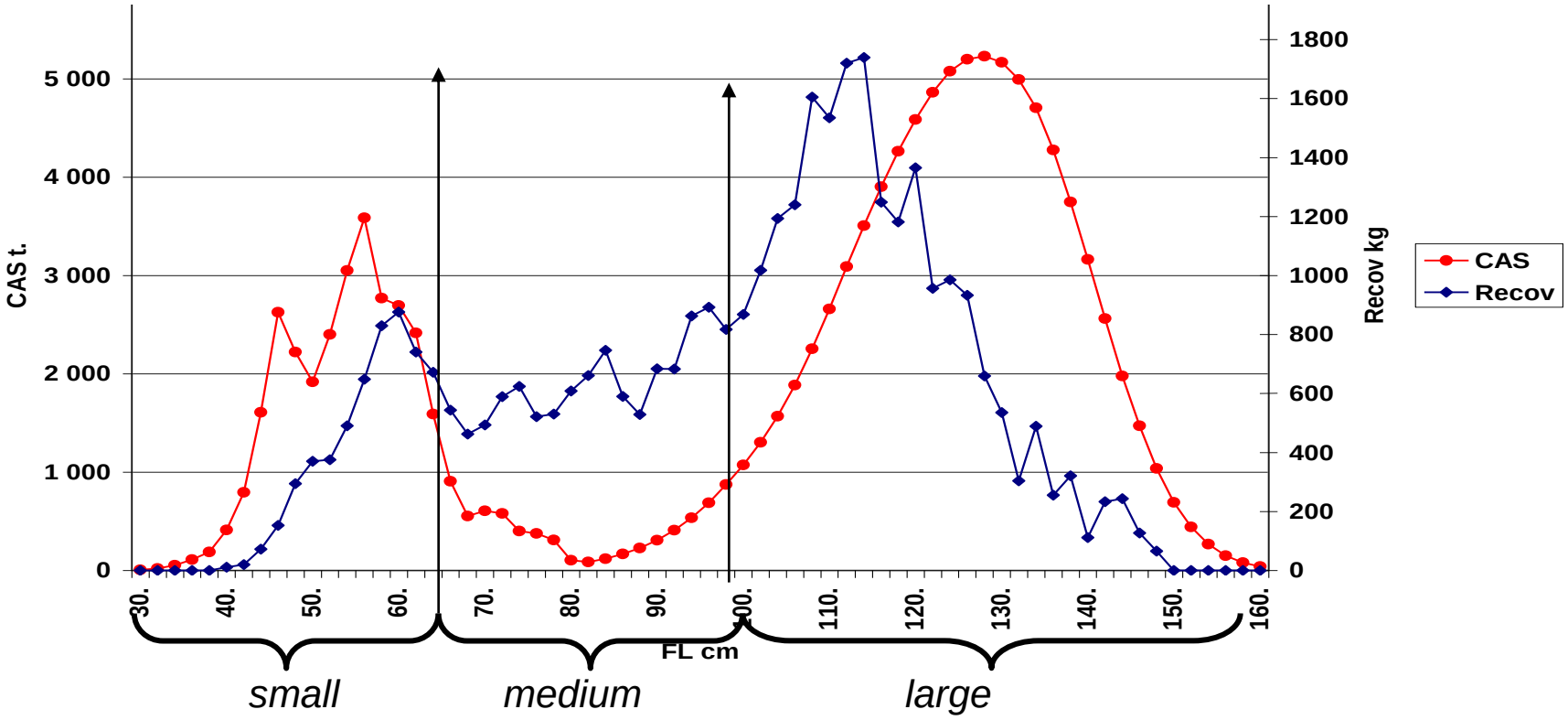


Purse seine & Gillnet catch at size, average 2000-2010

- Missing YFT sizes between 65 & 90 cm are the dominant sizes caught by the artisanal fisheries in the NW Indian Ocean
- Possibly corresponding to a movement of these pre adult YFT towards the Arabian Sea
- However, this hypothetical Northward migration has not been confirmed by the YFT recoveries,
- But may be because of a very reporting rates in the fisheries active in this area?

Analysis of YFT recoveries & catch at size

- During the IOTC tagging programme:
- ➢ Many small, medium and large tagged YFT have been recovered
- The analysis of these recoveries should help to undestand the bimodal structure of YFT sizes caught by PS in the Indian Ocean



Average catch at size of YFT taken by PS and numbers of tagged YFT reported at known sizes by PS during the period 2006-2010.

Size VPAs on the YFT catch at size

The interpretation of catch at size requires to estimate the size of the fished & of the tagged population in each interval of size;

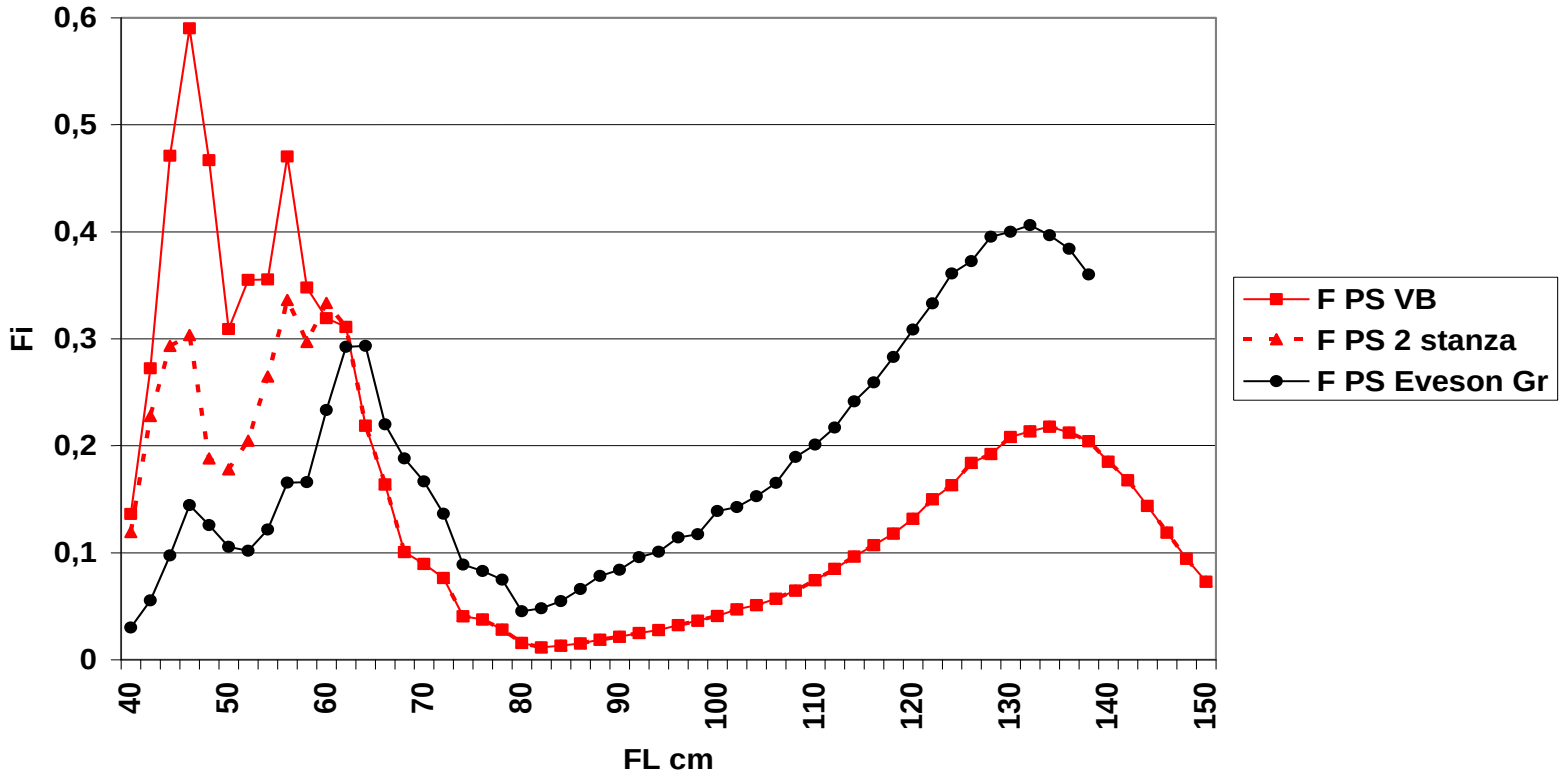
The size of the fished population at size can be estimated by size VPAs:

- Knowing the total catch at size & catch at size of PS,
- Knowing the growth pattern and the time duration of each cm intervals,
- Assuming natural mortality at size and an exploitation rate,

- It is easy to run size VPAs on the average levels of recent total CAS, for instance during recent years 2006-2010, the period of main recoveries.
- **Allowing to estimate trend in population at size, and Fishing mortality at size exerted by Purse seiners,**
- And to compare these VPA results with the observed levels of recoveries at size

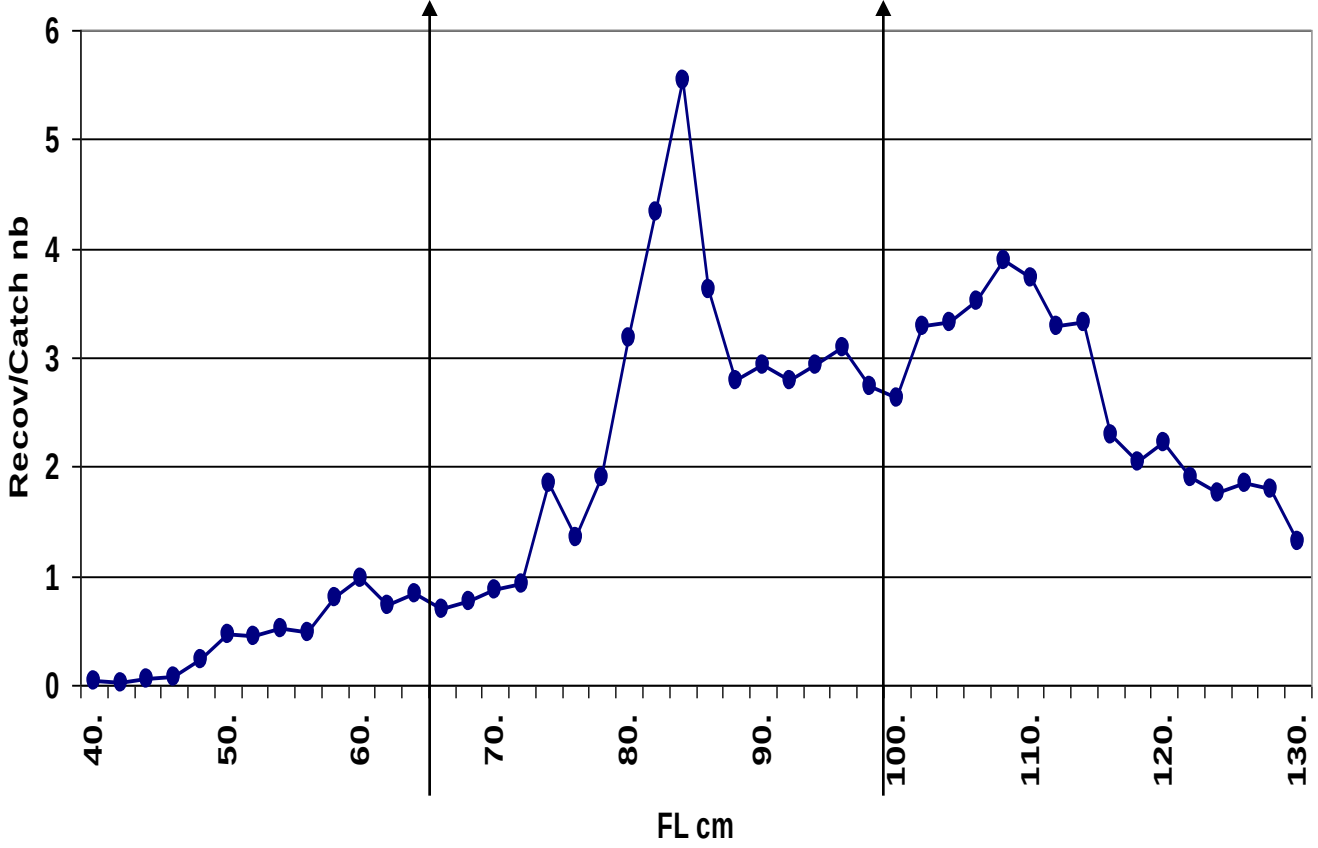
Fishing mortality at size estimated from size VPAs: under different growth models: VB & 2 stanza (Eveson & 2 cascading VB)

F



All size VPAs are producing results that are showing very strong & clear similarities :

1) A logical **bimodal structure of Fishing mortality**, showing 2 modes on small and on large fishes, and lower levels at intermediate medium sizes
2) A marked decline of PS fishing mortality at medium sizes, and always the lowest Fi between 75 & 95 cm
3) The 2 stanza growth curves always producing reduced levels of F on juvenile YFT, as the same catches are taken during a longer period.

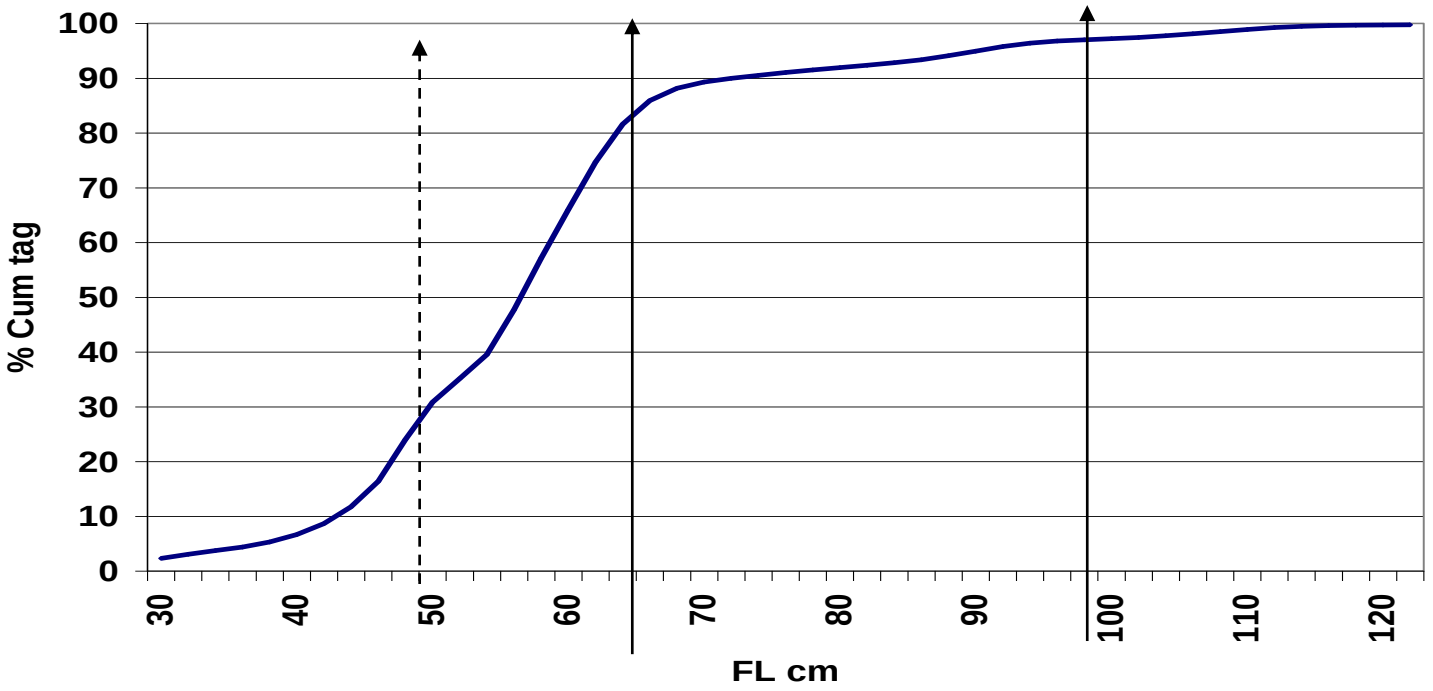


Small medium large

Ratio on numbers of recoveries/ numbers of fish caught by purse seiners, f (size)

Showing:
(1) increasing recovery rates of tags at sizes missing from the PS catches and quite stable rates of RR between 75 & 130 cm
(2) much lower recovery rates at small sizes, but simply because of the small numbers of small YFT tagged, & in comparison with the large size of this population.

Sizes of YFT tagged



Small medium large

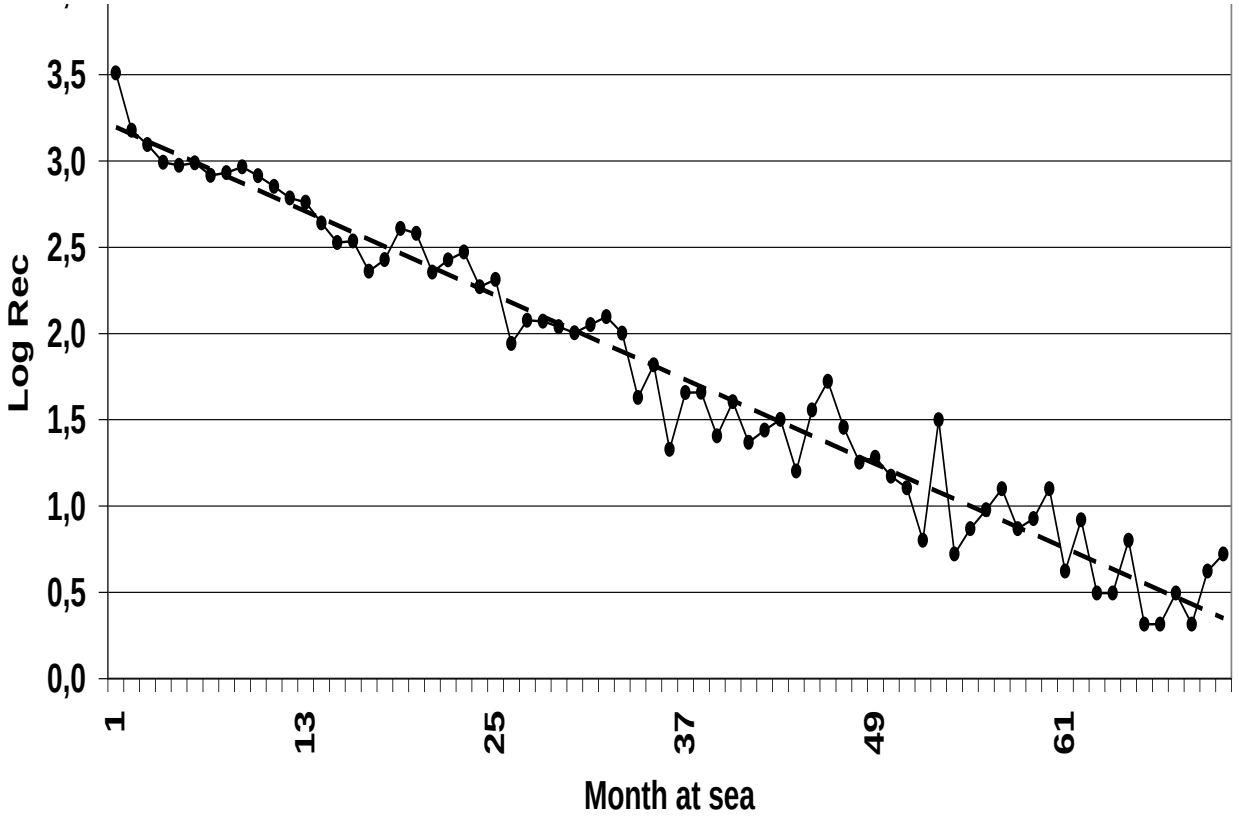
Cumulated numbers of YFT tagged as a function of their tagging sizes

A great majority of YFT have been tagged at small sizes <65 cm: 86%,
but very few of them have been tagged at very small sizes: for instance only 24% of YFT were tagged under 50 cm

Average sizes of tagged yellowfin swimming in the Indian Ocean during the 2006-2011 period?

The average numbers of tagged YFT as a function of their sizes can be estimated:

- Assuming that all the tagging were done the same day at their tagged sizes,
- Assuming a constant average total mortality to these tagged tunas, this Z being estimated by the attrition rate or recoveries at 0.5

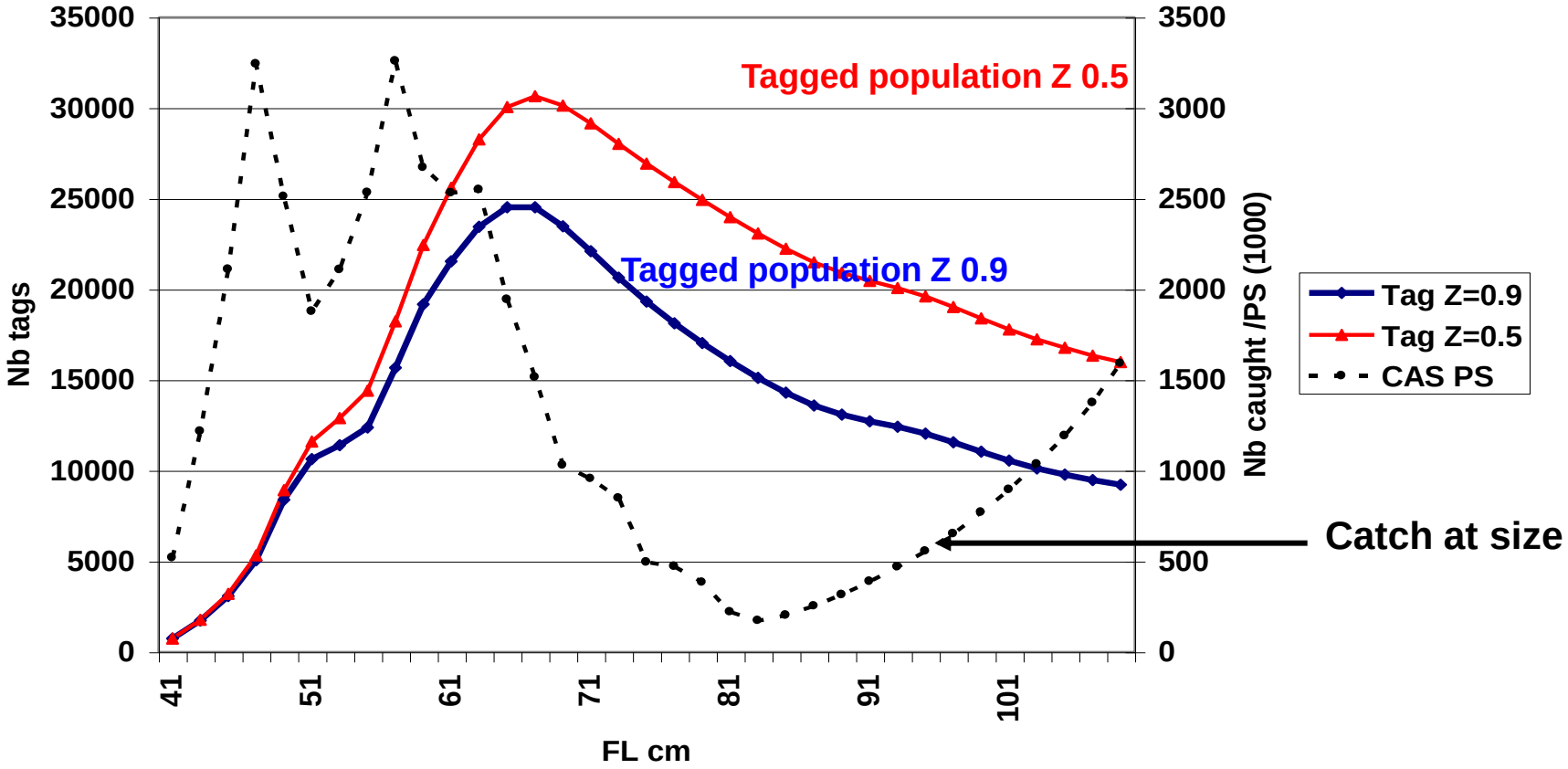


Apparent Z=0.5 yearly loss of Pop Size= 40%

(Possibly too low?)

(figure & rate based on recoveries corrected for fleets reporting rates)

Estimated numbers of numbers at size of tagged YFT swimming the Indian Ocean, as a function of fish length, under 2 hypothesis of 2 total mortality: 0.5 & 0.9

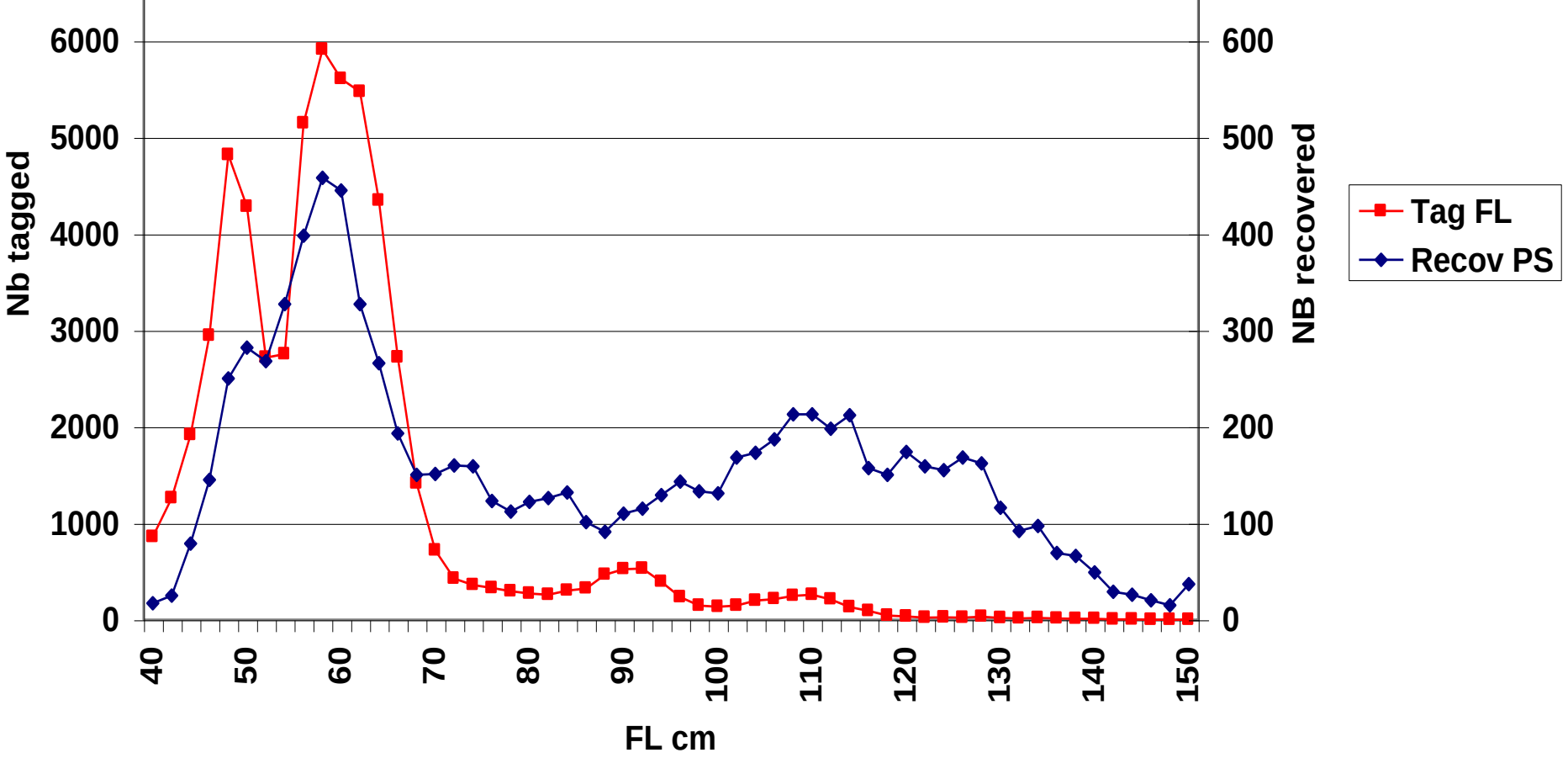


The average numbers of tagged YFT as a function of their sizes can be estimated:

(1) Assuming that all the tagging were done the same day at their tagged sizes,

(2) Assuming a constant Total mortality to these tagged tunas

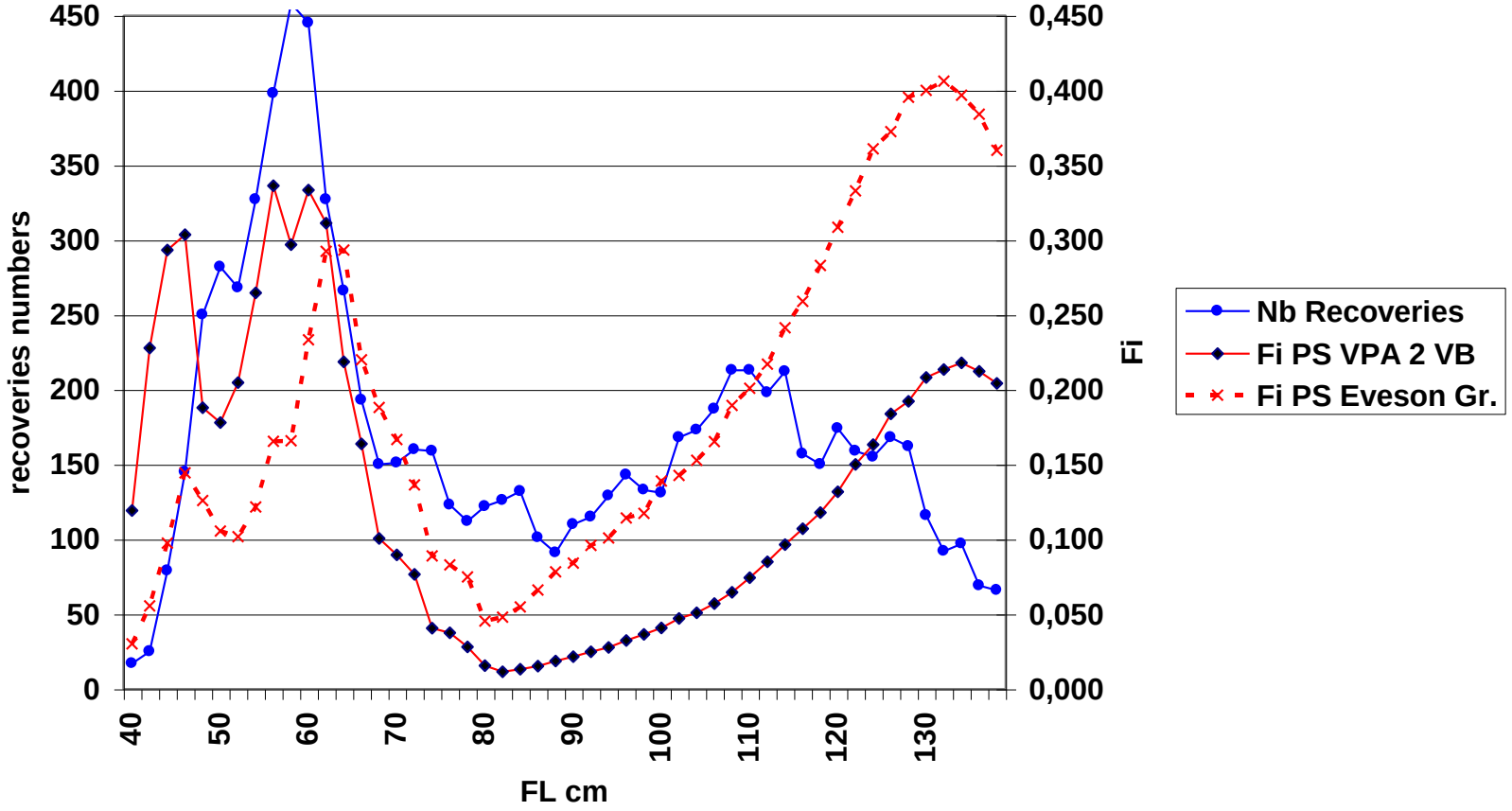
This figure shows some results of these simulated sizes: showing that for realistic Z, for instance between 0.5 and 0.9, the **number of tagged YFT would have been dominated by medium size YFT,** i.e. the missing sizes that are seldom caught by PS.



Total numbers of YFT tagged, and numbers recovered by PS as a function of their sizes at recovery

Recoveries at size of YFT by purse seine showing a quite flat bimodal pattern between 45 & 130 cm,

- a first mode between **45 & 65 cm**, at the dominant sizes tagged
- a second minor mode of adult recoveries between **1 & 1.3 m**.



Recoveries at size & estimated fishing mortalities at size under 2 growth hypothesis

✓ All size VPA tend to indicate a decline of Fishing mortality exerted by purse seiners in the range of sizes between 70 cm & 1 m.

✓ This decline of Fishing Mortality is not well visible in trend of PS recoveries at size,

✓ The quite high rate of recoveries at medium sizes was partly due to a **geographical effect**: large proportion of recoveries south of the Equator close to the Tanzanian tagging area

Conclusion

- No doubts that medium size YFT have been very seldom caught by purse seiners during recent years & during the tagging programme,
- When quite **large number of tagged YFT** have been recovered by the PS fishery in this interval of missing sizes
- Simulations of cohort growth, following the today 2 stanza growth model would indicate that the **acceleration of the YFT growth** observed during this period of low catches could widely explain this decrease in the medium size YFT catches.
- This decline of medium sizes catches is also possibly due (1) to changes in the schooling **behaviour & loss of FAD association, & (2) to a northern migration** of the missing medium size yellowfin
- When the quite **large numbers of recoveries** observed during this size range 70-90 cm of low catches would be due to a combination of

(1) a geographical effect: **proximity of fishing and of tagging zones**

(2) a **statistical accumulation of tagged YFT tunas in the interval of the missing YFT sizes.**