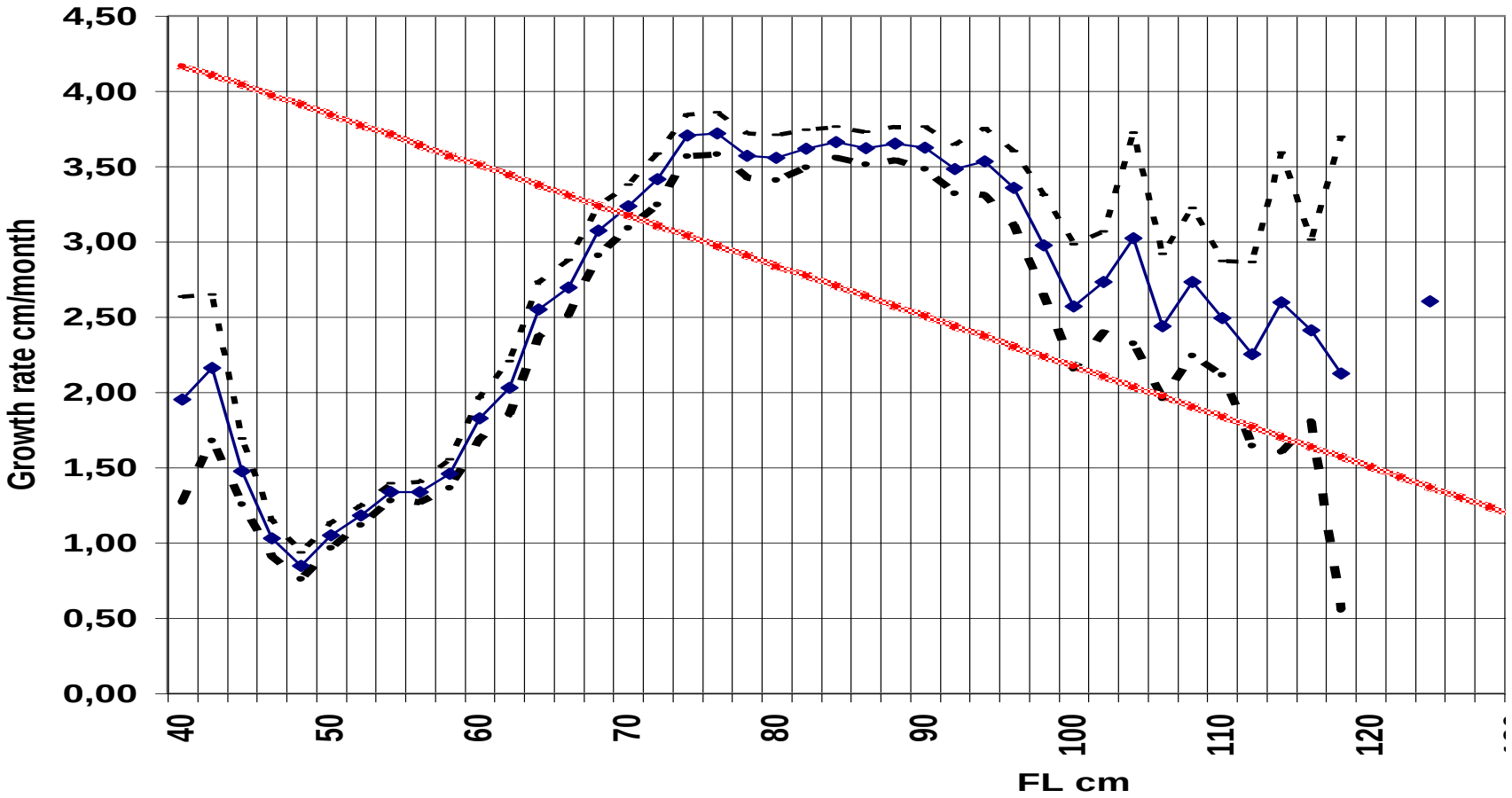
Growth rates and apparent growth curves, for yellowfin, skipjack and bigeye tagged and recovered in the Indian Ocean during the IOTTP

by Fonteneau Alain and Didier Gascuel



- **This study has a limited but interesting goal: to estimate apparent growth rates of each species as a function of their sizes, without targeting a modelling of these apparent growth rates.**
- **This result will show for the 3 species “an observed truth” in the size specific growth rates obtained from the tagging/recovery results (in the range of recovered sizes).**
- **On the opposite: complex growth models are often difficult to fit to recovery data, especially because they are often mis-specified when compared to the complex real growth patterns observed on the recovered tunas,**
- **and because of the basic and major uncertainties in the real biological asymptotic sizes of these recovered tunas: their real L infinity remain often uncertain**

- **At least these observed results could easily be compared to the estimated growth rates obtained from other more complex *ad hoc* growth models.**
- **These growth rates at size can be easily compared between species, this comparison being for instance very interesting between yellowfin and bigeye.**
- **These basic growth rates at sizes can also easily be compared between oceans: Atlantic, Western and Eastern Pacific,**
- **when the results obtained from more or less complex given growth models are often much more difficult to compare.**
- **These estimated growth rates at size may well allow to build a realistic catch at age table, without using a growth model.**

Elimination of questionable recoveries
present recovery file still contains errors that should be eliminated from growth analysis

Reliability of fish measurement

all the records with a “BAD” quality have been eliminated.

All length recorded in round fork length and in predorsal length have been converted in estimated fork length.

Unknown or doubtful recovery date

only the recoveries showing an uncertainty lower than

10% have been kept for the growth analysis.

Species changes between tagging and recovery:

A total of 53 recoveries (25 yellowfin, 13 skipjack and 15 bigeye) have been eliminated using this criterion.

Errors in tagging/recovery sizes

Several fishes showing highly unrealistic growth rates: too fast, too slow or quite often negative ones. A small and arbitrary percentage of 1% of the slower and faster growth rates have been eliminated for each species from the recovery file.

Minimum duration at liberty

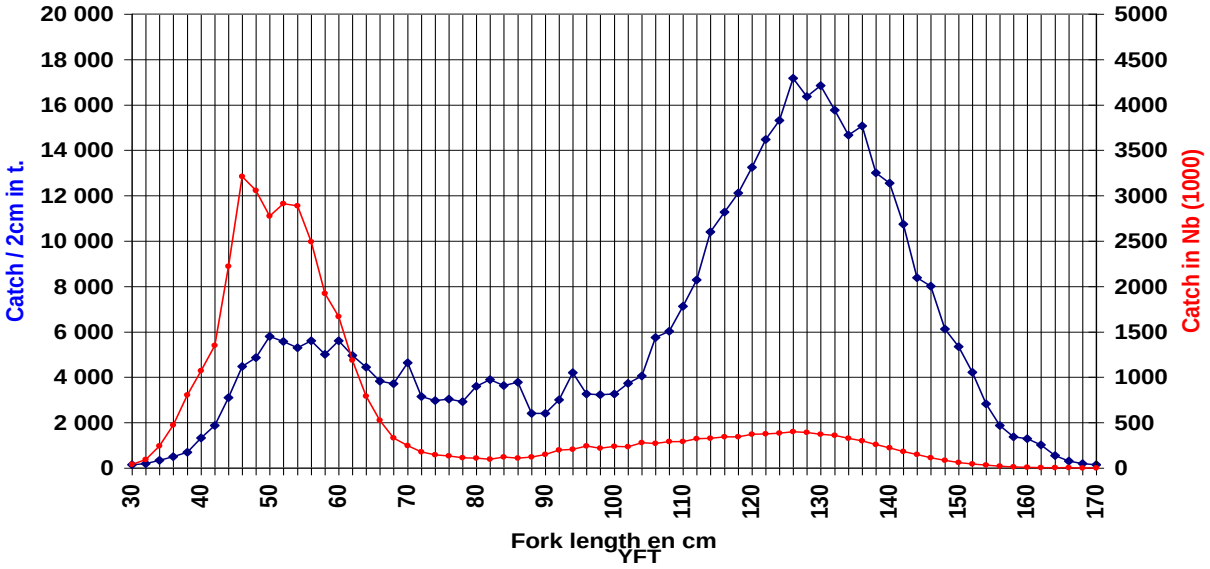
All the tunas with a too short duration at liberty over 30 days were kept for the present growth analysis in order to allow some visible growth between tagging and recovery.

Tuna shrinkage: 2%?

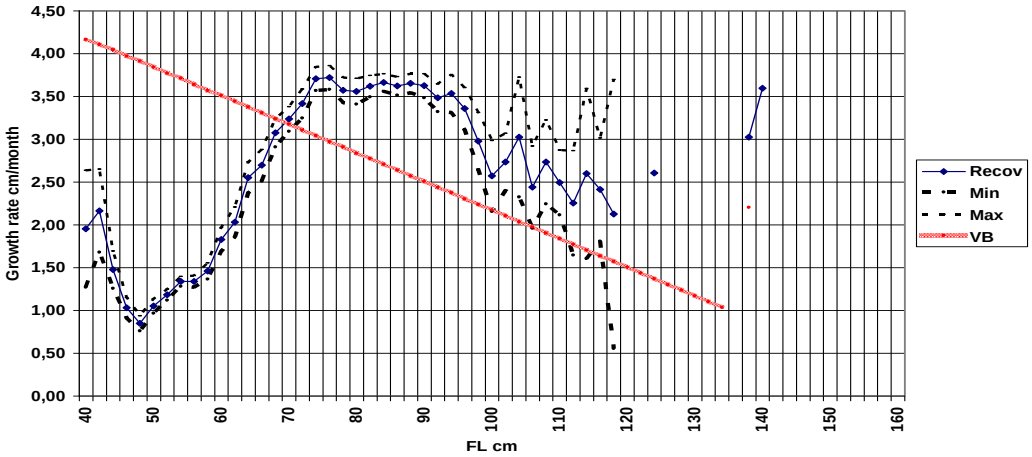
Numbers of selected recoveries:

Species	Total recoveries	Selected recoveries
Yellowfin	7994	4698
Skipjack	11502	6707
Bigeye	4528	2581
Total	24024	13986

Catch at size



Growth rates

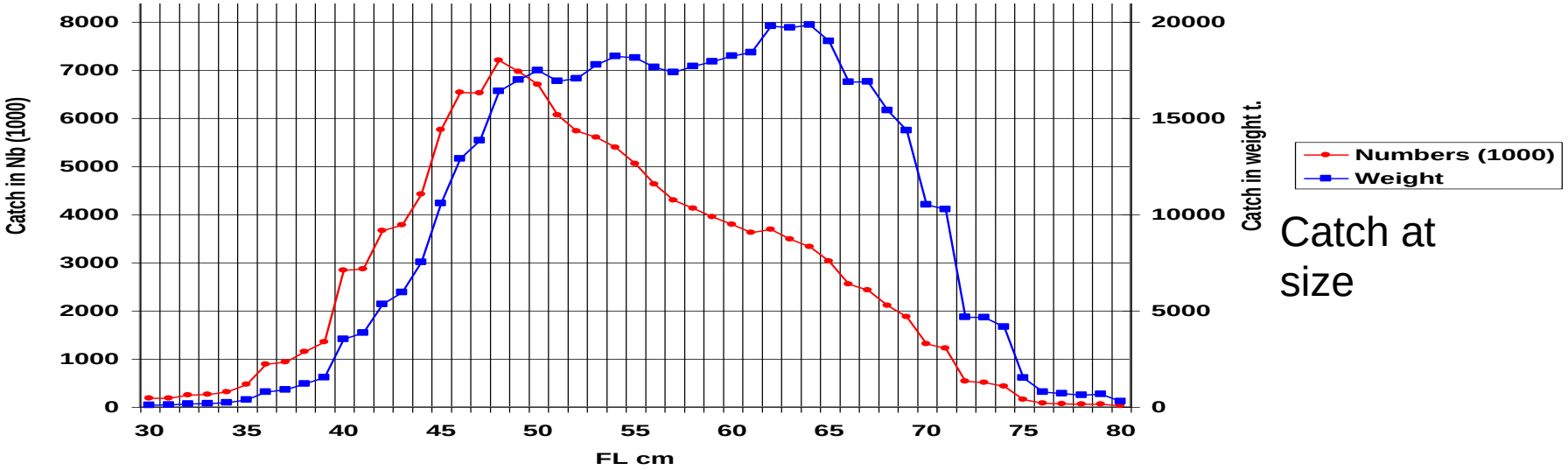


Yellowfin total catch at size (in number and in weight, 2000-2006) and growth rates at size estimated from tagging results. The Von Bertalanffy growth curve done with the parameters proposed by Stequert et al 1996.

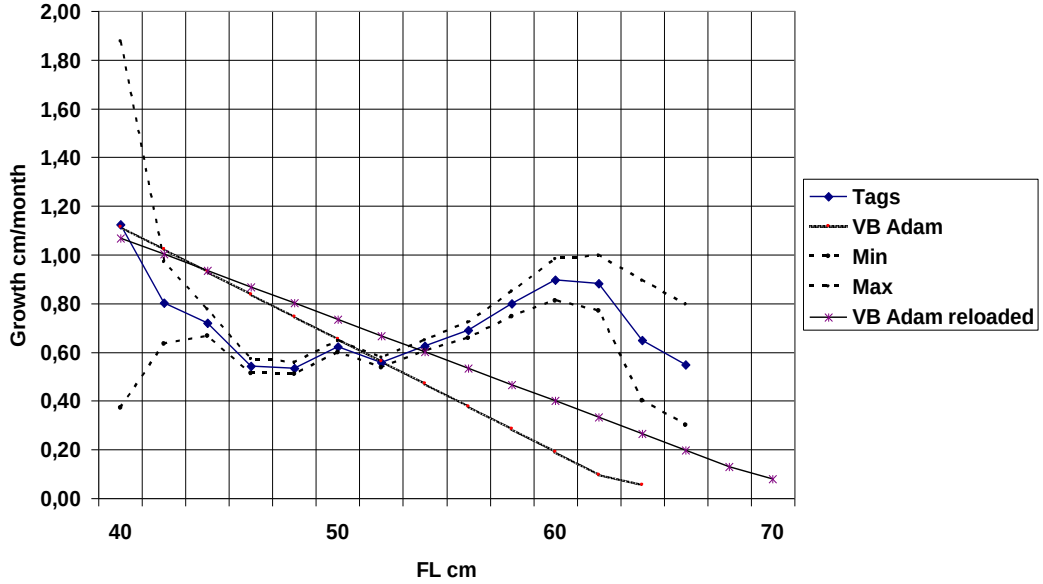
Duration between 40 & 80 cm:

=>from tagging: duration = 23.1 months

=> From VB: only 12 months



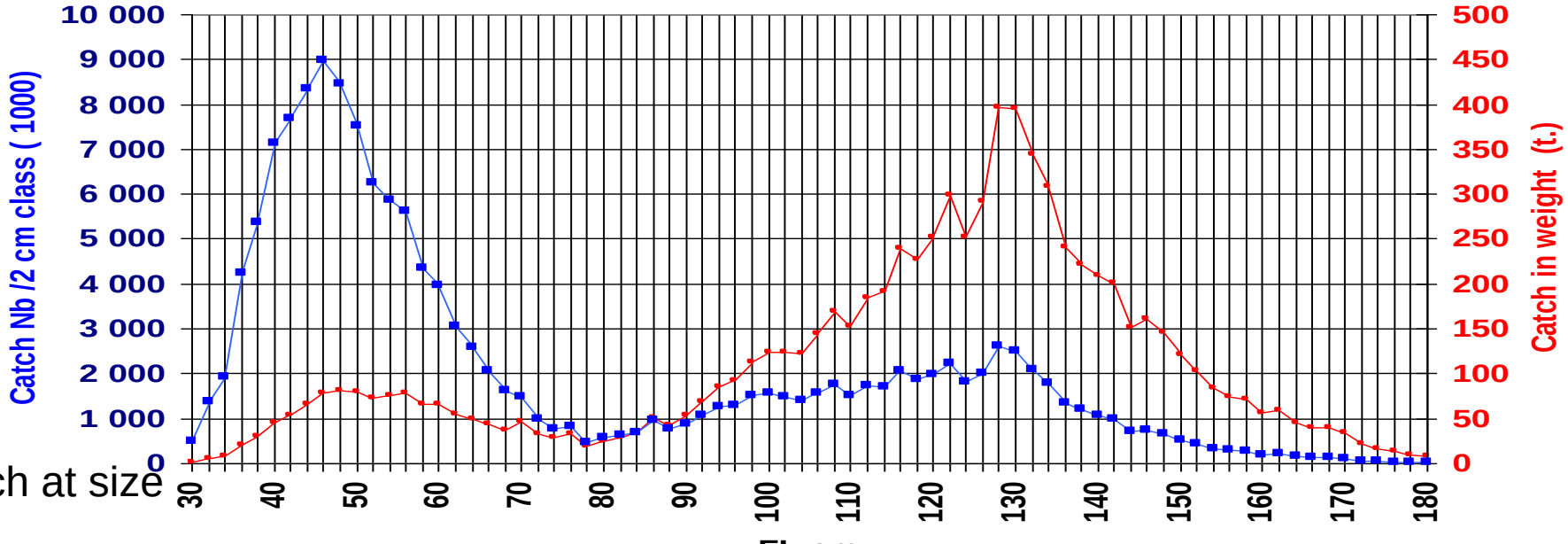
Catch at size



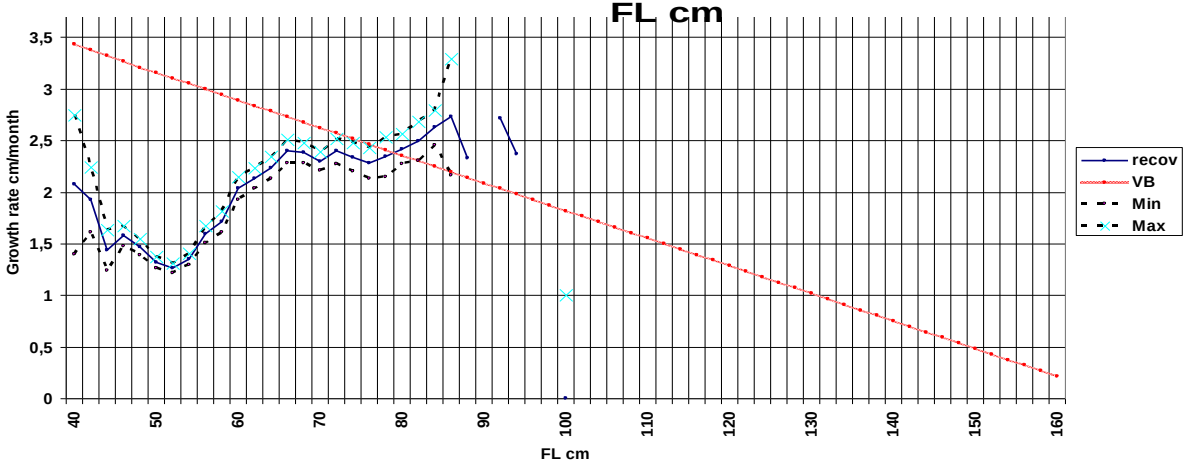
Growth rates

Skipjack **total catch at size (in number and in weight, 2000-2006) and growth rates at size estimated from tagging results. The 2 Von Bertalanffy growth curves shown are the original best one porposed by Adam 1999 (L infinity at 65cm, lower curve) and a revised and equivalent estimate proposed by Fonteneau 2003 (upper curve)**

Catch at size



Growth rates

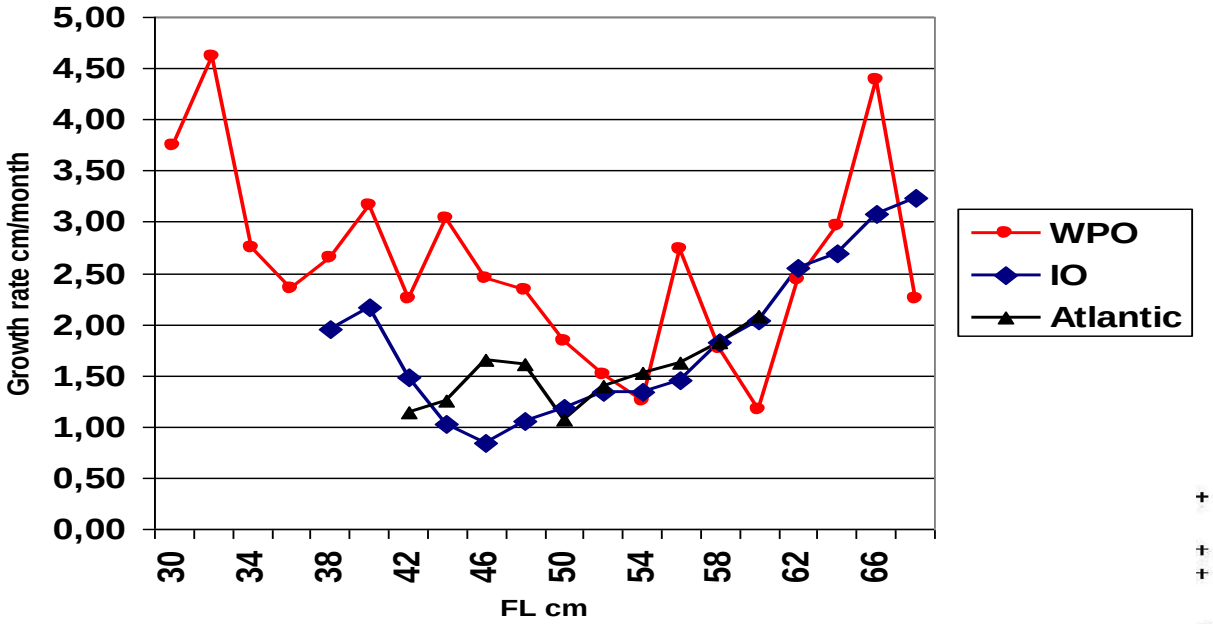


Bigeye total catch at size (in number and in weight, 2000-2006) and growth rates at size estimated from tagging results. The Von Bertallanfy growth curve done with the parameters proposed by Stequert et al 2004.

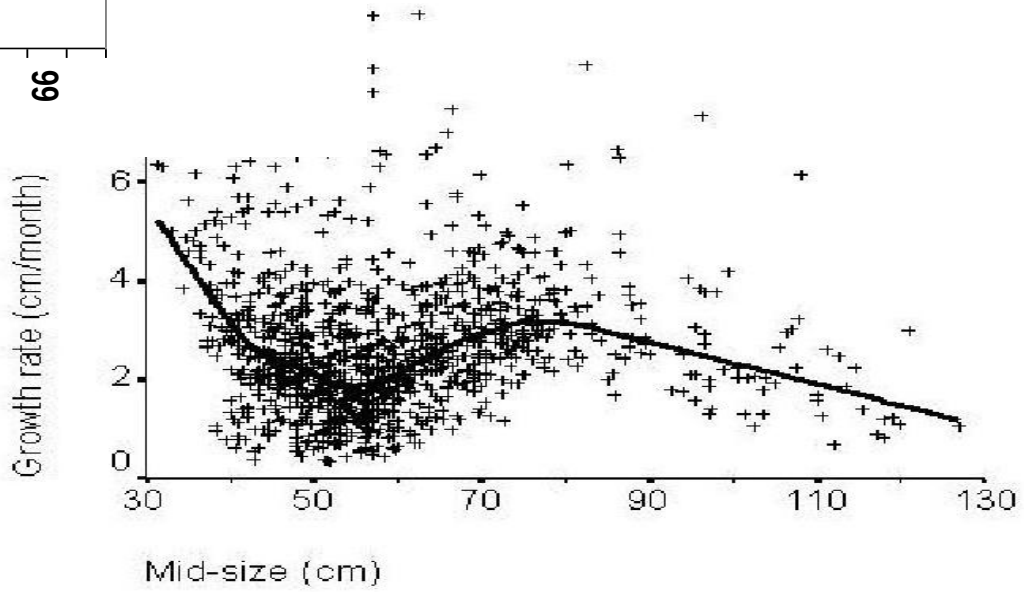
Duration between 40 & 70 cm:

=>from tagging: duration = 17.5 months

=> From VB: only 9.8 months

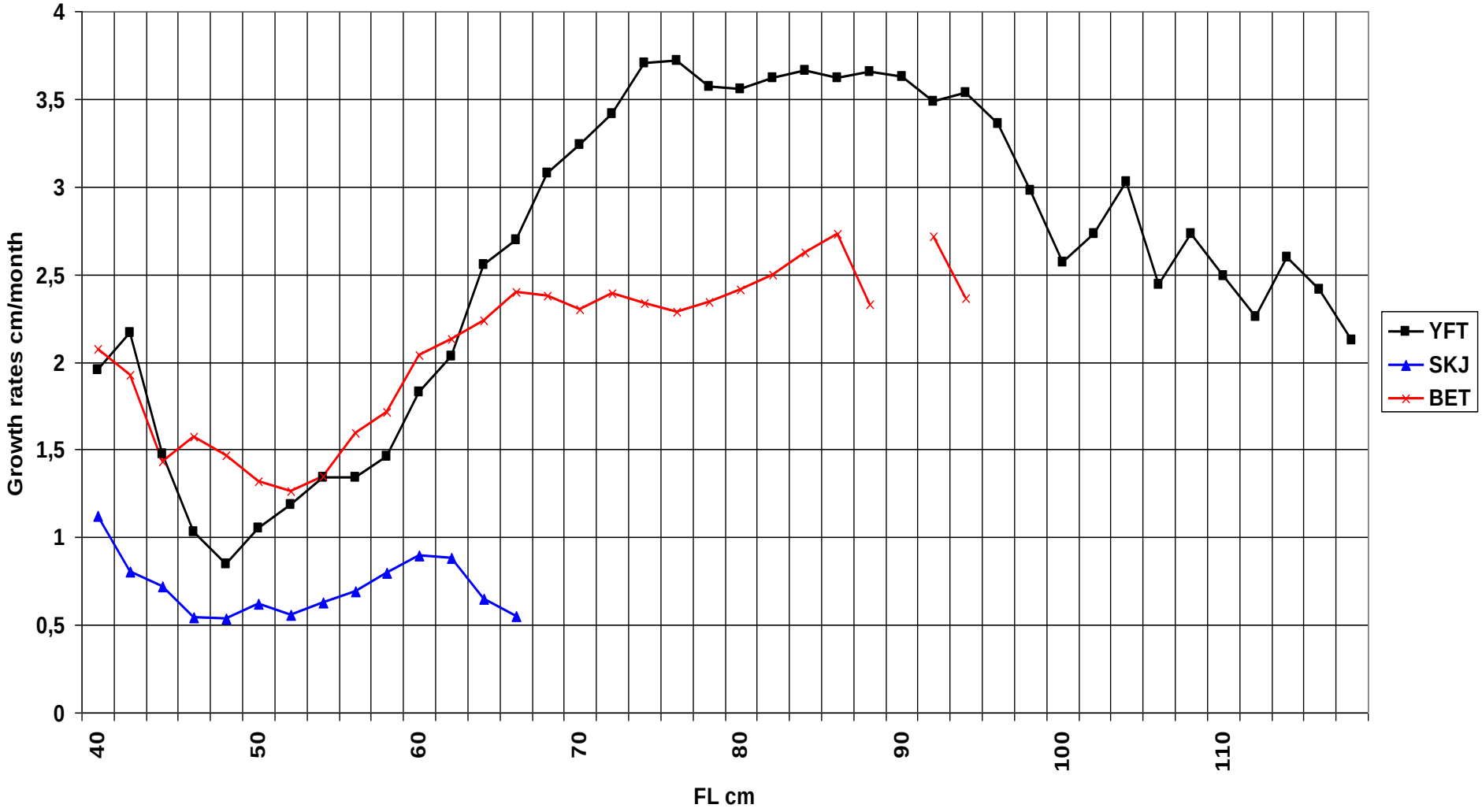


= juvenile yellowfin growth is similar world wide
= this slower growth of juvenile yellowfin was fully apparent in modal progressions (IO & Atl)

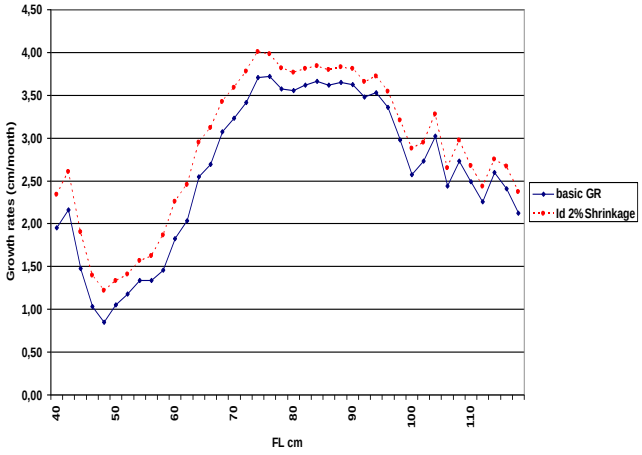


Growth rates at size (in cm/month) presently estimated for juvenile yellowfin from recovery data in the Western Pacific (Hampton subset of recovery data) and the Atlantic. Figure on the right taken from Lehodey, P., Leroy, B., 1999 shows the daily growth of individual recoveries in the Western and central Pacific.

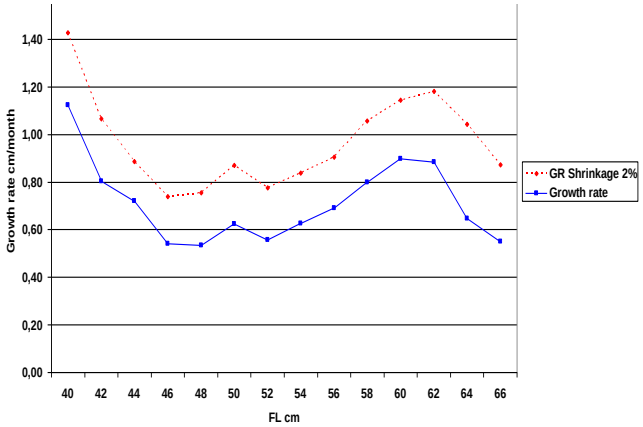
Average growth rates at size (in cm/month) presently estimated for yellowfin, bigeye and skipjack tuna from the recovery data



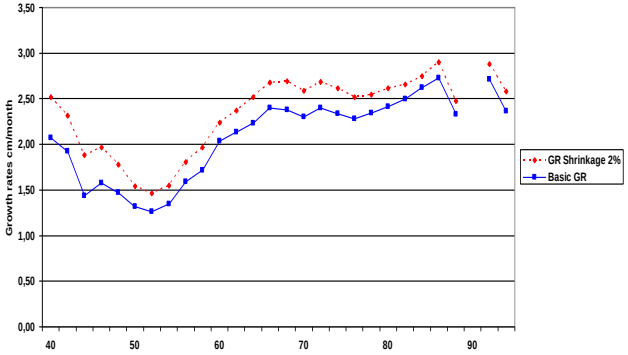
Potential effects of a 2% shrinkage?



Yellowfin
Average growth rates
10.6% higher



Skipjack
Average growth rates
36% higher



Bigeye:
Average growth rates
12% higher

Average growth rates at size (in cm/month) presently estimated for yellowfin, bigeye and skipjack tuna from the recovery data, without and after a 2% of shrinkage constant at all sizes

Tagging results are very strong compared to age readings

- **Our firm present conclusion is that the tagging results are much more significant than the previous hard parts reading, as the evidence of a given growth observed for a large number of well identified tunas tend to be much more convincing than theoretical results from few age reading, that are widely limited by various uncertainties and potential bias in the daily age readings, and by the potential lack/excess of daily rings in the hard parts.**
- As an example: the growth of juvenile yellowfin tuna that has been presently estimated based on 2040 significant recoveries of fishes recovered at sizes under 67 cm, showing an average growth rate of **only 1.6 cm/month**, are a much stronger proof of a small growth than the fast growth at **3.7 cm/month** previously estimated in the same range of small tunas from questionable age readings done on few fishes.

Why the Von Bertalanffy growth curve is not convenient to describe tuna growth?

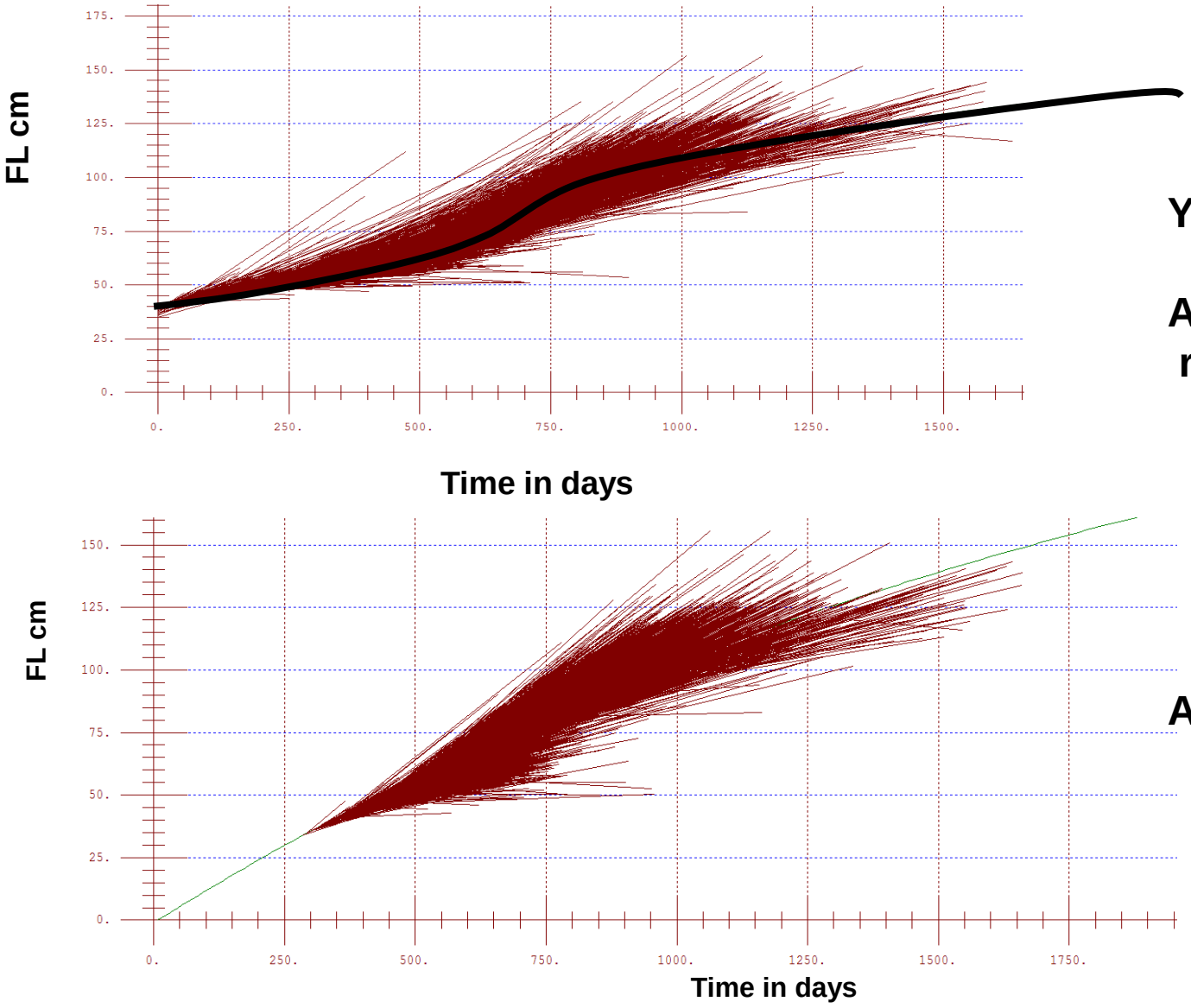
- Tropical tunas do not follow a Von Bertalanffy growth curve, but most often (yellowfin and bigeye) a much more complex growth curve in relation with the changes in the biology and in the ecology/behaviour of these fishes:
  - **Post larvae to 40 cm** (10g to 1 kg), yellowfin and bigeye: an initial fast growth necessarily takes place during the cryptic pre-recruitment and pre-tagging period, between the end of larval stages (first month in the life of a tuna) and the size at recruitment in the fisheries: these very young fishes are probably showing an increase of size between larvae and juvenile of about 30 cm during about 6 month (Eastern Pacific, Wild 1992) or during only 4 month in the Atlantic, based on the seasonality of the spawning season, i.e. with a fast average growth rate of these early pre-recruited fishes of about 5 cm or 7.5 cm /month.
  - At larger sizes in the **40 to 70 cm range**: juvenile growth is slowing down to low monthly rates as during this recruitment period juvenile tunas tend to be concentrated in their equatorial nurseries, in the shallow and warm equatorial waters, between 10°N and 10°S. During this period, most of these tunas are fishes in mixed species schools, often under FADs.

- At preadult sizes and during their sexual maturation, between **70 and 100 cm**, the marked increase of growth rates is probably in relation with a change in behaviour of these tunas : a reduced catchability in the purse seine fishery, these tunas abandon FADs, they are more mobile, deeper and scattered in a wider geographical area toward the south and the North, and probably also in relation with their sexual maturation and the biological effect of increasing sexual hormones.

- At **adult spawning sizes**, the geographical distribution of adult yellowfin and bigeye tend to be widely scattered, these fishes inhabiting a wider range of temperate colder waters (shown by the wide fishing zones of longliners); their growth rates tend to decrease at increasing fish sizes towards the L infinity of each species (as expected in most growth models).

- NB **Faster growth of early juveniles and at puberty** : tunas may well be like kids, growing at faster rates during their sexual maturation…as it was concluded by Davenport in 1922: “human growth curve shows 2 outstanding periods of accelerated growth, the circumnatal and the adolescent”, a conclusion that could be easily transferred to the world of tunas as :

“tuna growth curve shows 2 outstanding periods of accelerated growth, the post larval and the sexual maturation”

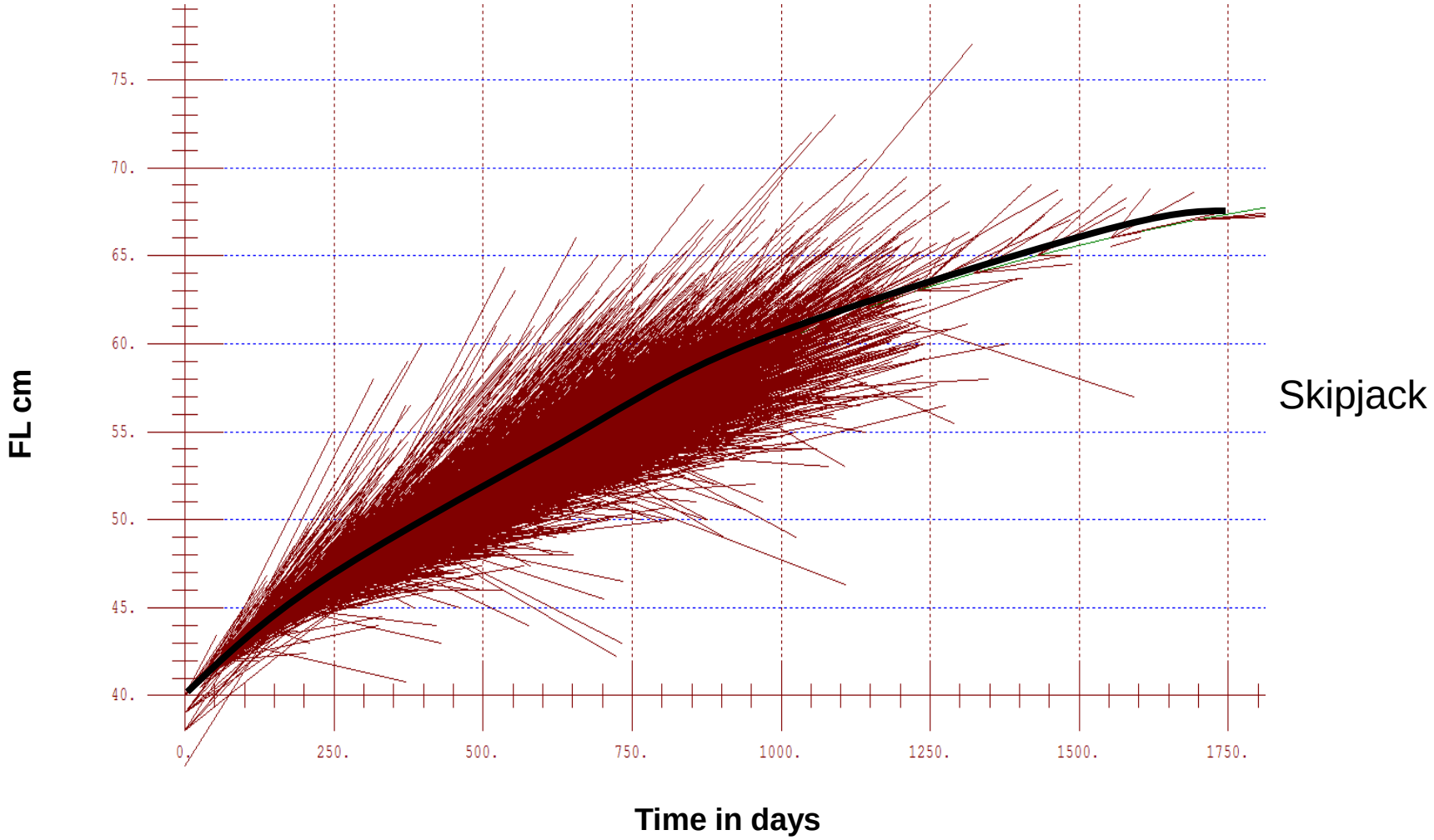


Yellowfin recoveries

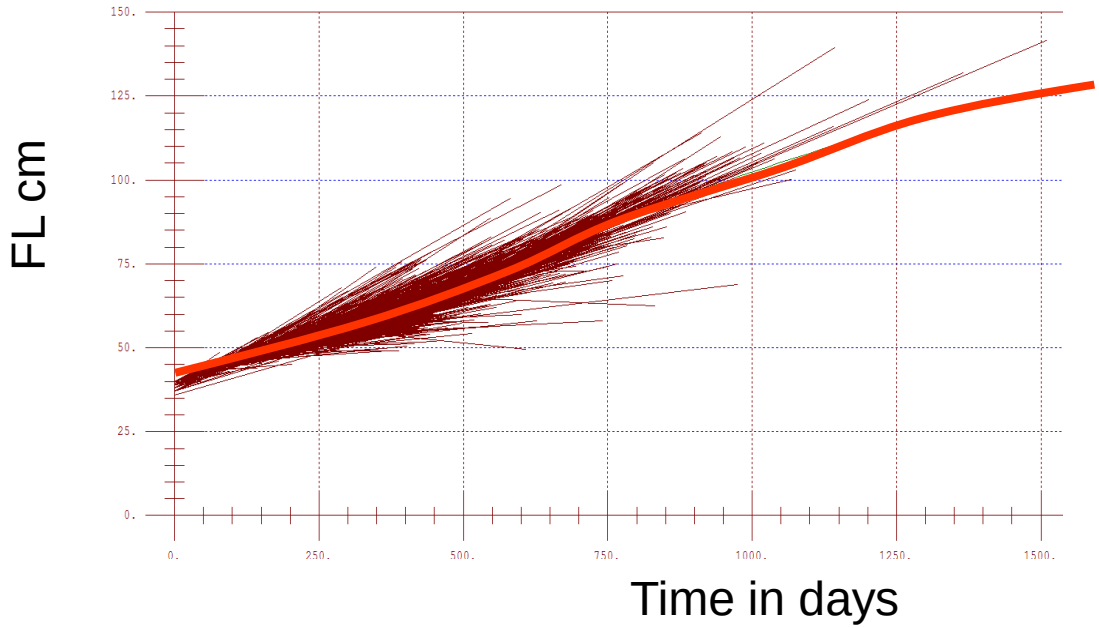
And estimated growth rates at size

And Stequert VB model

PLOTREC figure showing the changes at size of the yellowfin: recoveries adjusted to a Stequert VB model (lower figure) and to average growth rates at sizes followed by a Stequert VB cirve after 100 cm (upper figure)

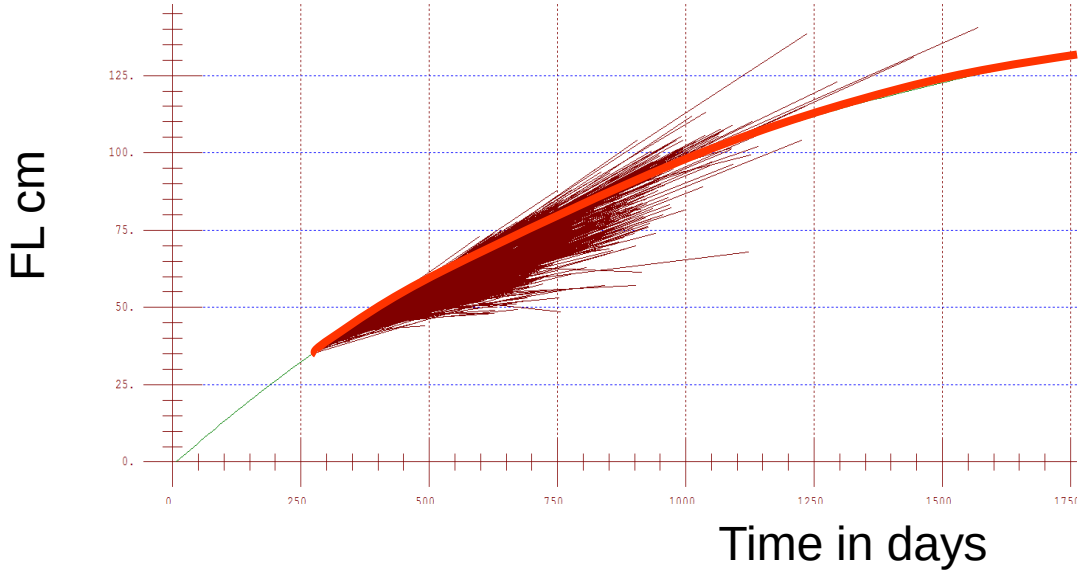


PLOTREC figure showing the changes at size for the skipjack recoveries adjusted to a the recovery data in the range 40 to 56 cm, followed by a VB growth curve using L infinity= 73cm and k=0.40)



Bigeye recoveries

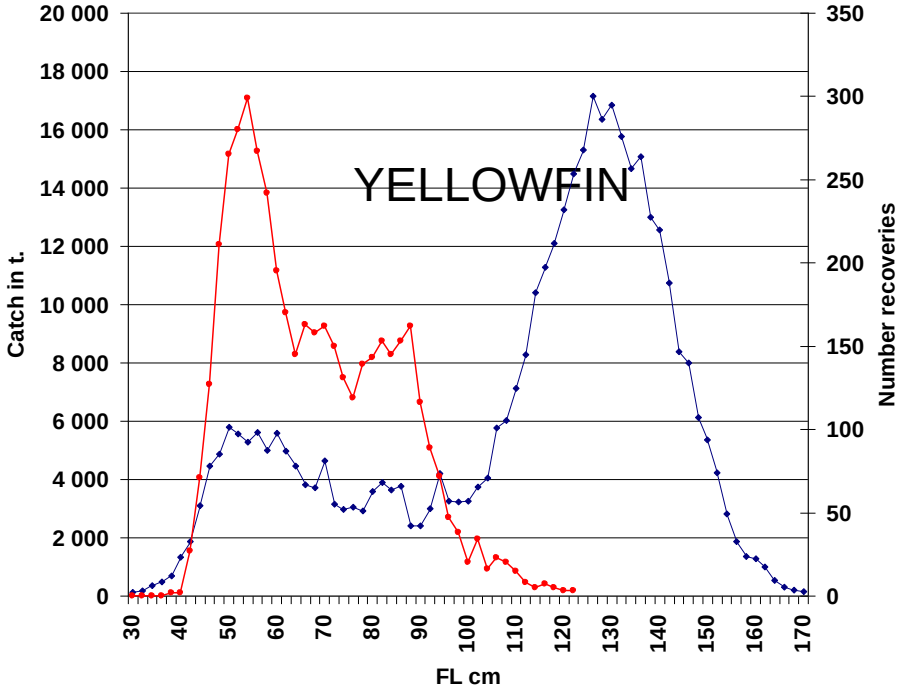
And estimated growth rates at size

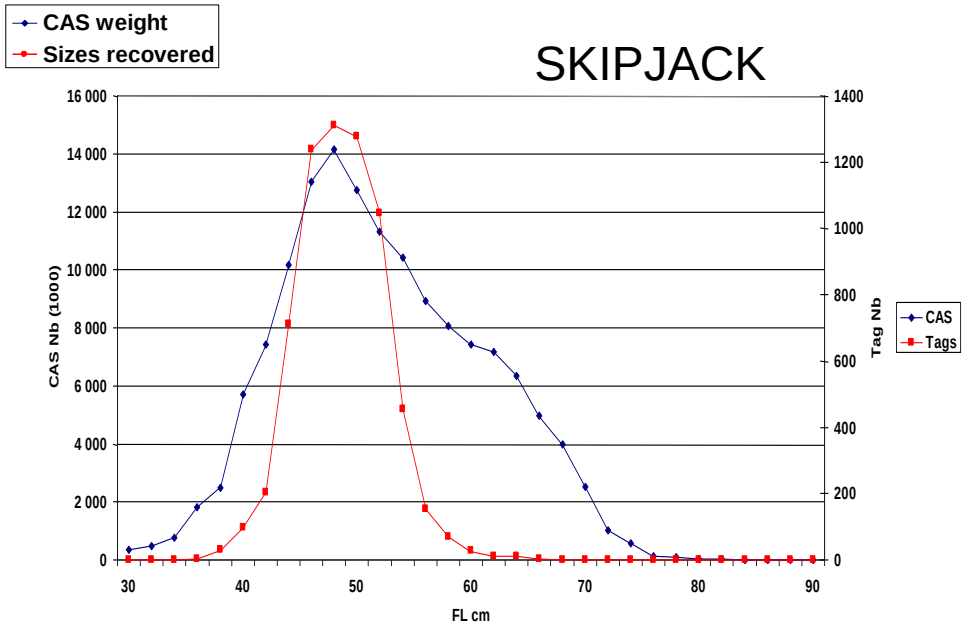


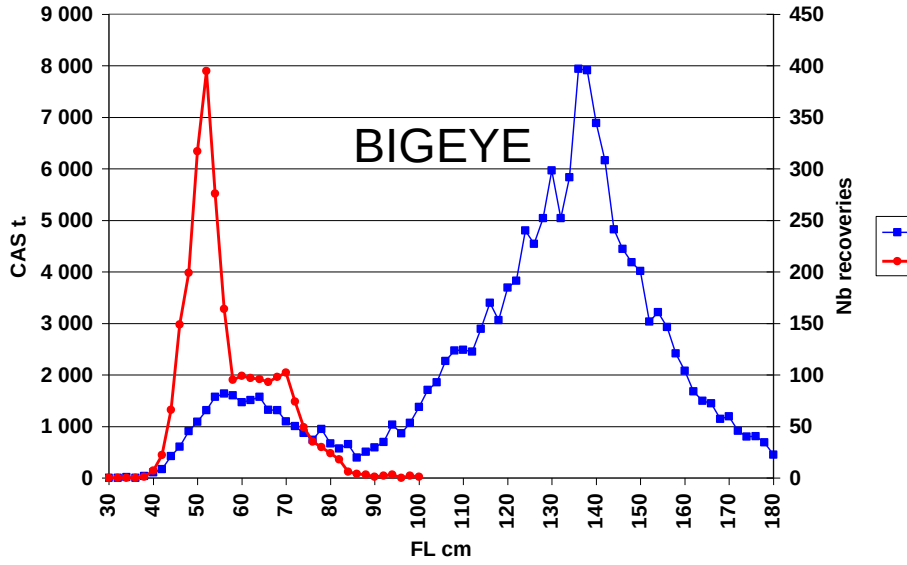
And Stequert VB model

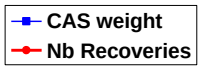
PLOTREC figure showing the changes at size for the bigeye: recoveries adjusted to a Stequert VB model (lower figure) and to average growth rates at sizes followed by a Stequert VB curve after 80 cm (upper figure)

Tagged sizes and total catch at size

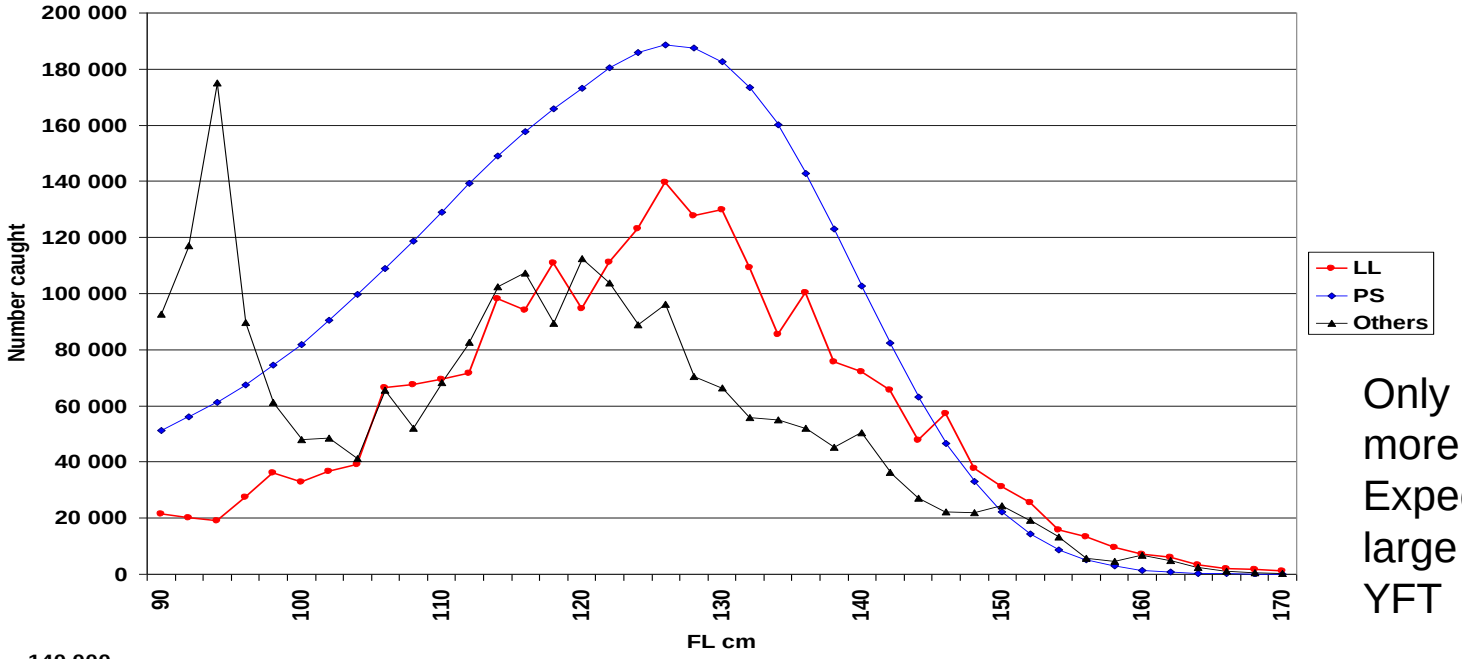






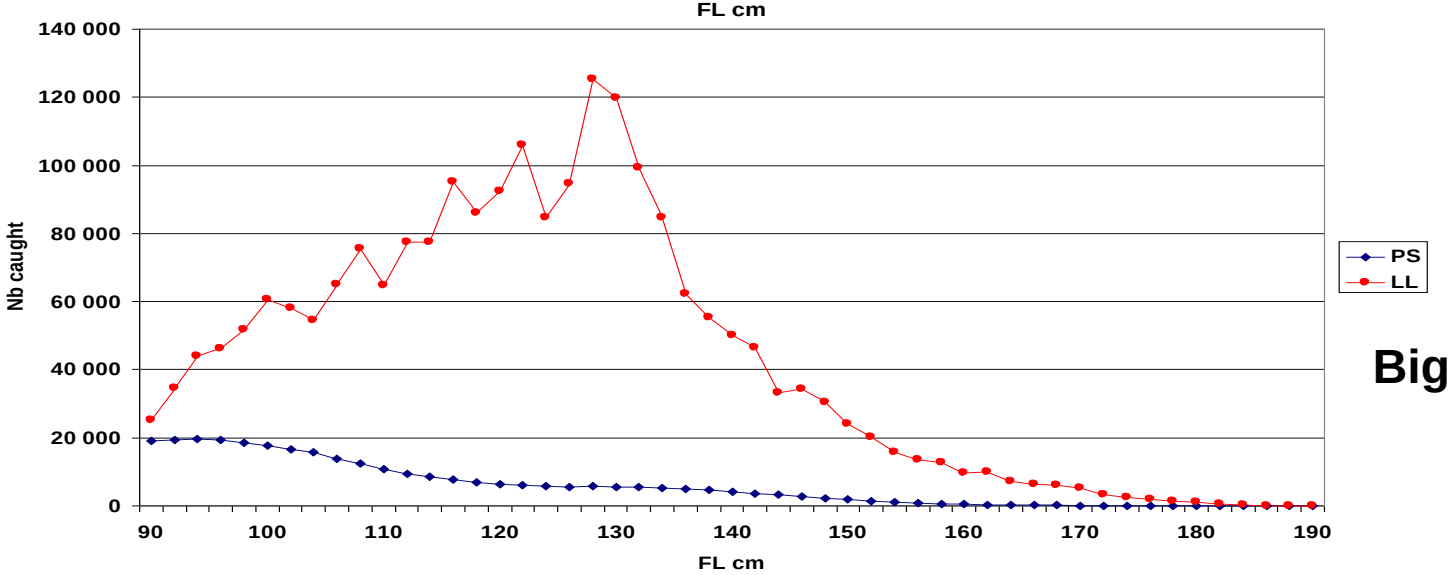


Average catch at size (in numbers of fishes) of yellowfin , skipjack and bigeye and numbers at sizes of the recovered tags for each species (sizes at tagging, in red)



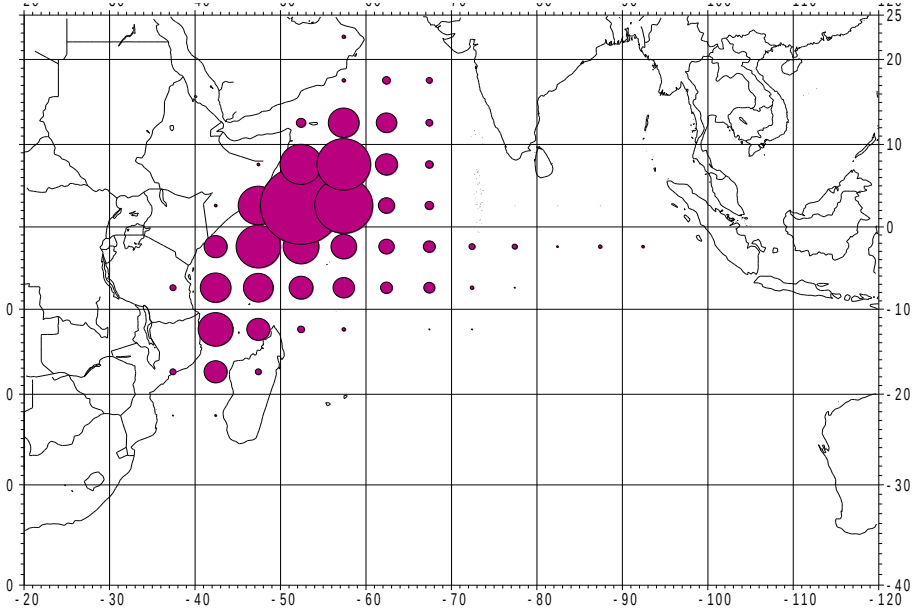
Yellowfin

Only 17 recoveries by LL, more than 500 recoveries Expected based on their large catches of large YFT



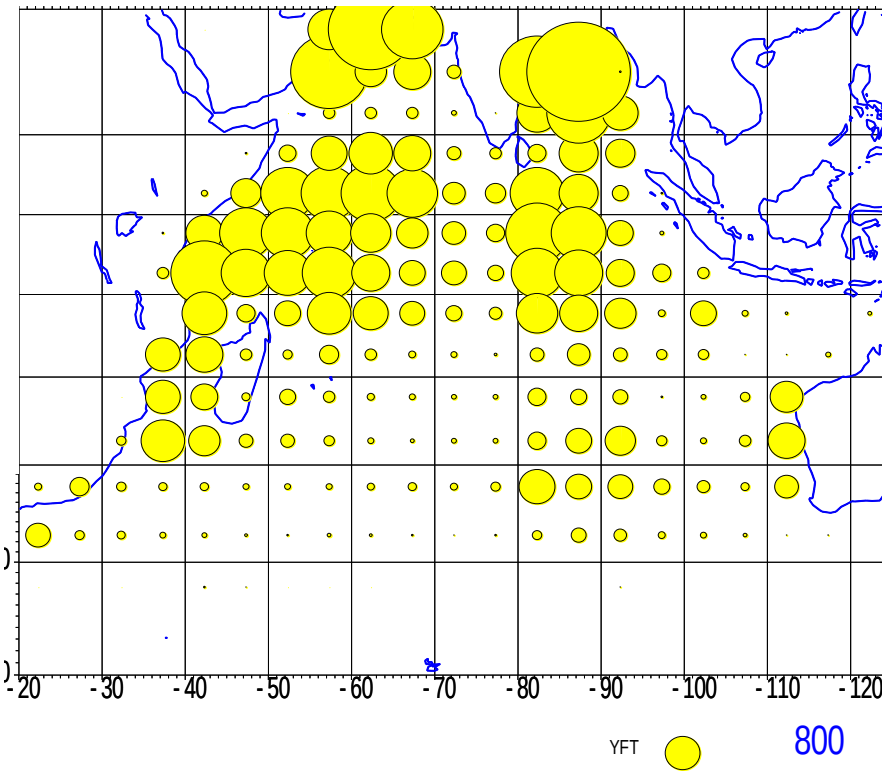
Bigeye

Average catch at size by gear of yellowfin and bigeye in the Indian Ocean during recent years (average period 2000-2005)

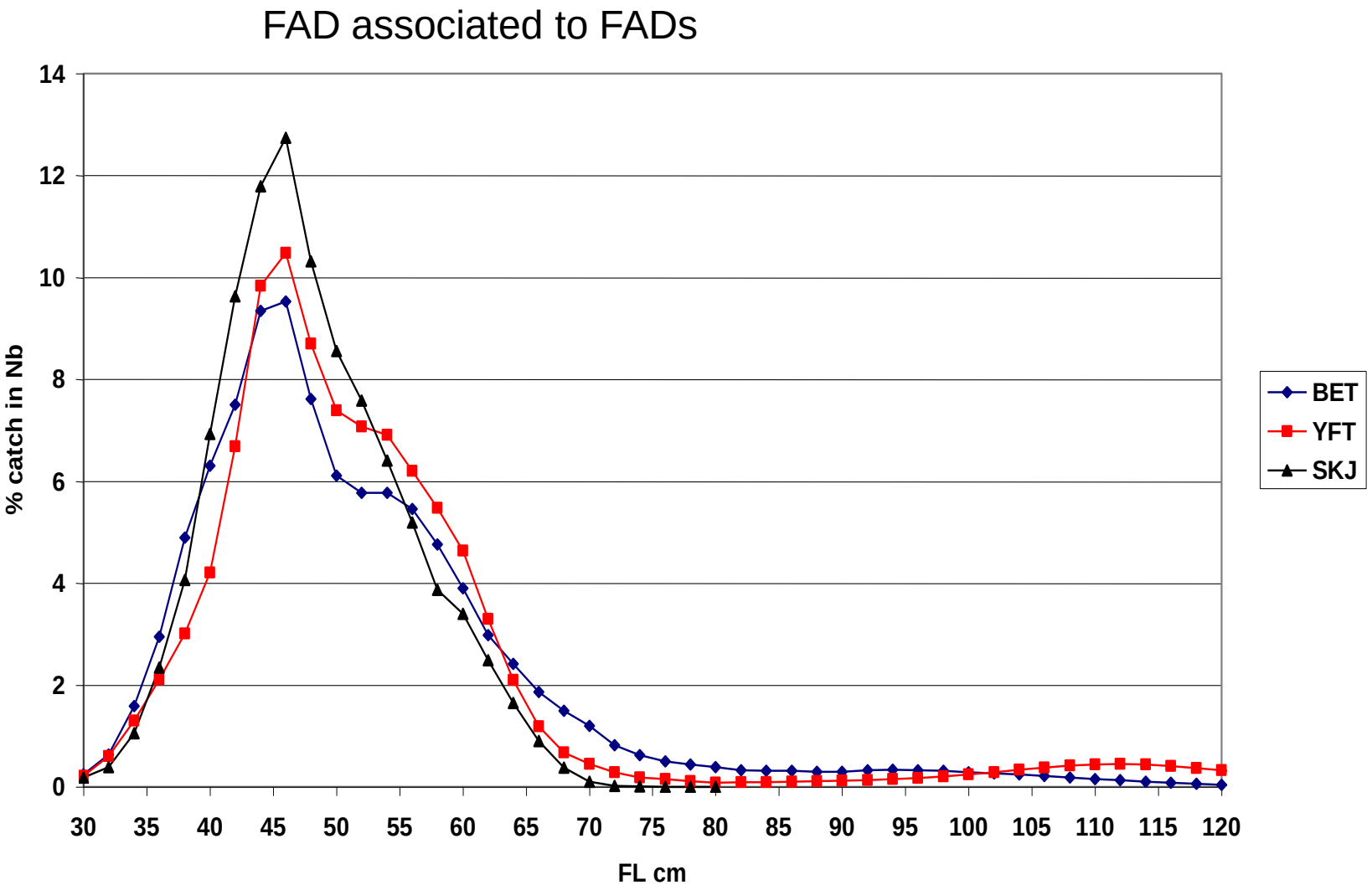


Purse seine

Longline



Fishing map showing the average catches of small yellowfin (<90cm) by purse seiners, left, and of large yellowfin by longliners, right (period 2000-2006). *Catches by longliners are showing well the potential geographical distribution of adult yellowfin, when catches by purse seiners tend to indicate some of the major yellowfin nurseries. These 2 figures are showing a well known fact that adult yellowfin have a much wider geographical distribution than the juveniles of the same species. The same observation can also be done for bigeye.*



Average sizes of yellowfin, skipjack and bigeye tuna smaller than 120 cm and caught in the Indian Ocean associated to FADs (1991-2006 period), the 3 size distributions being shown in term of percentages.

Yellowfin: present tagging results are showing that:

- Juvenile yellowfin tunas are exploited during a period of **23 months** between 40 and 80 cm (i.e. between 1 and 10 kg), while in the previous Von Bertalanffy model this range of size was exploited during a much shorter period of only **13.7 months**.
- It would also mean that the age at first spawning of 1 meter yellowfin would have now an age of approximately 3 years, while this spawning size was reached at an age of about only 2 years in the previously used Von Bertalanffy model.

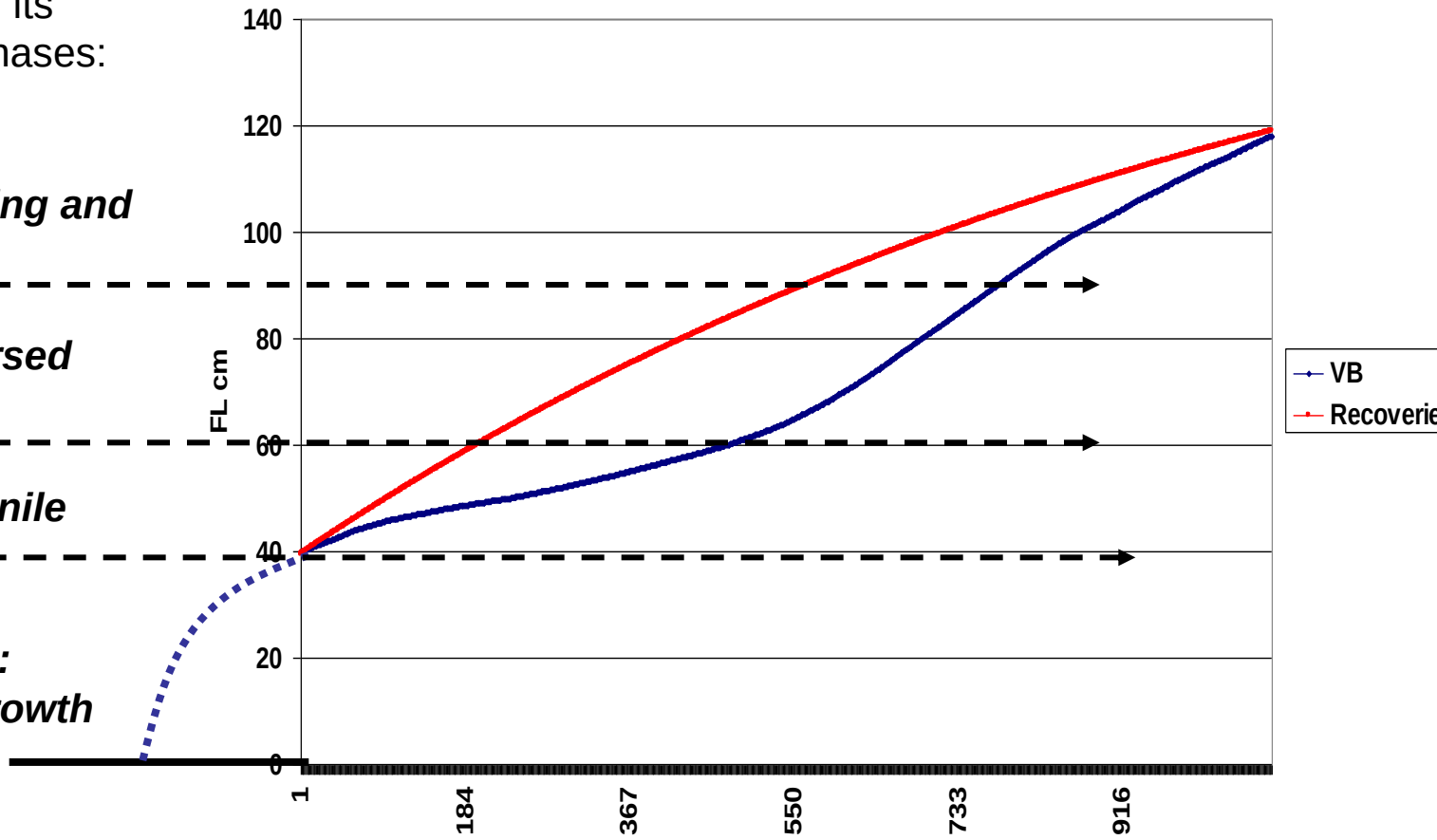
Yellowfin growth and its corresponding ecophases:

=> Adult migrating between their feeding and spawning grounds

=> Maturing dispersed tunas

=> FAD assoc juvenile

=> Cryptic nursery: 6 months & fast growth



- Juvenile bigeye tunas are exploited during a period of **17.5 months between 40 and 70 cm** (i.e. between 1 kg and 7.2 kg), while in the previous Von Bertalanffy model this range of size was exploited during a shorter period of only **9.8 month**.
- Skipjack tuna: the potential changes between the Von Bertalanffy and present tagging results are much less important, but may be still significant;

  they should be better analyzed.

- **These wider durations of the early exploitation should of course be kept in mind in the future modelling of the yellowfin and bigeye stocks, and also skipjack:**
- **such long duration of the early exploited lives and with a slow growth, when compared to a short duration and a fast growth (each cohort suffering in each interval of time a given natural mortality at age), could produce widely different results:**
  - **in terms of yield per recruit,**
  - **Of estimated fishing mortality at age,**
  - **Of levels of recruitments**
  - **of potential interaction between fisheries catching juvenile or adults tunas.**
- **This confirmation of slower growth patterns should also reinforce the pressure on IOTC scientists to use assessment models that are using a reduced time scale such as quarters**

Conclusion

- **Present recoveries are already fully conclusive to show growth of juvenile yellowfin and bigeye, and of skipjack, and their results can be used in stock assessments, & using small time intervals (at least quarters)**
- **They fully confirm the complexity of tuna growth patterns**
- **These results fully confirm that the simple, but too simplistic, Von Bertalanffy model should never been used for yellowfin and bigeye stock assessments**
- **The observed changes in growth patterns at size and age are probably corresponding to changes in the tuna ecophase, physiology and behaviour.**
- **These relationship between changes in growth and tuna ecology/physiology should be better analyzed in order to allow a full understanding of these phenomenons**