ANALYSIS OF TREND OF TOTAL YEARLY CATCHES OF YELLOWFIN TUNA *(THUNNUS ALBACARES)* IN THE INDIAN OCEAN AND STATUS OF STOCK.

By Alain Fonteneau[1] and Daniel Gaertner[2]

SUMMARY

This document analyzes the trend of the yearly total catches of Indian Ocean yellowfin tuna. The yearly indices RRCI or Relative Rate of Catch Increase are calculated during the entire fishery. This index has been reaching negative levels since 1996. As the fishing effort exerted on yellowfin stock has been permanently increasing during recent years, this index indicates that the yellowfin stock would have been overfished since 1996 with an MSY of about 325.000 tons. Some simulations have been done on a yellowfin like species and fishery and their results suggest that the RRCI analysis could provide reliable estimate of stock status. The conclusion is that this diagnosis of overfished stock is probably a realistic one despite of the simplicity method used, as this method appears to be quite robust.

INTRODUCTION

The trends of yearly catches is a very simple information that can be used to efficiently evaluate status of fish stocks exploited by fisheries. This very basic analysis is based on the fact that most fisheries, among them the Indian Ocean yellowfin fishery, are permanently increasing their fishing efforts, at least when the fishery is still profitable, and when there is no limitation to fishing efforts and/or catches. In such a case, the yearly rate of increase of catches tend to decrease when the MSY is approached and this rate is null or negative when the MSY is reached or exceeded. This basic and strong method has been convincingly used by Grainger and Garcia 1996 on a wide variety of stocks and also applied with minor improvements to tuna stocks by Gaertner et al 2001. This method can be of great interest in peculiar cases when detailed data upon the effective fishing effort or sizes taken are not available, and when the exploited stock is showing favorable conditions in the age structure of the fished stock and in the increase of fishing efforts. The present document will analyze the data available, primarily the trends of yearly catches, but also the trend of fishing efforts. This analysis will be done in conjunction of simulation done upon a yellowfin like species exploited by Indian Ocean like tuna fisheries.

DATA AND METHOD

The data primarily used in the analysis were the IOTC data base of yearly catches (table 1). The 1950-1969 series used was revised following scientific document submitted to IPTP in 1991 by Japan (an. 1991) and in agreement with the catch, effort and size statististics submitted to the IOTC by Japan. This data base is primarily built with official data submitted by fishing nations, and in some cases data obtained or estimated by the IOTC secretariat. The data base used was the series available at the end of April 2002 and covering the period 1950-2000.

The analytical method used was the method proposed by Grainger and Garcia 1996, which is an analysis of the rate of increase in the total catches from one year to the other. This method has been used with the minor adjustment described by Gaertner and al 2001. which were added to the original method in order to compensate for desequilibrium of catches which are most often observed during the periods of rapid increase of fishing efforts. A smoothing factor k of 6 years was used in the present calculation, based on the hypothesis that a wide majority of yellowfin catches were taken upon a total of six year classes.

ANALYSIS OF CATCH TREND

The Grainger and Garcia index modified by Gaertner et al. 2001 (or RRCI: Relative Rate of Catch Increase) has been showing erratic variations during the period 1950-1985 (figure 1), but this index tend to be more or less permanently positive during this early period dominated by the longline fishery. During this period, longline fisheries have been operating alone on a stock which was still clearly underexploited (with an average catch of only 43.000 tons yearly). During this early period, the fisheries were operating on the stock at a low exploitation rates, the fishing effort and catches fluctuating as a function of changes of fishing countries and of target species, but not as a function of exploitation rates (with probably several periods with a decrease of effective fishing effort targeting yellowfin). The full interest of the RRCI will be potentially expressed during the subsequent period 1983-2000 during which large and increasing fishing effort exerted by both longline and purse seine fleets have been developed. In such a case, the trend of yearly catches should now be in relation with the stock status. The observed rates of increase of yearly catches are shown by figure 1 and 2. These figures show that the **rate of yellowfin catch increase** tend to be null or negative since 1996, corresponding to an average catch of 325.000 t. This catch could then correspond to the MSY of the stock, at least if the fishing effort was increasing during the recent period.

[1] Fonteneau Alain, IRD scientist, IRD, PO Box 570, Victoria, Seychelles
[2] Gaertner Daniel, IRD scientist, laboratoire IRD, Rue Jean Monnet, 34207 Sète, France

SIMULATION AND ANALYSIS OF "YELLOWFIN LIKE" DATA

An analytical simulation was done using the traditional catch equation of a cohort with variable natural and fishing mortality at age (Ricker 1975). This simple simulation do allow to create series of yearly catches with fisheries showing a trend of fishing effort and selectivity similar to the trend and levels probably observed in the Indian ocean (figure 4), and exploiting a fish with biological characteristics (growth, natural mortality) similar to yellowfin tuna (figure 6). This simulation was done with constant recruitment (no stock recruitment relationship, a situation most often observed world wide for tropical tunas and for yellowfin) with a fishery reaching situation of overfishing before the end of the simulation; a multiplier of fishing mortality at age were used shown by figure 7. The simulated serie of yearly catches was subsequently introduced as input of the Grainger and Garcia model. A typical example of these results is given figure 8 showing the corresponding trends of the RRCI under increasing F (reaching the MSY at the end of the simulation).

Similar simulations were done by Gaertner et al 2001 on a "skipjack like" stock, and this simulation indicates that the MSY of such stock could be estimated within an uncertainty of about 10% by the analysis of RRCI.

Further similar simulations should be done on yellowfin like population and fisheries in order to explore the present uncertainties in the fish biology and in the fishery characteristics and trends. Such simulation should possibly allow to better estimate the uncertainty in the MSY was has been presently obtained.

At this stage, the general conclusion of such simulation is the following: for a species like yellowfin exploited with a constant and high rate of increase in the fishing effort, **the RRCI should provide a quite robust estimate of the status of the stock**. It should indicate quite well its risk of being overfished at a given level of fishing effort.

DISCUSSION

Overall

The analysis of the trend of yellowfin catches in the Indian Ocean appear to be quite conclusive, showing the recent stagnation of yellowfin catches despite of increased fishing efforts probably due to the overfishing of the stock. In parallel, the simulation of an "Indian Ocean yellowfin like" stock and fishery also suggest that the RCCI index used to analyze the simulated trend of yearly catches could be, in such a situation and despite of its extreme simplicity, an efficient tool to estimate the global level of stock overfishing.

Main limitations

However, there are of course various limitations to the present conclusion concerning the presently estimated MSY and optimal fishing effort. The two major limitations are probably in relation with effort and with catch trends, but other factors may also be taken into consideration:

Increasing fishing effort:

One of the main potential limitation in the interpretation of the RRCI index is to determine if the fishing mortality (or the effective fishing efforts) have been permanently increasing during recent years. If this is not the case, the recent stagnation or decrease of yellowfin catches could be simply due such decrease of effective effort. If there is strong evidence, even a semi quantitative one, that the effective effort was probably increasing during the period, then the diagnosis of overfishing (and effort exceeding the effort producing the MSY) would tend to be validated.

In our peculiar case of the Indian Yellowfin stock, there is a high probability that the global effort exerted on yellowfin has been permanently increasing for each of the 3 fisheries, longliners, purse seiners and artisanal ones:

purse seiners at least if one assumes an increase of fishing efficiency (figure 3 done under the hypothesis of a yearly 3% increase of fishing efficiency). However, if the increase of fishing power in the purse seine fishery are negligible (but this is an unrealistic hypothesis) the fishing effort of purse seiners has been stable or possibly decreasing during recent years.

Longliners: The total numbers of hooks set yearly in the Indian Ocean by long liners was first estimated based upon the IOTC catch and effort data, all fleets (see Fonteneau et al 2001). This nominal multispecies effort was later converted and expressed in a scale of fishing efforts similar to purse seiners as a function of the relative catches taken by the two gears (figure 3).

Artisanal fisheries, which have been showing an increasing trend of their catches (figure x), a trend that can only be explained by an increase of their fishing efforts, not by an increase of the yellowfin biomass.

As a conclusion, there is very little, or even absolutely no doubts, that the effective fishing effort targeting yellowfin tuna, and also the fishing mortality suffered by the stock, has been permanently increasing during recent years.

Yearly catches being assumed correct:

It is quite clear that if the yearly catches used in the model are nor correct, its results could be biased in proportion of the error done. This problem is more or less equally faced by all assessment methods.

Past and future changes in the fisheries:

The present conclusion that the yellowfin stock has been overfished since 1996 would be a valid one (1) only under the present biological productivity of the stock and (2) only under the fishing patterns of present fisheries: stable sizes exploited, area exploited, combination of gear used. For instance, the spectacular decline of average size in the yellowfin landings which was observed since 1994 (due to FAD fisheries), is possibly a source of decreased productivity of the stock (lower yield per recruit). If this was the case, the MSY estimated at 325.000 tons would underestimate the potential biological productivity of the stock. On the opposite, some fraction of the stock may still remain "cryptic" in some areas. Furthermore some new fishing gears could possibly provide in the future additional sustainable catches. Such phenomenon already occurred in the past: before 1980 there are very strong reasons to consider that the longline fisheries could never catch alone the present level of MSY over 300.000 t.. Such conclusion of a low MSY was for instance obtained by Wang 1988 using sequential population analysis on the 1952-1984 statistics. The recent development of purse seine and artisanal fisheries has clearly produced a sustainable increase of yellowfin catches, reaching levels of sustained productivity that could never be obtained by longline fisheries operating alone. This phenomenon has been observed world wide for all yellowfin fisheries. This type of limitation is not typical of the Grainger and Garcia model, and will be faced in a similar way by most assessment methods.

CONCLUSION

As a conclusion, the plateau of total catches observed since 1996 in the fishery and the corresponding decline in the rate of increasing catches which was observed during the last 15 years, should probably be interpreted as corresponding to level of recent catches which are close to the stock MSY. If this is the case, recent fishing efforts would have been at levels above the reference point of efforts producing to the MSY. This analysis is a very simple one, using a limited amount of data, but this conclusion is probably quite robust, at least as a first step of the stock assessment. More detailed analysis should be done in order to provide independent diagnosis on the stock status, but these more complex analysis will probably be difficult to run because of the serious weakness in the data base (catch, effort, size) and in the present knowledge of biological para meters (Natural mortality at age, growth, stock structure and movement). One of the major difficulty in the Indian Ocean yellowfin fisheries will probably be the standardization of their effective fishing effort: if it is quite easy to conclude that fishing efforts are increasing, it is extremely difficult to estimate their absolute rates of increase (for all fisheries: purse seiners, longliners and artisanal). In the context of precautionary approach and management of fish stocks with incomplete information (Hilborn and Peterman 1996), the results of such analysis should at least be considered as an indicative milestone for management.

CITED LITTERATURE

AN NATIONAL RESEARCH INSTITUTE OF FAR SEAS FISHERIES.1991. Status report of Japanese longline fishery with respect to yellowfin tuna in the Indian Ocean. IPTP Collective Vol. of working documents (yellowfin stock assessment working group), Vol. 6, pp 149-153.

FONTENEAU A. AND N. RICHARD 2001. Relationship between catch, effort, CPUE and local abundance for non target species, such as billfishes, caught by Indian Ocean long line fisheries. Submitted for publication to the Australian journal "Marine and Freshwater Research".

GAERTNER D., A. FONTENEAU AND F. LALOË 2001. Approximate estimate of the maximum sustainable yield from catch data without detailed effort information: application to tuna fisheries. Aquat. Living Resour. 14 (2001) 1-9., pp 1-9

GRAINGER R.J.R. AND S. GARCIA 1996. Chronicles of marine fishery landings (1950-1994). Trend analysis and fisheries potential. FAO Fish. Tech. Pap. 359, 1-51.

HILBORN R.M. AND PETERMAN R.M. 1996. The development of scientific advice with incomplete information in the context of precautionary approach. Precautionary approach in fisheries, part 2: Scientific papers, FAO Fish. Tech Paper, 350, pp 77-101.

RICKER W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 382p.

WANG C.H. 1988. Development of a multi-cohort analysis method and its application to the Indian Ocean yellowfin tuna length composition.BULL. FAR SEAS FISH. RES. LAB., no. 25, pp. 1-72

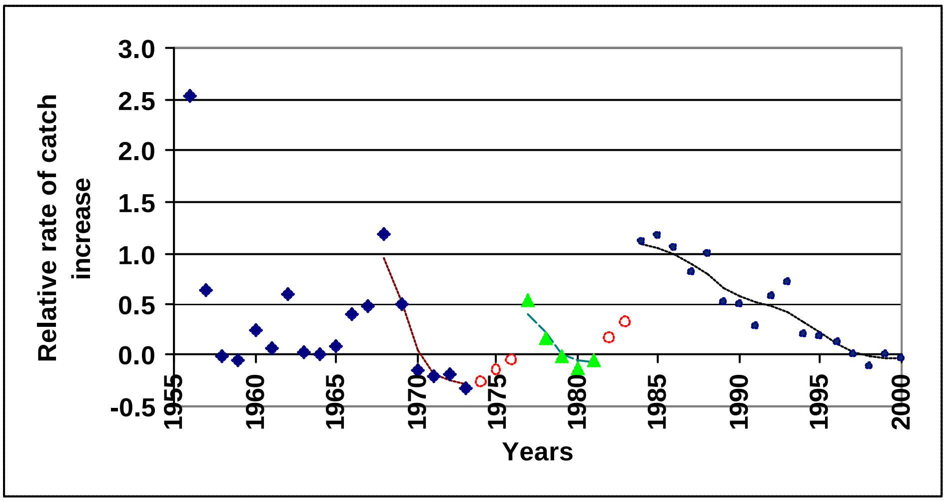

Figure 1: Relative Rate of Catch Increase (RRCI index) of the Indian Ocean yellowfin total catches during the period 1960-2000.

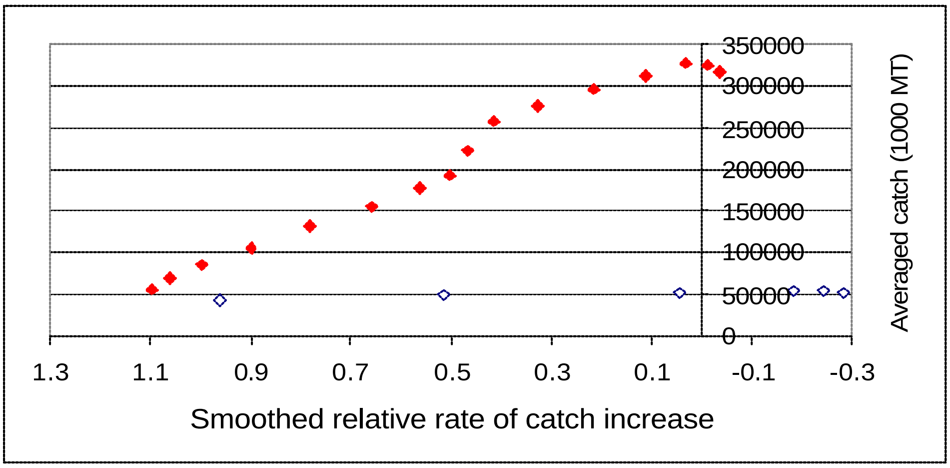

Figure 2: Smoothed rates of increase of the Indian Ocean yellowfin total catches as a function of average catches during recent years.

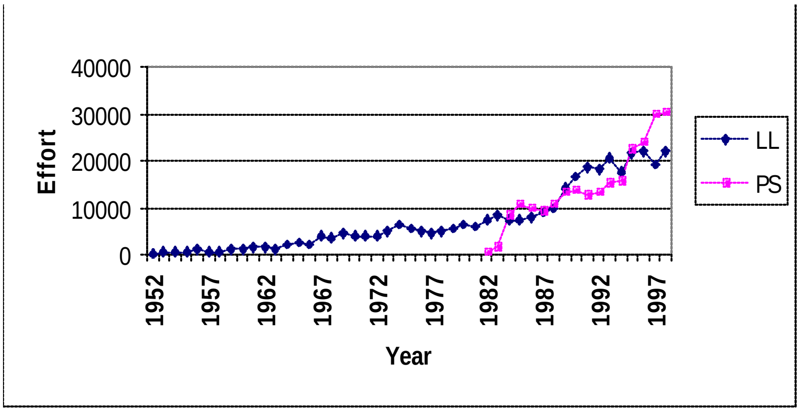

Figure 3: Fishing effort estimated for longliners and purse seiners (increase efficiency of 3% yearly)

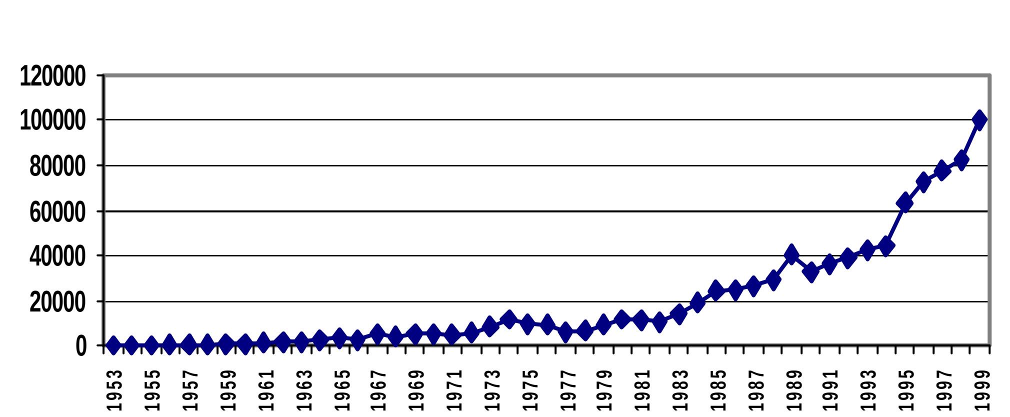

Figure 4: Estimation of the total fishing efforts exerted on Indian ocean yellowfin, expressed in purse seiner fishing days units. This effort is an estimated total of efforts by all gears.

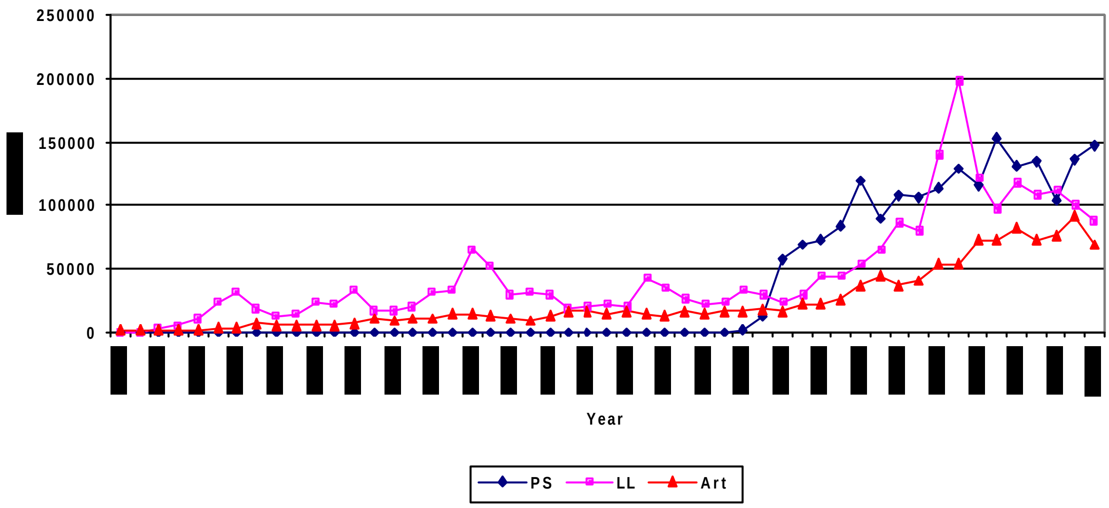

Figure 5: Catches of Indian Ocean yellowfin tuna by the three fisheries: purse seiners, longliners and artisanal

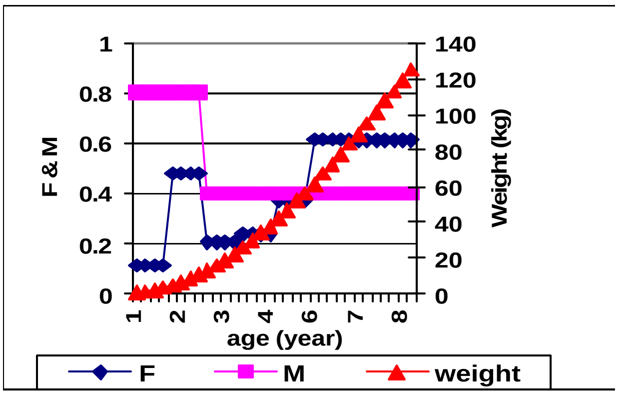

Figure 6: Biological parameters and selectivity curve used in the present simulation

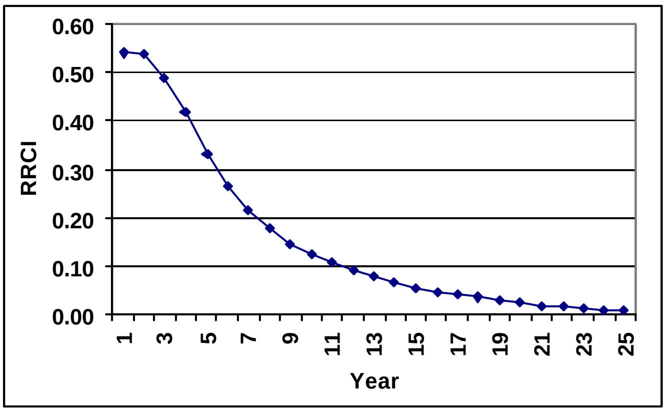

Figure 7: Examples of Relative Rate of Catch Increase obtained in a "yellowfin like" simulated fisheries in a fishery with constant rate of increase of F and reaching its full exploitation after 25 years of exploitation.

Table 1: data used in the present study and results of the analysis

Year	Total catch	Delta	C/6	Delt/c6
1950	2030			
1951	2230			
1952	5570			
1953	8392			
1954	14224			
1955	27151		9933	
1956	35083	25150	15442	2.53
1957	25010	9568	19238	0.62
1958	18942	-296	21467	-0.02
1959	20201	-1266	23435	-0.06
1960	29011	5576	25900	0.24
1961	27594	1694	25974	0.07
1962	41073	15100	26972	0.58
1963	27652	680	27412	0.03
1964	27343	-69	28812	0.00
1965	31334	2522	30668	0.09
1966	42909	12241	32984	0.40
1967	48708	15724	36503	0.48
1968	80237	43734	43031	1.20
1969	64342	21312	49146	0.50
1970	41774	-7372	51551	-0.15
1971	40954	-10597	53154	-0.21
1972	42755	-10399	53128	-0.20
1973	35618	-17510	50947	-0.33
1974	37614	-13333	43843	-0.26
1975	37357	-6486	39345	-0.15
1976	37337	-2008	38606	-0.05
1977	58846	20240	41588	0.52
1978	48286	6698	42510	0.16
1979	42325	-185	43628	0.00
1980	38229	-5399	43730	-0.12
1981	41398	-2332	44404	-0.05
1982	51586	7183	46778	0.16
1983	61319	14541	47191	0.31
1984	99690	52500	55758	1.11
1985	120710	64952	68822	1.16
1986	141176	72354	85980	1.05
1987	154777	68797	104876	0.80
1988	210164	105288	131306	1.00
1989	199569	68263	154348	0.52
1990	231223	76875	176270	0.50
1991	226335	50065	193874	0.28
1992	306041	112167	221352	0.58
1993	379078	157727	258735	0.71
1994	308491	49756	275123	0.19
1995	323277	48154	295741	0.18
1996	331585	35844	312468	0.12
1997	313373	905	326974	0.00
1998	293184	-33790	324831	-0.10
1999	328629	3798	316423	0.01
2000	303933	-12490	315664	-0.04