Historical shifts in hooks between floats and potential target species of the Japanese longline fishery in the equatorial Western Indian Ocean

by Pascal Bach [1] and Alain Fonteneau [1]

Abstract

The number of hooks between floats (HBF) is classically considered in standardization studies of the longline fishing effort as a proxy indicator of the maximum fishing depth. The explanation of this choice is easy for understanding : an increase of the HBF (then an increase of the length of the mainline between floats represents a increase in fishing depths. Probably, this relationship has been valid for traditional longlines until the end of eighties. However, the modernization of the fishing gear (monofilament mainline, shooter, snaps) has considerably modified the tradition and has led to a wide diversification of setting tactics. As a related consequence of this modernization, HBF has lost his property as a proxy indicator of the maximum fishing depth. In this work, we show briefly why the relationship between HPB and the maximum fishing depth is artificial. This hypothesis is supported from a comparative analysis of temporal series of the average HBF and the weight contribution of albacore and bigeye in catches. This fact underlines the problem of the use of HBF in the frame of the measure of the effective fishing effort in longline fisheries (GLM approach). In this context, the necessity of additional information characterizing longlining strategies is discussed.

1 - IRD/CRH – BP 171 – 34203 Sète Cedex – E-mail : bach@ird.fr

1 – Introduction

Longlines are strings of hooks deployed along distances of several tens of miles and maintained at the surface by buoys regularly disposed along the mainline. The well known longline fishing unit called "basket" corresponds to a longline section delimited by two buoys. Several factors govern the efficiency of the fishing operation. However one of major factors is the overlap between the vertical distribution of the hooks and the vertical distribution of the individual fishes targeted. The longline catchability depends mainly on the overlap between vertical distributions of both hooks and resources. The existence of possible variations in the longline catchability has stimulated studies of the standardization of the fishing effort and, more recently, of habitat based model approaches ((Hinton et Nakano, 1996 ; Bigelow et al., 2002 ; Goodyear et al. ; 2003 ; Campbell, 2004). The estimation of the impact of longlines on the resource is traditionally related to the distribution of hook fishing depths as longline catch patterns clearly show that the species selectivity for longlines depends on the depths of the fishing operations (Boggs, 1992; Nakano et al., 1997; Bach et al., 2003). In this context, the number of hooks between floats (HBF) has been used and is still used as a proxy indicator of the maximum fishing depth. This choice based on the traditional longline gear (Yamaguchi 1989 a, b) is relevant until the modernization of the longline gear (monofilament, drum or mainline tank, line shooter, snap). The catenary theory and analysis of data for the Japanese longline fishery in the western equatorial Indian Ocean suggest that the HPB is no more a relevant proxy indicator of the vertical distribution of hooks. A thought for defining new indicators of longline fishing strategies must be carried out.

2 – Matérial and methods

2 A – The catenary geometry

The theoritical depth of a hook j can be estimated by using the catenary geometry (Yoshihara, 1951, 1954; Suzuki et al., 1977) :

$$D_j = LF + LB + (LLBF/2) * \{(1 + \cot^2 \varphi)^{1/2} - [(1 - (2j / N))^2 + \cot^2 \varphi]^{1/2}\} \quad (1)$$

and

$$SR = DBF/LLBF = (\cot \varphi) * \ln [(\tan(45° + \varphi /2)] \quad (2)$$

where D_j is the depth of the jth hook, LF is the length of the floatline, LB is the length of the branchline, LLBF is the length of the mainline between two consecutive floats (basket), N is HPB + 1, j is the jth hook from the floatline, φ is the angle between the horizontal and the tangential line of the mainline, SR is the sagging rate and DBF is the horizontal distance between floats. The angle φ is estimated by iteration of the sagging rate from the formula (2), (Figure 1).

At the mid-point of the basket mainline (i.e. the point where dbf_j = DBF/2 or j = N/2), the expressions (1) is written as :

$$D_j = LF + LB + (LLBF/2) * \{(1 + \cot^2 \varphi)^{1/2} - (\cot^2 \varphi)^{1/2}\} \quad (3)$$

or

$$\{(D_j - (LF + LB)\}/LLBF = \{(1 + \cot^2 \varphi)^{1/2} - (\cot^2 \varphi)^{1/2} \}/ 2 \quad (4)$$

Assuming that the depth at the mid-point of the basket mainline corresponds to the maximum fishing depth (MFD), the formula (5) clearly shows that the ratio between the theoretical MFD and the length of the mainline between floats only depends on the angle φ (i.e., the sagging rate). Consequently, for given values of LF and LB, one unique relationship describes the relationship between the theoretical value of the ratio MLF/LLBF and the sagging rate (Figure 2).

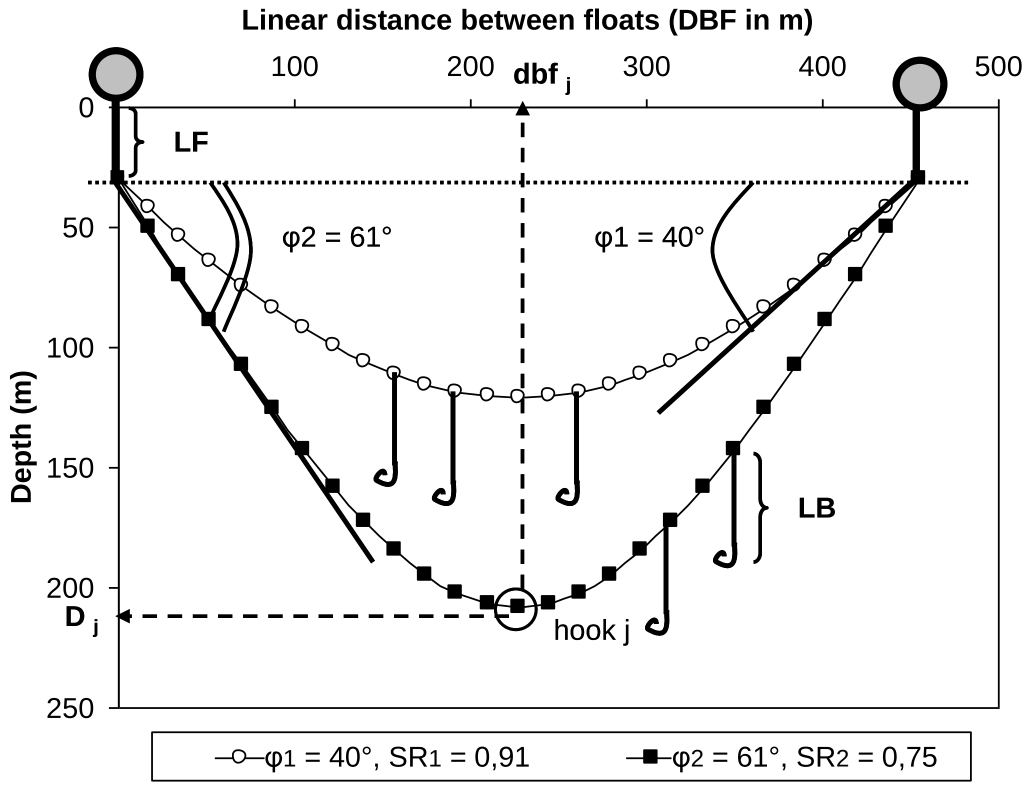

Figure 1 – Theoritical catenary shape of two baskets defined by respective values of the sagging rate of 0,91 (φ1 = 40°) and 0,75 (φ2 = 61°). D_j is the depth of the hook j located at a distance dbf_j form the floatline, LF is the length of the floatline and LB is the length of the branchline (from Bach et al., 2005).

2 B – Japanese longline fishery data

We consider data for the Japanese longline fishery in the western equatorial Indian Ocean (area located at the west of the longitude 70° and between latitudes 10° N and 10 ° S). Historically, this area corresponds to the major fishing activity of the fleet.
Temporal series of the annual mean value of the HPB and weight contributions of albacore tuna (YFT) and bigeye tuna (BET) in catches are compared.

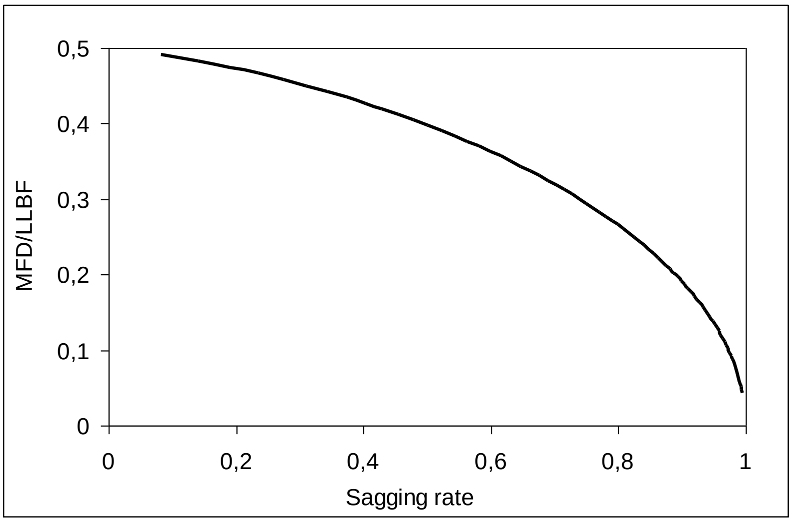

Figure 2 – Theoritical relationship between the ratio MFD/LLBF and SR (0 < SR < 1). MFD is the theoretical maximum depth, LLBF is the length of the mainline between floats and SR is the sagging rate. On this figures the value of the length of floatline (LF) and the length of branchline (LB) is supposed equal to zero (from Bach *et al.*, 2005).

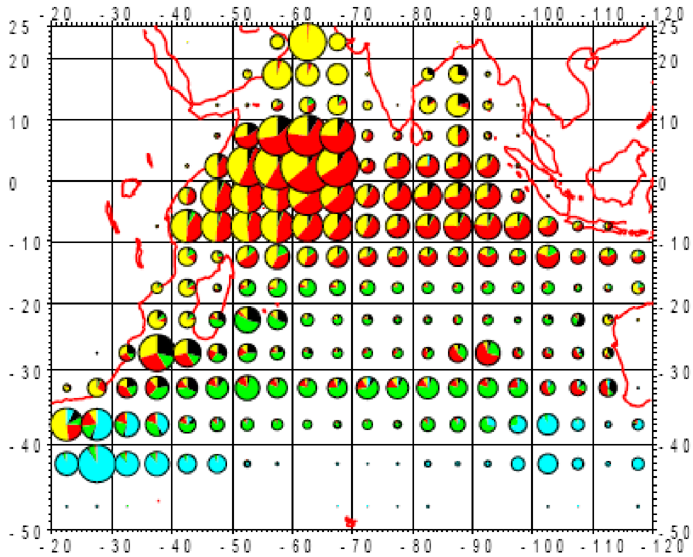

Figure 3 – Spatial distribution of cumulated catches of the japanese longline fishery (period 1970 – 2003). The area considered in the study (10° S < latitude < 10° N, west of the longitude 70 ° W) corresponds to major capture for both yellowfin and bigeye.

3 – Résults

3 A – Setting characteristics and maximum fishing depth

We commonly consider that the maximum fishing depth of baskets with 20 hooks can reach a depth up to 400 m. From a theoretical point of view, we can observe some setting tactics allow to target the oceanic surface layer for baskets with such a configuration (Figure 4). As mentioned above, the theoretical maximum fishing depth depends on the horizontal distance between floats (or the mainline length between floats) and the sagging rate. Then, with high values of the sagging rate (SR > 0.95) coupled with a setting speed quite low, several tactics induces a deployment of hooks in the first 200 m depth of the ocean.

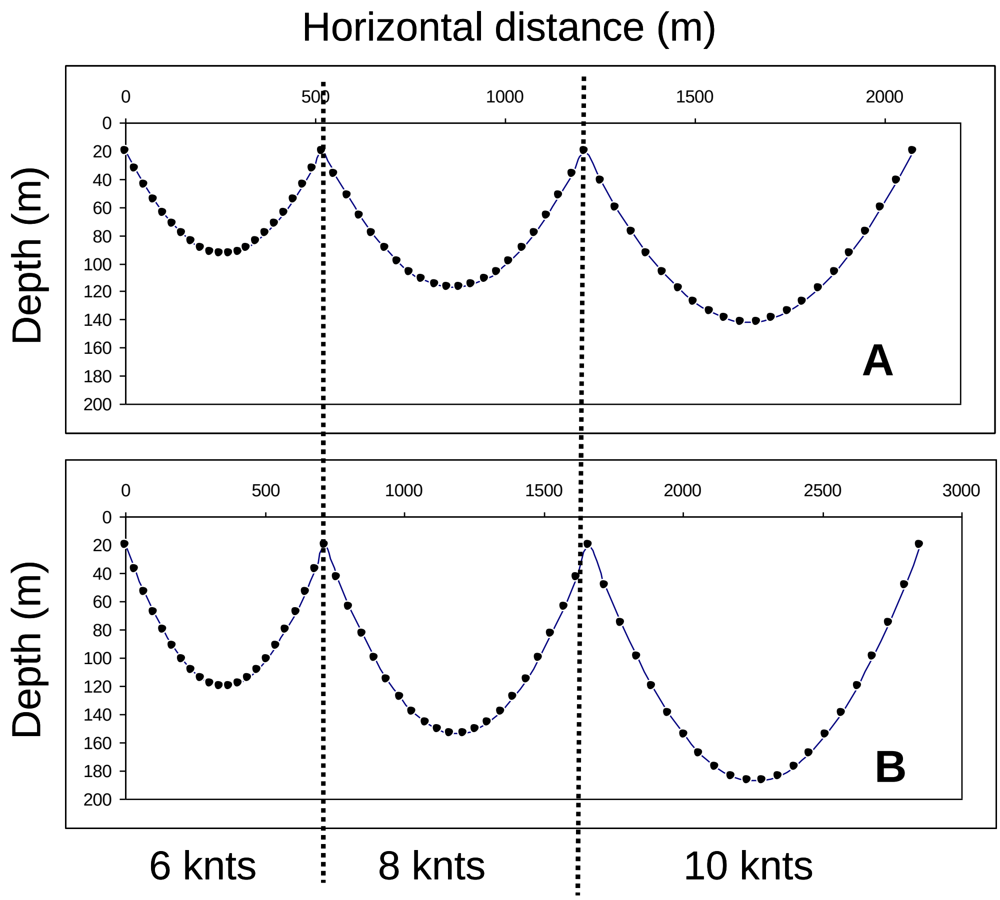

Figure 4 – Variations of the theoretical maximum fishing depth of the mainline for similar baskets in terms of both HBF = 20 hooks and the sagging rate = 0.95 according to different time intervals between hooks (A = 8 s, B = 11 s) and setting speeds of boat (6 knts, 8 knts and 10 knts).

3 B – Observations des séries historiques du nombre d'hameçons entre flotteurs et des contributions de l'albacore (YFT) et du patudo (BET) dans les captures.

3 B – Observations of temporal series of annual values of HBF and weight contributions of yellowfin tuna and bigeye tuna in catches

The observation of temporal series of annual values of (i) HBF and (ii) weight contributions of yellowfin tuna (YFT) and bigeye tuna (BET) for the Japanese longline fishery in the western equatorial Indian Ocean clearly shows three distinct periods (Figure 5 and 6) :

1) Until 1974-1977 (and probably at the beginning of the fishery in 1954), longlines were deployed with 5 HPB with a mainline length between hooks of 50 m then a mainline length between floats of 300 m). Some studies (Bigelow *et al.*, 2002) have shown that the maximal fishing depth was about 200 m with a main part of hooks located in the surface layer (i.e. in the first 100 m depth that correspond in the considered fishing area to the layer from the surface to the thermocline). During this period, weight contributions of YFT and BET in catches are quite similar.
2) From 1978, the longline with 5 HBF is no more used in this area. It is replaced by longlines with HBF ranged from 9 to 14. This change of fishing strategy induces immediately an increase of the BET contribution in catches. This shift of the target species is logical and related to the rapid increase of BET prices on the sashimi market. Moreover, BET nominal CPUE increases at the same time (Figure 7). Surely, a higher number of hooks per basket has had for consequence an increase of the maximum fishing depth with a large part of hooks deeper than 300 m depth (Bigelow *et al.*, 2002).
3) From 1992, very quickly the longline HPB changes from an old practice with 9 – 14 HBF to 20 HBF. Then, this new increase of the HBF suggests a related increase of the maximum fishing depth. Nevertheless, in terms of species contributions in catches we observe an opposite results compared to the expected one. On one hand, the contribution of YFT in catches increases. On the other hand, the nominal CPUE for YFT reaches values never observed 30 years ago (Figure 7). This selection of the YFT rather than BET would be logical in terms of market. During the recent period, the difference between BET prices and YFT prices on the sashimi is become very weak.

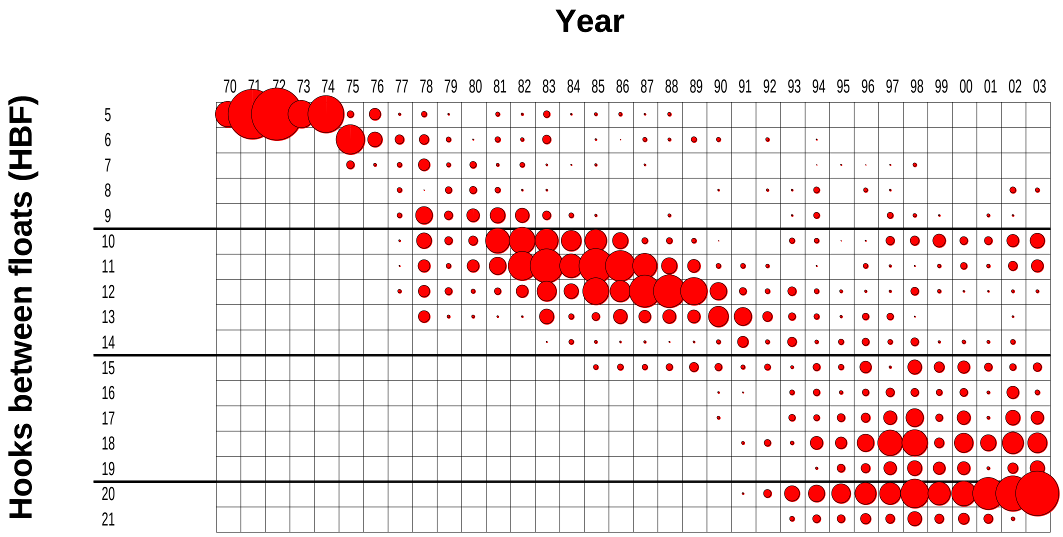

Figure 5 - Temporal series of the average hooks between floats statistics for the Japanese longline fishery operating in the Western Indian Ocean, showing 3 major periods of increasing HBF.

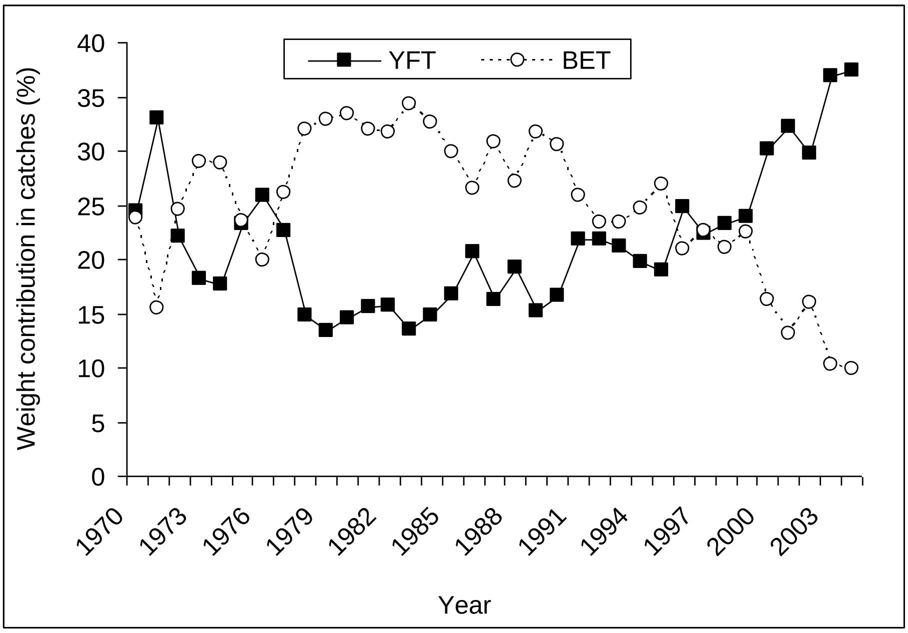

Figure 6 – Historical series of weight contributions of BET and YFT in catches for the Japanese longline fishery operating in the Western Equatorial Indian Ocean showing 3 major periods of the fishing strategy.

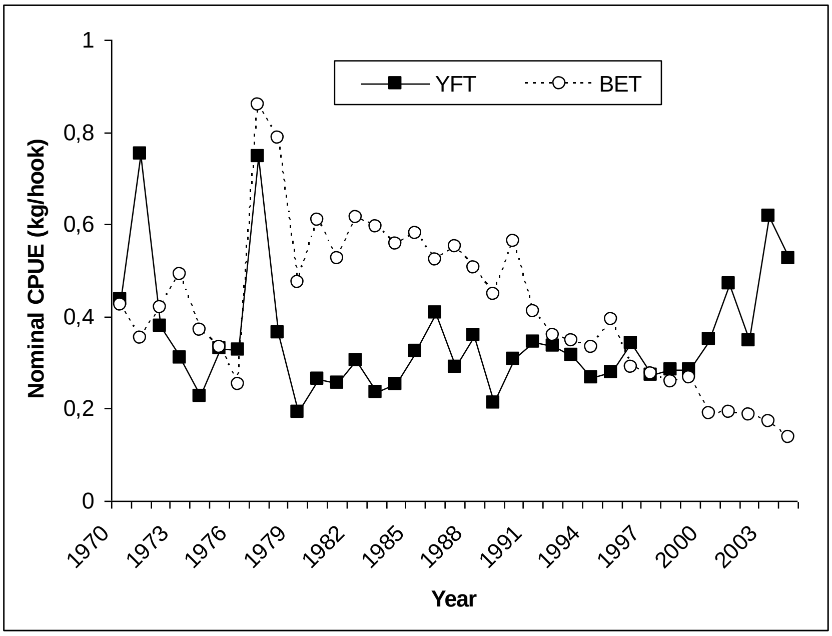

Figure 7 – Yellowfin (YFT) and bigeye (BET) nominal CPUEs for the Japanese longline fishery in the Western Equatorial Indian Ocean.

4 - Discussion

4 A - HBF, maximal fishing depth and target species for the recent period

Both weight contributions of YFT and BET in catches and nominal CPUEs for each species suggest that the relationship between HBF and the maximal fishing depth has been verified until the end of eighties. On the opposite, it is biologically impossible that the new increase in HBF observed from 1992 induces an increase of the maximum fishing depth.

From knowledge of both oceanographic characteristics of the fisheries (thermocline quite stable between 100 m and 120 m depths, figure 8) and preferential habitat of the two species (Brill *et al.*, 1999 ; Dagorn *et al.*, 2000 ; Musyl *et al.*, 2003 ; figure 9) we can assume that this 20 HBF fishing strategy target individual fishes living in the surface layer above the thermocline, YFT essentially.

Regarding the longline fishing technology, as described previously (cf. § 3 A)) this result is not astonishing. The modernization of the longline fishing gear (monofilament on a drum or in a tank, line shotter, snap-on-branchline) allow a deployment of hooks in ocean surface layers even by using recent setting strategies of 15 or 20 HBF (cf. Bach *et al.*, 2005).

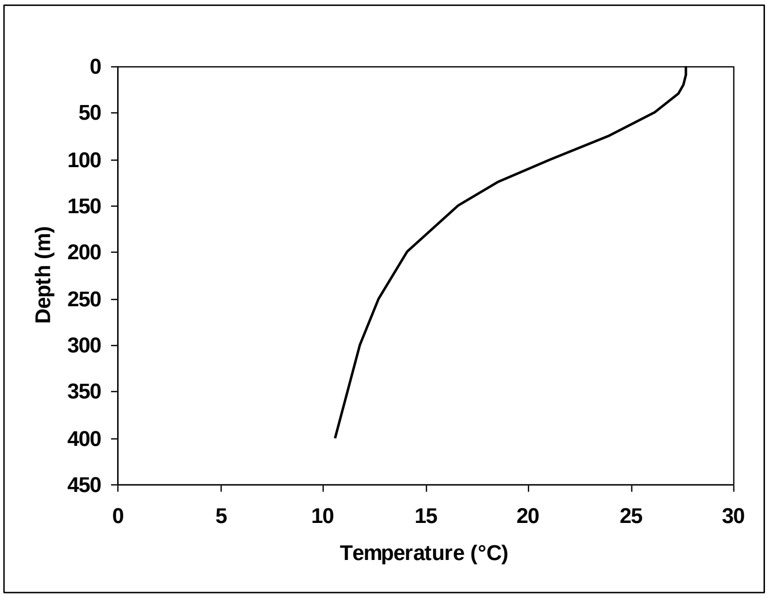

Figure 8 - Average temperature profile in the central Western Indian Ocean (data obtained from the World Ocean Atlas 2001, ftp://ftp.nodc.noaa.gov/pub/WOA01/temperat/).

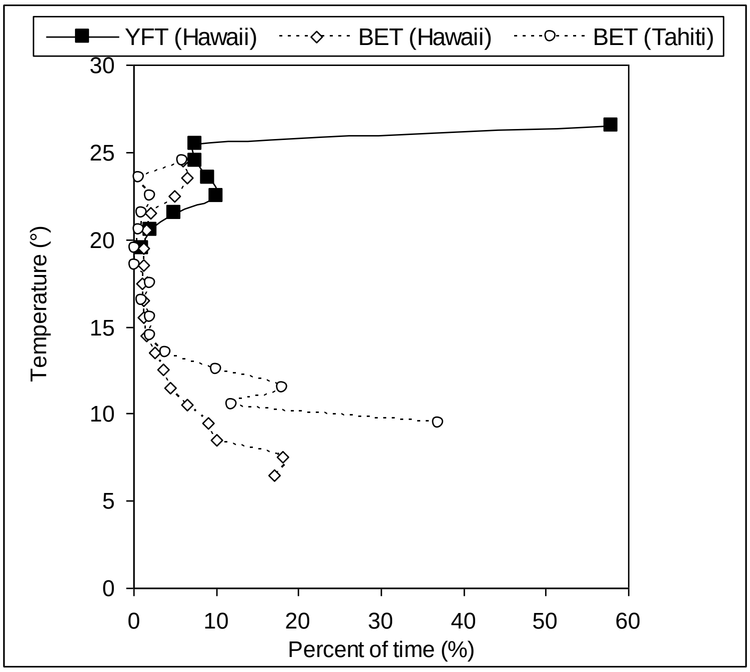

Figure 9 – Time-at-depth curves during daytime for the yellowfin (YFT in Hawaii, from Brill et al., 1999) and the bigeye (BET in Hawaii, from Musyl et al., 2003 and in Tahiti from Dagorn et al., 2000).

4 B – HBF consideration in studies of fishing effort standardization and/or habitat based models

From the beginning of nineties, some major facts show that HBF is not a good proxy indicator of the maximum fishing depth. Currently, this parameter is not sufficient to define the fishing strategy (in terms of target species) developed by a given longlining fleet.
The HBF is an indicator of how the line is set and detailed information on the line setting strategy are needed (boat setting speed, line shooter speed, setting time per basket, HBF, length of floatline, length of branchline, times for setting, times for hauling, bait type).
For reading or estimating longline depths, it is essential (1) to collect data on field (deployment of time depth recorders by observers) and/or (2) to develop a database of setting tactic information that could be collected by observers. However, some samples of this kind of detailed data probably exist and it would be important to analyse it in this context.
This hypothesis explains probably the well marked difference between nominal CPUEs of Japanese and Taiwanese fleets fishing on the same fishing ground (figure 10) with an average HBF similar :
- for the Japanese longline fishery YFT CPUEs increase while BET CPUEs decrease,
- for the Taiwanese longline fishery, YFT CPUEs decrease while BET CPUEs are stable.

These differences of target species with similar longlines in terms of HBF would arise from longline setting tactics that generate hook depth distributions highly different.

Currently, fishery scientists involved in longline data analysis run a risk by using HBF as sole proxy indicator of the fishing strategy in CPUE standardization studies (GLM). Taking the species composition of catches into account can not remove this problem. Indeed, we can not inferred the species variation of CPUES : reduction of the local density or diminution of the catchability. An other way to explore concerns analysis of bycatches CPUEs (in particular billfishes as marlins mostly distributed in oceanic surface layers) in order to perform a qualitative analysis of hook depth distributions.

Knowing that questions regarding the ocean and the fishing ground are secondary factors in such a world topic, analyses might be performed for longline fisheries of the world ocean. Studies of these fisheries working in various fishing grounds would provide valuable additional information.

Finally, longlining scientific surveys might be also carried out for (i) studying the behaviour of the fishing gear and for (ii) providing data to analyse nominal CPUE versus effective CPUE relationships for target species.

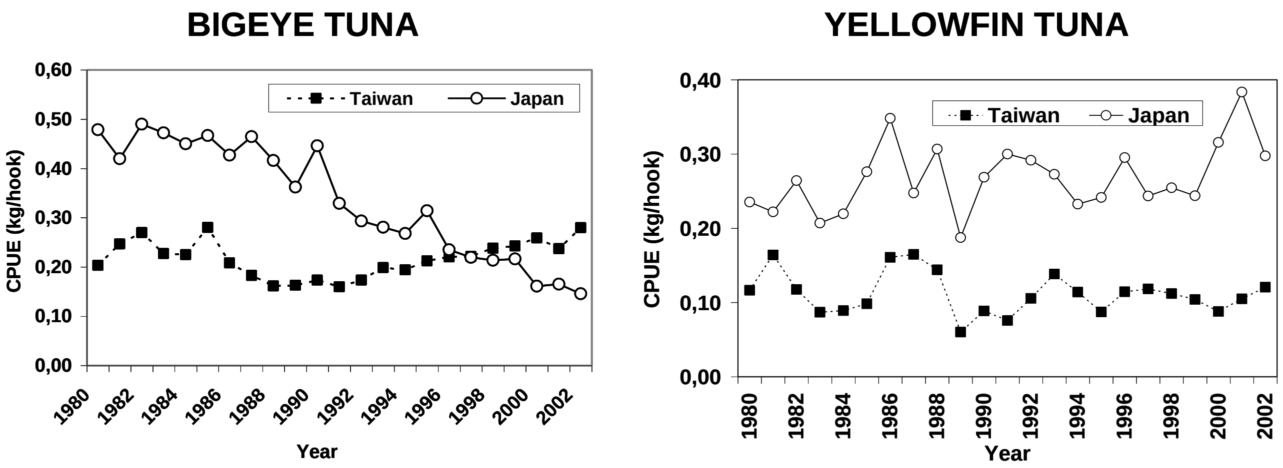

Figure 10 – Temporal series of annual nominal CPUEs for bigeye and yellowfin tunas of both Japanese and Taiwanese longline fisheries in the western equatorial Indian Ocean.

5- Conclusion

Observations of both longline fisheries data and oceanographic data in the western equatorial Indian Ocean suggest that the parameter HBF should not be considered in the frame of YFT and BET CPUEs standardizations studies at least from nineties data series.
Active research programs for performing alternative and/or complementary methods by IOTC in collaboration with the others tuna commissions at a worldwide level. The aim of these researches would consist to select relevant parameters and/or proxy of the setting strategy and the specific composition of catches that characterize fishing strategies and then discriminate target species in longline fisheries.

Acknowledgements

This paper was primarily done using the Japanese catch and effort data set provided by Japanese scientist from the Shimizu laboratory, as well as the information upon the HBF configuration developed by Japanese longliners, a valuable data set kindly provided to us by Dr Okamoto San. We deeply acknowledge our Japanese scientists for their fully active scientific cooperation providing to us their valuable dataset.

Références

Bach P., L. Dagorn, A. Bertrand, E. Josse, C. Misselis, 2003. Acoustic telemetry versus monitored longline fishing for studying the vertical distribution of pelagic fish : bigeye tuna (*Thunnus obesus*) in French Polynesia. Fish. Res., 60 (2-3), 281-292.

Bach P., P. Travassos, D. Gaertner, 2005. Why the number of hooks per basket (HPB) is not a good proxy indicator of the maximum fishing depth in drifting longline fisheries ? Doc. ICCAT, SCRS/2005/112, 19 p.

Bigelow K. A., J. Hampton, N. Miyabe, 2002 – Application of a habitat-based model to estimate effective longline fishing effort and relative abundance of Pacific bigeye tuna (*Thunnus obesus*). Fish. Ocean. 11 (3) : 143 – 155.

Boggs C. H., 1992 – Depth, capture time, and hooked longevity of longline-caught pelagic fish: timing bites of fish with chips. Fish Bull. 90 : 642 – 658.

Brill R.W., B.A. Block, C.H. Boggs, K.A. Bigelow, E.V. Freund, D.J. Marcinek, 1999 – Horizontal movements and depth distribution of large adult yellowfin tuna (*Thunnus albacares*) near the Hawaiian Islands, recorded using ultrasonic telemetry: implications for the physiological ecology of pelagic fishes. Mar. Biol., 133: 395 – 408.

Campbell R., 2004 – CPUE standardisation and the construction of indices of stock abundance in a spatially varying fishery using general linear models. Fisheries Research, 70 : 209 – 227.

Dagorn L., P. Bach, E. Josse, 2000 – Movement patterns of large bigeye tuna (*Thunnus obesus*) in the open ocean determined using ultrasonic telemetry. Mar. Biol., 136 : 361 – 371.

Goodyear C. P., D. Die, D. W. Kerstetter, D. B. Olson, E. Prince, G. P. Scott, 2003 – Habitat standardization of CPUE indices: Research needs. Coll. Vol. Sci. Pap. ICCAT, 55 (2) : 613 – 623.

Hinton M.G. and H. Nakano, 1996 – Standardizing catch and effort statistics using physiological, ecological, or behavioural constraints and environmental data, with an application to blue marlin (*Makaira nigricans*) catch and effort data from the Japanese longline fisheries in the Pacific. IATTC Bull. 21 : 169 – 200.

Koido T., 1985.- Comparison of fishing efficiency between regular and deep longline gears on bigeye and yellowfin tunas in the Indian Ocean. IPTP document TWS/85/25.

Musyl M.K., R.W. Brill, C.H. Boggs, D.S. Curran, T.K. Kazama, M.P. Seki, 2003 – Vertical movements of bigeye tuna (*Thunnus obesus*) associated with islands, buoys and seamounts of the Hawaiian Archipelago from archival tagging data. Fish. Oceanogr. 12:3 : 152 – 169.

Nakano H., M. Okazaki, H. Okamoto, 1997 – Analysis of catch depth by species for tuna longline fishery based on catch by branch lines. Bull. Far Seas Fish. Res. Lab. 34 : 43 – 62.

Suzuki Z., Y. Warashina, M. Kishida, 1977 – The comparison of catches by regular and deep tuna longline gears in the western and central equatorial Pacific. Bull. Far Seas Fish. Res. Lab. 15 : 51 – 89.

Yoshihara T.,1951. Distribution of fishes caught by the longline-II. Vertical distribution. Bull. Jap. Soc. Sci. Fish. (Japanese, English abstract) , 16 (8), 370-374.

Yoshihara T.,1954. Distribution of catch of tuna longline-IV. On the relation between k and φ° with a table and diagram. Bull. Jap. Soc. Sci. Fish. (Japanese, English abstract), 19 (10), 1012-1014.