出國報告（出國類別：其他）

參加印度洋鮪類委員會（IOTC）旗魚工作小組會議出國報告

服務機關：行政院農業委員會漁業署　　中華民國對外漁業合作發展協會
姓名職稱：張水鍇科長　　　　　　　　王識鈞助理研究員

派赴國家：模里西斯
出國期間：中華民國 93 年 9 月 25 日至 10 月 3 日
報告日期：中華民國 93 年 12 月 28 日

摘　　要

一、 雖然前屆會議希望不要再增加印度洋劍旗魚的捕撈壓力，但本次會議發現歐盟近三年增加四十艘釣船在模里西斯及附近水域作業，並以劍旗魚爲主要魚種。與會者對此作業船數的增加表示關切，並憂心對資源的再度傷害。會中因此作成建議，希望ＩＯＴＣ儘快實施劍旗魚產證制度。

二、 我國印度洋劍旗魚漁業，由於部分漁船已轉移至其他目標魚種，不再以劍旗魚爲主，因此近幾年劍旗魚漁獲量持續緩慢減少。

三、 資源評估結果顯示，我國在西南印度洋（主要漁獲區）及部分漁區，漁獲率呈下降趨勢，日本之漁獲率則在全印度洋區都呈非常劇烈的下降趨勢，特別是西南印度洋區。對於兩國之分析結果，會中認爲日本結果太過劇烈，不完全合理；另對我國結果則認爲我國漁業目標魚種之轉移太快，此效應可能未被完全去除，因此也需再進一步研究。

四、 由於台、日兩國評估結果都顯示在西南印度洋漁獲率呈現下降趨勢，因此工作小組憂心西南印度洋有正被過漁的危險，尤其近幾年又持續增加作業船，爲此，小組認爲ＩＯＴＣ不應允許任何漁獲量或捕劍旗魚之努力量的增加，並建議應採取控制或降低西南印度洋區努力量的管理措施。

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壹、 目的

印度洋鮪類委員會（IOTC）爲負責印度洋鮪類資源管理委員會之國際漁業組織，隸屬於聯合國糧農組織。自 1996 年成立以來，該組織即積極對該洋區主要漁獲魚種進行資源評估，其中劍旗魚由於自九Ｏ年代起，即大量被補撈，且在部分海區已呈現區域性資源崩潰現象，因此爲近年來該組織最關切之魚種之一。

印度洋爲我國鮪釣漁船主要作業漁場之一，近年來我國在該洋區作業的中大型鮪釣船達 300 餘艘，年漁獲量達十萬公噸，位居各國前茅，其中劍旗魚產量更超越各國，佔全洋區漁獲量的四至六成，因此對該洋區鮪類資源之保育與管理，我國實佔有相當重要之地位。由於目前各國際組織爲達資源永續利用之目標，正積極加強對各魚種資源的管理，並以漁獲配額爲管理手段。因此爲避免影響我國漁船於印度洋作業權益，並善盡漁業國之責任、及獲取各國支持我國參與 IOTC 之立場，我國乃派員參加本次會議。

貳、 會議時地、代表

本屆旗魚工作小組會議於模里西斯召開，會議於九月二十七日起，至十月一日結束。會議主席爲澳洲ＣＳＩＲＯ海洋研究中心科學副主任 John Gunn 博士，與會代表包括ＩＯＴＣ秘書處及澳、法等六國，共十一位科學家，我國代表爲漁業署遠洋漁業組資源評估科張水鍇科長，參加全程會議。

參、 過程

自九Ｏ年代起，我國即為印度洋之最大劍旗魚漁獲國，而與此洋區相關之遠洋漁獲資料以我國及日本最為完整，但由於日本承辦科學家目前正在海上進行漁撈試驗且該國漁獲量亦小，故本次未派員參加，而僅以電子郵件傳遞資料以供會議分析。因此，會議中之討論及研究大部分皆針對我國。

以下依會議順序，報告會議中之重要紀事：

一、統計資料

會議在主席開場及各國代表自我介紹後，開始由秘書處報告統計資料蒐集情形及各國之提供情形。

2003 年秘書處在統計資料蒐集量及品質改善上有許多進展，包括葉門、莫三鼻克及印尼的生鮮鮪魚量等估計上，都有收穫。藉其港口採樣計畫（OFCF－IOTC sampling program），許多沿岸國的產量都有重新估計，包括我國小釣在泰國普吉島的產量。

秘書處報告時，有概略提及我國早期資料未提供之舊問題，由於各代表皆瞭解原因，因此會中未有討論。不過，會中較關心我國小釣問題，詢問我國是否有自己的估計量，及為何小船不回報、我國是否無法管。

我代表回應，我國在多年前就開始估計小釣船產量，但前年在中國大陸的黃鰭鮪會議時，有決議採用 IOTC 港口採樣計畫之估計值，所以產量上未顯示出來。另外，針對其他問題，我代表表示，由於小釣船機動高，且船數多，所以不容易完全掌握，這在許多有小船的國家都是如此（如日本），因此不是不管，而是不容易管

理。爲加強這方面資料的蒐集，我國已在規劃港口採樣計畫，希望能藉此計畫取得我國小釣船進出港口的漁獲資料。

主席表示很高興台灣終於開始重視小釣漁獲資料，並認爲小釣船單船量雖低，但上百艘的作業，也造成很大問題。秘書處對此亦表示歡迎，但希望能與 IOTC 之採樣計畫合作，以替雙方取得最大利益。我代表同意，並表示在規劃過程，會與 IOTC 討論。

二、各國漁業報告

與會之各國代表對其國家漁業概況，作簡要說明。其中較特殊的爲，歐盟（主要爲法國，少部分爲西班牙）近三年增加四十艘釣船在模里西斯及向東海域作業，並在模里西斯轉載。這些船捕了 4,299 噸的遠洋漁獲，其中有 48%是劍旗魚，44%是鯊魚。除了歐盟的船之外，模里西斯也預估，模國自己的鮪釣船在往後幾年間也將會增加，因爲其政府已同意提供誘因給當地的漁業公司。與會者對此作業船數的增加表示關切，並憂心對資源的再度傷害。

另秘書長表示，據瞭解自 2002 年起（特別是 2003 年），仍有一些 FOC 船（貝里斯、宏都拉斯、萬那杜等），捕大目鮪、黃鰭鮪，並混獲劍旗魚，在模里西斯、南非轉載或卸魚。另外，以前有一些 FOC 船轉掛菲律賓旗，但菲國漁獲量卻未增加，秘書長質疑這些船還是 IUU。針對在模里西斯轉載的，秘書長表示，依規定模國應拒絕這些漁船的轉載行爲。爲杜絕這些問題，會中作成建議，希望ＩＯＴＣ儘快實施劍旗魚產證制度。

另外，會中亦質疑西班牙船隊未提供完整漁獲資料。西班牙自 1993 年開始專捕劍旗魚，而自 2001 年起，西國船隊顯著擴大其漁獲範圍，並且有很高的釣獲率。西國報告中之解釋爲（西國未派員參加），高釣獲率主要是因更改使用美國釣具及向東延伸漁場（以前從未有船隊專捕劍旗魚的漁場）。由於西國船隊只提供劍旗魚產

量，而未提供任何其他鮪類及類鮪類漁獲資料，因此秘書處高度關切西國不提供之理由。

至於我國漁業，由於部分漁船已轉移至其他目標魚種，因此漁獲量持續緩慢減少。惟在 2003 年，索馬利亞海域之漁獲情形不錯，在該劍旗魚有約略回升情況。

三、觀察員計畫執行情形

澳洲自 2003 年 4 月開始針對鮪釣漁業進行試驗性的觀察員計畫，涵蓋率以鉤數計，約 3.7%。2003 年法國和西班牙亦開始圍網漁業的觀察員計畫，涵蓋率約 5 至 10 %（航次）。留尼旺亦表示，將很快在其海域有有新的觀測計畫。我國則表示，我國自 2001 年起在三大洋開始有試驗性的觀察員計畫，今年在印度洋已增加至三位觀察員（預計觀測六航次）。

工作小組歡迎各國都開始有這樣的觀測計畫，認為觀察員計畫是最好蒐集資料的方式，並希望能持續蒐集性別的旗魚體長資料，因為這對資源評估的品質有很大的影響。

四、資源評估

有關資源研究，會中對我國所提出之研究報告相當肯定，秘書長表示我國報告已完成大部分基礎研究，因此本次會議可集中於其他的試驗。會中認為目標魚種的轉移可能是最重要的影響因子，因此針對如例調整漁區、季節等，以降低目標魚種問題，作了相當多的測試，並進行多次的泛線性模式漁業率標準化作業。由於日本代表不在場，而我國漁獲量最高，因此大部分會議中指定要作的研究都是由我國代表完成。

會中另也針對我國體長資料，要求我國作 25%及 75%的趨勢圖，以瞭解漁獲體型的變化，結果顯示在主要漁場（西南印度洋區）有體型變小的現象。

會中，也進行我國劍旗魚漁獲量與漁獲率關係圖的討論。秘書長作出之結果質疑，兩者關係在各區都完全一致，意思爲漁民對漁獲率作業的反應太快，似乎不符常理。

爲確定此現象是否爲真，我國代表亦連夜按秘書長之作法重作一次，並於會中說明並非完全如此，有時是先漁獲率高，後漁獲量高，有時則相反，其實是依據當時狀況變動的，並非系統性的誤差。歐盟代表則反應，我國漁民船隊式作業，機動性大，資料實在是複雜。

最後結果，我國在西南印度洋（主要漁獲區）及部分漁區，漁獲率皆呈下降趨勢，日本之漁獲率則在全印度洋區都呈非常劇烈的下降趨勢，特別是西南印度洋區。

對於兩國之分析結果，會中原傾向接受日本結果（因較符合資源理論），並懷疑我國資料品質。後經多次資料分析及討論，最後認爲日本結果太過劇烈，不完全合理；另對我國結果雖也有可能是資料品質問題，但認爲我國漁業目標魚種之轉移太快，此效應可能未被完全去除，因此也無法完全接受。

然而由於兩國結果在西南印度洋都呈現下降趨勢，因此小組結論，對西南印度洋有正被過漁的危險表示憂心，尤其近幾年又持續增加作業船。小組認爲ＩＯＴＣ不應允許任何漁獲量或捕劍旗魚之努力量的增加，並建議應採取控制或降低西南印度洋區努力量的管理措施。

本次會議由於時間不及，且仍有部分漁獲率標準化問題未釐清，因此未進行資源評估模式的運算，儘進行標準化後漁獲率的年代比較：日本選 1985-1990 年當作參考年，因這段期間日本的漁獲率最穩定；我國則選 1995-96 年爲參考年。將 2001-02 年漁獲率對參考年作比較後，發現最近幾年之漁獲率的確都是下降，只是兩國的下

降幅度不同。這個分析結果，也得到如上述相同的結論，因此小組確定作這樣的管理建議是恰當的。

肆、 心得與建議事項

一、 會議中有關我國統計資料問題，由於七月之大目鮪會議中我代表已有完整說明，因此未再有討論。但針對小釣資料議題，與會代表有許多詢問，包括小船爲何不回報、我國何以不管及未來將如何改善等，我代表簡略說明小釣漁業之機動性及難掌握性，並表示我國擬將推動港口採樣計畫，以改善資料的蒐集。秘書長則建議在規劃過程能與ＩＯＴＣ接洽，以使雙方之港口採樣計畫能互補，取得最大利益。

二、 就各國漁業部分，較特殊的爲歐盟近三年增加四十艘釣船在模里西斯作業，並以劍旗魚爲主要魚種。與會者對此作業船數的增加表示關切，並憂心對資源的再度傷害。另據聞有許多ＩＵＵ漁船在模里西斯轉載，秘書長表示，依規定模國應拒絕這些漁船的轉載行爲。會中並作成建議，希望ＩＯＴＣ儘快實施劍旗魚產證制度。至於我國漁業，由於部分漁船已轉移至其他目標魚種，因此漁獲量持續緩慢減少。

三、 有關資源研究，由於我國我國報告已完成大部分基礎研究，因此本次會議集中於其他的試驗，包括漁區調整等。最後結果，我國在西南印度洋（主要漁獲區）及部分漁區，漁獲率皆呈下降趨勢，日本之漁獲率則在全印度洋區都呈非常劇烈的下降趨勢，特別是西南印度洋區。

四、 對於兩國之分析結果，會中原傾向接受日本結果（因較符合資源理論），並懷疑我國資料品質。後經多次資料分析及討論，最後認爲日本結果太過劇烈，不完全合理；另對我國結果，雖不排除資料品質問題，

但認為我國漁業目標魚種之轉移太快，此效應可能未被完全去除，因此也無法完全接受。

五、 但由於兩國結果在西南印度洋都呈現下降趨勢，因此小組憂心西南印度洋有正被過漁的危險，尤其近幾年又持續增加作業船，小組認為ＩＯＴＣ不應允許任何漁獲量或捕劍旗魚之努力量的增加，並建議應採取控制或降低西南印度洋區努力量的管理措施。

六、 會中亦特別對我國之派員參加及研究貢獻表示感謝，並於會議報告中作成紀錄。

七、 為使業者瞭解目前研究結果及管理趨勢，建議向業者說明本次會議結論，並向業者宣導提供詳實資料之重要性，及勸導不要再增加印度洋劍旗魚之漁捕壓力，以避免對資源的繼續傷害。

八、 為能反應真實資源狀況，未來建議繼續加強漁獲率之研究，希望能真正去除目標魚種效應。

伍、 會議報告

一、 我國於會議中提報之研究報告（附件一）

二、 第四屆劍旗魚工作小組會議報告（附件二）

CPUE Standardization of Indian Ocean Swordfish from Taiwanese Longline Fishery for Data up to 2002

Shui-Kai Chang[1] and Shyh-Jiun Wang[2]

INTRODUCTION

Taiwanese longline fishery in the Indian Ocean commenced in mid-1950s and targeted on yellowfin tuna in the beginning. Following the development of the fishery, two different operation patterns were currently established: The first targets on albacore (ALB) for canning and the other on tropical tuna species (bigeye, BET and yellowfin, YFT) for sashimi market (Chang and Liu, 2000; Chang, 2002). But, since 1990s, swordfish (SWO) has become a seasonal target species to some of the fleets, which have made the major portion (about 40-60%) of the overall catch in the Indian Ocean during recent decades (Figs. 1 and 2).

Besides of Taiwan, there were about 15 countries utilizing the Indian Ocean swordfish stock (IOTC, 2003) and made the overall catch increase three-folds from 10,000 tons before 1990s to 30,000 tons in 2002, with a peak of 40,000 tons in 1998 (Fig. 1). With the rapid increase of catch, significant decrease of catch rates in some regions was observed (IOTC, 2003). This observation and the recent increase of fleet size fishing for swordfish have caused concerns on the resource and therefore analysis on the stock status is required.

Historically most of the swordfish catch in the Indian Ocean was made by longline fisheries. Among the longline fishing nations, Taiwan (seasonal targeting fishery) and Japan (bycatch fishery) have the longest period of catch data series. And, Taiwanese data are of importance due to its targeting feature and the high-proportion to the total catch. Studies on CPUE standardization of Taiwanese data is thus important for understanding the stock status, but however is not straightforward because the data have confounded with many factors, especially the target-shifting effect. This paper performs several trials (runs) using the GLM approach on data series up to 2002 and provides

[1] Fisheries Agency, Council of Agriculture, Taipei, Taiwan

[2] Overseas Fisheries Development Council, Taipei, Taiwan

comparisons and discussions on the results, based on the similar studies performed during the 2003 meeting of the IOTC Working Party on Billfish (IOTC 2003).

MATERIAL AND METHODS

The data

The Taiwanese catch and effort data are compiled from logbooks and start from 1967 to 2002, with year 2002 being preliminary. For years of 1967-1978, only aggregated 5°x5° square monthly data are available, and from 1979 onwards, both original logbooks and aggregated data are available. The logbook data contain basic information on fishing time, area, hooks and catches of 14 species including major tunas (albacore, bigeye, yellowfin, bluefin tunas) and billfishes (swordfish and marlins). Only years after 1995 contain hooks per basket (HPB) information. These data were provided by the Overseas Fisheries Development Council of the Republic of China.

The data between 20°E and 30°E in the waters adjacent to South Africa has been included in the dataset for study.

The model

The statistical model used for standardization was GLM under lognormal error structure, with main factors of year (Y), quarter (Q), area (A), target (T), sea surface temperature (sst, S), and mixing layer depth (mld, D) effects:

$$\ln\left(\frac{C_{y,q,a,t,s,d}}{E_{y,q,a,t,s,d}} + x\right) = \mu + Y_y + Q_q + A_a + T_t + S_s + D_d + (Interactions) + \xi_{y,q,a,t,s,d} \qquad (1)$$

where, $C_{y,q,a,t,s,d}$ and $E_{y,q,a,t,s,d}$ are catch (kg) and effort (1000 hooks) for year *y*, quarter *q*, area *a*, target category *t*, sst (in integer code), and mld (in the order of tenth). μ is the global mean and ξ the error term. The variable *x* is the overall mean CPUE to avoid the zero catch rate problems.

The factors

Quarter factor was considered in the model because swordfish is a seasonal target species to the fleets and hence the catches (Fig. 3, top) and catch rates of some quarters were higher than the others. Normal definition of four quarters (Qt), i.e., Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec, were used in the model for several runs (Table 1), but from Fig. 4, the catch pattern is a little bit different from the normal definition. To make it homogeneous within a quarter, we slightly changed the definitions of second and third quarters to be Apr-May and Jun-Sep respectively and renamed as Qt_new.

Based on the homogeneity of historical swordfish catch distributions (Chang, 2003), the same ten areas were defined as in 2003 WPB meeting (Area_2003 in Table 1), except that Area 7 has been extended southward to 45°S and westward to 20°E (Fig. 5). From the bottom panel of Fig. 3, different area has significant trend of swordfish catch. As suggested in 2003 WPB meeting, Areas 3 and 7 have been further split into Areas 31/32 and 71/72 respectively in this study (Fig. 5), according to Longhurst ecosystem criteria. For the study, as did in 2003, Areas 5 and 6 were combined as Area 56, Areas 8 and 9 were combined as Area 89, to reduce the number of area.

The target-shifting practice may affect the swordfish catch rate and hence needs to be accounted for in the model. Due to insufficient information on gear configuration (e.g., HPB), this study used three indices to express the target effect: (1) Target_%_4q: quartile of catch composition of swordfish against the four main species (albacore, bigeye, yellowfin tunas and swordfish). (2) Target_%_hpb: three categories of swordfish catch composition defined based on the information of HPB of 1995-2001, i.e., <8%, 8-15%, >15%. This index has been used in the 2003 WPM meeting. (3) Target_HpB: four categories of HPB defined based the study made in 2003 meeting, i.e., <9, 10-12, 13-14, >14. This index applied only for data with HPB information since 1995.

Sea surface temperature data and mixing layer depth data have been applied in the model this time for some trial runs.

Adjustment by area size

A year-area interaction term was included in the model to capture the effect of catch rates in different area changing at different rates over time. It is commonly assumed that the catch rate for a year and an area is proportional to the fish density in the area during that year (Punt *et al.*, 2000). Hence, the final standardized catch rate could be obtained from the equation:

$$U_y = \sum_a S_a U_{y,a} \qquad (2)$$

where, U_y is the standardized catch rate for year y and $U_{y,a}$ is the standardized catch rate for year *y* and area *a* obtained from the GLM running. S_a is the relative size of the area *a* to the overall studied area.

RESULTS

With combinations of different options of the above-mentioned factors and the consideration of discrepancy in the nature of CPUE in terms of number and weight, we have performed several GLM model runs. Table 1 lists results of some of the specific runs for comparison discussions.

Run 2 & 3

The Run 2 (coded as R-2 in Table 1) is basically the same run as in 2003 meeting, except that the data included 20°S-30°S area in the waters off South Africa and with revised 2001 and preliminary 2002 data. Interactions among the main factors have been examined and those were insignificant, or significant ($P < 0.001$) but led to negligible effects on the change of deviance, were removed from the final model. And thus, only Year*Area and Area*Target were remained in the final model. Areas 1, 2, and 89 were also excluded from the final model.

Since the catch and data records between 40°S-45°S of Area 7 were very few, these data were excluded in Run 2, but were included in Run 3 for comparison. The result in Table 1 shows no obvious difference between them.

Both Run 2 and 3 used swordfish catch composition categories (three) defined from HPB information (Target_%_hpb) in 2003 WPM meeting as the target factor. Only half of the variances could be accounted for by this model (R^2=0.5). No significant trend is observed for the resulted standardized CPUE for these two runs (Fig. 6).

Run 4 & 5 & 6

After Run 4, the target factors all used quartile of swordfish catch composition (Target_%_4q) which has also been applied in 2003 meeting, instead of the pre-defined categories.

Run 4 used the same model and conditions as Run 2 except the target factor. The R^2 (0.71) is much higher than Run 2. Most of the variance can be explained by target effect. The resulted standardized relative CPUE (Fig. 6) is much fluctuated than Run 2 although the pattern is a little bit similar.

Since Run 5, the applied area definition was the new revised one (Area_2004): Area 7 was split into 71 and 72. Area 3 has been split in the beginning but the run can not get reasonable estimation, and thus was combined as one in the final. Since Run 5, the applied definition of quarter was also the new one (slightly changed quarters 2 and 3). Data of 1979 and 1980 were removed for the convenience to interpret the CPUE trend.

The result of Run 5 is similar to that of Run 4 from the deviance analysis in general, but for interpretation of the area effect, Run 5 is more preferable in the study.

Run 6 is based on Run 5 but used CPUE in terms of catch in number, instead of in weight. This is because of the consideration that the mean size of swordfish catch in different area may change by years after a heavy exploitation. The result indicates an improved R^2 (0.74).

Run 7 & 8

Run 7 and 8 have included additional factors of sst and mld in the GLM model. Run 7 used CPUE in terms of catch in number (as in Run 6), but Run in terms of weight. For these two, result of Run 7 is better than Run 8 in terms of R^2. Standardized CPUE trend seems slightly different between them in the early years (1992-1994) when swordfish became a seasonal target.

Run 10 & 11

Run 10 and 11 were based on Run 7 and 8, respectively, and conduct standardizations individually on Area 3, 4, 71 and 72 where are concerned most by the WPB. The resulted relative CPUE is shown in Fig. 7.

Run 12 & 13

These two runs conducted based on Run 7 and 8, respectively, but applying HPB information as target factor (Target_%_HpB). R^2 of these runs are much smaller than all the runs. Area and quarter factors become more important in explanation of the variance than target factor.

Run 14

Run 14 was conducted based on Run 7. It contains two separate runs: one using data of 1967-1979 using monthly aggregated catch and effort data; the other one using shot by shot data of 1979-2002. Standardized CPUE series of the two runs were combined as one in Fig. 8. The R^2 are 0.92 and 0.75, respectively. This run is to provide an idea about long time series trend of the CPUE.

DISCUSSION

Target factors and interpretation of CPUE trends

In WPTT 2004, the meeting discussed a lot about the Lee and Nishida criteria to deal with the target effect. But the criteria does not consider swordfish and thus not applicable in this study for comparison. This study conducted runs based on three other methods (Table 1). Run 2 and 3 applied the Target_%_hpb; Run 12 and 13 applied Target_HpB and the rest Target_%_4q. Fig. 9 shows example residual plots of the three types of runs. Runs of Target_%_4q and Target_HpB have better fitting results to normal distribution assumption than Target_%_4q. However, Target_HpB model provides least variance explanation and the target factor became not so important.

As to the relative trends of standardized CPUE (Fig. 6), Target_%_hpb model shows relatively flatter trend. Target_HPB on the other hand shows sharp declining trend since 1997 when the swordfish catch was decreasing (Fig. 2). The percentage of HPB reported was lower than 50% before 2001 and increased significantly since 2001 (Fig. 10). This trend may affect the performance of modeling of Target_HPB.

The trend from Target_%_4q models in Fig. 6 show a declining trend since 1981 to a low level during 1989-1991 and then increased in 1992 to a similar level as 1988. Trends of the following years are somewhat different among different runs, but in general have been high during 1992-1997 then declined to 1999 with a slowly increasing trend to 2002.

When viewing the whole series of relative CPUE from 1967-2002 in Run 14 (Fig. 8), the above described trend becomes part of a two-mode CPUE pattern. The series starts with a continuous declining trend since 1967, and then displays two modes in 1978-1989 and 1991-1999 or 2000. For the recent two years of 2001-2002, the CPUE starts to increase again.

The recent increasing trend might be relating to the continuous decrease of catch and relaxing of fishing pressure since 1998. Take the number of vessels access to fishing license in Somalia waters as example. In 1996 when the swordfish catch was good, there were about 80 vessels in the waters for swordfish (and partly bigeye). The number has been decreased to 40 in 1998 and decreased further to 10 in 2000 due to the unprofitable price and low CPUE. Recently the number has been increased again in 2002 for a good fishing condition.

Environmental factors

Environmental factors of sst and mld have been included in some of the runs. Run 5 and 8, and Run 6 and 7, can be two pairs for comparison. From the deviation analysis (Table 1) and relative CPUE (Fig. 6), there is no obvious difference noted between the two runs of each pair. This indicates that there might be no significant relationship between swordfish CPUE and environmental factors.

A preliminary test on the relationship of sst against CPUE of the four main species (albacore, bigeye, yellowfin tunas and swordfish), showed that strong relationships exist for albacore, bigeye and yellowfin tunas ($r>\pm0.6$), but not for swordfish ($r<0.15$). Similar situation was also noted for mld. This test has supported the results of model runs here.

CPUE in terms of catch in number and weight

Swordfish has been heavily exploited in mid-1990s which might cause changes in size of catch. Therefore, comparison runs have been conducted to see the effect. Run 5 and 6, Run 7 and 8, Run 10 and 11, and Run 12 and 13 are pairs for the discussion. All of the runs show that models with CPUE in number have higher R^2 than with CPUE in weight. As to the CPUE trends, no obvious difference is noted, except for years 1992-1994. In general, CPUE in number shows more clear declining trend after 1993 then CPUE in weight.

The differences in CPUE trends are slightly more obvious for Run 10/11 in Area 7 (Fig. 7) where swordfish was caught mostly, and the declining trends are clearer for model results with CPUE in weight than with CPUE in number, a different impression as above. This might have connections with the decreasing trend of size of catch.

CPUE trends by major area

Fig. 7 shows the standardized relative CPUE by major fishing areas: Areas 3, 4, 71 and 72, from Run 10 and 11. Both Areas 3 and 4 have a mode after 1992, but in general the trends are relatively flatter than Areas 71 and 72. CPUEs of Areas 71 and 72 have reached the highest level in 1992 and 1993, respectively.

After the highest level, both declined continuously and sharply to 2000, and then increased a little bit to 2002.

Considerations on unit stock assumption

This study takes swordfish in the whole Indian Ocean as a unit stock. The nuclear and mitochondrial DNA analyses of Chow and Takeyama (2000) indicated no genetic differentiation between the swordfish samples from the Pacific and Indian Oceans, and assumed that they are one breeding unit. However, a recent study using mitochondrial DNA (Lu, *et al.*, personal comm.) has suggested a three stocks structure for the Indian Ocean swordfish: (1) the northern Madagascar region; (2) the Bay of Bengal; and (3) the rest Ocean region. Since most of the swordfish was made in the western Indian Ocean, especially for Taiwanese fishery, conclusions on stock status presumably will be very different from the current if the one-stock assumption is invalidated.

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Table 1. Analysis of deviance table for generalized linear models with different runs fitted to Indian Ocean swordfish data from Taiwanese longline fishery. All the factors listed in the table are significant (P<.0001). Definitions of the runs are listed on the bottom rows of the table. Refer to text for further descriptions. (DF: degree of freedom; SS: sum of square; MS: mean square)

	R-2			**R-3**			**R-4**			**R-5**			**R-6**			**R-7**			**R-8**		
Source	DF	SS	MS	DF	SS	MS	DF	SS	MS	DF	SS	MS	DF	SS	MS	DF	SS	MS	DF	SS	MS
Year	23	232	10	23	235	10	23	443	19	21	630	30	21	647	31	21	623	30	21	612	29
Qt	3	250	83	3	247	82	3	130	43												
Qt_new										3	133	44	3	120	40	3	105	35	3	124	41
Area_2003	4	374	93	4	375	94	4	362	90												
Area_2004										5	268	54	5	266	53	5	142	28	5	86	17
Target_%_4q							3	22110	7370	3	19747	6582	3	20240	6747	3	19927	6642	3	19445	6482
Target_%_hpb	2	9707	4854	2	9715	4858															
Target_HpB																					
sst																19	61	3	19	84	4
mld																15	17	1	15	31	2
Year*Area	92	1011	11	92	1022	11	92	985	11	105	993	9	105	792	8	105	717	7	105	933	9
Area*Target	8	1097	137	8	1098	137	12	745	62	15	706	47	15	559	37	15	555	37	15	696	46
R**2	0.50			0.50			0.71			0.70			0.74			0.74			0.70		
Starting year	1979-			1979-			1979-			1981-			1981-			1981-			1981-		
Ref-Run	as 2003			R-2			R-2			R-4			R-5			R-6			R-7		
Note	*see bottom			inc. south of 40S			target from quartile			new Area & Qt			CPUE in number			CPUE in number			CPUE in weight		
										Area 31+32=3						inc sst, mld			inc sst,mld		

Condition changes of R-2 against 2003 run

1. including 20S-30S, revised 2001 and preliminary 2002
2. excluding south of 40S, without sst or mld, hook<1000, sp_rep_number<4
3. using 2003 Area definition, but exlcuded Area-1,2,89
4. using swo catch comp defined from HpB information as target factor (3 categories)

Table 1. (continuate)

	R-10-3			R-10-4			R-10-71			R-10-72			R-11-3			R-11-4		
Source	DF	SS	MS	DF	SS	MS	DF	SS	MS	DF	SS	MS	DF	SS	MS	DF	SS	MS
Year	21	359	17	21	170	8	21	148	7	21	221	11	21	506	24	21	266	13
Qt																		
Qt_new	3	82	27	3	60	20	3	8	3	3	5	2	3	139	46	3	48	16
Area_2003																		
Area_2004																		
Target_%_4q	3	13169	4390	3	19972	6657	3	1889	630	3	2928	976	3	12292	4097	3	18609	6203
Target_%_hpb																		
Target_HpB																		
sst	6	25	4	4	4	1	12	11	1	14	26	2	6	40	7	4	0	0
mld	9	21	2	7	16	2	11	12	1	11	12	1	9	28	3	7	43	6
Year*Area																		
Area*Target																		
R**2	0.60			0.83			0.75			0.79			0.56			0.77		
Starting year	1981-			1981-			1981-			1981-			1981-			1981-		
Ref-Run	R-7			R-7			R-7			R-7			R-8			R-8		
Note	only Area-3			only Area-4			only Area-71			only Area-72			only Area-3			only Area-4		
	CPUE in number			CPUE in number			CPUE in number			CPUE in number			CPUE in weight			CPUE in weight		

Table 1. (continuate)

	R-11-71			**R-11-72**			**R-12**			**R-13**			**R-14-1967**			**R-14-1979**		
Source	DF	SS	MS	DF	SS	MS	DF	SS	MS	DF	SS	MS	DF	SS	MS	DF	SS	MS
Year	21	163	8	21	290	14	7	258	37	7	255	36	12	30	3	23	620	27
Qt																		
Qt_new	3	12	4	3	4	1	3	248	83	3	295	98	3	5	2	3	106	35
Area_2003																		
Area_2004							5	620	124	5	524	105	5	5	1	5	140	28
Target_%_4q	3	1841	614	3	2672	891							3	4482	1494	3	21445	7148
Target_%_hpb																		
Target_HpB							3	60	20	3	104	35						
sst	12	13	1	14	40	3	18	138	8	18	142	8	15	5	0	18	61	3
mld	11	16	1	11	14	1	15	76	5	15	75	5	12	2	0	12	20	2
Year*Area							35	772	22	35	741	21	60	21	0	115	769	7
Area*Target							15	167	11	15	185	12	15	22	1	15	598	40
R**2	0.73			0.77			0.23			0.23			0.92			0.75		
Starting year	1981-			1981-			1981-			1981-			1967-1978			1979-2002		
Ref-Run	R-8			R-8			R-7			R-8			R-7			R-7		
Note	only Area-71			only Area-72			Target from HpB			Target from HpB			Excld area 1 2 10			Excld area 1 2 89		
	CPUE in weight			CPUE in weight			CPUE in number			CPUE in weight								

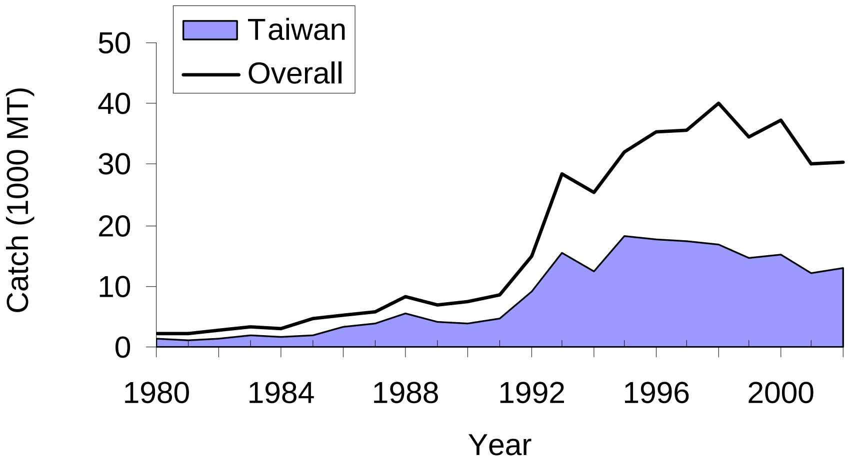


Fig. 1. Catch series of the Indian Ocean swordfish during 1980-2002.

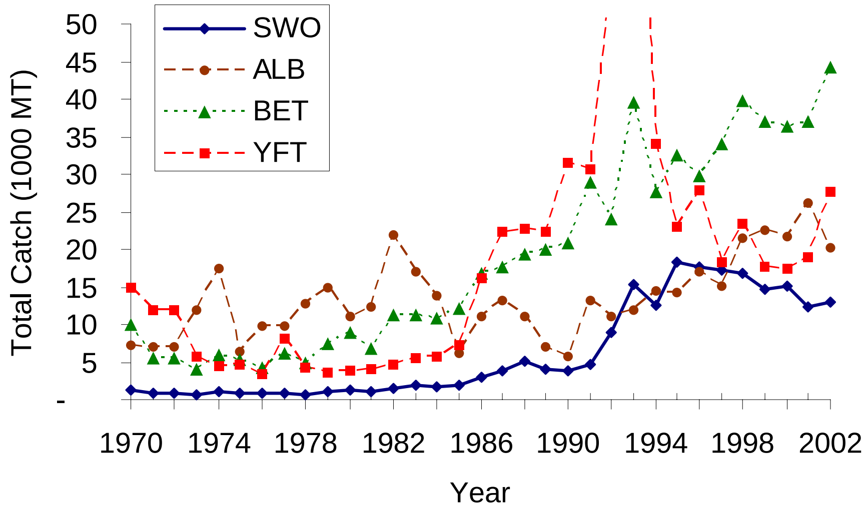


Fig. 2. Annual catches of the major tunas (ALB, BET, YFT) and swordfish (SWO) of the Indian Ocean by Taiwanese longline fishery, 1970-2002. The specific high catches of YFT in 1992 (56,000 MT) and 1993 (88,000 MT) are omitted for clarity of the trends of other species.

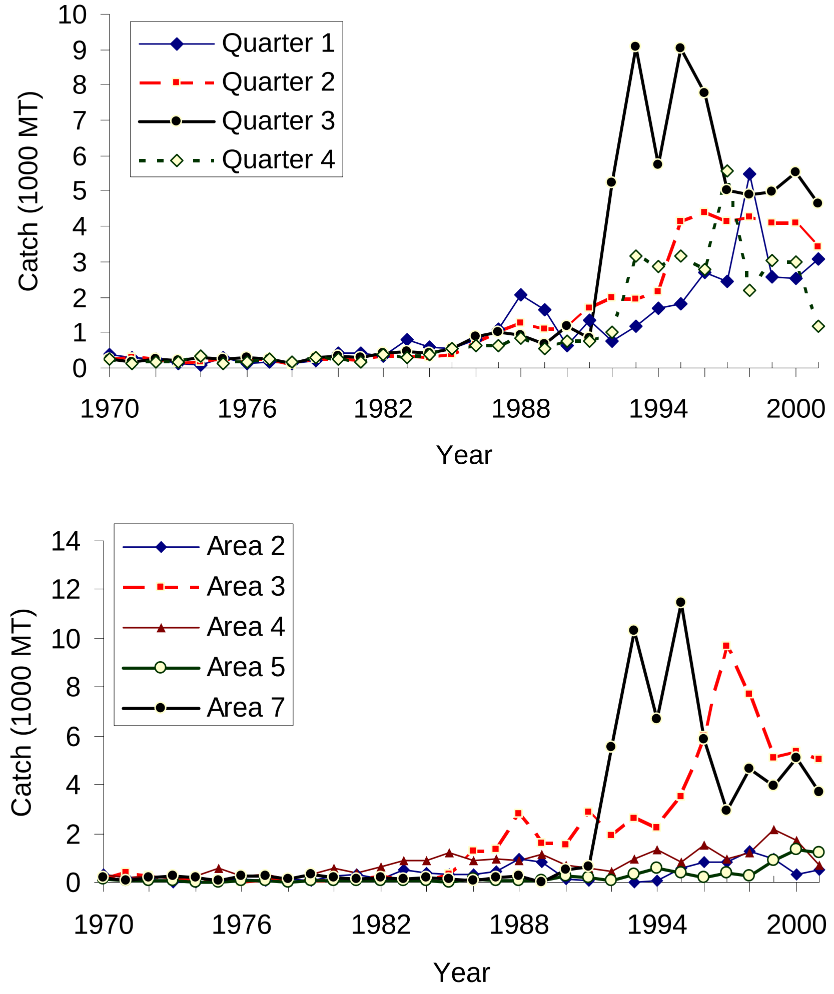


Fig. 3. Catch trends by quarter and area of the Indian Ocean swordfish by Taiwanese longline fishery, 1970-2001. Refer to Fig. 5 for area definition. Only five areas with significant catches are shown in the bottom panel for clarity.

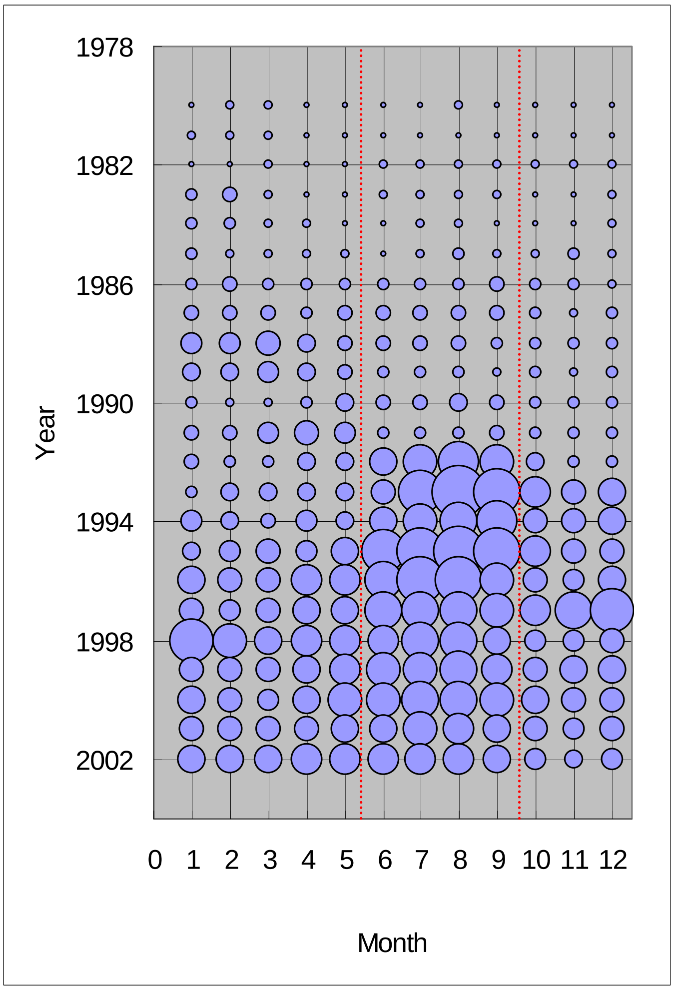


Fig. 4. Monthly catch pattern of the Indian Ocean swordfish by Taiwanese longline fishery during 1979-2002.

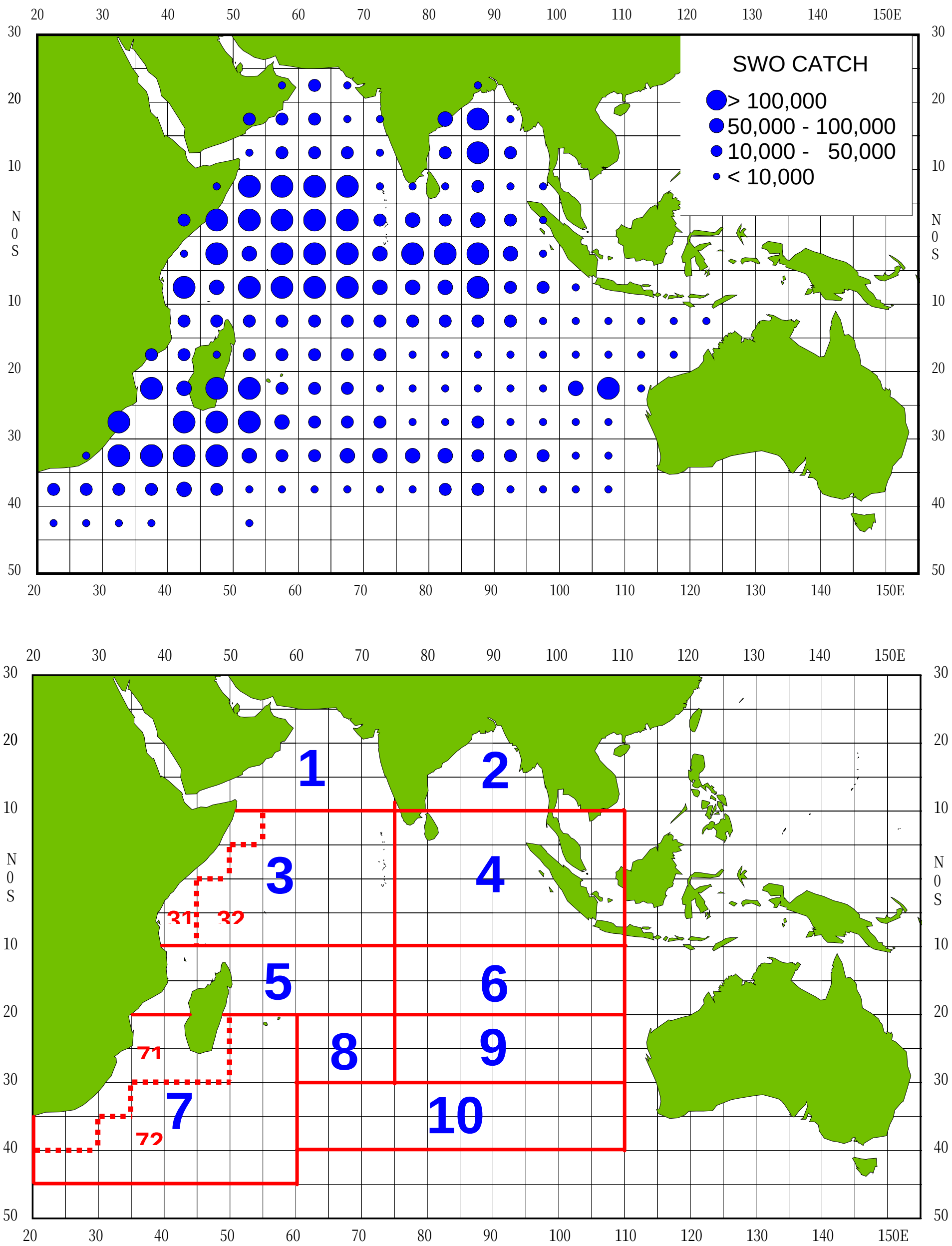


Fig. 5. Average catch distribution of the Indian Ocean swordfish by Taiwanese longline fishery in 1990s (top) and the area stratification (bottom) used in the analysis.

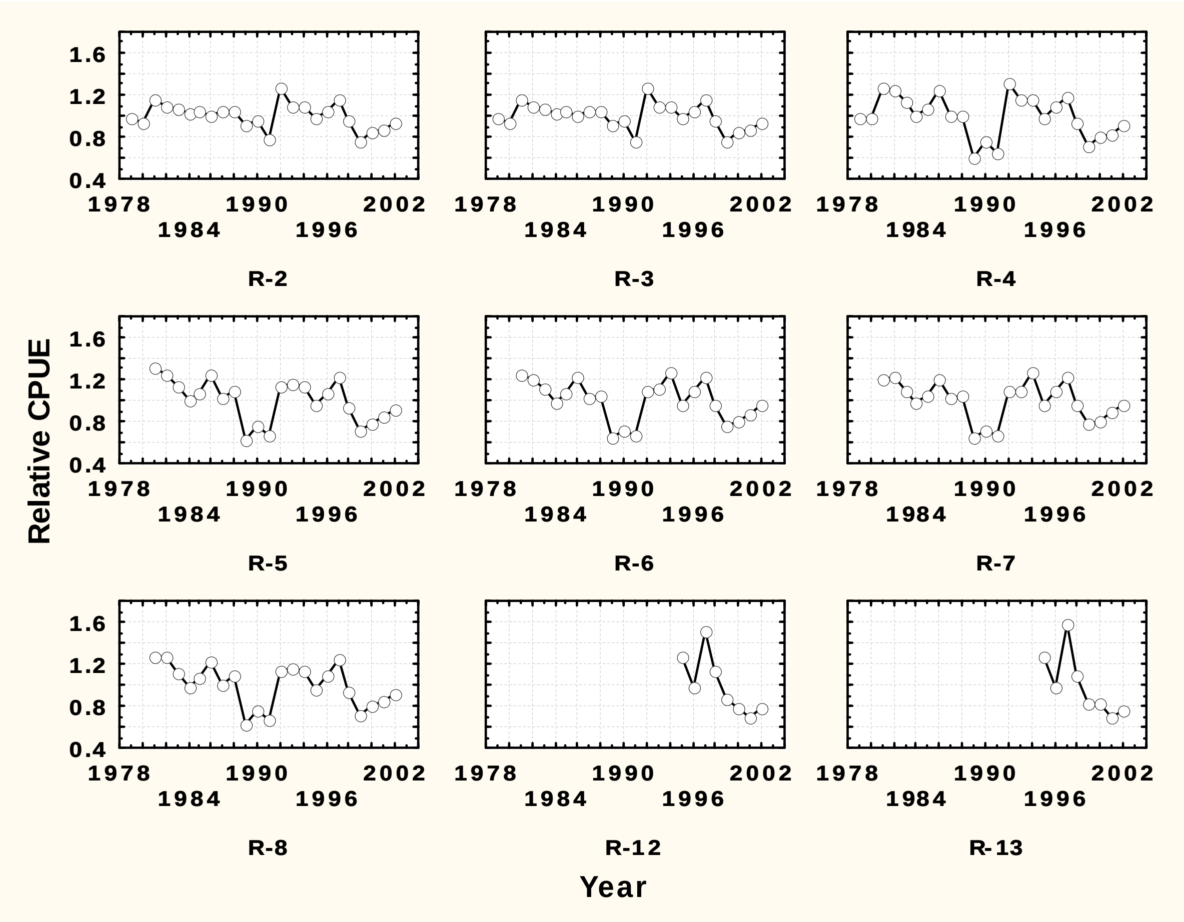


Fig. 6. Results of relative CPUE (standardized) of Indian Ocean swordfish from different runs. Refer to text and Table 1 for definitions of the runs.

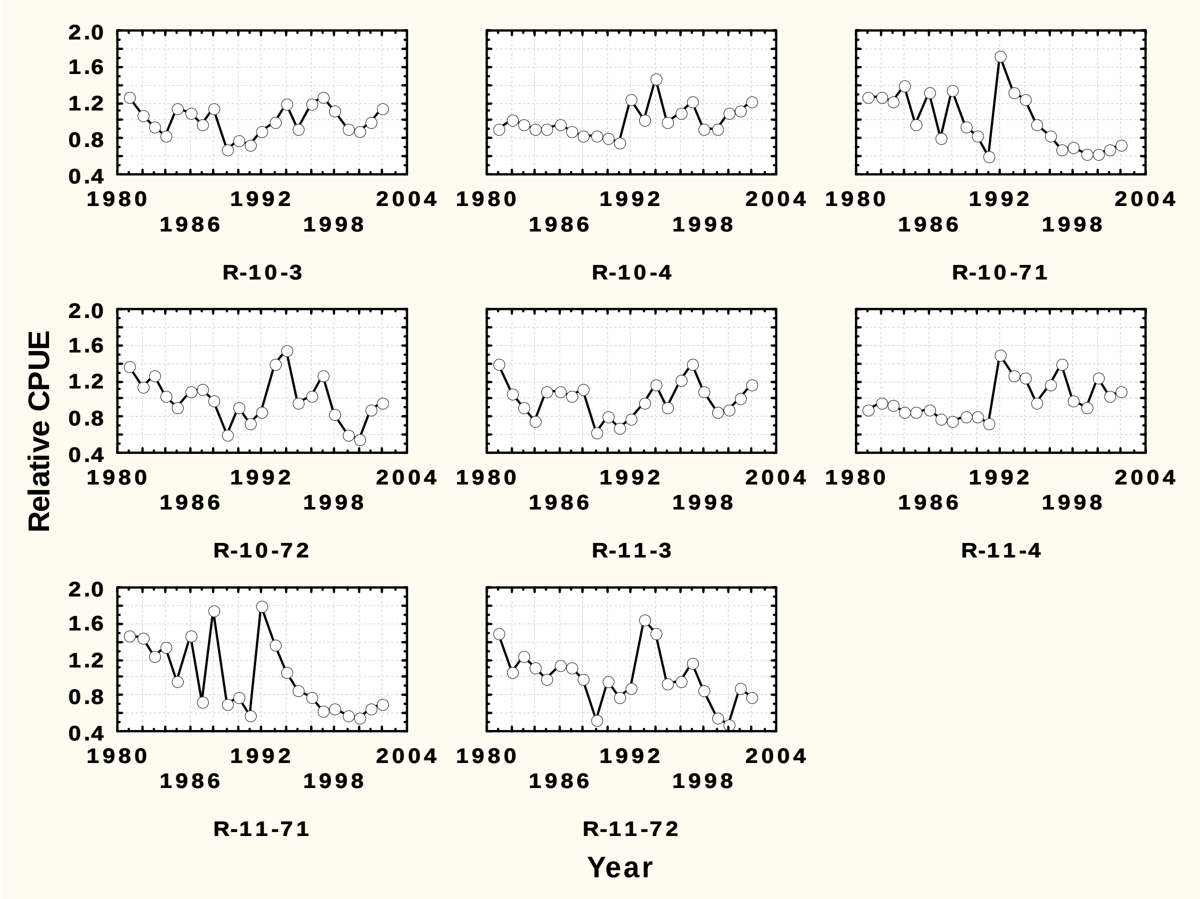


Fig. 7. Results of relative CPUE (standardized) of Indian Ocean swordfish from Run 10 and 11 for Areas 3, 4, 71 and 72. Refer to text and Table 1 for definitions of the runs.

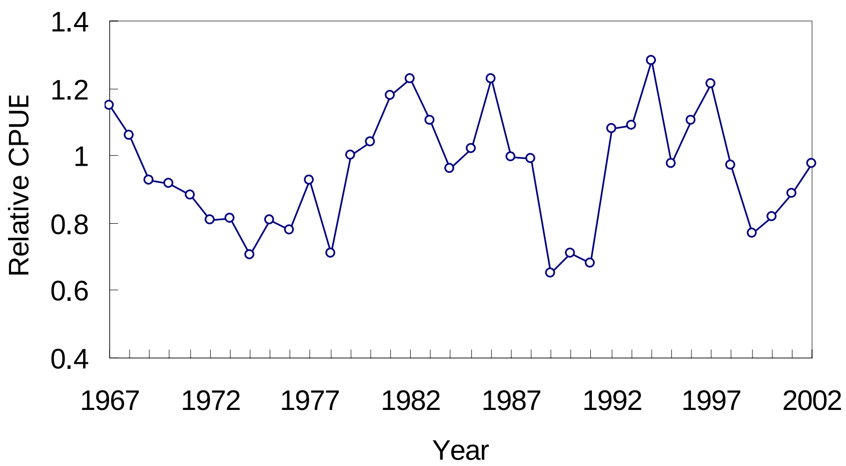


Fig. 8. Relative CPUE from GLM fitting to Taiwanese swordfish data of the Indian Ocean. Data of 1967-1978 were calculated based on monthly aggregated data and that of 1979-2002 on shot by shot logbook data.

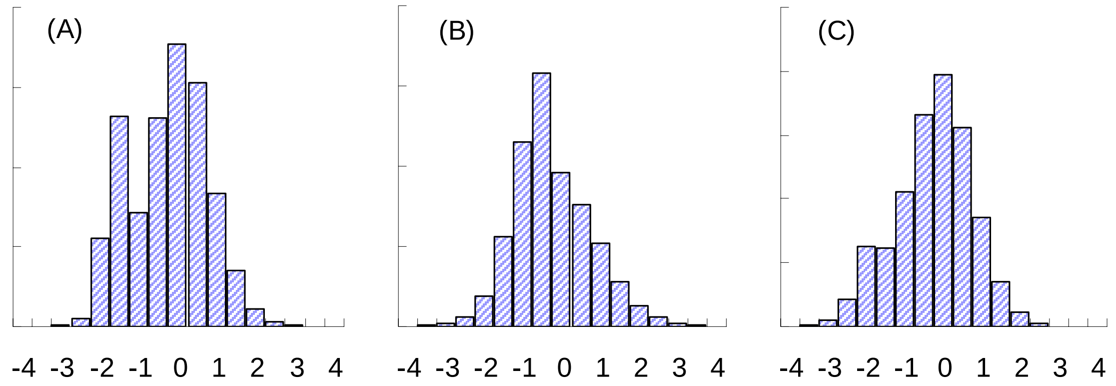


Fig. 9. Three principle histograms of residuals for analysis based on log-normal error-model for three different assumptions on target factors: (A) Target_%_hpb, (B) Target_%_4q, and (C) Target_HpB. Refer to Material and Methods section of the definition.

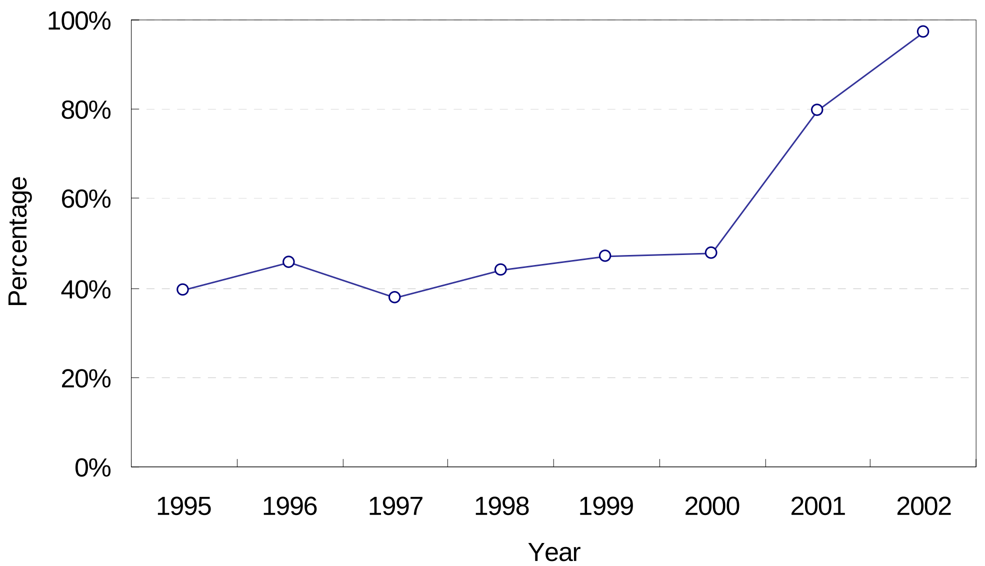


Fig. 10. Percentage of data records with hooks per basket information reported to the overall data records in the logbooks of Taiwan Indian Ocean longline fishery.

Indian Ocean Tuna Commission
Commission des Thons de l'Océan Indien

Report of the 4th Session of the IOTC Working Party on Billfish

Mauritius, 27 September – 1 October 2004.

Summary

1. OPENING OF THE MEETING

The fourth meeting of the Working Party on Billfish (WPB) was opened on 27 September 2004 at the Albion Fisheries Research Centre, Albion, Mauritius, by the Chairperson, Dr. John Gunn, who welcomed the participants (Appendix I) and thanked the Albion Fisheries Research Centre for hosting the meeting.

The Agenda for the Meeting was adopted as presented in Appendix II. The list of documents presented to the meeting is given in Appendix III.

2. REPORTS ON CATCH STATISTICS

The IOTC Secretariat presented IOTC-2004-WPB-01 which provides a detailed review of the billfish statistics held by the IOTC. These data are available for scientists through the IOTC data base.

2.1. *Revision of the IOTC databases*

Nominal catch data in the IOTC IOTDB database are not always reported under individual gears or species.

Decomposition of catches from data aggregated by species and/or gear aggregates is, in some cases possible, when the Secretariat has access to alternate sources of information such as publications or fishery bulletins.

Another database has been especially designed to assist decompose the catches in IOTDB to the individual gear and species levels. However, in general these data are uncertain and their use is limited.

The Secretariat conducted several reviews of the Nominal Catch (NC) database during 2003 and 2004. These revisions led to important changes in the estimates of catches of sailfish (SFA) and blue marlin (BUM) and, to a lesser extent, black marlin (BLM), swordfish (SWO), striped marlin (MLS) and shortbill spearfish (SSP). More details about these reviews can be found in IOTC-2004-WPB-INF01.

Swordfish

Swordfish are caught mainly by pelagic longliners (95%) followed by gillnets (5%) and other gears (Figure 1). Until the early 1990's swordfish were mainly a by-catch of industrial longline fisheries, with catches increasing slightly from 1950 to 1990 in proportion with increases in longline effort and catches of target species (tropical and temperate tunas). Throughout the 1990's catches of swordfish greatly increased to a peak of 36,000 t in 1998, the maximum recorded catch for the species in the Indian Ocean. Current catch levels are around 30,000 t (Figure 1). The change in target species from tunas to swordfish by part of the Taiwanese fleet along with the development of longline fisheries in the region (Australia, Réunion Island, Seychelles and Mauritius) and the arrival of longline fleets from the Atlantic Ocean (Portugal, Spain), all targeting swordfish, are the main reasons for the increase.

Marlins

Blue marlin (BUM), black marlin (BLM) and striped marlin (MLS) are caught mainly by pelagic longlines (70%) and gillnets (20%) and some troll and hand line gear (Figure 2). These species are generally caught as by-catch of industrial and artisanal fisheries but are targeted by sport fisheries. Catches of BUM are larger (by a factor of 2) that those of BLM or MLS. The total catch of all marlin species varies from year to year. It reached a maximum of 17,000 t in 1998; and was around 8,000 t in 2002 (Figure 2). The bulk of the marlin catch in the Indian Ocean is taken by the Taiwanese and Japanese fleets, but recently Indonesia and several IUU fleets have begun to record significant catches.

Indo-Pacific Sailfish and Shortbill Spearfish

Indo-Pacific Sailfish represent 90% of this catch group, and are caught mainly by gillnets (80%), troll and hand lines (10%), longlines (7%) or other gears (Figure 3). Information on shortbill spearfish catches are available from pelagic longline catches only, although this species is probably a by-catch of other artisanal fisheries and mislabelled or reported aggregated. The catches of sailfish have increased markedly since the mid-1980's proportionally to the development of the gillnet / longline fishery in Sri Lanka. The largest catches were recorded in 2000 (16,500 t) with current catches only slightly lower than those (Figure 3).

Data Availability and Data Quality

Most of the catches of swordfish and other billfish species have been estimated for years prior to 1970 as catch statistics are either not available or were not recorded to the species level by fleets for which billfish species made up part of the catch. These estimates affect the catches of swordfish and marlins, as these species represented a larger proportion of the catches than, for example, sailfish and spearfish.

There is considerable uncertainty associated with the catch estimates for the following fisheries:

- **Sri Lankan gillnet and longline fisheries**: The catch series of billfish in Sri Lanka were re-estimated for 1950-2002. Discrepancies between the different catch estimates produced in the country are of concern and make it difficult to estimate catches. The new catches series estimated are, nevertheless, thought more accurate than the previous. The catches of Sri Lanka domestic fisheries, mainly gillnet, were re-estimated in 2004 for the period 1950-2002. The re-revised catch estimates for swordfish, Indo-Pacific sailfish and marlins are lower than those recorded previously. The new estimates are based on information collected through different missions by IOTC and OFCF staff to Sri Lanka.

- **Yemen gillnet fishery**: The information collected during several missions to Yemen by FAO staff indicates that gillnet catches in Yemen may be around 45,000 t per year, with large catches of yellowfin tuna taken in recent years. This figure is five times higher than that recorded in the FAO database, which, unfortunately, is the only information available to the Secretariat.

- **Mozambique** : Swordfish and Indo-Pacific sailfish catches reported by Mozambique between 1983 and 2002 have been erased from the IOTC Database as these data pertain to foreign fleets operating in the EEZ not to domestic fleets.

- **Fresh tuna longliners based in Indonesia**: The data collected since June 2002 has allowed the estimation of catches of longline vessels based in Benoa for 2003. The new catch estimates differ from those obtained by using the previous catch estimation procedure (CSIRO-RIMF sampling). Therefore, the catch series is expected to change once that new catches are estimated for 2003 (all previous estimates were based on the catches obtained through CSIRO-RIMF sampling in Benoa). The current catch series are, therefore, not thought fully accurate.

- **Other fresh tuna longline fleets**: Although the catches of fresh tuna longline vessels based in various ports of the Indian Ocean were re-estimated from data coming from past or recent sampling schemes, the precision of the estimates is still considered to be poor, especially for those fleets operating from ports not covered by the schemes, and where past catches have been estimated using recent catch levels..

- **Deep-freezing longline fleets**: The Secretariat re-estimated catches for the period 1992-2002 using new information collected during 2003. These catch estimates remain uncertain due to the many assumptions made in estimating total catches and the species breakdown. The number of vessels operating under flags of non-reporting countries has decreased markedly since 2001. The reason for this decrease is not fully known and revisions to the catch estimates may be undertaken when more information become available.

Estimation of catches of non-reporting fleets

The estimates of catches of non reporting fleets were updated in 2004 thanks to new information available during the year:

- **Fresh tuna longline**: Catches by fresh tuna longliners were estimated for each port where the different fleets were based. Most of the fresh tuna longline catch appears to be taken by Taiwanese vessels.

- **Indonesia**: The catches by Indonesian vessels during 2002 were estimated on the basis of previous reviews. Information collected through the multilateral catch monitoring programme in Indonesia will assist catch by species to be re-estimated.

- **Thailand**: The catches of fresh tuna longliners from Taiwan,China and Indonesia in Phuket were estimated using data collected through the AFRDEC (Andaman Sea Fisheries Research and Development Centre)-OFCF (Overseas Fishery Cooperation Foundation of Japan)-IOTC Sampling Programme.

- **Malaysia and Singapore**: The catches by fresh tuna longliners based in Malaysia and Singapore since 1992 were estimated using data from the IPTP Sampling Programme, new estimates from the Fisheries Research Institute of Penang, and vessel activity information for Singapore (Jurong).

- **Sri Lanka**: The catches by fresh tuna longliners that unload to processing plants in Sri Lanka were estimated on the basis of previous data collected by NARA (National Aquatic Resources Research and Development Agency) in Colombo and estimates from Phuket and Penang sampling.
- **Maldives:** The catches by fresh tuna longliners were not estimated due to lack of reliable information on their numbers and activity.

Deep-freeze longline: The catches by large longliners from several non-reporting countries were estimated using IOTC vessel records and the catch data from Taiwanese longliners, based on the assumption that most of the vessels operate in a way similar to the longliners from Taiwan,China. The collection of new information on the non-reporting fleets during the last year, in particular the number and characteristics of longliners operating, led to improved estimates of catches. The number of vessel operating since 1999 has decreased and this has led to a marked decrease in catch levels. The reason for this decrease in the number of vessels (and catches) operating in the Indian Ocean is not fully explained. Nevertheless, this decrease is somewhat proportional to an increase in the number of vessels recorded operating under flags of reporting countries, such as Philippines and the Seychelles.

Data related issues for billfish species

The following data related issues were identified for billfishes:

- Marked differences between the catches of Korean longliners reported as nominal catch and the catch and effort.
- Little information on the catches, effort and size-frequency from fresh tuna longline vessels, especially from Taiwan,China and several non-reporting fleets (1985-1992).
- Little information on the catches, effort and size-frequency from non-reporting fleets of deep-freezing tuna longliners, especially since the mid-1980's.
- Lack of accurate catch, effort and size-frequency data for the Indonesian longline fishery (1973-1995).
- Little information on the catches, effort and size-frequency data for gillnet and other artisanal fisheries, especially the gillnet/longline fishery in Sri Lanka.

Improvements have taken place in a number of areas. These include:

A better level of reporting: New NC, CE and SF datasets have been obtained from several countries as for South Africa and Seychelles longline fisheries.

Revision of the IOTC databases: Several revisions of the IOTC databases have been conducted during the last two years.. This has led to new datasets being input, especially regarding CE and SF statistics (Indonesia, Sri Lanka and Mozambique) and revised series of NC data for some countries.

Disaggregation of catch data: Revisions have been conducted o the IOTC Secretariat aiming at assigning catches by species in the IOTC database to the corresponding species.

An improved Vessel Record: More information has been obtained on the number and type of vessels operating under flags of non-reporting parties. This information comes mostly from various licensing schemes in the Indian Ocean and has become an important element in the estimation of the catches of non reporting fleets.

Improved estimation of catches of non-reporting fleets: The collection of historical and current information on the landings of small fresh tuna longliners in ports in the Indian Ocean has improved the accuracy of earlier estimates. The more complete Vessel Record also permitted the estimation by flag of the catches of deep-freezing longliners.

IOTC/OFCF sampling programmes: The collection of information on the activities of fresh tuna longliners landing in Phuket and Penang has continued during 2004. This has led to more complete and accurate estimates of catches by these fleets. Other valuable data collected in the scope of these programmes includes length frequencies which will allow length-length, length-weight and weight-length relationships to be up-dated.

Plan of Action in Indonesia: A large scale operation involving several local and foreign institutions was initiated in April 2002 in Indonesia. The primary objective of this multi-lateral cooperation is building capabilities in Indonesia that will enable them to produce good quality fisheries statistics in the near future. Sampling of landings of fresh tuna longliners operating in Indonesia started in June 2002. By July 2004, more than 14,000 samplings had been conducted (and 1 million fish measured. This equates to a coverage levels of 30% to 40% of the catches unloaded by longliners in Indonesia.

Plan of Action in Sri Lanka: A multi-lateral cooperation between NARA (National Aquatic Resources Research and Development Agency), OFCF (Overseas Fisheries Cooperation Foundation of Japan)-IOTC will be initiated before the end of 2004. The objective of this collaboration is to strengthen data collection and processing systems on Sri Lankan tuna and billfish fisheries (offshore gillnet and longline fisheries and coastal longline fishery for large yellowfin tuna), leading to more accurate estimates of effort and catch by area and by species. The project is also expected to significantly improve the size frequency data collected for tropical tuna and billfish species in Sri Lanka.

2.2. National reports on fisheries and statistics

Documents describing the fishing activities of Sri Lanka, Spain, La Réunion (France), Mauritius, Australia, and Taiwan,China were considered by the WPB. In addition, data held in the IOTC data base was used by the WP to describe the Japanese Indian Ocean longline fishery.

Swordfish fishery in Mauritius

IOTC-2004-WPB-02 described the evolution of the Mauritian swordfish longline fishery. Commercial fishing in Mauritius started in 1999 when a small surface longliner started fishing for swordfish. Since then, the number of vessels has increased to six in 2003. Two types of vessels are involved: small vessels (<20m) operate in coastal waters of Mauritius; whereas large vessels (>20m) fish in offshore areas between 55° and 90°E. Both the number of trips and effort (in terms of number of hooks) have increased steadily over the last fours years. The catch of swordfish increased from 4.4 tonnes in 1999 to 601.5 tonnes in 2003. Annual catch per unit effort (in number / 1000 hooks) decreased from 10 in 1999 to 6.3 in 2001; it then increased in 2002 to 13.4 before declining slightly in 2003 to 12.3. Monthly catch per unit effort showed two periods of high catch rates (March to June and September to November). Lower catch rates were recorded during December to February and July to August. The fishing zones of the longliners were widespread from 15oS to 30o S and 55oE to 90oE. Highest CPUE (24.43 swordfish/1000 hooks) was between 20oS and 25oS and 85oE and 90oE. Mauritian scientists undertake port sampling on the catch from the longliners, collecting pectoral-caudal length and pectoral-anal length. .

The WPB noted that over the last three years, fishing opportunities were provided to 40 EU (France and Spain) vessels to operate in the Mauritian EEZ under the EU-Mauritius Fishing Agreement. During 2003, 36 EU vessels fished in Mauritian waters and 21 transhipped from Mauritius. These vessels caught 4299 tonnes of pelagics, 48% of which was composed of swordfish and 44% of shark (Figure 4). The Mauritian delegation expected that the number of Mauritian longliners will increase over the next few years as authorities are providing incentives to local fishing companies. It was also noted in discussions that in recent years Mauritius has been a transhipment port for some EU longliners; however this is decreasing following measures taken by the Mauritian authorities.

Noting the increasing numbers of vessels targeting swordfish in the Indian Ocean, and the increasing development of arrangements between distant water fleets and coastal states, the WPB recommended that a statistical documentation scheme, similar to that operating for bigeye in the Indian Ocean, be developed for swordfish.

Sri Lanka billfish fishery

IOTC-2004-WPB-03 documented recent trends and the present status of billfish fisheries in Sri Lanka. Sri Lanka has a well-established offshore fishery targeting tuna and shark. The annual production of large pelagics in Sri Lanka was 126,165 t in 2003. Although there is no target fishery for billfish, billfishes makes up to 12% of the total large pelagic landings in Sri Lanka and represents 32% of the Indian Ocean billfish catches. Billfish catches have been increasing since the early 1980's. Marlins typically dominated the billfish catches (being up to 50% of the catch until late 90's); catches of sailfish and swordfish have increased over the last 5 years. Gillnet is the main gear used in all areas, while longline, trolling and handlines are used in a multi-gear fishery. Gillnet vessels can carry up to 150 net pieces and up to 700 longline hooks depending on the size of the craft. The majority of the catch comes from the multi-day (ice) boats operating in the offshore fishery. Most sailfishes are caught as incidental catches in coastal, small-scale fishing targeting other species. More billfishes are caught in the northeast and eastern areas of Sri Lanka. Length data are very poor for billfish.

The WPB noted of the importance of the Sri Lankan billfish fisheries and the necessity to obtain detailed statistics of catches and effort by species and by fishing gear, time and area strata. The need for size sampling of these fishes was also stressed. The WPB discussed the recent increase in catches by Sri Lanka. At this stage it is not clear whether these are due to increased fishing effort from a combination of gears in both coastal and offshore areas, or to improved statistical reporting.

La Réunion swordfish fishery

IOTC-2004-WPB-04 described trends and the current situation in the French swordfish fishery based in La Réunion Island. The longline fishery in La Réunion began in 1991 and the number of boats and catch increased quickly. However in 2001-2002 there was a decrease in number and size of longliners and a significant decrease in the catch of target species. Swordfish catches decreased from 1500 t in 2002 to less than 800 t in 2003. Swordfish CPUE stabilized in 2003 after the decline observed during previous years. A southward expansion of the fishery has begun recently. The size of swordfish landed by the fishery was stable between 1993 and 2003. The WPB noted that the collection of log book data from the swordfish fishery has been poor since 2001, and recommended that all the basic statistical data that are compulsory for the IOTC member countries should be urgently collected and submitted to the IOTC.

Spanish longline fishery

IOTC-2004-WPB-05 described the recent catches of the Spanish longline fleet in the Indian Ocean. This fleet has targeted swordfish since 1993. Since 2001, the fishery has greatly expanded its geographic range within in the area 20-40° S, and in 2002 it had reached as far as 90°E. Since 2001, the fleet has obtained very high catch rates (following 8 years of declining CPUE). This increased catch rate has been explained by the use of the American long line gear and by the eastward expansion of the fishery. The area primarily fished by Spanish longliners since 2001 is the central south Indian Ocean gyre, in an area where swordfish had not previously been targeted by any fishery. The WPB noted that the statistics reported by this fleet have never reported it's catches of tuna and by-catch species (except swordfish). The WPB stressed the need for the Spanish longline fleet to report all its catches to the IOTC because these data are of prime importance for stock assessments and other scientific studies.

Australian longline fishery

IOTC-2004-WPB-10 described the Australian longline fishery that operates in the eastern Indian Ocean (including the Great Australian Bight in the Southern Ocean). The fishery developed rapidly throughout the late 1990's targeting swordfish, bigeye and yellowfin tuna. Most effort has been in inshore waters, within the Australian EEZ, between 20-36°S. In recent years however, there has been some expansion of the fishery onto the high seas. Swordfish catches in the fishery peaked in 2001 at 2,162 tonnes and have since declined to a little over 1,000 tonnes in 2003 due to drops in effort in the fishery as a result of economic factors rather than fish availability. A fishery monitoring programme provides weight measurements of a high proportion of the catch, and in 2003 a pilot scientific monitoring (observer) programme began examining operations, catch/by-catch composition and biology of key components of the catch (IOTC-2004-WPB-INF03).

Taiwanese longline fishery

Analyses of catch and effort data are provided in IOTC-2004-WPB-09 (see CPUE Analysis section below). Taiwan,China caught swordfish as a by-catch of tuna fisheries throughout the Indian Ocean for over 30 years, until in 1992 a seasonal fishery targeting swordfish began in waters east of southern Africa and south of Madagascar. Over the next five years, swordfish targeting expanded east and north from this area into tropical and equatorial waters of the western Indian Ocean. Recently, Taiwanese longliners have also recorded increased catches of swordfish in waters south and east of the Indian sub-continent. The highest swordfish catch recorded by Taiwan,China was 18,000 t in 1995. Subsequently, catches declined to 12,900 t in 2002 and 12,700 t in 2003. Taiwan,China noted that these most recent decreases in catch were likely to reflect decreased targeting of swordfish in the western Indian Ocean. In addition to the declared catch by Taiwan,China, 800 t of extra catch was made by vessels re-registered as Taiwanese vessels under Japan-Chinese Taipei Joint Action Plan in 2003. It was noted that the number of vessels fishing with licenses in the waters off Somalia has been increased in 2002 and 2003, after a major decline in vessels in the late 1990's (80 vessels in 1997 to 10 vessels in 2000) due to unprofitable prices and the poor quality swordfish fish. A range of species is targeted by the fishery, depending on the seasons and years. In 2002 and 2003, swordfish constituted about 20% of the catch.

Japanese billfish fisheries

There was no document presented to the WPB on the Japanese billfish fisheries, but it was noted that all the data corresponding to this fleet have been submitted to the IOTC and they were fully available to the WG during its meeting. Although none of the billfish species have been a major target species for the Japanese fleet, all the billfish species have been constantly fished as by-catch species and well recorded in the statistics. The available data is important for the assessments of the billfish stocks; in particular swordfish as it has been taken by the Japanese fishery since 1955 with an average catch of 1250 t.

2.3. Observer and port sampling programmes

The WPB considered a report on the activities of observers in the Australian longline fishery (IOTC-2004-WBP-INF03). This is a pilot project, and between April 2003 and June 2004 covered 104 shots/134,755 hooks – this being 3.7% of the total effort in the fishery during the observation period. Species composition, weight, length and related catch and discard information was collected, along with biological samples, information on the life status of the catch and a range of environmental information.

A sampling programme aboard French and Spanish purse seiners started in 2003, with the main objective of collecting data on by-catch with coverage of 5 to 10% of the fishing trips. No data from this programme were available at the time of the 2004 WPB meeting.

IFREMER reported that they will soon begin a new programme monitoring catch and effort data for fisheries operating out of La Réunion. It is expected that this will provide much needed continuation of the time series of size-by-sex data for swordfish caught by this fleet.

Taiwan,China also noted that they started a pilot observer program in 2001. The coverage was been increased in 2003 with 3 observers (6 trips) dispatched in the Indian Ocean

The WPB welcomed these initiatives, noting that onboard observers are in the best position to gather data on the sex and length of billfishes that are critical for stock assessments. The WPB recommended that measurements of size-by-sex be done routinely either through observer or port sampling activities (if whole fish were retained).

3. REVIEW OF DATA ISSUES

3.1. Predation by mammals

The high rates of predation by marine mammals (primarily false killer whales, genus *Pseudorca*) are a serious concern in the Seychelles swordfish fishery and in other areas also (e.g. La Réunion) for both fishermen (as this may have a severe negative impact on their profit) and scientists (as these fish are not routinely recorded as removals from the population).

The IOTC programme for a predation survey has had mixed returns. Data has been forthcoming from surveys conducted in the Seychelles swordfish fishery, but there has been little data from other regions. The success of the Seychelles survey has highlighted the need for this type of research and for similar data to be obtained from other regions.

3.2. Sex-ratio data

It is important when doing stock assessment on swordfish stocks, to take into account the differential growth and life-expectancy between the two sexes, and the sex ratios of the catches. In the Atlantic Ocean, swordfish sex-ratios vary by area.; this is also expected to occur in the Indian Ocean.

Unfortunately, these data are difficult to obtain without onboard observers, as the fish are gutted just after fishing.

Swordfish sex ratio has been evaluated for area 5 during the "Programme Palangre Réunionnais" (PPR) (Figure 5). In this area, while females are dominant, in the 110-140 cm and >2 m size ranges (LJFL[1], Figure 6[2]), sex ratio changes with season. The area has been identified as an area for reproduction between October and April (Figures

[1] LJLF – Lower Jaw to Fork Length

[2] Poisson F., Marjolet C., Fauvel C., 2001. Biologie de la reproduction de l'espadon (*Xiphias gladius*). *In:* L'espadon : de la recherche à l'exploitation durable. Poisson F., Taquet M. (coord). Programme Palangre Réunionnais, Rapport final, 170-211.

7,8[3], and 9[4]). The Authors concluded that this heterogeneity may indicate either a different migration pattern for males and females, or different catchability between the two sexes.

Hormonal analysis of landed fish provides an alternative means to estimate sex ratios. Such new technologies should be investigated.

4. REVIEW OF THE NEW INFORMATION ON BIOLOGY, ECOLOGY AND FISHERIES OCEANOGRAPHY

A paper analysing the various parameters influencing the efficiency of La Réunion longline fishery targeting mainly swordfish (*Xiphias* gladius) was presented to the WPB. Operational information on fishing gear configuration and the habits of fishers was collected for 3602 longline sets by the IFREMER scientists during the period 1998-2000 as part of the PPR programme[5]. Simultaneous satellite information on water temperature, colour and sea level of the fishing zones were analysed using a GAM model in conjunction with fishery data.

This analysis concluded that the operational factors may influence catches more than the environmental factors. The length of the buoys leaders sustaining longlines at the sea surface, number of hooks, retrieval time (of the line from the water), mean distance between two successive hooks, duration of the drifting of the longline at night, time of the beginning of the longline setting and duration of the setting appear to be the most important factors.

5. REVIEW OF STOCK INDICATORS

5.1. Marlins and Sailfish

In the absence of detailed analyses or working papers covering these species, the WPB used data held in the IOTC data base to briefly review catches and nominal catch rates of the istiophorid billfishes, Indo-Pacific sailfish and short-billed spearfish (Figures 2, 3).

Reported catches of the three marlin species increased throughout the 1980's and the early 1990's, but for all species, catches have decreased markedly since then. Blue marlin catches peaked in 1997 at 15,000 t and have since fallen to 9,000 t. Catches of black marlin also peaked in 1997, but were around 2000 t in 2002. And striped marlin catches which varied between 4,000 and 7,000 t for most of the 1980's and 1990'sdecreased to around to 3,000 t in 2002.

As these species are not clearly targeted by any fishery, the catch trends could be considered a useful indicator of relative abundance, depending on the extent of the changes in global fishing effort.

The catch of Indo-Pacific sailfish increased markedly during the 1990's reaching a peak of 6,000 t in 1997. Since then catches have fluctuated around this level – in 2002 the catch was 16,000 tonnes. The increase during the 1990's was primarily the result of catches by Sri Lanka, Iran and India.

Nominal catch rates (numbers caught per 1000 hooks) of blue and black marlin by the Taiwanese and Japanese long fleets (Figure 10) show very similar trends – with major declines during the late 1980's (coinciding with increased catches), followed by relatively stable but very low CPUEs throughout the 1990's through to the most recent years.

There are few size frequency data available for the marlin species and sailfish with the only regular reports coming from Japan (longline) and some very partial reports coming from Taiwan,China (longline) and Sri Lanka (gillnet/longline).

The amount of size data reported by Japan for black marlin and blue marlin has been decreasing since the early 1990's (Figures 11a, 11b),; furthermore, these data tend to be provided by research vessels rather than commercial longliners. The amount of specimens measured per stratum is generally very low, therefore the utility of the size frequency datasets is limited. Sri Lanka reported size data for sailfish from the gillnet fishery between 1988 and 1994 (Figure 12).

[3] idem

[4] idem

[5] PPR: Programme Palangre Réunion

No dramatic changes have been noticed in the size frequencies distribution for these three species (blue marlin, black marlin and sailfish). However, further increases in sampling size in the region would allow a better appraisal of this indicator

5.2. swordfish

As we did in 2003, the WPB focussed most of its attention towards reviewing data and analysing trends in abundance and biology of Indian Ocean swordfish.

A simple inspection of the catch trends reveals marked spatial differences in the current situation and the trends over recent years. In general, there are east-west difference in catches (Figures 13, 14), with recent catches concentrated in the south-western Indian Ocean. In more recent years, a larger proportion of the catch has been taken from the central gyre area.

Also, there is a latitudinal difference in the level of targeting, in that swordfish catch is mostly a bycatch to other fisheries in the equatorial while it is more likely to be a target species in the sub-tropical areas (Figures 15).

Changes in fishing zones

As noted and documented in the report of the previous meeting of the WPB, there has been clear changes in spatial distribution of the areas of operation of the fisheries, in particular for the Taiwanese fleet.

Changes in targeting practices, by which swordfish became a sought after species by this fleet, are behind these changes in fishing zones, as well as changes in other fishing practices such as changes in gear configuration and time of the day at setting,

The WPB discussed the ongoing changes in effort targeted at swordfish. It was mentioned that , in some areas, the Taiwanese fleet has decreased its targeting of swordfish. The reasons for this are not clear, but are thought to relate to either market and/or catch rate factors. The amount of Taiwanese effort in each geographical area has changed, and with it the total catch of swordfish. The WPB notes the continuing increase in effort and swordfish catch in Areas 3 and 4, and decreases in swordfish catch in areas 5 and 7 (Figure 15). Despite these changes, the Taiwanese catches have has been relatively stable at around 12,000 t over the last few years (down from an historical high of 18,000 t in 1995).

There have also been marked changes in the geographic distribution of effort by other fleets. In particular the expansion of Spanish and French effort targeting swordfish in Area 5 and in the western portion of Area 6 (Figure 16). Fishing under arrangements with the government of Mauritius, up to 40 vessels have achieved relatively high catch rates of swordfish as far east as 90°E. Previously these fleets had fished primarily in Area 7 and to the west of Réunion in Area 5.

5.3. Review of CPUE trends

When discussing trends in CPUE, the WPB devoted most of its attention, as it has been the case in the past, to the analyses of the data coming from the Japanese and Taiwanese fleets. This focus is the consequence of the wide distribution, in time and space, of effort spent by these fleets, as well as their long history which makes them more suitable for the analysis of the global situation of the resource. Trends coming from smaller, more localized fleets are useful in assessing changes as the sub-regional level, but offer only a partial view of the global situation of the resource.

CPUE of the Taiwanese longline fleet

Document IOTC-2004-WPB-06 described the catch and effort data from Taiwanese longliners and a standardised CPUE series for the period 1968 to 2002. The nominal series shows a large increase in 1992 which is considered to be due to targeting. The standardisation uses an area stratification, according to the areas used in the 2003 WPB meeting, with the addition of dividing the south-western area into two new areas on the basis of prevailing environmental conditions. Standardisation was done on shot-by-shot data. Due to a lack of information on hooks per basket prior to 1996, a proxy variable was constructed for targeting. Three approaches were considered, but trends in the standardised index were very similar for the three approaches. Environmental variables were also included, but they had little explanatory power in the runs conducted.

Further analyses of CPUE

One of the main concerns with the standardisation of CPUE relates to the issue of targeting. Only recent data (1996 onward) contain hooks per basket information, and the shot by shot records do not contain information about time-of-day (e.g. day or night setting). It is known that the Taiwanese fleet changed its targeting strategies since 1992, and the effects of this are difficult to identify in the standardisation. It should be noted that the interpretation of the data with regard to targeting has been a major difficulty in the past, and appears to remain a difficult aspect of standardisation, particularly when the full historic time-series is used.

A major concern with the Taiwanese analysis was that, given that the proxy was based on the proportion of the swordfish in the catch, it is possible that it was correlated with abundance. If this was the case, then using it as a standardizing factor would remove some of the information on the abundance of the stock and the CPUE would not longer be related to abundance.

For this reason, a new definition of areas was proposed, based on the idea that, if areas could be defined in which the targeting practices have not changed markedly over time, the area effect would account for most of the targeting, and the proxy for targeting could be omitted from the model. The new areas were defined upon inspection of the spatial distribution of catches by species of both the Taiwanese and Japanese fleets (Figure 17).

New analyses were conducted according to the new stratification for both the Taiwanese and the Japanese data. For the Japanese longline data, the model used was the same as that used in 2003, incorporating year, area and number of hooks between floats to account for targeting.

Under the new area stratification for the Taiwanese data, the results of the model when the proxy for targeting was omitted were similar to those obtained under the previous stratification. This suggests that the new stratification was not as effective as expected in removing the effects of targeting. The resulting trends (Figure 17) when including the proxy for targeting show small differences with the trends under the previous stratification.

For the Japanese equivalent analysis, catch data was insufficient to produce estimates in areas 1 and 5, and the results were considered to be unreliable for area 6, due to the low sample sizes.

A comparison of both the Taiwanese and the Japanese CPUEs indicated that there are still major differences in their trends (Figure 17). The Japanese CPUE shows large declines in almost all areas coinciding with the increase in catches in the area. The Taiwanese CPUE, also shows declines in the most heavily exploited areas, but the extent of the decline is much less than for the Japanese CPUE.

It was not possible to identify the reasons for these differences. As mentioned above, if the targeting effect is correlated with abundance, the Taiwanese CPUE would be less sensitive to changes in abundance than the Japanese CPUE, for which the variable used to account for targeting is independent of abundance. Furthermore, since swordfish has not been a target species for the Japanese longline fleet, it less likely that the CPUE would be affected by changes in targeting practices. On the other hand, the extent of some of the declines in the Japanese CPUE seem to be excessive when compared with the catches in the area (see area 8, in Figure 17)

The WPB noted there is a consistent pattern of declines in all areas that have been exploited. The severity of the declines is correlated with the magnitude of the catches in the most heavily exploited areas. This pattern is clear when the CPUE are compared between the areas are aggregated into a western (areas 1,3,5,7,and 9) and eastern (areas 2,4,6,and 8) areas (Figure 18)

To further illustrate the extent of the declines, the mean of recent nominal and standardized CPUE values (2001 and 2002) was compared with baseline mean values for the Japanese CPUE and the Taiwanese CPUE. For the Japanese CPUE, the years 1985-1990 were used for the comparison, as the CPUE tended to be stable during those years, and for the Taiwanese, the years used were 1995 and 1996, just after the major shift in targeting towards swordfish occurs.

The results of these calculations are listed in Table 1. In almost all cases, the values are below 1.0, indicating reductions in CPUE relative to the baseline years. In particular, when comparing the eastern and the western areas, declines are estimated to be of 63% (nominal) and 83% (standardized) relative to 1985-1990 in the western area and 38% (nominal) and 79% (standardized) for the eastern area, based on the Japanese CPUE data. Relative to the period 1995-1996, based on the Taiwanese data, declines are estimated to be of 48% (nominal) and 13% (standardized) for the western area, and 26%(nominal) and 16%(standardized) for the eastern area.

Table 1: Comparisons of swordfish catch rates in 2001/02 with those in the 1990's for the Taiwanese and Japanese fleets. Area strata are shown in Figure 15.

TW(CPUE: weigth/1000hooks)						
	Reference years (1995-96)		Current (2001-2002)		Current /Reference	
AREA	nominal	adjusted	nominal	adjusted	nominal	adjusted
1	17.45	0.87	15.30	1.03	0.88	1.19
2	108.08	1.37	76.55	1.34	0.71	0.98
3	41.02	1.10	42.10	1.11	1.03	1.01
4	24.45	1.04	30.29	1.10	1.24	1.06
5	144.08	0.80	32.99	0.70	0.23	0.88
6	55.10	1.34	24.27	0.79	0.44	0.59
7	123.54	1.12	71.73	0.94	0.58	0.84
8	17.44	1.15	21.30	0.89	1.22	0.77
9	37.24	1.37	26.29	0.81	0.71	0.59
E	51.27	1.23	38.10	1.03	0.74	0.84
W	72.67	1.05	37.68	0.92	0.52	0.87

JP(CPUE: nummber/1000hooks)

	Ref years(85~90)		Curr(2001-2002)		Curr/Ref	
AREA	nominal	adjusted	nominal	adjusted	nominal	adjusted
1	0.53		0.14		0.26	
2	1.08	0.68	0.60	0.31	0.56	0.45
3	0.71	1.34	0.57	0.46	0.80	0.34
4	0.21	1.23	0.20	0.35	0.97	0.29
5	0.49		0.06		0.12	
6	0.29	1.27	0.14	0.15	0.48	0.12
7	0.48	1.18	0.15	0.16	0.32	0.14
8	0.07	1.43	0.07	0.20	1.12	0.14
9	0.38	1.58	0.04	0.09	0.11	0.06
E	0.41	1.15	0.25	0.25	0.62	0.22
W	0.52	0.82	0.19	0.14	0.37	0.17

5.4. Trends in size distributions of the catch

The size distribution of the catch is a useful indicator of swordfish population status. Swordfish are sexually dimorphic with females reaching significantly larger lengths and weights than males, and maturing at older ages.

Punt et al. (1999)6 examined the relative sensitivity of various biological and fishery parameters to changes in population size and concluded that the upper quartile of the size distribution (often an indicator of the relative abundance of large females in the population) was one of the most sensitive.

The average weight in the catch of the main longline fleets does not show any consistent trend (Figure 19) with the possible exception of a decrease in the size caught by the Seychelles's fleet. For the larger, more mobile fleets this overall trend might be affected by fleet movements between areas or documented changes in fishing practices (e.g. the increase in weight in Spanish catches).

The WPB examined trends in size of swordfish caught by the Taiwanese and La Réunion fleets. In the case of Taiwan,China, 30 fish are measured from the catch of each shot. Although sample sizes vary among areas and years, these data provided the opportunity to undertake analyses of the spatio-temporal variation in the median, 25th and 75th percentiles of length (Figure 20) . Median, upper and lower quartiles of length vary significantly between years in all area strata. There is little evidence of declines in large fish in any strata, although in Areas 3,4 and 5, the strata in which most of Taiwan,China's swordfish catches are taken, there is an indication of small declines in the median and larger size classes. It was noted that these declines are very small when compared with the patterns seen in the Atlantic where swordfish have been overfished.

Size data collected by scientific observing and port monitoring of the Réunion longline fleet swordfish catch show no trends over an 11 year history of exploitation (Figure21). The Réunion fishery operates in the Area 5 of the spatial stratification used for the analysis of Taiwanese size data. The latter showed slight indications of declining median and upper size ranges over the same period.

5.5. *Production modelling of swordfish*

The nominal and standardised CPUE series in the swordfish areas (used in the standardisation; Figure 15) show very different patterns over time. In general, the lightly fished areas show little or no decline whereas the more heavily fished areas show some decline since about 1992. The declines are particularly marked for the Japanese CPUE. These patterns suggest that full mixing of the stock (on an annual time scale) is probably not a realistic assumption for swordfish (as it is for all other tuna stocks). The standard stock production models used in the past (e.g. Schaefer or Fox models) assume full mixing. A stock production model for the whole of the Indian Ocean, using an overall CPUE series, was not conducted this year. Instead, attempts were made to fit a spatial production model which assumes no mixing between the areas. This is an extreme assumption, and we recognise that in reality there is likely to be some mixing. The model assumed a common rate of increase (r-value in the production model) and common catchability coefficient in all areas, but a different level of carrying capacity (K-value in the production model) in each area. Inputs are the catches by area and the Japanese or Taiwanese standardised CPUE by area.

Unfortunately, trial runs did not lead to sensible estimates even when only those areas which show some decline were included. The rate of increase had to be bounded and was either estimated at the lower bound, at unrealistically low levels (less than 0.01) or, in a few cases, at the upper bound (e.g. >1.0). There are many possible reasons for this: the inputs, structure of the model and/or underlying assumptions. There was insufficient time at the meeting to fully explore the model and alternative assumptions, but it was agreed that this approach is worth further consideration.

The relationship between yearly catches and various estimations of effective effort (catches/ nominal CPUE of Japan) were examined by the WPB. This relationship shows that recent catches has been levelling off and declining following a nearly constant increase of fishing effort.

Although it is difficult to estimate a realistic MSY from this figure (as the rates and patterns of mixing and effective effort remain questionable), it suggests that the present effort is by far excessive, and probably producing catches that are above the equilibrium production of the stock (as swordfish is a long living species) (Figure 22)

Summary of trends in indicators and assessment

Consideration of the stock indicators suggest that there has been a marked decline in the stocks of Indian Ocean swordfish since targeting of the species began in the early 1990's. Although there is uncertainty, the indicators and

[6] Punt, A.E., Campbell, R.A. and Smith, A.D.M. (1999). Evaluation of performance indicators in the Eastern Tuna and Billfish Fishery - a preliminary study. Final report to the Australian Fisheries Management Authority, Canberra, 45pp

previous assessments suggest that the situation may be more serious in the western Indian Ocean than the eastern Indian Ocean.

The total catches have decreased slightly over the recent five years after reaching a peak of 36,000t in 1998. However, the effective effort (estimated as the catch divided by the standardised Japanese CPUE) has continued to increase over this period (Figure 22). This suggests that the decrease in the catch is not as a result of a reduction in effective effort, but more likely to be as a result of a decrease in the swordfish biomass.

The WPB agreed that there was scope for improvements to the standardisation and interpretation of CPUE and assessments. On the one hand the Japanese fishery does not target swordfish, so the interpretation of the CPUE data is relatively simple. However, this fleet only takes a relatively small proportion of the catch, and has changed targeting practices on tunas. The WPB attempted to account for these changes in standardizations using hooks per basket as a proxy for targeting, but it unclear whether this has been effective as in some areas there has been major declines in standardized CPUE despite little catch. On the other hand, the Taiwanese fleet takes the majority of the catch, but targeting practices for swordfish have changed noticeably and this makes standardisation of CPUE more difficult. In 2004, the WPB attempted to standardize out the effect of targeting and through changes in area stratification aimed to have within area homogeneity in targeting practices. This has resulted in only minor changes to those seen in 2003.

The WPB compared CPUEs (nominal and standardized) in most recent years with those from reference periods in the early and mid-1990's in an attempt to gauge the level of decline/depletion. All ratios examined indicated declines, with the scale of decline varying between the fleets and time periods used in the ratios.

It was considered encouraging that there are not yet clear signals of declines in the size-based indices, but these indices should be carefully monitored. It was noted that since females mature at a relatively large size, a reduction in the biomass of large animals could potentially have a strong effect on the spawning biomass.

Concerns were also expressed with regard to the apparently localised behaviour of swordfish. There is some indication of localised depletion in response to high catches in some areas.

5.6. Stock status and Management recommendations

Following analyses conducted by the WPB in 2003 indicating the possibility of significant declines in the abundance of swordfish in the Indian Ocean, in 2004 the WPB again concentrated its efforts on swordfish assessment.

The WPB was able to further improve on the procedures and analyses conducted in 2003. The standardized CPUE of swordfish for both the Japanese and Taiwanese fleets show continuous declines since the mid-1990's, particularly in the western Indian Ocean. These decreases in CPUE follow substantial increases in catches throughout the 1990's, particularly in the western Indian Ocean. These declines in CPUE have continued over the last few years despite recent decreases in catches.

On the basis of the stock indicators the WPB concluded that the current level of catch (about 30,000 t) is unlikely to be sustainable. Of particular concern are the trends in abundance of swordfish in the western Indian Ocean, where the highest catches are currently taken. The spatial structure of the CPUE suggests that there may already be localised depletion of swordfish in the south-west Indian Ocean. Localised depletion has occurred in other parts of the world where swordfish have been heavily targeted (e.g. the south-west and south-east Pacific Ocean and in the north Atlantic Ocean). The WPB considered that these factors, combined with apparent recent increases in effort targeting swordfish in this area, increase the risk that the swordfish stocks in western Indian Ocean, particularly the south-west areas, are being overfished.

The WPB expressed concern regarding the very rapid increase in effort targeting swordfish in the Indian Ocean and the relatively large incidental catch of swordfish in fisheries targeting bigeye. These increases in effort exploiting swordfish have continued since 2000.

The WPB considered that any increase in the catch of, or fishing effort on, swordfish should not be allowed. Furthermore, management measures focussed on controlling and/or reducing effort in the south-west Indian Ocean are recommended.

6. RECOMMENDATIONS

6.1. Recommendations concerning data

The WPB noted and made special acknowledgement of the contributions of Taiwan,China to the meeting. The advances in swordfish stock assessment made at the 2003 meeting were facilitated principally through access to the Taiwanese fine scale CPUE and size data.

1) **Taiwanese data:** The WPB recognized the valuable contribution in new data and analyses provided by Taiwanese scientists. As to the availability of information on gear configuration of Taiwanese longliners (e.g. hooks per basket) and the heterogeneity of the configuration among vessels. it was noted that these data were only collected after 1995. In the Taiwanese analyses, data prior to 1979 were aggregated by 5x5 degree areas. Taiwan,China reported that since 2003 their longline vessels logbooks has included a field for time of setting the line, which the WPB noted was critical for evaluating the targeting practices of this important fleet. Catch, effort and size data for the Taiwanese deep-freezing longline fleet were made available for use at the meeting, and a Taiwanese scientist provided valuable scientific support to the WPB. These efforts are acknowledged and appreciated.

The data deposited at the Secretariat for the Taiwanese fleet does not include information on catch and effort in the south-west Indian Ocean (between longitudes 20° and 30°E). Given that this area has been heavily exploited for swordfish, it will be important to request submission of the missing data.

2) **Marlins and sailfishes**: there is a critical lack of statistical data for this group of fishes. It is strongly recommended to better estimate catches and discards by species and by gear, by size and sex.

3) **Purse seine landings:** It is strongly recommended that past and future catches of marlins taken as by-catches by purse seiners be estimated. The historical yearly landing of marlins by tropical purse seiners could be estimated from observer data, and in the future, landings data should be monitored (preferably by species and by size). It is also recommended to develop permanent observer programmes on these fleets, at least at a small scale, in order to better estimate by-catches of billfishes.

4) **Sex ratio by size**: It is necessary to sample the size of swordfish and marlins as a function of their sex simultaneously.

5) **IOTC-OFCF project:** The WPB emphasizes its support to the Japanese IOTC-OFCF project and recommends that priority be given to countries with substantial catches of swordfish and billfishes which are not properly monitored or are reported as aggregates (e.g.: Sri Lanka gillnet fisheries).

6) Written **statistical reports** should be obtained from scientists from each fishing country on all fisheries, even when a country cannot participate in the working group meeting. The IOTC Secretariat should request these reports before WPB meetings.

7) **Billfishes length measurements:** Length data should be reported to the IOTC in a standard format to facilitate comparison of data from different countries. When these lengths are collected in a non-standard way, they should be converted to the standard form of reporting using robust methods. The basic data used to establish these conversions should be kept by IOTC. The WPB strongly recommends that size measurements should be always taken in straight length, never in round length (this is because the condition factors and shapes of fishes are highly variable at a given size between time and area strata).

6.2. Research recommendations

Swordfish stock structure and tagging of swordfish

The WPB considered tagging swordfish as being of key importance to determine realistic hypotheses concerning stock structure. Genetic results are clearly of great interest, but they cannot be used to make realistic hypotheses on movement rates between strata. It was recognized that tagging of swordfish is a difficult and expensive task. However, taking into account the absolute need to validate growth and to determine stock structure, the WPB strongly recommend conducting swordfish tagging in the IOTTP (as was planned in the original IOTTP).

Such tagging could be done in various ways such as:

Scientific tagging, primarily with electronic tags, using small rented longliners with short sets of few hooks.

Encouraging longline fishermen to tag small swordfish. Such tagging is already conducted in Australia and could be done by observers. .

Swordfish growth

The WPB recommended researchers to try to validate the growth studies already done, and to conduct similar comparative studies in other areas.

Size data analyses

The following additional analyses of Taiwanese size data are recommended:

- Comparison of size frequency distributions for Areas 3 and 7,
- Conversion of lengths to ages using different assumptions on sex ratios at size/age.
- Examination of trends in the 90% quantile for the whole Indian Ocean and specifically for Areas 3 and 7.

Where size data are available for other fisheries the trends in size over time should be similarly examined.

Stock status indicators

Further research is recommended concerning the definition and estimation of stock indicators that reflect the status of stocks of billfish species. Special attention should be given to the choice of indicators which could well measure changes in abundance of older fishes (which are the first to disappear in case of overfishing) and changes in the geographical patterns of the fisheries. The various stock indicators recommended by the WPB in 2001 should be calculated in advance of the WPB meeting in cooperation between scientists from fishing countries and the IOTC Secretariat; and these indicators should be available at the beginning of the WPB meetings.

Analysis of apparent movement of swordfish based on fishery data

The analysis of size specific CPUE by sex and by time and area strata, together with biological data on feeding, sex ratio, reproductive condition etc offer potential to evaluate the apparent movement and stock structure of swordfish. These studies are highly recommended.

Stock assessment – CPUE Standardization:

Following analyses at the 2004 WPB the following further efforts towards standardization of the CPUE series from Taiwanese fleet are recommended, including:

- Improving the definition of variables that could be used as a proxy for targeting.
- Consideration of alternative ways of combining area-specific indices into a global index using different weighting schemes.
- Consideration should be given to defining area strata that take into account environmental factors and fishery distribution and characteristics.

Given the importance of these recommended actions to the swordfish assessment, the WPB encourages a collaborative approach to the work be taken.

Efforts should be made to provide additional CPUE series from other fisheries (e.g. La Réunion, Seychelles) for the next WPB.

Stock assessment – Modelling: Ideally, at the next WPB a suite of different types of stock assessment models (including stock production and simple size-based models) should be applied to the available data. The IOTC Secretariat and the WPB Chair should assist in the co-ordination of stock assessment efforts before the next WPB meeting.

Research on biology of Istiophorids

The WPB recommended that following research on istiophorids be undertaken.

Genetic studies of the main istiophorid species, concentrating on obtaining robust sample sizes from widely separated locations in the Indian Ocean. If genetic studies cannot commence in the near future, samples should still be collected and preserved.

Hard parts from billfish (marlin, sailfish) should be collected and preserved for future age estimation studies. The third (largest) anal spine is probably best for this purpose, but this needs to be verified for each species (with respect to the extent of the matrix in larger fish).

Popup satellite tagging experiments should be conducted on blue ,black and striped marlins to provide information on many aspects of their biology, including long-term vertical behaviour, movement and mixing rates.

Increased tagging of billfish in the Indian Ocean should be encouraged on an opportunistic basis. This may be achieved through a coordinated, Indian Ocean wide sport fishery tagging programme, if initiated, as recommended by a recent IOTC consultancy. The forthcoming IOTTP will ensure widespread publicity and offers of rewards for tag returns, enhancing such a sport fishing based tagging programme.

Improved catch and effort statistics should be collected for artisanal fisheries of coastal countries with the help of IOTC and of the IOTC-OFCF project. This applies to all Istiophorids, but especially sailfish in areas of high recent catches such as Sri Lanka, Iran and Indonesia.

Selected catch and effort statistics should be collected from key billfish sport fishing areas to provide CPUE indices.

Selected indicators of stock status should be better identified, selected and prepared before the next WPB meeting and be made available to the WPB allowing to evaluate stocks trends, independently of stock assessments analysis.

7. ADOPTION OF THE REPORT AND ARRANGEMENT FOR NEXT MEETING

The report of the WPB was adopted on 1 October, 2004. Conditional on the approval of the Commission, the details of dates and place and venue for the next meeting are to be arranged by the Secretariat.

APPENDIX I : LIST OF PARTICIPANTS

Alain Fonteneau
Scientist
Institut de recherche pour le développement
P.O. Box 570
Victoria
SEYCHELLES
Tel: (+248) 22 47 42, Fax:
irdsey@seychelles.net

Alejandro Anganuzzi
Deputy Secretary
Indian Ocean Tuna Commission
P.O.Box 1011
Fishing Port
Victoria
SEYCHELLES
Tel: (+248) 225591, Fax: (+248) 224364
Alejandro.anganu@iotc.org

Baboo D. Ratacharen
Division Scientific Officer
Albion Fisheries Research Centre
Albion, Petite riviere
MAURITIUS
Tel:230 238 41 00, Fax: 230 238 41 84
fishmail@gov.mu

Devanand Norungee
Scientific Officer
Albion Fisheries Research Centre
Albion, Petite riviere
MAURITIUS
Tel:230 238 41 00, Fax: 230 238 41 84
fishmail@gov.mu

Dominique Miossec
Biologiste
IFREMER
BP 60
rue Jean Betho
Le Port 97822 CEDEX
LA REUNION
Tel: 02 62 42 03 40, Fax: 02 62 43 36 84
Dominique.Miossec@ifremer.fr

François Poisson
Fisheries statistician
Indian Ocean Tuna Commission
P.O.Box 1011
Fishing Port
Victoria
SEYCHELLES
Tel: (+248) 225591, Fax: (+248) 224364
francois.poisson@iotc.org

John Gunn
Deputy Chief
CSIRO Marine Research
P.O. Box 1538
Castray Esplanade
Hobart 7001
AUSTRALIA
Tel: 61-3-623 25 375 Fax: 61-3-623 25 000
John.gunn@csiro.au

Marc Taquet
Chef de Laboratoire RH
IFREMER
BP 60
rue Jean Betho
Le Port 97822 CEDEX
LA REUNION
Tel: 02 62 42 03 40, Fax: 02 62 43 36 84
Marc.Taquet@ifremer.fr

Marinelle Basson
Senior Research Scientist
CSIRO Marine Research
P.O. Box 1538
Castray Esplanade
Hobart 7001
AUSTRALIA
Tel: 61-3-623 25 492 Fax: 61-3-623 25 012
marinelle.basson@csiro.au

Noel Wan Sai Cheong
Senior Technical Officer
Albion Fisheries Research Centre
Albion, Petite riviere
MAURITIUS

fishmail@gov.mu

Shui-Kai (Eric) Chang
Section Chief
Deep Sea Fisheries Division
Fisheries Agency, Council of Agriculture
No. 2, Chaochow St.
Taipei 100-14
TAIWAN
Fax: +886-2-23316408
skchang@ms1.fa.gov.tw

Shyh-Jiun Wang
Scientist
Council of Taiwan
Overseas Fisheries Development
Fisheries Agency, Council of Agriculture
No. 2, Chaochow St.
Taipei 100-14
TAIWAN
Fax: +886-2-23316408
shyhjun@ms1.fa.gov.tw

Visakha Samaraweera
Resarch Officer
National Aquatic Resources Research and Development Agency
Colombo 15
SRI LANKA
visakha_ek@yahoo.com

Vishawa Mitra Chineah
Officer in Charge
Albion Fisheries Research Centre
Albion, Petite riviere
MAURITIUS
Tel:230 238 41 00, Fax: 230 238 41 84
fishmail@gov.mu

APPENDIX II. AGENDA OF THE MEETING

1. Opening of the Meeting
2. Review the statistical data for billfish species and the situation in reporting countries on data acquisition, for reporting to the WPDCS.
3. Review new information on the biology and stock structure of billfish, their fisheries and related environmental data.
4. Review of new information on the status of billfish.
    - 4.1. Stock status indicators
    - 4.2. Stock assessment
    - 4.3. Likely future trends under alternative exploitation scenarios
5. Develop technical advice on management options, their implications and related matters with priority given to the situation of swordfish.
6. Identify research priorities, and specify data and information requirements, necessary for the Working Party to fulfil its responsibilities.
7. Any other business
8. Adoption of the Report

APPENDIX III : LIST OF DOCUMENTS

IOTC-2004-WPB-01	Report on the Status of the Billfish statistics gathered at IOTC. *IOTC Secretariat*
IOTC-2004-WPB-02	Evolution of swordfish fisheries in Mauritius *D. Norungee, N. Wan Sai Cheong , R. Runnoo and B.D. Rathacharen*
IOTC-2004-WPB-03	Present status of billfish fishery in Sri Lanka *E.K.V. Samaraweera, C. Amarasiri*
IOTC-2004-WPB-04	Recent evolution of the Reunion longline fishery *Dominique Miossec and Marc Taquet*
IOTC-2004-WPB-05	A general overview of the activity of the Spanish surface longline fleet targeting Swordfish (Xiphias gladius) in the Indian Ocean during the year 2002. *B. García-Cortés, J. Mejuto, A. Ramos-Cartelle*
IOTC-2004-WPB-06	Exploratory analysis on Indian Ocean swordfish catch data of Taiwanese longline fishery. *Chang, S.K. and Wang, S.J.*
IOTC-2004-WPB-07	Standartization of size-based indicators for broadbill Swordfish in the Indian Ocean *Natalie Dowling and Marinelle Basson*
IOTC-2004-WPB-08	GAM analysis of operational and environmental factors affecting swordfish (*Xiphias gladius*) catch and CPUE of the Reunion Island longline fishery, in the South Western Indian Ocean. *David Guyomard, Martin Desruisseaux, François Poisson, Michel Petit*
IOTC-2004-WPB-09	CPUE Standardization of Indian Ocean swordfish from Taiwanese longline fishery for data up to 2002. *S.K.Chang and S.J.Wang*
IOTC-2004-WPB-10	Data summary for the southern and western tuna and billfish (SWTBF) *Jason Hartog, Nathalie Dowling and Marinelle Basson*
IOTC-2004-WPB-INF01	Disaggregation of catches recorded under aggregates of gear and species in the IOTC nominal catches database. *Secretariat*
IOTC-2004-WPB-INF02	Sequence Characters on Mitochondrial DNA of Swordfish in-situ Collected from Taiwanese Longliners *Ching-Ping Lu, Tzong-Der Tzeng, Cho-Fat Hui, and Shean-Ya Yeh*
IOTC-2004-WPB-INF03	Summary of data pertaining to longline caught billfish species from the pilot scientific monitoring program off the west coast of Australia *Don Bromhead, Daniel Curran and Peter Ward*
IOTC-2004-WPB-INF04	Reproductive dynamics of broadbill swordfish (*Xiphias Gladius*) in the domestic longline fishery off eastern Australia *Jock Young and Anita Drake*
IOTC-2004-WPB-INF05	Swordfish – Environment – Seamount – Fishery Interactions off eastern Australia *Robert Campbell and Alistair Hobbay*
IOTC-2004-WPB-INF06	Development of an operating model and evaluation of harvest strategies for the Eastern Tuna and Billfish Fishery Robert Campbell

APPENDIX IV : FIGURES REFERENCED IN THE TEXT OF THE REPORT

Figure 1: Catches of Swordfish per gear and year recorded in the IOTC Database (1963-2002).

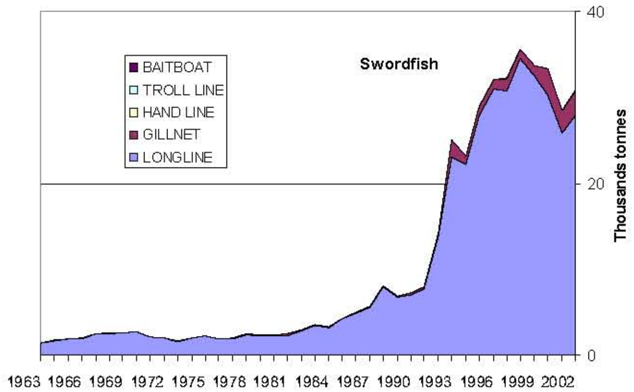


Figure 2: Proportion of the total catch (NC) of blue, black and striped marlin for which catch and effort data (CE) or size frequency data (SF) are available.

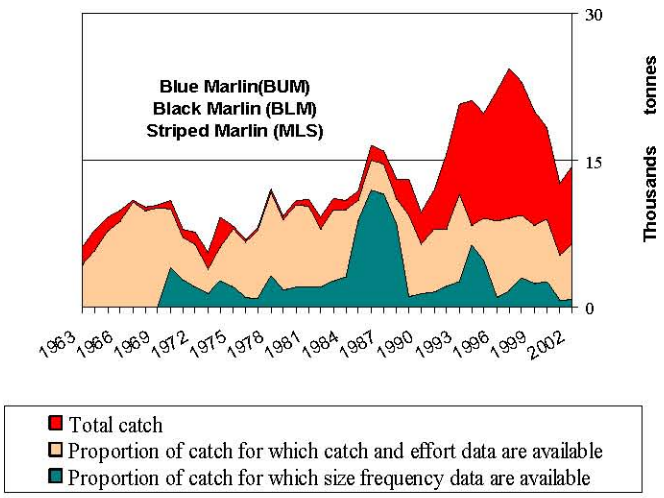
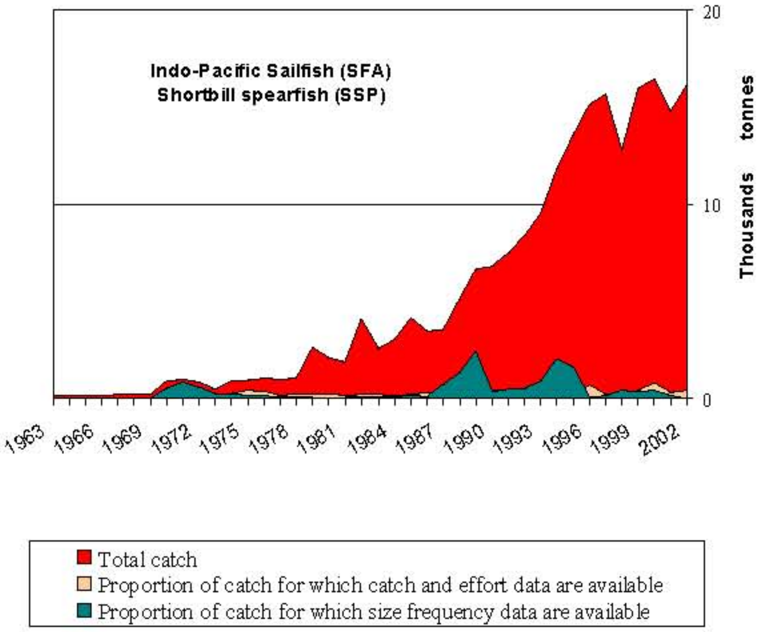


Figure 3: Proportion of the total catch (NC) of IP Sailfish (SFA) and Shortbill Spearfish (SSP) for which catch and effort data (CE) or size frequency data (SF) are available



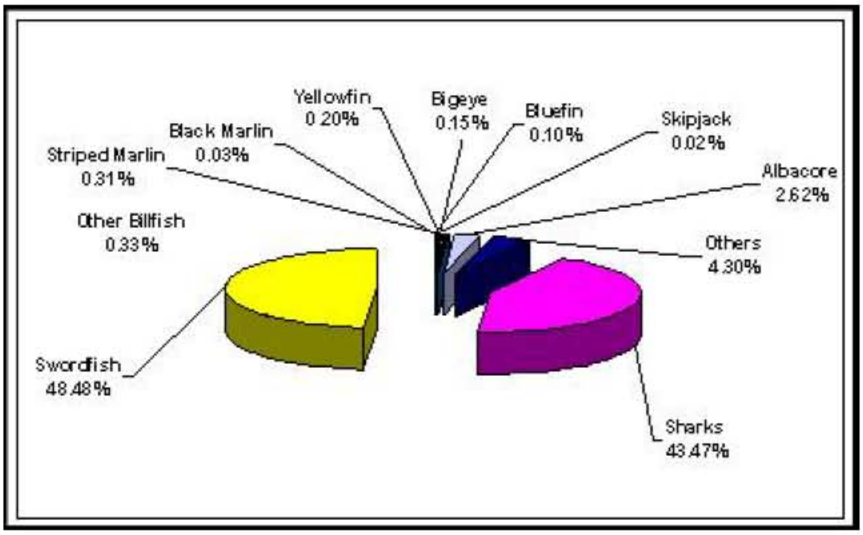


Figure 4: Catch composition of EU vessels fishing under a fishing agreement with the Mauritian government in the SW Indian Ocean

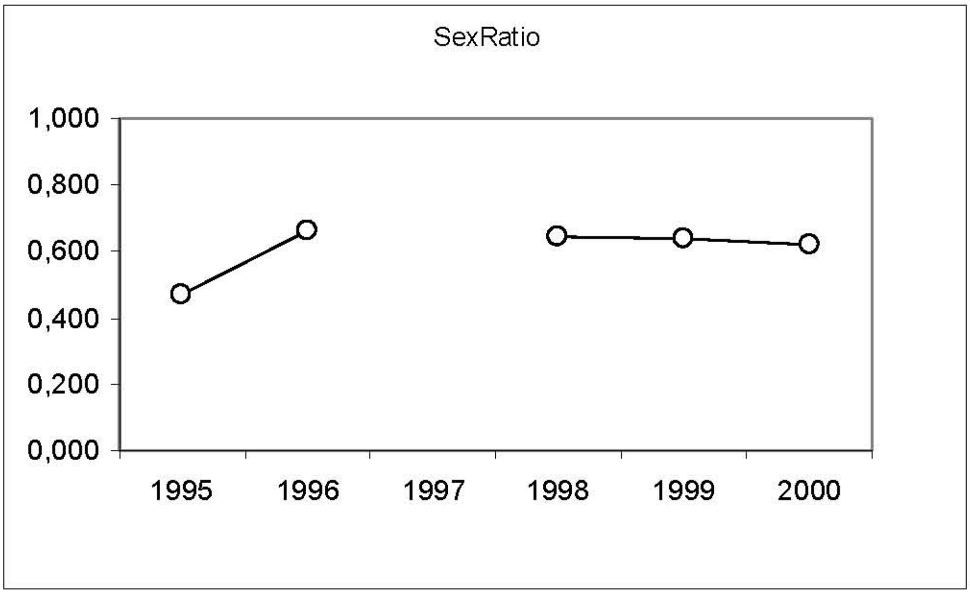


Figure 5: Yearly Sex ratio of swordfish (F/[F+M]) in area 5, calculated during the "Programme Palangre Réunionnais" from 1995 to 2000.

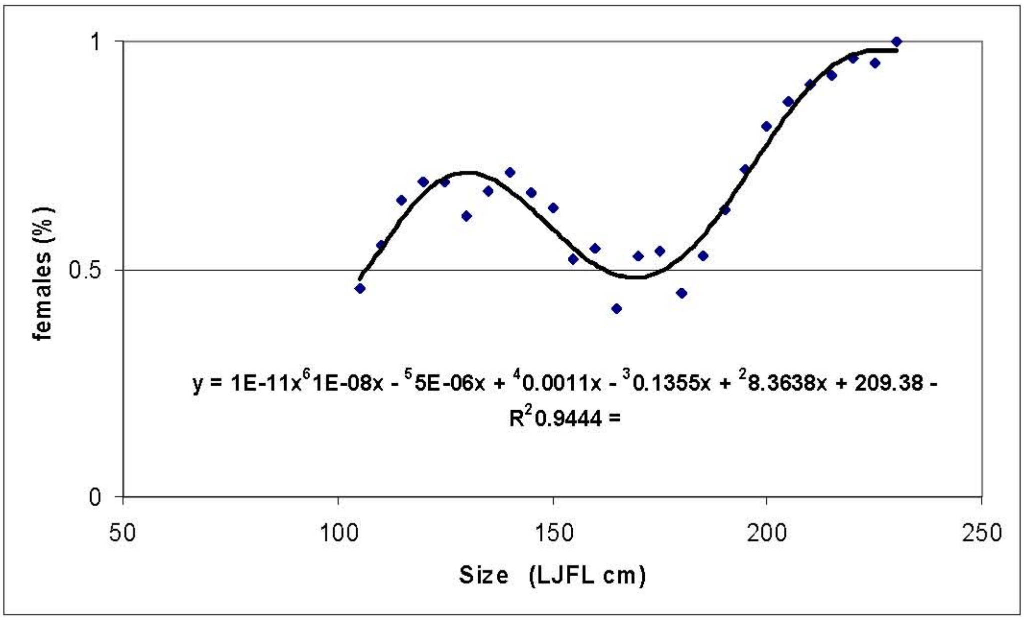


Figure 6: Relation between sex ratio of swordfish (F/[F+M]) and length (LJFL between 105 and 230 cm) for 5cm length classes in La Réunion (Poisson *et al*, 2001).

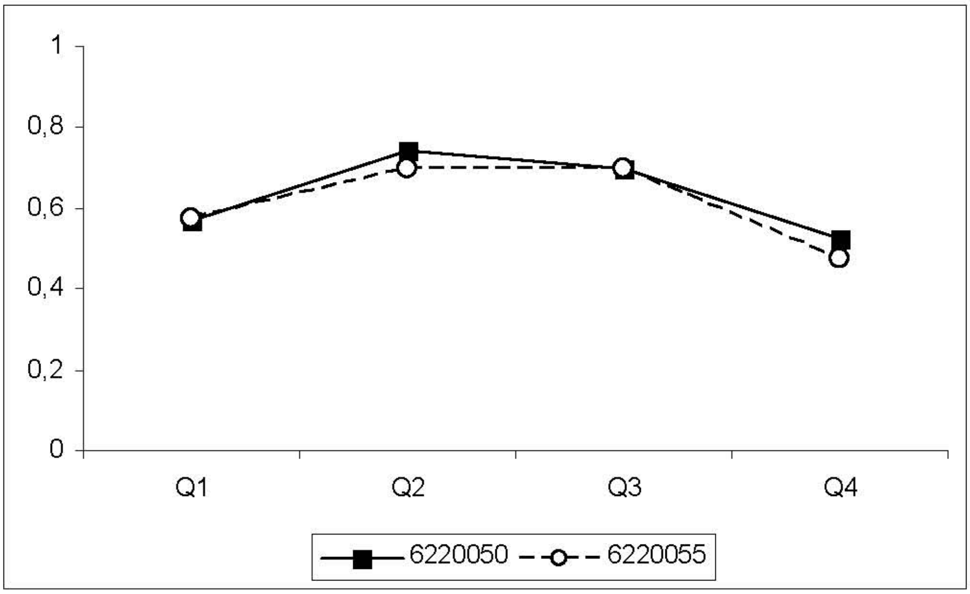


Figure 7 : Quarterly sex ratio of swordfish (F/[F+M]) in two 5° squares as calculated during the "Programme Palangre Réunionnais" from 1995 to 2000. 622005: between 20° and 25° South and 50° and 55° East.

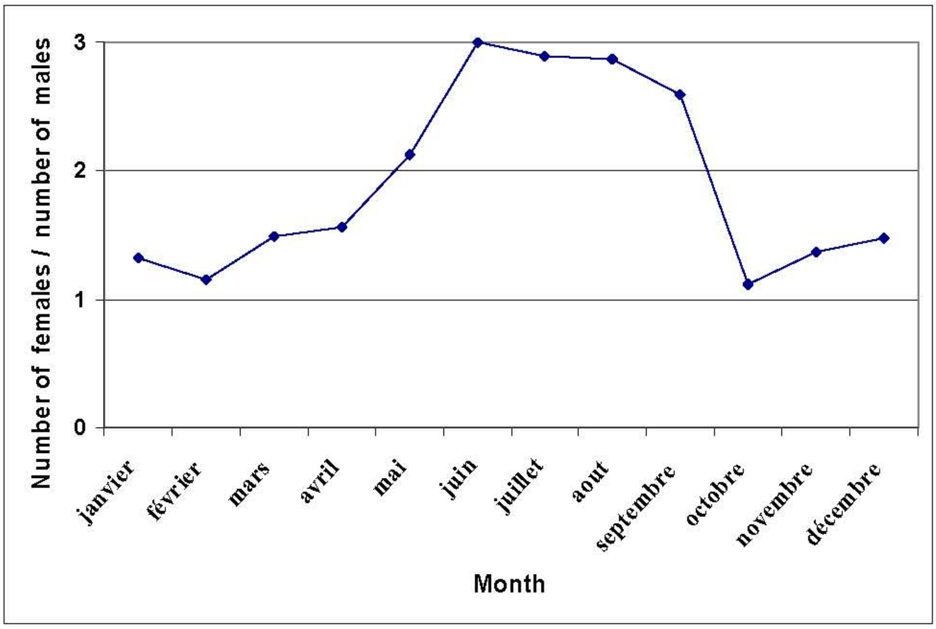
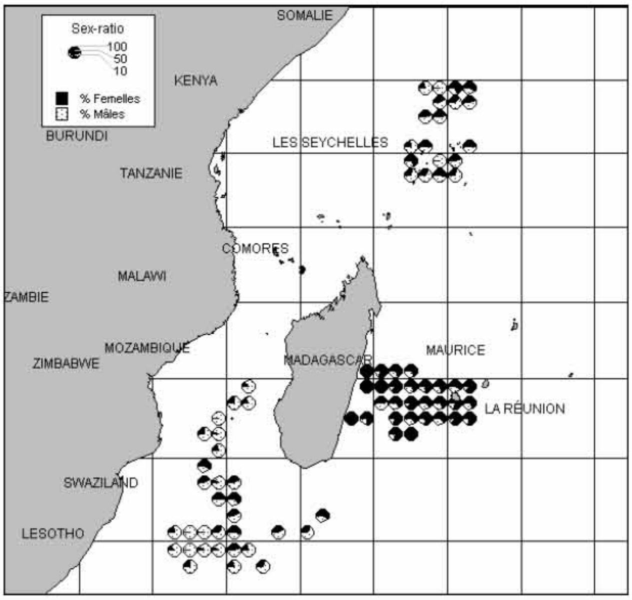


Figure 8 : Monthly sex ratio of swordfish (F/M) in two 5° squares as calculated during the "Programme Palangre Réunionnais" from 1995 to 2000(Poisson *et al*, 2001) .



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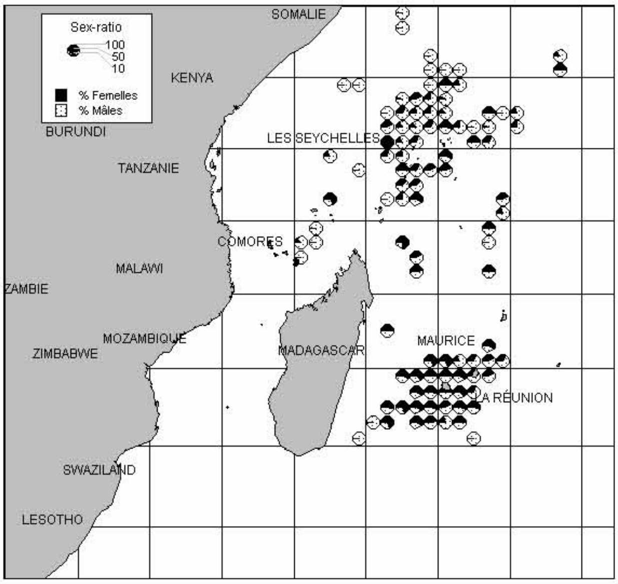
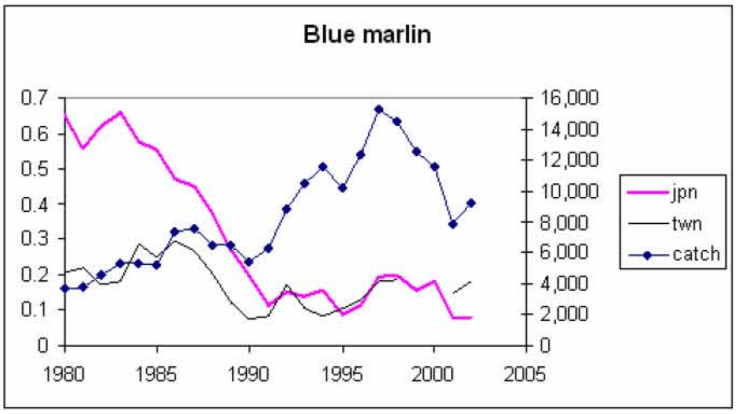


b

Figure 9: Percentage of individual by sex per 1 degree square from may to September (a) and during the spawning season (between October and April) in area 5 (b) as estimated during the "Programme Palangre Réunionnais" from 1994 to 2000.



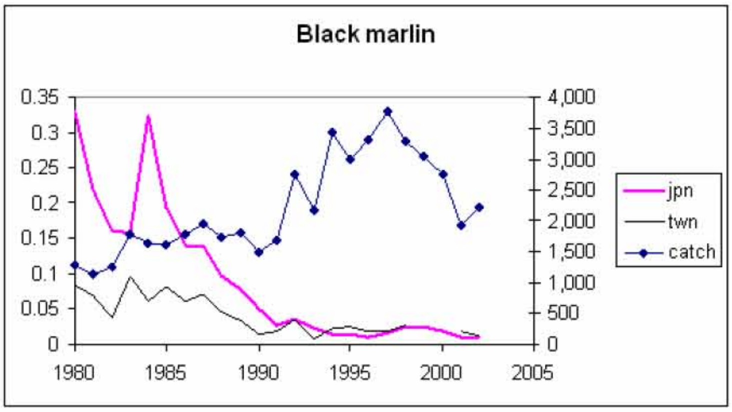


Figure 10: trends of the blue and black marlins CPUE (number of fish per 1000 hooks) from Japanese and Taiwanese fleet.

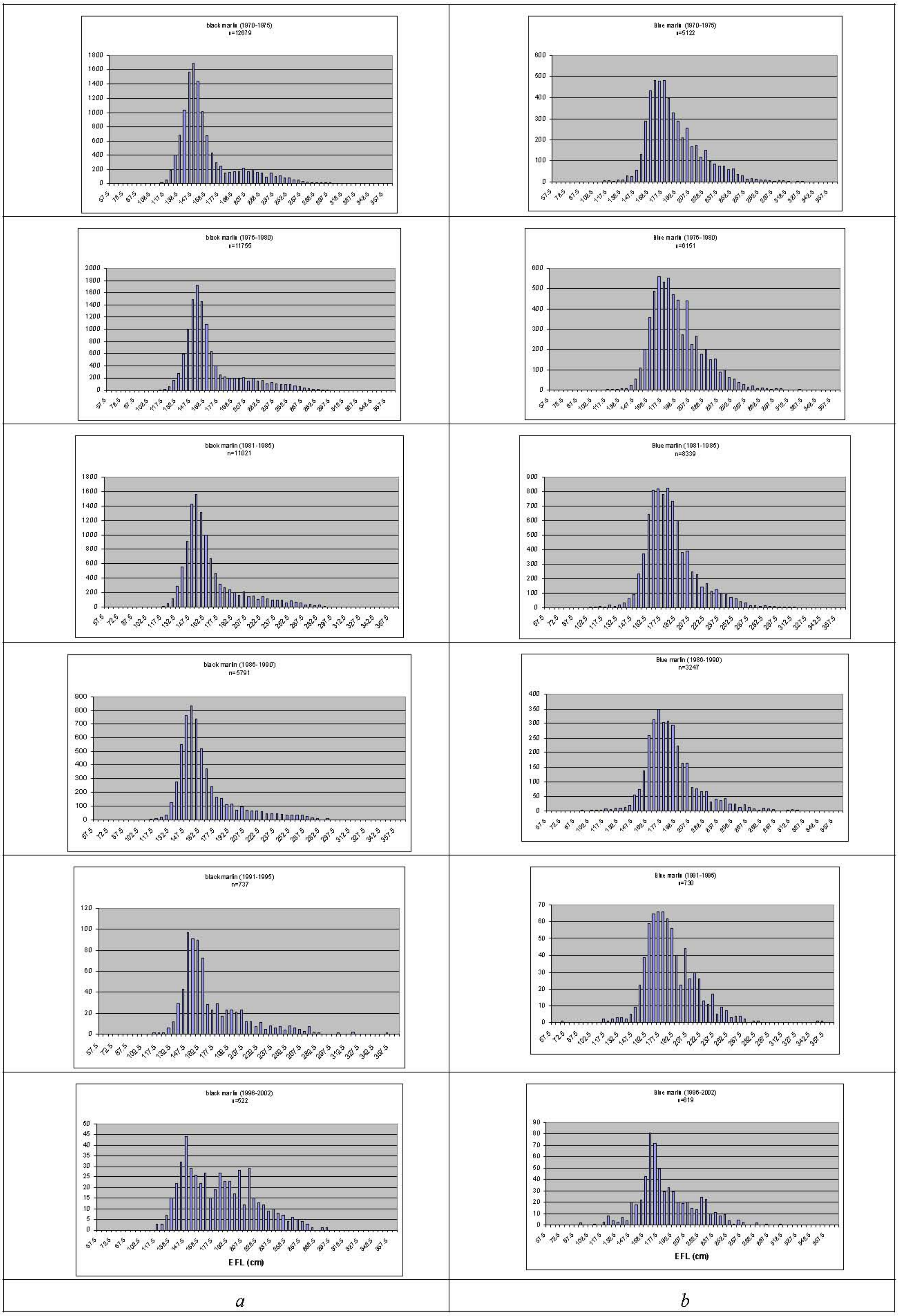


Figure 11: Size frequency distribution of Black Marlin (BLM) (a) and Blue Marlin (BUM) (b) caught under longline in Indian Ocean by Japanese fleet between 1970 and 2001 (not raised to the total catch)

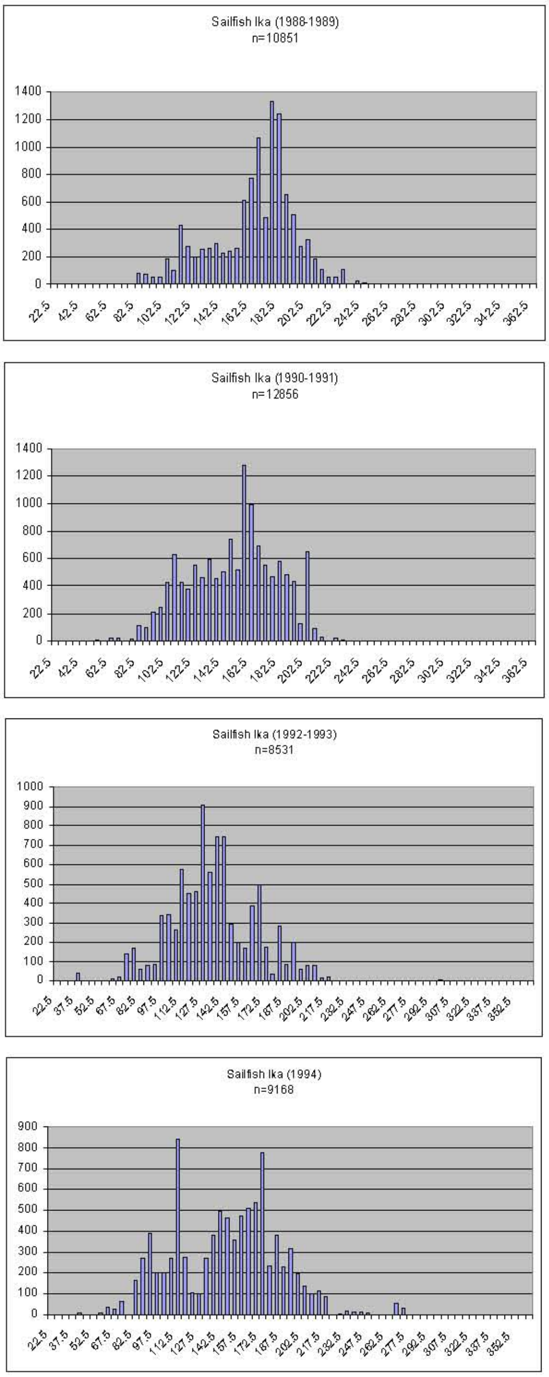


Figure 12: Size frequency distribution of Sailfish (SFA) caught under gillnet between 1988 to 1994 estimated from the data set provided by Sri Lanka (not raised to the total catch).

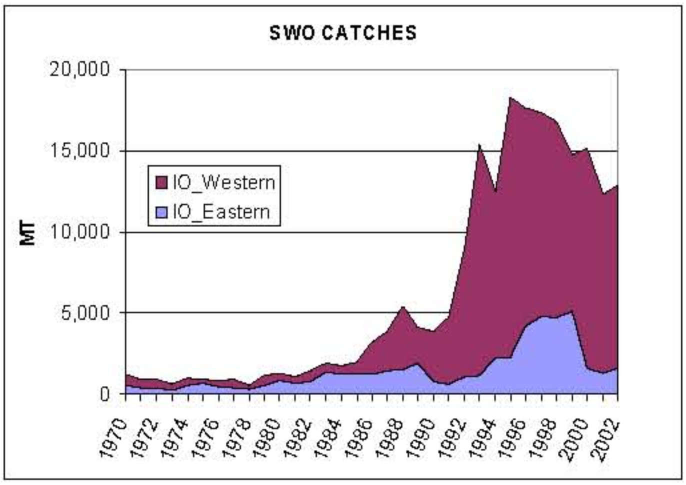


Figure 13: trends of the swordfish catches in the western and the eastern area of the Indian Ocean between 1970 and 2002.

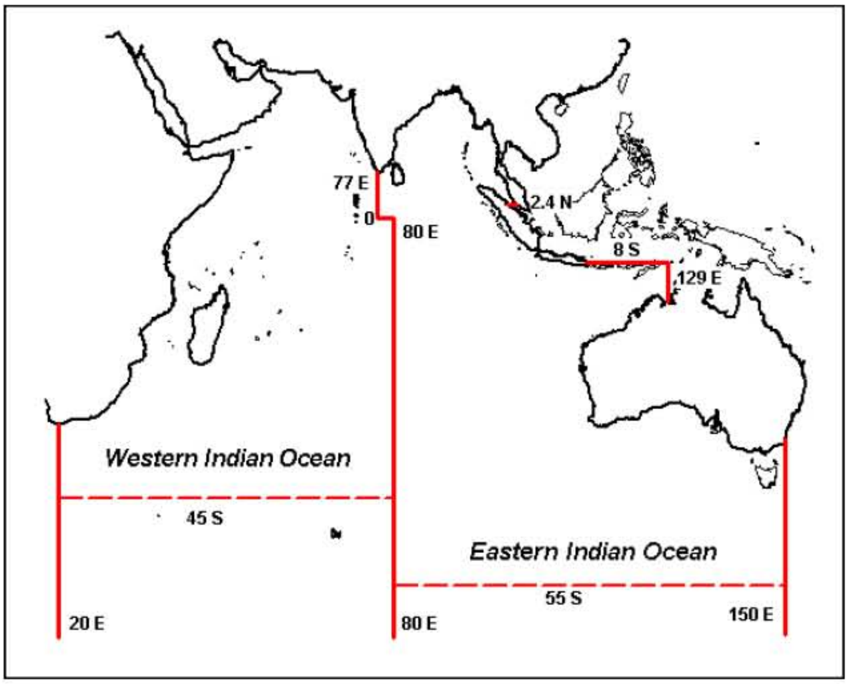
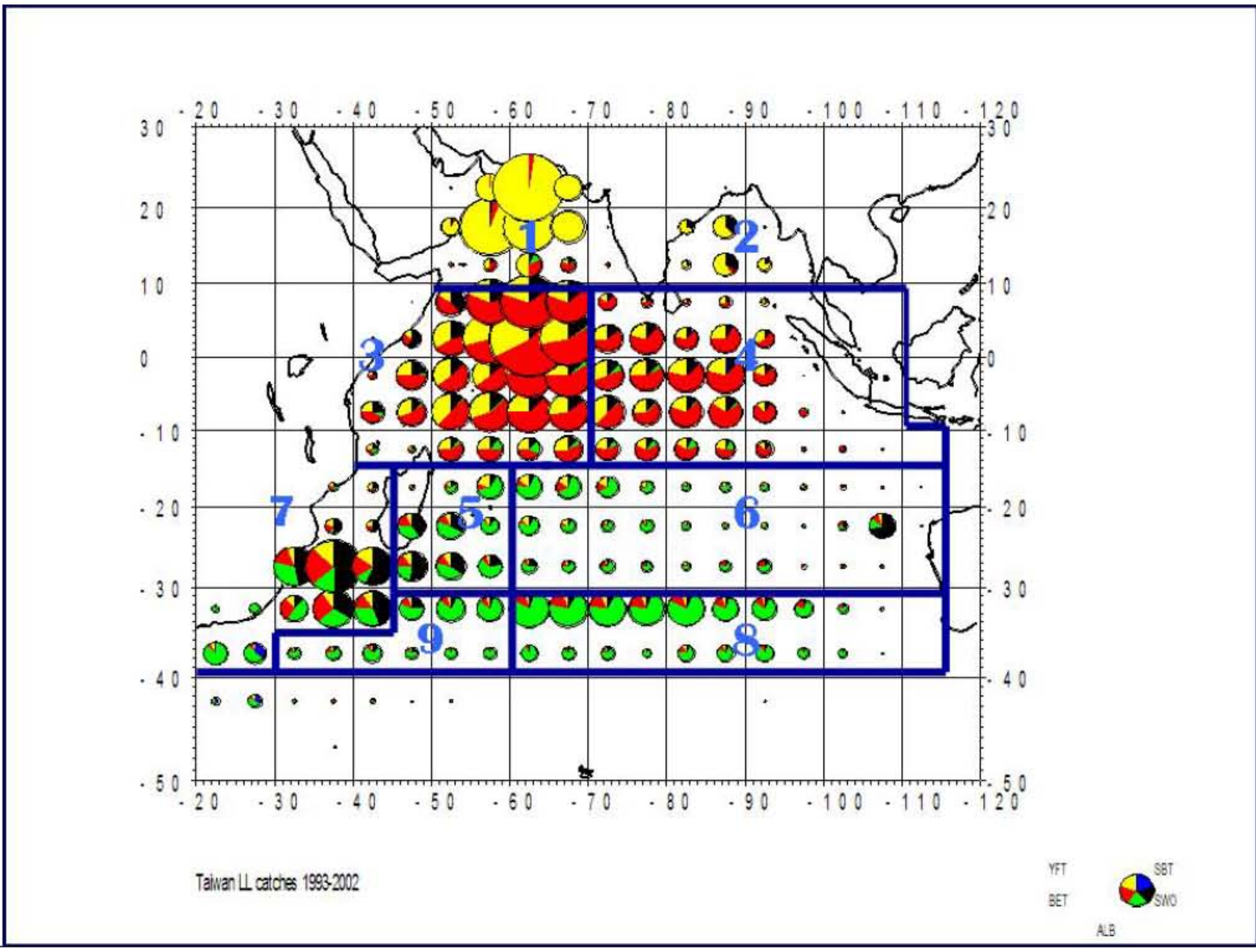


Figure 14: definition of the eastern and western areas in the Indian Ocean



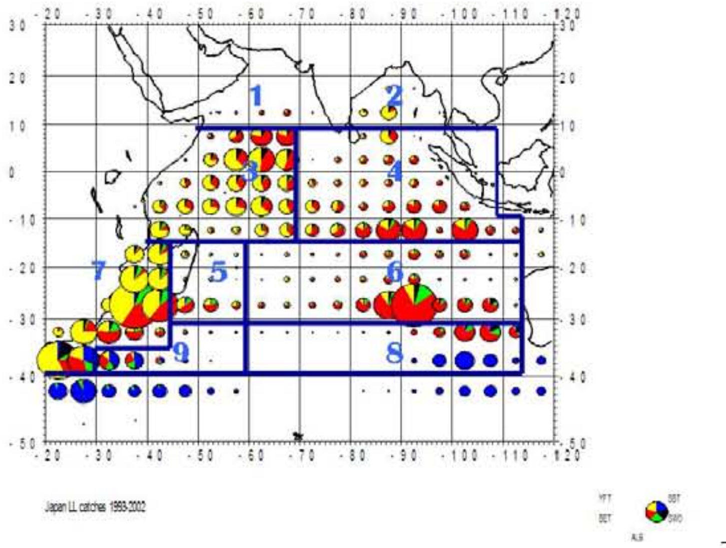


Figure 15: catches of the major species (SWO, BET, SBT, ALB, YFT) of the Taiwanese and Japanese fleets per area between 1993 and 2002.

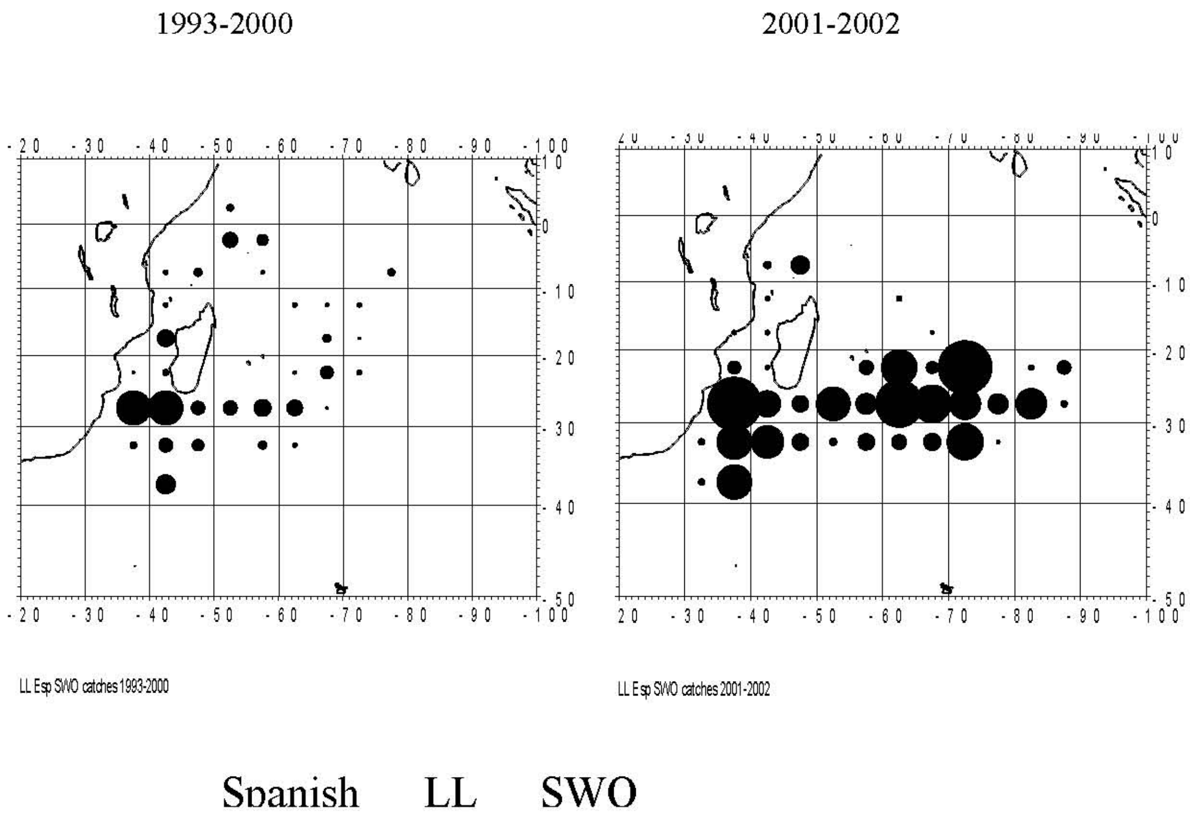


Figure 16: catches of swordfish (SWO) of the Spanish fleets per area between 1993 and 2002.

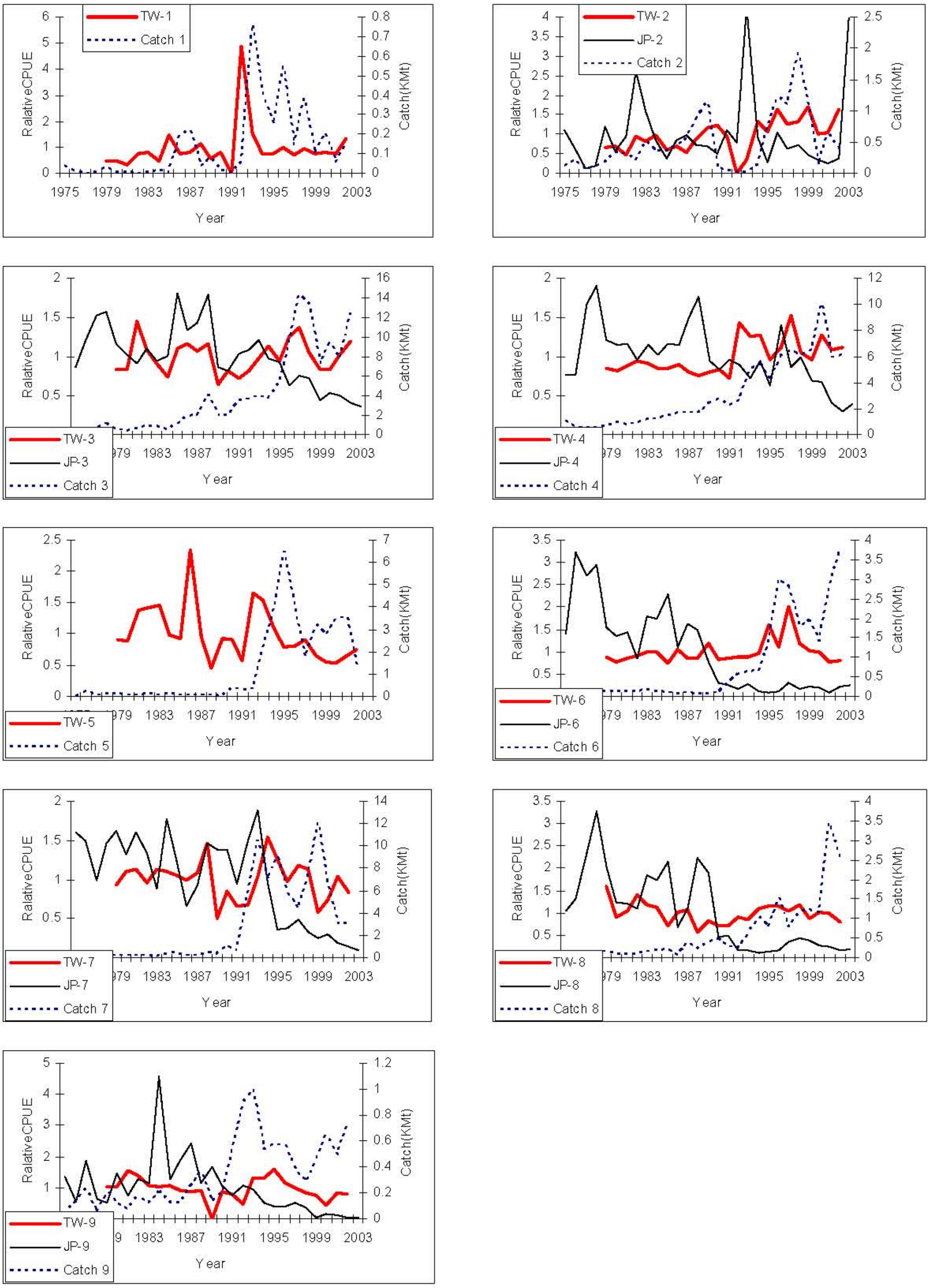


Figure 17 : Taiwanese and Japanese CPUE and catches by area.

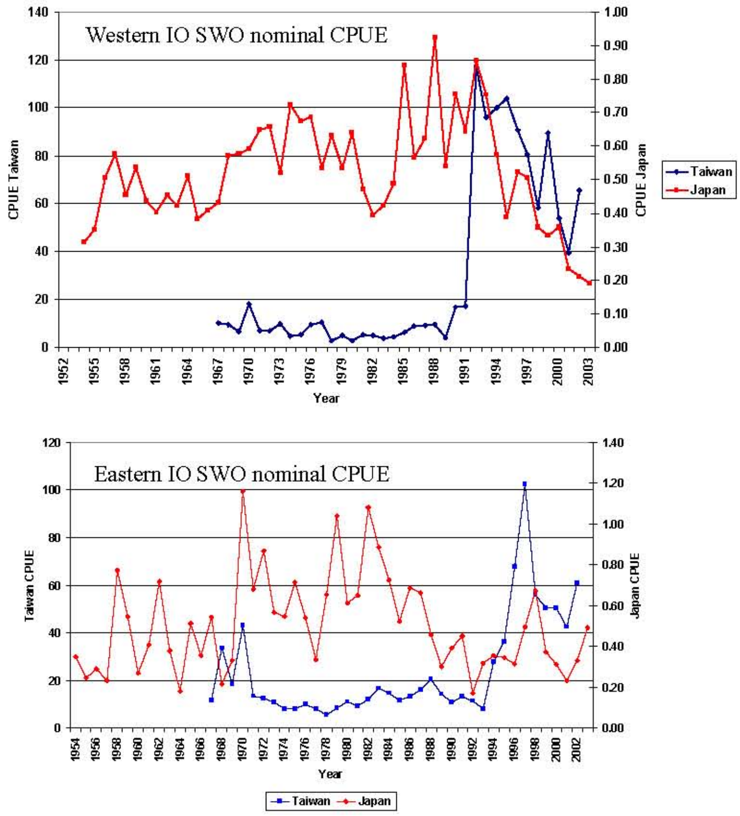


Figure 18: trends of the Taiwanese and Japanese fleets CPUE in the western and eastern areas in Indian Ocean.

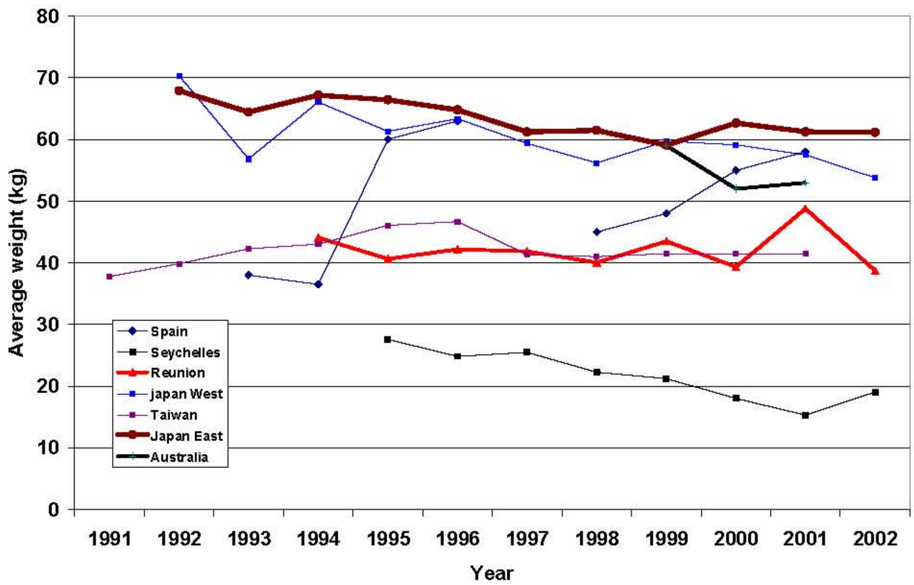


Figure 19 : average swordfish weight of the main swordfish fisheries (Australian data are represent the dressed weight).

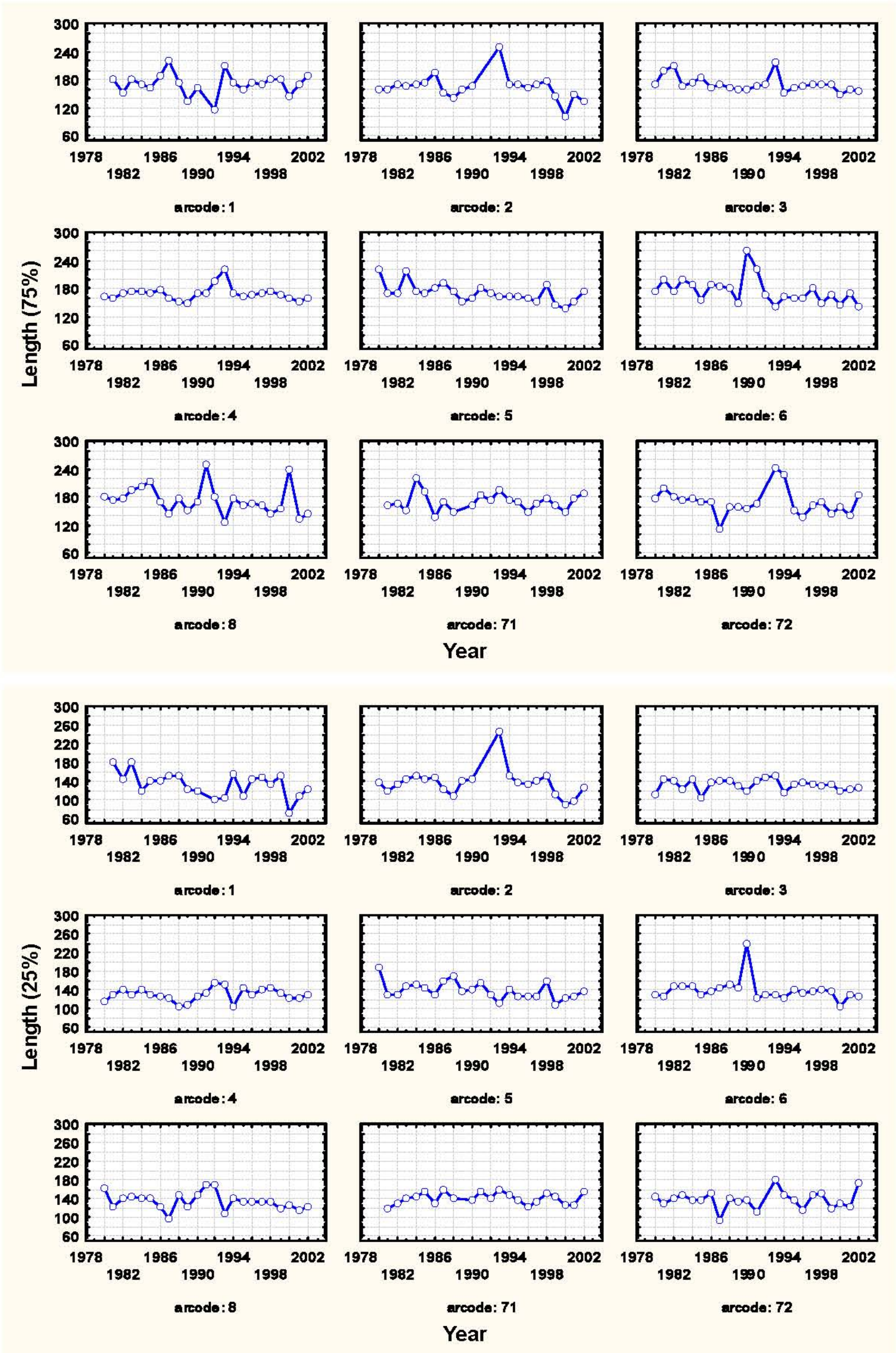


Figure 20: spatio-temporal variation in the median, 25[th] and 75[th] percentiles of swordfish length caught by the longline Taiwanese fleet per area (area 7- 2 is also called area 9)

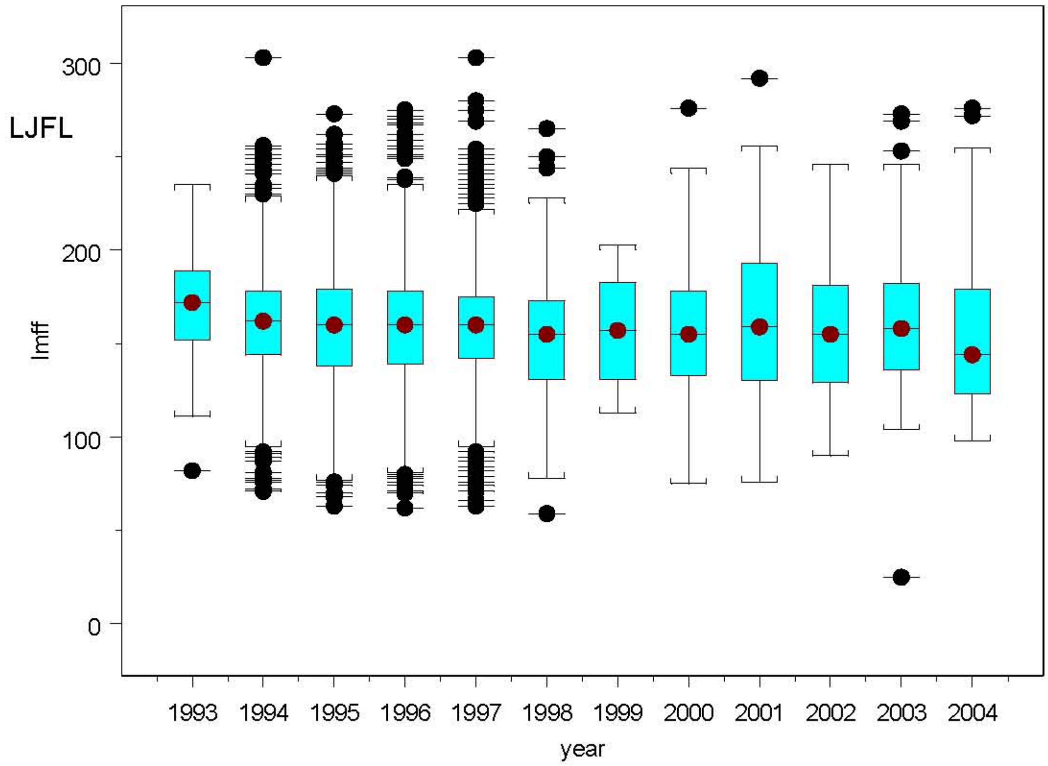


Figure 21: Swordfish size (LJFL cm) distribution from 1993 to 2004from Reunion longline fleet (Data collected by scientific observing and port monitoring)

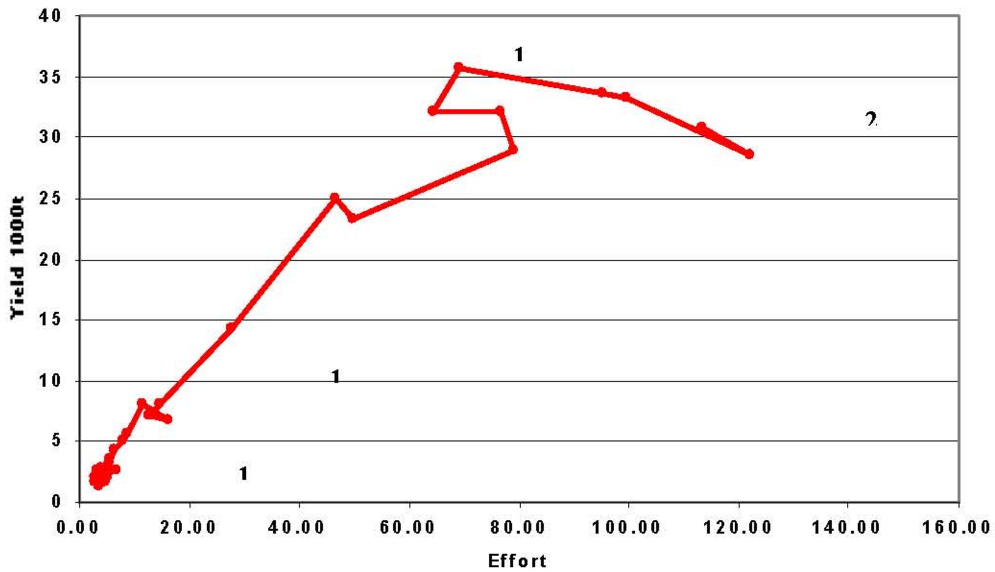


Figure 22: Possible interpretation of the evolution of catches and effort in relation to a production model. Effort represents effective effort as estimated from the standardized Japanese CPUE and total catches.