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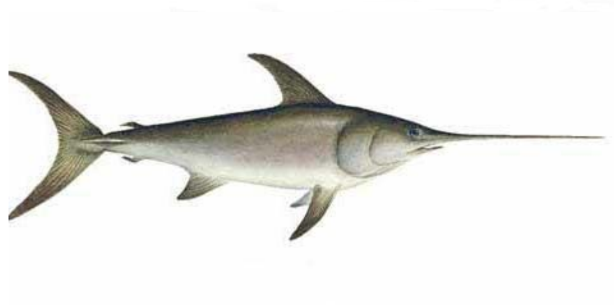

[1]Working document submitted to the ISC Billfish Working Group Workshop, January 8-15, 2008, Honolulu, Hawaii, USA. Document not to be cited without authors' written permission.

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# Estimation of the ratio of spawning biomass of striped marlin above 20$^o$N in the Central and Western North Pacific Ocean using the Japanese Distant Water Longline Fleet and the 2007 Stock Assessment

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**Abstract.**
Results of the 2007 stock assessment of striped marlin were used to estimate the ratio of spawning biomass north of 20$^o$N. Estimates of population number-at-age and selectivity patterns and CPUE catchability coefficients from the Japanese distant water longline fleet were used in the analysis. Results indicate that a majority of striped marlin in the western and central north Pacific occur north of 20$^o$N. This conclusion is consistent with the distribution of fishery catches since the 1960s.

## Introduction:

An assessment of striped marlin was completed for the North Pacific (NPO) stock in 2007 (Annex 8). The assessment was completed using an age-structure assessment model without estimating separate regional dynamics. However regional affects were incorporated by defining fisheries (estimating selectivity patterns) and CPUE series (index of abundance) by gear and region (Figure 1). Two equally plausible assessment models were forwarded as representations of the stock dynamics that differed only in that model 1 assumed a stock-recruitment (SR) steepness h=0.7 and model 2 assumed no SR relationship (h=1.0). For a complete description of the stock assessment model see Annex 8 and Piner (2007[a]: 2007[b]).

The most consistent data source across area and time was the Japan Distant Water Longline (JPDWLL) fleets. For this fleet, both size composition and CPUE data were available for all regions and over most years. Each area's CPUE series was estimating using the same methods and data, thus the cpue estimates were potentially additive. If each region had the same selectivity pattern for the JPDWLL fleet, the ratios of CPUE would be a good proxy for the abundance by region. However the selectivity patterns were different and thus to determine the distribution of biomass by region requires accounting for these processes.

The objective of this paper is to characterize the distribution of biomass of striped marlin in the Central and Western Pacific Ocean relative to the 20$^o$N management line for regional areas 1-4.

## Methods:

We defined the Northern (above 20$^o$N ) area to be regions 1 and 3 and the Southern area to be regions 2 and 4 (Figure 1). Region 5 was not used in the calculations except in the estimation of dynamics inside the stock assessment model. To estimate the fraction of the stock in the north, we used the estimates of JPNDWLL CPUE catchability (q) and the associated selectivity patterns. Estimates of q can be thought of as a measure of the density of the fully selected age/size classes in a particular area and for a specific gear. The associated selectivity pattern is an estimate of the relative availability of age/size classes in that area/gear. The product of q*selectivity by age-class is the actual or effective catchability (q') of that age-class. Because the q are derived from a CPUE (not swept area biomass) the q themselves are not easily interpretable. However, the ratio of q' in the north to the south reflects the age/size-class specific proportion of fish found in each area. Therefore we can use this to describe the relative abundance of each age class above and below 20$^o$N.

To calculate the same ratio for a spawning biomass available to the JPNDWLL fleets in a specific year, we multiplied the age specific q' * population numbers-at-age (for a given year) * weight at age. Summing across the age-classes we wish to compare, we can add up the northern areas and southern areas separately and weight these by the region specific fraction of the total area (Table 1). The ratio of the north to south gives us the proportional difference in the biomass in the northern areas relative to the south. For a full description of the methods see Appendix 1.

## Results and Discussion:

Our analysis indicates that the majority of the biomass of western and central NPO striped marlin is found above 20$^o$N.  Results do not differ for either assessment model. We estimate that q' is larger for all age-classes in the north relative to the south (table 1) due to the larger q estimates in those regions (initial CPUE was larger). The northern area is estimated to have 1.2X the number of age-1 fish relative to the southern areas, but that rises to 5X the southern areas in the oldest age-classes. In 1964 this results in roughly 4X the spawning biomass (sum across age $5^+$) located in the north relative to the south with 1969 showing nearly the same result (Table 3). The difference is somewhat less over age-$1^+$ because small fish tend to be relatively more abundant below 20$^o$N.

We produced the ratio of spawning biomass and total biomass for 1964 and 1969 as these years are representative of some of the earliest years before any potential changes in the JPNDWLL fleets (e.g. deep setting for bigeye tuna) and at the onset of major exploitation. Further, the spatial extent of the JPNDWLL was broadest in this decade – particularly in 1964. However, calculating the ratio in other years would be similar and the changes would only reflect changes in the proportion of fish in each age class. Because the age-specific q' are larger in the north for all age-classes, there are no possible population age distributions that would have a majority of the population in the southern areas. However, as the relative abundance of older age-classes declines, the proportion of biomass in the north will also decline.

One quick check of the validity of these results is to compare to the total catch of striped marlin by region with our estimates of biomass. The results presented in this paper are consistent with the region catch statistics as roughly 60-90% of the total catch (by decade) was taken above $20^{o}$N (Table 4), which is consistent with our estimates of ~2-4X the biomass found in those areas. It appears logical to assume that abundance is probably greater in the areas with the majority of the catch, especially if the species is not generally targeted.

As an integral part of the stock assessment process, all of the JPNDWLL indices of abundance (used herein) were standardized using GLM methods to account for fishing power factors such as season, depth, sub-area within region, and a variety of interactions. This analysis assumes that after standardization, a single unit of effort (1000 hooks) is equal in fishing power across all regions and that only local area-specific, age-specific density affects the catch rates. However, if major targeting of striped marlin occurred in some regions (beyond that which can be accounted for via GLM), it would call into question this assumption. The general consensus of the ISC Billfish WG is that striped marlin has not been targeted to any great extent by longline fishermen in the Central and Western North Pacific, occurring primarily as bycatch associated with the tuna-directed fisheries. Unless a major departure from this assumption is true, our results of the majority of adult striped marlin distributed above $20^{o}$N is likely to be a fairly robust conclusion.

## Literature Cited

Annex 8. Report of the Marlin and Swordfish working group joint report. March, 2007.

[a]Piner,K**.** Conser.R., DiNardo, G. and J. Brodziak. 2007. Evaluation of Model Performance from the 2007 ISC Striped Marlin Stock Assessment Meeting . Busan, Korea. ISC/07/SM-WG/04

[b]Piner,K. Conser.R., DiNardo, G. and J. Brodziak. 2007. Evaluation of Model Performance from the 2007 ISC Striped Marlin Stock Assessment Meeting . Busan, Korea. ISC/07/SM-WG/04

Table 1. The proportion of the combined area (Regions 1-4) within each of our geographic regions (Figure 1). Region 5 has been excluded.

| Region 1 | Region 2 | Region 3 | Region 4 |
|---|---|---|---|
| 0.22 | 0.29 | 0.24 | 0.24 |

Table 2. Estimates of the age-specific ratio of effective catchability (q') above 20$^{o}$N for both assessment models (h=0.7 and no SR assumption). As an example, the value of 1.2 indicates that the northern area has 1.28X the numbers of striped marlin in that age-class.

| age | model 1 | Model 2 |
|---|---|---|
| 1 | 1.28 | 1.34 |
| 2 | 1.83 | 1.93 |
| 3 | 2.64 | 2.78 |
| 4 | 3.42 | 3.58 |
| 5 | 4.06 | 4.22 |
| 6 | 4.54 | 4.68 |
| 7 | 4.88 | 5.00 |
| 8 | 5.12 | 5.22 |
| 9 | 5.29 | 5.38 |
| 10 | 5.41 | 5.49 |
| 11 | 5.50 | 5.58 |
| 12 | 5.57 | 5.64 |
| 13 | 5.62 | 5.68 |
| 14 | 5.66 | 5.71 |
| 15 | 5.68 | 5.74 |

Table 3. Estimates of the area weighted (excluding Region 5) relative ratio of striped marlin above 20$^{o}$N for both assessment models (h=0.7 and no SR assumption). This is the sum over the specified age range of age-specific q' * population numbers-at-age*weight at age. As an example, the value of 4.6 indicates that the northern area has 4.6X the biomass of striped marlin in the south area.

| Year | Model 1 | Model 2 |
|---|---|---|
| 1964 Age 5$^{+}$ | 4.1 | 4.0 |
| 1964 Age 1$^{+}$ | 3.2 | 2.9 |
| 1969 Age 5$^{+}$ | 3.6 | 3.9 |
| 1969 Age 1$^{+}$ | 2.5 | 2.7 |

Table 3. The average proportion of the total catch in numbers (Regions 1-4) coming from north of 20oN (areas 1 and 3) by decade.

| 1950's | 1960's | 1970's | 1980's | 1990's | 2000's |
|---|---|---|---|---|---|
| 0.96 | 0.82 | 0.66 | 0.67 | 0.77 | 0.73 |

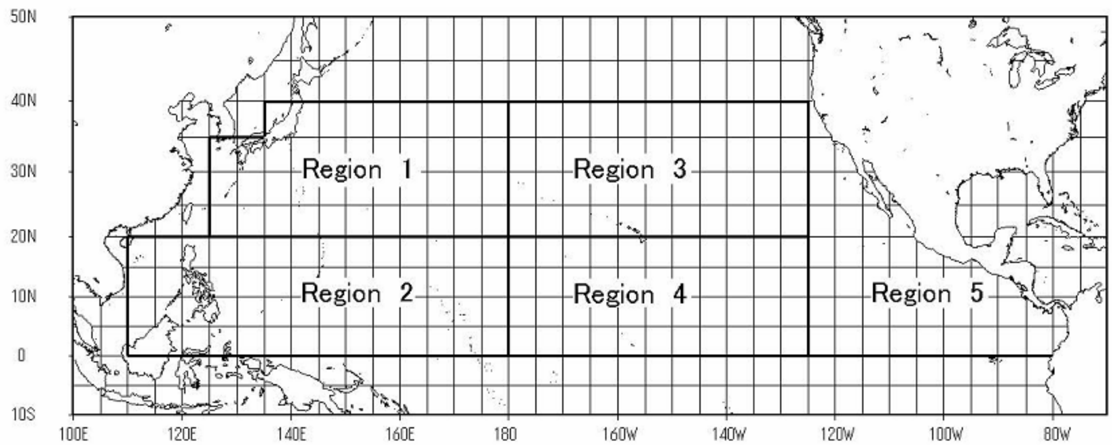


Figure 1. Map of the stock assessment areas. Region 1 and 3 correspond to the northern areas (above 20°N) and regions 2 and 4 are the southern areas. In all calculations area 5 (EPO) has been excluded.

**Appendix 1. Equations for regional biomass estimates.**

Define terms as follows:

| | |
|---|---|
| a | age in years (a=1,2,…,15?) |
| y | year (y=1964,1969) |
| r | region of the WCPO (r=1,2,3,4) as defined in the striped marlin assessment |
| JLL | Japanese distant-water longline fishery |
| $C_{ayr}$ | predicted JLL catch in number of age a fish during year y in region r (from SS2 output) |
| $N_{ay}$ | mean number of age a fish during year y in the total population. Approximated by the SS2 estimate of the number of age a fish in the population on July 1st (i.e. beginning of Quarter 3). |
| $W_{ar}$ | weight-at-age of fish in region r on July 1st (kg) |
| $q_r$ | catchability of JLL in region r (from SS2 output), i.e. the proportion of $N_y$ caught in region r within the area covered by 1000 longline hooks (unitless) |
| $A_q$ | area covered by 1000 JLL longline hooks ($km^2$), i.e. the area associated with $q_r$. |
| $A_r$ | area of the entire region r ($km^2$). |
| $\eta_{yr}$ | number of fish "vulnerable" to the JLL fishery in region r during year y (from SS2 output) |

Then the JLL fishing mortality rate ($yr^{-1}$) on age a fish during year y in region r is:

$$F_{ayr} = {C_{ayr}}\big/{N_{ay}} \quad (1)$$

Define the average "fully-recruited" JLL F in region r as:

$$F_{yr} = Max_a \left\{ F_{ayr} \right\} \quad (2)$$

The age-specific JLL selectivity in region r is:

$$S'_{ar} = {F_{ayr}}\big/{F_{yr}} \quad (3)$$

Note that $S'_{ar}$ is an age-based selectivity and from Equation (3), at least one age must be fully-selected. However, the striped marlin stock assessment was carried out (in SS2) assuming length-based selectivity. When the underlying selectivity is length-based, it is possible that age-based selectivity may be less than one for all ages, e.g. if only part of the length range associated with an age is fully selected. Define the appropriate age-based JLL selectivity by region as:

$$S_{ar} = \omega_r S'_{ar} \tag{4}$$

where $\omega_r$ corrects the nominal age-based selectivity ( $S'_{ar}$ ) to be consistent with true age-based selectivity when the underlying selection model is length-based. The correction factor is:

$$\omega_r = \frac{\eta_{yr}}{\sum_a S'_{ar} N_{ay}} \tag{5}$$

Then the mean number of age a fish during year y in region r is:

$$N_{ayr} = \frac{A_r q_r S_{ar} N_{ay}}{A_q} \tag{6}$$

The total biomass on July 1st of year y in region r is:

$$B_{yr} = \sum_{a=1}^{15} W_{ar} N_{ayr} \tag{7}$$

The spawning stock biomass on July 1st of year y in region r is:

$$SSB_{yr} = \sum_{a=5}^{15} W_{ar} N_{ayr} \tag{8}$$

The area covered by 1000 JLL longline hooks ($A_q$) is conceptually straightforward, i.e. the product of (i) the distance along the great circle arc covered by the part of the main line supporting 1000 hooks and (ii) the width of the band (orthogonal to the main line) from which fish will be attracted to the baited hooks. In practice, however, these components may be difficult to quantify – especially (ii).

But as long as $A_q$ is constant over regions, a relative measure of $N_{ayr}$ is:

$$N'_{ayr} = A_q N_{ayr} = A_r q_r S_{ar} N_{ay} \tag{9}$$

Analogously, relative measures of total biomass and SSB are:

$$B'_{yr} = \sum_{a=1}^{15} W_{ar} N'_{ayr} \tag{10}$$

$$SSB'_{yr} = \sum_{a=5}^{15} W_{ar} N'_{ayr} \tag{11}$$

Then the proportion of total biomass north of 20$^{o}$ N latitude is:

$$ {}_{N}B'_{y} = \frac{B'_{y1} + B'_{y3}}{\sum_{r=1}^{4} B'_{yr}} \tag{12} $$

and similarly, the proportion of SSB north of 20$^{o}$ N latitude is:

$$ {}_{N}SSB'_{y} = \frac{SSB'_{y1} + SSB'_{y3}}{\sum_{r=1}^{4} SSB'_{yr}} \tag{13} $$