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TRENDS IN TOTAL MORTALITY USING A LENGTH-BASED INDICATOR APPLIED TO ATLANTIC BLUE MARLIN (*MAKAIRA NIGRICANS*)

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SUMMARY

The maximum sizes in the catches were examined for changes in fishing mortality using ICCAT length data. Individuals sampled from longline gear were combined across ICCAT areas. Thresholds for the test statistic, NZ50, were set at 175 and 200 LJFL (lower jaw fork length). Trends in NZ50 exhibited a strong similarity to the trend in total landings as well as recent estimates in F/F_{MSY} *and* B/B_{MSY}*. The declining trend in NZ50,* F/F_{MSY} *and an increasing trend in* B/B_{MSY} *suggest that the decrease in landings is due to a decrease in fishing mortality and not one of a decline in overall population size. This suggests that recent ICCAT conservation measures for billfish maybe having the desired effect.*

RÉSUMÉ

Les tailles maximales des captures ont été examinées pour connaître les changements dans la mortalité par pêche au moyen des données de taille de l'ICCAT. Les spécimens échantillonnés de l'engin de palangre ont été combinés dans toutes les zones de l'ICCAT. Les seuils pour la statistique de test, NZ50, ont été fixés à 175 et 200 cm LJFL (longueur maxillaire inférieur-fourche). Les tendances dans NZ50 présentaient une forte similitude avec la tendance des débarquements totaux ainsi qu'avec les récentes estimations de F/F_{PME} *et* B/B_{PME}*. La tendance à la baisse de NZ50,* F/F_{PME} *et une tendance à la hausse de* B/B_{PME} *suggèrent que la diminution des débarquements est due à une diminution de la mortalité par pêche et non à un déclin de la taille globale de la population. Cela suggère que les récentes mesures de conservation de l'ICCAT pour les istiophoridés pourraient avoir l'effet souhaité.*

RESUMEN

Se examinaron las tallas máximas en la captura para detectar cambios en la mortalidad por pesca utilizando los datos de talla de ICCAT. Se combinaron los ejemplares muestreados a partir del arte de palangre de todas las áreas de ICCAT. Los umbrales para la estadística de prueba, NZ50, fueron fijados en 175 y 200 LJFL (longitud mandíbula inferior a horquilla). Las tendencias en NZ50 mostraban una fuerte similitud con la tendencia en los desembarques totales así como en las recientes estimaciones de F/F_{RMS} *y* B/B_{RMS}*. La tendencia decreciente en NZ50,* F/F_{RMS} *y la tendencia creciente en* B/B_{RMS} *sugiere que el descenso en los desembarques se debe a un descenso en la mortalidad por pesca y no a un descenso en el tamaño general de la población. Esto sugiere que las recientes medidas de conservación de ICCAT para los istiofóridos podrían estar teniendo el efecto deseado*

KEYWORDS

Blue Marlin, NZ50, Stock assessment,
size composition, maximum size, population dynamics

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1. Introduction

The assessment of the overall status of the Atlantic blue marlin population has always posed problems brought about by its data limited situation. Landings are not known with a great deal of certainty and CPUE trends are often times either conflicted or lack the contrast necessary to estimate overall productivity. However, length information is available from 1970-2016 and is likely the data collected with the highest degree of certainty. This situation makes blue marlin a good candidate for the exploration of length-based analysis.

The size distribution of the catch is an important characteristic considered in stock assessments. The mean and maximum sizes are readily understood indicators of population health because fishing tends to progressively reduce the abundance of older, larger fish in the population. The mean easily understood but because the maximum tends to increase with sample size it usually receives less attention during the assessment process. Goodyear (2015a, b) introduced a metric to monitor maximum size based on the position of an arbitrary large size threshold in the cumulative distribution of sizes in the catch. The statistic, termed NZ50, is the smallest number of observations which will include fish ≥ that threshold half the time and is uniquely determined by the cumulative probability (p) at the level of the threshold in the population from which the sample is drawn. Goodyear (2015a) showed NZ50 to be a sensitive indicator of changes in fishing mortality where gear selectivity is constant. Consequently, NZ50 from empirical estimates of cumulative size distributions of catch can be an indicator of changes in fishing mortality. Here we use this metric to explore size data from Atlantic blue marlin fisheries for patterns in the frequencies of the largest fish in the catches that might signify important changes in fishing mortality.

NZ50 is a measure magnitude of the impact of fishing. It is an estimate of the least number of observations required of a random sample to include one or more individuals a specified (threshold) size in 50% of such samples. Put another way, the smallest number of observations which will include a fish at least as big half the time. The impacts of fishing on numbers of observations needed to observe a large fish are in contrast to the changes in mean lengths for the same mortality combinations.

In contrast to mean size of the catch, NZ50 would be a particularly sensitive indicator of population recovery due fishing conservation measures.

2. Method

NZ50 is the least number of observations required of a random sample to include one or more individuals ≥ a specified threshold size in 50% of samples (the smallest number of observations required of a sample to include at least one observation at least as big as the threshold half the time). It is completely determined by the threshold value of p in the cumulative probability distribution of sizes in the catch (sample population) and can be calculated using the relation (Goodyear 2016):

$$NZ50 = (0.5)log(p)$$

The NZ50 methodology makes several assumptions, the violation of which can result in varying degrees of bias.

The first assumption is that the selectivity of the gears being sampled not changed over the time period of examination. Such changes can be caused either by changes in the ratio of the length samples collected between gear types of differing selectivities, or by changes in selectvity (or sampling) of the individual participating gear types. The majority of blue marlin landings are from longline gear (**Figure 1**). The gear specific landings show little indication of change in ratio between gear types except for the introduction of artisanal fishery in the mid- 1970’s. However, the classification “artisanal” is broad and contains several gear types (gillnet, short longline and handline) with an unknown catch distribution between those gears. Thus, we could not be assured that the data met the required criteria. Therefore, to ensure that the assumption of a constant sample ratio between gears and selectivities would not be an issue, the estimation of NZ50 was conducted on longline gear lengths only.

It is reasonable to assume that, for the most part, the selectivity of the longline gear has not changed significantly over the time period of analysis. While the depth of that the gear is fished is known to have changed over time, this has presumably only changed the overall catchability of the gear and not the underlying selectivity. While there was an introduction of circle hooks in 2005, this regulation would also effect only catchability as there has been no evidence of size related effect of these hooks. Although minimum size regulations were in acted for recreational caught blue marlin, no evidence of truncation in the length composition was evident (**Figure 2 top**).

Length composition data for this analysis was provided by the ICCAT Secretariat. Overall compositions were created from observed samples weighted by the catch associated with that sample. The NZ50 estimates of the trends in fishing mortality were compared to the estimates of the 2018 continuity stock assessment, conducted with the integrated assessment modeling platform Stock Synthesis. The continuity stock assessment here is defined as having the same model structure as the 2010 stock assessment with only the data updated. However, to ensure independence between the two estimated trends, the stock assessment was fit with all length data removed.

3. Results

Mean length of blue marlin caught from all longline gear indicates a decline trend from 1970 to 2000 where after a slight increase with a leveling off in 2005 (**Figure 2**). Assuming that non-random sampling is not an issue, the initial declining trend could be an indication of, *et alia*, increased fishing mortality, an increase in recruitment, or a change in gear configuration that overall resulted in larger fish being less vulnerable to the gear. The correlation of the trend with the trend in landings suggests that perhaps increased fishing mortality may be the cause.

Estimates of NZ50 for threshold of 175 and 200 cm LJFL are presented by year in **Table 1.** The number of samples per year ranged from 55 (1974) to 5160 (1996) with an average of 1447. The total number of length bins considered was 84 (25-430 cm). Consequently, estimates of NZ50 for 1973 (N=80), 1974 (N=55), 1979 (N=73) are less certain than those years with larger (approximately > 1000). The cumulative frequency distribution of a sample of years, along with the 200 cm threshold, is shown in **Figure 3, bottom**. Similar distributions (for each years) were used to calculate the annual NZ50 values. Examination shows a pattern of the position of the perceived 50th percentile can be detected. The pattern begins with the percentile moving from the larger lengths during the earliest years (1975, 1985), a progression to smaller lengths during the middle years (1995, 2005), and then back to the larger lengths in the latest year (2015).

The NZ50 method was originally conceived as applying to the very largest fish in a population (high thresholds). That requires very large sample sizes. However, it has been shown that the method also works well with lower thresholds which has the obvious advantage of including more of the length composition distributions. The remaining results apply to analysis carried our using a threshold of 200 cm. The annual trend in NZ50 was examined with a with a 2 year lag. This was considered appropriate given that NZ50 represents fishing mortality from previous years. The trends in landings and NZ50 showed a marked similarity to the trend in overall landings (**Figure 4**). Both trends generally increase during the late 1990, after which both depict a declining trend thereafter. The decline in both the landings and NZ50 in the last seven years (2010-2016) is during a time period that corresponds to with the conservation measures put into place for Atlantic blue marlin.

The synchronous trends suggests that the decreasing landings are due to a decrease in fishing mortality, rather than a steadily declining population size. This could be taken as an indicator that conservations are having the desired effects.

There was strong agreement between the trend in NZ50 and the trend in F/Fmsy from the stock assessment in the early years (**Figure 5**). The agreement is not as strong after 2000 with the NZ50 trend following the trend in landings more closely than the assessment model. While it was hypothesize that this may be due to the fact that the length information was not included in the stock assessment model which may provide important information on the trend in mortality, this was investigated and found not to be the case. While the agreement between these two independent approaches is not unequivocal, still greatly increases the veracity of each of the trends. The recent downward trend of the two mortality indicators as well as the landings suggests that the landings are decreasing due to a decrease in mortality rather than a lower population size. However, these observations do not lead to conclusion that the conservations measure are adequate enough to result in an increasing population. Even with a decreasing fishing mortality, if this mortality is high enough, a decrease in landings could still be indicative of a population in decline.

The trend in B/B_{MSY}, an indicator of stock abundance, estimated from the stock assessment was compared to the trend in NZ50 (**Figure 6**). The change in direction of the trend in the B/B_{MSY} in the terminal years coupled with the decreasing trend in NZ50 is evidence that the population is increasing in size. Taken together, these trends support the conclusion that that the population of blue marlin may be in a rebuilding phase, and that the conservation measures are bringing about the desired results.

4. Discussion

Results of stock assessments are very often difficult to verify or corroborate. This study documented an agreement between two independent methods of estimating mortality with independent data sources. It does not prove the accuracy the integrated assessment model results but does add substantial support to those estimates.

The NZ50 assumes no significant changes in selectivity during the time period under evaluation. One cause of a change in selectivity can come about from the fishery operating in a changing minimum size. Although several changes in minimum legal size for blue marlin have been put into place, these regulations applied to recreational fishing only and not to the longline gear used in this analysis.

Furthermore, the lack of truncation in the longline length compositional data does not show any evidence of truncation that would be indicative of any minimum size.

While NZ50 provides estimates of mortality trends, the metric cannot produce estimates of the status of the biomass of the stock similar to MSY-based benchmarks. However, when the two agree, NZ50 increases confidence in the benchmarks produced by parameterized assessment models fitted to observational data. In addition, NZ50 can be used to monitor mortality to maintain a stock at levels where the biomass has been judged adequate by a more complex assessment model.

Acknowledgements

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References

Goodyear, C. P. 2015a. Understanding maximum size in the catch: Atlantic blue marlin as an example. Transactions of the American Fisheries Society, 144:274-282.

Goodyear, C. P. 2015b. NZ50 a new metric for maximum size in the catch: an example with blue marlin. ICCAT SCRS/2015/026:1-6. (Withdrawn)

Table 1. Estimates of NZ50 for blue marlin from cumulative frequency distributions of LJFL from lengths from longline gear. The estimates of NZ50 used a threshold of 175 cm and 200 cm for comparison.

Year	*Nfish*	*NZ50 175 cm*	*NZ50 200 cm*	*Year*	*Nfish*	*NZ50 175 cm*	*NZ50 200 cm*
1970	108	0.2789	1.0846	1994	1636	0.5260	0.9740
1971	420	0.2491	0.5174	1995	3750	0.8019	1.2244
1972	212	0.1850	0.3121	1996	5160	0.7605	1.3060
1973	80	0.3333	0.5369	1997	3004	0.7160	1.4172
1974	55	0.0753	0.2384	1998	2137	0.6503	1.3101
1975	1031	0.2508	1.0127	1999	2517	0.7877	1.8544
1976	724	0.2839	0.7107	2000	1136	0.5746	1.3903
1977	404	0.2932	0.6366	2001	1301	0.7768	2.1327
1978	194	0.2257	0.5579	2002	1987	1.1795	2.6587
1979	73	0.3311	0.7508	2003	1756	0.7340	1.6964
1980	505	0.3813	0.5901	2004	1838	0.4244	1.1058
1981	1341	0.6271	1.1739	2005	7109	0.8229	1.8927
1982	1137	0.5400	1.0115	2006	4645	0.4081	0.9097
1983	1085	0.4891	0.7489	2007	2556	0.4001	0.8660
1984	1456	0.5211	0.8628	2008	1590	0.4307	0.9768
1985	1490	0.4757	0.9585	2009	2051	0.3136	0.7275
1986	964	1.1999	3.5728	2010	1833	0.3262	0.7042
1987	404	0.5593	1.3859	2011	2201	0.4354	0.9980
1988	636	0.4136	0.7952	2012	903	0.4814	1.1226
1989	1066	0.4007	0.6946	2013	636	0.4451	1.0277
1990	2000	0.5080	1.1385	2014	666	0.3694	0.8583
1991	992	0.4234	1.0418	2015	456	0.4126	0.8513
1992	650	0.7045	1.4728	2016	445	0.3806	0.8045
1993	718	0.4296	0.8577	2017	420	0.3654	0.7764

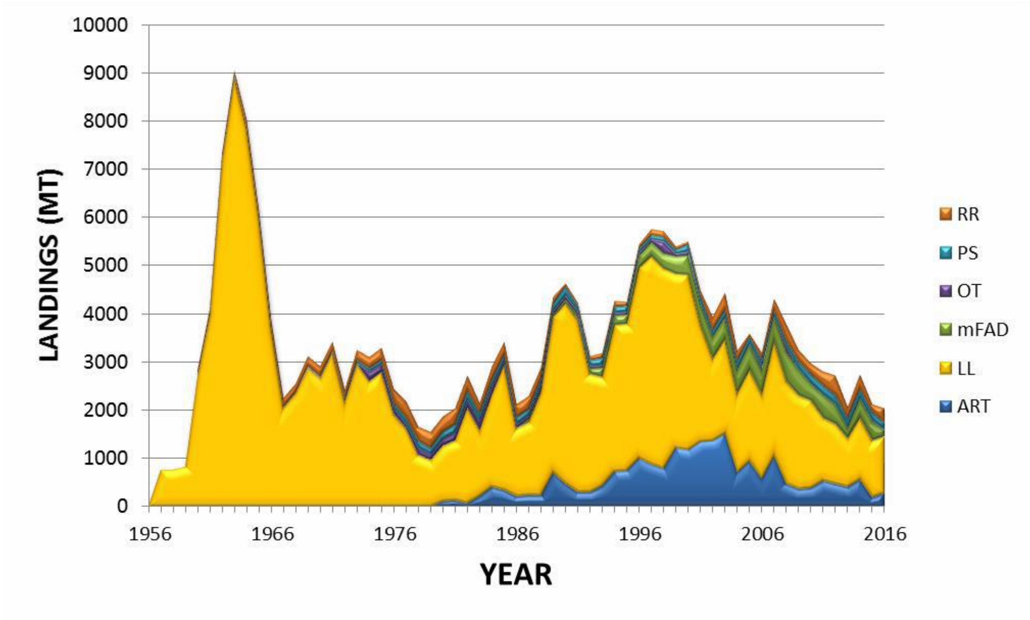

Figure 1. Longings of blue marlin by gear type (RR, rod and reel; PS, purse seine; OT, other; mFAD, fish aggregating devices; LL, longline; ART artisanal) 1956-2016.

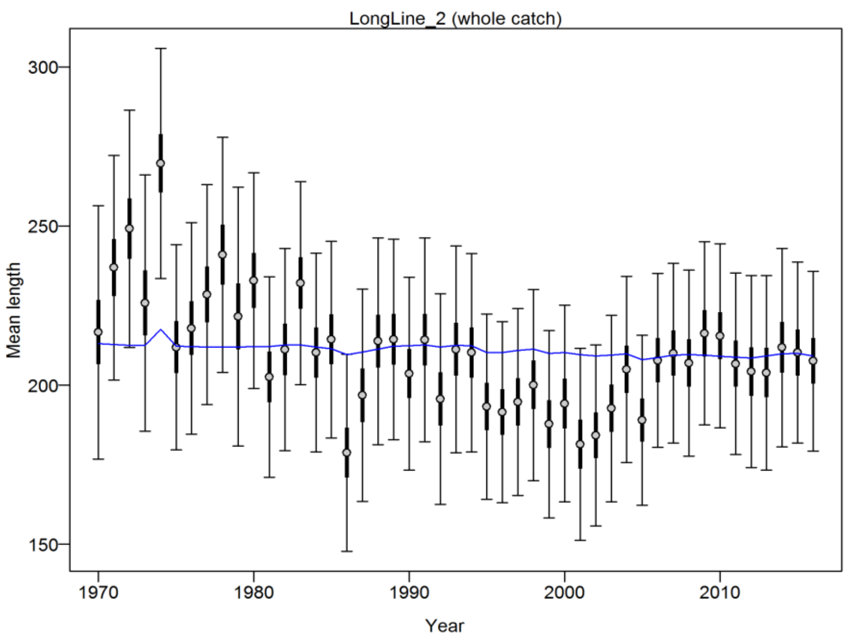

Figure 2. Mean length (LJFL) with spline fit of blue marlin caught by all longline gear in the Atlantic, 1970-2017.

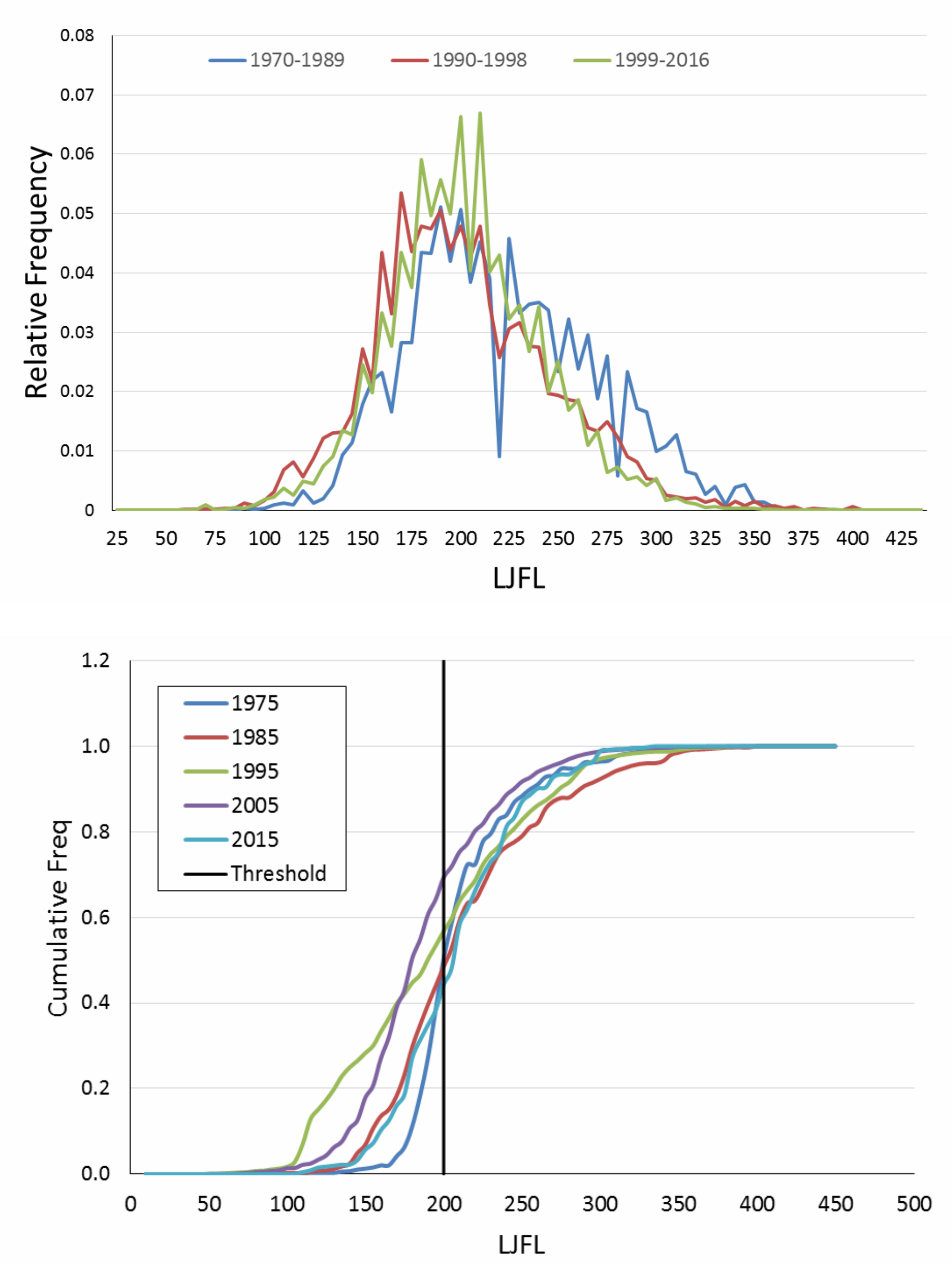

Figure 3. Relative frequency of longline length compositions for three different eras (top); cumulative frequency of length for 1975, 1985, 1995, 2005 and 2015 (bottom). Vertical line is NZ50 threshold value.

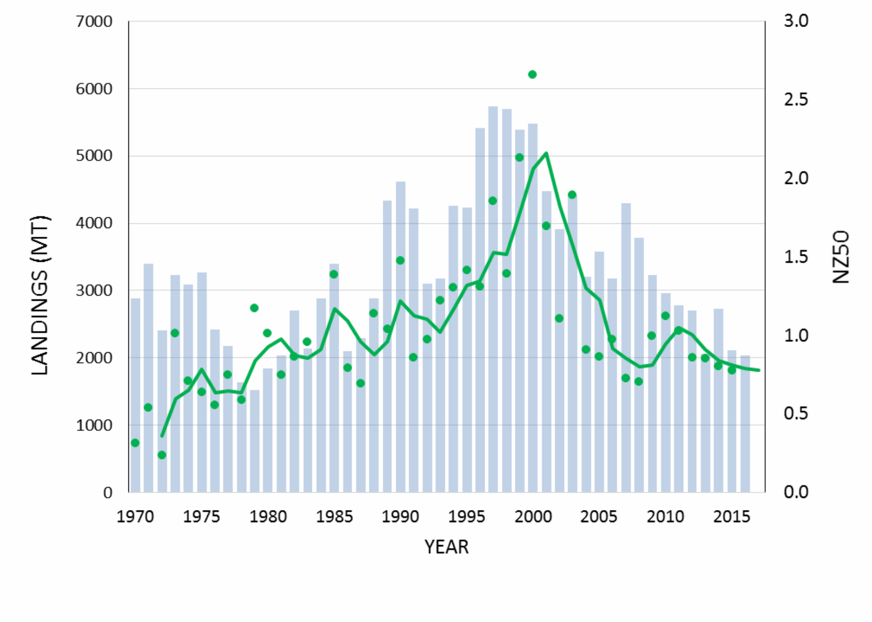

Figure 4. Total landings of blue marlin (bars, 1970-2016), NZ50 with a threshold of 200 cm LJFL (points) and 3 year moving average, 1970-2017.

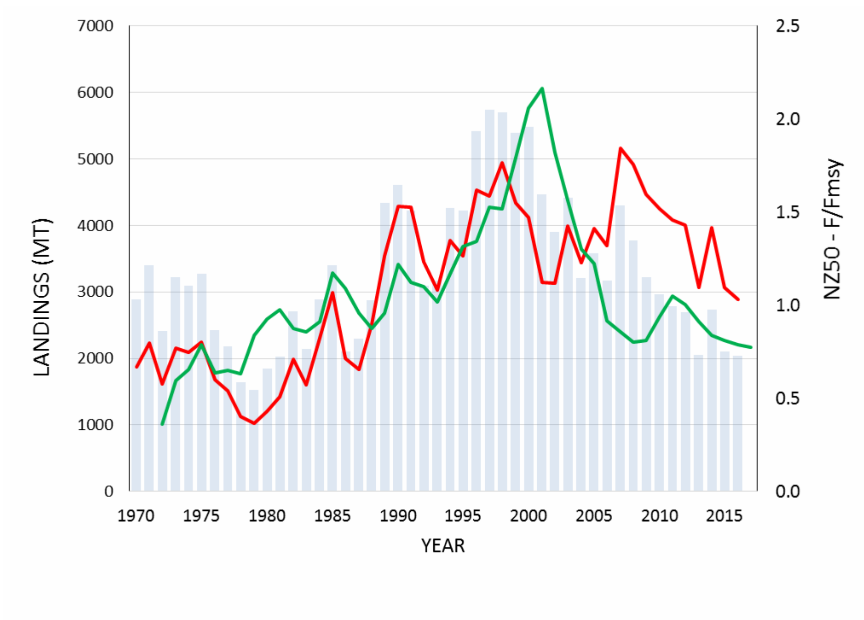

Figure 5. Total landings of Atlantic blue marlin (bars), NZ50 with a 200 cm threshold and lagged 2 years, 3 period moving average (green line), and F/F_{MSY} (red line) from the 2018 continuity stock assessment model fit with all length information removed.

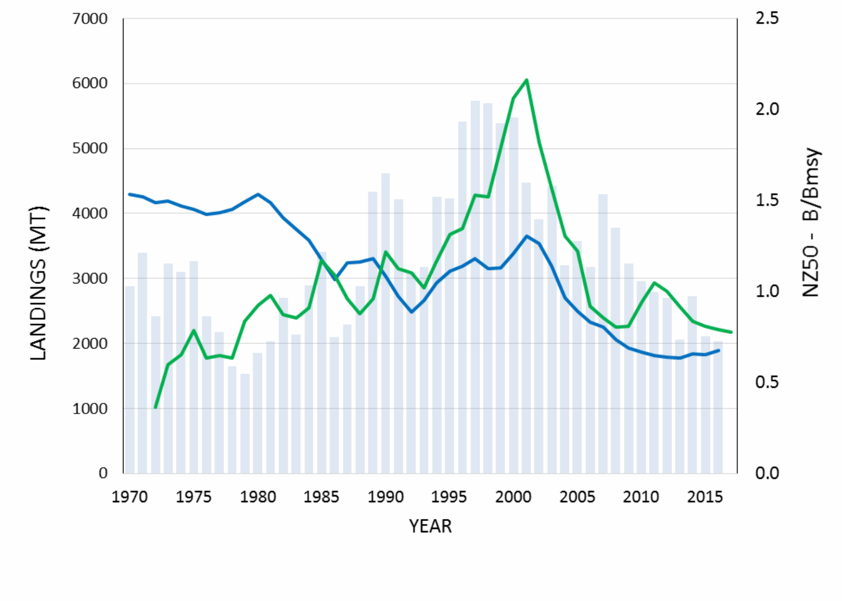

Figure 6. Total landings of Atlantic blue marlin (bars), NZ50 with a 200 cm threshold and lagged 2 years, 3 period moving average (green line), and B/B_{MSY} (blue line) from the 2018 continuity stock assessment model fit with all length information removed.