Analysis of Historical Charter Boat data to assess Black Marlin strikes rates in the recreational fishery off northern Queensland, Australia

by

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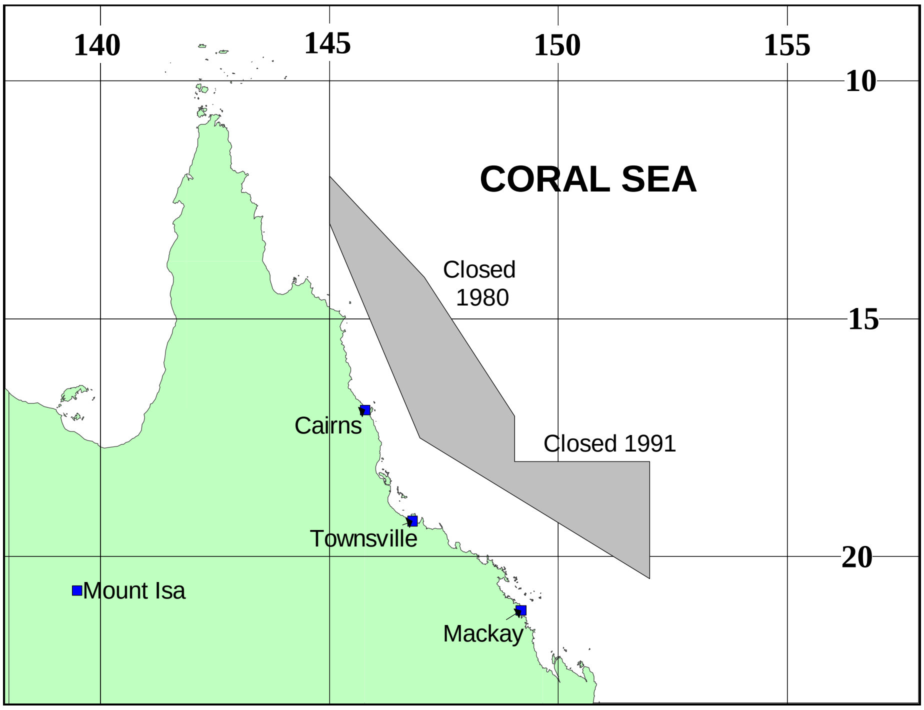
1. Introduction

The major tuna and billfish species which occur in the Coral Sea region of the Australian Fishing Zone are of considerable interest to both the commercial and recreational sectors of the Australian fishing industry (Campbell et al, 1996).

The Japanese longline fishery began fishing in the Coral Sea region in the early 1950s. Fishing lasted from October to March with two distinct seasons during this period. From October to December, black marlin comprised more than half the catch (by weight), while from January to March the black marlin disappeared from the fishing grounds and yellowfin tuna became the dominant catch (Williams et al, 1993). During the 1960s the region between Cairns and Lizard Island to the north also developed into a major recreational/charter-boat fishing region for black marlin. Game fishers from around the world were lured to the region in the hope of hooking a "thousand pounder" – large females associated with the spawning/pre-spawning aggregations which occur during the spring months. The region remains the only known spawning region for black marlin in the Pacific.

After the introduction of the AFZ in 1979 two major spatial closures and a voluntary release agreement with the Japanese longliners were directed specifically at reducing the catch of black and blue marlin in this region. The restricted areas, together with the year of closure, are shown in Figure 1. The closed areas have since become known as Area E and have a combined area of approximately 172,000 square kilometres. Since 1987 a domestic longline fishery operating out of Cairns has also developed targeting yellowfin and bigeye tunas. This fishery has undergone considerable expansion during the 1990s. To date thirteen permits have been granted which allow vessels to operate within Area E, though less than ten vessels are presently operating there

Figure 1. Map showing the region known as Area E off the north-eastern Queensland coast. The dates indicate the years in which each section was closed to Japanese longliners.



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While the commercial fishery does not target billfish, the potential for significant interactions between the domestic longline fishery and the recreational fisheries within Area E over the catch of billfish became a major management concern in 1995. Poor catches of black marlin by the recreational sector off Cairns in late 1994 triggered concerns that the local abundance of black marlin was becoming depleted due to the by-catch of this species by the domestic longliners. This concern led to calls for the cessation of commercial longlining within Area E and pressure to prohibit the taking of all marlin species by commercial operators. In response the Australian Fisheries Management Authority (AFMA) identified the interaction between the commercial and recreational sectors of the Eastern Tuna and Billfish Fishery as an important research area that needed to be addressed. A preliminary analysis of the situation by the Billfish Assessment Group (Campbell et. al. 1996), however, highlighted the complex nature of this fishery interaction issue and made a number of recommendations for future research. One of the conclusions was that in order to gain a better understanding of this issue, the collection of verified catch and effort statistics would be required from all sectors catching billfish in this region. Consequently, estimates of the number of black marlin caught by commercial longliners within Area E were obtained from observer based studies undertaken by CSIRO (Campbell, et al, 1997a,b,c).

2. Present Study

If the strike rates in the game fishery are being reduced as a result of the catch of black marlin by commercial longliners, then a decrease in longline effort should help alleviate this problem. Large reductions in longlining effort have occurred in the region in the past as a result of the exclusion zones created in 1980 and 1991 for the Japanese longliners. However, due to a lack of data it has not been possible to ascertain whether or not these reductions in longline effort resulted in increased strike-rates in the game fishery.

In order to assess changes in the strike rates in the recreational fishery targeting black marlin off northern Queensland, daily logbooks kept by the skippers of charter boat operators in the Cairns/Lizard Island region were collected. These data were used to calculate standardised annual strike rates of black marlin in this fishery. These indices were then correlated with the longline effort in the region in order to assess the size of the interaction between the recreational and longline fisheries. By correlating the strike rates with indices of environmental change in the area, such as sea-surface temperature, moon phase and current direction it is also hoped to understand some of the other factors which influence the changes in availability of black marlin to the recreational fishery. This work is not yet complete. As such, this report summarises some of the results obtained to date.

3. Collection of Logbook Data

The collection of personal diaries was undertaken during 1998 by Julian Pepperell who has many contacts with the game fishers who have fished in the Cairns/Lizard Island region. Julian was assisted in this task by Bill Edwards, a former charter boat operator in this region. A complete listing of those charter boat skippers who have supplied data to the project is given in Table 1. The individual years for which data has been supplied is shown in Figure 2. A list of the data which has been extracted from the diaries and the number of non-null data for each variable is shown in Table 2.

As indicated in Table 2, the number of fish involved per day's fishing ('the catch') is recorded in several ways. These are i) the number of fish raised, ii) the number of strikes, iii) the number of fish hooked, and iv) the number caught (composed of those fish caught and retained, tagged and released and released without tagging). Ideally, these numbers should be recorded for each day's effort, but unfortunately, this is often not the case. For example, there are 3,864 records indicating the number of fish hooked, but fewer than this number (3,661) indicating the number of fish raised. Given the frequent instances of missing data it was not

Table 1. Names of charter boat operators who have supplied data to the project, together with the number of years with data and the total number of days fished.

	Name	Number of Years	Number of days
1	Bill Edwards	17	828
2	Bill Spooner	3	133
3	Dennis Hayes	6	404
4	Dennis Wallace	11	566
5	Geoff Ferguson	1	59
6	Greg Edwards	8	422
7	Jim Dalling	4	168
8	Laurie Wright	18	993
9	Peter Bristow	8	453

Table 2. Structure of charter boat data showing number of non-null records and number of fish with recorded weights and fight-times.

Data Type	Number of Records	Number of Fish
Skipper	4,022	
Vessel	4,022	
Day	4,022	
Latitude	3,667	
Longitude	3,667	
Water Temperature	204	
Wind Speed	2,256	
Wind Direction	2,261	
Sea State	1,394	
Number of Fish Raised	3,661	
Number of Strikes	1,691	
Number of Fish Hooked	3,864	
Number of Fish Caught	2,952	
Number of Fish Tagged	3,728	
Number of Fish Released	82	
Capture Weight		335
Estimated Tagged Weight		1,863
Fight Time		104

possible to use all the data in calculating indices relating to each of the ‘catches’ referred to above. In this report the ‘catch’ associated with a day’s fishing is taken to be the total of the fish caught, tagged or released. The number of days with a recorded catch each year is shown in Figure 3 while the average annual catch per day for each year is shown in Figure 4.

The ‘catch’ associated with fishing is associated with the availability of fish to the charter boats. The availability of fish itself will be correlated with both the abundance of the resource (in this case black marlin) and the prevailing environmental conditions in the area of fishing. The skipper recorded several environmental variables at the time of fishing. However, the number of diary entries with these data recorded was generally low. Consequently, several external data sets have been utilised in order to ascertain the influence of environmental factors on strikes rates. These include monthly-one degree sea surface temperatures (SST, which are based on satellite/in situ data), the monthly value of the southern-oscillation index

Figure 2. Years for which data was collected from each of the nine charter boat skippers who made their data available to the project. The line indicates the total number of skippers supplying data for a given year.

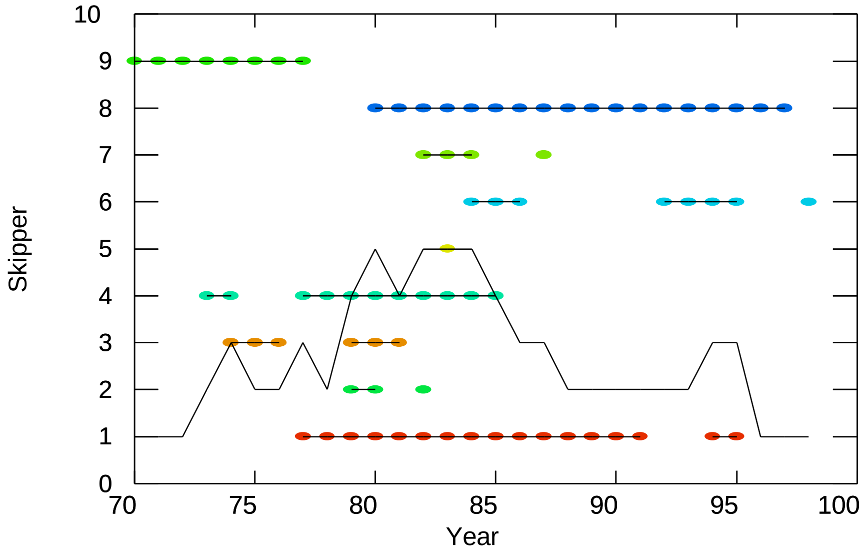


Figure 3. Histogram of the number of catch records by year.

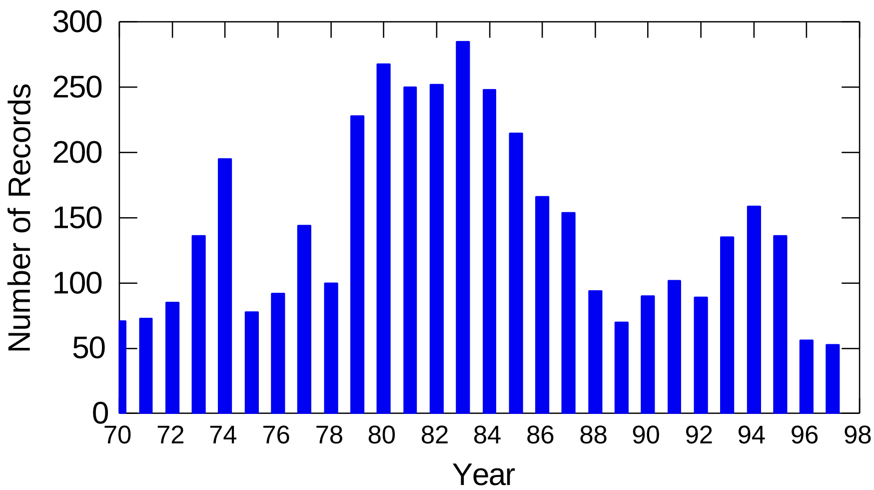
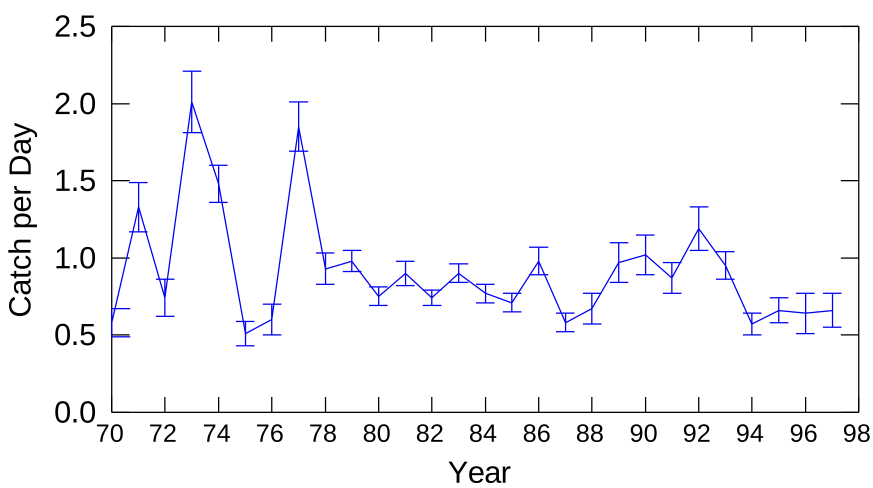


Figure 4. Mean black marlin catch per day (with standard error) in the recreational fishery off northern Queensland based on the data supplied by nine charter boat skippers.

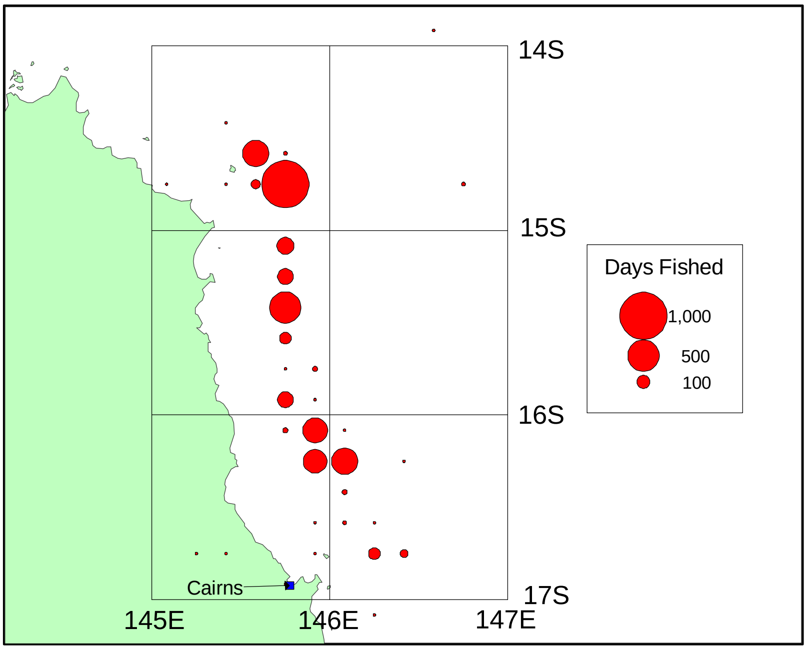


(SOI), and the daily phase of the moon. Additional data pertaining to current-speed and direction in the Queensland Trough region available from the Australian Institute of Marine Science is still to be added.

4. Area Fished

The fishing locations of the 3,667 data records for which the latitude and longitude were recorded are shown in Figure 5. The positions are grided by ten minutes of latitude and longitude. Apart from a few records (which are possibly in error) all fishing has occurred within the four one-degree squares shown in Figure 5. These four squares define the areas used in the following analysis.

Figure 5. Location of the fishing effort for the data collected from charter boat skippers off northern Queensland.



5. Data Analysis

The catch equation often utilised in analysing the data from fishing operations associates the catch with the amount of fishing effort expended and the local availability of the resource. This relationship can be expressed in the form:

$$C = qEB \qquad (1)$$

where E is the fishing effort, B is the available biomass and q is the catchability coefficient. From this equation an expression relating the available biomass of fish to the catch and effort in the fishery can be found:

$$B = {}^{C}\!/_{qE} \qquad (2)$$

ie. available biomass is directly proportional to the catch-rate (catch-per-unit-of-effort) in the fishery.

For the charter boat fishery, we have catch (in terms of the number of fish caught, tagged or released) as well as effort (number of days fished). For each year we can therefore calculate the average catch-per-day fished. However, a number of factors will influence the catch obtained in any days fishing. These factors will include the general availability of fish (which itself is influenced by the year, month and the area that the fishing takes place) the skill of the fisher as well as the pertaining oceanographic and environmental conditions. The catch-rate in the fishery is therefore a function of a number of variables:

$$C/E = f(B, M, A, S, Env) \qquad (3)$$

where *B* is the available biomass in year fished, *M* is the month, *A* is the area fished, *S* is the skill of the fisher and *Env* is a composite of environmental and oceanographic conditions. Given information on each of the above variables, statistical methods are available in order to determine the nature of the above functional relationship. A commonly used method is known as General Linear Modelling (McCullagh and Nelder, 1989)and is used here. Note that the available biomass in each year is usually associated with the corresponding year effect in the fitted models and in the models described below is indicated by the variable *Y* (instead of *B*).

In order to fit the model to the data it is important that the assumed model satisfies certain statistical properties within the data itself. If these properties are not satisfied then the model (and the results from such a model) may be deemed inappropriate. The models fitted to data to have been of two types.

Model 1: Poisson

It is assumed that the catch taken for a given effort by a charter boat has a Poisson distribution. This model assumes that the variance observed in the catch is proportional to the mean of the catch (for a given effort). The model also allows the inclusion of the zero catch information in the data since zero is a legitimate response value from a Poisson distribution (unlike the log-normal and gamma distributions often used in similar types of analyses). Assuming then that the catch, C, has a Poisson distribution with mean μ, and using a log link between this mean and the linear predicator of standardising variables, then from equation (3) above we have:

$$\log(m_{ijklm}) = \log(E_{ijkl}) + LinearPrediator(Y, M, A, S, Env)$$

The logarithm of the Effort, E_{ijkl}, is used as an offset, that is a regression variable with a constant coefficient of 1 for each observation. The log link function insures that the mean catch for each combination of factors will be positive. The GENMOD procedure in SAS statistical package was used to carry out the analysis.

Model 2: Binomial/Normal

This model fits the data in a two-stage process. In the first stage one models the probability of success (ie of obtaining a catch with a given effort) using the binomial distribution, while in the second stage one models the size of the successful catch if one is made (using the a normal or gamma distribution). As before, for both stages we can model the means as linear combinations of the factors likely to influence either the probability of a successful catch and the size of the catch.

The above process can be illustrated by means of a simple example. Consider an area for which there are *n* catch observations, *c*. The average catch can then be expressed as follows:

$$m = \frac{1}{n}\sum_{i=1}^{n} c_i = \frac{1}{n_S + n_F}\sum_{i=1}^{n_S} c_i = \frac{n_S}{n_s + n_F}\frac{1}{n_S}\sum_{i=1}^{n_S} c_i = p_S m_S$$

where n_S is the number of successful catch (c_i>0), n_F is the number of failed catches (c_i=0), p_S is the proportion of successful catches and m_S is the average of the successful catches. This result shows that the overall mean catch can be expressed as the combination of the parameters from the distributions used to model the probability of success and that used to model the non-zero catches.

The binomial distribution, with a logit link function, was used to model the probability, p_S, of a successful catch. The logit link is used to satisfy the probability restriction that *0 £* p_S *£ 1*. This function gives a generalised linear model of the form:

$$h = \log(\frac{p_S}{1-p_S}) = LinearPredictor(Y, M, A, S, Env)$$

The inverse of this relation gives the probability of a positive response as a function of the explanatory variables:

$$p_S = \frac{e^h}{1+e^h} = \frac{\exp(LinearPrdictor)}{1+\exp(LinearPredictor)}$$

Having fitted a model to the probability of obtaining a successful (non-zero) catch, we model the distribution of the non-zero catches themselves. For this purpose, the use of both the normal and gamma distributions was investigated with a log link. In both situations the model is of the form:

$$\log(m_S) = LinearPrediator(Y, M, A, S, Env)$$

where m_S is the mean catch for a given effort (*C/E*).

Model Fitting

For both models described above the factors *year, month, area* and *skipper* where fitted as categorical variables. In order to model the influence of the environment, monthly-1 degree sea-surface temperatures together with daily moon phase were fitted as covariates. A *year.month* interaction term was also included in each model. This term is aliased with the monthly index for the Southern Oscillation Index and so this latter covariate was not used. Further interactions were not investigated due to there being insufficient data to support the inclusion of these other terms. Note that there was data for all years and months, except for the September 1988. In order to avoid a zero index for this month, a dummy data record was added

The models were fitted to both the daily catch data (3,580 records in total and 1,971 non-zero catch records) and the data aggregated by month (541 records in total and 459 non-zero catch records). While the catch rate for a day's fishing is equivalent to the catch for that day (since the unit of effort was taken to be a fishing day), for the monthly aggregated data the mean catch rate was taken to be the total catch for that month divided by the total number of days fished during that month. When modelling the size of the non-zero catch-rate for a month, the catch rate was taken to be the total catch for that month divided by the total number of non-zero catch days for that month. As the mean catch rate in these situations is no longer an integer, the Poisson model described above is not appropriate in these situations. Instead, the mean monthly catch rates were modelled using either a normal or gamma distributions and a log link. The Poisson model was also not applicable when modelling the non-zero catch data, as the zero catch observations were not included.

The conclusions drawn from any statistical model depend on the validity of the model used. While models are not exact representations of the population under study, they should reproduce the main features of the population without major bias. Several statistical measures are available to ascertain the fit of the model to the data given the assumptions of the models. Most tests are associated with the analysis of the model residuals (the difference between the observed catch rate and that predicated by the model). While residual values should be small, the distribution of the standardised residuals should also be approximately Normal (Pierce and Schafer, 1986). This latter test is most readily undertaken using a Normal probability plot for the residuals (in which case the distribution of residuals should approximate a straight line) and is used in this report. The SAS statistical software was used for fitting the data (SAS, 1993).

6. Model Results

Poisson Model
The degree of fit between this model and the daily catch data was found to be poor. Consequently, the model was fitted to the aggregated monthly catch where the offset variable was the logarithm of the number of days fished within that month for a given skipper. The fit of the model in this situation was found to be reasonable. The normal probability plot for the residuals for this model is shown in Figure 6a.

Binomial-Normal Model
The binomial model was fitted to the monthly aggregated data, with the number of successful catch days used as the binomial random variable and the binomial number of trials parameter being equal to the number of days fished in the month. The fit of the model to the data was found to be reasonable and the normal probability plot for the residuals is shown in Figure 6b. In modelling the mean catch rates on successful fishing days, the fit of the data to the model using the gamma distribution was also found to be poor. The best fit was found assuming a normal distribution on the logarithm of the mean catch rates. The normal probability plot for the residuals for this model is shown in Figure 6c.

Time Series of Monthly Strike-Rates

The interaction between year and month was found to be significant within each model used, indicating that the annual pattern of indices is different between months. Consequently, annual indices are shown for each month. Comparisons of the indices of annual strike rate of black marlin in the charter-boat fishery are shown in Figure 7.

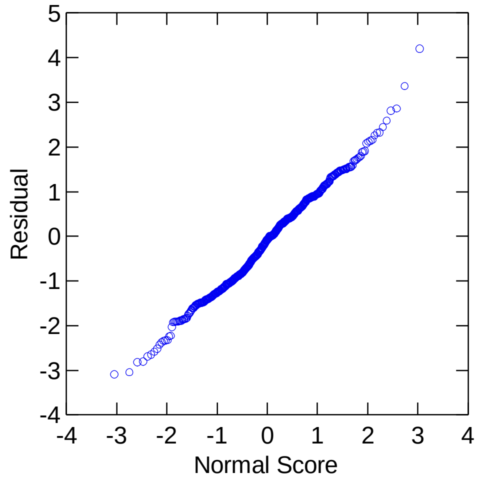
The indices shown are relative indices in the sense that the mean value of each index across all years is zero. Hence a positive value of the index represents an above average strike rate, and a negative value represents a below-average strike rate. The relative nominal strike rate (defined as the total catch for a year and month divided by the total number of days fished for that year and month) is also shown.

Several features are seen in these results:

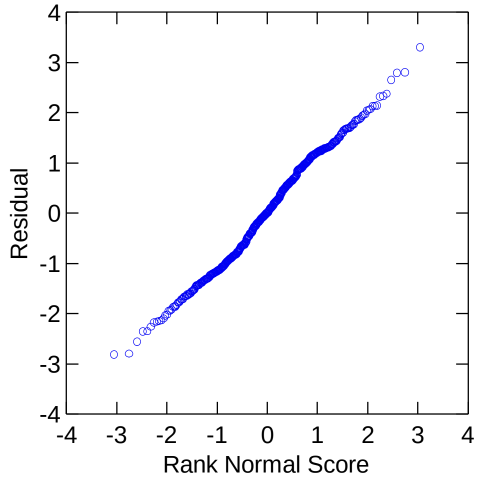
- First, the time series of the index for each month is similar for the two statistical models used to analyse the data. This supports the conclusion that each model fits the data well (as indicated by the Normality of the residuals in each case) and that further refinement of the models used is not warranted.
- Second, all models show a high degree of interannual variability, though this variability appears to be greatest in the 1970s. This may be a reflection of the quality of the data. The years showing the smallest degree of interannual variability (1980-85) correspond to those years where there is the most data (from 4 or 5 fishers). This is important, as it makes it difficult to conclude whether the trends and variations seen in the other years are related to changes in the availability of black marlin, or are just random effects associated with the small amount of data available for some of these years.

Figure 6. Normal probability plots of the residuals for each of the statistical models fitted to the charter boar data.

(a) Poisson Model



(b) Binomial Model



(c) Normal Model

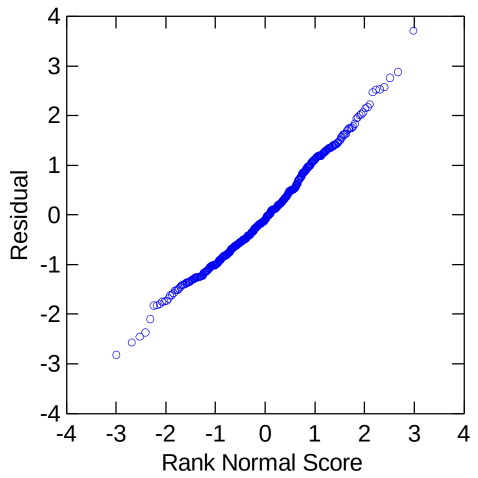
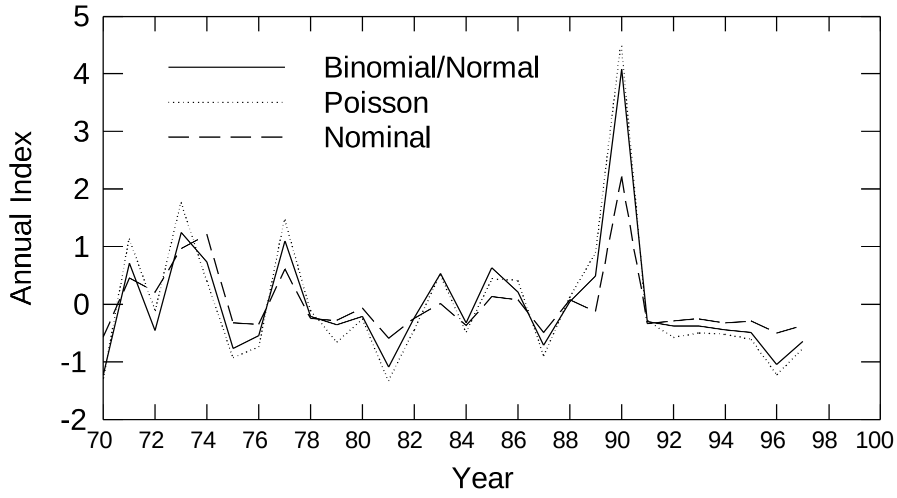
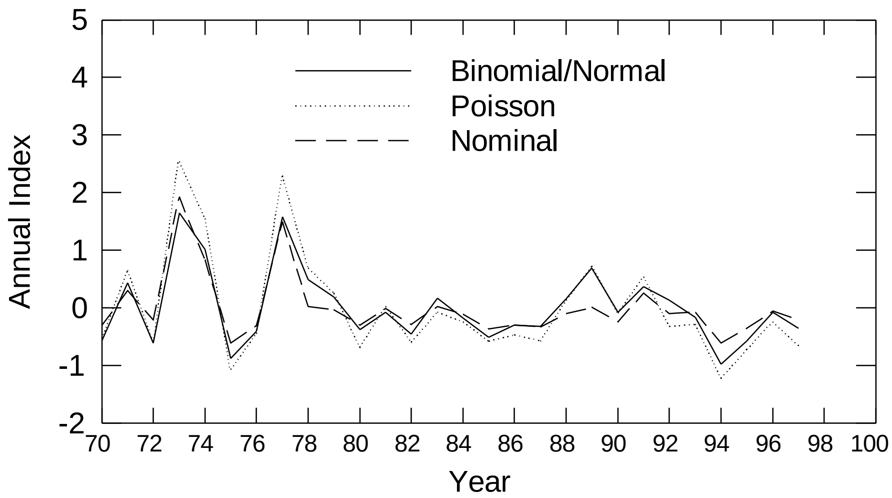


Figure 7. Comparison of relative indices of annual strike rate of black marlin in the charter boat fishery off northern Queensland.

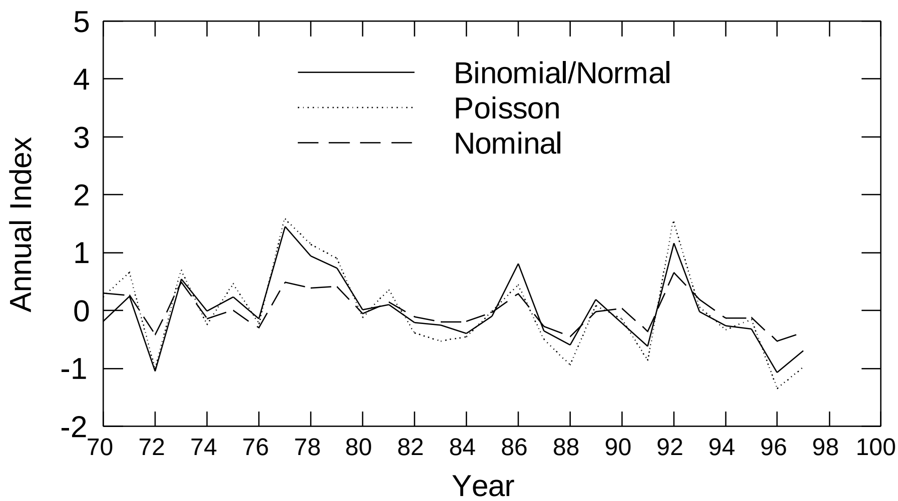
(a) September



(b) October



(c) November



- Third, the standardised indices generally indicate a lower strike rate in 1996 and 1997 than that indicated by the nominal strike rates.
- Fourth, there was an unusually high strike rate in September 1990. Furthermore, the standardised indices indicate a higher availability of black marlin than that indicated by the nominal strike rate.
- Fifth, the index since the early 1990s for all months is generally below the historical mean. This may indicate that the available of black marlin to the recreational fishery has been lower during the 1990s than during the previous twenty years.

The average index (and standard deviation) for each month during each decade is listed in Table 3. Due to the high value for September 1990 the means are also separately calculated for the period 1991-97. Note that only comparisons within months and across decades are possible. Comparisons across months are not possible as the average index across the entire 28 year period for each month has been set to zero. However, averaged over the entire 28-year period, strike rates have generally been highest in October and lowest in September.

Apart from the influence of the high strike rates in September 1990, for each month and model the mean index is highest in the 1970s and lowest in the 1990s, indicating a general decline in strike rates over these three decades. Excluding the high value in 1990, the decrease in strike rates since 1970 is found to be greatest for the Poisson model, with the index decreasing by 0.95. The decreases for September and December are 0.73 and 0.72 respectively. For the binomial/normal model, the change within each month is similar, varying between 0.55 and 0.52. For both models, the decline during September was greatest between the 1980s and 1990s (accounting for between 73-84% of the total decline), while for October and November the decline was greatest between the 1970s and 1980s (accounting for between 66-87% of the total decline).

Table 3. Mean value (with standard deviation) of the index of black marlin strike rate for each month during each decade.

		September		October		November	
Model	Decade	Mean	*s.d*	Mean	*s.d*	Mean	*s.d*
Poisson	70s	0.10	*1.06*	0.53	*1.26*	0.42	*0.76*
	80s	-0.10	*0.70*	-0.23	*0.44*	-0.20	*0.43*
	90s	0.00	*1.83*	-0.38	*0.52*	-0.28	*0.88*
	91-97	-0.64	*0.29*	-0.42	*0.55*	-0.30	*0.94*
Bin/Normal	70s	0.02	*0.85*	0.29	*0.91*	0.28	*0.69*
	80s	-0.07	*0.56*	-0.12	*0.37*	-0.08	*0.39*
	90s	0.05	*1.64*	-0.22	*0.42*	-0.25	*0.66*
	91-97	-0.52	*0.26*	-0.23	*0.45*	-0.26	*0.72*

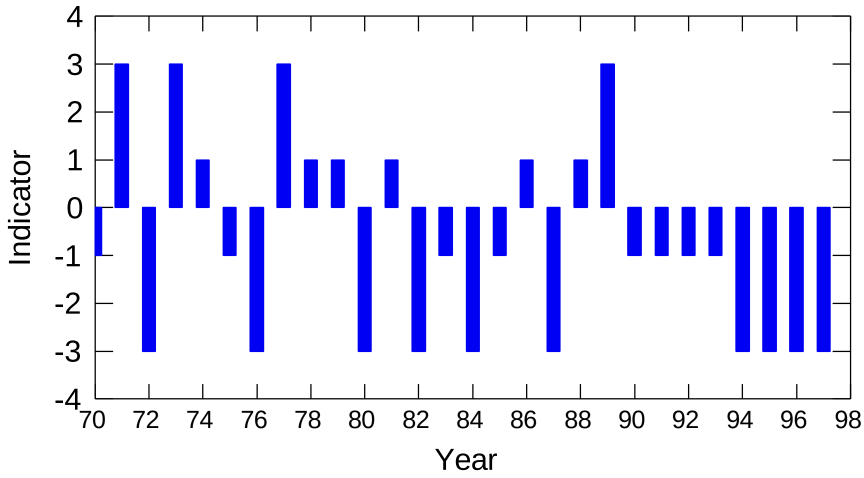
Within each month, the time-series of above average and below average years can also be analysed to ascertain the temporal sequence of such events. For this purpose, an indicator value, I, was assigned to each month based on whether the index for that month was above the long-term historical average (I=1) or below that average (I=-1). For each year, the sum of the three indicator values for the months September to November was then calculated. The results are shown in Figure 8 for each of the models. A value of 3 (or –3) indicates that all months were either above (or below) the historical average. A value of 1 indicators that 2 months were above average and one month was below average, while a value of -1 indicators that 1 month was above average and two months were below average.

Again, several results are of interest:

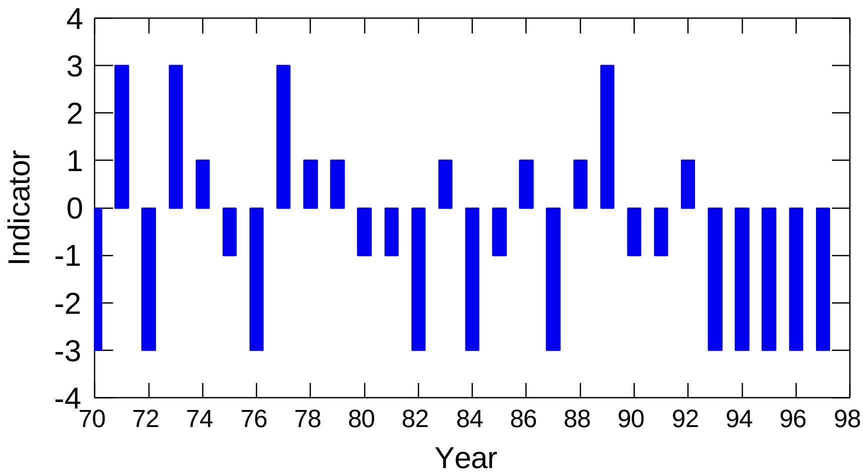
- First, for both models, there is a high degree of correlation between the months within a year. For the Poisson model, the results indicate that the strike rates in the three months

Figure 8. Annual indicator of above average and below average strike rates. The indicator is based on the sum of the indicator for each of the three months (September – November) where the value is +1 when the index is above the historical average and –1 when the index is below the historical average.

(a) Poisson Model



(b) Binomial/Normal Model



are either all above average or all below average for 14 of the 28 years shown (and for 15 years in the Binomial/Normal model).

- Second, for the Poisson model, the overall indicator is positive for half of the first twenty years between 1970 and 1989. After this time the overall indicator value has been negative, having a value of –1 between 1990 and 1993 and then decreasing to a value of –3 between 1994 and 1997.
- Third, the results for the Binomial/Normal model are similar. The overall indicator was positive for half of the first twenty years between 1970 and 1989. After this time the overall indicator value has been negative in all years but one, having a value of –1 for the years 1990 and 1991, then increasing to 1 for 1992, then decreasing again to a value of –3 between 1994 and 1997

- Fourth, for the first twenty years the run of above average or below average years for any particular month was never longer that three years. Furthermore, there was never two consecutive years when all months were either all above average or all below average.
- Fifth, the run of consecutive below average years during the 1990s is a significant departure from the historical pattern during the preceding twenty years of above or below average years.

6. Relation between longline effort and strike rates

The decline in the strike rates observed in the recreational fishery during the 1990s has been of great concern to the recreational fishing industry. Nevertheless, whether the decline is due to an interaction with longliners fishing further offshore, to an overall decline in the abundance of the black marlin stocks, or possibly due to some other effect, presently remains unknown.

The possibly that the recent decline in strike rates are due to a direct temporal interaction with offshore longline fleets is investigated here. For this purpose the mean strike rate in the recreational fishery in any month was correlated with the longline effort within two separate regions during that same month. The first region encompasses that region of the Coral Sea bounded by 10-20°S and 145-155°E. (cf. Figure 1). The second region is the smaller inshore region coincident with the recreational fishery itself and bounded by 14-17°S and 145-147°E. (cf. Figure 5). The total Japanese and domestic Australian longline effort within these two regions is shown in Figures 9 and 10. The value of Pearson's correlation coefficient, ρ, between the individual time-series of longline effort and recreational strike rates was calculated for each month and model and the results are given in Table 4. Because of the possibility that the data before 1980 may be less reliable than the data after this time, the calculations were repeated for the years 1980-1997 only.

Table 4. Value of Pearson's correlation coefficient, ρ, between the time-series of monthly longline effort and strike rates of black marlin in the recreational fishery.

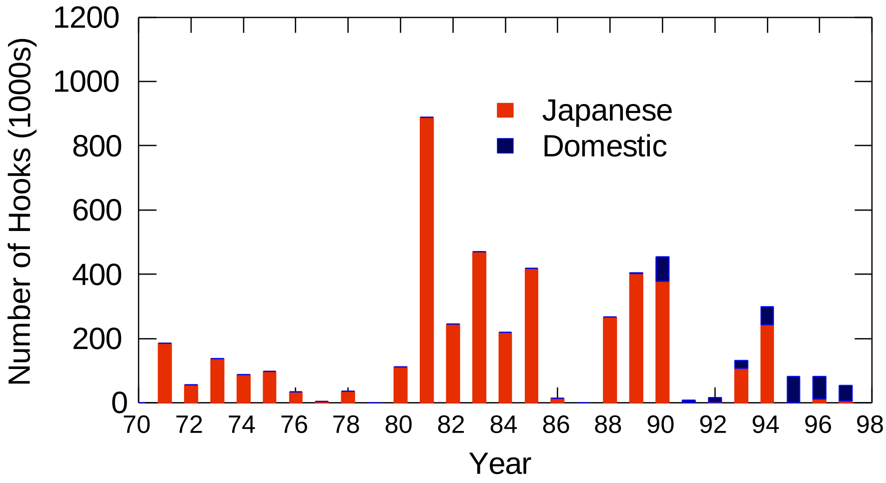
		1971-1997		1980-1997	
Model	Month	Coral Sea	Inshore	Coral Sea	Inshore
Poisson	September	0.185	-0.155	0.248	-0.145
	October	-0.081	0.235	0.084	-0.350
	November	0.064	0.179	-0.040	-0.296
	Total Period	-0.022	0.269	0.050	-0.439
Bin/Normal	September	0.210	-0.125	0.261	-0.143
	October	-0.073	0.210	0.008	-0.254
	November	0.090	0.114	-0.013	-0.375
	Total Period	-0.010	0.215	0.017	-0.423

The values of ρ shown in Table 4 are generally low and indicate that the there is not a strong relationship between the amount of longline fishing effort in the regions off northern Queensland and the strikes rates of black marlin in the recreational fishery in a given month. The relationship with the effort in the larger spatial region in the Coral Sea is particularly weak. The only consistent relationship (with is negative) is between the inshore longline effort and strike rates after 1980. This indicates a decrease in strike rates with an increase in longline effort in this region, but the relationship is not strong with the greatest value of R^2 being only 0.19.

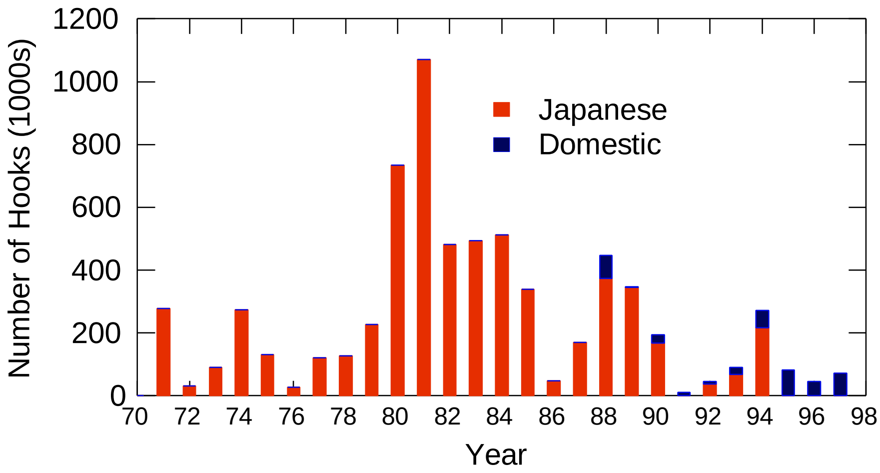
The fact that this analysis does not indicate a strong relationship between the level of longline effort within the regions close to the recreational fishery off northern Queensland is also supported by the absence of significant changes in strike rates after the two spatial closures

Figure 9. Japanese and Australian longline effort within the four five-degree squares within the Coral Sea bounded by 10-20°S and 145-155°E. (cf. Figure 1).

(a) September



(b) October



(c) November

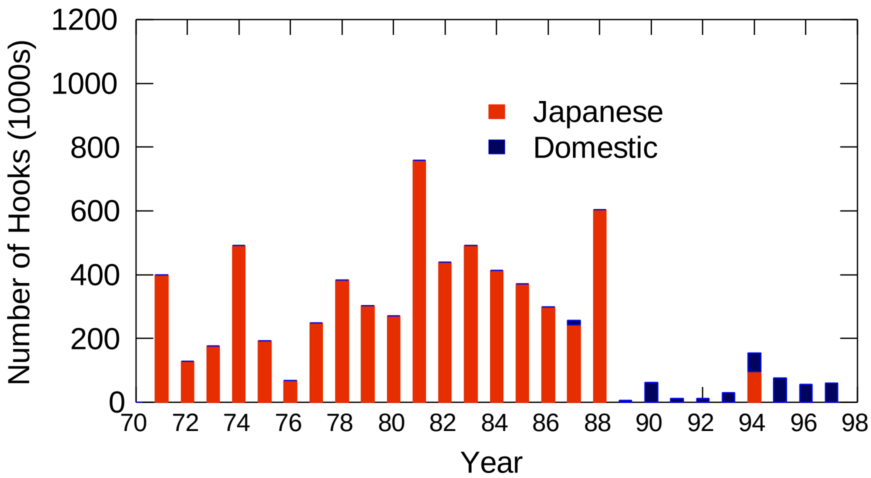
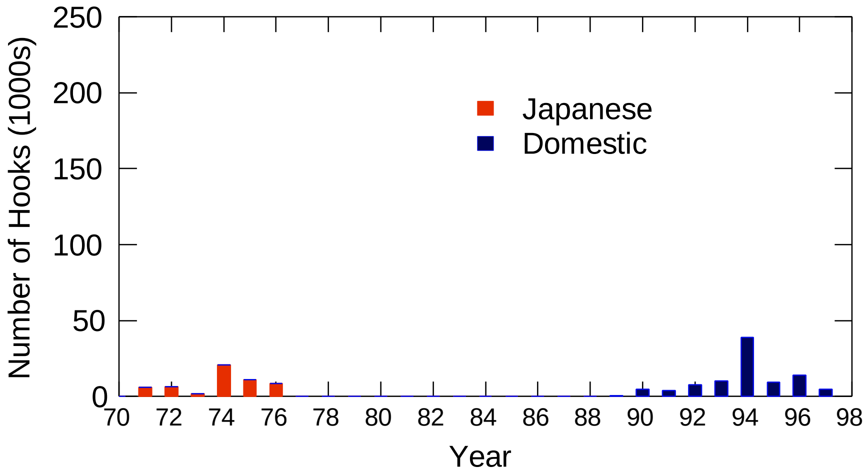
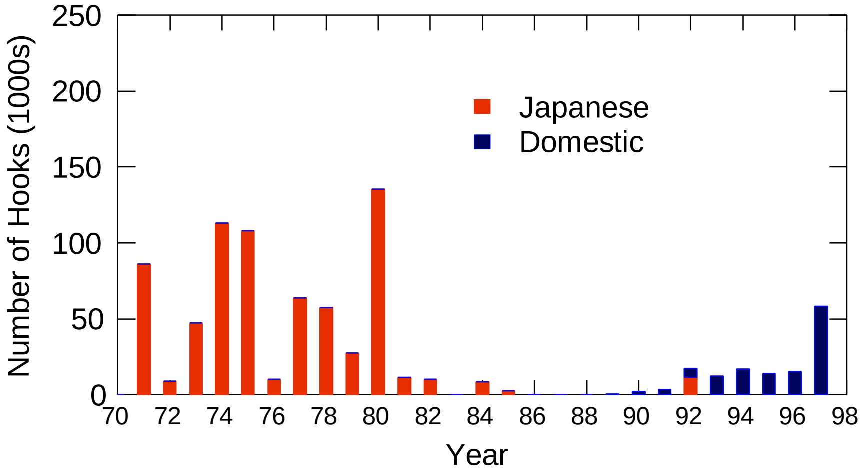


Figure 10. Japanese and Australian longline effort within the six one-degree squares bounded by 14-17°S and 145-147°E (cf.. Figure 5).

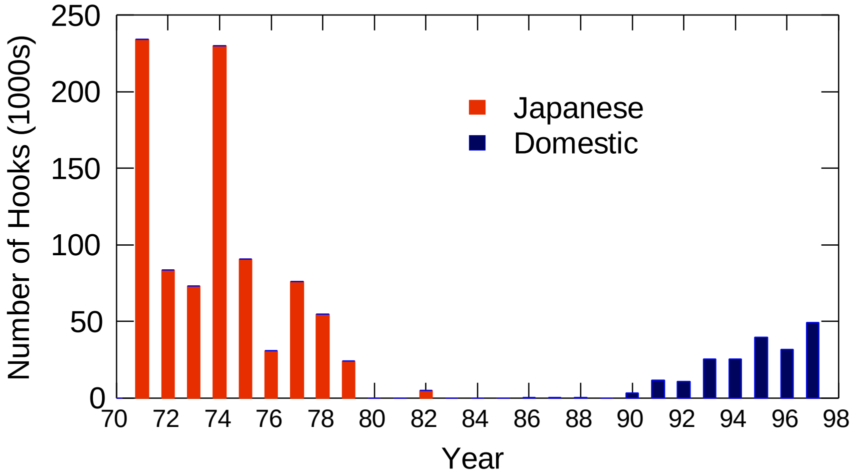
(a) September



(b) October



(c) November



mentioned in the introduction. The first closure took place in 1980 and, as is shown in Figure 10, resulted in a significant reduction in longline fishing effort in the region within close proximity of the recreational fishery (particularly for October and November). There is, however, no corresponding increase in strike rates in the recreational fishery after this time. After 1980 the level of effort within the larger offshore region increased (cf. Figure 9), but dropped significantly after the second spatial closure in 1991 (particularly in November). Again there is no corresponding increase in strike rates in the recreational fishery after this time. However, the decrease in Japanese longline effort after this time is to some extent offset by the increase in domestic Australian effort, particularly in the closer inshore region (cf. Figure 10).

7. Conclusions

The analyses presented here indicate that there has been a long-term decline in the strike rates of black marlin in the charter boat fishery off northern Queensland, Australia. Furthermore, within a given month, the mean strike rate in this fishery does not appear to be related to the levels of longline effort within the general region. However, these results are premised on the data that were available to the project. The levels of recreational data for many of the years included in the analysis were not high, and so the results given here are highly conditional on how representative this data is of the overall strike rates achieved in the fishery. Furthermore, while the Japanese logbook data is generally believed to be of a good quality, the domestic Australian logbook data remains unverified.

If there has been a general decline in the availability of black marlin to the recreational fishery, one needs to look for an explanation. While the analyses here do not indicate a direct temporal interaction between the recreational and longline fisheries, this does not rule out a more indirect temporal interaction. Longlining has been a major activity in the Pacific since the 1950s, and the present levels of longline effort in the Pacific remain high. Although black marlin is generally not a targeted species, the levels of bycatch are presently estimated to be between 500 and 1,000 tonnes per year (Williams and Bigelow, 1997). Black marlin is generally believed to be a long lived species, making it susceptible to overfishing at what, for shorter lived species, may be seen as only moderate catch levels. The sustainable catch which can be taken from the black marlin stock within the Pacific presently remains unknown. It is hoped that an attempt to determine such a catch level can be made in the next few years.

Finally, there is also the possibility that the decline in strike rates observed in the recreational fishery may be due to changes in the spatial distribution of the black marlin in the Coral Sea region. The unusual oceanographic conditions which have prevailed throughput much of the 1990s in the western Pacific may have influenced the spatial movement of the black marlin into and within the area where the recreational fishery occurs. The recreational fishery is usually confined to the edge of the outer reefs comprising the Great Barrier Reef. As such, the availability of black marlin to the fishery (and the concomitant strike rates) remains susceptible to shifts in the spatial distribution of the black marlin to regions further offshore. Anedoctal reports from longliners operating further offshore in recent years indicate higher black marlin abundance than in the inshore regions and lend some support to this hypothesis. However, longer term studies on the movements of black marlin in the Coral Sea region are needed to determine the truth of such a hypothesis.

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