SCIENTIFIC COMMITTEE
EIGHTH REGULAR SESSION

7-15 August 2012
Busan, Republic of Korea

Catch Per Unit Effort and Size Composition of Striped Marlin caught by Recreational Fisheries in Southeast Australian Waters

WCPFC-SC8-2012/ SA-IP-07 Rev 1

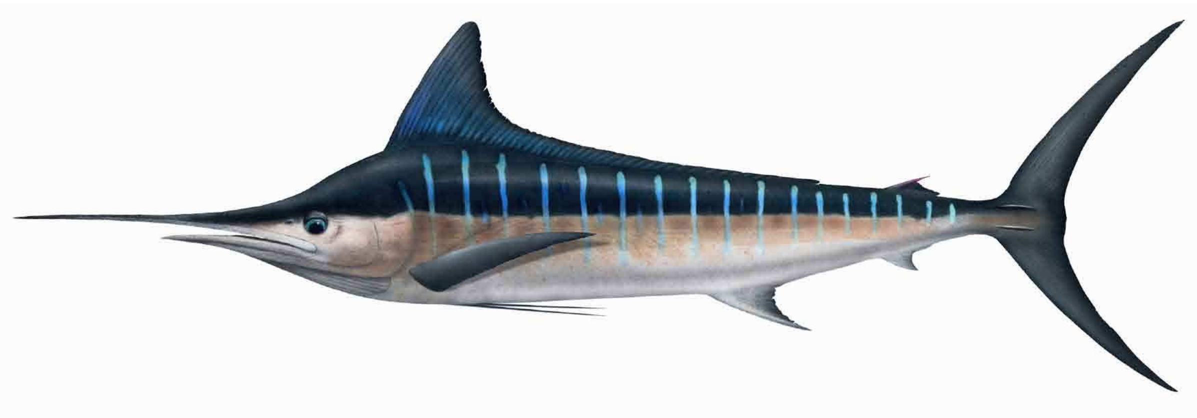
Danielle Ghosn, Damian Collins, Christopher Baiada and Aldo Steffe[1]

[1] Australia, New South Wales, Department of Primary Industries

Fisheries Research Report Series: 30

Catch per unit effort and size composition of striped marlin caught by recreational fisheries in southeast Australian waters

by
Danielle Ghosn, Damian Collins, Christopher Baiada and Aldo Steffe



Kajikia audax
Image © I & I NSW

April 2012

ISSN 1837-2120

Fisheries Research Report Series

This series presents scientific and technical information on general fisheries research and the documents in the series are intended to be progress reports on ongoing investigations. Titles in this series may be cited as publications, with the correct citation on the front cover.

Fisheries Research in New South Wales

Fisheries research activities in the NSW Department of Primary Industries are based at various centres throughout the state.

The studies conducted cover commercial and recreational fisheries and aquaculture, and conservation issues in coastal and riverine areas.

The major role of the research is to provide information upon which relevant fisheries management policies and strategies are developed, monitored and assessed in terms of the Department's obligations under the NSW *Fisheries Management Act*, 1994.

Title:	Catch per unit effort and size composition of striped marlin caught by recreational fisheries in southeast Australian waters
Authors:	Danielle Ghosn, Damian Collins, Christopher Baiada and Aldo Steffe
Published By:	NSW Department of Primary Industries
Postal Address:	Cronulla Fisheries Research Centre of Excellence, PO Box 21, Cronulla, NSW, 2230
Internet:	www.dpi.nsw.gov.au

ISSN 1837-2120

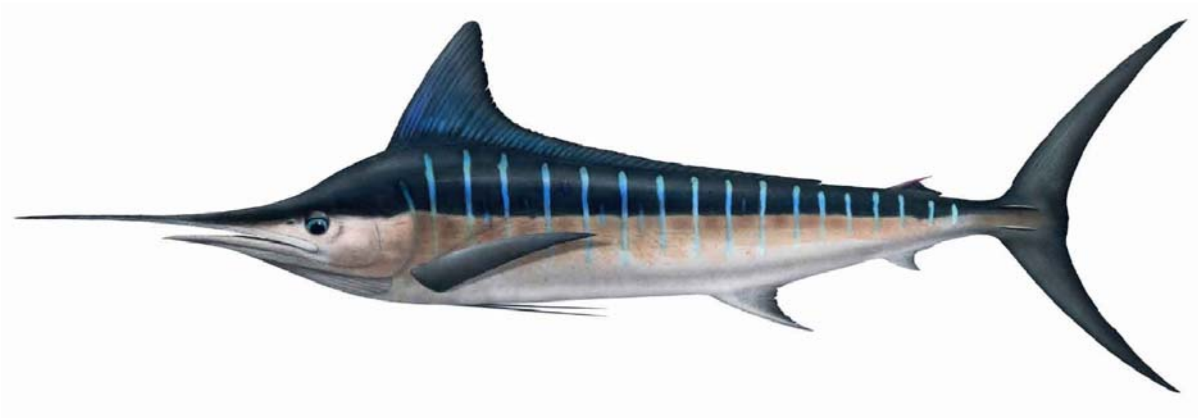
Note: Previous issues of the 'Fisheries Research Report Series' (ISSN 1837-2120) have been published as follows: (i) No.'s 1 – 10: 'NSW Fisheries Research Report Series' (ISSN 1442-0147); (ii) No.'s 11 – 22: 'NSW Department of Primary Industries – Fisheries Research Report Series' (ISSN 1449-9959); (iii) No.'s 23 – 28: 'Industry & Investment NSW – Fisheries Research Report Series' (ISSN 1837-2120).

Fisheries Research Report Series: 30

Catch per unit effort and size composition of striped marlin caught by recreational fisheries in southeast Australian waters

by
Danielle Ghosn, Damian Collins, Christopher Baiada and Aldo Steffe

Addendum



Kajikia audax
Image © I & I NSW

July 2012

ISSN 1837-2120

NSW GOVERNMENT | Primary Industries

1. INTRODUCTION

To meet the requirements of the 2012 SW Pacific striped marlin stock assessment being done by the Secretariat of the Pacific Community for the Western and Central Pacific Fisheries Commission, revisions were made to the standardisation models for the tournament catch and effort data. This addendum outlines those revisions.

2. DATA SOURCES AND METHODS

2.1. Models

Please refer to Table 3 on page 16 of the report for the full list of covariates and codes included in the model selection process. Changes to theses covariates include:

- Calendar year fitted as a factor instead of a spline with revised code yr.f and levels = 18
- Month of the event was replaced with the day of the year (1-365) with revised code s(dayyr) and fitted as a cubic cyclic spline (bs="cc" argument in R).

The revised predicted year effects from each of the two models were calculated on the transformed (or underlying) scale using the predict.gam function at average values of each of the other terms in the model (this was a slightly different approach to allow for year being fitted as a factor rather than a spline). There was no change to the methods for calculating the revised standardised index for each year.

Table 9. Revised Akaike Information Criteria (AIC) values for each stage of the stepwise model selection process for the covariate with the highest AIC value at each stage in developing the Probability of Catch (binomial) model for the probability of obtaining a non-zero catch. Note that the last (7th) stage represents the lowest AIC from all remaining covariates and was not included in the model as no further improvement could be gained by inclusion of this term.

Model selection stage	Introduced term	AIC
Null binomial model	yr.f	749.2
1st	s(sst)	648.9
2nd	s(long,lat)	629.9
3rd	s(t200)	614.3
4th	s(dayyr)	611.4
5th	port.f	609.0
6th	s(logbath)	607.5
7th	s(alt)	609.3

Table 10. Revised Akaike Information Criteria (AIC) values for each stage of the stepwise model selection process for the covariate with the highest AIC value at each stage in developing the Non-Zero Catch CPUE (log-normal) model for non-zero catch rates. Note that the last (5th) stage represents the lowest AIC from all remaining covariates and was not included in the model as no further improvement could be gained by inclusion of this term.

Model selection stage	Introduced term	AIC
Null log-normal model	yr.f	1451.4
1st	s(dayyr)	1421.7
2nd	s(long,lat)	1404.3
3rd	s(logbath)	1389.5
4th	s(alt)	1383.2
5th	port.f	1380.0
6th	s(moon)	1397.8

3. RESULTS

3.1. CPUE standardisation models for tournament catch and effort

The final revised model used for the probability of obtaining a non-zero catch was:

pa ~ yr.f + s(sst) + s(long,lat) + s(t200) + s(dayyr) + port.f + s(logbath) + ran(event.f)

(see Table 3 and Addendum Section 1.1 for denotation to covariate codes)

Revised predictions from the Probability of Catch (binomial) model indicate an increasing trend in the probability of catching a striped marlin up to 1999 and 2000 followed by an overarching slight decline in later years although confidence intervals are overlapping making it difficult to validate this trend. (Figure 7; Table 11). The approximate R^2 value provided by summary.gam in R was 0.43 for this revised Probability of Catch (binomial) model. Each of the terms included in this model had a significant effect ($p<0.05$) on the probability of catching a striped marlin (Table 12). There were no major changes in the trends of the explanatory variables with year fitted as a factor compared with year fitted as a spline. Refer to Figure 8 for revised plots of the predicted trends of each explanatory variable included in the revised model.

The final model used for the catch rate, given that the catch rate was non-zero was:

log(cpue) ~ yr.f + s(dayyr) + s(long,lat) + s(logbath) + s(alt) + port.f + ran(event.f)

(see Table 3 and Addendum Section 1.1 for denotation to covariate codes)

Predictions from the Non-Zero Catch CPUE (log-normal) model indicate an increasing trend in CPUE up to the early 2000's and then no change in the trend in consequent years (Figure 7; Table 11). The terms included in the Non-Zero Catch CPUE (log-normal) model explained 35.5% of the variability of the non-zero catch rates (adj. $R^2 = 0.355$ provided by summary.gam in R). There were significant differences ($p<0.05$) in the non-zero catch rates for each of the smooth terms and no significant differences in the non-zero catch rates for each of the factors (year and port) included in the Non-Zero Catch CPUE (log-normal) model. There were no major changes in the trends of the explanatory variables with year fitted as a factor compared with year fitted as a spline. Refer to Figure 9 for revised plots of the predicted trends of each explanatory variable included in the model.

There were no major changes to the overall trend of the standardised catch rates with year fitted as a factor compared with year fitted as a spline. Refer to Figure 4 and Table 6 for the revised predictions.

Table 11. Revised predictions for the catch rates given that the striped marlin catch was non-zero (Non-Zero Catch CPUE model), for the probability of a non-zero striped marlin catch (Probability of Catch model) and for the overall standardised catch rate (Non-Zero Catch CPUE and Probability of Catch models averaged). The raw annual catch rates (+/- 95% confidence intervals) are also provided.

	Non-Zero Catch CPUE model		Probability of Catch model		Standardised (Predicted)		Unstandardised (Raw)	
Calendar Year	**CPUE (>0)**	**± 95% CI**	**Pr (catch)**	**± 95% CI**	**CPUE**	**± 95% CI**	**CPUE**	**± 95% CI**
1994	0.062	0.023	0.350	0.247	0.022	0.018	0.076	0.031
1995	0.062	0.020	0.915	0.085	0.057	0.019	0.082	0.035
1996	0.116	0.038	0.929	0.077	0.108	0.037	0.149	0.045
1997	0.106	0.052	0.625	0.326	0.066	0.050	0.170	0.082
1998	0.141	0.048	0.924	0.081	0.131	0.046	0.084	0.024
1999	0.138	0.037	0.991	0.011	0.136	0.037	0.123	0.027
2000	0.189	0.049	0.989	0.011	0.187	0.049	0.193	0.048
2001	0.149	0.040	0.928	0.065	0.138	0.038	0.125	0.027
2002	0.149	0.043	0.964	0.040	0.143	0.041	0.130	0.024
2003	0.170	0.047	0.984	0.018	0.167	0.047	0.137	0.044
2004	0.144	0.040	0.933	0.062	0.134	0.038	0.172	0.035
2005	0.162	0.043	0.980	0.019	0.158	0.042	0.165	0.042
2006	0.104	0.028	0.979	0.025	0.102	0.028	0.140	0.038
2007	0.138	0.040	0.968	0.030	0.133	0.039	0.118	0.044
2008	0.160	0.043	0.953	0.049	0.152	0.042	0.222	0.054
2009	0.147	0.039	0.916	0.069	0.135	0.037	0.114	0.025
2010	0.146	0.037	0.959	0.043	0.140	0.036	0.252	0.074
2011	0.169	0.046	0.842	0.132	0.142	0.045	0.149	0.048

Table 12. Degrees of freedom (df) and revised approximate *p*-values (from anova.gam in R) for all terms in the Probability of Catch (binomial) model (using anova.gam function in R).

Variable	df#	p-value	Significance level
yr.f	17	0.00567	**
s(sst)	2.1	0.00333	**
s(long,lat)	2.0	0.00714	***
s(t200)	1.0	7.42E-05	***
s(dayyr)	6.6	1.65E-05	***
port.f	18	0.00164	**
s(logbath)	2.9	0.02803	*

* 0.05 ** 0.01 *** 0.001

[#] estimated degrees of freedom for smoothed terms

Table 13. Degrees of freedom (df) and revised approximate *p*-values (from anova.gam in R) for all terms in the Non-Zero Catch CPUE (log-normal) model (using anova.gam function in R)

Variable	df#	p-value	Significance level
yr.f	17	0.0783	ns
s(dayyr)	8.0	0.0173	*
s(long,lat)	13.8	6.02E-06	***
s(logbath)	3.3	2.89E-06	***
s(alt)	2.8	1.47E-04	***
port.f	18	0.5782	ns

*0.05 ** 0.01 *** 0.001 ns = not significant

[#] estimated degrees of freedom for smoothed terms

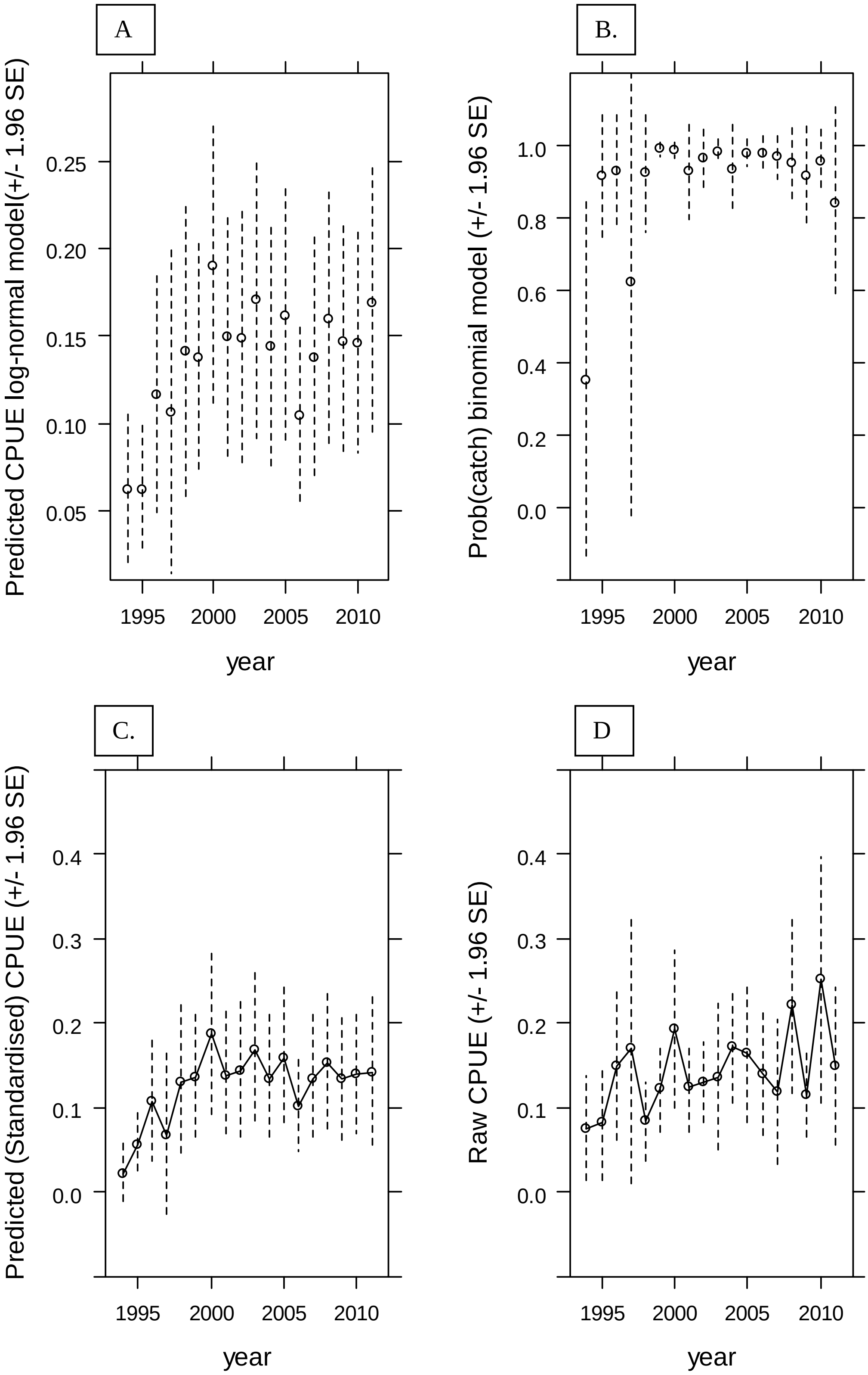


Figure 7. Plots of the revised predictions for: A. the catch rates given that the striped marlin catch was non-zero (Non-Zero Catch CPUE log-normal model); B. the probability of a non-zero striped marlin catch (Probability of Catch binomial model); C. the overall standardised catch rate (Non-Zero Catch CPUE and Probability of Catch models averaged); and D. plot of the raw annual catch rates (CPUE). Dotted lines show approximate 95% confidence intervals (±1.96 SE).

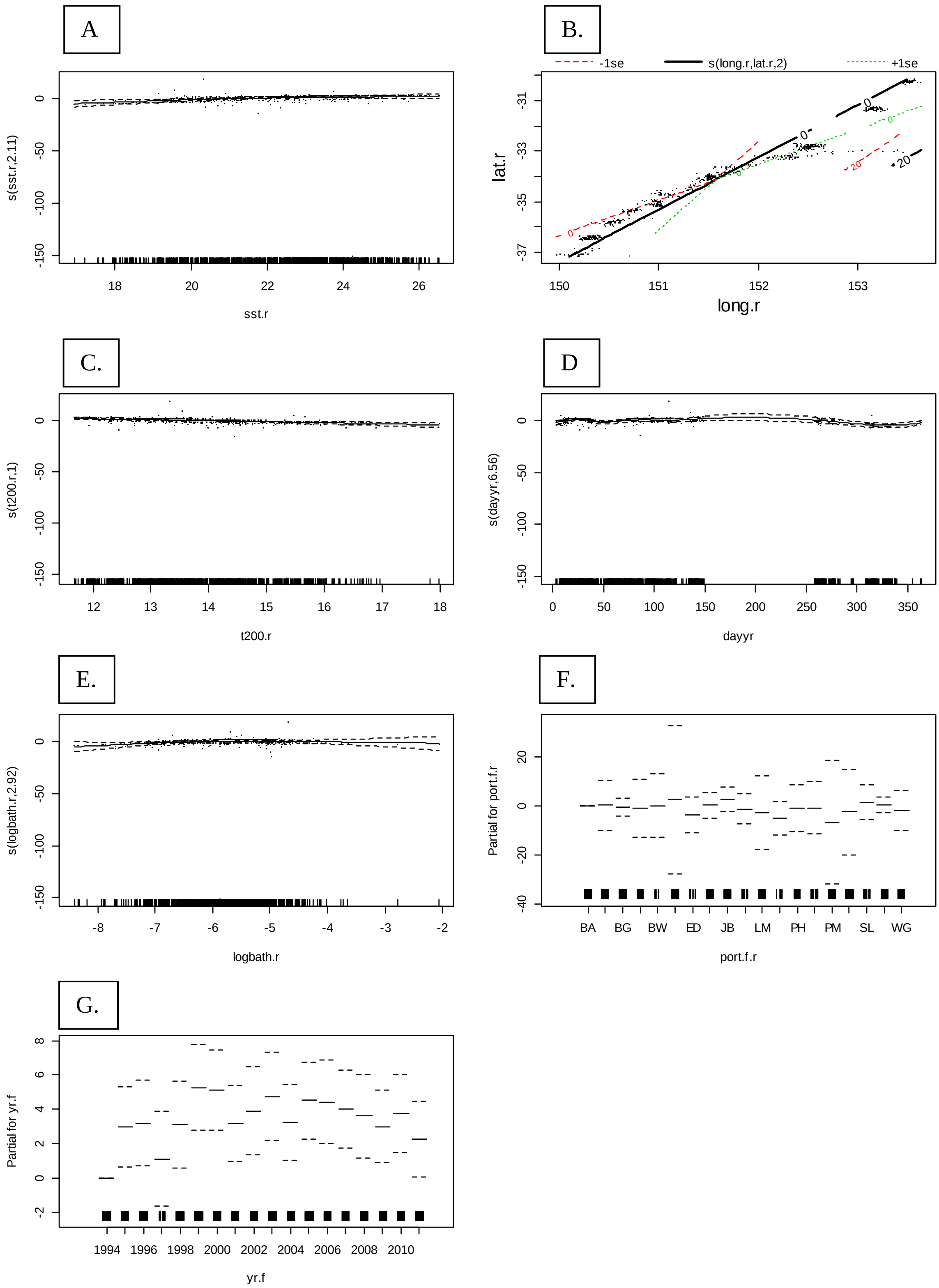


Figure 8. The revised predicted trends of each explanatory variable included in the Probability of Catch (binomial) model: A. s(sst); B. s(long,lat); C. s(t200); D.s(dayyr); E. s(logbath); F. port.f and G. yr.f. Dotted lines indicate approximate 95% confidence intervals for predictions (solid line) for the 1-dimensional smooth terms and categorical factors. Plotted points on each plot represent partial residuals for that term. See Table 3 and Addendum Section 1.1 for denotations to covariate codes. See Appendix 5 for a list of codes for port.f.

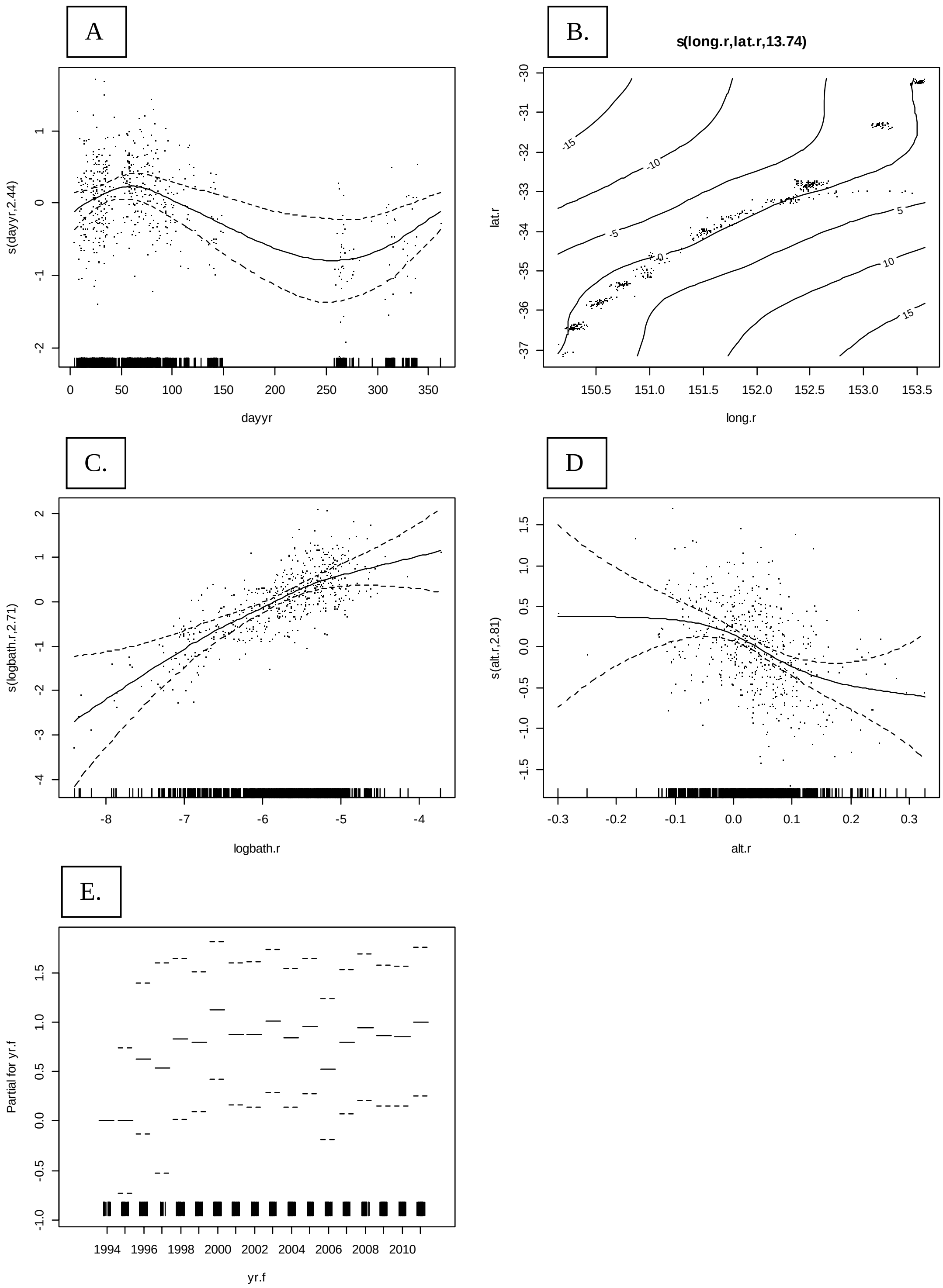


Figure 9. The revised predicted trends of each explanatory variable included in the log-normal (Non-Zero Catch CPUE) model: A. s(dayyr); B. s(long,lat); C. s(logbath); D. s(alt) and E. yr.f. Dotted lines indicate approximate 95% confidence intervals for predictions (solid line) for the 1-dimensional smooth terms and categorical factors. Plotted points on each plot represent partial residuals for that term. See Table 3 and Addendum Section 1.1 for denotations to covariate codes. See Appendix 5 for a list of codes for port.f.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACKNOWLEDGEMENTS

Funding for this project was provided by the Western and Central Pacific Fisheries Commission, the NSW Recreational Saltwater Trust and NSW DPI. Alistair Hobday from CSIRO is thanked for his assistance with the environmental datasets. Julian Pepperell is thanked for providing historic club records. The contribution and cooperation of game fish club anglers, tournament officials and State and National game fish association officials is also greatly appreciated. Matthew Ives, Bruce McCorkell, Charles Gray and Steve Kennelly from NSW DPI, Stephen Brouwer from New Zealand Ministry of Fisheries and Mark Chambers from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) are thanked for their comments on the draft manuscript of this report.

EXECUTIVE SUMMARY

This report provides an annual weight index and catch rate standardisation for recreational-caught striped marlin for southeast Australia (~30°S – 40°S) within sub-area 3 of the southwest Pacific Ocean (SWPO) striped marlin stock assessment region. The outputs of this report relate to SWPO sub-area 3 because of the concentration of the fishery in this region with minimal recreational catches in sub-area 2 (~15°S – 30°S) of about 3% compared with about 97% for sub-area 3.

Annual landed catch records from game fish clubs represent the only available long time series of catch data for the southeast Australian recreational striped marlin fishery. These records are combined with records from the New South Wales (NSW) Gamefish Tagging Program (GTP) to provide an annual weight index for recreationally-caught striped marlin from southeast Australian waters from 1936 to 2010. These weight data indicate a decline from 107kg in the mean weight of fish post World War II to an average centred on approximately 80kg from the 1980's onwards. This decline in mean weight may be influenced by the spatial distribution of catches with all striped marlin caught before World War II recorded for the Bermagui Big Game Anglers Club, which is on the south coast of NSW. A comparison in average weights between clubs from the north, central and south coasts of NSW from the 1980's onwards indicates increasing mean size from north to south (82kg, 84kg and 98kg, respectively).

The catch and effort data available for standardisation are derived from monitoring between 1994 and 2011 of NSW Game Fishing Association (NSWGFA) club tournaments affiliated with the GFAA. Standardised catch rates indicate an increasing trend to a peak in 2002 and then no change in the catch rate to 2011 although approximate confidence intervals were overlapping making it difficult to validate this trend. There is the potential for these catch rates to be hyperstable, particularly since the early 2000's due to an increase in the use of live baits for catching striped marlin. Further investigations are needed using post-fishing interview data collected over the past five years of the monitoring period to discern if there are any differences in fishing power between different fishing methods (for example, using live baits versus lures). Further refinements could also be made to the models, for example, month effects may be more parsimoniously modelled as a smoothed trend (rather than separate month effects).

1. INTRODUCTION

1.1. Objectives

- To estimate an annual striped marlin weight index for recreational fisheries in southeast Australian waters from game fish club records dating back to the 1930's and game fish tag and release records dating back to the 1970's.
- To standardise catch and effort data for striped marlin taken by recreational fishers between 1994 and 2011 as derived from a game fishing tournament monitoring dataset.

1.2. Description of the fishery and results of past fishing surveys

Striped marlin (*Kajikia audax*) is a highly migratory species widely distributed through the Pacific and Indian Oceans and is commonly caught by recreational game fishers who target istiophorid billfishes in southeast Australia. This species was the most common billfish observed in the NSW Gamefish Tournament Monitoring Program (Park 2007) and in a survey of NSW recreational trailer boats between September 1993 and August 1995 (Steffe *et al.* 1996).

The majority of striped marlin are caught by recreational fishers between December and May with catches peaking between January and April. The recreational striped marlin fishery on the east coast of Australia is concentrated on the southern east coast (Figure 1), that is, sub-area 3 of the southwest Pacific Ocean (SWPO) assessment regions (Langley *et al.* 2006). A total of 97% of all striped marlin tagged and released in east Australian waters have been caught in SWPO sub-area 3 (Danielle Ghosn, unpublished data).

The history of game fishing in Australia has been extensively documented and dates back to the early twentieth century (Goadby 1987, Campbell *et al.* 2002, Bromhead *et al.* 2003, Bromhead *et al.* 2004, McIntyre 2007, 2008). The first club to establish gamefishing rules in Australia was the Angler's Casting Club of Australia, which was formed in 1907 (McIntyre 2007). Spanish mackerel and tuna were the most common species caught by game fish anglers in these early days and then in 1913, the first marlin (a black marlin) to be caught on rod and reel in Australasia was landed off Port Stephens in NSW (McIntyre 2007). Game fishing continued to gain popularity in Australia with the formation of 18 NSW game fishing clubs and with game fishing becoming formalised by the establishment of the GFAA in 1938 (McIntyre 2007). GFAA (originally named the Big Game and Rod Fishers' Association of Australia) formalised game fishing by the introduction of a clear set of fishing rules and administration practices (McIntyre 2007). The GFAA is the longest-established national fishing association in the World (Anon. 2010).

Current rules governed by the GFAA and the affiliated NSW Game Fishing Association (NSWGFA) include minimum size limits for obtaining capture point scores and extensive fishing gear and method restrictions (Anon. 2010). In NSW, there are currently 24 game fishing clubs that are affiliated with the GFAA (Anon. 2010) with about 3500 members (Pat Jones, GFAA Secretary, pers. com.).

The recreational fishery for striped marlin in southeast Australia is comprised of both fishers affiliated and not affiliated with NSWGFA game fishing clubs, hereafter referred to as affiliated and non-affiliated fishers respectively. The ratio of affiliated to non-affiliated fishers is currently unknown and there is a lack of available datasets to represent the catch of non-affiliated fishers. This is due to the difficulties in monitoring game fish catches as anglers who target these species represent a very small proportion of the general angling population and hence are difficult to sample using traditional survey methods such as telephone-diary or access-point surveys (Pollock *et al.* 1994). For example, the results of the National Recreational and Indigenous Fishing Survey in the year 2000 showed that of the 1.3 million persons that were recorded to have fished at least once in NSW, only 3% of fishers listed game fish (marlin, sharks and tunas) as their primary target (Jeff Murphy, Fisheries NSW, pers. com.).

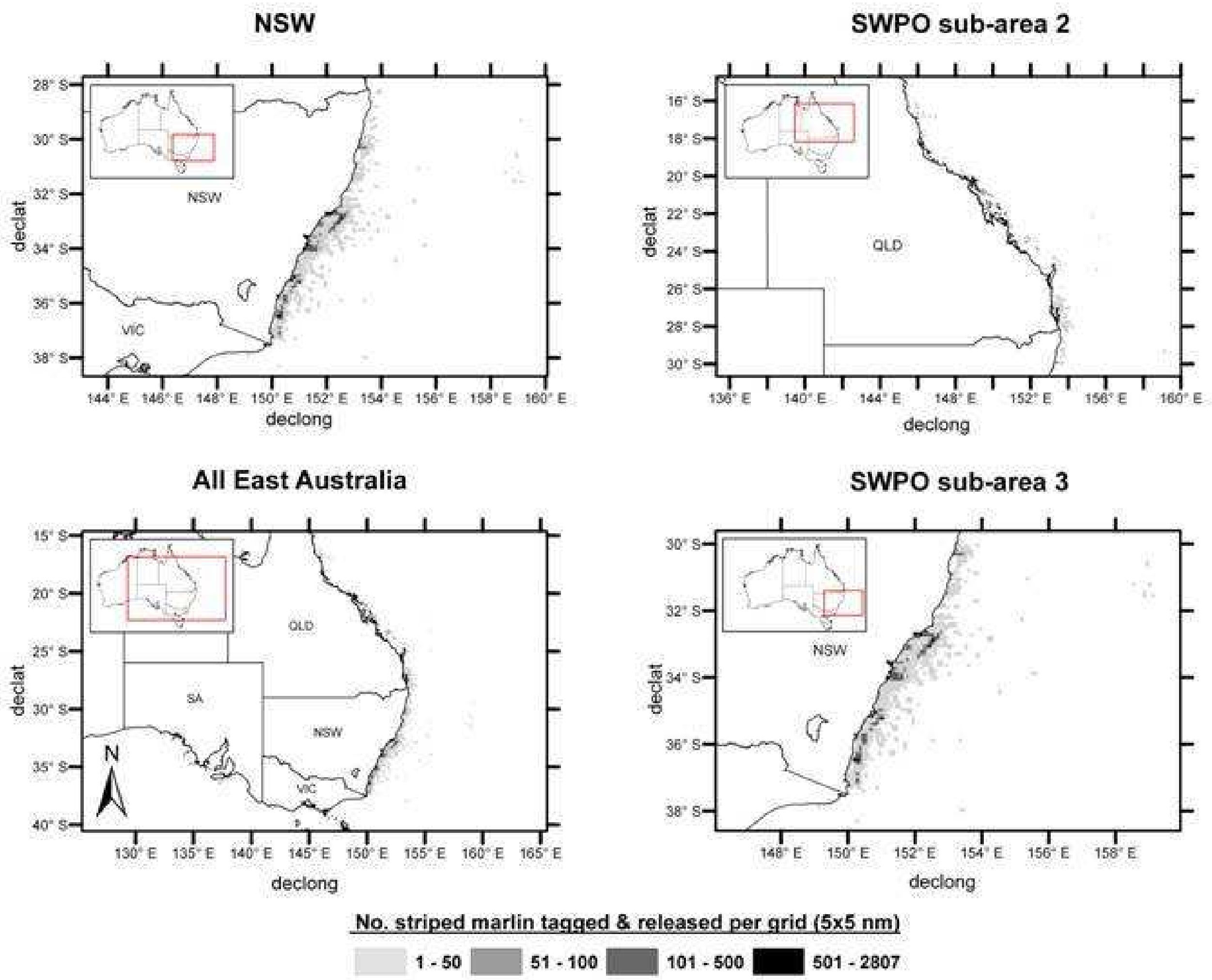


Figure 1. Spatial distribution of striped marlin tagged and released as recorded in the NSW Gamefish Tagging Program database for records originating from: NSW, east Australian coast, Australian waters within the SWPO sub-area 2 (30°S – 40°S) and Australian waters within SWPO sub-area 3 (15°S – 30°S). Individual records are summed by 5x5 nautical mile grids to represent the number of striped marlin tagged and released by spatial grid.

Furthermore, the raw catch data of NSW game fish fishers from this National survey included only 16 catch records for marlin with only three of those specified as striped marlin (Jeff Murphy, NSW DPI, unpublished data). The majority of the NSW catch of game fishers in this survey included tuna species (Jeff Murphy, NSW DPI, unpublished data). These survey data indicate that direct targeting of marlins likely represents an even smaller percentage of fishers than 3% of the general recreational fishing population in NSW. This ‘needle in a haystack’ problem, along with game fish fisheries being episodic, means that the cost of any probability-based survey with the spatial and temporal resolution required to effectively sample game fish catch and effort across the whole recreational fishery is prohibitive.

The results of a survey undertaken between September 1993 and August 1995 by Steffe *et al.* (1996) is the only other available data on striped marlin catch in NSW. This survey reports two annual NSW state-wide catch estimates for striped marlin for each of three spatial zones although is limited to the catch by fishers aboard trailer boats who returned to large access points in NSW (Table 1). These estimates do not include the catch of fishers aboard marina-berthed vessels or charter boats who may represent a large proportion of the fishers who target and catch striped marlin.

Table 1. NSW catch estimates for striped marlin from Steffe *et al.* (1996) for NSW by spatial zone (North, Central and South) for survey year 1 (September 1993 – August 1994) and survey year 2 (September 1994 – August 1995).

	SURVEY YEAR 1				SURVEY YEAR 2				TOTAL			
NSW REGION	NO. FISH	S.E.	WEIGHT (kg)	S.E.	NO. FISH	S.E.	WEIGHT (kg)	S.E.	NO. FISH	S.E.	WEIGHT (kg)	S.E.
North	62	24	7761	2974	*	*	*	*	62	24	7761	2974
Central	*	*	*	*	*	*	*	*	*	*	*	*
South	219	122	24087	12404	287	90	25237	8043	506	212	49324	20447
Total	**281**	**146**	**31848**	**15378**	**287**	**90**	**25237**	**8043**	**568**	**236**	**57085**	**23421**

* striped marlin not detected

2. DATA SOURCES AND METHODS

Due to the lack of available data on the catch and effort of non-club fishers, the characterisation in this report of striped marlin recreational fisheries in southeast Australia is primarily based on the club-based game fish fishery on the east coast of Australia. Although this component of the fishery may not be representative of the overall recreational fishery for striped marlin, available data currently represents minimal estimates for striped marlin catch and fishing effort in southeast Australia. All data are aggregated by calendar year to correspond with the SW Pacific stock assessment process.

2.1. Size composition data

2.1.1. Game fish club annual catch report data

The club-based game fish fishery in Australia is the only component of the Australian recreational fisheries where a long time series of catch data are currently available for analysis. The majority of NSWGFA clubs have kept detailed catch records of fish weighed and tagged and released for pelagic game fish for many years, in some cases since 1925. Records obtained for the current analyses date back to 1933, however, the first striped marlin was not recorded until 1936. Annual report catch records form the basis of what is largely known about the recreational fishery for striped marlin in southeast Australia.

These annual reports are provided by the clubs by fiscal year, which coincides with the game fishing season. Reports include species caught, date of capture, fish weight, line class and angler details. Some anglers are members of more than one club resulting in the possibility of individual fish being reported in more than one club report. All records in the final annual report dataset were checked for duplicates and duplicated striped marlin weights were removed prior to analysis. These club catch records will be referred to throughout this report as landed catch.

Annual reports were traditionally provided as a hard copy publication that was sent to all club members however over the past 15 years the production of these reports has changed with most clubs now keeping their records electronically and some have ceased to produce a hard copy publication. Dr Julian Pepperell collated the majority of the records up to year 2000. Over the past year, a concerted effort has been made to collate data for missing years prior to 2000 and to make the data series as complete as possible. An ongoing effort to access data for more of the missing years and clubs is needed. A summary of the landed catch from club-based fishery annual report data by club and fiscal year (game fishing season) are provided in Appendix 1. Note that Victorian clubs (Latrobe Valley, Victorian and South Gippsland) have been included in this dataset as most of the anglers from these clubs target billfish out of Bermagui on the southern coast of NSW. Annual reports for Queensland clubs were also investigated and found to include very few capture records (Julian Pepperell, unpublished data). This lack of landed catch records can be explained by the fact that landing of billfish in Queensland is very rare as anglers prefer to release all of their catch. Low catches of striped marlin are also seen in the Gamefish Tagging Program with less than 3% of all striped marlin tag and release records originating from Queensland waters. Based on these results, Queensland club annual reports have been excluded from further analysis here.

The proportion of the total southeast Australian recreational striped marlin landed catch that these club-based records represent is unknown. Insight into this issue can be found through a direct comparison of annual landed catch numbers from these annual report data and landed catch estimates from Steffe *et al.* (1996). Consideration of the potential for overlapping data is also required (as game fish club members were potentially interviewed as part of the trailer boat survey). However, direct comparison indicates that club-based landed catch represents less than 25% of the total annual recreational striped marlin landed catch in southeast Australian waters, at least over the two years of the Steffe *et al*. (1996) survey between September 1993 and August 1995.

2.1.2. NSW Game Fish Tagging Program data (GTP)

The NSW Gamefish Tagging Program (GTP) has been in operation since 1974. Since inception, tag and release of billfish has gained popularity with the majority of all billfish caught during club-based events tagged and released. Tag and release increased over time and this coincided with changing fisher attitudes towards the conservation of billfish and the introduction of minimum size requirements for captured individuals. The minimum sizes for billfish are currently 60kg or 80kg for billfish caught on line classes 10kg and under or 15kg and over, respectively. The high proportion of tagged and released individuals in the recreational fishery necessitates the inclusion of this dataset for characterisation of the striped marlin fishery in southeast Australia. This dataset includes information on the date and location of capture and an estimated weight (kilograms).

2.1.3. Calculation of an annual weight index

Records from the GTP are combined with landed catch records from game fish club annual reports to provide an annual weight index for recreationally-caught striped marlin from southeast Australian waters. The spatial range of the annual report dataset is exclusive to SWPO sub-area 2 of the assessment region. Thus, the combined mean weight index only includes records from within SWPO sub-area 2 (this removed 568 out of 19921 game fish tagging records from the dataset).

Fish weights from the GTP are estimated by recreational fishers upon capture alongside their vessels. The accuracy of these estimated weights is uncertain, however, investigation of a limited recapture dataset indicates that there is not likely to be any inherent bias on the average weight of tagged and released individuals with estimation errors within 50% of the recapture weights, the mean and median of the difference between recapture and release weights close to zero and 50% of the data points between -20% and +5% (Figure 2). The recapture dataset from the GTP included 31 records of which the striped marlin had all been at liberty for less than 90 days and the recapture weight could be assured to be a whole actual weight in kilograms that had not been estimated.

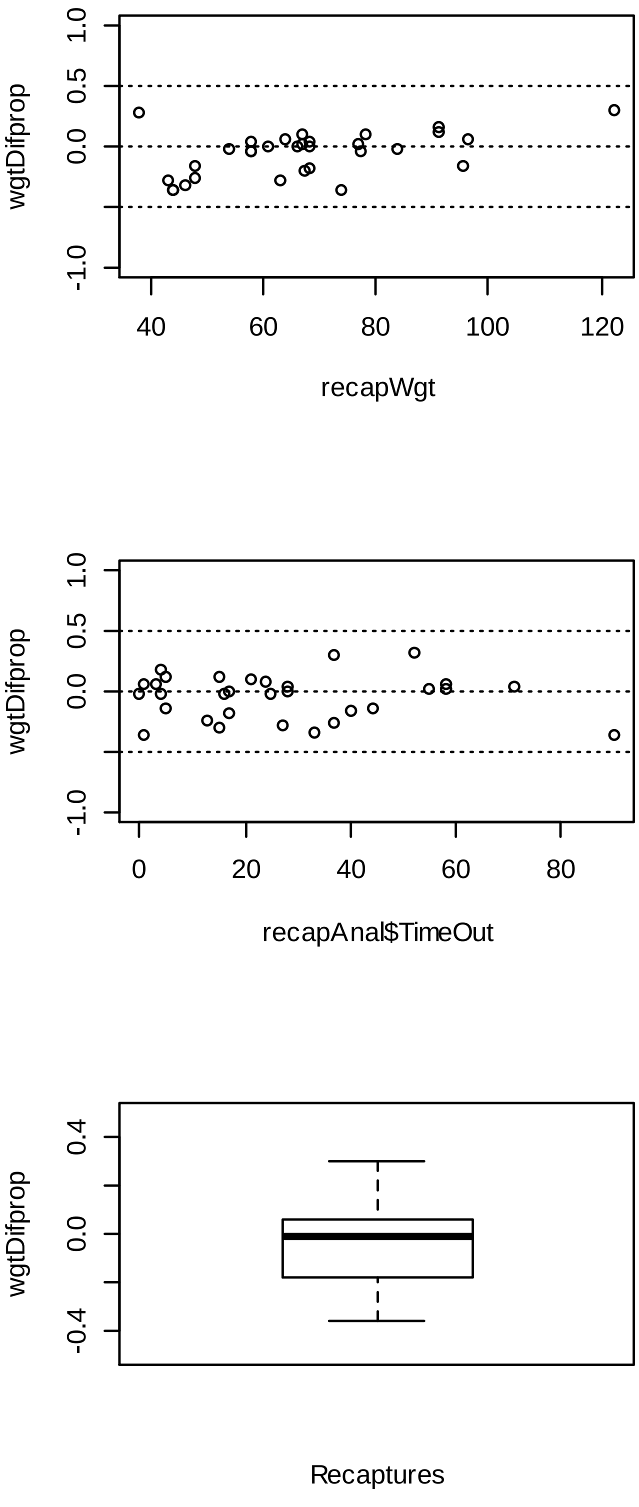


Figure 2. Derivations between recapture (actual weights) and release (estimated weights) plotted as a proportion of the recapture weight (wgtDifprop) against recapture weight (recapWgt) and time at liberty (recapAnal$Timeout). A boxplot of the derivations as a proportion of the recapture weight is also shown with the centre line indicating the median.

2.2. NSW Game Fish Tournament Monitoring Catch and Effort Data (GTMP)

Catch and effort data are derived from the NSW Gamefish Tournament Monitoring Program (GTMP), which was developed as a consequence of the difficulties of monitoring game fish fisheries using traditional survey methods. The Australian government recognised these difficulties and consequently supported a study by West (1990) to investigate monitoring options. West (1990) identified a system that was being used by the GFAA and its affiliated clubs to monitor their vessels whilst at sea during competitions. This was a mandatory radio schedule reporting system (known as ‘scheds’) that was identified as a potential source of effort and catch data. Scheds involves a marine radio base (usually situated on land) and a radio operator who contacts each participating vessel at regular intervals for information about the location of the vessel (as a spatial alpha-numeric grid), their fishing activity (travelling, trolling, drifting or anchored) and a fishing report, which includes details of fish strikes, fish hooked and fish captured or tagged and released.

The existence of this radio reporting system and the investigations of West (1990) led to the start of the GTMP in 1993. The GTMP formalised the collection of data from scheds and is ongoing and currently coordinated by Fisheries NSW. The potential problem with data from the GTMP is that it is currently unknown how representative these data are of the catch of game fish for the whole recreational fishery i.e. GFAA-affiliated and non-affiliated fishers combined. West (1990) undertook pilot surveys of clubs on the east coast of Australia and of anglers through fishing tackle stores as well as analysis of the NSW gamefish tagging database. These pilot analyses indicated that GFAA-affiliated clubs may be responsible for a substantial majority of the recreational catch of marlin (80%), indicating that information from GFAA-affiliated clubs was potentially a good representation of catch and effort trends for these species (West 1990). The analysis of existing tag and release data and the survey of fishing tackle stores, as well as a series of assumptions, suggested that only 20% to 30% of marlins caught by recreational anglers may be attributable to non-affiliated fishers (West 1990).

These results highlight the apparent importance of information on the recreational fishery through monitoring of the effort and catch of GFAA-affiliated fishers. However, these GTMP data can not provide information about the total effort and catch of gamefish species and thus do not replace the need for probability-based surveys that have the ability to sample both GFAA-affiliated and non-affiliated fishers. Rather, GTMP data can potentially provide an independent source of information on catch and effort trends or size composition for gamefish species.

2.2.1. Calculation of raw CPUE

Daily catch per unit effort (CPUE) was calculated as the total number of striped marlin caught divided by the total number of boats fishing (known as the ratio of the means estimator; Pollock *et al.* 1994) for each event. These daily event catch rates formed the basis of the dataset for catch rate standardisation. For annual raw CPUE, mean daily catch was divided by mean daily effort (number of boats) for each event (as event is the primary sampling unit) and then averaged for each year. Confidence intervals around these raw CPUE estimates were calculated using the first order Taylor expansion variance equation for ratio estimators (Elandt-Johnson and Johnson 1980, Stuart and Ord 1998).

Boat day was used as the unit of effort rather than hours fished due to uncertainty in the number of hours fished as obtained from scheds. A game fishing trip also usually involves considerable travel time within a day and other activities such as bait collecting or the targeting of other species resulting in further uncertainty about the number of hours fished as can be obtained from scheds. Daily catch and fishing effort were excluded for boats that reported on the scheds as not fishing or if they did not report on the majority of the scheds that day.

Boats that report on scheds to be trolling are assumed to be directing their effort towards billfish. Ideally, CPUE for an abundance index should exclude fishing effort directed towards the targeting of other species apart from striped marlin. However, there has been an increasing trend over the monitoring period towards targeting striped marlin by drifting with live baits and some sched operators also do not consistently record fishing method (i.e. trolling, drifting or anchored) on the scheds. For these reasons, it was not possible from sched data to partition the fishing effort directed at billfish from the fishing effort directed at other species such as sharks and tunas, particularly for the later years of the monitoring period. Consequently, all CPUE estimates presented in this report include all fishing effort recorded on the scheds during tournaments. This is likely to reduce the catch rates by less than 15% based on previous estimates of the proportion of boats that target species other than billfish during tournaments (Park 2007). Conversely, an increase in the use of live baits and drifting for catching striped marlin in the later years of monitoring may result in higher catch rates over time if this method is more efficient.

Future analyses aimed at validating the proportion of boats directing their effort towards billfish should be investigated using existing post-fishing interview data. Knight *et al.* (2006) suggested that future analyses should investigate the use of a subset of data for boats that fish tournaments and also meet other criteria such as having fished for at least 5 years and marlin making up greater than 50% of their total tag-release record from the NSW Gamefish Tagging Program database. Recent work to uniquely identify tournament vessels has identified that numerous boats in NSW have the same boat name. For example, there is one boat name that has been linked to five different vessels fishing NSW tournaments (Danielle Ghosn, unpublished data). Uncertainty in unique identification of tournament vessels and potential bias that these criteria may impose means that it is not possible to use subsets of data as suggested by Knight *et al.* (2006) for future analyses of CPUE from the GTMP catch and effort dataset.

2.2.2. Environmental data

Environmental data sets investigated for their use as independent explanatory variables in the standardisation of the GTMP catch and effort dataset were obtained from various sources. These variables and their source are shown in Table 2. Using sched data from the GTMP catch and effort dataset, all environmental data were spatially matched to the midpoint of the alpha-numeric spatial grid reported on each sched by boat and event day. These covariates were then averaged across boats for each event day to provide event day estimates for each environmental variable.

Table 2. Environmental variables investigated for use in the standardisation of the tournament catch and effort dataset including the source of each variable dataset.

Variable	Source
Daily Sea Surface Temperature (SST)	CSIRO
10 Day Sea Surface Temperature (SST)	CSIRO
Sea surface height anomaly (altimetry)	CSIRO
Bathymetry	CSIRO
Temperature at 200m depth	CSIRO
Chlorophyll a	CSIRO
Wind speed	CSIRO
Magnetic anomaly	CSIRO
Southern Oscillation Index	Aust. Gov., Bureau of Meteorology (BOM)
Moon phase	U. S. Naval Observatory (USNO)

2.2.3. Models

Standardisations of the tournament catch rates were obtained using a delta-lognormal model (Maunder and Punt 2004) comprising of separate models for the probability of a non-zero catch and the non-zero catch rate. The probability of obtaining a non-zero catch was modelled using a generalized additive mixed model (GAMM) with a binomial response. Non-zero catch rates were modelled using a GAMM assuming a log-normal distribution (i.e. applying a log transformation to the catch rate). The use of a GAMM allowed both for the inclusion of smooth terms for each of the environmental covariates, as well as the additional inclusion of random event effects. Random event effects allowed for correlations in catch rates between successive days in an event (and culminated in wider, but more realistic, estimates of uncertainty for the standardised year estimates).

All models were fitted in R (R Development Core Team 2008) using the gamm4 function in the gamm4 library (Wood 2011). The gamm4 function calls lmer function of the lme4 library (Bates *et al.* 2011) to fit the GAMM and calculate the likelihood and AIC statistics (note that lmer uses the Laplace approximation to the likelihood for non-normal models). No optional arguments were used in the call to gamm4, and so the default options for gamm4 were applied.

Explanatory variables considered for inclusion in each model are given in Table 3. Daily SST and chlorophyll data were also investigated but could not be included in the model selection process as these datasets contained too many missing values. All terms were fitted as smooth functions apart from month and port, which were fitted as categorical factors. A two-dimensional smooth function was fitted for fishing position, that is, the combination of longitude and latitude. As per the gamm4 default, a thin-plate regression spline basis was used for all the smooth terms.

Some preliminary descriptive and exploratory analyses were performed prior to the standardisation to check and validate these data. Each explanatory variable was plotted against the response (either catch/no-catch or log catch for catch > 0) to anticipate the trends that may appear in the formal analysis (and to check for unusual trends or data points). In addition, multicollinearity between the explanatory variables was examined by both calculating the linear correlations between all variables and plotting each variable against one another (Appendix 2; using the 'pairs' function in R). Although there were some clear associations between the explanatory variables, as would be expected, none of these associations were considered extreme enough to necessitate the removal of any of the explanatory variables from consideration.

Model selection of covariates was performed using a forward stepwise approach, starting from a base model with only random event effects, using Akaike's Information Criteria (AIC) as the criteria for inclusion of a term in the model. At each stage of the model building process all remaining terms not already in the model at that stage were tested for inclusion. This testing was performed by adding each term to the current model individually in succession and examining the change in AIC compared to the current model. If a reduction in the AIC was observed for at least one term, the term giving the greatest reduction in the AIC was added to the model. Model selection ceased when the inclusion of any remaining terms did not improve (reduce) the AIC (Tables 4 and 5).

Table 3. Covariates (and their code) included in the model selection process for standardisation of striped marlin catch and effort from the tournament dataset including a description of each, the type of variable (factor or spline) and the number of levels (for factors only).

Covariate	**Code**	**Description**	**Factor or Spline**	**Levels**
Calendar year	s(calyr)		Spline	
Event	ran(event.f)	Represents each game fishing tournament	Factor (ran)*	57
Month	month.f	Includes all months except June, July and August, which were removed due to the lack of events occurring over this period where billfish are directly targeted	Factor	9
Port	port.f	Port of origin of the game fishing club hosting each tournament event	Factor	19
Fishing location	s(lat,long)	Latitude by Longitude derived from the midpoint of the alpha-numeric grids reported by each boat on scheds during tournaments and averaged for each boat and for each event day	2D Spline	
Bathymetry	s(logbath)	The log of bathymetry was included in the final model selection process after identifying the need to down-weight the influence of a small number of data points at greater water depths	Spline	
10 day SST	s(sst)	10 Day composite of sea surface temperature data. CSIRO product #103. SpatialResolution: '0.036^o Latitude, 0.042^o Longitude; Units: Degrees Celsius; Temporal Resolution: 2.02 Days	Spline	
Sea Surface Height Anomaly (Altimetry)	s(alt)	Calculated based on the difference between the observed and the average sea surface height as observed by the TOPEX satellite. CSIRO product # 210; Spatial Resolution: 0.193^o Latitude, 0.333^o Longitude; Units: metres; Temporal Resolution: Weekly	Spline	
Temperature at 200m depth	s(t200)	CSIRO product # 114; SpatialResolution: 0.2^o Latitude, 0.2^o Longitude; Units: Degrees Celsius; Temporal Resolution: 3.83 Days	Spline	
Wind speed	s(wind)	Calculated by adding the squared u-wind speed (east west direction) to the squared v-wind speed (north-south direction) to the power of 0.5 - [$(u^2 + v^2)^{0.5}$]; CSIRO product # 306 (u-wind) & 307 (v-wind). SpatialResolution: 0.25^o Latitude, 0.25^o Longitude; Units: metres per second; Temporal Resolution: 1 Day	Spline	
Magnetic anomaly	s(maga)	Variation in the Earth's magnetic field or deviations in values of a magnetic field on the surface of the earth from the normal values	Spline	
Moon phase	s(moon)	Fraction of the Moon Illuminated, at Noon Eastern Standard	Spline	
Southern Oscillation Index	s(soi)	Differences in pressure between Tahiti and Darwin with sustained positive values indicating La Nina episodes and sustained negative values indicating El Nino episodes	Spline	

*ran = random effect

Table 4. Akaike Information Criteria (AIC) values for each stage of the stepwise model selection process for the covariate with the highest AIC value at each stage in developing the Probability of Catch (binomial) model for the probability of obtaining a non-zero catch. Note that the last (6th) stage represents the lowest AIC from all remaining covariates and was not included in the model as no further improvement could be gained by inclusion of this term.

Model selection stage	Introduced term	AIC
Null binomial model	s(CalYr)	768.2
1st	s(sst)	686.6
2nd	s(long,lat)	657.9
3rd	s(t200)	645.8
4th	month.f	642.7
5th	port.f	626.5
6th	s(logbath)	631.3

Table 5. Akaike Information Criteria (AIC) values for each stage of the stepwise model selection process for the covariate with the highest AIC value at each stage in developing the Non-Zero Catch CPUE (log-normal) model for non-zero catch rates. Note that the last (5^{th}) stage represents the lowest AIC from all remaining covariates and was not included in the model as no further improvement could be gained by inclusion of this term.

Model selection stage	Introduced term	AIC
Null log-normal model	s(CalYr)	1466.3
1st	month.f	1441.8
2nd	s(long,lat)	1425.6
3rd	s(logbath)	1406.5
4th	s(alt)	1395.3
5th	s(maga)	1397.8

The model selection approach was complemented by visual examination of the fitted smooth functions at each stage of the model selection process (with the partial residuals superimposed, using the plot.gam function with res=T) to check the adequacy of the fit for each of the smooth terms, as well as check for unusual changes in the fitted trends for the terms already included in the model. An additional backward deletion step was made for the binomial model where magnetic anomaly (maga) had been included in the model (at the fourth stage of forward selection). After inclusion of port effects maga appeared no longer useful (either with respect to the statistical significance or the fitted trend) and its removal resulted in a further improvement in the AIC. This is not surprising given the likely collinearity between maga and port.f, which is directly related to latitude (see Appendix 2 showing correlations between maga and lat of -0.45). The other terms in the model were also consequently checked but the removal of other terms did not result in any improvement in the AIC.

Predicted year effects from each of the two models were made on the transformed (or underlying) scale using the predict.gam function (with arguments 'se=T' and type='iterms' and then adding the grand mean to each). A standardised index for each year was calculated by multiplying the predictions from the two models:

Predicted CPUE = (Predicted Probability of non-zero catch) x (Predicted Catch Rate when Catch > 0

Approximate standard errors for the predicted CPUE were calculated using the variance of a product of two random variables and using the delta method to back-transform SEs (Oehlert 1992). Approximate 95% confidence intervals are calculated as +/-1.96 SE.

3. RESULTS

3.1. Annual weight index

Striped marlin weight data derived from the recreational club-based fishery in SWPO sub-area 3 indicates a decline from 107kg in the mean weight of fish post World War II (WWII) to an average centred on approximately 80kg from the 1980's onwards (Figure 3; Appendix 4). This decline in mean weight may be influenced by the spatial distribution of catches with all striped marlin caught before World War II recorded for the Bermagui Big Game Anglers Club, which is on the south coast of NSW. A comparison in the size composition (Appendix 3) and average weights between clubs from the north, central and south coasts of NSW from the 1980's onwards indicates increasing mean size from north to south (82kg, 84kg and 98kg, respectively). After removing the influence of port location a decline is still apparent with mean size of 107kg before WWII and mean size of 98kg for clubs on the south coast of NSW from the 1980's onwards (Appendix 3).

Annual number, weight and mean weights of striped marlin from the club landed catch and Game Fish Tagging Program datasets are provided in Appendix 4.

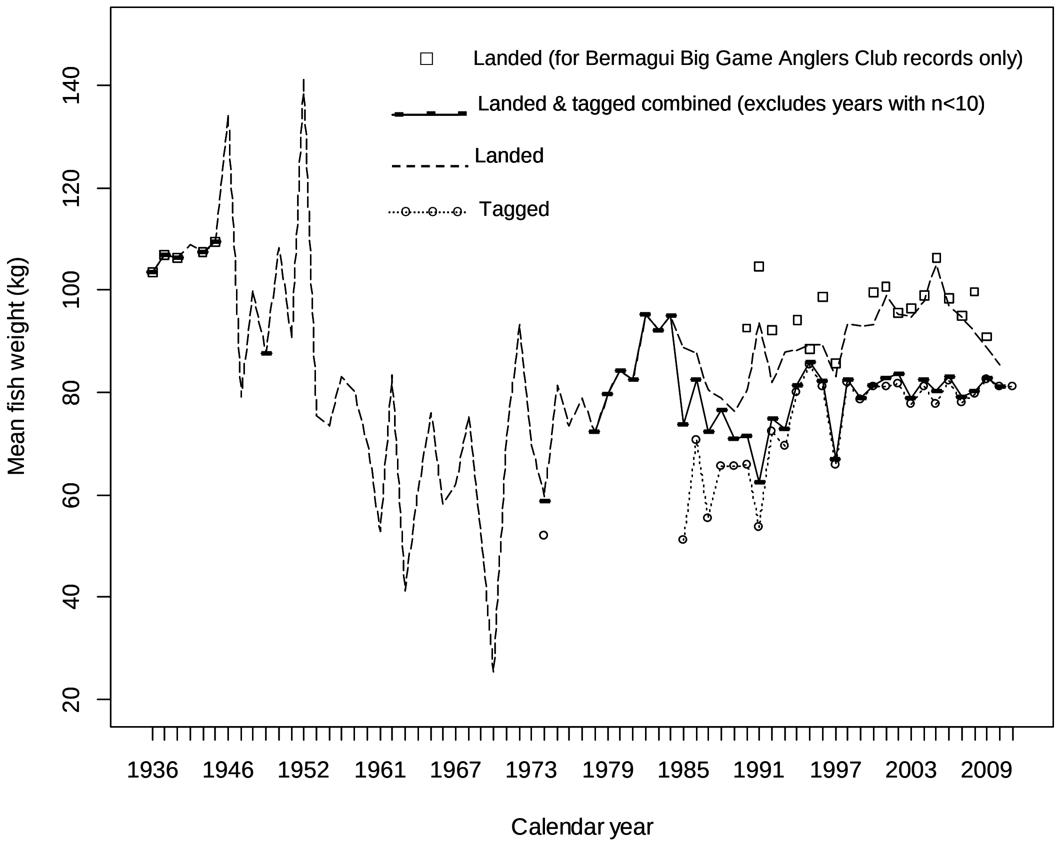


Figure 3. Mean annual weight (kg) of striped marlin for: the Bermagui Big Game Anglers Club (this club has the longest time series), all gamefish club annual report catch data records (Landed), all NSW Gamefish Tagging Program records (Tagged & Released) and an overall (landed & tagged datasets combined) excluding years where the total number of striped marlin was less than 10.

3.2. CPUE standardisation models for tournament catch and effort

The final model used for the probability of obtaining a non-zero catch was:

pa ~ s(calyr) + s(sst) + s(long,lat) + s(t200) + month.f + port.f + ran(event.f)

(see Table 3 for denotation to covariate codes)

Predictions from the Probability of Catch (binomial) model indicate an increasing trend in the probability of catching a striped marlin up to the early 2000's and then a slight decline in later years although confidence intervals are overlapping making it difficult to validate this trend. (Figure 4; Table 6). The approximate R^2 value provided by summary.gam in R was 0.341 for this Probability of Catch (binomial) model. Each of the terms included in this model had a significant effect ($p<0.05$) on the probability of catching a striped marlin (Table 7). The probability of catching a striped marlin increased with increasing SST, with more northerly latitudes and with more easterly longitudes (Figure 5). Conversely, the probability of catching a striped marlin decreased with increasing temperature at 200m depth (Figure 5). The probability of catching a striped marlin was highest between January and May (Figure 5).

The final model used for the catch rate, given that the catch rate was non-zero was:

log(cpue) ~ s(calyr) + month.f + s(long,lat) + s(logbath) + s(alt) + ran(event.f)

(see Table 3 for denotation to covariate codes)

Predictions from the Non-Zero Catch CPUE (log-normal) model indicate an increasing trend in CPUE up to the early 2000's and then no change in the trend in consequent years (Figure 3; Table 6). The terms included in the Non-Zero Catch CPUE (log-normal) model explained 34% of the variability of the non-zero catch rates (adj. $R^2 = 0.342$ provided by summary.gam in R). There were significant differences in the non-zero catch rates for each of the smooth terms included in the Non-Zero Catch CPUE (log-normal) model (Table 8). Similar trends to the Probability of Catch (binomial) model were found in the Non-Zero Catch CPUE (log-normal) model for fishing location and month with non-zero catch rates highest at more northerly latitudes, more easterly longitudes and between January and May (Figure 6). There was a significant negative trend for Sea Surface Height Anomaly and a significant positive trend for the log of bathymetry for the Non-Zero Catch CPUE (log-normal) model (Table 8; Figure 6).

Standardised catch rates indicate an increasing trend to a peak in 2002 and then no significant change in the catch rate to 2011 (Figure 4; Table 6). There is some evidence for a slight decline in the standardised catch rates although approximate overlapping confidence intervals make it difficult to validate this trend.

Table 6. Predictions for the catch rates given that the striped marlin catch was non-zero (Non-Zero Catch CPUE model), for the probability of a non-zero striped marlin catch (Probability of Catch model) and for the overall standardised catch rate (Non-Zero Catch CPUE and Probability of Catch models averaged). The raw annual catch rates (+/- 95% confidence intervals) are also provided.

	Non-Zero Catch CPUE model		Probability of Catch model		Standardised (Predicted)		Unstandardised (Raw)	
Calendar Year	**CPUE (>0)**	**± 95% CI**	**Pr (catch)**	**± 95% CI**	**CPUE**	**± 95% CI**	**CPUE**	**± 95% CI**
1994	0.073	0.025	0.627	0.314	0.046	0.028	0.077	0.056
1995	0.084	0.022	0.737	0.210	0.062	0.024	0.082	0.068
1996	0.096	0.021	0.818	0.137	0.079	0.022	0.149	0.081
1997	0.109	0.021	0.873	0.093	0.095	0.021	0.170	0.160
1998	0.122	0.022	0.909	0.066	0.111	0.021	0.078	0.043
1999	0.133	0.022	0.932	0.049	0.124	0.022	0.118	0.049
2000	0.142	0.022	0.944	0.040	0.134	0.022	0.182	0.086
2001	0.147	0.022	0.951	0.035	0.139	0.022	0.123	0.052
2002	0.148	0.022	0.955	0.032	0.141	0.021	0.128	0.044
2003	0.148	0.021	0.956	0.031	0.141	0.021	0.130	0.081
2004	0.146	0.021	0.955	0.032	0.139	0.021	0.168	0.064
2005	0.144	0.021	0.951	0.034	0.137	0.021	0.161	0.076
2006	0.142	0.021	0.946	0.037	0.135	0.021	0.150	0.072
2007	0.142	0.021	0.936	0.043	0.133	0.021	0.122	0.080
2008	0.142	0.022	0.924	0.050	0.131	0.021	0.225	0.099
2009	0.142	0.023	0.906	0.063	0.129	0.023	0.112	0.047
2010	0.142	0.027	0.882	0.087	0.126	0.027	0.248	0.144
2011	0.143	0.037	0.852	0.132	0.122	0.037	0.149	0.094

Table 7. Degrees of freedom (df) and approximate *p*-values (from anova.gam in R) for all terms in the Probability of Catch (binomial) model (using anova.gam function in R).

Variable	df#	p-value	Significance level
s(CalYr)	2.591	0.004043	**
s(sst)	1	0.01208	*
s(long,lat)	2	0.000388	***
s(t200)	1	4.42E-05	***
month.f	8	0.000849	***
port.f	18	5.43E-08	***

* 0.05 ** 0.01 *** 0.001

estimated degrees of freedom for smoothed terms

Table 8. Degrees of freedom (df) and approximate *p*-values (from anova.gam in R) for all terms in the Non-Zero Catch CPUE (log-normal) model (using anova.gam function in R)

Variable	df#	p-value	Significance level
s(CalYr)	2.864	5.34E-03	**
month.f	8	1.11E-05	***
s(long,lat)	13.845	5.86E-10	***
s(logbath)	3.264	4.81E-06	***
s(alt)	2.79	2.97E-05	***

** 0.01 *** 0.001

estimated degrees of freedom for smoothed terms

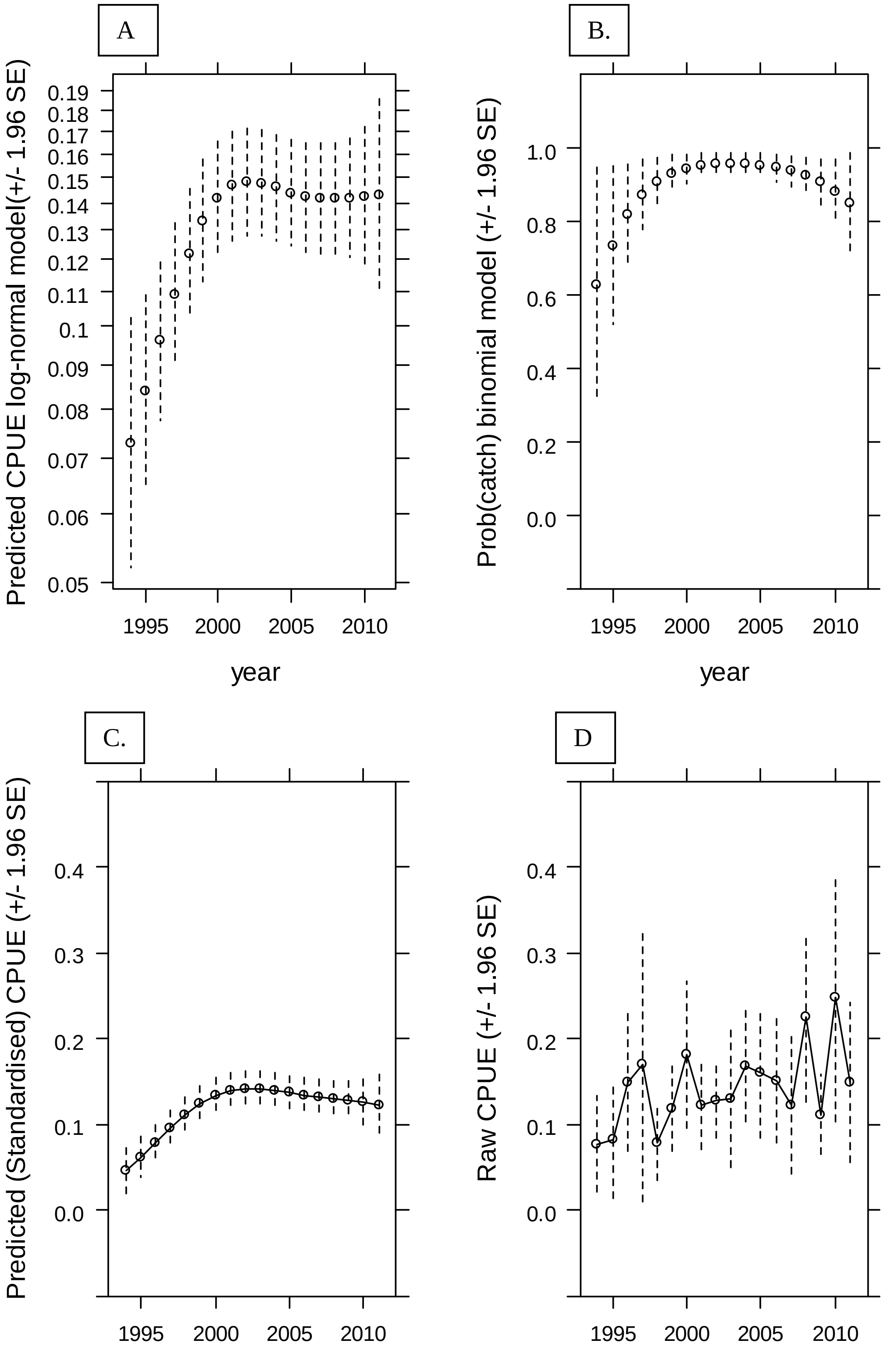


Figure 4. Plots of the predictions for: A. the catch rates given that the striped marlin catch was non-zero (Non-Zero Catch CPUE log-normal model); B. the probability of a non-zero striped marlin catch (Probability of Catch binomial model); C. the overall standardised catch rate (Non-Zero Catch CPUE and Probability of Catch models averaged); and D. plot of the raw annual catch rates (CPUE). Dotted lines show approximate 95% confidence intervals (±1.96 SE).

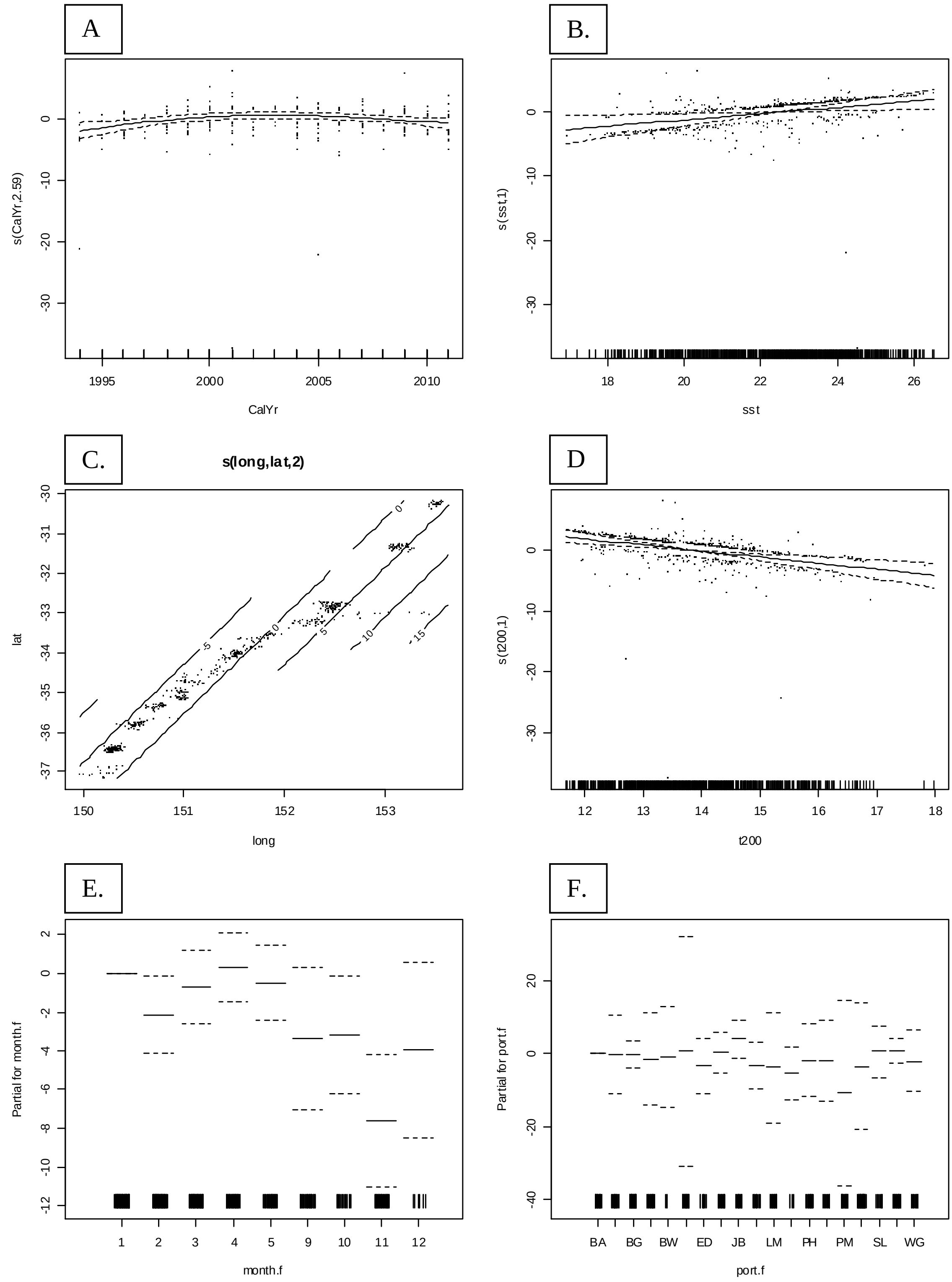


Figure 5. The predicted trends of each explanatory variable included in the Probability of Catch (binomial) model: A. s(calyr); B. s(sst); C. s(long,lat); D. s(t200); E. month.f and F. port.f. Dotted lines indicate approximate 95% confidence intervals for predictions (solid line) for the 1-dimensional smooth terms and categorical factors. Plotted points on each plot represent partial residuals for that term. See Table 3 for denotations to covariate codes. See Appendix 5 for a list of codes for port.f.

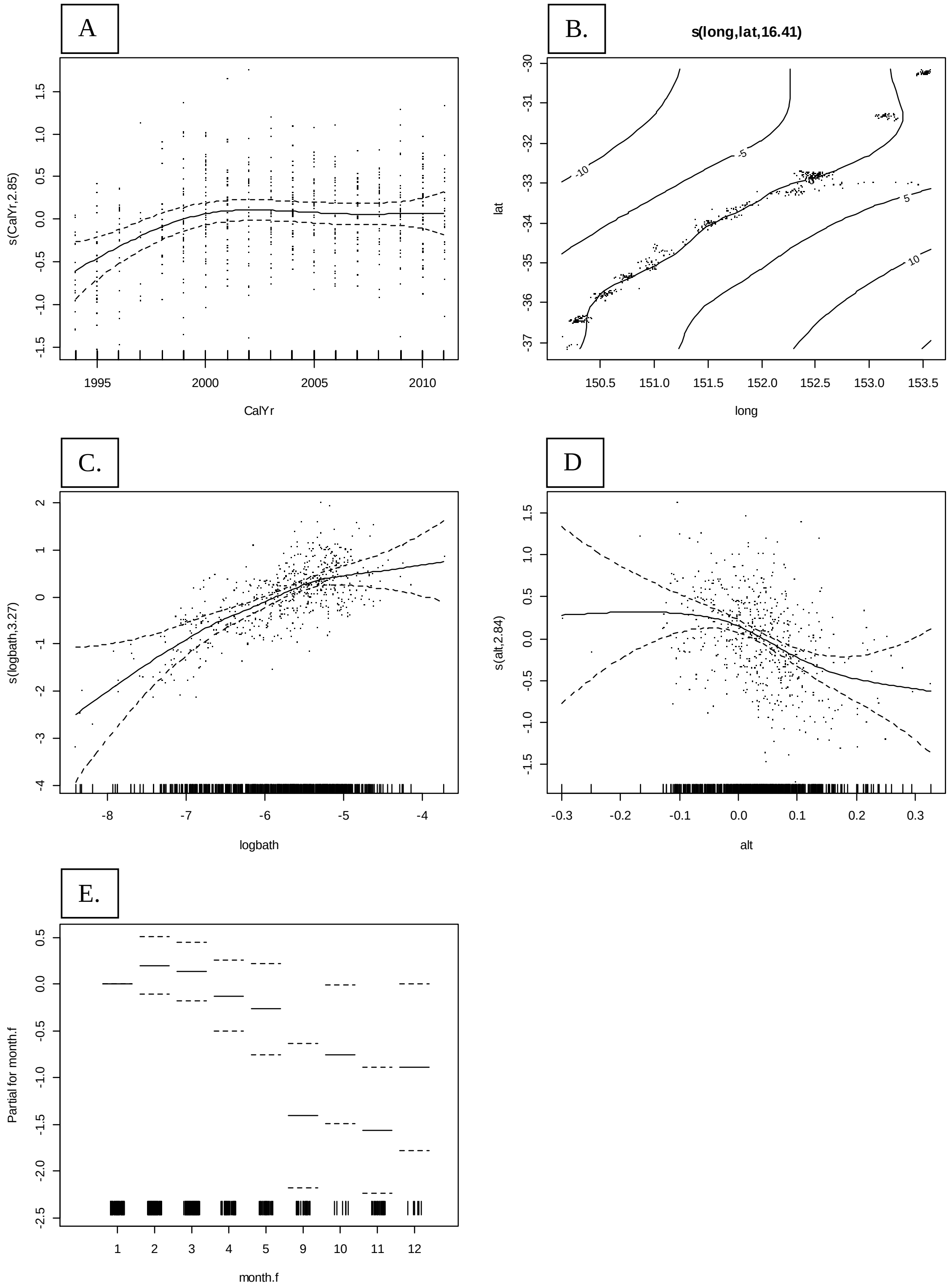


Figure 6. The predicted trends of each explanatory variable included in the log-normal (Non-Zero Catch CPUE) model: A. s(calyr); B. s(long,lat); C. s(logbath); D. s(alt) and E. month.f. Dotted lines indicate approximate 95% confidence intervals for predictions (solid line) for the 1-dimensional smooth terms and categorical factors. Plotted points on each plot represent partial residuals for that term. See Table 3 for denotations to covariate codes. See Appendix 5 for a list of codes for port.f.

4. DISCUSSION

This report provides an annual weight index and catch rate standardisation for recreational-caught striped marlin for southeast Australia (~30°S – 40°S) within sub-area 3 of the previous southwest Pacific Ocean (SWPO) striped marlin stock assessment region (Langley *et al.* 2006). The outputs of this report relate to SWPO sub-area 3 because of the concentration of the fishery in this region with minimal recreational catches in sub-area 2 (~15°S – 30°S) of about 3% compared with about 97% for sub-area 3.

Annual landed catch records from game fish clubs represent the only available long time series of catch data for the southeast Australian recreational striped marlin fishery. These records were combined with records from the New South Wales (NSW) Gamefish Tagging Program (GTP) to provide an annual weight index for recreationally-caught striped marlin from southeast Australian waters from 1936 to 2010. Investigation of limited recapture data from the GTP indicated that there is not likely to be any inherent bias on the average weight of tagged and released individuals as a result of fish weight estimation.

Striped marlin weight data derived from the recreational club-based fishery in SWPO sub-area 3 indicates a decline from 107kg in the mean weight of fish post World War II to an average centred on approximately 80kg from the 1980's onwards. This decline in mean weight may be influenced by the spatial distribution of catches with all striped marlin caught before World War II recorded for the Bermagui Big Game Anglers Club, which is on the south coast of NSW. A comparison in average weights between clubs from the north, central and south coasts of NSW from the 1980's onwards indicates increasing mean size from north to south (82kg, 84kg and 98kg, respectively).

Standardised catch rates derived from the GTMP indicate an increasing trend to a peak in 2002 and then no significant change in the catch rate to 2011 (Figure 4; Table 6). There is some evidence for a slight decline in the standardised catch rates although approximate overlapping confidence intervals make it difficult to validate this trend. There is the potential for these catch rates to be hyperstable masking a decline in striped marlin abundance, particularly since the early 2000's due to increased catchability from, for example, an increase in the use of live baits for catching striped marlin. The use of live baits for catching striped marlin is perceived to be a more efficient fishing method. Further investigations are needed using post-fishing interview data collected over the past five years to discern if there are any differences in catchability between different fishing methods (for example, using live baits versus lures). If there is hyperstability in these catch rates, it is expected that the masked declining trend would remain within current uncertainty limits.

There are some differences between these updated models and that done by Knight *et al.* (2006). Firstly, to remove pseudoreplication issues, the updated models incorporate tournament level structures (with event being fitted as a random effect rather than fishing days being used as replicates within a year). Random event effects allowed for correlations in catch rates between successive days in an event (and culminated in wider, but more realistic, estimates of uncertainty for the standardised year estimates). Secondly, additional covariates were investigated for inclusion in the model selection process and oceanographic covariates such as Sea Surface Temperature (SST) and altimetry were matched to tournament catch and effort data at finer spatial scales.

The standardised catch rate estimates (and uncertainties) presented in this report may be further refined and improved in various ways. Investigations into directed fishing effort components of the tournament dataset should be incorporated into the models. The uncertainty associated with the standardised catch rate index may be improved, for instance, by using a bootstrap approach (such as in Knight *et al.*, 2006) rather than the analytic approximations used here. Other refinements to the environmental covariates and factors and the modelling process may also be possible. For instance, month effects may be more parsimoniously modelled as a smoothed trend (rather than separate month effects).

Collation of historic club records is also ongoing and the future role of these data needs to be investigated. Australian recreational fisheries datasets for striped marlin could be improved in the future with the introduction of a game fishing permit or fishing licence system with no exemptions (for example, pensioners that would normally be exempt would be required to obtain a licence but would not be required to pay for that licence). With a licence or permit system in place the cost of probability-based surveys with the resolution to sample recreational billfish catches would no longer be prohibitive.

5. REFERENCES

Anon. 2010. The Official GFAA Gamefishing 2010 Journal. Bluewater Publishing Pty Ltd.

Bates, D., M. Maechler, and B. Bolker. 2011. Linear mixed-effects models using S4 classes.

Bromhead, D., J. Pepperell, and J. Findlay. 2003. Striped marlin: An analysis of fishery interactions of the southeast coast of Australia. Working Paper BBRG-14. 16th Meeting of the Satnding Committee on Tuna and Billfish, Mooloolaba, Australia, 9–16 July 2003.

Bromhead, D., J. Pepperell, B. Wise, and J. Findlay. 2004. Striped marlin: biology and fisheries. Bureau or Rural Sciences, Canberra, Australia.

Campbell, R., T. Davis, B. Edwards, G. Henry, J. Kalish, B. Lamason, J. Pepperell, and P. Ward. 2002. Assessment of black and blue marlin in the Australian fishing zone. Department of Agriculture, Fisheries and Forestry,, Canberra, ACT, Australia.

Elandt-Johnson, R. C. and N. L. Johnson. 1980. Survival Models and Data Analysis. John Wiley & Sons, New York.

Goadby, P. 1987. Big fish and blue water. Gamefishing in the Pacific. Angus and Robertson, Sydney and London.

Knight, E., T. Park, D. Bromhead, P. Ward, S. Barry, and R. Summerson. 2006. Analyses of interactions between longline and recreational gamefish fisheries taking or tagging striped marlin off New South Wales. Bureau of rural Sciences, Canberra, Australia.

Langley, A., B. Moloney, D. Bromhead, K. Yokawa, and B. Wise. 2006. Stock assessment of striped marlin (*Tetrapturus audax*) in the southwest Pacific Ocean. Working Paper SA WP-6. 2nd Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Manila, the Philippines 7–18th August, 2006.

Maunder, M. N. and A. E. Punt. 2004. Standardizing catch and effort data: a review of recent approaches. Fisheries Research **70**:141–159.

McIntyre, J. 2007. The Foundations of Australian Gamefishing. The Official GFAA Gamefishing 2007 Journal:24–31.

McIntyre, J. 2008. The Post-World War II era of Australian gamefishing. The Official GFAA Gamefishing 2008 Journal:25–32.

Oehlert, G. W. 1992. A Note on the Delta Method The American Statistician **46**:27–29.

Park, T. 2007. NSW Gamefish Tournament Monitoring – Angling Research Tournament Monitoring Program. 94, NSW Department of Primary Industries, Cronulla Fisheries Research Centre, Cronulla, NSW, Australia.

Pollock, K. H., C. M. Jones, and T. L. Brown. 1994. Angler Survey Methods and their Applications in Fisheries Management. American Fisheries Society.

R Development Core Team. 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing,. Vienna, Austria.

Steffe, A., J. Murphy, D. Chapman, B. E. Tarlinton, G. Gordon, and A. Grinberg. 1996. An assessment of the impact of offshore recreational fishing in New South Wales waters on the management of commercial fisheries. 94/053, NSW Fisheries Research Institute, Cronulla, NSW.

Stuart, A. and K. Ord. 1998. Kendall’s Advanced Theory of Statistics Volume 1: Distribution Theory. 6th Edition edition. Arnold, London.

West, L. 1990. A review of existing and potential data systems for recreational fishing for tunas and billfishes: East Coast of Australia / for Department of Primary Industries and Energy and East Coast Tuna Management Advisory Committee. Kewagama Research, Tewantin, Queensland.

Wood, S. 2011. gamm4: Generalized additive mixed models using mgcv and lme4.

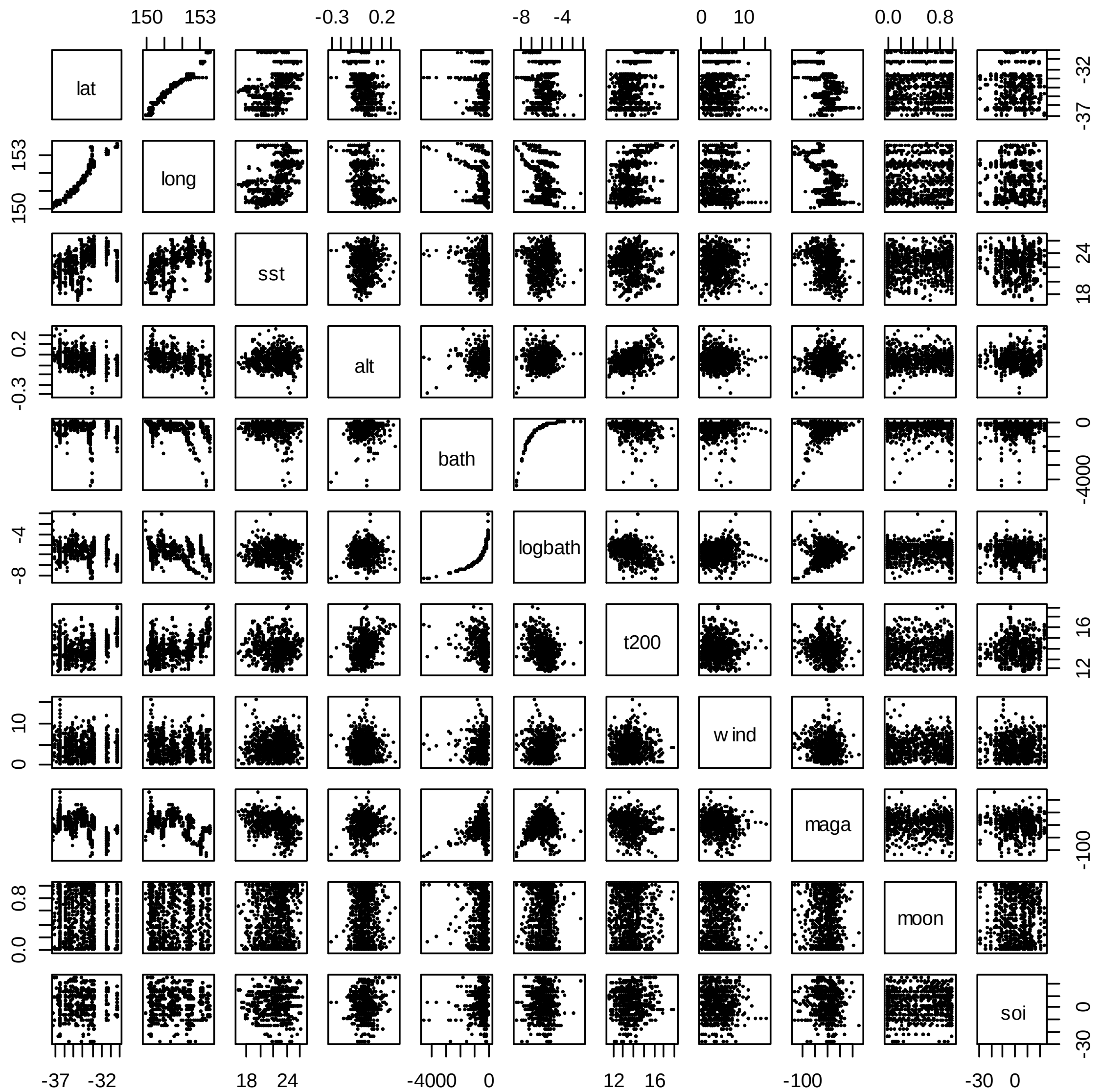
6. APPENDICES

Appendix 1. A summary of the catch (number and weight in kilograms of striped marlin) from club-based fishery annual report data by club and fiscal year (game fishing season). Clubs by year with zero catch denotes that an annual report was obtained and no striped marlin landings were recorded.

Club ==>	Batemans Bay GFC		Bermagui BGAC		Botany Bay GFC		Broken Bay GFC		Canberra GFC		Eden S&GFC		Jervis Bay GFC		Lake Maquarie GFC		Latrobe Valley GFC		Merimbula GFC	
FiscalEndYr	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg
1936			46	4729																
1937			20	2121																
1938			24	2540																
1939			3	344																
1940			32	3448																
1941			11	1203																
1946			1	134																
1948			4	434																
1949			8	772																
1950																				
1951			1	117																
1952			1	142																
1953																				
1954																				
1955																				
1956			2	166																
1959																				
1960																				
1961																				
1962																				
1963							3	130												
1964							1	68												
1965																				
1966																				
1967							2	161												
1968			1	94			3	158												
1969							2	103												
1970																				
1971							2	161												
1972			1	118			1	89												
1973																				
1974							5	204							2	148				
1975			1	87			4	368							1	80				
1976							3	151							1	103				
1977			1	96	1	162	2	108												
1978			1	81	1	71	3	227							1	40				
1979			2	252	3	182	1	68							1	90				
1980	6	547	3	283			3	216							4	293				
1981			24	2489			3	179							3	255				
1982	3	219	6	701			4	389							5	371				
1983	2	190	7	794			2	93							1	78				
1984			10	982			6	600							2	156	1	88		
1985					1	45	3	232												
1986	1	79	8	692			12	1125	2	204					10	954				
1987			3	311	1	70	16	1361	3	222					7	577				
1988					17	1282	18	1470	1	110					11	942	1	65		
1989					13	983	14	1036							13	925	1	74		
1990	1	97	10	884	15	1295	6	433	1	81					3	239				
1991					5	405	3	252												
1992			11	1014	20	1745	10	830							11	776	1	101		
1993	2	194	9	962	4	349	3	232							7	583				
1994			19	1779	13	1120	11	984	5	402					1	66	2	188		
1995			20	1794	8	699	15	1441	2	179					4	373	2	177		
1996	5	419	33	3337	19	1705	23	1980	5	508					39	3222	5	397		
1997	8	705	18	1541	17	1298	9	811							17	1322	2	200		
1998			2	181	4	384	1	84	2	229					5	480	2	211		
1999	4	355	10	1007	5	483	4	349	1	131					8	616	3	304		
2000	4	397	12	1218	1	140	8	648	3	365					17	1373				
2001	1	120	50	5005	4	302	8	676							1	65				
2002	1	120	145	13903	5	426	10	983	2	222										
2003			54	5193	3	278	2	156												
2004			60	5909	1	83	14	1192	4	493	3	384								
2005	7	849	101	10662			12	1082	6	745										
2006	2	213	33	3330	2	205	6	481	1	99					4	309				
2007	4	391	44	4167	1	108	3	233	1	98	5	380								
2008	3	307	15	1475			7	643			2	156			10	801				
2009			10	917	1	75	3	250												
2010			11	1043	1	84	10	830					1	97	23	1974			1	99
2011	5	519	12	1151			6	541					3	266	9	763				
Total	**59**	**5720**	**900**	**89600**	**166**	**13975**	**287**	**23801**	**39**	**4086**	**10**	**920**	**4**	**364**	**221**	**17969**	**20**	**1805**	**1**	**99**

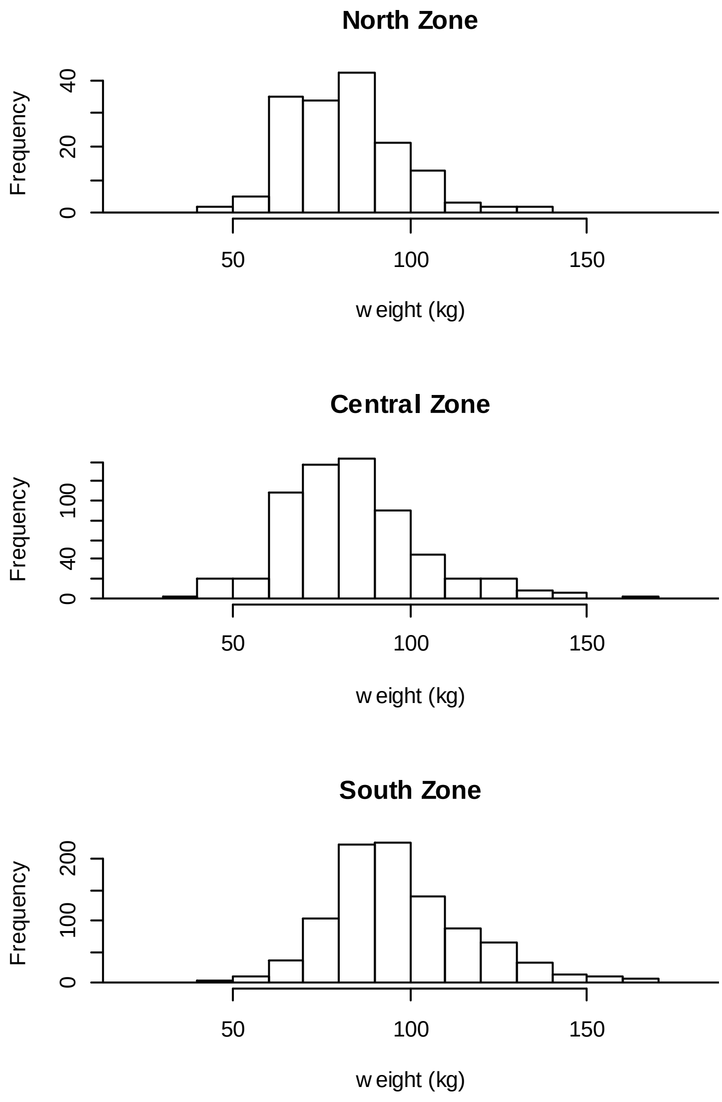
Club ==>	NC & Pt Stephens GFC		NSW GFC		Port Macquarie GFC		Port Hacking GFC		Shellharbour GFC		Shoalhaven GFC		South Gippsland GFC		Sydney GFC		Ulladulla GFC		Victorian GFC		Total	
FiscalEndYr	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg
1936																					**46**	**4729**
1937																					**20**	**2121**
1938																					**24**	**2540**
1939																					**3**	**344**
1940																					**32**	**3448**
1941																					**11**	**1203**
1946																					**1**	**134**
1948			7	606																	**11**	**1039**
1949			7	562																	**15**	**1334**
1950			3	313																	**3**	**313**
1951			6	516																	**7**	**633**
1952																					**1**	**142**
1953															4	303					**4**	**303**
1954															2	159					**2**	**159**
1955															1	61					**1**	**61**
1956																					**2**	**166**
1959															4	321					**4**	**321**
1960															4	281					**4**	**281**
1961	4	184													2	150					**6**	**333**
1962															3	250					**3**	**250**
1963							1	35													**4**	**165**
1964	2	127													4	255					**7**	**450**
1965															1	46					**1**	**46**
1966							1	98							1	43					**2**	**141**
1967	2	87													1	74					**5**	**323**
1968	1	45													1	76					**6**	**374**
1969															3	263					**5**	**366**
1970	1	25																			**1**	**25**
1971							1	59							4	277					**7**	**498**
1972															1	73					**3**	**280**
1973							1	7													**1**	**70**
1974	1	55					1	45							5	308					**14**	**761**
1975															3	225					**9**	**760**
1976															3	204					**7**	**458**
1977																					**4**	**366**
1978	4	256					1	49							3	230					**14**	**953**
1979	2	136					3	22													**12**	**948**
1980	6	480					2	155							2	180			3	276	**29**	**2429**
1981	1	43					1	52							3	162			6	518	**41**	**3696**
1982	1	78					2	166											3	375	**24**	**2298**
1983	1	59																			**13**	**1214**
1984	1	46					1	113			1	73			5	488					**27**	**2546**
1985	6	510									5	471			12	1151					**27**	**2409**
1986	4	325			1	83	3	248							12	910			2	154	**55**	**4774**
1987	9	772					2	176			6	514			19	1358			5	471	**71**	**5831**
1988	16	1289			2	159	5	42			5	424			17	1264			3	201	**96**	**7607**
1989	11	814			6	432	4	282			2	106			11	867			7	611	**82**	**6128**
1990	4	309			3	197	11	816							9	703			1	82	**64**	**5134**
1991	4	349			2	128							1	94	3	231			3	285	**21**	**1742**
1992	7	563			2	153	5	356					1	104					2	228	**70**	**5868**
1993	2	155			1	71	1	82			3	260			5	362			3	264	**40**	**3513**
1994	4	341			2	140	3	248			4	317			8	709					**72**	**6291**
1995	3	282					2	157			6	520	1	94	4	351					**67**	**6066**
1996	14	1203			2	171	4	342							3	290					**152**	**13573**
1997	5	400			2	163					6	496	2	189	3	211			3	293	**92**	**7627**
1998	2	186			2	199	2	149			2	158	1	93					5	452	**30**	**2804**
1999	1	69									4	375							6	620	**46**	**4307**
2000	3	274											5	520							**53**	**4934**
2001	3	310					2	223											1	84	**70**	**6784**
2002					2	190					3	303	1	104							**169**	**16252**
2003	5	402									3	247									**67**	**6275**
2004	3	271									2	197									**87**	**8527**
2005	4	314									3	323									**133**	**13976**
2006	2	185									1	64			3	232					**54**	**5118**
2007					1	106			2	176	2	302			2	237	1	167			**66**	**6365**
2008	6	603			2	134			3	390	2	191			5	415	2	196			**57**	**5309**
2009									9	810	1	82			4	333					**28**	**2467**
2010									4	338	2	205			18	1482	4	320			**75**	**6472**
2011	2	163							6	550					3	254	2	221			**48**	**4429**
Total	**147**	**11708**	**23**	**1997**	**30**	**2327**	**59**	**4543**	**24**	**2265**	**63**	**5626**	**12**	**1197**	**201**	**15785**	**9**	**904**	**53**	**4911**	**2328**	**209600**

Appendix 2. Pairwise plots and correlations for all covariates considered in the model selection process.



	lat	long	sst	alt	bath	logbath	t200	wind	maga	moon	soi
lat	1	0.98	0.43	-0.34	-0.21	-0.22	0.37	0.02	-0.45	0.01	0.01
long	0.98	1	0.47	-0.33	-0.29	-0.27	0.37	0.02	-0.48	0.02	-0.01
sst	0.43	0.47	1	0.04	-0.02	0.05	-0.02	0.01	-0.26	0.05	0.06
alt	-0.34	-0.33	0.04	1	0.08	0.09	0.32	-0.02	0.17	0.05	0.01
bath	-0.21	-0.29	-0.02	0.08	1	0.85	-0.35	0.04	0.4	0	0.1
logbath	-0.22	-0.27	0.05	0.09	0.85	1	-0.4	0.13	0.23	0.05	0.08
t200	0.37	0.37	-0.02	0.32	-0.35	-0.4	1	-0.01	-0.2	-0.04	-0.02
wind	0.02	0.02	0.01	-0.02	0.04	0.13	-0.01	1	-0.11	-0.06	-0.01
maga	-0.45	-0.48	-0.26	0.17	0.4	0.23	-0.2	-0.11	1	-0.02	-0.02
moon	0.01	0.02	0.05	0.05	0	0.05	-0.04	-0.06	-0.02	1	0.03
soi	0.01	-0.01	0.06	0.01	0.1	0.08	-0.02	-0.01	-0.02	0.03	1

Appendix 3. Frequency histograms and mean and median weights (kilograms) of landed catch for spatial zones: North, Central and South from 1980 onwards. Clubs in the: North zone = Port Macquarie GFC and NC & Pt Stephens; Central zone = Botany Bay GFC, Broken Bay GFC, Lake Macquarie GFC, NSW GFC, Port Hacking GFC, Shellharbour GFC and Sydney GFC; South zone = Batemans Bay GFC, Bermagui BGAC, Canberra GFC, Eden S&GFC, Jervis Bay GFC, Latrobe V GFC, Merimbula GFC, Shoalhaven GFC, South Gippsland GFC, Ulladulla GFC, Victorian GFC, Victoria GFA.



Zone	Mean weight (kg)	Median weight (kg)
North	82.03	81.02
Central	83.75	81.55
South	97.59	95.00

Appendix 4. Landed, tagged and released and combined (landed + tagged) catch of striped marlin in number, weight (kg) and mean weight by calendar year from Game Fish Annual Report and Game Fish Tagging Program datasets.

	Landed			Tagged & released			Landed & Tagged Combined		
Calendar Year	No.	Weight (kg)	Average weight (kg)	No.	Est. Weight (kg)	Average est. weight (kg)	No.	Est. Weight (kg)	Average weight (kg)
1936	45	4657	103	0	0	0	45	4657	103
1937	20	2137	107	0	0	0	20	2137	107
1938	25	2659	106	0	0	0	25	2659	106
1939	6	654	109	0	0	0	6	654	109
1940	26	2794	107	0	0	0	26	2794	107
1941	11	1203	109	0	0	0	11	1203	109
1946	1	134	134	0	0	0	1	134	134
1947	3	237	79	0	0	0	3	237	79
1948	8	802	100	0	0	0	8	802	100
1949	15	1313	88	0	0	0	15	1313	88
1950	2	217	108	0	0	0	2	217	108
1951	7	633	90	0	0	0	7	633	90
1952	1	142	142	0	0	0	1	142	142
1953	4	303	76	0	0	0	4	303	76
1954	3	220	73	0	0	0	3	220	73
1956	2	166	83	0	0	0	2	166	83
1959	4	321	80	0	0	0	4	321	80
1960	5	350	70	0	0	0	5	350	70
1961	5	264	53	0	0	0	5	264	53
1962	3	250	83	0	0	0	3	250	83
1963	4	165	41	0	0	0	4	165	41
1964	6	366	61	0	0	0	6	366	61
1965	3	228	76	0	0	0	3	228	76
1966	2	117	58	0	0	0	2	117	58
1967	4	249	62	0	0	0	4	249	62
1968	7	528	75	0	0	0	7	528	75
1969	4	212	53	0	0	0	4	212	53
1970	1	25	25	0	0	0	1	25	25
1971	7	498	71	0	0	0	7	498	71
1972	3	280	93	0	0	0	3	280	93
1973	1	70	70	0	0	0	1	70	70
1974	15	893	60	2	104	52	17	997	59
1975	8	653	82	0	0	0	8	653	82
1976	8	587	73	0	0	0	8	587	73
1977	2	158	79	0	0	0	2	158	79
1978	15	1085	72	0	0	0	15	1085	72
1979	14	1117	80	0	0	0	14	1117	80
1980	29	2444	84	0	0	0	29	2444	84
1981	26	2149	83	0	0	0	26	2149	83
1982	22	2098	95	0	0	0	22	2098	95
1983	12	1105	92	0	0	0	12	1105	92
1984	26	2469	95	0	0	0	26	2469	95
1985	24	2129	89	16	820	51	40	2949	74
1986	56	4912	88	24	1696	71	80	6608	83
1987	70	5651	81	35	1941	55	105	7592	72
1988	99	7808	79	21	1380	66	120	9188	77
1989	80	6105	76	77	5053	66	157	11158	71
1990	61	4918	81	95	6255	66	156	11173	72
1991	35	3282	94	126	6756	54	161	10038	62
1992	62	5087	82	164	11856	72	226	16943	75
1993	40	3520	88	182	12650	70	222	16170	73
1994	66	5823	88	284	22706	80	350	28529	82
1995	75	6694	89	445	37949	85	520	44643	86
1996	146	13039	89	943	76555	81	1089	89594	82
1997	88	7311	83	1188	78159	66	1276	85470	67
1998	36	3359	93	1296	106452	82	1332	109811	82
1999	41	3818	93	1591	125140	79	1632	128958	79
2000	55	5125	93	1816	147130	81	1871	152255	81
2001	69	6837	99	713	57934	81	782	64771	83
2002	165	15740	95	1096	89653	82	1261	105393	84
2003	67	6342	95	823	63990	78	890	70332	79
2004	87	8518	98	946	76789	81	1033	85307	83
2005	134	14053	105	1210	94034	78	1344	108086	80
2006	54	5237	97	824	67715	82	878	72952	83
2007	67	6345	95	1115	87144	78	1182	93490	79
2008	51	4666	91	1117	89156	80	1168	93822	80
2009	30	2667	89	853	70396	83	883	73063	83
2010	71	6056	85	1191	96497	81	1262	102553	81
TOTAL	2244	201993	90	18193	1435910	79	20437	1637903	80

Appendix 5. List of ports (codes for port.f) and the number of fishing days and events by port as derived from the tournament catch and effort dataset.

Port Code	Port	No. of fishing days	No. of events
BA	Batemans Bay	61	23
BB	Botany Bay	29	13
BG	Bermagui	123	45
BK	Broken Bay	31	15
BW	Brisbane Waters	4	2
CH	Coffs Harbour	55	16
ED	Eden	14	5
GP	Greenwell Point	29	12
JB	Jervis Bay	29	10
KI	Kiama	17	10
LM	Lake Macquarie	40	20
ME	Merimbula	6	3
PH	Port Hacking	31	18
PJ	Port Jackson	19	11
PM	Port Macquarie	58	23
PS	Port Stephens	137	62
SL	Shellharbour	10	5
UL	Ulladulla	53	20
WG	Wollongong	20	11

Other titles in this series:

ISSN 1442-0147 ***(NSW Fisheries Research Report Series)***

No. 1 Otway, N.M. and Parker, P.C., 1999. A review of the biology and ecology of the grey nurse shark (*Carcharias taurus*) Rafinesque 1810. 36pp.

No. 2 Graham, K.J., 1999. Trawl fish length-weight relationships from data collected during FRV Kapala surveys. 105pp.

No. 3 Steffe, A.S., Chapman, D.J. and Murphy, J.J., 1999. A description of the charter fishing boat industry operating in the coastal and estuarine waters of New South Wales during 1997-98. 33pp.

No. 4 Reid, D.D. and Smith, I.R., 1998. The 1998 Pacific oyster survey. 14pp.

No. 5 Walford, T. and Pease, B., 2000. Strategies and techniques for sampling adult anguillid eels. Proceedings of a workshop held at FRI, Cronulla, Australia, August 1999. 176pp.

No. 6 Heasman, M. and Lyall, I., 2000. Proceedings of the workshop held on 3 March 2000 at the Sydney Fish Markets: Problems of producing and marketing the flat oyster *Ostrea angasi* in NSW. 57pp.

No. 7 Heasman, M., 2003. Proceedings of the Sydney Rock Oyster Hatchery Workshop held on 8 and 9 August 2002 at Port Stephens, NSW. 164pp.

No. 8 Allan, G.A., 2003. Proceedings of the Aquafin CRC Snapper Workshop held on 26 September 2002 at the Convention Centre, Melbourne (Aquafin CRC 2001/208). 107pp.

No. 9 Faragher, R.A., 2004. Hooking mortality of trout: a summary of scientific services. 9pp.

No. 10 Daly, T., 2004. Summary of Proceedings from the *Perkinsus* Workshop held at the Cronulla Fisheries Centre on 3 September 2003. 32pp.

ISSN 1449-9959 ***(NSW Department of Primary Industries - Fisheries Research Report Series)***

No. 11 Baumgartner, L., 2005. Fish in Irrigation Supply Offtakes: A literature review. 22pp.

No. 12 Ganassin, C. and Gibbs, P., 2005. Descriptions of the wildlife species that commonly occur in the marine and estuarine waters of NSW. 88pp.

No. 13 Nell, J., 2006. Manual for mass selection of Sydney rock oysters for fast growth and disease resistance. 57pp + 110pp attachments.

No. 14 Gilligan, D. and Rayner, T., 2007. The distribution, spread, ecological impacts and potential control of carp in the upper Murray River. 25pp.

No. 15 Baumgartner, L., 2007. Fish communities of the Nepean River in the vicinity of Pheasants Nest Weir. 18pp.

No. 16 Gilligan, D., 2007. Annual progress report towards achievement of the Lower Murray Darling Catchment Action Plan 2004 – 2015: Fish Community Monitoring 2005/06. 42pp.

No. 17 Gale, R., Silberschneider, V. and Stewart, J., 2007. A biological and economic assessment of the 2001 change in the Minimum Legal Length (MLL) of snapper in NSW. Report to the NSW Ocean Trap & Line Management Advisory Committee, December 2007. 43 pp.

No. 18 Rowling, K., 2008. Review of 'Bobbin Gear' in the NSW Ocean Trawl Fishery. 15 pp.

No. 19 Baumgartner, L., Cameron, L., Faragher, B. and Pogonoski, J., 2008. An assessment of the trout fishery in Oberon Dam and the Fish River. 23pp.

No. 20 O'Connor, W., Dove, M., Finn, B. and O'Connor, S., 2008. Manual for hatchery production of Sydney rock oysters (*Saccostrea glomerata*). 53pp.

No. 21 Gillson, J.P., Scandol, J.P. and Suthers, I.M., 2008. Impacts of freshwater flow on catch rates of estuarine fisheries resources in New South Wales. 66pp.

No. 22 Gilligan, D., 2008. Lower Murray-Darling Catchment Action Plan 2004 – 2016: Fish community monitoring report card for 2006/07. 58pp.

ISSN 1837-2120 ***(Industry & Investment NSW – Fisheries Research Report Series)***

No. 23 Ghosn, D., 2009. Data summary from the monitoring of Australian bass and native fisheries via competition-based angling in NSW: 1988 – 2008. Interim Report. 74pp.

No. 24 Gilligan, D., 2009. Lower Murray-Darling Catchment Action Plan: Fish Community Monitoring Report Card for 2008/09. 62pp.

No. 25 Knight, J.T. 2010. Penrith Lakes Fish Scheme – 2009 Fish Monitoring Program. 69pp.

No. 26 Stewart, J., Ballinger, G. and Ferrell, D., 2010. Review of the biology and fishery for Australian sardines (*Sardinops sagax*) in New South Wales – 2010. 59pp.

No. 27 Stewart, J., Rowling, K., Hegarty, A-M. and Nuttall, A, 2010. Size and age at sexual maturity of snapper *Pagrus auratus* in New South Wales 2008/09. 38pp

No. 28 Gilligan, D., 2010. Lower Murray-Darling Catchment Action Plan: Fish Community Monitoring Report Card for 2009/10. 62 pp.

ISSN 1837-2120 ***(Fisheries Research Report Series)***

No. 29 McKenzie, R.D. and Montgomery, S.S., 2012. A preliminary survey of pipis (*Donax deltioides*) on the New South Wales south coast. 23pp.

No. 30 Ghosn, D., Collins, D., Baiada, C and Steffe, A., 2012. Catch per unit effort and size composition of striped marlin caught by recreational fisheries in southeast Australian waters. 34pp