

**Changes in the Structure of Demersal Fish Communities of the South
East Australian Continental Shelf from 1915 to 1961**

by

Neil L. Klaer, B.Sc. M.App.Sc.
Applied Ecology Research Group
University of Canberra
Canberra ACT 2602

A thesis submitted in fulfilment of the requirements for a degree of Doctor
of Philosophy at the University of Canberra

May 2006

Certificate of Authorship of Thesis

Except as specially indicated in footnotes, quotations and the bibliography, I certify that I am the sole author of the thesis submitted today entitled -

**Changes in the Structure of Demersal Fish Communities of the South East
Australian Continental Shelf from 1915 to 1961**

in terms of the Statement of Requirements for a Thesis issued by the University Higher Degrees and Scholarships Committee.

Signature of Author _____

Date _____

Acknowledgements

There are a large number of people who have made substantial contributions to this thesis. Professor Robert Kearney (University of Canberra) was my primary supervisor for this project, providing support, encouragement and review of my work over the past five years despite the difficulties in supervising work being done externally in Hobart. Dr Tony Smith (CSIRO) was my secondary supervisor, providing support generally for my work, and review of drafts of this thesis.

Mr Richard Mansfield, a former owner of Red Funnel Trawlers Pty Ltd (one of the main steam trawler companies operating in the SE Fishery) supplied company catch records that helped considerably with the interpretation of details in the per-haul data already held. He also helped with first-hand knowledge of operating procedures in the 1950s and early 1960s. Mr Norm Colless, who was an apprentice on the steam trawl vessels after World War II, also provided valuable information on the operating procedures of the vessels.

Richard Tilzey (Bureau of Rural Sciences), Kevin Rowling and Ken Graham (NSW Fisheries) assisted with investigations of the location and documentation of steam trawl data held at NSW Fisheries. Mark Bravington (CSIRO) gave useful advice on the design and interpretation of the log-linear model analyses, and Rob Campbell, Peter Thompson (CSIRO) and Andre Punt (University of Washington) provided useful comments on the chapter on abundance indices. Keith Jones from the South Australian Research and Development Institute helped locate unpublished information on the biology of Chinaman leatherjackets. Ron Thresher (CSIRO) provided the sunspot, SOI, and latitude of the sub-tropical ridge mean annual data series. Ian Barnes-Keoghan (Australian Bureau of Meteorology) provided access to standardised data sets of mean annual rainfall and temperature by collection station. Beth Fulton and Cathy Bulman (CSIRO) assisted with parameter values and comments on modelling using Ecopath.

Parts of this work detailed in Chapters 3 and 4 and the Appendix were carried out under a project funded by the Fisheries Research and Development Council. The History of Marine Animal Populations sub-project of the Census of Marine Life project of the US

Sloan Foundation assisted with funding the work presented in Chapters 5, 6, 7 and 8. The remainder of the work has received support from CSIRO as part of the assessment work for the SE Fishery, and within a more comprehensive SE Australian marine ecosystem project.

Last but not least, I would like to thank my 10-year-old daughter Nicole who particularly wanted to be mentioned in my thesis as she understood it to be an important piece of work.

Abstract

Haul-by-haul steam trawler catch and effort data for 1918–23, 1937–43 and 1952–57, which covers a large portion of the history of steam trawling in the Australian South East Fishery, were examined in detail for the first time. There were 64,371 haul records in total. The catch-rate for all retained catch combined shows a strong decline overall, with a brief recovery during World War II, probably due to increased retention of previously discarded species. The fishing fleet moved to more distant fishing grounds and deeper waters as the catch-rate declined. The catch-rates of the main commercial species followed a similar pattern in a number of regions within the fishery. The catch-rate of the primary target species – tiger flathead (*Neoplatycephalus richardsoni*) – dropped considerably from the early, very high, catch-rates. Chinaman leatherjacket (*Nelusetta ayraudi*) and latchet (*Pterygotrigla polyommata*) – species that were apparently abundant in the early years of the fishery – virtually disappeared from catches in later years. The appearance of greater catches of jackass morwong (*Nemadactylus macropterus*), redfish (*Centroberyx affinis*), and shark/skate during the war and afterwards was probably due to increased retention of catches of these species. The disappearance of certain species from the catch may be due to high fishing pressure alone, or to a combination of fishing pressure, changes in the shelf habitat possibly caused by the trawl gear, and environmental fluctuations.

Catch-rates in weight per haul per species were standardised to annual indices of abundance using a log-linear model. Standardised annual index trends for flathead, latchet and leatherjacket indicate a strong to severe decline over the period covered by the data. All species showed seasonal patterns, but the peak season varied depending on the species. The distribution of standardised catch-rate by area also differed greatly by species, and no single area showed consistent differences across all species. Day trawls caught more flathead, redfish and latchet, while night trawls caught more morwong and leatherjacket. Moon phase had less influence on catch-rates than the other factors examined. Correlation of annual index trends with a number of annual mean environmental factors was examined and no strong correlations were found.

Annual catches of the major commercial trawl species on the SE Australian shelf were estimated from recorded total trawl catches, catch species composition from subsamples and estimates of the rate of discarding. These annual catches, standardised indices of abundance and biological population parameters were used in single-species stock reduction models to estimate absolute biomass trends. Biological population parameters and the biomass estimates were used to calculate management reference point fishing mortality rates $F_{0.1}$, F_{spr30} and F_{msy} . Results showed that simple plausible population models can be constructed that account for catches over the long period of time from 1915 to 1961.

Simple mass-balance ecosystem models were built for the demersal community of the SE Australian shelf for 1915 and 1961 using the Ecopath software. Model inputs were consistent with a more comprehensive SE marine ecosystem model in development by CSIRO. The models demonstrate that biomass estimates produced by the single species stock reduction models can be consistently integrated into simple plausible mass-balance ecosystem models.

Modern stock assessments for the main commercial species in this fishery today mostly used data collected since about 1985. Abundance indices and total catch estimates from this study have been used in the most recent assessments for tiger flathead and morwong, allowing construction of the exploitation history for these species spanning almost 100 years. Use of the historical information has increased confidence in the estimates of the modern stock assessments – particularly management reference points, and has allowed us to quantify changes in fish abundance that have simply been documented anecdotally in the past.

Table of Contents

Certificate of Authorship of Thesis.....	i
Acknowledgements.....	ii
Abstract.....	iv
List of Figures.....	ix
List of Tables	xi
CHAPTER 1 - Introduction	1
CHAPTER 2 – Sources of available data	5
CHAPTER 3 – Conversion of CSIRO/NSW historical data	7
3.1 Introduction	7
3.2 Data from 1918-23.....	8
3.2.1 Raw data description	8
3.2.2 Loading procedure.....	9
3.2.3 Data quality	9
3.2.4 Data summary	13
3.3 Data from 1937-43.....	15
3.3.1 Raw data description	15
3.3.2 Loading procedure.....	16
3.3.3 Data quality	16
3.3.4 Data summary	19
3.4 Data from 1951-57.....	22
3.4.1 Raw data description	22
3.4.2 Loading procedure.....	23
3.4.3 Data quality	23
3.4.4 Data summary	24
3.5 Final data formats.....	26
CHAPTER 4 – Conversion of Red Funnel Trawlers historical data.....	27
4.1 Introduction	27
4.2 Skipper Logbooks 1952-61	28
4.2.1 Raw data description	28
4.2.2 Loading procedure.....	29
4.2.3 Data quality	32
4.2.4 Data summary	35
4.3 Landing records 1938-59	38
4.3.1 Raw data description	38
4.3.2 Loading procedure.....	40
4.3.3 Data quality	41
4.3.4 Data summary	45
4.4 Radio Reports 1946-57	49
4.4.1 Raw data description	49
4.4.2 Loading procedure.....	50
4.4.3 Data quality	52
4.4.4 Data summary	57
4.5 Final data formats.....	60

CHAPTER 5 – Trends in catch rates and species composition.....	65
5.1 Introduction	65
5.2 Methods.....	68
5.2.1 Data summary	68
5.2.2 Mean catch-rate of all landed commercial species.....	69
5.2.3 Catch-rate by main commercial species by area	69
5.3 Results	71
5.3.1 Data summary	71
5.3.2 Mean catch-rate of all landed commercial species.....	74
5.3.3 Catch-rate by main commercial species by area	79
5.4 Discussion.....	85
CHAPTER 6 – Abundance indices	90
6.1 Introduction	90
6.2 Methods.....	90
6.2.1 Input data.....	90
6.2.2 Astronomical Events	91
6.2.3 Conversion of continuous variables into factors	92
6.2.4 Sensitivity tests.....	93
6.2.5 Log-linear model (LLM).....	93
6.2.6 Standardised annual abundance index correlation with available long-term environmental data	94
6.3 Results	96
6.3.1 LLM results for all retained catch	96
6.3.2 Species-specific LLM results	102
6.3.3 Species-aggregated LLM results.....	104
6.3.4 Standardised annual abundance index correlation with available long-term environmental data	105
6.4 Discussion.....	106
6.4.1 Model design and possible biases in the methods and data processing	106
6.4.2 Changes in fishing practices through time	108
6.4.3 Conclusions	111
CHAPTER 7 – Population modelling	113
7.1 Introduction	113
7.2 Methods.....	113
7.2.1 Catch history per main commercial species.....	113
7.2.2 Stock reduction modelling	118
7.2.3 Management Reference Points.....	121
7.3 Results	124
7.3.1 Stock reduction modelling	124
7.3.2 Management reference points	128
7.4 Discussion.....	129
CHAPTER 8 – Ecosystem modelling.....	132
8.1 Introduction	132
8.2 Change in the SE shelf ecosystem prior to 1915	132
8.2.1 Natural fluctuations	133
8.2.2 Human extraction of marine organisms	133
8.2.3 Human-assisted invasions of exotic species.....	137
8.2.4 Human alteration to the physical environment.....	138
8.3 Methods.....	139
8.4 Results	141
8.5 Discussion.....	145

CHAPTER 9 – General discussion	147
9.1 Implications of the results for current management and further research	147
9.2 International significance of this work.....	153
References	155
Appendix 1 –Red Funnel Trawlers conversion tables.....	165

List of Figures

Figure 2.1. Summary of historical per-haul data available for the SE Australian shelf region by source (see text for explanation of sources).....	5
Figure 3.1. Catch positions - 1918-23.....	10
Figure 3.2. Estimated catch positions - 1937-43.....	17
Figure 3.3. Estimated catch positions - 1951-57.....	23
Figure 4.1. Estimated catch positions (200 and 1000 m isobaths also shown).	34
Figure 4.2. Comparison of catches per individual trip from skipper logbooks and corresponding landings by species.	44
Figure 4.3. Estimated radio report positions.	56
Figure 5.1. Photograph of the steam trawler <i>Moona</i> – one of the last to operate in New South Wales waters.	66
Figure 5.2. Early trawl grounds in shelf waters after Colefax (1934) (shaded blocks), and spatial strata used for the analyses in this study (between the horizontal lines).....	67
Figure 5.3. CPUE for steam trawlers only for all landed catch (from Houston 1955).....	75
Figure 5.4. CPUE for retained commercial catch by year. CPUE from haul-by-haul records in kg/h are shown as points on solid lines, and historical CPUE as presented by Houston (1955) in trawler-ton-months is shown as dashed lines.	75
Figure 5.5. Mean latitude fished by year.....	77
Figure 5.6. Mean latitude fished by year and month.....	78
Figure 5.7. Mean latitude fished by month over all years.....	78
Figure 5.8. Mean depth fished by year.....	78
Figure 5.9. Proportion of total hours trawled for hauls with location information (as per Figure 5.2) that were made in each area.....	79
Figure 5.10. Contribution per species to the total commercial CPUE by year for area D.	80
Figure 5.11. Contribution per species to the total commercial CPUE by year for area G.	81
Figure 5.12. Contribution per species to the total commercial CPUE by year for area H.	82
Figure 5.13. Percentage of hours trawled by depth for the periods 1918–23, 1937–43 and 1952–57 in area D.....	83
Figure 5.14. Percentage of hours trawled by depth for the periods 1918–23, 1937–43 and 1952–57 in area G.....	83
Figure 5.15. Percentage of hours trawled by depth for the periods 1918–23, 1937–43 and 1952–57 in area H.....	84
Figure 5.16. Contribution per species to the total commercial CPUE by year for area H in depths of less than 100 m.	85
Figure 6.1. Fitted vs residual values and normal quantile-quantile plot for the all retained catch LLM.	97
Figure 6.2. LLM results for year. Transformed (antilog) values are shown, as well as 95% confidence intervals. The percentage of all records having zero or <20 kg catches for that species is shown as connected dots.....	99
Figure 6.3. LLM results for each factor other than year. Transformed (antilog) values are shown, as well as 95% confidence intervals.	100
Figure 6.4. Comparison of the standardised annual index for all retained catch with un-standardised catch per hour trawled, and with estimates as presented by Houston (1955) as catch per trawler-ton.	101
Figure 7.1. Flathead base case stock reduction model results.....	124
Figure 7.2. Morwong base case stock reduction model results.....	125
Figure 7.3. Redfish base case stock reduction model results.....	125
Figure 7.4. Leatherjacket base case stock reduction model results.....	126
Figure 7.5. Latchet base case stock reduction model results.....	126
Figure 8.1. Simplified SE Australian shelf demersal food web.....	142
Figure 8.2. Comparison of estimated biomass values by functional group for 1915 and 1961.....	144
Figure 8.3. Differences in biomass per group from 1915 to 1961.	145

Figure 9.1. Base-case assessment of tiger flathead spawning biomass from 1915 to 2004 from Cui <i>et al.</i> (2004).	150
Figure 9.2. Base-case assessment of jackass morwong spawning biomass from 1915 to 2004 from Fay <i>et al.</i> (2004).	150

List of Tables

Table 3.1. 1918-23 Data description.....	8
Table 3.2. Vessel codes.....	9
Table 3.3. Data completeness.....	10
Table 3.4. Species codes in the 1918-23 data, and assumed identification.....	11
Table 3.5. Total retained catch and number of hauls by year.....	13
Table 3.6. Catch and number of hauls by vessel.....	13
Table 3.7. Total retained and discarded catch weight by depth interval.....	14
Table 3.8. Total retained catch (kg) by species by year.....	14
Table 3.9. 1937-43 Data description.....	15
Table 3.10. Data completeness 1937-43.....	16
Table 3.11. Fishing ground codes and assumed locations.....	18
Table 3.12. Species codes in the 1937-43 data, and assumed identification.....	19
Table 3.13. Total retained catch and number of hauls by year.....	19
Table 3.14. Catch and number of hauls by vessel.....	20
Table 3.15. Total retained catch weight by depth interval.....	20
Table 3.16. Total retained catch (kg) by species by year.....	21
Table 3.17. 1951-57 Data description.....	22
Table 3.18. Data completeness 1951-57.....	23
Table 3.19. Species codes in the 1951-57 data, and assumed identification.....	24
Table 3.20. Total retained catch and number of hauls by year.....	24
Table 3.21. Catch and number of hauls by vessel.....	25
Table 3.22. Total retained catch weight by depth interval.....	25
Table 3.23. Total retained catch by species by year.....	25
Table 4.1. Skipper logbook raw data description.....	28
Table 4.2. Fishing grounds and designated positions (degrees and minutes).....	31
Table 4.3. Data coverage for important fields.....	33
Table 4.4. Assumed species identification and CSIRO species codes.....	35
Table 4.5. Catch and effort summary – <i>Matong</i>	35
Table 4.6. Catch and effort summary – <i>Moona</i>	35
Table 4.7. Catch and effort summary – Total.....	36
Table 4.8. Skipper summary by vessel and number of trips.....	36
Table 4.9. Total retained catch weight by depth interval.....	37
Table 4.10. Total retained catch (kg) by species and year.....	37
Table 4.11. Landings raw data description.....	39
Table 4.12. Number of landings and unloadings by duration in days.....	41
Table 4.13. Comparison of catch per trip from skipper logbooks and corresponding landings by vessel, skipper and year.....	43
Table 4.14. Landings by vessel and year (kg).....	45
Table 4.15. Landings by vessel and year (kg).....	46
Table 4.16. Landings by species and year (kg).....	47
Table 4.17. Average price (cents/kg per financial year).....	48
Table 4.18. Radio reports raw data description.....	49
Table 4.19. Radio reported catch compared to skipper logbook.....	53
Table 4.20. Grounds fished by skipper logbook compared with radio reports.....	55
Table 4.21. Number of radio reports.....	57
Table 4.22. Total catch by radio report (kg).....	57
Table 4.23. Radio report trips.....	58
Table 4.24. Radio report days fished.....	58
Table 4.25. Radio report catch and effort summary.....	59

Table 5.1. Estimated annual total commercial landed catch for the New South Wales South East Fishery fishery, and for steam trawlers the total catch, number of vessels and the proportion of the total catch taken by steam trawl each year.....	72
Table 5.2. Number of hauls by vessel and year.....	73
Table 5.3. Total number of hauls, hours trawled and catch per commercial species from SEF haul-by-haul records for the period 1918 to 1957.....	74
Table 6.1. Reasons for removal of haul records from analyses.	91
Table 6.2. Valid records remaining for analysis per species and time period.....	91
Table 6.3. Vessel, time and environmental factors included in the LLM analyses and discrete classes defined for each factor.	92
Table 6.4. Measures of the effect of removing factors individually from the full LLM using data for all retained catch.....	96
Table 6.5. Proportion of the variance in the data explained by the LLM for all retained catch and each major species.	97
Table 6.6. Annual relative abundance indices and estimated 95% confidence intervals.	104
Table 6.7. r^2 correlation coefficient values of standardised abundance indices versus various annual environmental data series.	106
Table 7.1. Estimated total catch and catch by steam trawl and Danish seine by calendar year 1915 to 1961.	114
Table 7.2. Catch proportions by species for steam trawl.	115
Table 7.3. Catch proportions by species for Danish seine.	116
Table 7.4. Total estimated catch per species including discards taken on the SE Australian shelf by NSW fishing vessels.	117
Table 7.5. Biological parameters for the five major species.	121
Table 7.6. Stock reduction analysis sensitivity analyses per species.	127
Table 7.7. Management reference points.	128
Table 8.1. Density of fish biomass per species assuming distribution of the 1915 and 1961 populations are confined to trawl fishing grounds alone, or across the whole SE Australian shelf area.	139
Table 8.2. Average annual catch of the main species from 1957-1961 and the corresponding catch density on the trawling grounds, the implied F value of these catches using the 1961 total biomass estimates, natural and total mortality rates.	140
Table 8.3. Diet composition matrix by predator and prey functional groups.....	141
Table 8.4. Basic parameter estimates for the 1915 SE shelf demersal ecosystem.	143
Table 8.5. Basic parameter estimates for the 1961 SE shelf demersal ecosystem.	143