Using Innovative Techniques to Analyse Trends in Abundance for Non-Target Species

Malcolm Haddon

CSIRO Wealth from Oceans Flagship
Castray Esplanade,
GPO Box 1538,
Hobart,
TAS 7001,
Australia

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PRINCIPAL INVESTIGATOR: Dr M. Haddon
ADDRESS: CSIRO Wealth from Oceans Flagship
Castray Esplanade,
GPO Box 1538,
Hobart, TAS 7001, Australia
Telephone: 03 6232 5097

OBJECTIVES:

1. Investigate analysis methods capable of providing trend in abundance estimates for by-product and bycatch species
2. Conduct two workshops, aimed at identifying the management issues and the techniques available for analyzing trends in abundance in non-target species.

Contents

1 NON-TECHNICAL SUMMARY

Outcomes Achieved To Date:

Key outcomes of the workshops included:

- An increased awareness and recognition of the issues associated with non-target species (excluding Threatened, Endangered and Protected species)
- An increased awareness and recognition of the options currently used and that could be used when assessing non-target species (excluding Threatened, Endangered and Protected species)
- An appreciation of some of the implications of these various options for the future development of management strategies to be developed or adopted in the various jurisdictions
- A decision to develop a collaborative project proposal to explore the limits and choices in catch rate standardization through the use of simulated multi-species catch rate data. By knowing the alternative underlying realities that derive from multiple operating models it will be possible to examine how the various analytical methods are adapted to different underlying assumptions in different datasets

A major outcome of the workshops was an increased awareness and recognition of: (i) the issues associated with non-target species, and (ii) the options currently used and that could be used when assessing non-target species (excluding Threatened, Endangered and Protected species). Equally important was the appreciation of some of the implications of these various options for the future development of management strategies to be developed or adopted in the various jurisdictions:

- Across all jurisdictions two strategies were apparent for dealing with non-target species: either use a semi-quantitative risk assessment of some kind or conduct an analysis of catches and catch rates. No other strategies appear to be used currently. Simple mapping of catch distributions is becoming more common though how best to use this information is still being explored.
- Risk assessments take the form of the Commonwealth ERA process or a less detailed but more rapid multi-criterion decision analysis, which summarizes what is known about a species, and then a weight of evidence approach is used to determine whether a particular fishery was placing the species at risk of serious depletion.
- Assessments of non-target species are usually highly uncertain because they tend to be either semi-quantitative or data poor. This exacerbates problems that arise when making decisions about how to manage fisheries that include non-target species.
- It was recognized that relatively uncertain estimates of abundance trends in non-target species had potentially important implications for sustainably fished target species especially in multi-species fisheries.
- It was recognized that there is a growing need to provide management advice for more and more species, however, the requirement for more data analysis and assessment comes when resources for such work are declining. This situation of increasing needs/demands for broader management advice in the face of flat or decreasing funds requires further consideration and potentially re-prioritization. The development of simpler empirical fishery assessment methods may alleviate this issue, however, without a better understanding of the operation of these there is a risk

of reduced catches because of the increased uncertainties associated with simpler methods.
- Further consideration is needed to identify technical solutions for proceeding when a well-managed targeted fishery will be impacted by non-target species deemed to be at risk.

A second major outcome was an increased appreciation of how some of the conclusions reached during the workshops could be used to improve assessments and the management of non-target species. These included:

- Where a non-target species is less abundant in the catch than the target, but is known to be more productive in its life-history characteristics, the idea that looking after the target species would also take care of the sustainability of the non-target species was recognized as a possible positive outcome from the weight of evidence approach.
- Many alternative methods were identified for the standardization of catch rates (Delta method, GLMs, GAMs, GLMMs, and MVMMs), however, given our ignorance concerning the underlying reality being statistically modelled it appears impossible to determine whether there is an optimum analytical strategy. It is not the case that the most complex method is necessarily the best.
- When applying catch rate standardization it was possible to conclude that there were advantages to the inclusion of zero catches but it wasn't possible to identify whether there was an optimum method for doing this.
- However, relatively simple methods for the spatial analysis of the development and present operational expression of each fishery help understand the scope, the overlap with other fisheries, and the spatial focus of a fishery. Such methods can identify areas where shots might be expected to contain a species, and thus be useful for identifying zero shots for inclusion in cpue standardization. The methods included a formal use of GAMs to fit a surface to catch distributions or a more simple empirical mapping approach, but either gave the option of identifying some threshold catch level for the formal definition of the area usually inhabited by a species.
- Fishery dependent data, such as catch rates, always have data quality issues. These include everything from rounding errors (catches to the nearest 1 or 5 kgs, effort to the nearest half hour or hour, etc.), to deliberate misreporting (perhaps of positions in an attempt to keep a favoured location secret). It was recognized that diagnostic plots can aid in identifying such issues but the impact of such data quality issues is poorly understood and currently there are no effective solutions.

A third major outcome was the decision to develop a collaborative project proposal to explore the limits and choices in catch rate standardization through the use of simulated multi-species catch rate data. By knowing the alternative underlying realities that derive from multiple operating models it will be possible to examine how the various analytical methods are adapted to different underlying assumptions in different datasets. This idea for the proposal arose from the increased appreciation during the workshops of the limits to the use of commercial catch rate data as an index of relative abundance.

- For most fisheries in Australia commercial catch rates are the only available index of relative abundance. Unfortunately, the advent of quotas (catch limits), closed areas (of many kinds), and changes to the marine environment, all mean that the interpretation of catch rates becomes more difficult and uncertain.
- There are advantages in applying more than one standardization method when dealing with new data. Each method has different assumptions and the outcomes can provide insight concerning the information content of the available data.
- Unfortunately, many aspects of commercial catch rate standardization require more work. The impacts of any preliminary data selection, the impact of data quality (e.g. rounding errors) on the statistical properties of catch rate data, and the impact of different strategies for identifying zero shots on the outcome, would all benefit from further exploration. In addition, how catch rates alter in the face of TACs, quotas, closed areas, and other influences needs elucidation if they are to continue to be used in assessments.

2 ACKNOWLEDGEMENTS

Much of this report is directly the work of the workshop participants and their enthusiasm and efforts are greatly appreciated. These included James Larcombe, Peter Ward, Mark Chambers, and Veronica Rodriguez, from Commonwealth ABARES; Neil Klaer and Eva Plaganyi-Lloyd from Commonwealth CSIRO; Michael O'Neill and George Leigh from QLD DEEDI; Klaas Hartmann, Jessica Andre and Craig Mundy from TAS IMAS; Rowan Chick from SA SARDI; and Bruce Taylor from VIC DPI.

3 BACKGROUND

In May 2010 the ComFRAB put out a call for research proposals to address an array of fisheries management issues. The analysis of trends in abundance for non-target species was identified, in that research call, as an issue needing attention. The description of the project envisaged by ComFRAB focussed primarily on catch rates as an index of relative abundance:

"Typically CPUE's [catch per unit effort time series] have been standardised using GLM's [General or Generalized Linear Models] or other analysis techniques for only target or quota species. With more emphasis being placed on the management of byproduct and bycatch species there is a growing need for information on trends in abundance of a much wider range of species. Most fisheries now have reasonable time-series of precise spatial data on catch and effort data. The proposed work will investigate using innovative analysis techniques to analyse trends in abundance of byproduct and bycatch species. Respondents addressing this scope are required to arrange a 1 day workshop for CPUE experts to explore and scope out preferred methodology options." (ComFRAB, 2010a).

However, following submission of a pre-proposal, ComFRAB came back with the suggestion that the proposal should move forward as a FRDC Tactical Research Fund project and that instead of a single large workshop "that two smaller workshops be held with only the attendance of core experts (6-8) being funded. …. These workshops should explore at a broad level how this issue is currently being approached and scope the range of methodologies that might be suitable for application." (ComFRAB, 2010b).

The issue of non-target and by-product species is common to all jurisdictions and interest in the workshops was high. So, in accord with this advice a proposal was put forward for two workshops with invitations for participants from Queensland, New South Wales, Victoria, Tasmania, South Australia and the Commonwealth organisations ABARES and CSIRO.

The project commenced on March 2011. The first workshop was held on 21–22 March 2011 which focused on Introducing and elucidating the issues relating to non-target species, reviewing how non-target species are currently treated in the various jurisdictions within Australia, and beginning to work on the various sub-projects relating to methods for use with non-target species. The second workshop was held on 8–9 June 2011 and focused on completing the sub-projects on particular methods to a point where they could be reported on to the workshop, discussing a number of concepts and issues to gain a better appreciation of the diversity of approaches used with non-target species, and making final reports to the workshop of the practical applications explored during the two workshops.

4 NEED

To fulfil the requirements of Ecosystem Based Fishery Management with respect to non-target species requires two things: 1) performance indicators for a wide range of species that interact with fisheries, and 2) systems to monitor those performance indicators. However, generally there is no routine monitoring of the status of the many commercially important byproduct and bycatch species. The assessment of these non-target species remains important in terms of the Commonwealth Harvest Strategy Policy and AFMA have expressed a need for a solution to how to assess the relative status of these species. Such monitoring is required for strategic assessment under the Environment Protection and Biodiversity Conservation Act (1997).

Most non-target species are not under quota and while not directly targeted they can still experience significant fishing mortality and add value to the landed catch. Currently, if they are assessed at all, the assessments merely apply the same strategies as adopted for target species. There is often a perception that CPUE should be disregarded "because the species was not targeted". There is a need to determine whether alternative methods should be applied to such species that take into account the fact that their catch is incidental to the main activities of the fishers and hence the fishery dependent data for the non-target species will have different qualities. By definition these fisheries are multi-species in nature and this too can complicate their assessment. Technically this is not a trivial problem and more clarity is needed concerning the scope of the issue and how to deal with it. Rather than launch immediately into a relatively long term attempt at finding a solution, a more efficient approach is proposed that involves expert examination and rapid review to map the road ahead. Hence there is a need to conduct workshops aimed at clarifying the management requirements and the most cost effective approach to solving these management issues, which apply to all multi-species data poor fisheries.

5 OBJECTIVES

1) Investigate analysis methods capable of providing trends in the abundance estimates for byproduct and bycatch species
2) Conduct two workshops, aimed at identifying the management issues and the techniques available for analyzing trends in abundance in non-target species.

The workshops provided a rapid overview of the methods currently used in different jurisdictions to assess non-target species and at the same time described the management frameworks used in the various jurisdictions represented at the workshops, which went some way to identify the management issues related to non-target species. This achieved the second objective.

In addition, the workshops also providing a range of suggestions for other potentially useful analytical methods and potentially productive alternative methods suitable for further exploration. Examples were explored and preliminary analyses were conducted to illustrate the potential of some previously uncommon methods to provide insight into distribution and abundance. These activities achieved the first objective.

6 MATERIALS AND METHODS

6.1.1 Structure of the Report

This report includes all the PowerPoint slides presented at the two workshops (excluding a few containing only titles). Where written comments were included with the PowerPoint presentation these have also been included in this document as an aid to understanding the PowerPoint slides. The presentations provide the summary of the issues raised and the following discussions, however, there remained a requirement to elucidate the details and describe the discussions in more detail. Summaries of the various sessions and topics will be provided with reference being made to the various PowerPoint presentations where appropriate.

6.1.2 Outline of Approach

In order to adequately and rapidly review current methods and practice as well as provide an environment in which alternatives and untried possibilities could be suggested, examined and discussed, a workshop environment was used in which active participants in the field of stock assessment were invited (lists of attendees are given below). It was envisaged that in order to generate a workable report in the available time, two workshops of two days duration would be required with some intercessional work in between.

The intention of the two workshops was to gather people experienced in dealing with assessing the stock status of different resources and have them consider the issues relating to those species that are not the principle targets of fishing. This was to include by-catch and byproduct species (distinguished by what is discarded and what is retained).

The first workshop started with three introductory talks, one concerning the issues surrounding the analysis of catches and catch rates and two discussing problems with respect to the identification of targeting behaviour. During the workshops there was prolonged discussion of what constitutes a targeted shot. This was not a discussion about terminology but rather concerned the details of how it might be possible to identify from all the shots in a region those that were intended to capture a particular species.

The presentations on issues were followed by presentations relating to the situation with respect to stock assessment and management in each of the jurisdictions represented at the meeting and how non-target species were treated in each case.

Following the discussions participants joined together in small groups to work on specific issues and illustrative examples with the aim of demonstrating the potential value of different analytical strategies.

The second workshop picked up where the first had finished with participants first presenting summaries of work that had been completed or at least started. This included presentations on the simulation of commercial catch rates, developments in the spatial analyses that could be used to identify targeting and hotspots of fishing, and the targeting of multiple species. This was followed by further sessions working on the specific examples being considered by the sub-groups so as to articulate the examples further.

Finally there was a discussion session that canvassed opinions concerning specific issues but also to allow participants to express themselves on issues that had arisen in their work either in the workshops or elsewhere.

The species considered are invariably relatively data poor (catches, effort, sometimes location information, but rarely any age or length frequency data from the catches; occasionally some data on growth and other aspects of the biology). Because of this any analyses can usually be completed relatively rapidly once implemented in software. The growth in the use of the statistical/programming environment, R, lends itself to rapid and automated analyses that, once programmed, only require formatting of data. It was therefore expected that it would be possible to explore alternative methods on given case studies during the workshops (and especially intercessionally). What was envisaged were active hands-on workshops with introductory presentations, the identification of alternatives, followed by sub-division into groups to tackle the alternatives identified with a return to the group so that direct comparisons could be made and the difficulties that can arise could be identified. Each workshop session would need a chair to moderate any discussion and a recorder to note a skeleton of the important points in the discussion.

The use of real case studies meant that data sets needed to be pre-treated to avoid any confidentiality issues (vessel names removed, exact locations shifted north and east by unknown amounts, whatever it takes to satisfy the stewards of the data). In the end confidentiality agreements were not required for workshop participants as none of the data provided included means of identifying fishers and none of the data left the workshop or were retained by those it did not belong to.

In order to facilitate the generation of the final report each sub-group that worked on a case study was also tasked with generating a brief report of what was done; this could be as brief as a series of PowerPoint slides plus some written conclusions that could be included as an appendix. However, eventually significant amounts of time had to be spent writing interpretative text to simplify reading the report; the hope that the material would be essentially self-documenting was woefully mistaken.

The terminology used when dealing with non-target or byproduct species has its difficulties in that a species can be a primary target but may be discarded if quota is not available to reconcile the catch. Such activities do not imply these species are bycatch. More confusing are species which are treated as bycatch by some fishers and as byproduct by other fishers. In fact, the terminology used is not of primary interest, the primary issue is one of whether a species is ever targeted or does it generally constitute a welcome but unintended byproduct while targeting a different species.

6.2 Workshop Structure

6.2.1 Workshop 1.

Definition of the Scale of the Problem and Possible Solutions

Tue/Wed 22nd - 23rd March 2011
Venue: Freycinet Room, CSIRO, Castray Esplanade, Hobart.
Pre-prepared presentations (all containing real examples wherever possible) on:

1) The issues at the base of the problem of managing byproduct and bycatch species (what is currently available and used, what is missing, what is wanted?).
2) Short presentations of case studies of management issues, data problems, and current solutions. These are to include a detailed description of the data sets that should be made available to participants for the later active investigation of methods.
3) Whole group discussion of the case studies with a brain storming over possibilities which are collated.
4) Sub-division into smaller groups (minimum of two workers) to implement the most promising of the alternatives.
5) Each sub-group reporting their findings, results, and ideas back to the whole group.
6) End of workshop synthesis of directions and findings. This will be used to identify the most promising options to be expanded on during intercessional work. Some of the intercessional work will include a written report on the first workshop.

- In the case studies, participants will review methods currently used to standardise CPUE for target and non-target species, including:
- Data selection: A variety of approaches have been employed ranging from highly selective subsetting of data, to modelling all the available data. The concept of targeting for byproduct/ bycatch species is problematical and would favour more inclusive data selection approaches.
- Model selection: The prominence of zero catches with non-zero effort would favour ap-

proaches that can handle zeros such as the Poisson or Binomial distribution models and two-stage models.
- Index series construction: consideration needs to be given to how to construct the index series from the model parameters, including issues of weighting.

6.2.2 Workshop 2.

Have We Done Enough to Know How to Proceed?

Wed/Thu 8th – 9th June 2011
Venue: Freycinet Room, CSIRO, Castray Esplanade, Hobart.

1) Pre-prepared presentation summarizing the first workshop, any intercessional work and the findings.
2) Group discussion: Do we need to develop a full research proposal to examine particular pathways identified or should we expand on the exemplification of the methods already available using more case studies, or both?
3) If there is perceived to be a real need to further develop identified possibilities for the assessment of non-target species then a sub-group will take on the task of developing a full proposal for research funding.
4) If further exemplification of methods is chosen then, further case studies of real data sets will be described by contributors and sub-groups will arrange to work through these generating short reports and presentations of what they find.
5) An outline of the final report will be described with individual contributions and any further work needed being identified.

6.2.3 Workshop Agendas

Expected Attendees	Malcolm Haddon, Neil Klaer, Eva Plaganyi-Lloyd, James Larcombe, Peter Ward, Mark Chambers, Michael O'Neill, George Leigh, Cameron Dixon, Stephen Mayfield, Craig Mundy, Jessica Andre, Klaas Hartmann, Bruce Taylor, Terry Walker	
Time	**Item**	**By**
Tuesday 22nd		
0845-0900	Room setup, coffee etc.	
0900-0915	Welcome, Introductions, Structure of Meeting	Malcolm
0915-1030	Identification of Problem Areas and Issues in Commonwealth	
	a) Mixed Fisheries and Targeting (25 mins)	Neil
	b) The Use of Catches and Catch Rates (25 mins)	Malcolm
	c) The Use of Spatial Analyses (25 mins)	Mark
1030-1050	Morning Tea	
1050-1230	Identification of State Issues	
	d) Issues in Queensland (20 mins)	Mick
	e) Issues in Victoria (20 mins)	Bruce
	f) Issues in Tasmania (20 mins)	Klaas
1230-1330	Lunch (may be a shorter period depending)	
1330-1500	Identification of specific problem situations to be worked on by sub-groups (need, issue, specific example problem, data). Split into between 3 – 5 groups to work on specific problems.	
1500-1520	Afternoon Tea	

1520-1630	Continue working on specific sub-group problems.
1630-1700	Plenary: preliminary reports on directions and decisions from each sub-group.
Wednesday 23rd	
0845-0900	Room setup, coffee etc.
0900-0930	Plenary: Discussion of expansions on preliminary reports or expansion of options for consideration (for any sub-group).
0930-1030	Continuation of sub-group analyses or selection of new problem to investigate by sub-groups.
1030-1050	Morning Tea
1050-1230	Continuation of analyses within sub-groups and preparation of preliminary presentations to be given to plenary on outcomes from sub-group investigations.
1230-1330	Lunch (may be a shorter period depending)
1330-1430	Continuation of investigations and preparation of presentations
1430-1530	Plenary: Presentation of Sub-Group results and conclusions (possibly still preliminary)

Expected Attendees	Malcolm Haddon, Neil Klaer, Eva Plagani-Lloyd, James Larcombe, Peter Ward, Mark Chambers, Michael O'Neill, George Leigh, Cameron Dixon, Stephen Mayfield, Craig Mundy, Klaas Hartmann, Bruce Taylor
Time	**Item**
Wednesday 8th	
0845-0900	Room setup, coffee etc.
0900-0915	Welcome, Introductions, Structure of Meeting
0915-1030	Expanded description of the potential value and importance of the various methods exemplified in the previous workshop. Where next with this work and why should it be pursued? Eva and Malcolm - Simulation of catch rates
	Michael, George, and Peter - Specialized CPUE standardization
	Mark, Neil, and Craig - Spatial analysis to identify targeting and hotspots
	James, Klaas, & Bruce - Targetting multiple species
1030-1050	Morning Tea
1050-1230	Return to the specific problems/strategies being worked on in Workshop 1 (or start something completely new)
	Split into groups again to work on these specific problems.
1230-1330	Lunch (may be a shorter period depending)
1330-1500	Continue working on specific sub-group problems.
1500-1520	Afternoon Tea
1520-1630	Continue working on specific sub-group problems. Begin development of report contribution.
1630-1700	Plenary: preliminary reports on any developments from each sub-group.
Thursday 9th	
0830-0845	Room setup, coffee etc.

0845-1030	Continuation of sub-group analyses and report production
1030-1050	Morning Tea
1050-1230	Discussion Session: Issues The tail wagging the dog - Should major fisheries be restricted by apparent problems with bycatch species? Will looking after the primary target species in a fishery also look after the other species taken? Are there policy gaps that need addressing? How will the approaches used and exemplified in the workshop last time assist with bycatch species?
1230-1330	Lunch (may be a shorter period depending)
1330-1430	Report production
1430-1530	Plenary: Presentation of Sub-Group results and conclusions

7 RESULTS

7.1.1 Attendance

Twelve people attended the first workshop (Table 1) held over the 22nd – 23rd March 2011 and a slightly different 12 people attended the second workshop; both of which were in Hobart. Overall, attendance was good, although SARDI participants were only able to attend the second workshop due to conflicting work commitments. Attendees appreciated the opportunity to discuss the issues surrounding the analysis of abundance trends and targeting/non-targeting. Simply collecting together analysts from different jurisdictions provided an opportunity for the different groups to understand the different strategies adopted by others when dealing with the same problems.

Table 1. List of people invited and attending workshop 1 (22nd – 23rd March) and workshop 2 (8th – 9th June). Eventually 12 people attended the first workshop and 12 the second including people from Queensland, Victoria, South Australia, Tasmania, and Commonwealth organisations.

	Name	Organisation	Workshop 1	Workshop 2
1	James Larcombe	ABARES	X	
2	Peter Ward	ABARES	X	X
3	Veronica Rodriguez	ABARES		X
4	Mark Chambers	ABARES	X	X
5	Malcolm Haddon	CSIRO	X	X
6	Neil Klaer	CSIRO	X	X
7	Eva Plaganyi-Lloyd	CSIRO	X	X
8	Klaas Hartmann	TAS IMAS	X	X
9	Jessica Andre	TAS IMAS	X	
10	Craig Mundy	TAS IMAS	X	X
11	Michael O’Neill	QLD DEEDI	X	X
12	George Leigh	QLD DEEDI	X	X
13	Cameron Dixon	SA SARDI		
14	Stephen Mayfield	SA SARDI		
15	Rowan Chick	SA SARDI		X
16	Bruce Taylor	VIC DPI	X	X

7.2 First Workshop

The first workshop began with seven presentations and related discussions. The first presentation was an introductory talk by Malcolm Haddon on the objectives and expected outcomes of the workshops (Sections 5, 6.2 & 16.1.1). This was followed by talks from Neil Klaer on Targeting in mixed fisheries (Sections 7.2.2 & 16.1.2), a talk by Malcolm Haddon on the Use of Catches and Catch Rates (Sections 7.2.3 & 16.1.3), and then Mark Chambers gave a talk on spatial methods for use with non-target species in mixed fisheries (Sections 7.2.2 & 16.1.4).

These four presentations on general subjects were followed by specific descriptions of any issues relating to the characterization of abundance trends in fisheries within each jurisdiction, with especial comments on any non-target species. This involved detailed presentations from Bruce Taylor on the Victorian situation (Sections 7.2.5 & 16.1.5), from George Leigh and Michael O'Neill on the issues in Queensland (Sections 7.2.4 & 16.1.6), and finally some commentary on the issues and situation in Tasmania from Klaas Hartmann (Section 7.2.6).

7.2.1 General Points from the First Workshop Presentations

- Non-target species are common in mixed fisheries in all jurisdictions.
- Two strategies were apparent from all Jurisdictions for assessing the status of non-target species: either use a risk assessment of some kind or conduct an analysis of catches and catch rates.
- Risk assessments could take the form of the Commonwealth ERA process or a more general multi-criterion decision analysis, which is essentially a summary of all that is known about a fished species, and then use a weight of evidence approach to determine whether a fishery was placing a given species at risk of serious depletion.
- Any assessments of non-target species are usually highly uncertain because they tend to be data poor. This exacerbates the problems that arise when making decisions about how to manage non-target species.
- Non-target species include bycatch and by-product, where bycatch species would not be retained while byproduct species would be retained as added value to the total catch.
- It was recognized that relatively uncertain estimates of abundance trends in non-target species (be they byproduct or bycatch) had the potential to interfere with or disrupt sustainably fished target fisheries if the non-target species appeared to be badly depleted.
- Further consideration is required on how to manage non-target byproduct species and their interactions with target fisheries.
- In some mixed fisheries (e.g. abalone in South Australia) there are multiple targets and so, when considering the individual species it is not possible to say which was specifically targeted. Such situations are not immediately of interest to the issues being addressed here but any analytical methods that might be useful with non-target species would presumably be useful for such multi-target fisheries.
- Fishing behaviour influences the species mix in many mixed fisheries but invariably multiple species are taken in all cases.

- While there is a National Bycatch Policy there would be advantages to developing procedures for data collection and sharing among jurisdictions.
- Ensuring the sustainability of byproduct species is rarely considered.
- Not all byproduct species stay as non-target species (ocean jackets in the Commonwealth SESSF fishery is an example). Some species recognized as non-target (e.g. John Dory in the SESSF) are still included in quota systems.
- Where the non-target species was less abundant in the catch than the target, but was more productive in its life-history characteristics, the idea that looking after the target species would also take care of the sustainability of the non-target species was recognized as a possible positive outcome from the weight of evidence approach.
- The analyses of catch rates immediately raised the issue of what constitutes a targeted catch.

7.2.2 Major Points from the Discussion of Targeting

Targeting was considered in two presentations. In the first talk by Neil Klaer of CSIRO (Appendix 3: 16.1.2), a multi-species view of fishing, using previously reported catch statistics, was used to empirically determine the dominant species expected in a particular location and depth at a particular time of year and time of day. This is an approach that considers the vessels catching in a particular stratum of location, depth, month, and time of day rather than the behaviour of individual vessels across the whole fishery. It considers the sum of the behaviours of the vessels reporting from a mixed fishery.

- Analyses of catch rates raises issues of data selection; need at least to remove incomplete or clearly incorrect data and atypical data categories.
- Definition of targeting – within a mixed species fishery, the targeted species in a particular stratum is that with the greatest portion of total catch value in a 0.5 degree, 50m depth, month, and time of day stratum (it is important to note that this measure combines both total catch and relative value of each species).
- A performance measure with potential for use in mixed fisheries is the Shannon-Weiner diversity index applied to species occurrence and relative abundance in the catches.

An alternative empirical definition of targeting using an analysis of the geographical distribution of records of catch for single species was presented by Mark Chambers of ABARES (Appendix 3: 16.1.4). The aim was to determine what areas to use when selecting records where a particular species would be expected to occur in catches. In this way the proportion of records with positive and with zero catches could be determined in a defensible and defined quantitative manner. This was an extension to the notion of using simple presence absence as an indicator of which areas to consider.

- Extended a method proposed by Stephens & MacCall (2004), who proposed to subset commercial catch and effort records, to focus on targeted shots, by using species presence/absence as a predictor of appropriate locations to include (where there were up to 30 species potentially present in a shot).
- Stephens & MacCall (2004) used a logistic regression to estimate the probability of capture of the species of interest and were able to exclude those shots where the probability was below some chosen threshold.

- Instead of logistic modelling it was proposed to use General Additive Models (GAMs) to generate isotropic smoothing on latitude and longitude (location) data, incorporating location specific information such as depth *i.e.* Logit(Pr(Sps)) ~ s(Longitude, Latitude) + s(Depth).
- The data are summarized into 0.1 degree squares (C-squares were used).
- GAB trawl fishery was used to exemplify the methodology, especially Jackass Morwong.
- Shots were selected for more classical analyses from those C-squares which had a probability of catching Jackass Morwong > 0.3 (though the sensitivity of the analysis to this choice is open to evaluation).
- This provides a defensible method for the selection of areas within which to estimate zero shots.
- Other potential applications might be to estimate the spatial range of species and compare with fisheries effort data.

7.2.3 Major Points from the Discussion of Catch Rate Analyses

A presentation on catches and catch rates was made by Malcolm Haddon of CSIRO (Appendix 3: 16.1.3) which attempted to identify some of the potential weaknesses of catch rate data and how that could influence an assessment, with flow on effects on the interpretation of the Harvest Strategy used.

- Primary objective of an assessment is to determine what management actions are needed to drive a fishery in a desired direction (i.e. towards some target and away from some limit reference point; be they based on biomass, catch rates, depletion state, fishing mortality, etc.). This is all made more difficult in data poor situations.
- An alternative to risk assessment is to use a weight of evidence involving all commercial catch records plus biological information concerning growth and maturity to try to understand the relative productivity and relate that to catches.
- In the empirical Tier 4 control rule in the SESSF, designed for relatively data poor fisheries which only have catch and catch rate data, we use proxies for reference points which effectively define the direction in which we want the fishery to move. Can achieve a target and avoid a limit but need to acknowledge these are merely pragmatic rather than actually achieving the HSP target and limit reference points.
- The Commonwealth HSP is explicit that not all species in a mixed fishery can be expected to achieve their Target Reference Points (but all should avoid the LRP).
- Perhaps the best that can be achieved with non-target species is to aim for a minimum of negative changes (status quo or positive).
- Alternative strategies: Weight of evidence or Multi-criterion decision analysis – what is known and does the likely productivity match the fishery.
- ERA – habitat/distribution; mobility/stock structure; Natural mortality/maximum age; growth/maturity/spawning season; recruitment/early life history; fishery dynamics; likelihood of impact vs consequences.
- Analysis of fishery data: catch rates; seasonality; TIER 3 or 4; inter-relationships/ time series/ patterns in time and geography.
- Fisheries data quality remains an issue – rounding to nearest round number in catches and hours of effort – leads to granular data distributions that have poor statistical properties (examples given from Commonwealth and Queensland). This suggests

that agonizing over which statistical distribution to use may not be as useful as it might appear.

- Two aspects to CE standardization – positive shots and zero shots; numerous strategies for dealing with this – e.g. delta distribution; tweedie distributions, Poisson distribution.
- Identification of zero shots is really a question about targeting and the presentations by Neil Klaer and Mark Chambers are relevant.
- Some fundamental issues with catch rates – do catch rates reflect abundance? Can add a γ term to the relationship between $C/E = qB^{\gamma}$ but including the γ will affect the *q* values too. These issues are rarely considered in practice though they should be.
- Fisheries data are often abundant so many terms in standardization models are statistically significant. What really counts is whether they influence the final CE trends. Sometimes standardization has little effect, other times very large effects – not predictable.
- There is often debate as to the best statistical distribution to use in the analysis of catch rates, but the key issue is how the choice of distribution (log-normal, Gaussian, Poisson, etc) affects the trend through time.

7.2.4 Queensland ByCatch Issues

Following the presentations about targeting and catch rates three presentations were made concerning issues relating to assessment and especially about non-target species in the various State jurisdictions. This session was started by George Leigh from QLD DEEDI (Appendix 3: 16.1.6) who discussed the situation in Queensland.

- Generally no clear measure of catch rate for non-target species (how much effort expended to catch the non-target species?)
- Very large number of non-target species – implies any analyses developed or required should be easy to repeat and consistent.
- Data and analytical issues: any data may be coarse scaled geographically and through time; there is often a great deal of variation; it is debatable whether catch rates are an index of relative abundance for many species.
- Strategies for analysis of catch rates:
    - Assess data quality
    - Match analysis to management procedures and requirements
    - Develop criteria to select a two component model ie. Binomial +
    - Alternative analyses of positive shots.
- Assess non-random fishing patterns – as fisheries develop the area fished can alter dramatically.
- Need methods which can be applied widely and which are robust to variation.

7.2.5 Victorian Fisheries Assessment

The second presentation in this session was given by Bruce Taylor of VIC DPI who described the assessment issues in Victoria.

- Provided a summary of the abalone, rock lobster and Bays and Inlets Fisheries.
- In 2006/07 a risk assessment of Victorian fisheries was carried out using the National Fisheries ESD reporting framework.
- A lack of understanding of the relationship between habitat requirements and production was identified as a major risk factor in selecting appropriate management.
- Allocation and resource sharing issues are important in the management of many of the smaller fisheries – most of which are multi-species and a mix of commercial and recreational.
- There is a lack of cost effective assessment, partly due to a lack of fishery performance measures and reference points.
- Assessments restricted to consideration of catch and catch rate trends, and trends in size and age distribution for some species. No assessment models. Currently considering alternative performance measures and reference points for the main fisheries.
- Surveys of recreational fisheries and an annual trawl survey in Port Phillip Bay; plus continued monitoring of juvenile King George Whiting and juvenile snapper.
- Recreational fisheries an important part of Victorian fisheries.
- Non-target species not given special attention.

7.2.6 Tasmanian Assessment Issues

Finally, a presentation was given by Klaus Hartmann of IMAS describing the scalefisheries of Tasmania.

- Scalefish fishery in Tasmania has a number of targeted species for which analysis of trends in catches, catch rates, and any other information available is considered. These species include Banded Morwong, calamari, Striped Trumpeter, Bastard Trumpeter, sea garfish, and Wrasse.
- In addition, species shared with the Commonwealth are also given particular treatment: Blue Warehou, Australian Salmon, and Flathead.
- Other species have their catches recorded with little further analyses. These species are worth so little they receive little time for assessment.
- Essentially the minor species are noted in the fishery assessment document but no other treatment or management unless some particular issue is raised by the Industry.

7.3 Second Workshop

7.3.1 Introduction

The second workshop provided another opportunity for a collection of workers in the field to gather and pursue further some of the ideas developed in the first workshop. The presentations reflected the work that was begun in the last workshop and included work to define what would be required to adequately simulate catch rates (Malcolm Haddon & Eva Plaganyi), more specialized catch rate standardizations (Michael O'Neill, George Leigh, and Peter Ward), spatial analyses to identify targeting and hotspots (Mark Chambers, Neil Klaer, and Craig Mundy), and finally Targetting of Multiple Species (Klaas Hartmann & Bruce Taylor).

7.3.2 Major Point from the Introduction to the Second Workshop

Malcolm Haddon of CSIRO gave an introductory presentation that outlined the issues that needed to be faced when attempting to characterize abundance trends for non-target species. In addition he also gave a presentation that focused on how the terms bycatch and byproduct were used, how the term targeting can also be used in a number of ways, and how different types of data can be used in assessments (sections 17.1.1 and 17.1.2).

- Under Ecosystem Based Fisheries Management (EBFM) there is the potential for the status of non-target species to restrict fisheries for target species. But any assessment of non-target species is likely to be more uncertain than for a target species – should the same reference points be used in both cases?
- When non-target species are less abundant in the catches but as a species are more productive than the target species then looking after the target species should be enough to look after the non-target species.
- Most non-target species are considered to be of low value and tend to be managed in a reactive ad-hoc manner.
- Are there enormous numbers of assessments that we are not doing, or do the risk assessments being conducted allay such fears?
- There is some confusion over terminology because “targeting”, byproduct”, and “bycatch” are terms that relate to the intention of the fisher and this remains unknown, even when fishers fill in targeting fields in log books.
- Byproduct species are those species which are generally retained commercially but whose management recognizes they are taken as incidental catch in another fishery.
- Generally, bycatch of quota species occurs when the fisher cannot obtain quota or the species is bycatch only. Other bycatch tends to be discarded (including TEPs) while byproduct tends to be retained (though not always).
- Targeting – species expected in the catch as a function of location and date/time – can also be characterized as the dominant species in the catch. However, can also be identified in relation to what was taken in the immediately previous shot.
- Three useful strategies for improved assessment of non-target species:
    - Improved or increased observer coverage.
    - Fishery Independent surveys
    - Improved reporting of discarding and of catches of non-managed species (quota or input controlled).

7.3.3 Major Points from the Bycatch Analysis Case Study from QLD

George Leigh, assisted by Michael O’Neill, both of QLD DEEDI, gave a presentation on the issues surrounding non-target species in Queensland (section 17.1.3).

- Moses Perch catches in the Gulf of Carpentaria were analyzed as a case study for comparison of alternative methods for characterizing the status of the species.

- Spatial analysis of shots and occurrence informative – demonstrated that positive locations not constant across years.
- Data quality issues with respect to rounding and related poor statistical behaviour.
- Poisson and two-stage models that both account for zeros gave similar CPUE trends.
- But these trends imply implausible changes in either abundance or availability, which is not expressed in the positive-shot only analyses.
- The question of whether the reporting of the byproduct species is representative through time is raised – that is, was there greater discarding previously, or merely a lack of reporting for what was assumed to be an unimportant species?
- Including (or not) the other species captured influences the outcome.
- Analysis of the catch rates of byproduct species is generally more uncertain than that of target species.

7.3.4 Major Points from the study of Multi-variate CPUE Standardization

George Leigh, assisted by Michael O'Neill, both from QLD DEEDI, also gave a presentation on an exploration they had made with multi-species (multivariate) CPUE standardization (Section 17.1.4).

- Generally individual species are analysed separately but could treat all catches as random variables and handle all species at once in a single multi-variate GLM.
- Explored the option in GenStat of using a Multi-variate linear mixed model.
- Potential advantages are that MLMM can explore correlations between the species and provide reassurance (or otherwise) of independence between species (which would support the uni-species approach).
- Outcomes hold promise but further analyses are required to fully understand this option.

7.3.5 Alternative Catch Rate Analyses

Mark Chambers from ABARES and Neil Klaer from CSIRO together considered alternative approaches to analysing catch rate data (section 17.1.5).

- Using a test data set from a fishery with two main targets, alternative catch rate analyses were applied, including the use of GAMs to identify the zero shots (as described in section 16.1.4).
- The alternative analyses included data filtering using a GAM (Yes/No) (D), a Binomial GAM modelling presence and absence (Yes/No) (B) and a GAM using normal errors modelling log(CPUE by area (G). These were compared with a simple log-linear model of positive shots and a multivariate analysis of both species together (as per sections 7.3.4. and 17.1.4).

- For one species the multiple methods gave very similar results but all differed somewhat from the log-linear modelling. For the second species there were real differences between methods.
- It was possible to conclude that there were advantages to the inclusion of zero catches but it wasn't possible to identify whether there was an optimum method for doing this.

7.3.6 Simulation of Catch Rates

Malcolm Haddon and Eva Plaganyi made some preliminary investigations in to the simulation of multi-species catch rate data (17.1.6).

- Lots of comparative studies of different ways to analyses catch rates but the outcomes always appear to depend on the circumstances in the particular fishery involved.
- Without knowing the underlying reality it appears impossible to determine whether there is an optimum strategy for analyzing catch rates.
- Many significant questions could be answered if realistic catch rate data could be simulated.
- Began the process by trying to develop some pseudo-code to describe the required algorithm.
- Standardization is a formal means of dis-aggregating components of the catchability.
- Would need to include location along a coast and depth (~location off the coast). Also need to include seasonal patterns of changing catchability, different vessels and daily records as well as multiple species.
- To be general it would be necessary to be able to predict zero shots (including false zeros).
- While a preliminary simulation was produced using R, it was clearly too simple, albeit still complex.
- A simulation should involve selectivity being different between species and certainly different base line catchabilities across species.

7.4 Summary of Activities and Results

- Two workshops were arranged in Hobart (March 22st – 23rd 2011 and June 8th – 9th 2011) where analysts, experienced with working on fishery abundance trends, gathered to explore how each jurisdiction was dealing with the issue of non-target abundance trends. In addition, they considered how this issue was currently being approached around Australia and the range of methodologies that might prove useful for solving the problems raised by the issue.
- Two strategies are apparent from all jurisdictions for dealing with non-target species: either use a risk assessment of some kind or conduct an ad hoc analysis of catches and catch rates. No other strategies appear to be used currently.
- Risk assessments take the form of the Commonwealth ERA process or a less detailed multi-criterion decision analysis, which is essentially a summary of all that is

known about a fished species, and then use a weight of evidence approach to determine whether a fishery was placing a given species at risk of serious depletion.

- Where the non-target species are less abundant in the catch than the target, but are more productive in its life-history characteristics, the idea that looking after the target species would also take care of the sustainability of the non-target species was recognized as a possible positive outcome from the weight of evidence approach.
- Simple and routine methods for the spatial analysis of the development and present operational expression of each fishery are helpful in understanding the scope, the overlap with other fisheries, and the spatial focus of a fishery. Such methods can help in identifying areas where shots might be expected to contain a species, and thus be useful for identifying zero shots for inclusion in cpue standardization.
- There are advantages in applying more than one standardization method when dealing with new data. Each method has different assumptions and the outcomes can provide insight concerning the information content of the available data. However, in each case this implies the analyses would take more time and generally all available time for analysts is allocated to species that make up targeted fisheries.
- Aspects of commercial catch rate standardization require more work. The impacts of any preliminary data selection, the impact of data quality (rounding errors) on the statistical properties of catch rate data, and the impact of different strategies for identifying zero shots on the outcome, would all benefit from further exploration.
- It was recognized that relatively uncertain estimates of abundance trends in non-target species had potentially important implications for sustainably fished target species especially in multi-species fisheries.
- It was recognized that there is a growing need to provide management advice for more and more species, however, the requirement for more data analysis and assessment comes when resources for such work are declining. This situation of increasing needs/demands for broader management advice in the face of flat or decreasing funds requires further consideration and potentially re-prioritation. The development of simpler empirical fishery assessment methods may alleviate this issue, however, without a better understanding of the operation of these there is a risk of reduced catches because of the increased uncertainties associated with simpler methods.

8 DISCUSSION

8.1 General Impressions

During the first workshop it quickly became apparent that there were shared issues relating to non-target species among jurisdictions. However, it was equally obvious that, while a recognized issue everywhere, there were few resources allocated to finding workable solutions to producing management advice relating to non-target species. The general feeling was that such issues tended to be dealt with on a species by species, reactive and ad hoc basis. Given that resources and time for conducting assessments on the major target species is already limited and limiting, the situation with respect to non-target species does not seem likely to change in the near future. However, the various workers in the different jurisdictions do occasionally get to work on non-target species and this adds to the understanding and experience in handling the special problems relating to such analyses.

There are many methodologies that can be applied to available fisheries data. These include General Linear Models, Generalized Linear Models, Generalized Additive Models, General Linear Mixed Models, and even Multi-Variate CPUE Standardization. However, without knowledge of the true underlying trends, it is not possible to identify the optimum approach to be used in particular situations. The use of multiple methods has advantages but, as stated above, there is rarely time to conduct a comprehensive analysis when dealing with a relatively unimportant species. While it appears uncommon that different methods will lead to completely different management advice, including an analysis of zero shots, or not, is often influential over the outcome of an analysis. This is problematical because zero shots in non-target species can arise for many reasons other than changes in the overall abundance.

With regard to non-target species the usual problems relating to data quality that arise with fishery dependent data can be exacerbated by non-reporting or different levels of reporting through time. The impacts of any preliminary data selection and the impact of data quality (rounding errors) on the statistical properties of catch rate data would certainly benefit from further exploration. The development of individual fisheries through time often entails an expansion of fishing grounds so that the early history of each fishery entails a number of marked changes in fishing behaviour. More spatial analyses are needed in attempts to account for this. This is a particular problem for non-target species where the reporting of catches may have been neglected early on if the species was considered unimportant.

Multiple participants declared that an advantage of the workshop format was that it provided them with time to explore options they had not previously tried or had not had time to fully explore. In addition, the opportunity to discuss issues with their peers was of great value in itself, as such opportunities are uncommon due to Australia's geographical size.

8.2 Spatial Methods

The spatial methods discussed in the workshops for identifying areas in which to expect catches of a species should be helpful in such analyses. This is a field that deserves further examination. Whether it is necessary to use relatively sophisticated analyses using GAMs on presence absence or Ln(cpue) on longitude and latitude and depth rather than simply using fine scale plotting into 6 x 6 nautical mile squares can be debated. But in the end, usage of both approaches will identify weaknesses and strengths and, eventually, improve the completeness of the treatment of the available data. For example, such plots were helpful in a recent SharkRAG meeting when illustrating the distribution of trawl caught saw shark catches in the GAB. This was the first time this fishery (trawl caught sawsharks in the GAB) had been looked at and the plots were useful in demonstrating that more are taken in the west than the east and that the distribution of fishing grounds where sawsharks are recorded is tightly defined (Figure 1). This data can be used to conduct analyses selecting different sets of 0.1 degree squares (or some other selected scale) to analyse and hence learn about the information available in the data.

Besides the advantages in determining where to expect catches of a species (and hence where shots without that species might be considered as zero shots) the spatial analysis of all fisheries is an analytical approach that needs more attention. The spatial development of a fishery can have large impacts on the history of a fishery statistics. Many of the rapid and large falls in catch rates that can be seen in numerous Commonwealth fisheries could simply be the results of initial fishing focusing on hotspots and quickly depleting them before expanding fishing to larger areas.

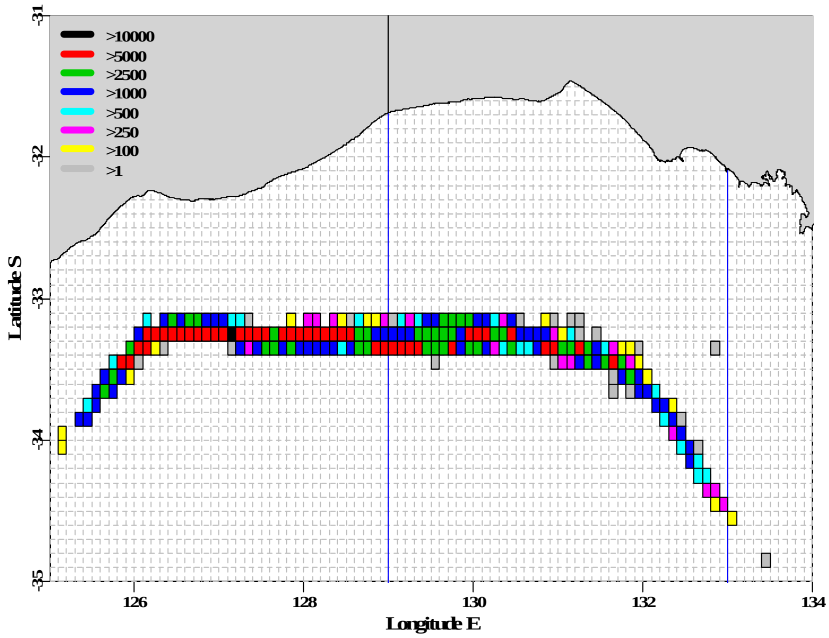

Figure 1. Schematic map depicting trawl caught catches of sawsharks in the GAB summarized over the period 1987 – 2010. The legend depicts the total accumulated catch across 23 years in kgs in each 0.1 x 01.nm square.

8.3 Catch Rate Analysis Methods

Numerous methods are currently used in the analysis of catch rates, and some new methods, such as multi-variate linear modelling, were examined and to some extent compared. The common diagnostics used when applying linear models (qqplots and related statistics) are obviously useful for selecting optimal models within a given framework, but the choice of residual error structure and how to deal with zero shots was far more difficult to determine. Applying more than one method to a dataset has some value in providing a more thorough examination of the implications of the available data. Similarly examining alternative approaches for identifying those shots that have been made that can be considered as zero shots for the species of interest has value in determining the sensitivity of the analysis to such decisions.

The field of cpue standardization remains diverse and surprisingly poorly defined. Not surprisingly, the initial data selection (sometimes referred to as data cleaning!) can be very influential on the final outcome. Despite this very little has been written regarding this aspect of standardization. In addition, the impact of the typical quality control issues with catch rate data (rounding of catch and of effort leading to the grid like patterns seen in catch rate plots) on the statistical properties of commercial catch rate data should be further investigated.

The strategy of simulating commercial catch rate data from a mixed fishery in a realistic manner is seen as a strategy that would provide answers to many of the problems that still plague catch rate standardization methods. By knowing the underlying trends within the simulation framework, the best ways of recovering those trends can be determined in a defensible manner. A research proposal has been developed to pursue this strategy of generating simulated multi-species catch rate data (using both the Atlantis framework and a less complex modelling approach). Once simulated cpue data can be generated this will allow the circumstances under which cpue data and how it is analyzed provides a valid index of relative abundance.

8.4 Interactions between Target and Non-Target Species

Non-target species are a difficult management issue because an assessment for a non-target species can have serious implications for the management of a possibly well managed on-target target fishery. It is possible, for example, for the endeavour prawn fishery in the Northern prawn fishery (which targets tiger prawns) to be assessed as being below its limit reference points and thus lead to reduced effort levels in the whole multi-species fishery, even if the target species are at or above their own targets. A further example is available in the SESSF fishery for School and Gummy sharks. Gummy sharks are currently considered to be in a healthy state with sustainable catches. However, in the Gummy shark fishery there continues to be a bycatch of School sharks which, while they are known to be depleted their exact status is unknown precisely because they are a bycatch only species and there is currently insufficient information to establish their exact status. The baseline assessment for non-target species is some kind of risk assessment that aims to determine the risk to the non-target species posed by the fishery. Further consideration is needed on how to operate when dealing with such uncertain assessments.

9 BENEFITS

The primary beneficiaries of this work will be the Fishery Managers in the various States as well as the Commonwealth. The project has identified the common ground among jurisdictions but also the remaining problems that arise when attempting to provide management advice on non-target species. Whether any of this will have a financial impact is difficult to determine. Some non-target species are valuable components to the overall value of the catch in some fisheries. The biggest risk to current fisheries that this work aids in clarifying is the growing idea that the status of non-target species can determine access to target species. In this way, improving fishery management arrangements around Australia can have very large implications.

10 FURTHER DEVELOPMENT

Four areas were identified as being ready for further work or more activity.

1. Improvements can be made in the spatial analysis of the development and on-going dynamics of different fisheries. Improved computing power will assist with these developments.
2. Catch rate standardization is a common technique used when only fisheries statistics are available. In the end, however, until we can simulate realistic fisheries data and thus open the way to the simulation testing of the wide range of methods available improvements will be difficult.
3. There is especially a need to explore the impact of any preliminary data selection on the outcomes, the impact of data quality (rounding errors) on the statistical properties of catch rate data, and the impact of different strategies for identifying zero shots on the outcome of the analysis.
4. To implement some of the suggestions for further work given in points 1 to 3 it was concluded that there was a need to develop a research proposal to solve some of the issues raised and articulate some of the recommendations for further work from the workshops (since the workshops a research pre-proposal has been produced).

In the meantime, there are advantages to applying more than one method to the same data set and how we spatially select data for analysis can easily be improved (as in point 1).

There remains a need for policy to address the possible actions required when a non-target species is deemed at risk (either through some kind of ecological risk assessment or some simple stock or fishery assessment). Without such policy, management of non-target species will stay reactive and ad hoc and contribute to uncertainty in management.

11 PLANNED OUTCOMES

The three planned outcomes for this work were:

1. A workshop report detailing the discussion and findings, providing guidance on how to approach the issue.
2. If it is concluded that further work is required, a full research proposal aiming to articulate the recommendations from the workshop.
3. Eventually the means for routinely assessing the status of non-target species and providing management advice for their sustainable and profitable exploitation.

The first two have been achieved in this project while the third is being addressed with the improved community of practice and increased sharing of methodologies and ideas across jurisdictions.

Thus, the outcomes included the report of the meetings, which is this document. By including all of the presentations given it is expected this document will provide a resource to managers and researchers allowing them to understand the range of approaches for dealing with non-target fisheries (and fisheries management in general) present in Australia (no participants from Western Australia could make the meetings).

At least one further research proposal was developed from this work and this relates to exploring catch rate standardizations using simulated data and involves researchers from CSIRO, Queensland DEEDI, and Industry consultants. Alternative avenues for progressing this work are also being explored.

The project has improved connections among the analysts employed in the different jurisdictions and this will lead to an improved chance of developing a community of practice across Australia. This in turn will assist managers and Industry as they will become more used to being exposed to the same kinds of analyses when looking for advice from analysts.

The project results will be communicated to managers in the various jurisdictions by distributing the final report widely.

12 CONCLUSIONS

This project investigated analytical methods capable of identifying trends in relative abundance estimates for byproduct and bycatch (non-target) species. This was largely achieved through two cross-jurisdictional workshops; key conclusions based on workshop discussions are summarised below:
The major recommendations from the workshop were:

1. Further consideration is required to identify the possible actions required when a non-target species is deemed at risk (either through some kind of ecological risk assessment or some simple stock or fishery assessment); and
2. A decision by workshops participants to develop a collaborative project proposal that will explore the limits and choices in catch rate standardization through the use of simulated multi-species catch rate data. By knowing the alternative underlying realities that derive from multiple operating models it will be possible to examine how the various analytical methods are adapted to different underlying assumptions in different datasets.

Other conclusions were:

- Non-target species are common in mixed fisheries in all jurisdictions; how they are managed is thus also a common issue.
- Two strategies are apparent from all Jurisdictions for dealing with non-target species: either use a risk assessment of some kind or conduct an analysis of catches and catch rates. No other strategies appear to be used currently.
- Risk assessments could take the form of the Commonwealth ERA process or a less detailed multi-criterion decision analysis, which is essentially a summary of all that is known about a fished species, and then use a weight of evidence approach to determine whether a fishery was placing a given species at risk of serious depletion.

- Where the non-target species was less abundant in the catch than the target, but was more productive in its life-history characteristics, the idea that looking after the target species would also take care of the sustainability of the non-target species was recognized as a possible positive outcome from the weight of evidence approach.
- Simple and routine methods for the spatial analysis of the development and present operational expression of each fishery are helpful in understanding the scope, the overlap with other fisheries, and the spatial focus of a fishery. Such methods can help in identifying areas where shots might be expected to contain a species, and thus be useful for identifying zero shots for inclusion in cpue standardization.
- There are advantages in applying more than one standardization method when dealing with new data. Each method has different assumptions and the outcomes provide insight concerning the information content of the available data.
- There are numerous aspects of the standardization of commercial catch rates that require more work. The impact of any preliminary data selection on the outcomes, the impact of data quality (rounding errors) on the statistical properties of catch rate data, and the impact of different strategies for identifying zero shots on the outcome, are three areas that would benefit all workers if further explored.

The research described here addressed both objectives of the project (as listed on page 2).

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14 APPENDIX 1 - INTELLECTUAL PROPERTY

Apart from the data used all participants were happy to share analytical algorithms with other analysts. As such no strict intellectual property issues arise with this work. The content of each PowerPoint presentation should be referred back to the original presenter.

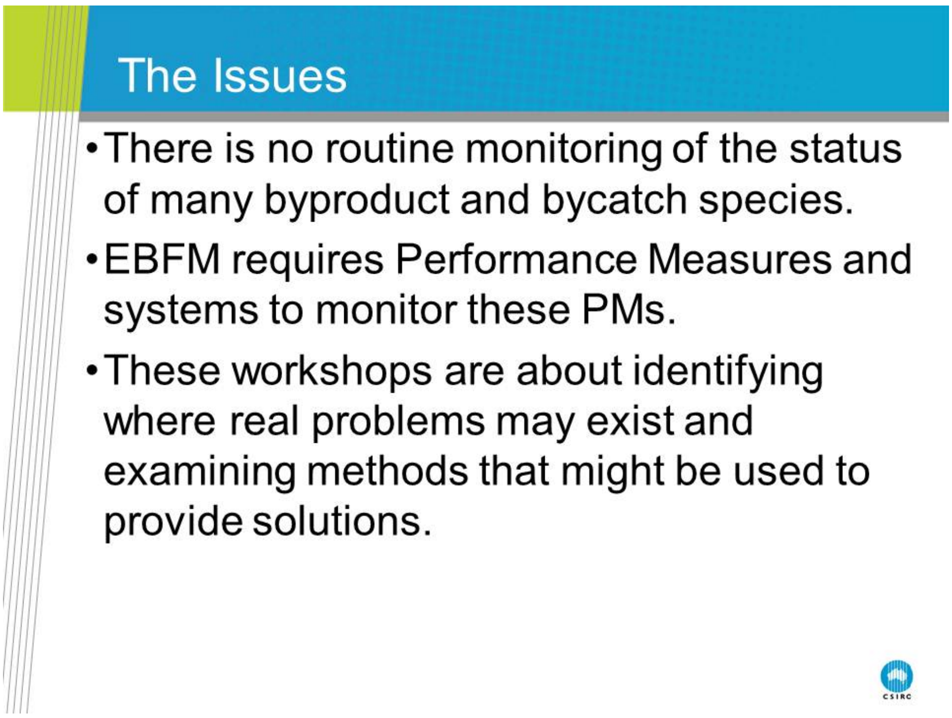
15 APPENDIX 2 - STAFF

Table 1 on page 7 lists all the staff and participants in this project. Malcolm Haddon took on the primary role of organising the meetings and compiling, annotating and writing the final report. George Leigh provided review and editorial comments.

16 APPENDIX 3 – WORKSHOP 1 PRESENTATIONS

16.1.1 Trends in the Abundance of Non-Target Species – Malcolm Haddon

This was only intended to be an introductory talk to the workshops but everyone agreed that the issue of assessing non-target species and bycatch species was common to all jurisdictions at some level.



Non-Target?

- Can include truly mixed species fisheries
- Bycatch and ByProduct species
  - Incidental catch taken with a known target
  - Those species below the LRP, for which there should be no targeted fishing – bycatch only TAC
- Minor fisheries for which only a few fishers attempt to catch a relatively low value species – data poor? Discarding
- Any other neglected species
- Anything else? – Not TEP,

Workshop Structure

- Introductory talks to begin discussion.
- Identification of specific problems for the various groups to investigate (case studies).
- Develop a presentation for the plenary (and final report) about each group's problem.
  - Identify alternative approaches
  - Generate analyses, graphics and explanations for each alternative attempted

Objectives

- Identify the management issues relating to abundance in non-target species in the various jurisdictions.
  - Which species are highest priority.
  - What biases might there be in our current views of these species.
- Investigate analytical methods capable of providing abundance estimate trends for byproduct and bycatch species.

Outputs

- A final report detailing strategies to be used in managing non-target species.
- There will be case studies illustrating the use of such methods.
- This is a very low cost project so there is little time available to produce the final report outside the workshops.
- If the conclusion is there is more work still needed, a full research proposal will be developed.

Analytical Sessions - outcomes

- Issues will be identified during discussion.
- Different groups will work on different issues.
- The resulting powerpoint (+ supplementary document if too many supporting results and details to present):
  - Clarify the problem/issue
  - Identify any alternatives for addressing the issue - an algorithm for each?
  - Produce analyses, results, any discussion and conclusions. for each alternative investigated
  - Key summary points.
  - Supplementary material can be like an appendix of detailed results, with annotations.

16.1.2 SEF1 Otter Trawl Targetting and Diversity – Neil Klaer

SEF1 otter trawl targeting and diversity

- **Data filtering**
- **Trends in targeting**
- **Trends in catch diversity**

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SEF1 data filtering - rules

Reason code	Invalid range
Key	Operation key to link to catches does not exist
Date	Date not given
Zone	SEF zone 10, 20, 30, 40, 50 or 60 not assigned
Lat	The latitude of the start position of the operation not given
Long	The longitude of the start position of the operation not given
Method	Fishing method not given
Lowhours	Hours < 0.5 if depth fished is < 500m, or hours = 0 otherwise
Highours	Hours > 10
Avdep	Average depth fished < 10m or > 2000m
Catchoth	Total catch of species other than orange roughy in one operation > 50t
Catchoro	Catch of orange roughy in a single operation > 100t

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SEF1 data filtering – rules continued

Reason code	Invalid range
ORO	orange roughy catch in average depth < 450m
FLT	tiger flathead catch in average depth > 550m
GRE	blue grenadier catch in average depth < 50m
RED	redfish catch in average depth > 600m
WHS	school whiting catch in average depth > 300m
MOW	jackass morwong catch in average depth > 600m
TRT	blue warehou catch in average depth > 800m
TRS	spotted warehou catch in average depth > 800m
LIG	pink ling catch in average depth > 1000m
DOM	mirror dory catch in average depth > 600m
DOJ	John dory catch in average depth > 600m
TRE	silver trevally catch in average depth > 500m
PRR	royal red prawn catch in average depth < 200m

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SEF1 data filtering - results

Method	Year	Total	Invalid	Invalid %	Date	Strip	Zone	Lat	Long	Start time	End time	Low hrs	High hrs	Av depth
TW	1985	7,171	302	4.21	0	34	133	3	2	17	54	30	7	55
TW	1986	28,041	2,507	8.94	0	87	750	2	4	1,387	81	150	19	156
TW	1987	26,255	3,930	14.97	0	552	1,033	503	505	2,826	921	935	5	1,010
TW	1988	29,680	3,519	11.86	0	482	918	433	430	2,311	966	976	0	684
TW	1989	32,227	3,170	9.84	0	256	537	219	220	1,844	1,168	1,136	1	464
TW	1990	32,639	5,268	16.14	0	73	213	68	70	2,969	2,467	2,332	4	908
TW	1991	31,162	5,184	16.64	0	269	525	240	248	2,249	3,602	2,818	110	1,201
TW	1992	25,162	2,921	11.61	0	61	296	56	60	899	1,901	1,450	49	877
TW	1993	31,185	3,864	12.39	0	133	852	118	119	1,068	2,293	1,793	7	1,030
TW	1994	33,187	3,535	10.65	0	113	1,094	50	50	772	1,769	1,512	7	751
TW	1995	33,712	3,074	9.12	0	350	1,312	68	68	848	1,358	832	6	597
TW	1996	36,145	3,091	8.55	0	377	1,492	56	56	539	971	602	8	647
TW	1997	37,611	2,933	7.80	0	270	1,577	12	12	438	795	545	13	477
TW	1998	34,844	2,379	6.83	0	15	1,131	4	4	401	729	566	8	316
TW	1999	37,400	2,490	6.66	0	194	1,233	35	35	294	696	670	19	398
TW	2000	40,034	2,759	6.89	0	406	1,480	1	1	84	662	904	36	317
TW	2001	39,083	3,029	7.75	0	52	1,694	0	0	65	511	931	79	422
TW	2002	36,551	2,106	5.76	0	9	929	3	2	64	417	731	68	282
TW	2003	38,509	3,200	8.31	0	51	1,424	9	9	172	616	1,066	119	470
TW	2004	38,333	3,039	7.93	0	72	1,485	8	8	110	586	1,077	139	394
TW	2005	34,723	2,356	6.79	0	12	1,173	5	4	105	481	686	41	486
TW	2006	29,943	1,941	6.48	0	17	883	7	6	105	439	584	74	433

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SEF1 data filtering - results

Method	Year	ORO	FLT	GRE	RED	WHS	MOW	TRT	TRS	LIG	DOM	DOJ	TRE	PRR
TW	1985	1	2	14	1	1	1	1	0	0	0	2	4	1
TW	1986	8	11	2	7	6	2	0	9	6	7	8	11	12
TW	1987	33	6	13	6	9	3	0	7	1	7	8	0	14
TW	1988	69	6	15	3	9	4	1	4	1	22	10	3	15
TW	1989	57	12	26	1	5	6	0	5	0	12	2	8	4
TW	1990	178	2	76	1	8	2	0	1	1	2	2	9	18
TW	1991	278	13	149	3	7	9	4	5	0	5	2	7	32
TW	1992	83	7	20	2	2	1	1	3	3	1	4	4	11
TW	1993	107	1	61	1	1	2	1	2	0	9	2	13	8
TW	1994	31	1	35	1	0	1	1	1	0	7	0	0	26
TW	1995	62	2	24	1	0	3	2	7	3	13	1	7	8
TW	1996	39	1	36	0	2	2	1	16	0	25	0	4	17
TW	1997	52	2	24	0	0	4	2	10	5	27	0	2	10
TW	1998	40	0	26	0	1	3	1	18	3	25	1	1	19
TW	1999	31	2	26	1	0	4	1	17	1	12	1	0	33
TW	2000	47	0	25	0	1	3	2	10	6	17	0	0	10
TW	2001	55	16	21	1	0	3	1	72	19	58	2	3	2
TW	2002	22	4	30	1	5	6	1	106	18	66	0	0	10
TW	2003	56	16	37	2	3	11	3	147	41	112	3	3	13
TW	2004	47	5	42	2	1	11	0	96	19	119	5	3	13
TW	2005	43	6	82	1	1	5	1	6	4	37	2	14	19
TW	2006	42	7	53	0	2	7	2	16	3	18	5	7	3

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SEF1 otter trawl targeting - rule

The target species is the species with the greatest portion of the total catch value in a 0.5 degree subdivision, 50 m depth, month, time of day stratum.

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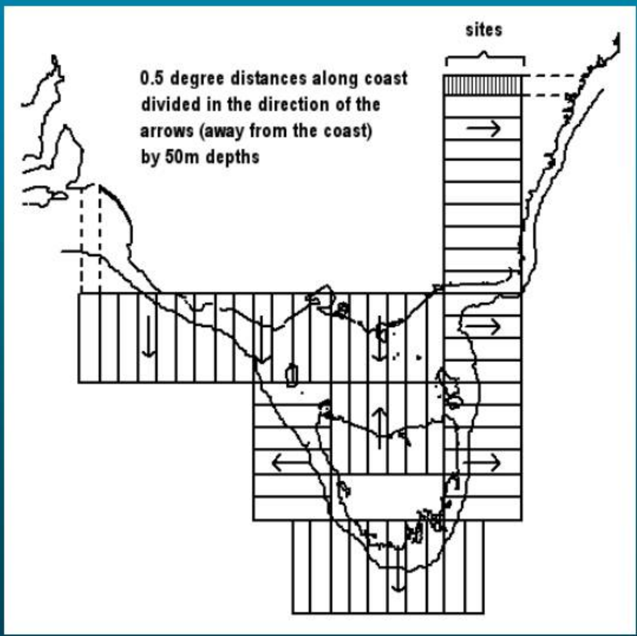
SEF1 otter trawl targeting



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SEF1 otter trawl targeting - prices

CAAB code	Scientific name	Common name	Price
27 701004	*Haliporoides sibogae*	royal red prawn	$3.89
37 227001	*Macruronus novaezelandiae*	blue grenadier	$2.80
37 228002	*Genypterus blacodes*	ling	$4.50
37 255009	*Hoplostethus atlanticus*	orange roughy	$4.03
37 258003	*Centroberyx affinis*	redfish	$1.48
37 264003	*Zenopsis nebulosus*	mirror dory	$2.46
37 264004	*Zeus faber*	John dory	$7.31
37 287001	*Helicolenus percoides/barathri*	ocean perch	$3.47
37 296001	*Neoplatycephalus richardsoni*	flathead	$2.48
37 330014	*Sillago flindersi*	school whiting	$2.24
37 337062	*Pseudocaranx dentex*	silver trevally	$2.18
37 377003	*Nemadactylus macropterus*	jackass morwong	$2.27
37 439002	*Rexea solandri*	gemfish	$4.35
37 445001	*Hyperoglyphe antarctica*	blue-eye trevalla	$6.80
37 445005	*Seriolella brama*	blue warehou	$2.42
37 445006	*Seriolella punctata*	spotted warehou	$1.63
		other	$1.43

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SEF1 otter trawl targeting

Target	Ops	DOJ	DOM	FLT	GEM	GRE	LIG	MOW	ORO	OTH	PRR	RED	REG	TBE	TRE	TRS	TRT	WHS	TOT
		Percentage catch composition																	
DOJ	15,501	15.3	0.5	19.3	0.3	0.1	0.6	3.6	0.0	30.4	0.0	22.1	0.5	0.0	5.8	0.5	0.5	0.5	100
DOM	3,577	0.1	44.1	1.4	6.2	2.9	6.7	0.7	0.0	21.6	1.7	5.8	4.3	0.5	0.0	3.7	0.1	0.0	100
FLT	90,009	3.1	0.5	42.9	0.3	0.1	1.2	11.0	0.0	24.1	0.0	6.6	0.4	0.0	3.6	3.4	2.4	0.6	100
GEM	22,858	0.1	7.0	0.9	66.4	4.1	3.8	1.6	0.0	8.7	0.7	2.4	0.9	0.3	0.0	2.6	0.6	0.0	100
GRE	44,946	0.0	0.9	0.0	1.0	77.6	4.2	0.1	0.1	4.8	0.0	0.0	0.7	0.4	0.0	9.6	0.5	0.0	100
LIG	55,079	0.1	4.9	0.8	2.4	11.7	39.8	0.9	0.1	15.6	0.7	2.2	7.7	0.6	0.1	11.8	0.6	0.0	100
MOW	31,991	1.0	0.3	14.0	0.9	0.6	1.2	48.2	0.0	18.2	0.0	3.3	0.3	0.0	0.8	5.2	5.7	0.0	100
ORO	75,193	0.0	0.0	0.0	0.0	0.1	0.0	0.0	94.8	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
OTH	60,547	0.6	1.0	3.8	0.6	1.6	1.6	1.7	2.5	77.2	0.1	3.1	0.9	0.1	0.9	2.7	1.5	0.2	100
PRR	17,594	0.0	3.5	0.1	1.6	0.5	5.4	0.0	0.0	8.2	75.5	0.3	4.6	0.1	0.0	0.0	0.0	0.0	100
RED	30,995	2.1	1.7	7.7	0.9	0.1	0.9	2.0	0.0	15.5	0.0	65.2	0.7	0.0	1.6	1.0	0.4	0.1	100
REG	2,998	0.1	3.8	0.5	1.3	2.6	15.7	0.6	1.5	22.5	5.2	2.0	42.6	0.2	0.1	1.2	0.1	0.0	100
TBE	1,725	0.1	3.9	1.1	3.1	15.3	4.6	0.8	1.0	13.2	0.0	0.2	0.7	40.0	1.1	12.3	2.5	0.0	100
TRE	14,230	2.9	0.1	12.3	0.1	0.1	0.5	1.9	0.0	23.8	0.0	6.6	0.2	0.0	46.2	1.7	1.6	2.1	100
TRS	26,646	0.2	1.2	2.6	1.0	5.2	4.1	2.5	0.0	10.1	0.0	1.3	0.5	0.4	0.3	67.2	3.3	0.0	100
TRT	18,736	0.6	0.2	5.9	0.7	0.6	0.9	6.6	0.0	18.4	0.0	2.1	0.1	0.2	1.5	14.4	47.8	0.0	100
WHS	6,265	0.9	0.0	12.0	0.0	0.0	0.0	0.2	0.0	22.1	0.0	2.0	0.0	0.0	5.3	0.0	0.0	57.3	100

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SEF1 otter trawl targeting

Target	Ops	DOJ	DOM	FLT	GEM	GRE	LIG	MOW	ORO	OTH	PRR	RED	REG	TBE	TRE	TRS	TRT	WHS
		Percentage of total species weight caught																
DOJ	15,501	23.9	0.4	3.7	0.1	0.0	0.2	1.0	0.0	2.0	0.0	4.7	0.6	0.1	5.3	0.1	0.2	1.8
DOM	3,577	0.1	12.7	0.1	0.6	0.1	0.7	0.1	0.0	0.5	0.6	0.5	1.8	0.8	0.0	0.2	0.0	0.0
FLT	90,009	35.9	2.6	60.9	0.5	0.1	2.3	23.0	0.0	11.7	0.0	10.4	2.8	0.6	24.1	3.2	7.1	15.2
GEM	22,858	0.6	28.0	0.9	85.7	1.6	5.4	2.4	0.0	3.0	3.1	2.7	5.3	6.4	0.2	1.7	1.2	0.0
GRE	44,946	0.2	11.2	0.1	3.9	89.3	17.3	0.6	0.0	4.9	0.1	0.1	11.2	24.5	0.1	18.9	3.0	0.0
LIG	55,079	0.9	20.3	0.8	3.2	4.7	57.2	1.4	0.0	5.5	3.4	2.5	44.8	12.0	0.5	8.1	1.3	0.5
MOW	31,991	6.1	1.0	10.7	0.9	0.2	1.3	54.1	0.0	4.8	0.0	2.8	1.3	0.6	3.0	2.7	9.3	0.4
ORO	75,193	0.0	0.0	0.0	0.0	0.2	0.1	0.0	99.5	14.3	0.0	0.0	0.8	2.1	0.0	0.0	0.0	0.0
OTH	60,547	6.4	5.8	5.3	1.0	0.9	3.2	3.5	0.4	36.8	0.4	4.8	7.0	1.9	6.3	2.4	4.4	4.2
PRR	17,594	0.0	3.6	0.0	0.5	0.1	1.9	0.0	0.0	0.7	91.2	0.1	6.7	0.4	0.0	0.0	0.0	0.0
RED	30,995	15.5	6.3	7.1	1.1	0.0	1.2	2.6	0.0	4.8	0.1	66.3	3.3	0.4	7.1	0.6	0.8	1.5
REG	2,998	0.0	0.6	0.0	0.1	0.0	0.9	0.0	0.0	0.3	1.0	0.1	9.9	0.2	0.0	0.0	0.0	0.0
TBE	1,725	0.0	0.8	0.1	0.2	0.3	0.3	0.1	0.0	0.2	0.0	0.0	0.2	38.9	0.3	0.4	0.3	0.0
TRE	14,230	4.9	0.1	2.6	0.0	0.0	0.1	0.6	0.0	1.7	0.0	1.5	0.2	0.2	45.3	0.2	0.7	7.9
TRS	26,646	1.9	6.0	3.2	1.6	2.5	7.2	4.7	0.0	4.3	0.0	1.9	3.5	9.1	1.8	55.6	8.9	0.1
TRT	18,736	3.0	0.6	3.7	0.6	0.1	0.8	6.0	0.0	3.9	0.0	1.5	0.5	1.8	4.5	5.9	62.8	0.3
WHS	6,265	0.5	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.1	0.0	0.0	1.6	0.0	0.0	68.1
TOTAL	518,890	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

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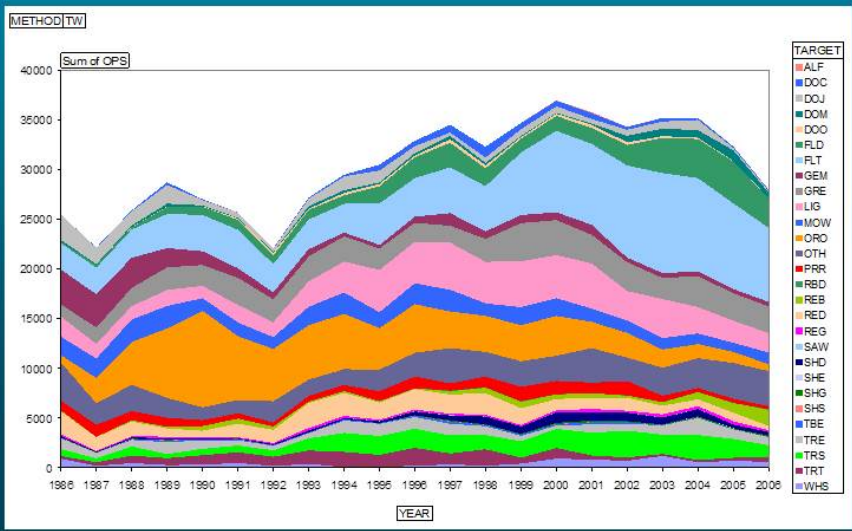
SEF1 otter trawl targeting

Number of operations each year assigned to each target species.



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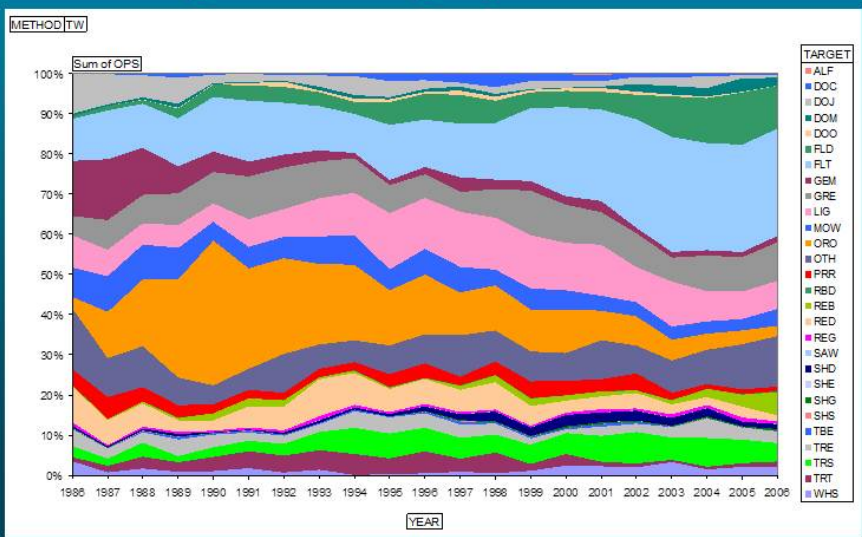
SEF1 otter trawl targeting

Proportion of operations each year assigned to each target species



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Companion species

Where catches of the primary species in the most recent year are arranged in sorted order according to the target, then the companion species are those target species that are included in the top 50% of the total catch of the primary species.

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Companion species (2006)

Primary	%	Companion	%	Associated	%	Other	%
ALF	8.0	GRE	73.3	LIG	15.4		3.3
DOC	45.4	ORO	14.5	SHD,GRE	26.8		13.3
DOJ	9.0	FLT	62.3	OTH	11.6		17.1
DOM	35.0	LIG	21.6	GRE	12.4		31.0
DOO	89.6			ORO	10.0		0.4
FLD	66.3			REB	22.6		11.1
FLT	80.0						20.0
GEM	75.3						24.7
GRE	87.9						12.1
LIG	53.3			GRE	22.8		23.9
MOW	40.8	FLT	31.9				27.3
ORO	99.1						0.9
OTH	24.7	FLD,FLT	34.6	REB	11.4		29.3
PRR	92.8						7.2
RBD	23.8	SHD	34.0	GRE,ORO	25.3		16.9
REB	70.6			FLD	23.3		6.1
RED	46.6	FLT	20.7	OTH	18.3		14.4
REG	15.8	LIG,GRE	41.2				43.0
SAW	2.0	FLD,FLT,OTH	57.3				40.7
SHD	59.6			ORO	14.6		25.8
SHE	0.0	FLT,OTH	66.7				33.3
SHG	7.4	FLD,FLT	45.3				47.3
SHS	3.1	GRE,TRS,FLT	47.8	OTH	11.8		37.3
TBE	41.7	GRE	27.2	TRS	14.8		16.3
TRE	53.6			FLT	35.8		10.6
TRS	61.4			GRE	22.5		16.1
TRT	75.2						24.8
WHS	67.7			FLT	23.2		9.1

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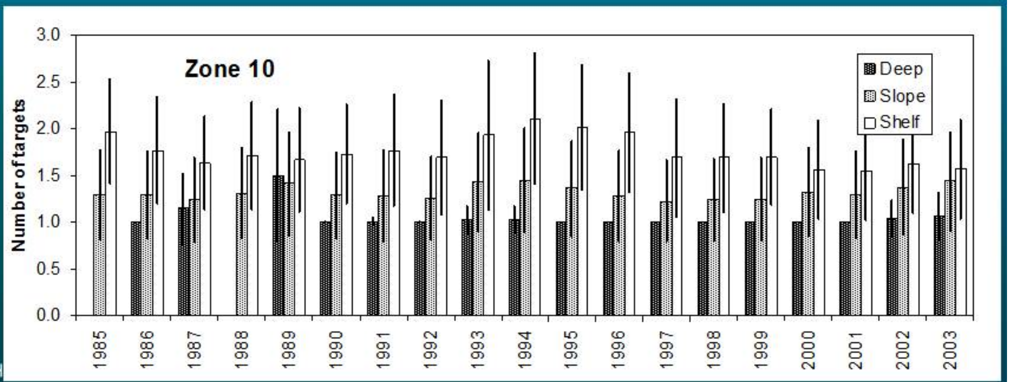
SEF1 otter trawl – number of targets

How many species catch values in a stratum/month are needed to make more than half of the total

- Deep (>800) normally 1.0
- Slope (200-800) 1.0-1.5
- Shelf (<=200) 1.3-2.0

(zones 10, 20, 30 similar)



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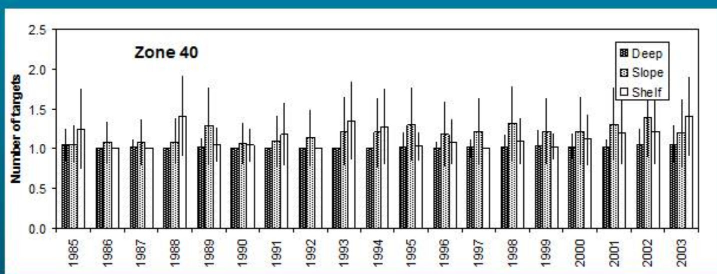
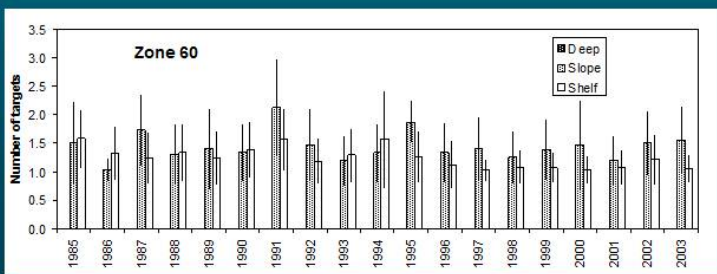
SEF1 otter trawl – number of targets

No obvious trends..





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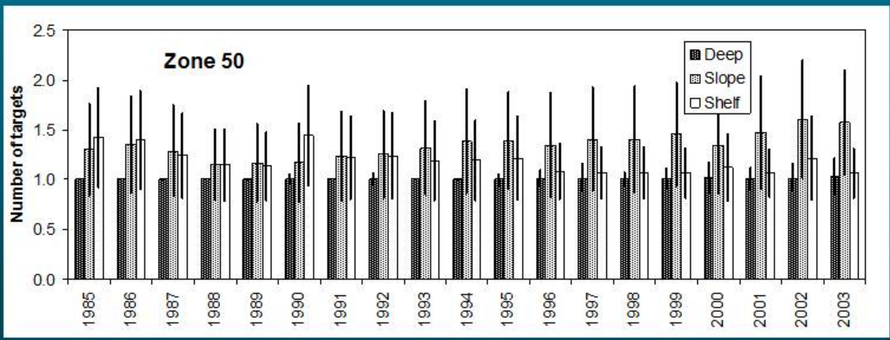
SEF1 otter trawl – number of targets

Zone 50 – off Portland

- number of target species on the slope declined from 1985 to about 1989
- has steadily increased since that time



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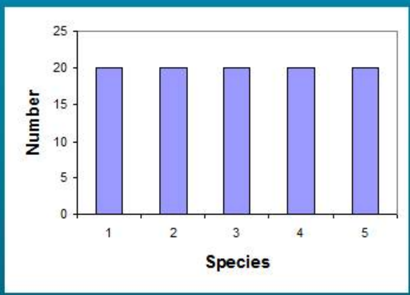
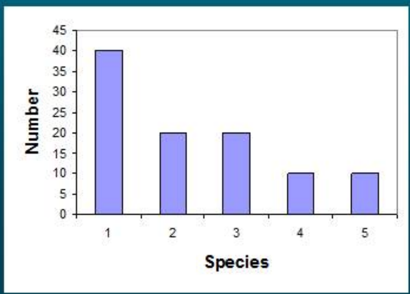
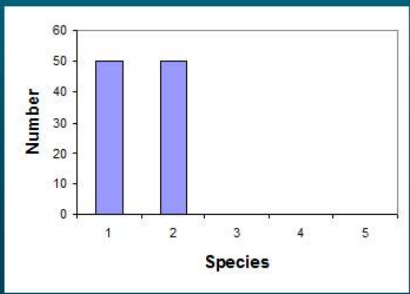
SEF1 otter trawl – diversity



Lower evenness



Lower richness



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SEF1 otter trawl - diversity

$$H = -\sum_{i=1}^{S} (p_i)(\log_2 p_i)$$

where	H	=	Shannon-Wiener index of diversity
	S	=	number of species
	p_i	=	proportion of the total sample belonging to the ith specie

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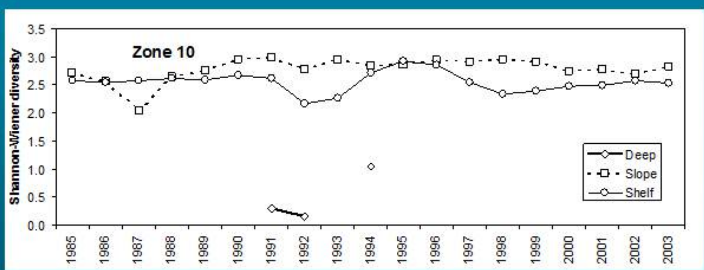
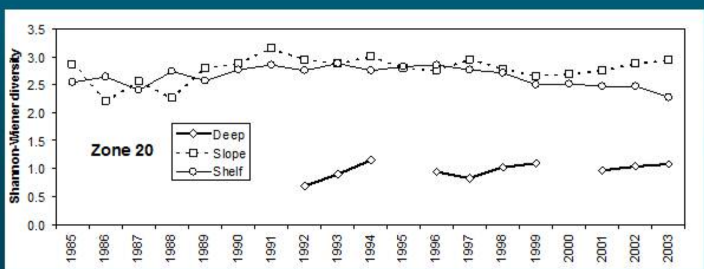
SEF1 otter trawl diversity trends

No strong trends – similar pattern to number of targets





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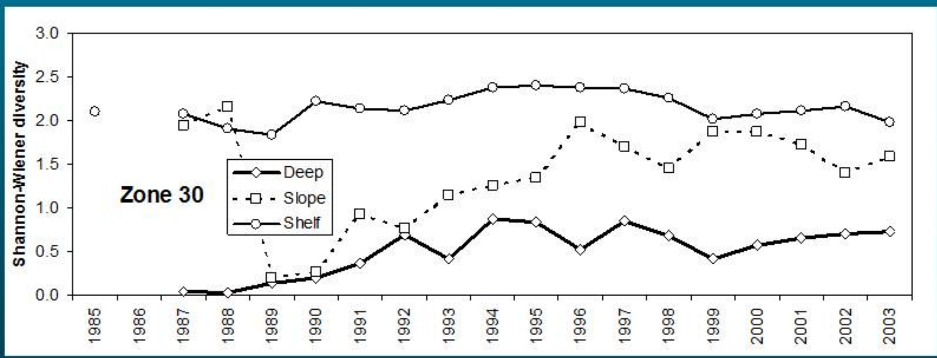
SEF1 otter trawl diversity trends

- Diversity for slope catches in zone 30 showed a strong drop from 1988 to 1989, then a considerable continuous increase to about 1996 then a levelling off
- Catch diversity in deep waters for zone 30 increases to about 1994 then levels off



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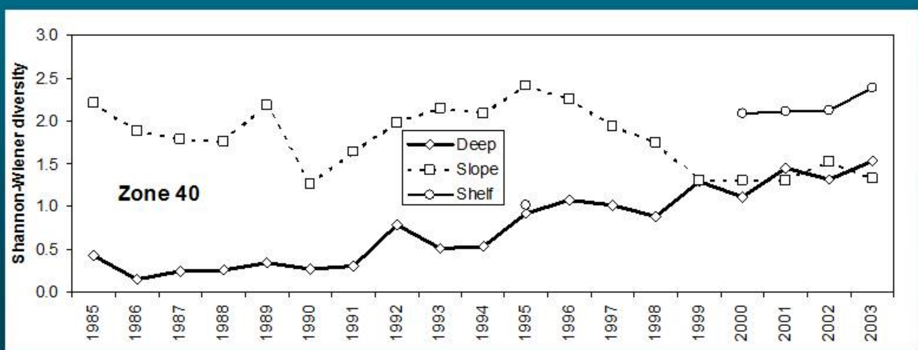
SEF1 otter trawl diversity trends

- Diversity for slope catches in zone 40 decreases from 1985 to 1990, increases to 1995, decreases to 1999, then a levelling off (grenadier fishing dominates?)
- Catch diversity in deep waters for zone 40 increases throughout



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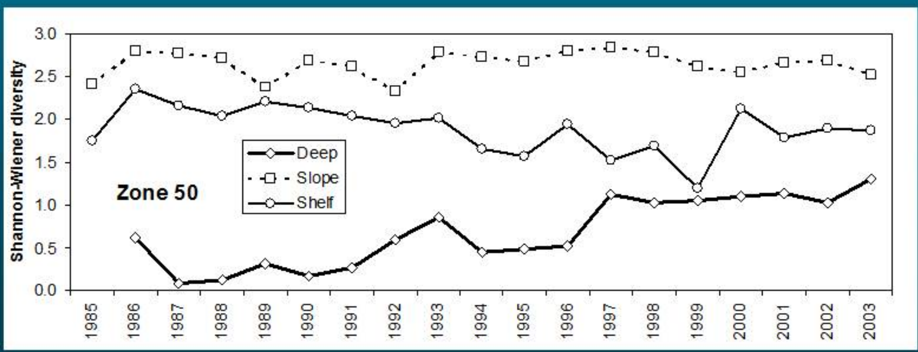
SEF1 otter trawl diversity trends

- No strong trends for shelf or slope
- Steady increase for deep
- Increase in number of targets for the slope has not apparently affected the diversity index



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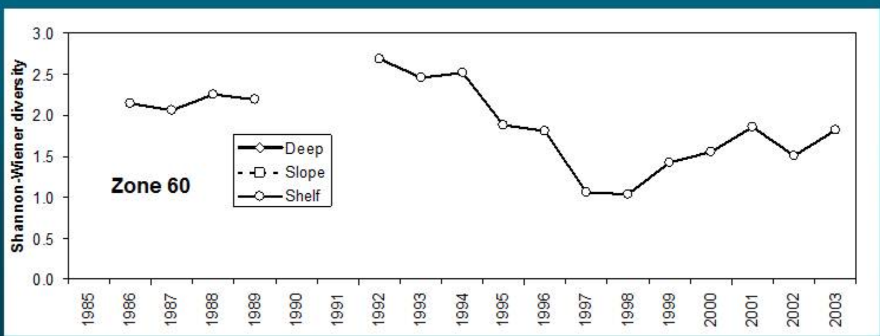
SEF1 otter trawl diversity trends

- Decline from 1992 to 1998, then increase



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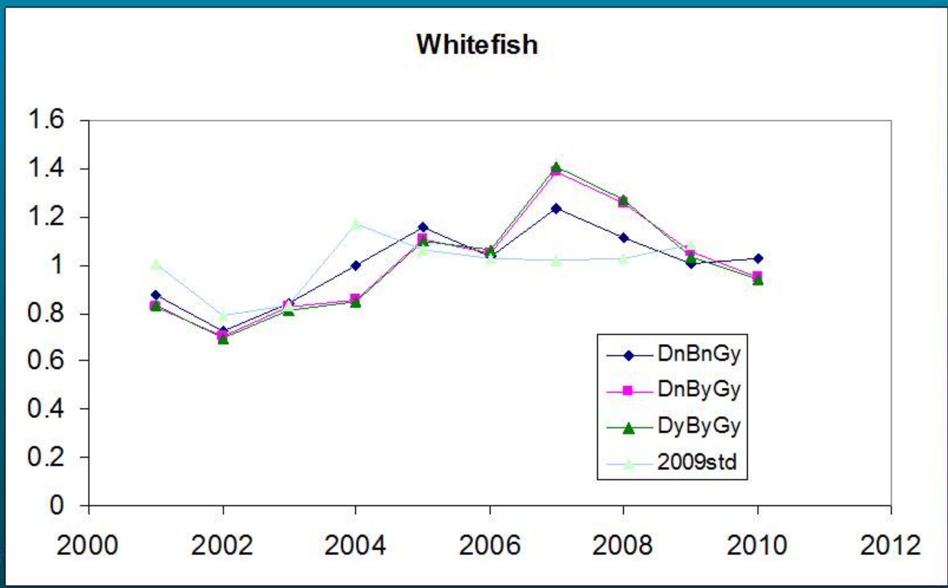
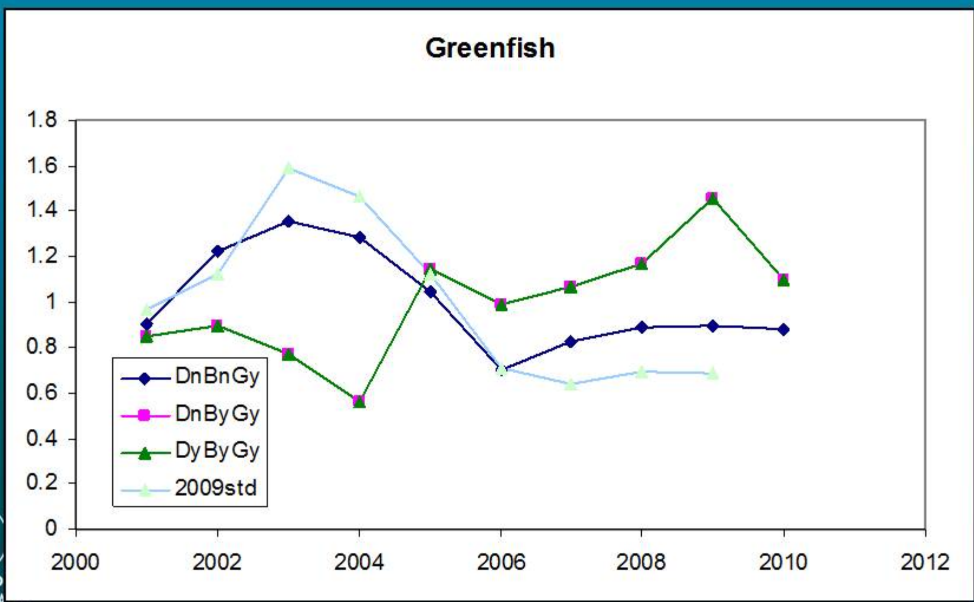
Whitefish



Greenfish



SEF1 otter trawl diversity trends

- Different zones and depths show very different historical patterns, indicating the development of new target fisheries
- No indication of strong trends in catch diversity for the past 5 years in any areas/depths

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16.1.3 Catches and Catch Rates – Malcolm Haddon

Non-Target = Data Poor?

- Often, only data from commercial logs.
  - Might contain, date, location, depth, catch, effort – thus we have more than catch and effort.
- Possibly some biological studies (growth, maturity – aspects of productivity).
- A weight of evidence approach can be used to assess such species.
- This means using all available information to determine if a stock is stable, increasing, or decreasing.

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Objectives of Assessment

- The Commonwealth Harvest Strategy Policy talks in terms of B_{MEY} and B_{LIM} as B_{48} & B_{20}.
- Proxies can replace the specific target and limit reference points (TRP & LRP).
- Rules exist for selecting the proxy targets and limits, but whether they are even close to B_{48} or B_{20} is never really known.
- In effect, we attempt to determine the direction in which we want the fishery to move forward.
- Can achieve a target and avoid a limit, but must acknowledge that these be merely pragmatic.

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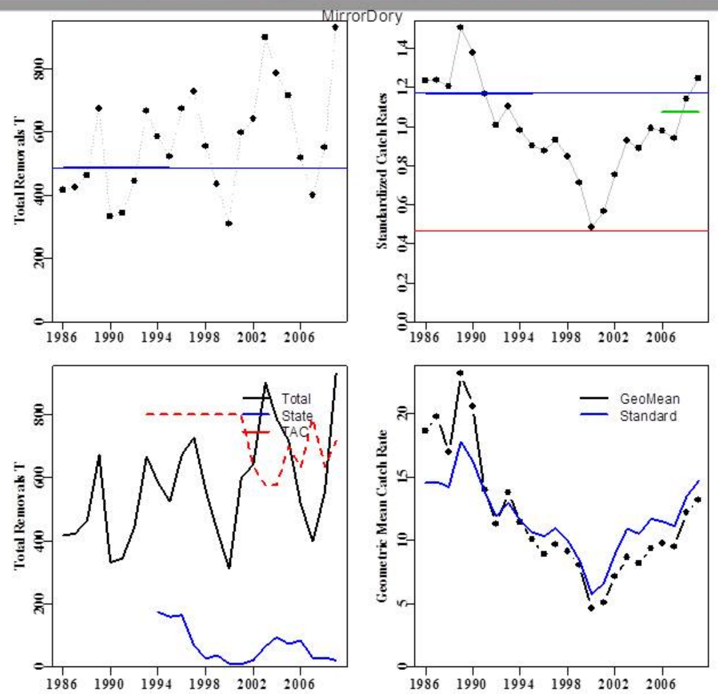
e.g. TIER 4 from SESSF



Harvest Strategies

- Perhaps the best that can be achieved with non-target species is to aim for a minimum of negative changes (status quo or positive).
- The notions of a Target and Limit Reference Point assume some kind of equilibrium.
- For short lived, opportunistic species, with variable recruitment, TRP and LRP may be too static to be realistic.
- The Commonwealth HSP makes clear that not all species in a mixed fishery can be expected to achieve their TRPs.

Weight of Evidence?

- Multi-Criterion Decision Analysis
  - What is known and how productive is it likely to be
- Ecological Risk Assessment
  - Habitat/Distribution
  - Mobility/stock structure
  - Natural Mortality/Maximum Age
  - Growth/maturity/spawning season
  - Recruitment/Early Life History
  - History of fishery/Expected fishery dynamics
- Analysis of Fishery Data
  - Catch rates/seasonality
  - Tier 4 or Tier 3
  - Inter-relationships/time series/patterns in time and geography.

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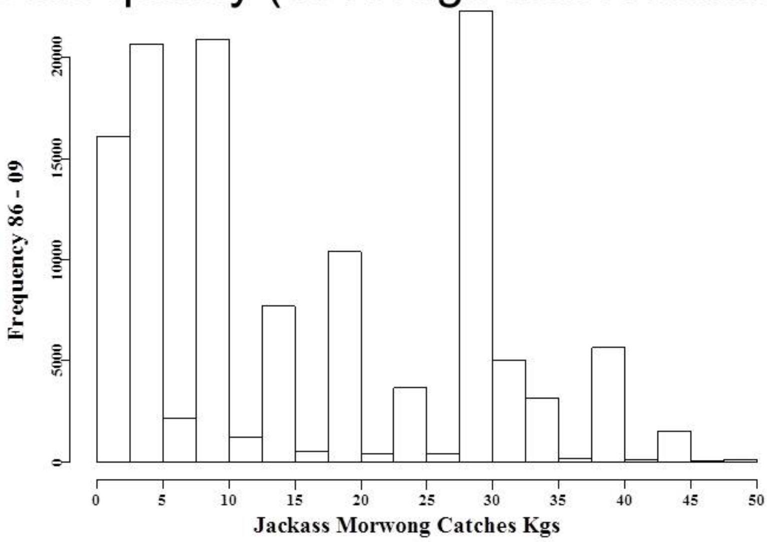
Catch and Catch-Rates

- Initial data exploration important.
- Data quality (coverage and reliability)



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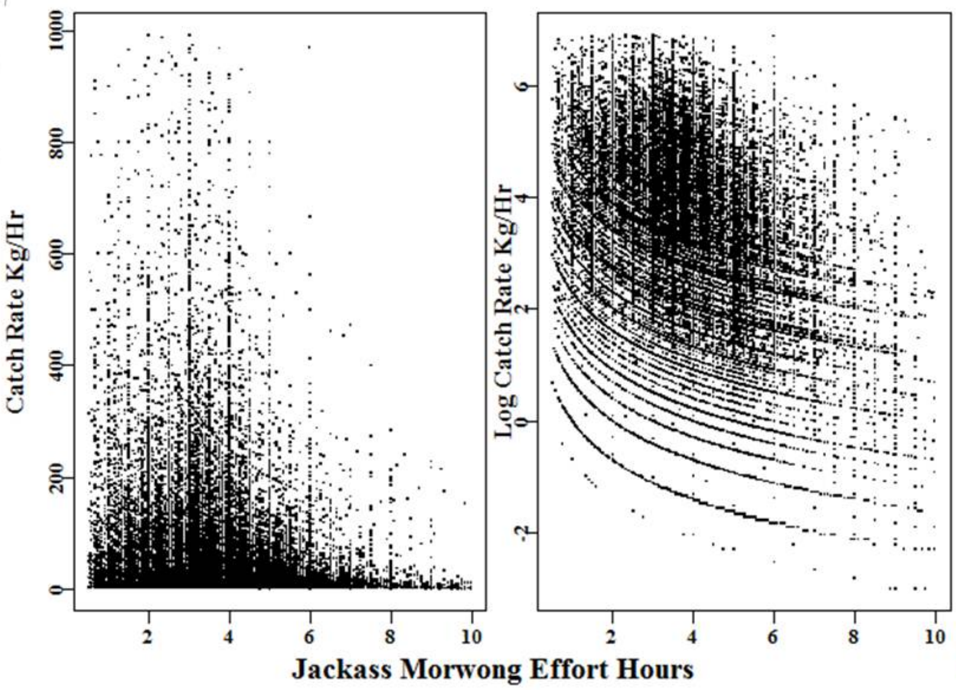
Implications of Rounding



Catch Rate Standardization

$$\mathrm{Ln}\left(CPUE_i\right) = \alpha_0 + \alpha_1 x_{i,1} + \alpha_2 x_{i,2} + \sum_{j=3}^{N} \alpha_j x_{ij}$$

$$CPUE_t = e^{\left(\gamma_t + \sigma_t^2/2\right)}$$

$$CE_t = \frac{CPUE_t}{\left(\sum CPUE_t\right)/n}$$

Standardization – Inclusion of Zeros

$$\ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 x_{i,1} + \beta_2 x_{i,2} + \sum_{j=3}^{N} \beta_j x_{ij}$$

$$\hat{p}_t = \frac{\exp(\beta_0 + \lambda_t)}{1+\exp(\beta_0 + \lambda_t)}$$

$$Yr_t = p_t CPUE_t$$

Lots of caveats: Is it possible to accurately identify zero shots – this is really a question about targeting by shot? Are the reference points for the various factors typical?

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Issues

- Is the log-normal the best for the job (can use Poisson, gamma, negative-binomial).
- Pre-selection of data – the idea being to avoid vessels/records where the species was not being targeted
  - Minimum number of years in fishery by vessels
  - Minimum catch per vessel
  - Minimum catch per shot (very bad choice)
- Interaction terms – cannot include Year
- Mixed effects modelling,
- Calculations can be difficult in R when there are a large number of records – "biglm"
- Do catch rates reflect abundance?

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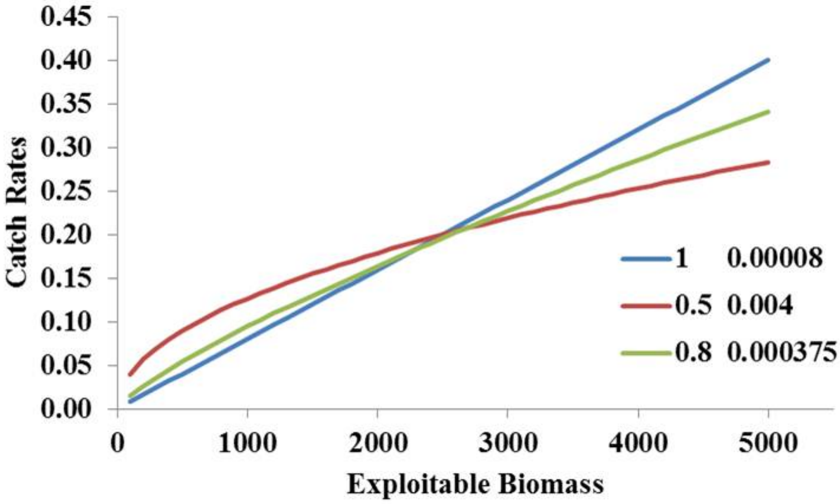
Do catch rates reflect abundance

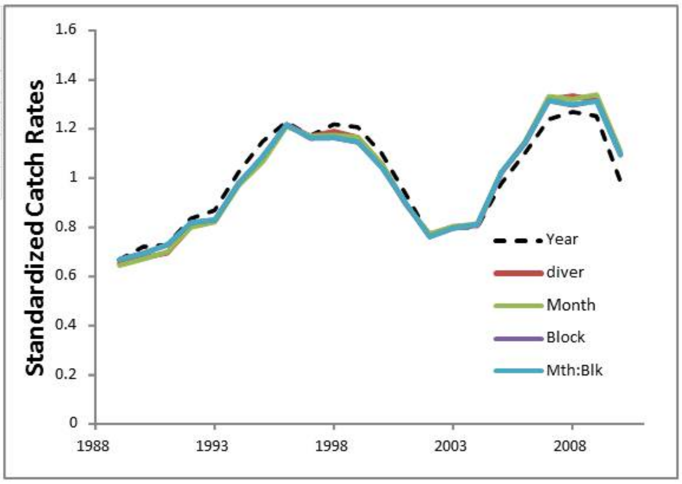
$$I_t = \frac{C_t}{E_t} = qB_t^{\gamma}$$

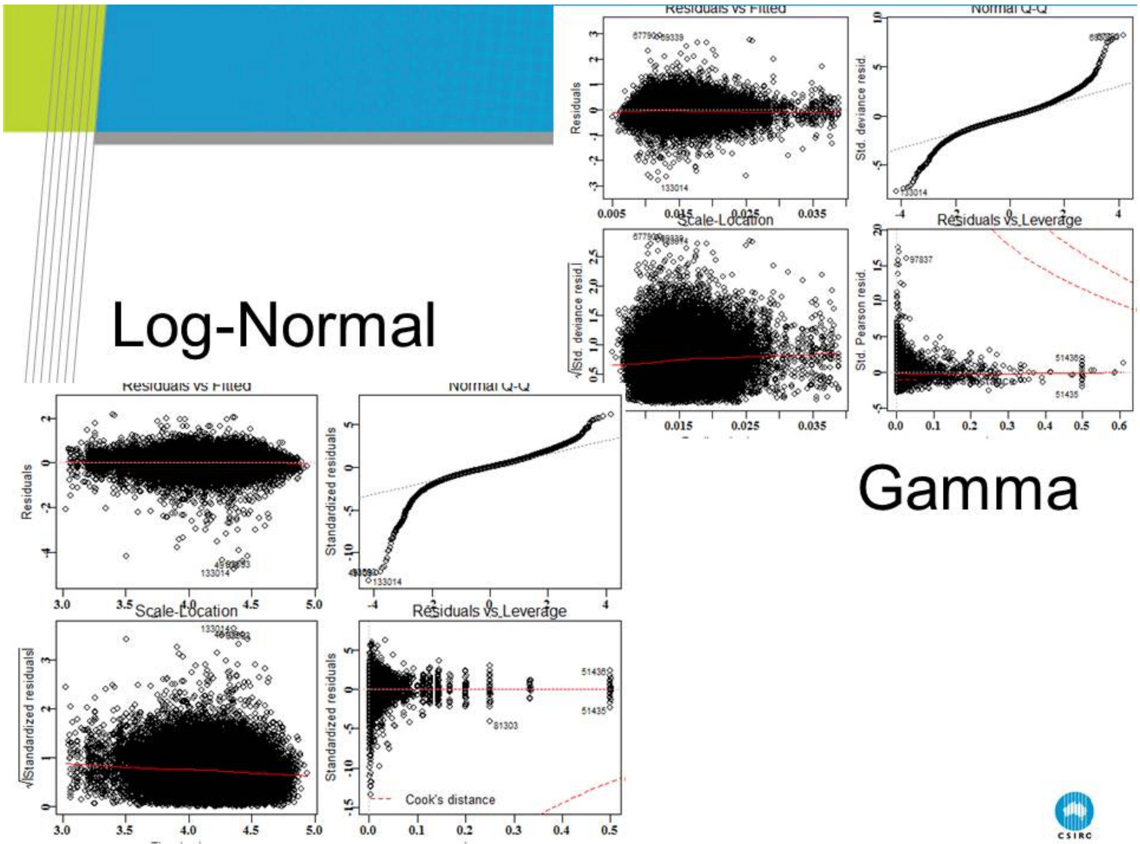


Tasmanian Abalone Blocks 13 & 14

	Npars	adj_r2	%Change
Year	22	19.995	
Diver	253	36.811	16.816
Month	265	38.329	1.518
Block	266	39.630	1.301
Mth:Blk	277	39.681	0.051

- Mth:Blk significant but little effect on trend.
- Most of signal in the Diver.
- The other factors make minor alterations.

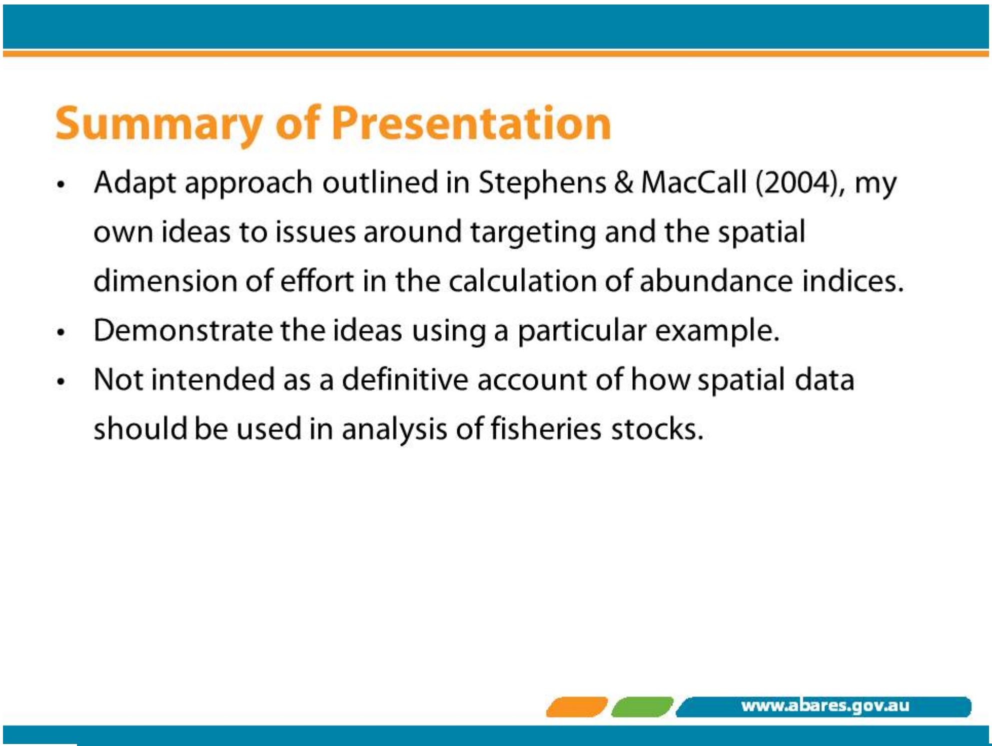


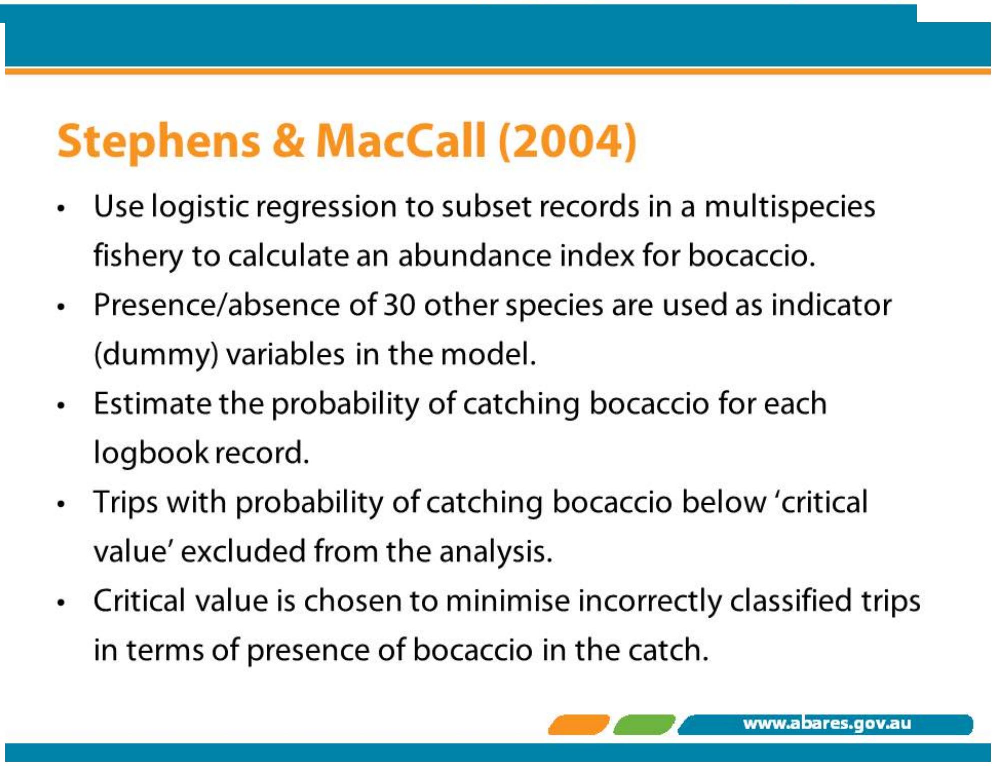


Pre-selection of Data

	10	20	30	40	50	60	70	82	83	84	85	91
1986	180.613	35.645	NA	0.170	1.241	5.014	NA	1.230	0.060	NA	NA	4.877
1987	160.722	34.725	0.310	0.070	0.843	1.277	NA	1.117	0.005	NA	NA	4.843
1988	130.591	43.912	0.365	NA	0.060	0.978	NA	0.685	0.010	NA	0.458	2.658
1989	147.471	56.168	0.205	NA	NA	2.788	NA	1.314	0.206	0.006	0.013	3.647
1990	104.864	50.554	0.845	0.600	0.064	1.633	NA	0.163	0.679	NA	NA	3.130
1991	96.375	54.560	0.163	0.500	0.110	2.193	NA	1.452	2.237	NA	NA	4.895
1992	85.733	35.762	0.030	NA	NA	2.358	NA	0.465	0.802	0.010	NA	0.846
1993	140.534	55.144	0.490	0.043	0.075	8.453	NA	1.240	0.536	NA	NA	16.592
1994	165.227	57.093	0.070	2.220	0.830	9.267	NA	0.735	0.228	NA	NA	21.396
1995	122.297	48.678	0.062	NA	0.400	2.154	NA	0.457	0.080	NA	NA	7.620
1996	109.875	41.022	0.039	NA	0.172	2.419	NA	0.535	0.025	NA	NA	4.334
1997	48.201	34.211	0.171	NA	0.308	2.257	NA	0.410	0.204	NA	NA	1.472
1998	67.329	34.486	0.090	NA	0.059	2.835	NA	1.095	1.326	0.005	NA	1.437
1999	81.780	44.339	0.023	NA	0.008	2.160	NA	0.963	1.848	0.008	0.001	1.204
2000	98.585	59.415	0.045	NA	0.065	2.191	NA	1.031	1.898	0.031	NA	0.449
2001	60.516	61.839	0.440	0.050	0.034	2.238	NA	1.008	1.418	0.018	0.004	0.994
2002	75.128	68.680	0.122	NA	0.059	3.532	NA	0.586	2.278	0.020	0.005	0.203
2003	76.140	71.729	0.159	NA	0.192	3.073	0.020	0.853	3.157	0.094	0.006	0.690
2004	88.467	67.336	0.173	NA	0.252	4.995	NA	0.717	1.706	0.025	0.002	1.246
2005	39.346	57.714	0.213	0.020	0.223	6.723	NA	0.875	1.236	NA	NA	0.615
2006	31.300	46.238	0.173	NA	0.402	4.533	NA	0.651	0.855	0.009	0.165	0.613
2007	27.964	29.032	0.212	NA	0.251	2.119	NA	1.388	1.323	0.044	0.003	0.113
2008	67.765	41.520	0.238	NA	0.274	3.203	0.004	0.611	1.127	0.026	0.008	1.834
2009	53.325	34.246	0.194	0.161	0.048	2.274	NA	0.355	0.738	0.018	0.009	0.271

16.1.4 Spatial Methods for Non-Target Species in Fisheries – Mark Chambers





The example that I go through here is a fairly quick analysis that I did specifically for this talk.

Use spatial data if available

- Generalized Additive Models now permit isotropic smooths on latitude and longitude.
- Incorporating location specific variables related to probability of catching target species allows more general models whilst still enabling mapping.
- Bathymetric data is always available for instance.

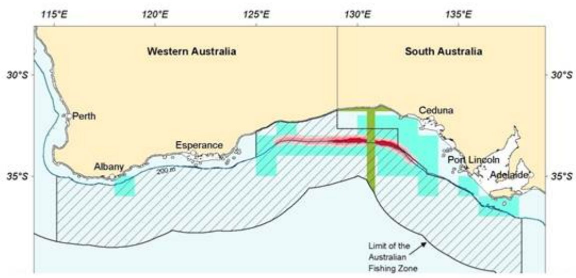
http://www.ngdc.noaa.gov/mgg/gdas/gd_designagrid.html

- I exclude the temporal variable (e.g. Year) from these models.

www.abares.gov.au

GAB Trawl

- Stocks assessed: Bight redfish, deepwater flathead, ocean jacket and orange roughy.
- Key byproduct species: blue grenadier, jackass morwong, gemfish.
- GVP 2008-09 $9 million, 4 active vessels.

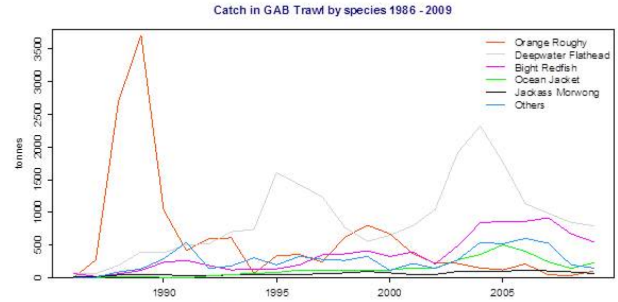


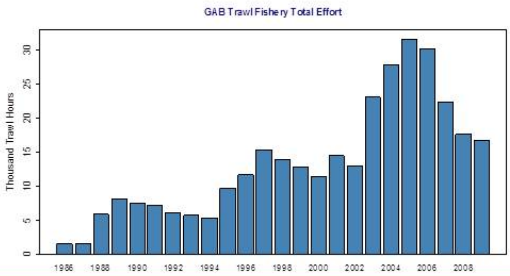
Generally a variety of species retained from a given trawl.

www.abares.gov.au

Stephens & MacCall suggest using species presence/absence as predictors in their sub-setting model when data on fishing location is unavailable, suggesting that subsetting would be based on location if appropriate regions could be identified. Alternatively the same modelling procedure can be used with spatial predictors.

Species in the GAB





Here others includes latchet, gemfish, boarfish as well as unclassified catch.

Effort

www.abares.gov.au

Logbook records for a total of 67 vessels were considered. In recent years the number of vessels operating has generally been 10 or less.

Jackass morwong in the GABTF

- First consider modelling the probability of catching JM using a GAM including trawl location data.
- I find I get better results here if I aggregate presence/absence data to the 6 minute C-square level.
- For each C-square we define a bivariate response variable detailing y shots catching jackass morwong from a total number of n shots in the C-square.
- Just over 1,400 C-squares were fished in the GAB, but many squares had a handful or less shots.

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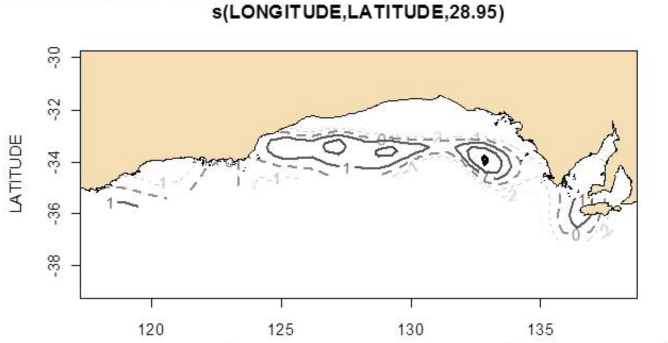
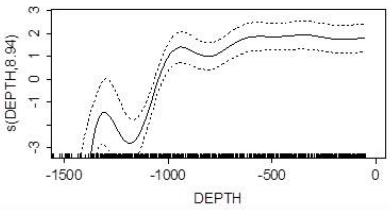
Binomial GAM smooths

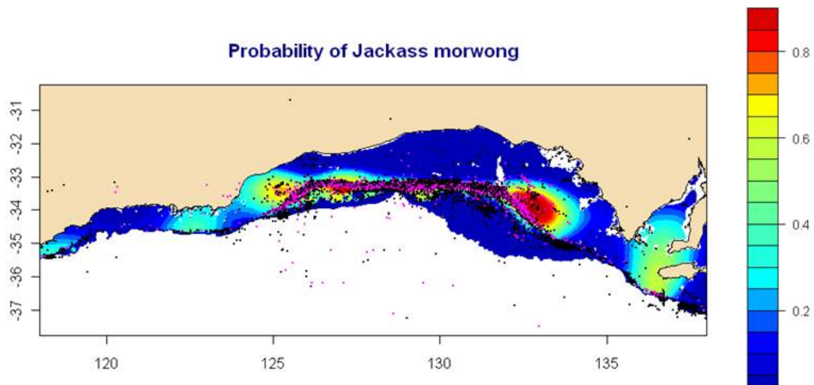


$$\mathrm{logit}(\Pr(JM)) \sim s(Longitude_{c-sqr}, Latitude_{c-sqr}) + s(Depth_{c-sqr})$$



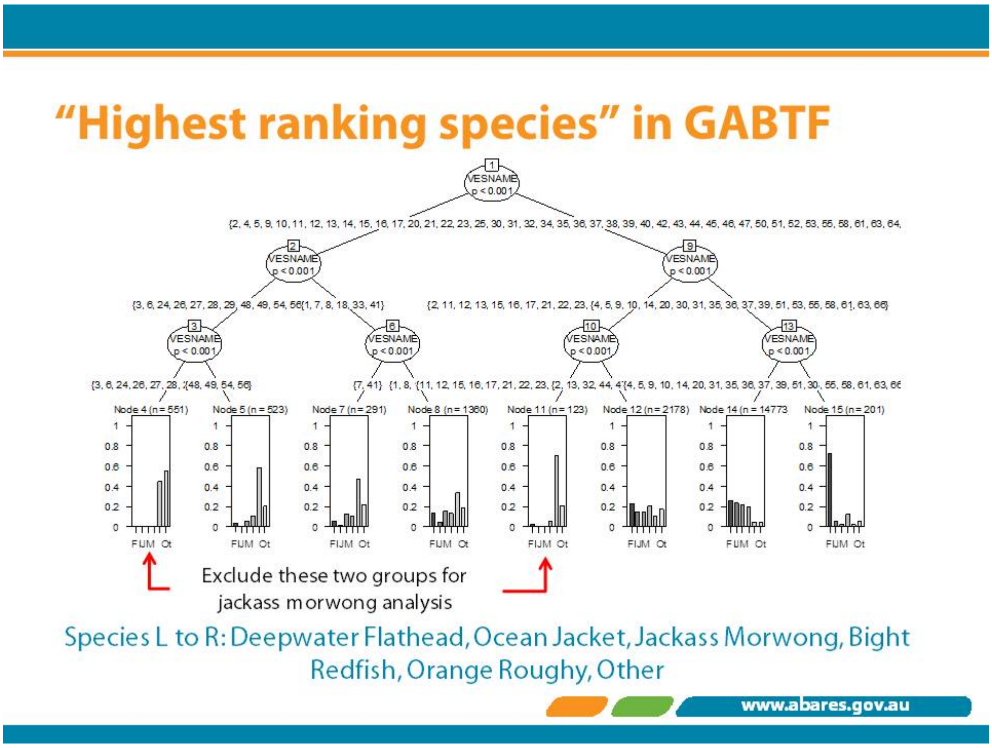
C-square can also be used as a categorical variable – say for random effects. Might want to use a coarser scale in this case. Morwong catch was recorded in around 550 C-squares.

Probability of Jackass Morwong

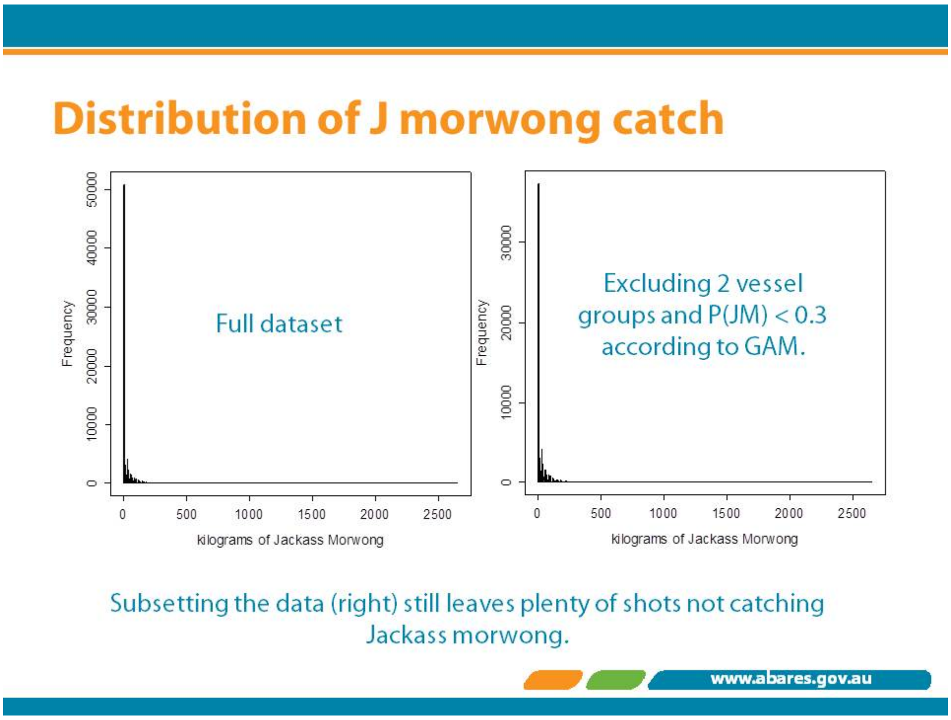


Shots whose fitted probability of catching jackass morwong is less that 0.3 are excluded from further analysis.

Because the GAM is fit to the aggregated 1200 data points (c-squares) rather than 70,000 +, it fits quickly even in R.



If a binomial GAM incorporating an isotropic smooth in latitude and longitude is fit to the data a predictive map can be produced plotting the probability of catching jackass morwong (or whatever). Depth from bathymetric data can be obtained to get some linking information for areas with little data, but it's primarily the areas being fished that we're interested in.



Random Sample of 20 thousand observations used here. Necessary to ensure that some shots from any vessel to be included in the analysis in the sample. Here, the first two groups are of little interest to analyses other than Orange Roughy. Other classifying methods eg random forests can alternatively be used.

Binary Presence/Absence GLM

- logit(Pr(*JM*)) ~ logit_{GAM}*$YEAR$ + $VesselGroup$

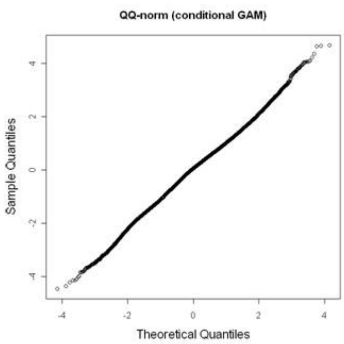
From the data subsetting GAM model considering latitude, longitude & depth

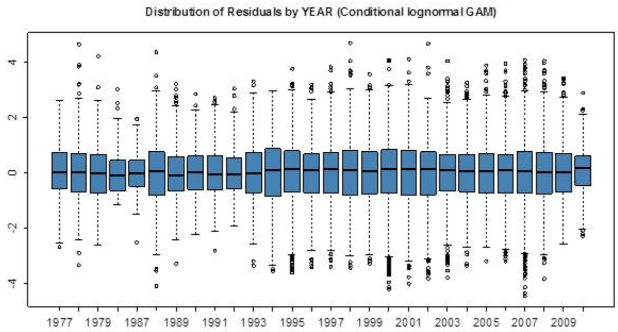
From the classification trees model.

The vessel Group is from the classification tree model.

Conditional GAM

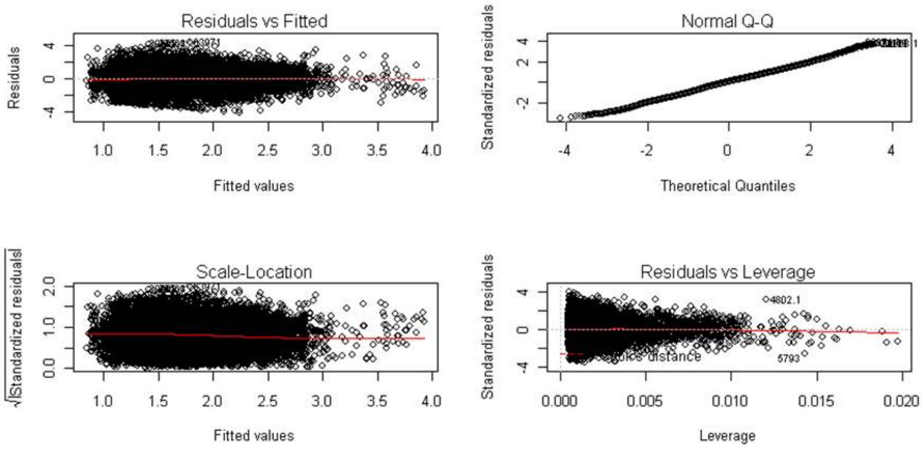
- log(CPUE)~s(LONGITUDE,LATITUDE)+s(DEPTH)+Vessel Group+YEAR





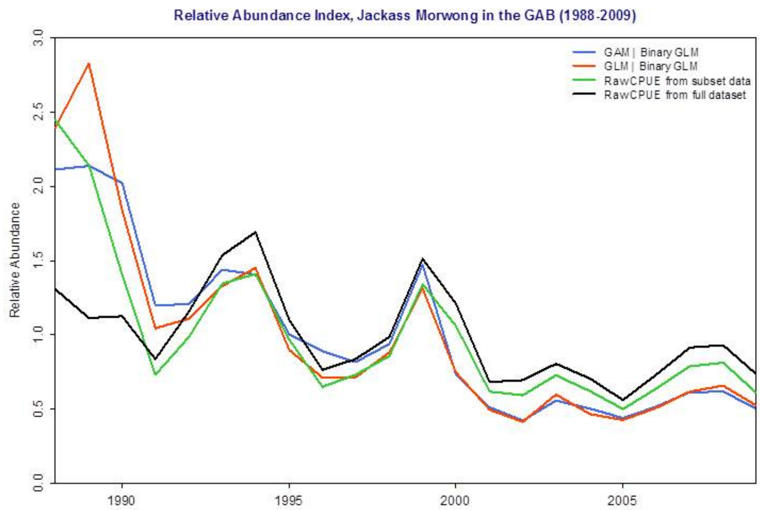
Conditional Linear Model

- log(CPUE) ~ YEAR*Binomial GAM Logit + Vessel Group



www.abares.gov.au

Abundance indices

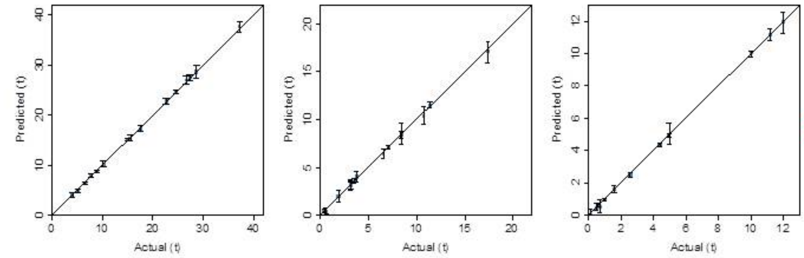


www.abares.gov.au

Confidence intervals here based on fairly comprehensive bootstrapping. Perhaps the surprising thing here is that it was the initial data subsetting that had most of the effect, not the subsequent modelling.

Other applications

- Estimate the spatial range of species and compare with fisheries effort data for ERA/PSA, "SAFE" type methods.
- More defensible exclusion of zero shots to use in a one stage model (with perhaps addition of small constant for lognormal models).
- Classify unspecified bycatch data.

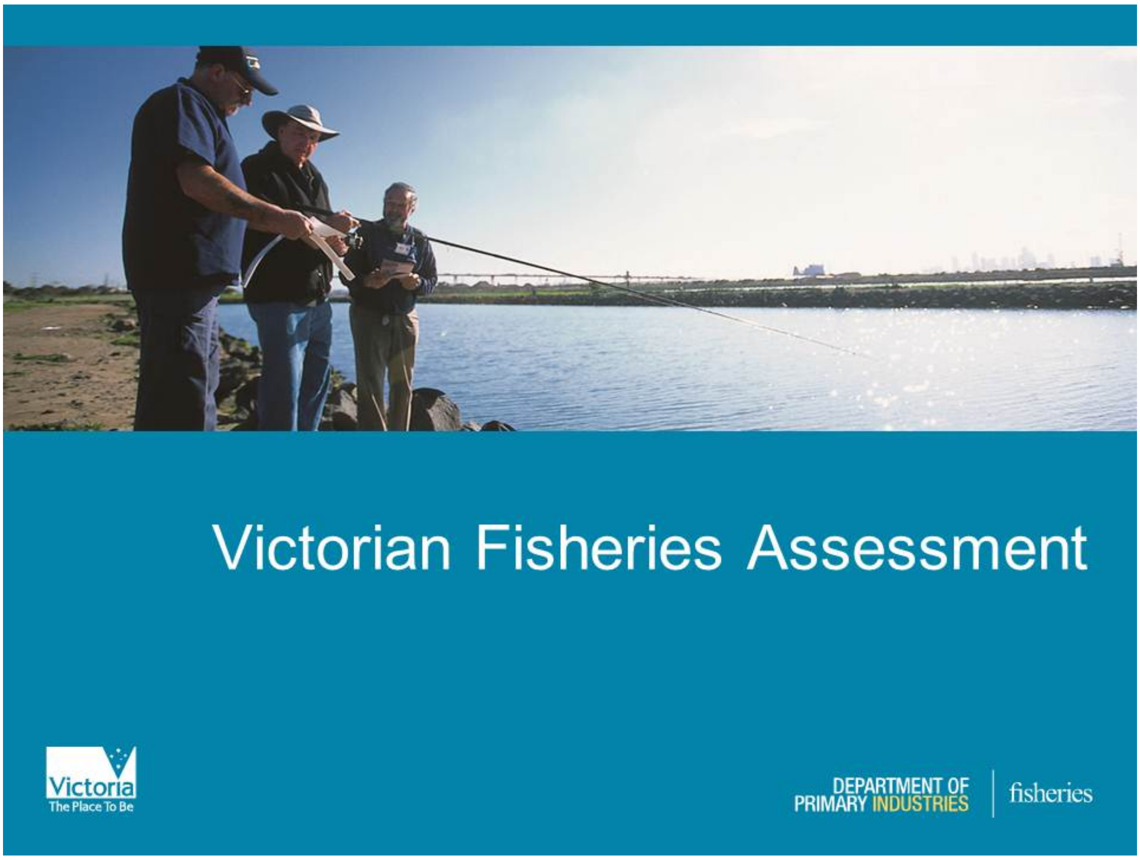


Example demonstrating classification of scampi species.

www.abares.gov.au

Stephens, A. & MacCall, A. 2004, 'A multispecies approach to subsetting logbook data for purposes of estimating CPUE', Fisheries Research, Vol. 70, pp. 299-310.

16.1.5 Victorian Fisheries Assessment – Bruce Taylor

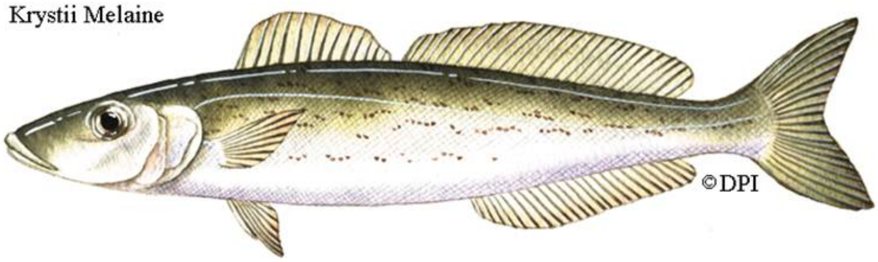


Summaries of:

- Abalone
- Rock Lobster
- Bays and Inlets Fishery
    - Port Phillip Bay
    - Western Port Bay
    - Corner Inlet
    - Gippsland Lakes

Risk Assessment

A Risk Assessment of Victorian Marine and Estuarine Finfish Fisheries was carried out in 2006/07 in accordance with National Fisheries ESD Reporting Framework Guidelines



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Priority issues identified by risk assessments

1. Lack of understanding of the essential habitat/environment requirements that underpin production of key target finfish species
   - impedes effective advocacy for protection of critical fish habitat (and therefore fisheries values) from a range of localised human activities
   - prevents/impedes ability to realistically model climate change impacts on fisheries production and thus to provide advice on adaptation to such changes

Some progress has been made toward understanding environmental linkages through on-going monitoring of KGW and snapper larval survival

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Priority issues identified by risk assessments

2. Need for clear resource sharing objectives for key marine & estuarine target finfish species. This lack of clarity

- ➲ has led to uncertainty regarding the future of commercial fishing for these species
- ➲ has prevented the development of ESD-based fishery management plans for Victoria's larger bay and inlet fisheries

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Priority issues identified by risk assessments

3. Need for clear 'adaptive' management arrangements (including cost-effective monitoring and assessment, fishery performance indicators, reference and trigger points, decision rules and management responses) to

- ➲ minimise the risk that management arrangements are ineffective in maintaining fishing pressure at sustainable levels given fluctuating stock abundance
- ➲ maximise stakeholder understanding/acceptance of management measures introduced for stock protection reasons

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Fishing methods

Commercial

- mostly haul seine
- some hooking and mesh netting

Recreational

- mostly boat-based line fishing

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Features of marine & estuarine finfish fisheries

Commercial

- multi species fishery
- haul seine catch include KGW, snapper (pinkies), rock flathead, calamari, garfish, flounder

Recreational

- preferred bait mostly squid, pilchards and pipis

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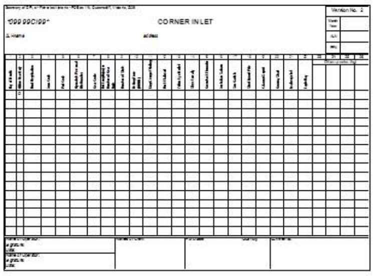
Commercial fishery assessment methods



Catch Trends
- time series 'census' data from logbooks
- effort, catch and cpue

Size cohort/distribution analyses
- change in size range
- strength of year class

Age cohort/distribution analyses
- change in age structure
- strength of age class

Routine data collection for key species

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Assessment methods based on time series of catch and effort logbook data. Some of the key species would also consider size and age analyses, but there have been no routine collection of these data for east Gippsland commercial fisheries. Some periodic collection of black bream size and age data from Lake Tyers and Mallacoota, these were presented at assessments for these fisheries in 2006 and 2007.

Recreational fishery assessment methods

Off-site (telephone-diary) surveys
- National Recreational Fishing Survey 2000/01
- recreational fishing in coastal Victoria 2006/07

On-site (boat-ramp) surveys (on-going)
- annual access point surveys in mid/late 90's
- 1995/96 to 1996/97; 2002/03 to present

Angler Diary Program (on-going)
- general anglers → everyday fishing activity
- research anglers → use prescribed gear

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Off-site (telephone-diary) surveys

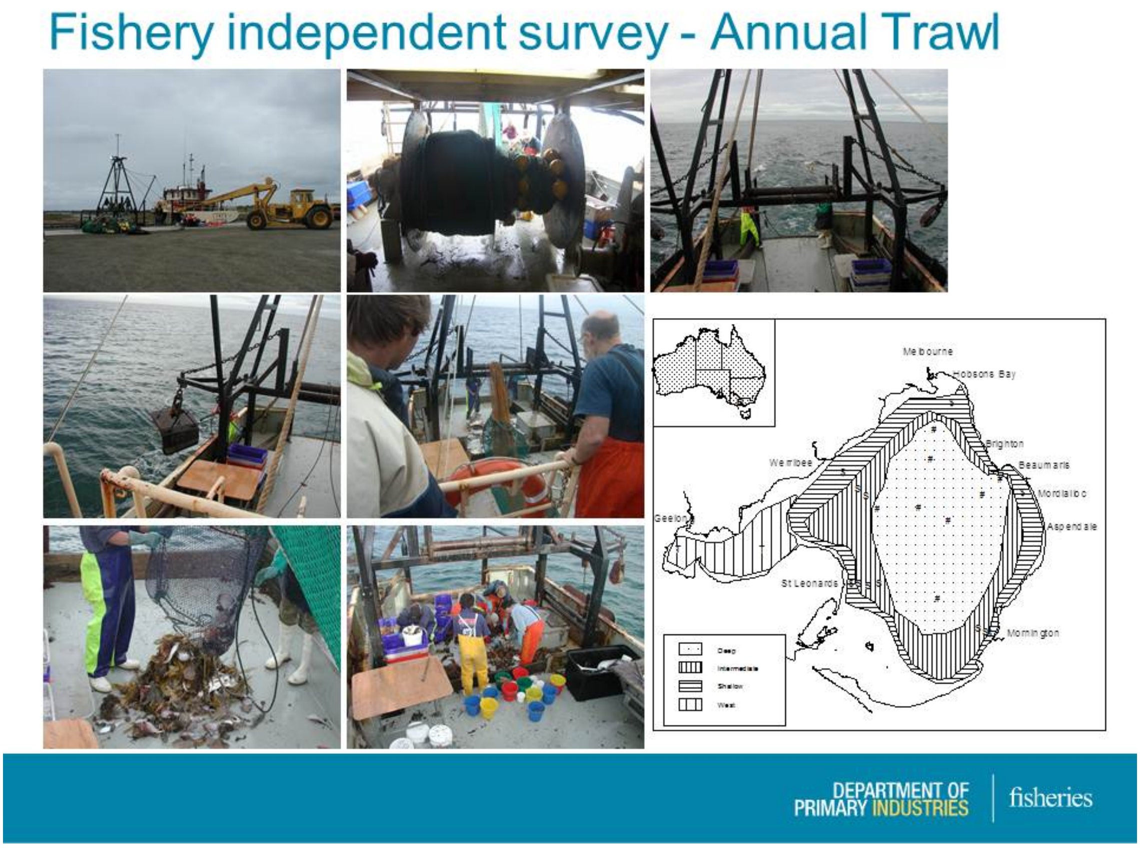
- provide estimates of total recreational harvest
- National Recreational Fishing Survey 2000/01
- recreational fishing in coastal Victoria 2006/07

On-site (boat-ramp) surveys

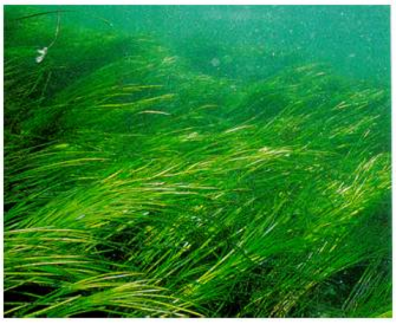
- provide time series of estimated catch rates and size structure for key species
- PPB 1996/97 then on-going from 2002/03 to present (not May–Sep prior to 2008)
- commencement of the annual access point surveys in mid/late 90's

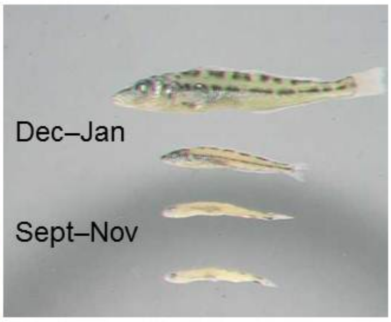
Angler Diary Program

- ➢ 200 general anglers have provided catch, effort and gear data for their everyday fishing activity (on-going)
- ➢ 100 research anglers using prescribed gear to provide information on size and under-size components of target fish populations (on-going)



Juvenile KGW monitoring program (1999+)





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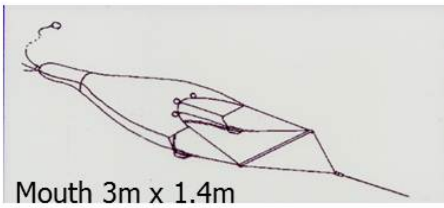
Juvenile snapper monitoring program (2000+)



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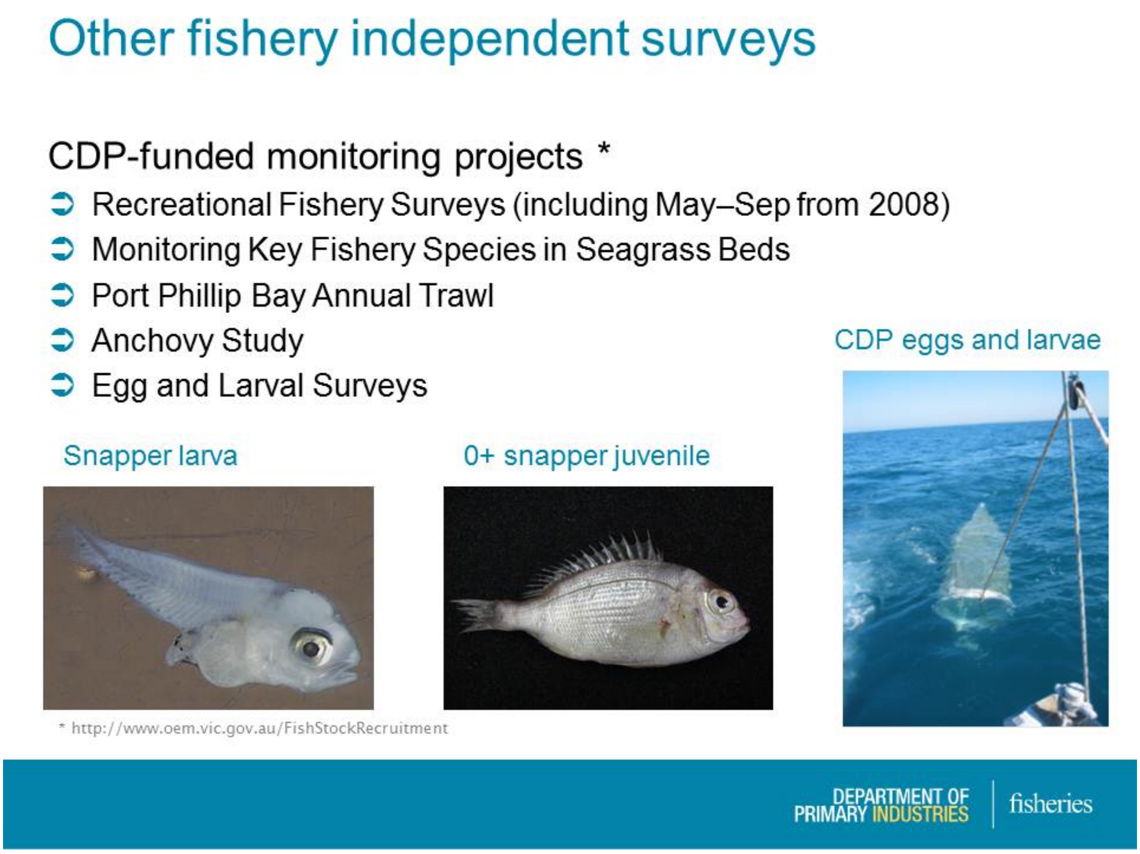
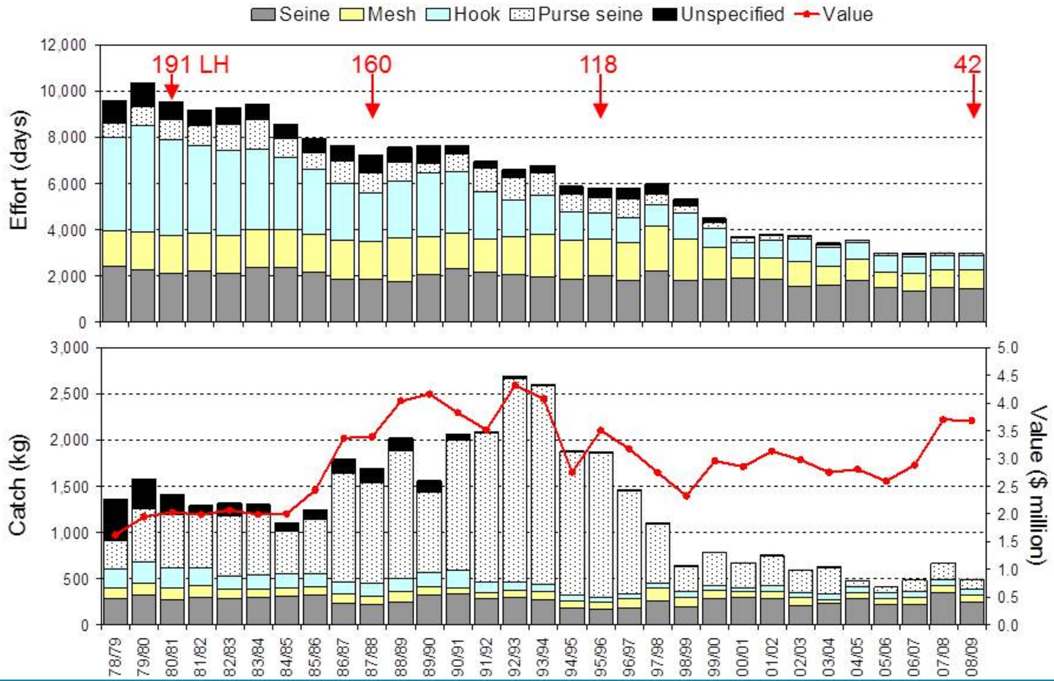


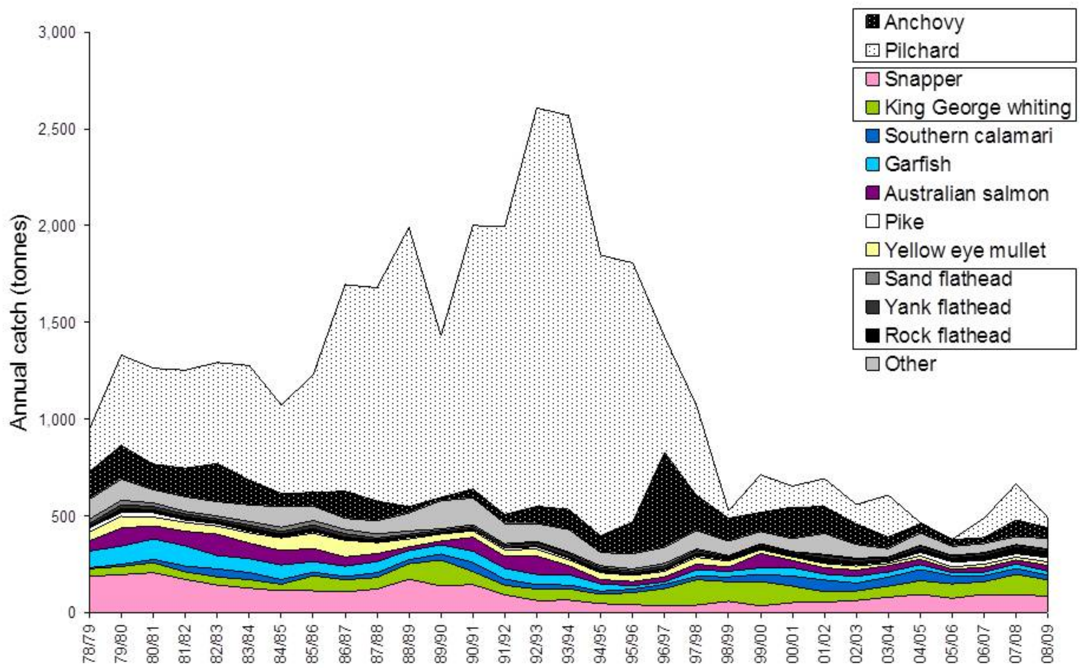
CDP-funded monitoring projects

- Sub-program 1: Port Phillip Bay Annual Trawl: The aim of this sub-program is to detect interannual changes in the abundance of all common fish in Port Phillip Bay outside of expected variability.
- Sub-program 2a: Egg and Larval Surveys: The aim of this sub-program is to detect interannual changes in the abundance of snapper and anchovy eggs and larvae outside of expected variability.
- Sub-program 2b: Anchovy Study: The aim of this sub-program is to collect data on anchovy abundance, distribution in the Bay and population structure that will fill existing knowledge gaps and assist in the assessment of changes observed in other Baywide programs.
- Sub-program 3: Recreational Fishery Surveys: The aim of this sub-program is to detect changes in the abundance and recruitment of key recreational fishery species outside of expected variability.
- Sub-program 4: Monitoring Key Fishery Species in Seagrass Beds: The aim of this sub-program is to collect data on they types and abundance of fish in shallow and deeper seagrass beds that will fill existing knowledge gaps and assist in understanding the significance of any observed changes in seagrass habitat for these fish.

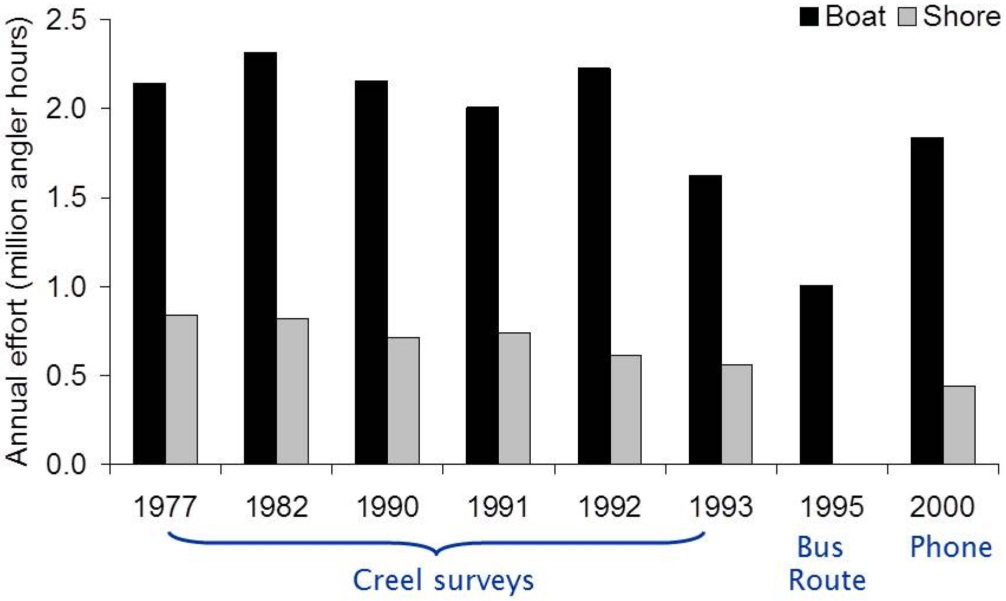
Commercial effort, catch and value by gear



Key commercial species



Recreational - total annual effort



Source: Beinssen (1977), MacDonald & Hall (1987) , Coutin *et al.* (1995), Conron & Coutin (1998), NRIFS (2003)

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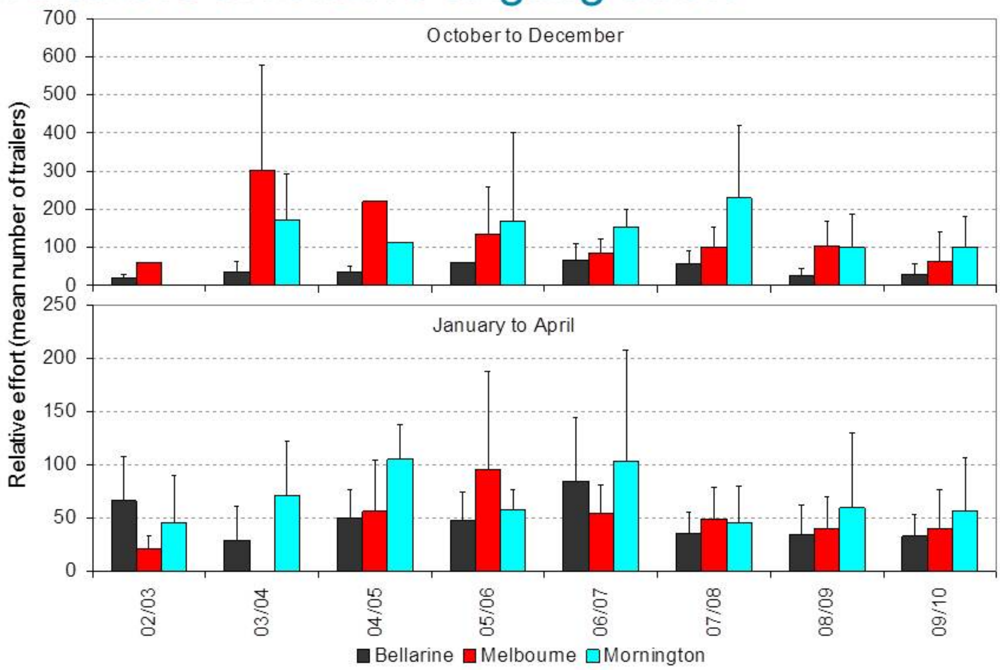
Indicators of relative angling effort



Key ramps: Bellarine (Clifton Springs/Limeburners Point), Melbourne (Altona) and Mornington (Carrum/Patterson River)

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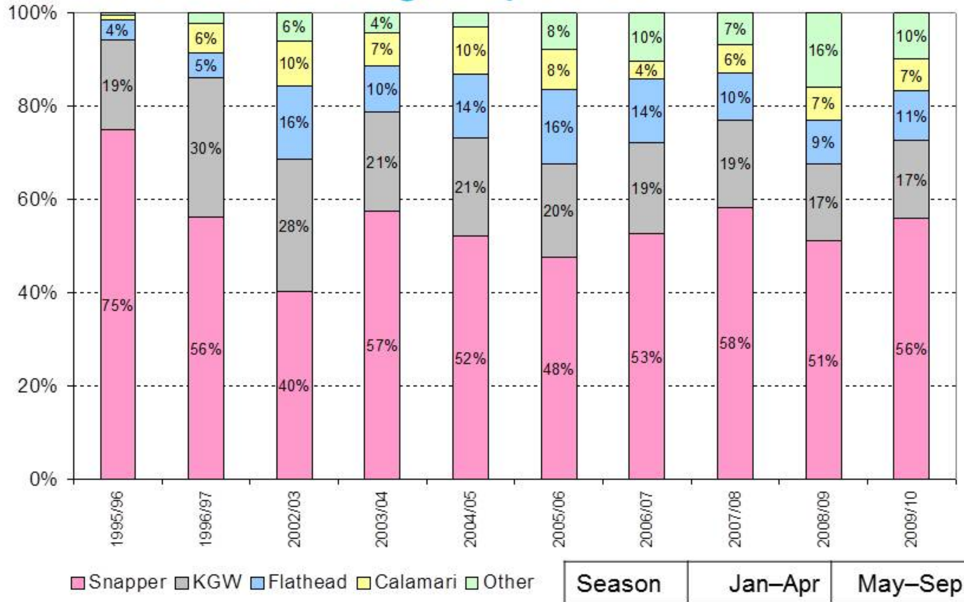
Recreational target species



Season	Jan–Apr	May–Sep	Oct–Dec
Snapper	40%	43%	75%
KGW	30%	10%	8%

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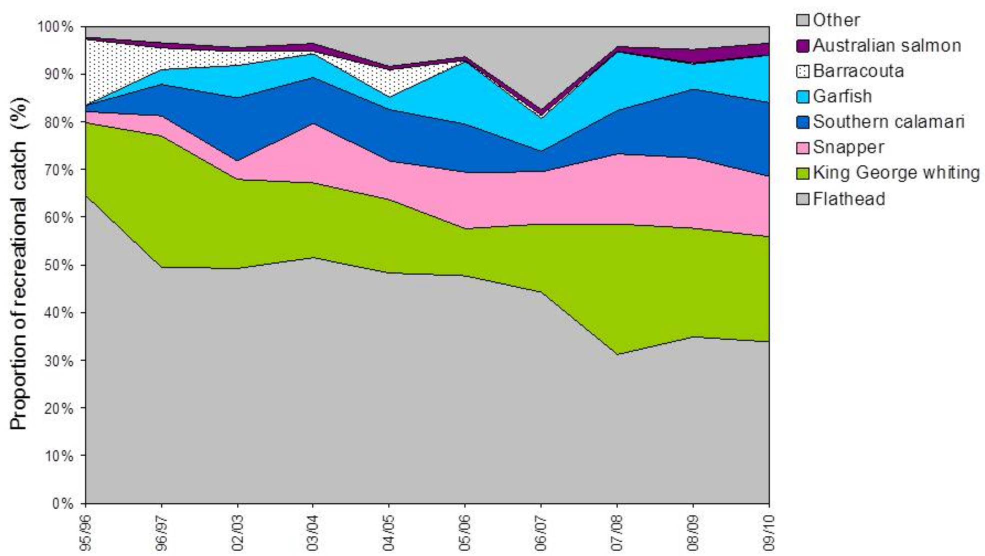
Key recreational species



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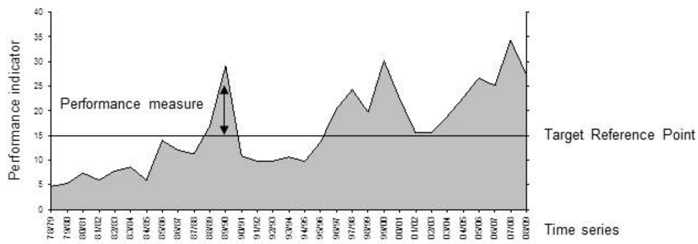
Biological indicators of stock/fishery status

Potential/available indicators for management action

- effort, catch and CPUE levels from reference years
- catch rate (overall and individual cohorts) change over 30%
- significant change in size/age composition
- significant change in recruitment patterns



Identify good indicators from existing data collection programs

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Basically, we need to identify any good indicators from existing data collection programs and, if an unusual trend is detected for a particular species, any R & D that might help us to understand why this trend is occurring and whether or not fishing is contributing to it.
The performance measure is KGW cpue (kg/shot) from 1978/79 to 2008/09

Figure after Sainsbury et al 2004, reference lines are precise, so this doesn't capture uncertainty in any estimate, see Phillipe's report pages 20-21

Uncertainty is the probability that an indicator is above/below a specified threshold, estimated by Monte Carlo simulations or resampling (bootstrapping)

Performance indicators are quantities to be measured in order to track the status of the fishery. Reference points represent the desired levels of the indicators. Trigger points indicate when the level of the indicator is unacceptable to the extent that immediate remedial action is required
Reference points & potential best practice can relate to:

- target and retained species
- by-catch species
- threatened, endangered or protected species and communities
- habitats
- food webs

Perspectives of the fishery

Identify potential drivers of changes in fishery indicators from

- biological changes (distribution, migration patterns)
- environmental/habitat factors
- changes in locations fished
- changes in gear/equipment
- shift in effort towards other species
- other changes in effort
- compliance
- any other changes

Observations and views on the status of the PPB fishery

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Management implications

- do available indicators suggest changes in stock status?
- do anecdotal reports suggest compliance with fisheries management?
- is there an indication for a review/change of fisheries management?
- are current regulations constraining retained catches of recreational species?

Identify need for review of fisheries management

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Research, monitoring and assessment

Research, monitoring and assessment needs and priorities

- improve understanding of fishery dynamics
- identify whether or not fishing is contributing to changes in stock status
- reflect the requirement for rigorous quantitative assessments within an ecosystem-based fisheries management (EBFM) framework
- develop adaptive management decision framework with appropriate performance indicators and trigger reference points

Identify future priorities to understand stock/fishery status

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Australian salmon (*Arripis trutta*, *A. truttacea*)

Previous assessment

- commercial catches vary with targeted effort and fluctuating demand/prices
- abundance influenced by variable schooling behaviour and seasonal movement
- catches peaked at 178 t in 1950 followed by declining trend

Aging using scales *

- in Victoria, samples were mostly 1+ to 3+ yrs, but ranged from 0+ to 5+ years
- in Tasmania and Victoria, ages primarily 0+ to 2+ years
- in NSW, ages from 4+ years with fish > 5+ years moving northwards in NSW

Commercial fishery		Recreational fishery		Trawl survey		Other	
Medium		Medium		Very low			
Catch rates	Size/age	Catch rates	Size/age	Biomass	Size/age	Egg & larvae	
✓		✓	✓				

* Stanley 1978

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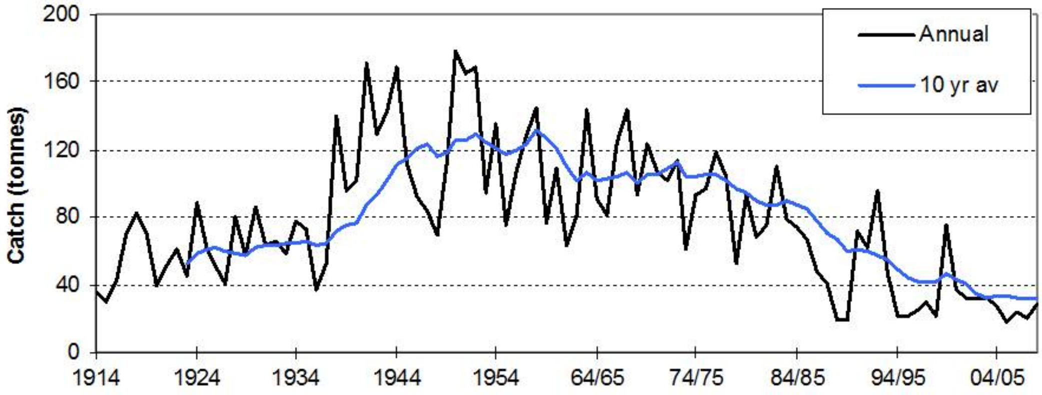
Australian salmon - commercial catch history



- annual catch has averaged 28 t over the last 9 years
- Australian salmon catch in 08/09 was 6% by weight of total PPB catch

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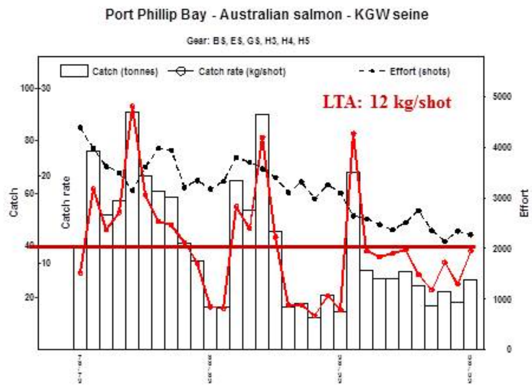
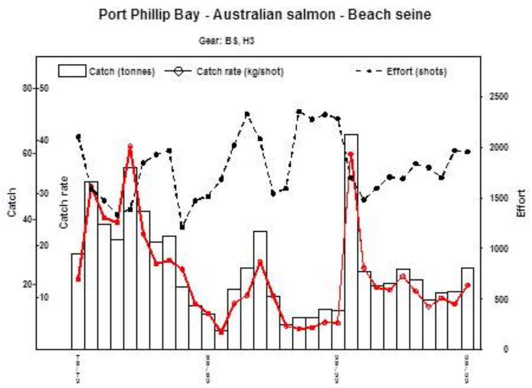
Australian salmon - commercial catch rate





- haul seines account for 84% of catch since 78/79
- effort halved from 4,419 shots (78/79) to 2,350 shots (08/09)
- catch rate ranges from 4–28 kg/shot with peaks during 82/83, 92/93 and 99/00
- gear specific catch (BS&H3) account for 52% of seine total, but as low as 26% in 1990/91, and may not be representative of all years

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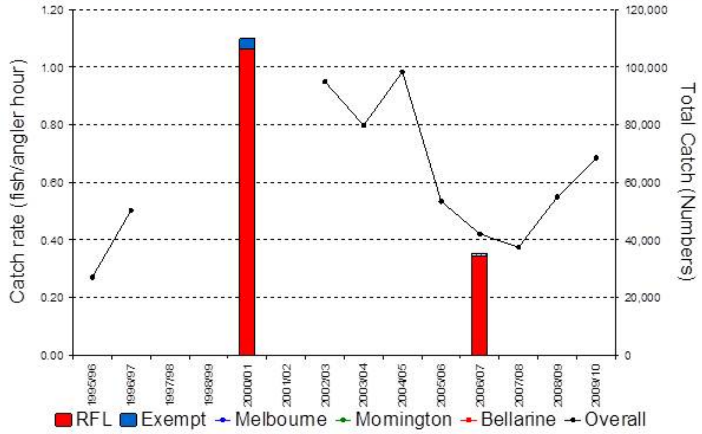
Australian salmon – recreational catch rates



- release rates are variable 6–60%; 21% in 2000/01 and 24 % in 2006/07
- retained catch rates by avid anglers targeting Australian salmon in 2009/10 were not significantly different from previous years

Melbourne 11%	Mornington 74%	Bellarine 14%

Spring 6%	Summer 20%	Autumn 15%	Winter 59%

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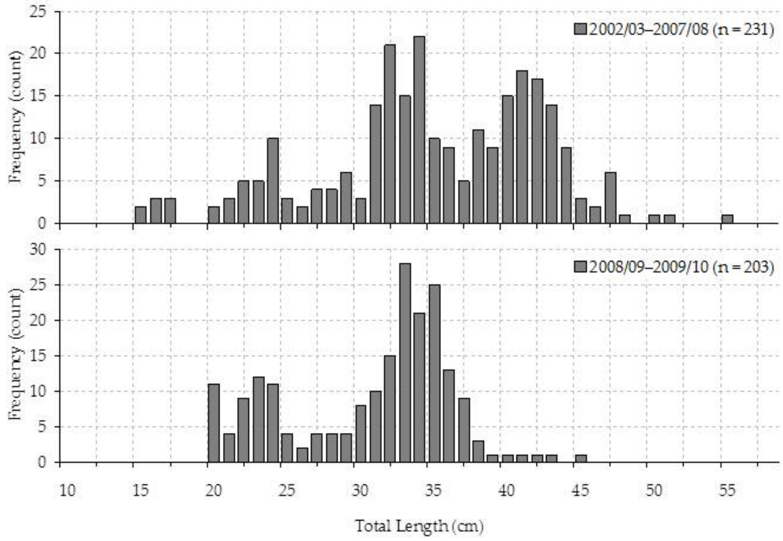
Australian salmon – length distribution



- total lengths range from 15–55 cm
- distribution from 2008/09-2009/10 is significantly different from previous years

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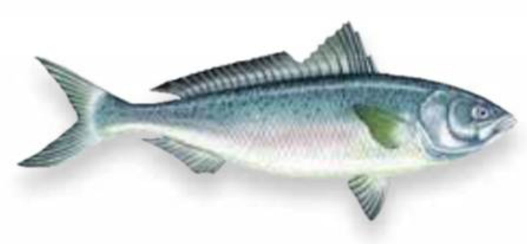
Australian salmon – discussion

- Biological indicators of fishery and stock status
- Perspectives on the fishery
- Management implications
- Research, monitoring and assessment needs and priorities

Australian salmon
Scientific name: *Arripis spp.*
Minimum legal size: 21cm.
Bag/possession limit: a total limit of 20 Australian salmon and/or Australian herring.



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Southern sea garfish (*Hyporhamphus melanochir*)

Previous assessment

- dedicated stock assessment conducted in 2008/09
- catches variable, increasing in 1920's–1970's, peaking at 105 t in 1980/81, then declining despite good market price and potential to target with garfish seines
- catch appears to have inverse relationship to KGW catch

Commercial fishery		Recreational fishery		Trawl survey		Other	
Medium		Medium		Very low			
Catch rates	Size/age	Catch rates	Size/age	Biomass	Size/age	Egg & larvae	
✓		✓	✓			✓	

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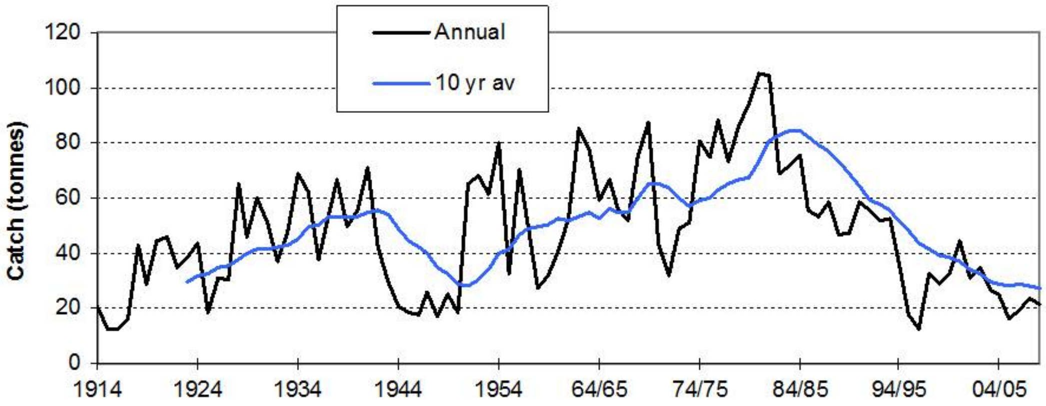
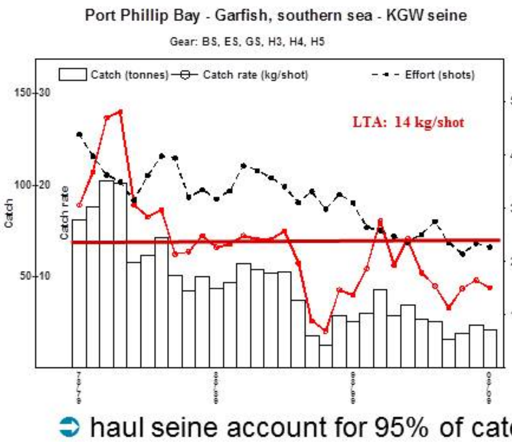
Garfish - commercial catch history

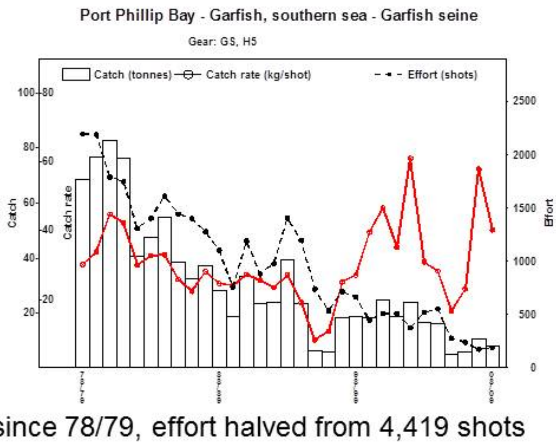


- annual catch has declined from declined from 44 t in 2000/01 to 21 t in 08/09
- garfish catch in 08/09 was 4% by weight of total PPB catch

Garfish - commercial catch rate

OR





- haul seine account for 95% of catch since 78/79, effort halved from 4,419 shots (78/79) to 2,350 shots (08/09)
- catch rate was variable and declining, ranging between 4–29 kg/shot with peaks during 80/81 and 00/01
- gear specific catches (GS&H5) account for 63% of seine catch, but as low as 29% of the catch in some years (05/06 and 06/07) & may not be representative

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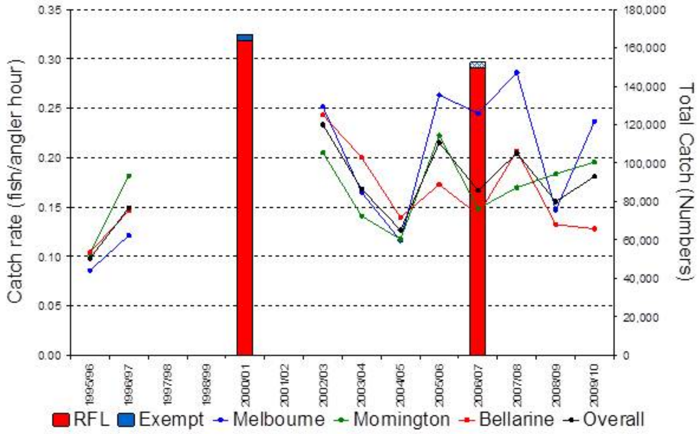
Garfish – estimated recreational catch rates



- release rates are stable 3–8%
- for all anglers, retained catch rates in 2009/10 are significantly different from previous years (in Melbourne, Mornington and across all regions)

Melbourne 0%		Mornington 6%	Bellarine 94%
Spring 2%	Summer 32%	Autumn 60%	Winter 6%

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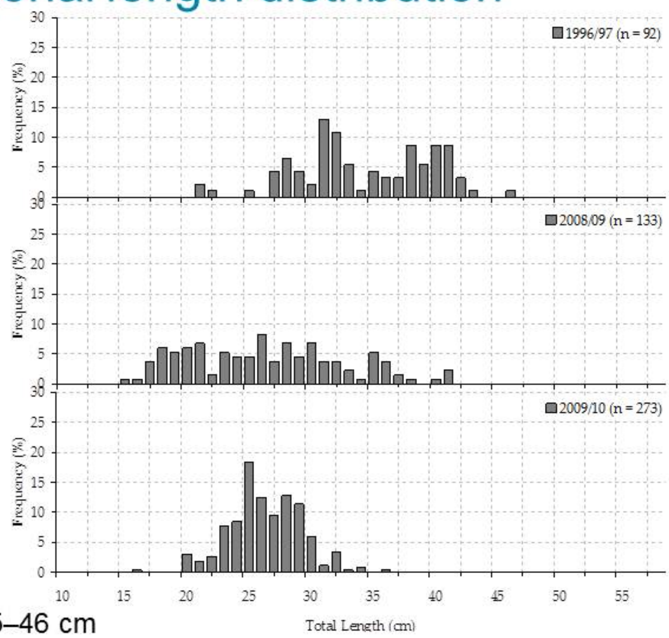
Garfish – recreational length distribution



- total lengths range from 15–46 cm
- distribution from 2008/09-2009/10 is significantly different from previous years

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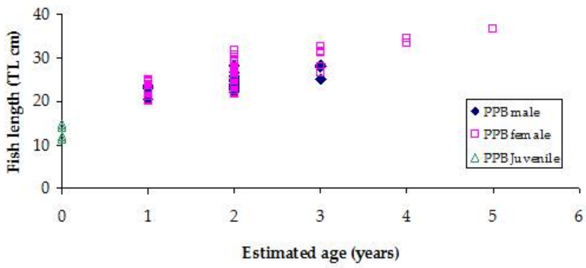
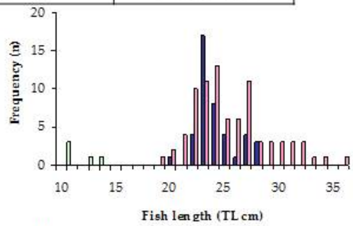
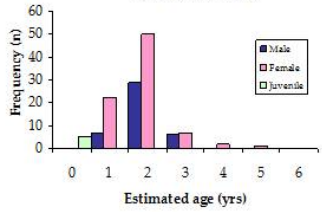
Garfish - age and growth

Species	Data from	n	Length range of aged sample	Age range
Garfish	PPB (1994-09)	129	11 - 36 cm	0+ to 5+ yrs







- age data has been presented in the recent garfish stock assessment workshop
- the garfish population in PPB is dominated by 2+ fish
- females grow at a faster rate and reach a larger size (19–36 cm, 1–5yrs) than males (20–28 cm, 1–3yrs)

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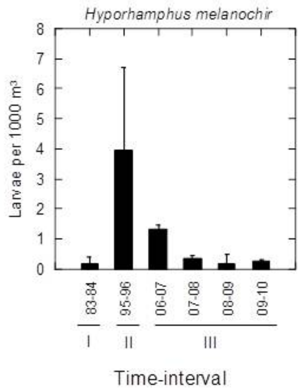
Garfish - eggs and larvae study



- garfish larval density in PPB (excluding Pt Wilson) from sampling in 1983/84, 1995/96 and 2006/07–2009/10

Acevedo, Jenkins, Hamer, Kent and Neira (in prep)

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Garfish - discussion

- Biological indicators of fishery and stock status
- Perspectives on the fishery
- Management implications
- Research, monitoring and assessment needs and priorities

Garfish (all species)
Scientific name: Hemiramphidae
Minimum legal size: no minimum.
Bag/possession limit: 40.

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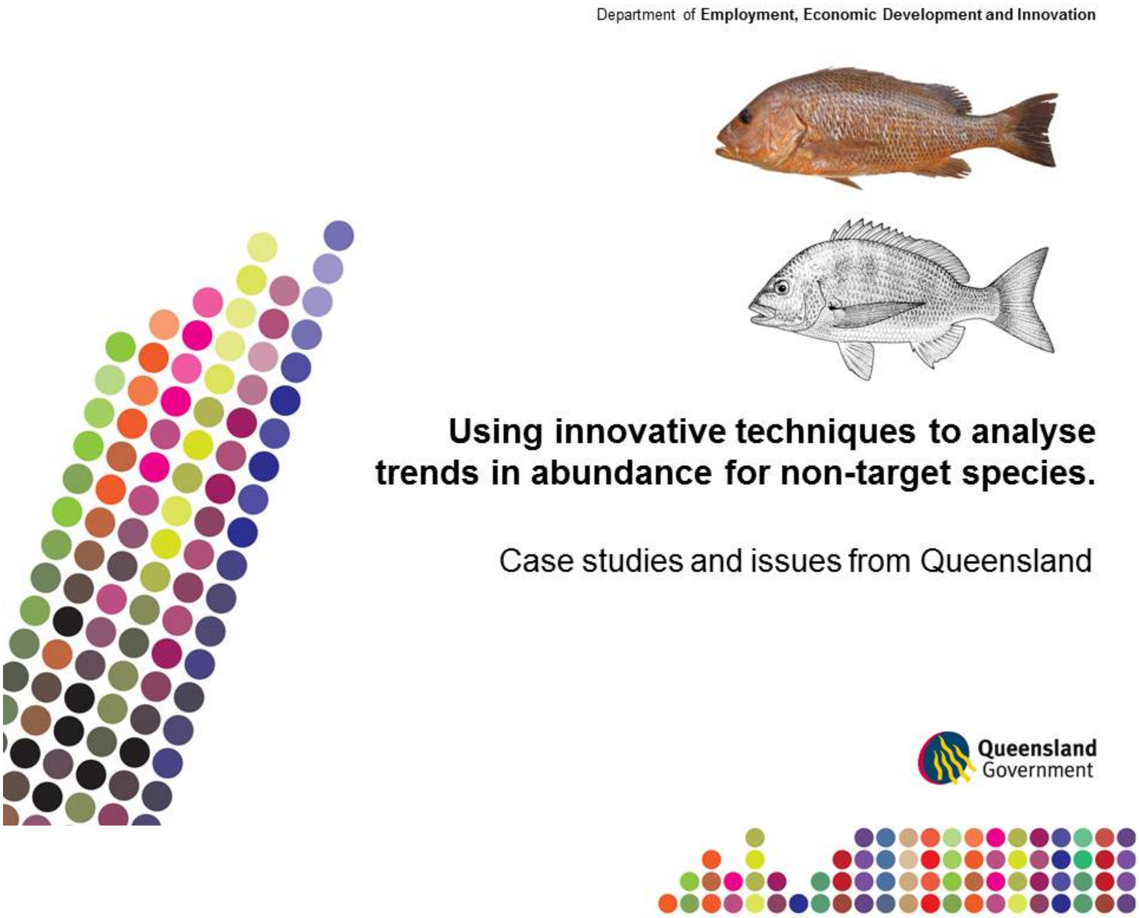
16.1.6 Queensland ByCatch Issues – George Leigh & Michael O'Neill



Example PMS for by-product species

Queensland issue = no catch rate measures

Fishery	**Species**	Objective	Indicator	Measure
Otter Trawl	Permitted species (i.e. by-product)	Maintain permitted species catch within historical levels to prevent targeting of these species.	1. Commercial logbook data for trawl fisheries	1. Catch of the species in the reporting year is 10% greater than the upper, or 10% below the lower, catch limits, based on the highest and lowest historical catch recorded between 2001–06.
GoC Fish Trawl	By-product	Ensure the sustainability of by-product species taken in the GOCDFTF.	1. Total by-product landings taken by the trawl fishery. 2. Landings of the major by-product species taken by the trawl fishery	Annual total weights of any of the following by-product species in the GOCDFTF: red emperor golden snapper, goldband snapper, and mangrove jack change by ±30% over three consecutive years.

 2

Issues related to assessing non-target species

- Development of critical indicators – recognizing variance of data.
- Catch rate $\propto$ abundance
- Quality of data
  - Coarseness of data may limit statistical power and alias parameters.
  - Predictions may be required from two-component models at year*season*grid
  - Analysis costs to be kept low, easy to repeat and consistent.
- Fisher behaviour – non random fishing pattern
- Fish biology – hyperdepletion

 3

Aspects of target catch rates

Fisher behaviour:
– Efficient at finding fish at local scale. – Vessels can travel large distances; at sea and from different ports. – Improved knowledge and information sharing that leads to non random spatial fishing. – Increased fishing power from using better vessels, gear, techniques and improved knowledge. – Aggregation of effort at higher catch times.
Fish biology:
– The dynamics of schooling and movement of fish. – Type of concentration profile: the density of fish distributed spatially in time (Hilborn and Walters 1992).
Commercial logbooks:
– Limited catch validation via linking catch, disposal and quota reporting systems. – No data codes to link fishing trips over multiple days. – No daily recording of each fishing operation's target species, vessels, gear, travel time, search time and efficiency, locations fished, active fishing time, zero catches and catchability. – Determinants of effort by fishers. – Determinants of area fished.

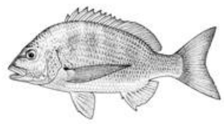
 4

Conditional models	*L. erythropterus*	*L. malabaricus**	*L. sebae*	*L. johnii*	*L. argentimaculatus*	*P. multidens*
Binomial GLMM						
Summary of analysis						
% zero catches	12	1.4	28.1	85.5	78.6	18.3
Deviance: -2*LL	54788.25	1697.5262	41926.94	47843.04	44846.41	57293.23
Residual d.f.	14530	14537	14530	14606	14606	14530
Dispersion	0.952 (0.0112)	Fixed at 1	1.009 (0.012)	1.004 (0.012)	1.014 (0.012)	0.956 (0.0112)
Fixed terms						
Year * zone2	2.72, <0.001	24.3, 0.042	8.4, <0.001	5.57, <0.001	7.02, <0.001	8.05, <0.001
Problem trawls	59.89, <0.001	–	15.25, <0.001	–	–	37.13, <0.001
Log trawl area	11.25, <0.001	182.3, <0.001	85.17, <0.001	–	–	118.92, <0.001
Log Spanish mackerel	29.32, <0.001	–	24.12, <0.001	26.89, <0.001	43.29, <0.001	–
Log shark	9.17, 0.002	–	47.93, <0.001	17.51, <0.001	31.33, <0.001	4.8, 0.028
Log other fish	139.54, <0.001	–	657.85, <0.001	227.06, <0.001	392.53, <0.001	326.61, <0.001
Random terms - Variance components						
Vessel	–	–	–	–	–	0.0869 (0.1943)
Month	0.0433 (0.0228)	–	0.055 (0.026)	–	–	0.0661 (0.0324)
Area	0.7619 (0.2624)	–	0.245 (0.094)	0.234 (0.098)	0.065 (0.033)	0.5802 (0.2011)

Case study 1 – Northern tropical snappers

Conditional models	*L. erythropterus*	*L. malabaricus*	*L. sebae*	*L. johnii*	*L. argentimaculatus*	*P. multidens*
Linear mixed model (REML)						
Summary of analysis						
Deviance: -2*LL	15963.61	6952.48	510.73	2302.64	3509.49	2164.15
Residual d.f.	12777	14328	10450	2079	3095	11871
Residual variance	1.256 (0.036)	0.583 (0.0947)	0.341 (0.0612)	1.017 (0.093)	1.075 (0.057)	0.432 (0.0398)
Fixed terms						
Year*zone2	4.53, <0.001	18.7, <0.001	12.25, <0.001	2.39, 0.003	2.88, <0.001	11.27, <0.001
Problem trawls	–	15.45, <0.001	–	–	–	–
Log trawl area	5.81, 0.016	356.4, <0.001	5.1, 0.024	19.22, <0.001	7.06, 0.008	38.35, <0.001
Log Spanish mackerel	–	0.01, 0.929	–	6.5, 0.011	–	–
Log shark	–	3.08, 0.079	–	5.11, 0.024	–	–
Log other fish	241.65, <0.001	316.14, <0.001	257.82, <0.001	15.72, <0.001	37.21, <0.001	596.4, <0.001
Random terms - Variance components						
Vessel	–	0.0092 (0.0146)	–	–	–	–
Month	0.021 (0.01)	0.0057 (0.0027)	–	–	–	–
Area	0.099 (0.036)	0.3186 (0.0947)	0.2098 (0.0612)	0.225 (0.093)	0.149 (0.057)	0.1232 (0.0398)

Case study 2 – Recreational fisheries



Yellowfin Bream		Truncated Poisson		Truncated Negative Binomial		Extended Poisson Process Model 1		Extended Poisson Process Model 2 *
Log-likelihood		-2060		-1643.7		-1638.4		-1637.1
Deviance		2471		799		-		908
Pearson χ^2		3277		1147		-		1039
Degrees of freedom		873		872		871		870
		Estimate (se)		**Estimate (se)**		**Estimate (se)**		**Estimate (se)**
Intercept		0.0405 (0.182)		-0.664 (0.231)		-0.629 (0.189)		-4.045 (14.325)
Estuary								
Burnett River	B	-0.201 (0.094)	B	-0.349 (0.124)	B	-0.286 (0.109)	B	-0.355 (0.122)
Maroochy River	A	0.051 (0.085)	A	-0.019 (0.115)	A	-0.034 (0.092)	A	-0.048 (0.111)
Pumicestone Passage	A	0	A	0	A	0	A	0
Season								
Winter 1997	A	0.739 (0.143)	A	0.937 (0.163)	A	0.747 (0.178)	A	0.902 (0.165)
Spring 1997	B	-0.325 (0.187)	B	-0.317 (0.185)	B	-0.275 (0.161)	B	-0.295 (0.180)
Summer 1998	B	0.089 (0.177)	B	0.120 (0.185)	B	0.093 (0.158)	B	0.127 (0.179)
Autumn 1998	B	0	B	0	B	0	B	0
Winter 1998	A	0.914 (0.134)	A	1.161 (0.150)	A	0.895 (0.200)	A	1.079 (0.156)
Day type								
Weekday	A	0	A	0	A	0	A	0
Weekend day	A	-0.078 (0.071)	A	0.016 (0.093)	A	0.022 (0.075)	A	0.031 (0.089)
Fishing platform								
Boat	A	0	A	0	A	0	A	0
Shore	A	-0.177 (0.323)	A	-0.050 (0.362)	A	-0.089 (0.304)	A	0.009 (0.349)
Covariates								
Hours fished	+	0.120 (0.013)	+	0.183 (0.025)	+	0.135 (0.034)	+	0.171 (0.024)
Number of boat fishers	0	0.006 (0.042)	0	-0.003 (0.057)	0	-0.020 (0.046)	0	-0.023 (0.055)
Number of shore fishers	0	-0.266 (0.186)	–	-0.417 (0.196)	–	-0.335 (0.174)	–	-0.409 (0.194)
Number of boat fishing lines	0	0.067 (0.036)	0	0.057 (0.048)	0	0.053 (0.039)	0	0.067 (0.047)
Number of shore fishing lines	0	0.193 (0.148)	0	0.221 (0.150)	0	0.193 (0.129)	0	0.212 (0.149)
Additional parameters								
δ		—		1.222 (0.156)		—		—
$1/\delta$		—		—		0.309 (0.443)		0.019 (0.281)
c		—		—		1.240 (0.181)		0.121 (0.287)
$\log d$		—		—		—		-2.801 (2.651)

Strategies for analysis of catch rates (abundance data)

- Have clear purpose within management procedures (HSF).
- Assess data quality
- Criteria to choose two component models, binomial + :
  - Truncated Poisson
  - Truncated Negative Binomial
  - Gamma
  - Log-Normal
  - Or advanced [EPPM]; maybe as 2^{nd} tier analysis
- Spatial analyses – assess non-random fishing pattern (Walters, 2003 ; Folly and fantasy …)
- Outputs to focus on consistent methods and robust predictions of trends

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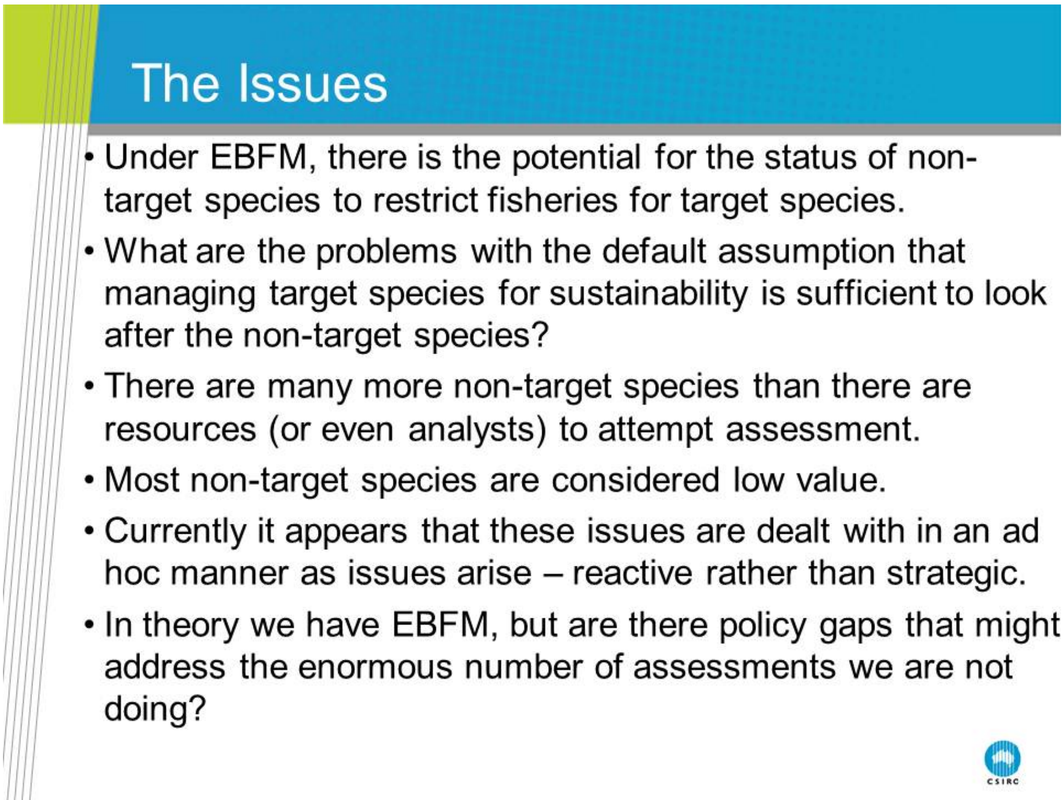
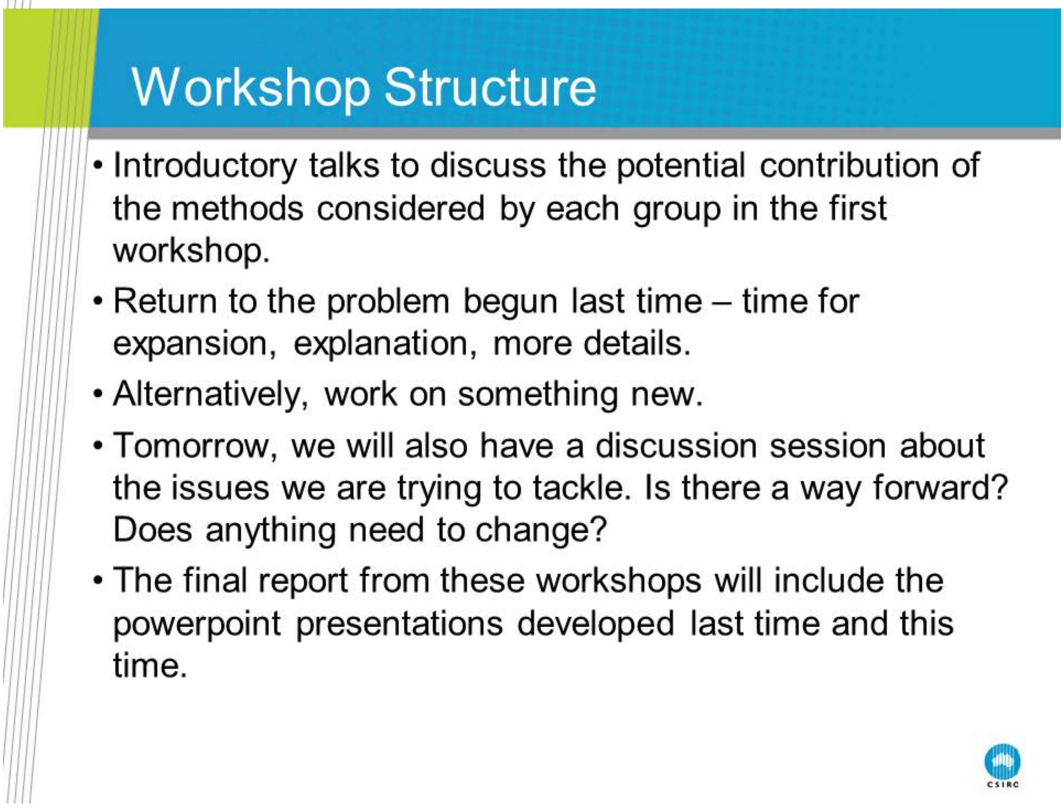
17 APPENDIX 4 – WORKSHOP 2 PRESENTATIONS

17.1.1 Introduction: The Issues – Malcolm Haddon





Commonwealth EOI

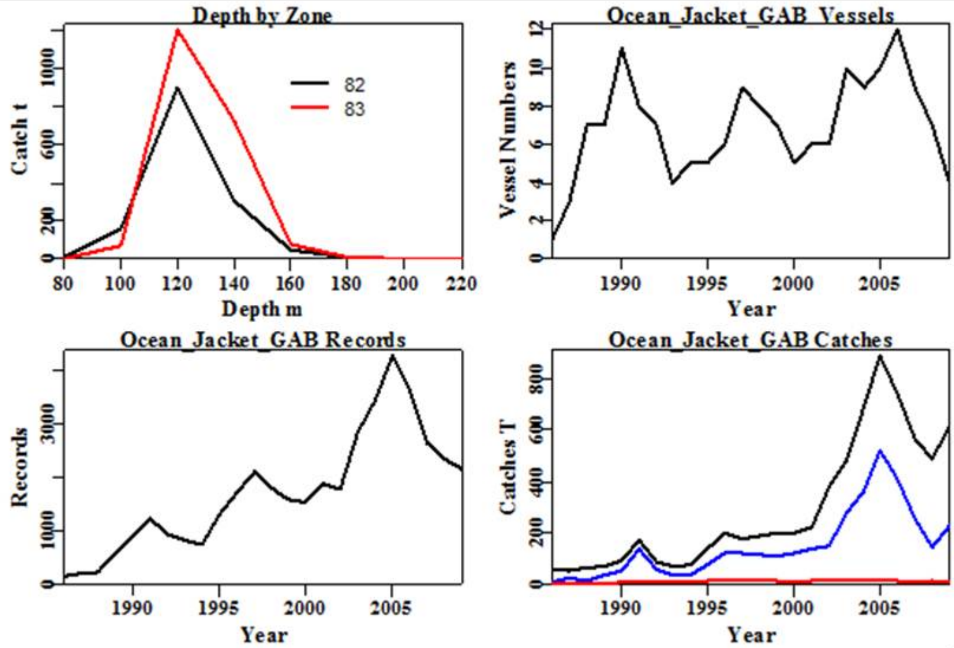
- Trend of abundance for byproduct species

AFMA has recently focussed much attention to implementing harvest strategies for key commercial species, but limited management attention to byproduct species not identified as high risk in the Ecological Risk Assessment process. As Total Allowable Catches are introduced or reduced in some key fisheries, this has the potential to change targeting behaviour of fishers and potentially increase fishing pressure on species previously considered to be byproduct.

Most of AFMA's major fisheries now have a reasonable time series of good logbook data for major byproduct species as the result of requiring exact positional data and species specific (i.e. no mixed fish) reporting in logbooks 5 – 10 years ago. This is a powerful time-series of data for species that are largely retained, discard species are generally poorly recorded in logbooks. Analyses have previously been completed in the SESSF observer data by MAFRI, which included trend in abundance over time for each species.

1. Assess the feasibility in analysing a large number of byproduct species in major AFMA fisheries to produce an estimated trend in abundance over time using innovative statistical techniques (e.g. spatial models used for FIS design) using logbook data. This should only be attempted for those species where observer data indicates there are small levels of discarding.
2. estimate potential changes in species from byproduct to targeted species

Example - LeatherJackets



17.1.2 What is meant by Bycatch and Byproduct – Malcolm Haddon

Terminology

Commercial Catch		
Target Sp.	Commercial	eg flathead
	Bycatch TAC	eg eastern gemfish
ByProduct	not discarded	e.g. endeavour prawn
bycatch that's kept	sometimes discarded	
Bycatch	discarded	Common
	incl TEPS	rare

CSIRO

Targeting

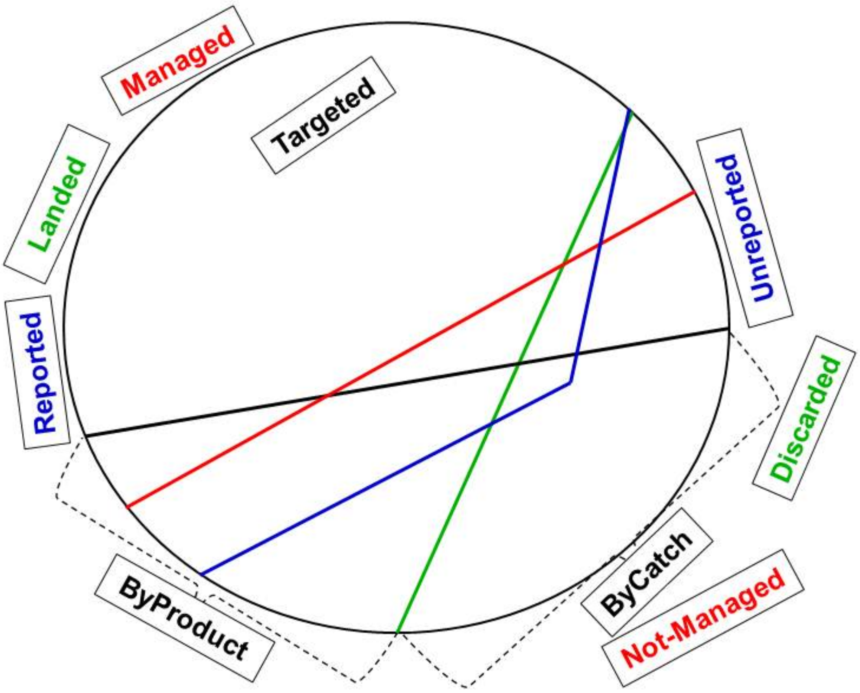
- Those species whose capture is the primary objective of a fishery are the target(s). All other species captured are either byproduct (retained) or bycatch (discarded).
- Species expected in the catch as a function of location and date (average expectation over many years).
- Dominant species in the catch (over many years).

CSIRO

ByProduct Species

- The meanings given to the terms "Targeting", "Byproduct", and "Bycatch" are uncertain because they relate to the intention of the fishers concerned.
- Byproduct species are those commercially retained species whose fishery and management depend upon being an incidental catch in another fishery.
- Byproduct species are taken incidentally in a different fishery (e.g. squid in the NPF; possibly John Dory in the SESSF; Wahoo in the ECTF).
- Byproduct species are those which are opportunistically fished commercially whilst ostensibly targeting other species and their catches may therefore be highly variable from year to year..
- There is often uncertainty due to variation in the level of accurate reporting through time for byproduct species. Without accurate estimates of discarding, assessment may not be possible.
- Catch rates may still provide an index of relative abundance provided that the available data constitutes a representative sample from the fishery.
- Byproduct species may be "targeted" opportunistically within the context of another fishery; this is another source of confusion over terms.

Structure of Catches



Usefulness of Data

	Presence/Absence				CPUE				Size		
Catch Component	**Land**	**Log**	**Obser**	**FIS**	**Land**	**Log**	**Obser**	**FIS**	**Land**	**Obser**	**FIS**
Quota Species	√√	√√	√√	√√	~	√√	√√	√√	√√	√√	√√
Target - avoid	~	~	√	√	x	~	√	√	~	√	√
Byproduct - non-quota	√√	√	√√	√√	x	√	√	√√	x	√√	√√
Bycatch - common spp.	x	x	√√	√√	x	x	√√	√√	x	√√	√√
Bycatch - rare spp.	x	x	√	~	x	x	~	x	x	√	~
Cavaets	Poor spatial resolution	Need to screen or standardize for targeting	Needs representative coverage or adequate sample size	Needs representative coverage or adequate sample size	Poor spatial resolution, inadequate effort data for interpretation	Need to screen or standardize for targeting	Need to screen or standardize for targeting	Need to screen or standardize for targeting		Need to screen or standardize for targeting	Need to screen or standardize for targeting

√√	**Good Potential**
√	**Potentially Useful**
~	**Uncertain**
x	**Not Useful**

Conclusions

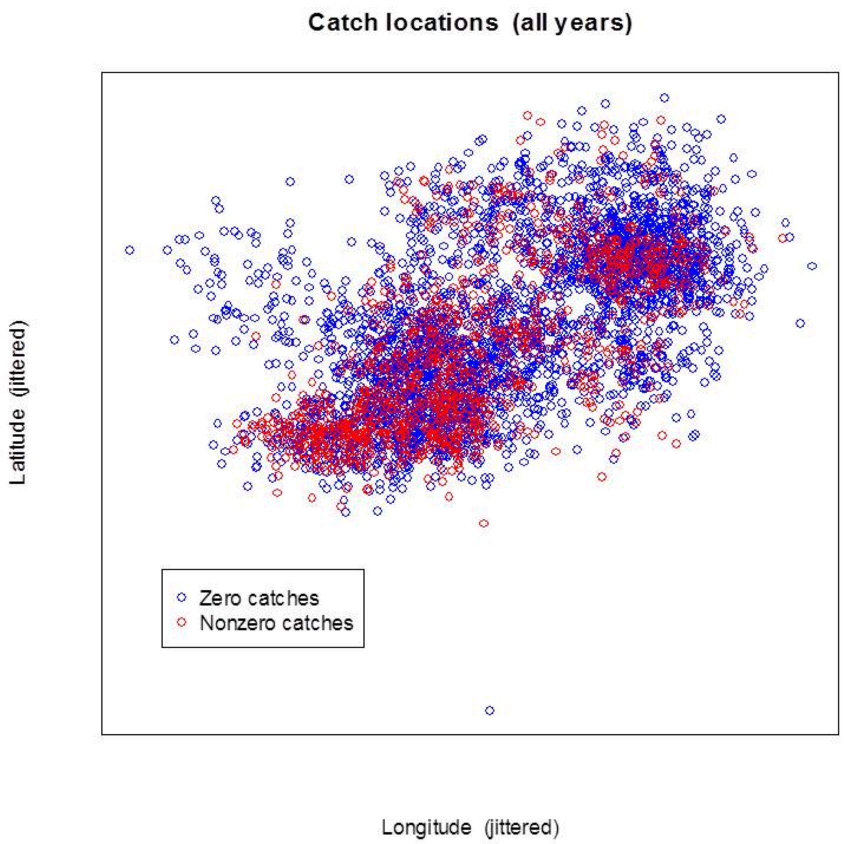
- There are three strategies available for improved assessment of non-target species

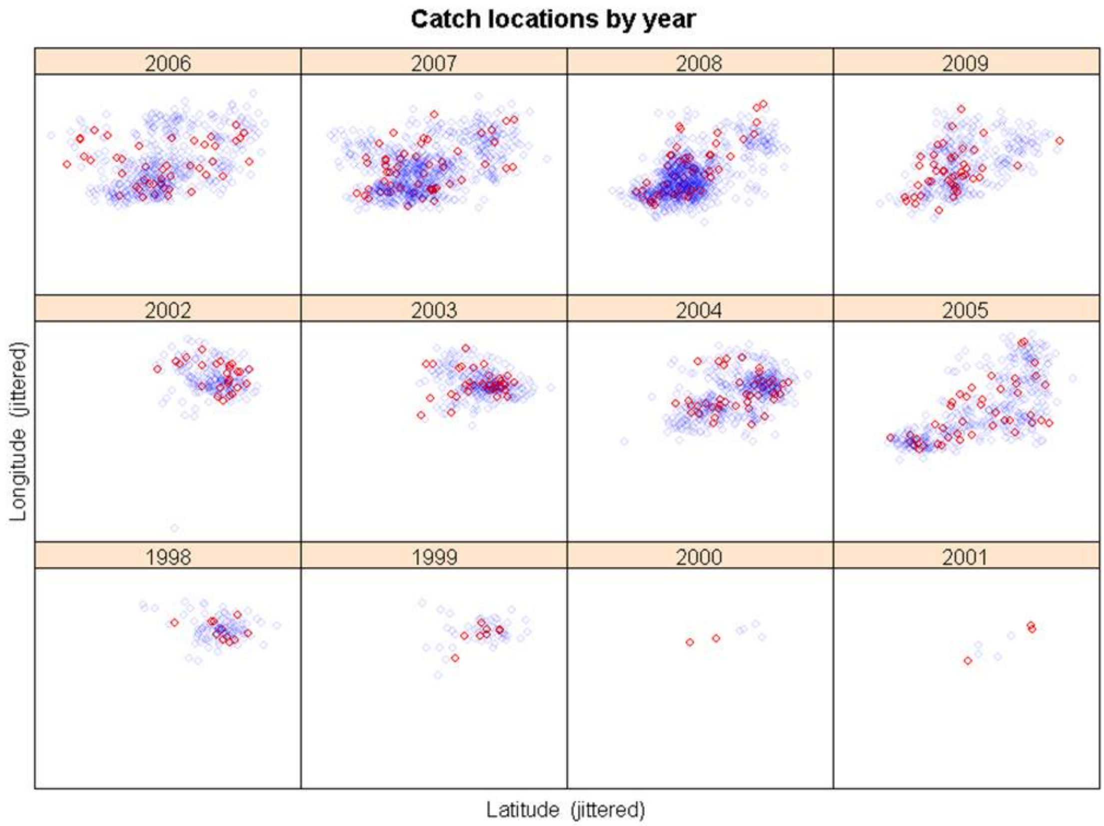
1. Improved or increased observer coverage.
2. Fishery Independent surveys.
3. Improved reporting of discarding and of catches of non-managed (quota or input controlled species).

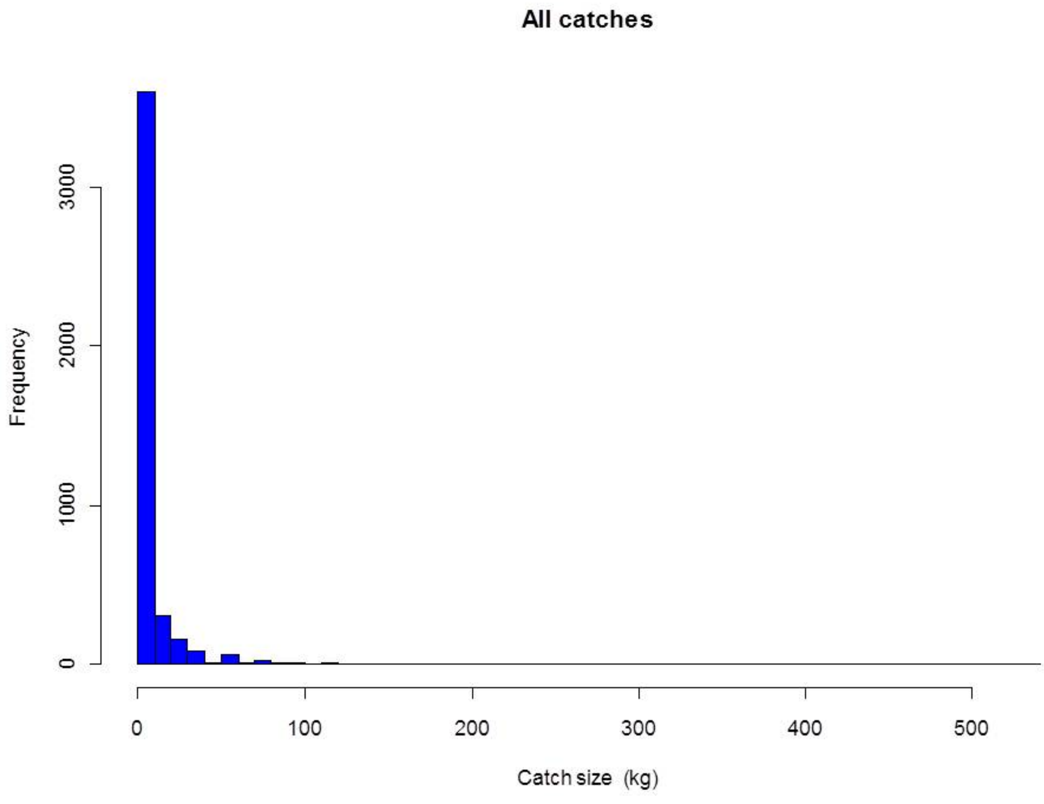
17.1.3 Bycatch Species in Queensland – George Leigh & Michael O'Neill

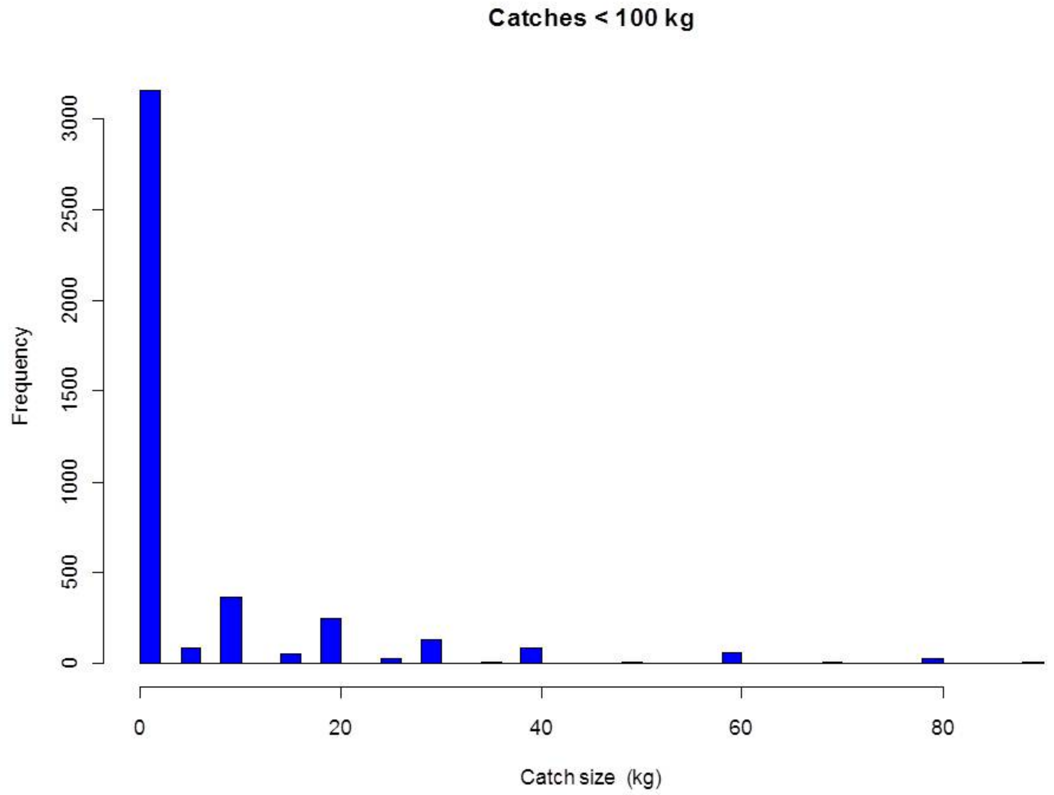
Lutjanus russelli (Moses perch), bycatch from Gulf of Carpentaria fish trawling

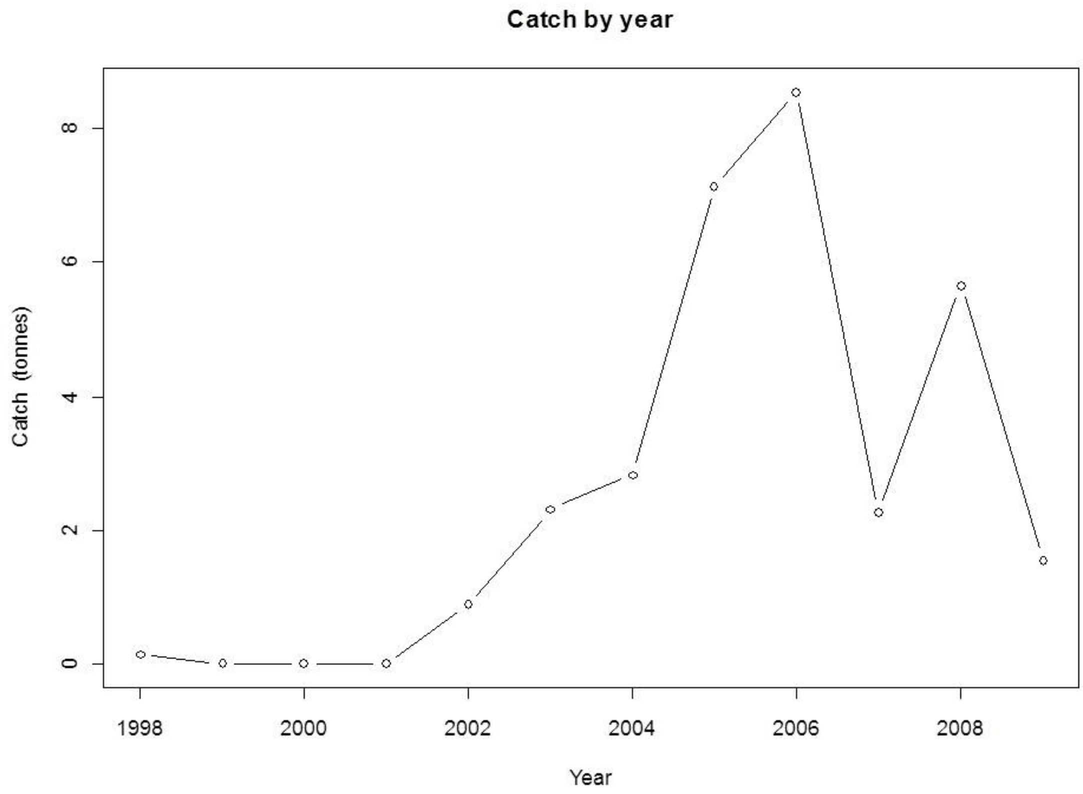
Picture: NSW Department of Primary Industries

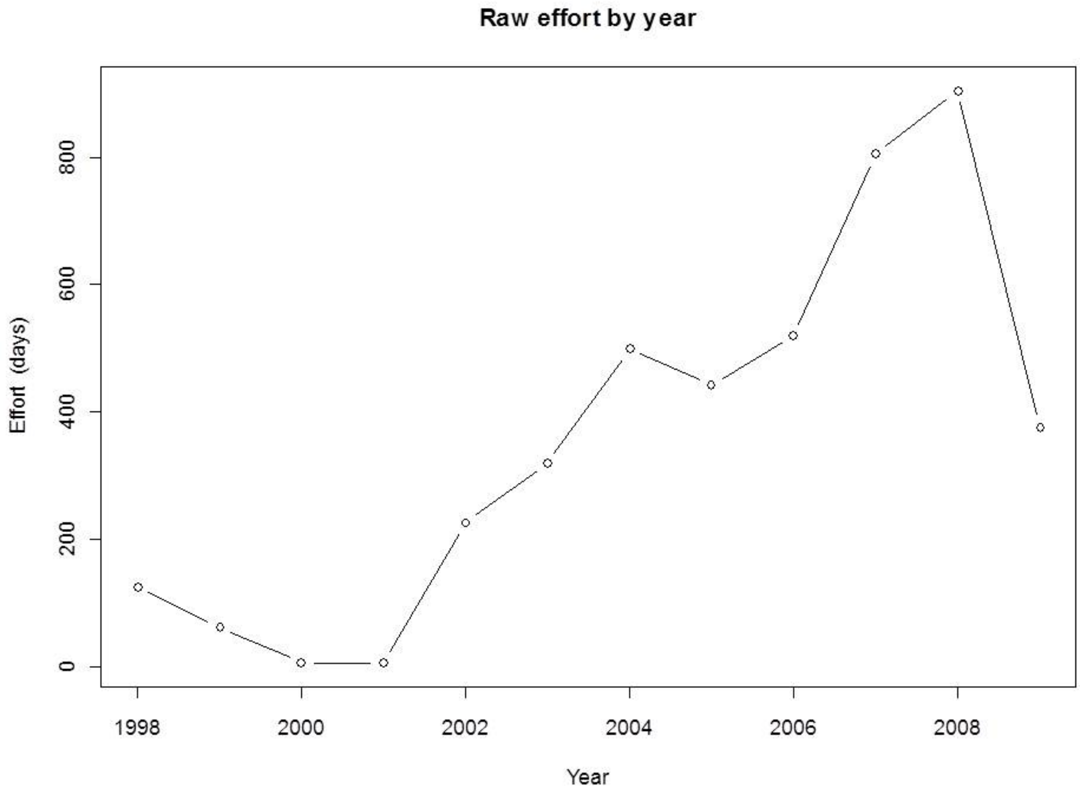



Catch locations by year
2006
2007
2008
2009
2002
2003
2004
2005
1998
1999
2000
2001
Longitude (jittered)
Latitude (jittered)


All catches
Frequency
0
1000
2000
3000
0
100
200
300
400
500
Catch size (kg)

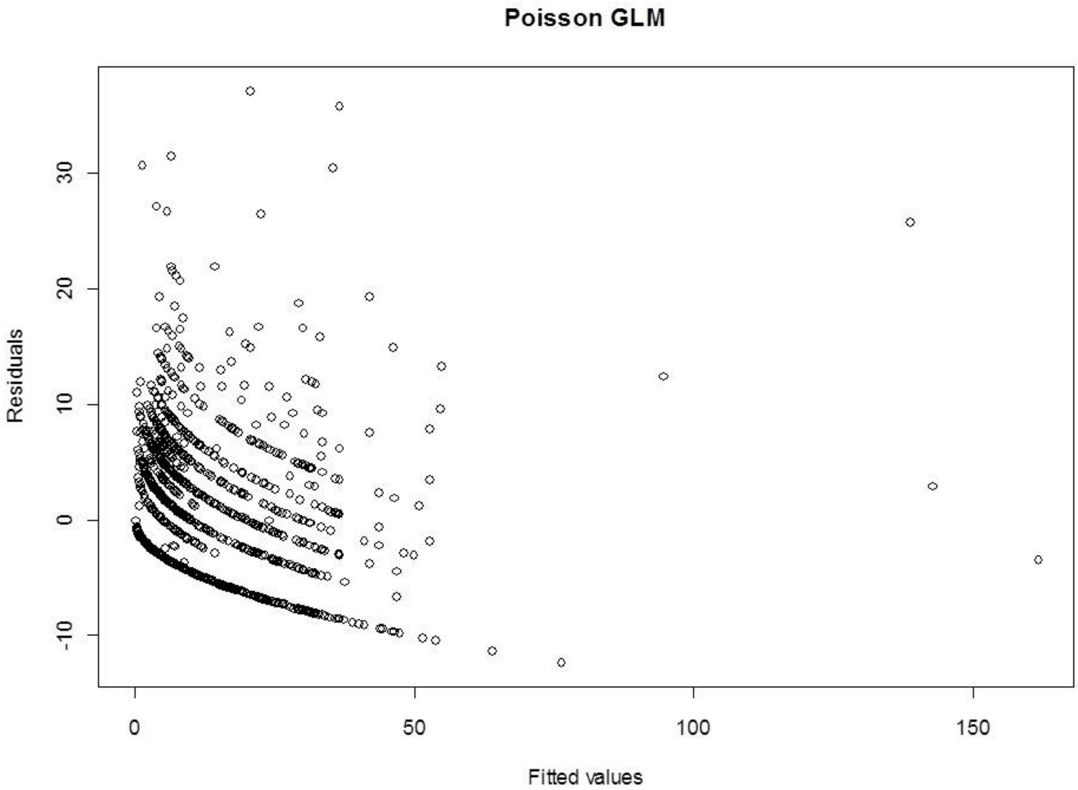

Catches < 100 kg
Frequency
0
500
1000
1500
2000
2500
3000
0
20
40
60
80
Catch size (kg)

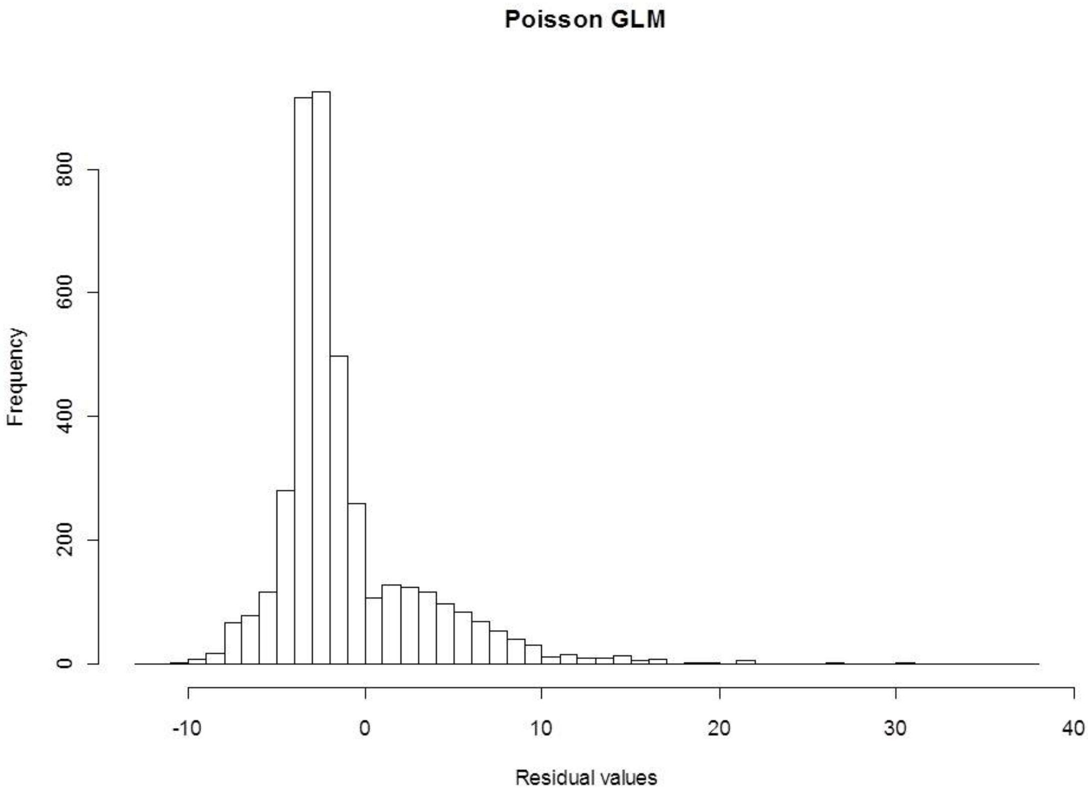

Catch by year
Catch (tonnes)
0
2
4
6
8
1998
2000
2002
2004
2006
2008
Year

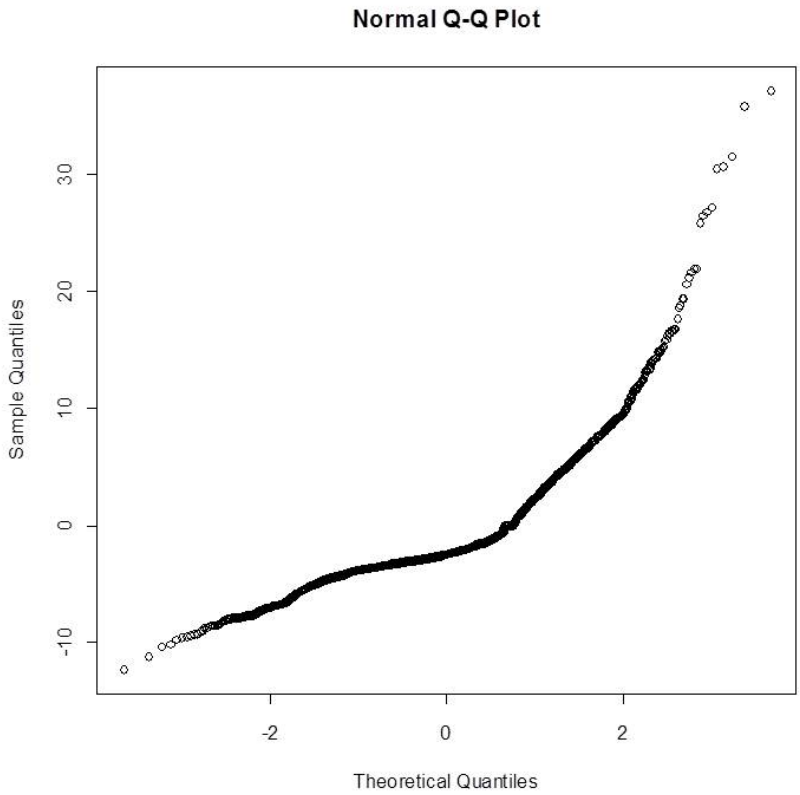


Poisson model: Anova table

	Df	Deviance	Resid. Df	Resid. Dev	Mean dev	F
NULL	NA	NA	4093	107724.09	NA	NA
fYear	7	12140.64	4086	95583.45	1734.38	98.43
fMonth	11	3253.77	4075	92329.68	295.80	16.79
grid.	61	9446.55	4014	82883.12	154.86	8.79
boat.	3	3444.40	4011	79438.72	1148.13	65.16
lunar	1	598.74	4010	78839.98	598.74	33.98
lunar_adv	1	16.42	4009	78823.56	16.42	0.93
LogOthers	1	8199.47	4008	70624.09	8199.47	465.33


Poisson GLM
Residuals
-10
0
10
20
30
0
50
100
150
Fitted values


Poisson GLM
Frequency
0
200
400
600
800
-10
0
10
20
30
40
Residual values



Two-stage model: Anova tables (fixed effects only)

Binomial model

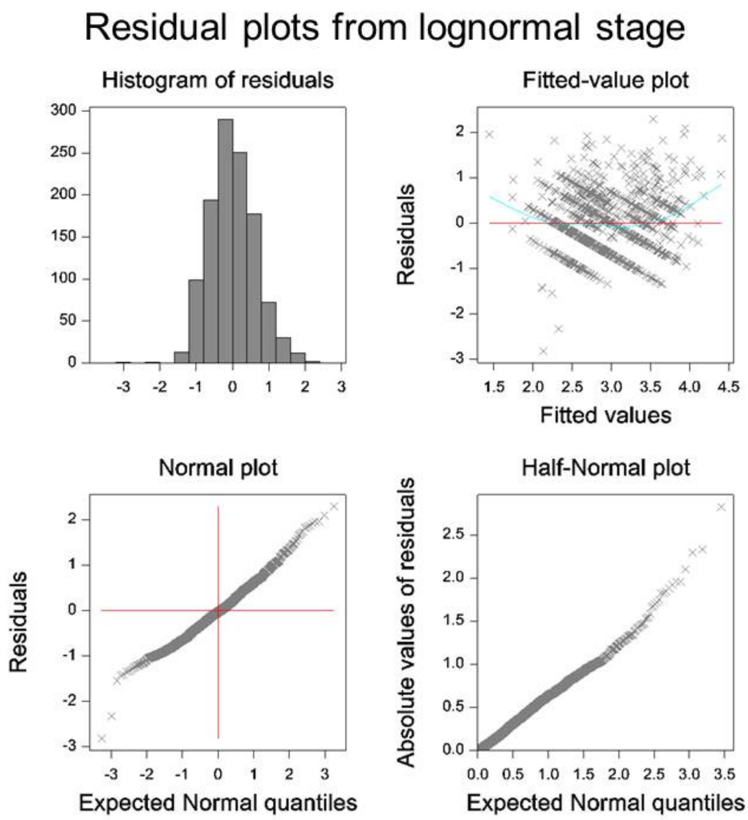
Dropping individual terms from full fixed model

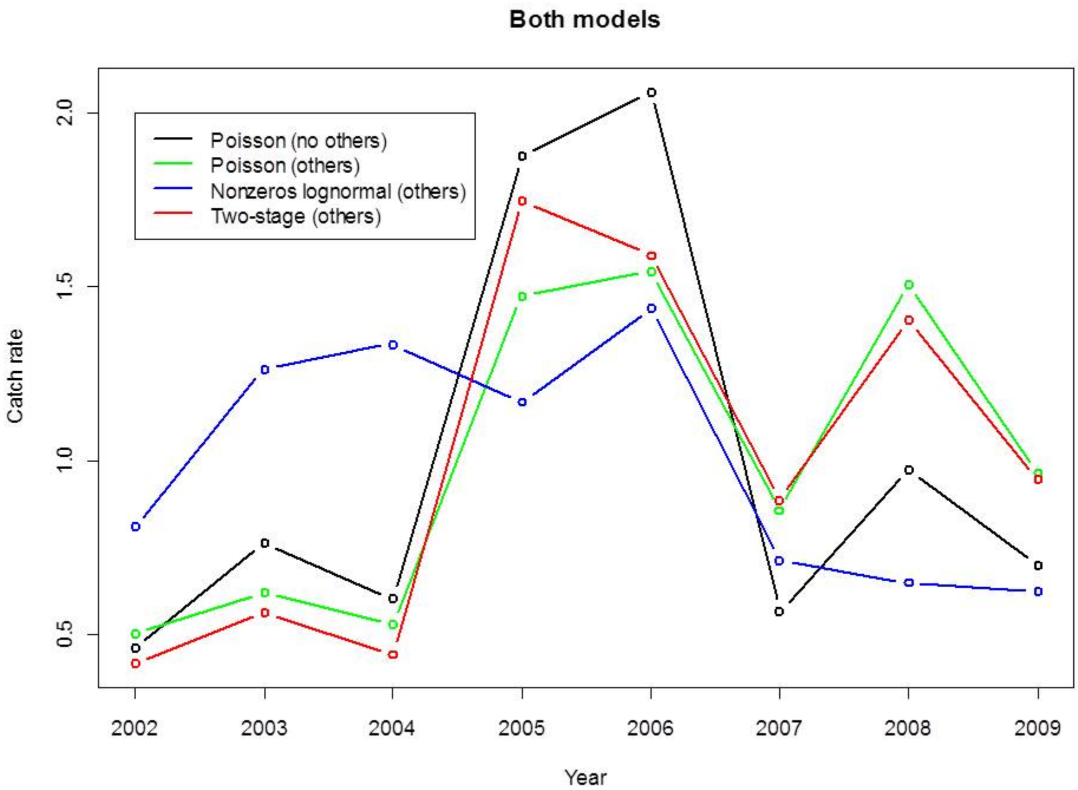
Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Year	119.65	11	10.87	3330.9	<0.001
lunar	9.87	1	9.87	4254.5	0.002
lunar_adv	2.22	1	2.22	4249.4	0.136
Otherslog	66.42	1	66.42	4255.0	<0.001

Lognormal model

Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
year	70.49	8	8.31	66.6	<0.001
lunar	2.06	1	2.06	1111.9	0.151
lunar_adv	0.13	1	0.13	1119.7	0.719
otherslog	148.23	1	148.23	1124.2	<0.001


Residual plots from lognormal stage
Histogram of residuals
Fitted-value plot
Residuals
Fitted values
Normal plot
Residuals
Expected Normal quantiles
Half-Normal plot
Absolute values of residuals
Expected Normal quantiles


Both models
Poisson (no others)
Poisson (others)
Nonzeros lognormal (others)
Two-stage (others)
Catch rate
Year

Conclusions

- Poisson and two-stage models gave similar CPUE trends.
- Important to identify and include zero catches.
  - Is there a problem with reporting of this species before 2005?
- We don't believe that fish abundance really varies this much for a long-lived species: must be subject to very large sampling error.
- Makes a difference whether catch of other species is included.
  - Catch rates of main target species have fallen in recent years. Possibly the catch of target species is not a consistent indicator of effort applied to the bycatch species.
  - This may also be a problem in other fisheries, in that major target species may be fished down but bycatch species not.

17.1.4 Multivariate CPUE Standardization – George Leigh – Michael O'Neil

Multivariate CPUE standardisation

- Existing analyses (in Qld at least) analyse each species separately.
  - Catches of other species become deterministic explanatory variables in a GLM.
  - They are actually random variables.
- Making catch a vector (by species) may work better.

$$\vec{C} = (C_A, C_B, C_C, \ldots) \text{ for species } A, B, C, \ldots.$$

  - Handle all species at once in a single, multivariate GLM.
  - Treat all catches as random variables.

Multivariate Linear Mixed Models

- In some circumstances, it is desirable to analyse two (or more) variables simultaneously to investigate correlation between the variables and their response to treatments.

Example model framework in GenStat

- This menu provides facilities for analysis of multivariate linear mixed models and estimation of variance components using the method of residual maximum likelihood (REML), which is also sometimes called restricted maximum likelihood.

Data

- This specifies the list of data variates to be analysed. The button allows multiple selections to be copied from Available Data.

Fixed Model

- The fixed model describes imposed treatment factors and covariates for which the effect of specified levels or values are of interest. The model is described using a formula, which can combine main effects and interactions of factors and also covariates.

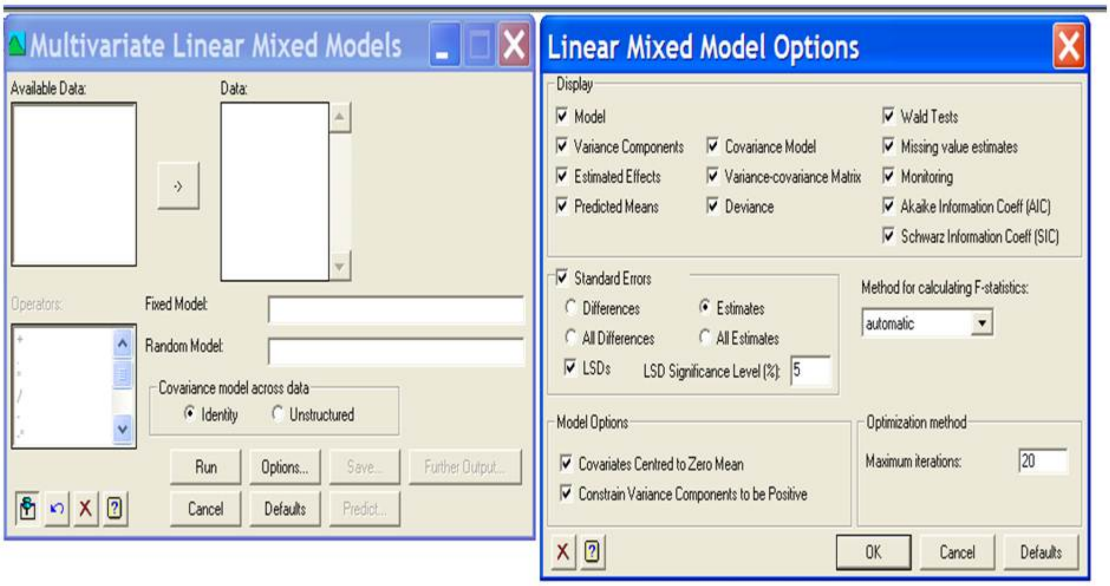
Random Model

- The random model is generally used to describe those factors for which the values present in an experiment can be considered drawn from some large homogeneous population. The model is described using a formula, which can combine main effects and interactions of factors and also covariates.

Covariance Model Across Data

- Allows you to specify the type of covariance model across the data. You can select either Identity or unstructured.

Example screen capture of GenStat MLMM



GLMM in R

- Examples use the packages "SabreR." and "mixAK" – GLMM_MCMC

- Two quick references:
  - Komarer et al, 2010, Statist. Med. 29
  - Doran and Lockwood 2006

Comments

- MLMM can investigate correlation between the variables and their response to treatments.
- Provide reassurance of independence between species (support univariate analyses).
- Method limited by % zeros and model terms by species.
- Need flexible methods for two stage analysis (GLM and HGLM).
- Two example analyses:
  - Crimson snapper, Red emperor and Moses snapper from Qld GoC.
  - Play data: whitefish and greenfish.

Crimson snapper, Red emperor and Moses snapper

Estimated parameters for covariance models

Random term(s)	Factor	Model(order)	Parameter	Estimate	s.e.
%_grid.%_variable	%_grid	Identity	-	-	-
%_variable	Unstructured		v_11	0.2444	0.0735
			v_21	0.04847	0.04293
			v_22	0.1872	0.0481
			v_31	0.04811	0.03240
			v_32	0.01999	0.02578
			v_33	0.09166	0.02651

Residual variance model

Term	Factor	Model(order)	Parameter	Estimate	s.e.
%_variable.%_units		Sigma2	1.000	fixed	
	%_variable	Unstructured	v_11	3.697	0.080
			v_21	0.4510	0.0410
			v_22	1.862	0.040
			v_31	0.3633	0.0389
			v_32	0.3808	0.0280
			v_33	1.699	0.037

Crimson snapper, Red emperor and Moses snapper

Tests for fixed effects

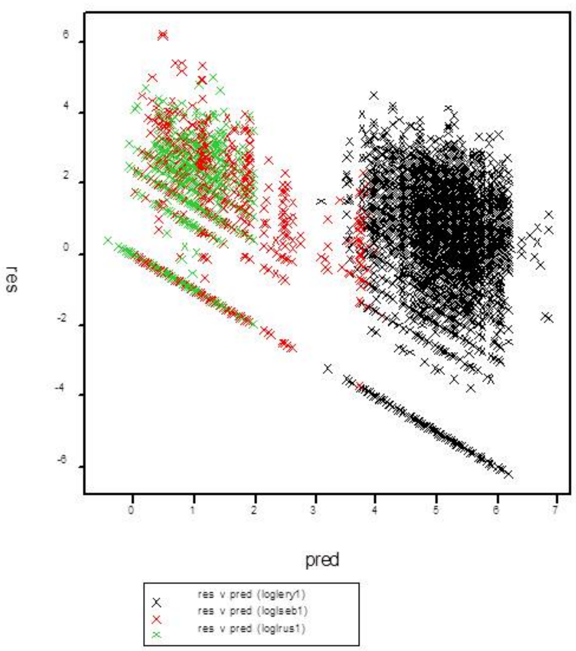
Sequentially adding terms to fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
%_variable	3618.68	3	1153.93	44.1	<0.001
%_variable.%_year	1231.71	33	37.29	9622.9	<0.001

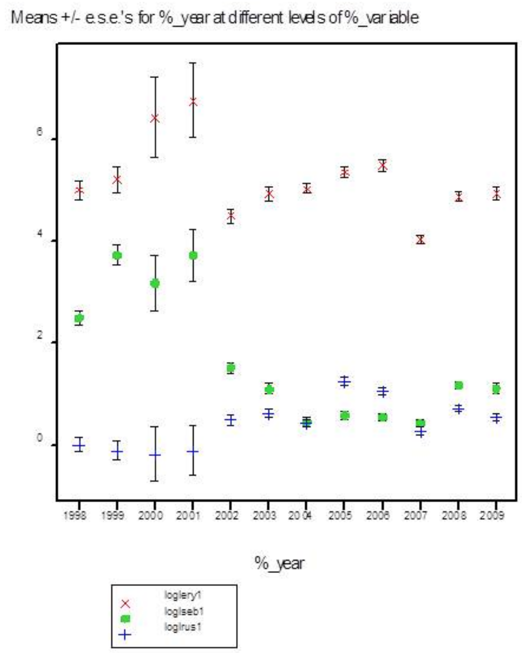
Dropping individual terms from full fixed model

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
%_variable.%_year	1231.71	33	37.29	9622.9	<0.001

Residuals by species



Crimson snapper, Red emperor and Moses snapper



Play data: greenfish & whitefish

Estimated parameters for covariance models

Random term(s)	Factor	Model(order)	Parameter	Estimate	s.e.
%_vessel.%_variable					
%_vessel	Identity	-	-	-	
%_variable	Unstructured		v_11	0.1735	0.0763
			v_21	0.05628	0.05424
			v_22	0.1589	0.0652
%_month.%_variable					
%_month	Identity	-	-	-	
%_variable	Unstructured		v_11	0.01054	0.00469
			v_21	-0.005675	0.013021
			v_22	0.1652	0.0709

Residual variance model

Term	Factor	Model(order)		Parameter	Estimate	s.e.
%_variable.%_units		Sigma2	1.000	fixed		
	%_variable	Unstructured		v_11	1.561	0.011
				v_21	0.03831	0.01102
				v_22	3.240	0.022

Play data: greenfish & whitefish

Tests for fixed effects

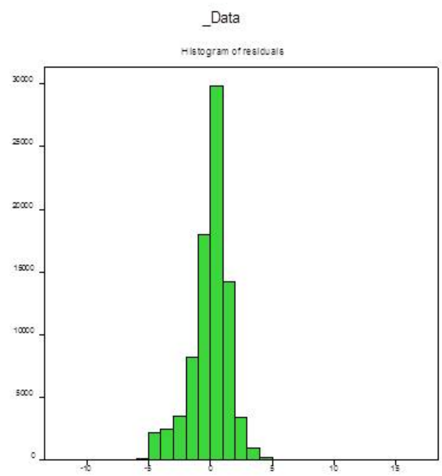
Sequentially adding terms to fixed model

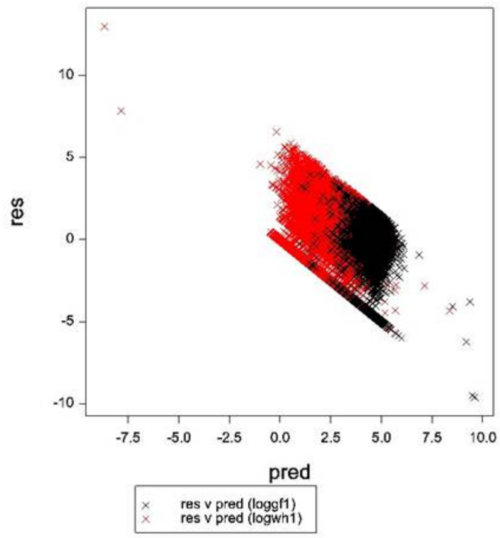
Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
%_variable	1923.00	2	914.84	17.2	<0.001
%_variable.%_year	848.54	22	38.57	70613.9	<0.001
%_variable.%_loghours	1402.54	2	701.25	40357.2	<0.001
%_variable.%_logdepth	268.92	2	134.46	41669.8	<0.001
%_variable.%_tod	13205.98	6	2200.92	55518.3	<0.001
%_variable.%_lat	1474.30	2	737.13	40967.9	<0.001
%_variable.%_lon	30.12	2	15.06	41660.1	<0.001

Dropping individual terms from full fixed model

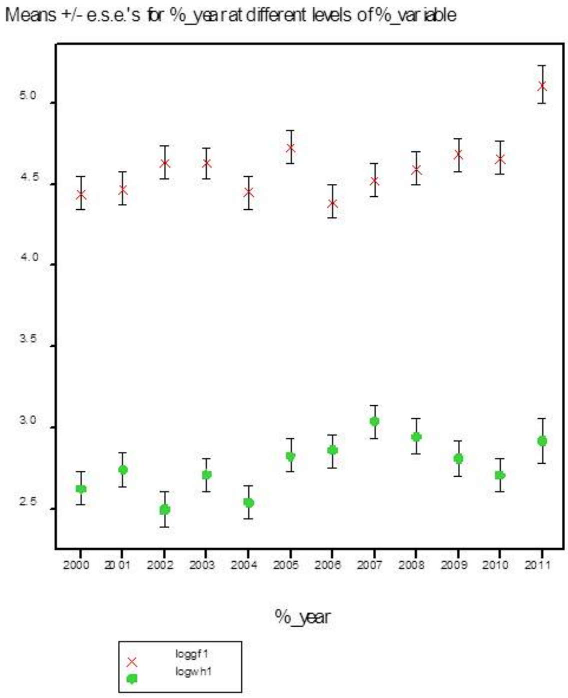
Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
%_variable.%_year	646.98	22	29.41	70613.9	<0.001
%_variable.%_loghours	1158.03	2	579.00	40357.2	<0.001
%_variable.%_logdepth	101.25	2	50.62	41669.8	<0.001
%_variable.%_tod	13169.22	6	2194.79	55518.3	<0.001
%_variable.%_lat	1478.21	2	739.09	40967.9	<0.001
%_variable.%_lon	30.12	2	15.06	41660.1	<0.001

Play data: residuals

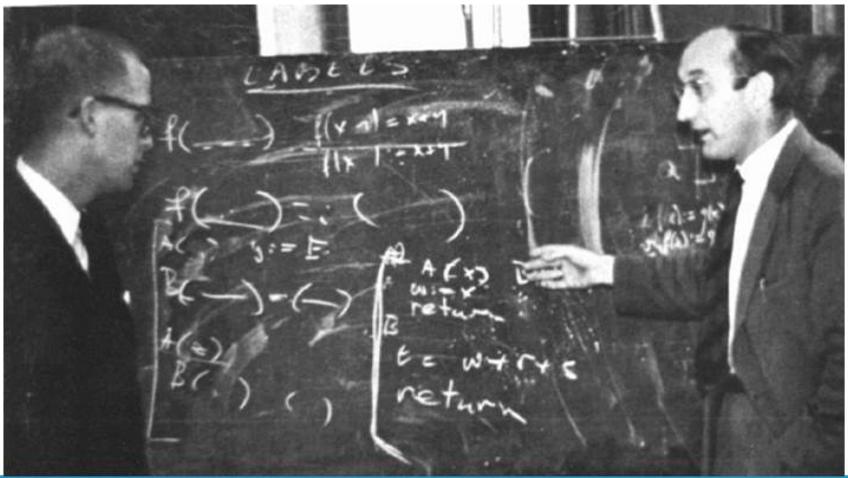




Play data: greenfish & whitefish



17.1.5 Alternative Catch Rate Analyses – Neil Klaer and Mark Chambers



www.csiro.au

Using innovative techniques to analyse trends in abundance for non-target species.

N Klaer, Mark Chambers May/June 2011

CSIRO

CPUE standardisation analyses – effect of targeting

- Catches of a species can be apportioned into that which is targeted and non-targeted
- All fishing operations may not catch the species in question at all – zero catches
- Usually, non-targeted operations have a higher probability of zero catch than targeted ones
- Some non-targeted operations are normally made in areas/times where the species in question does not occur
- Standardisation analyses are required that account for this effect of targeting and the occurrence of zero catches

CSIRO. Non-target

CSIRO

Play data set

- A play data set was created from actual fishery data that contained fishing targeted at two species only
- Both species are commercial, and are specifically targeted individually at certain space/times by the fishing fleet
- The data therefore contains fishing operations that caught only one species, or different proportions of both, where individual shots may have targeted either one, or both species
- Depending on the targeting pattern, either species can be considered to be non-target in certain areas/times
- We know that the distribution of the species differs by space/depth/time
- Fields vessel, year, month, day, TOD, lat, lon, depth, hours, kgWhitefish, kgGreenfish

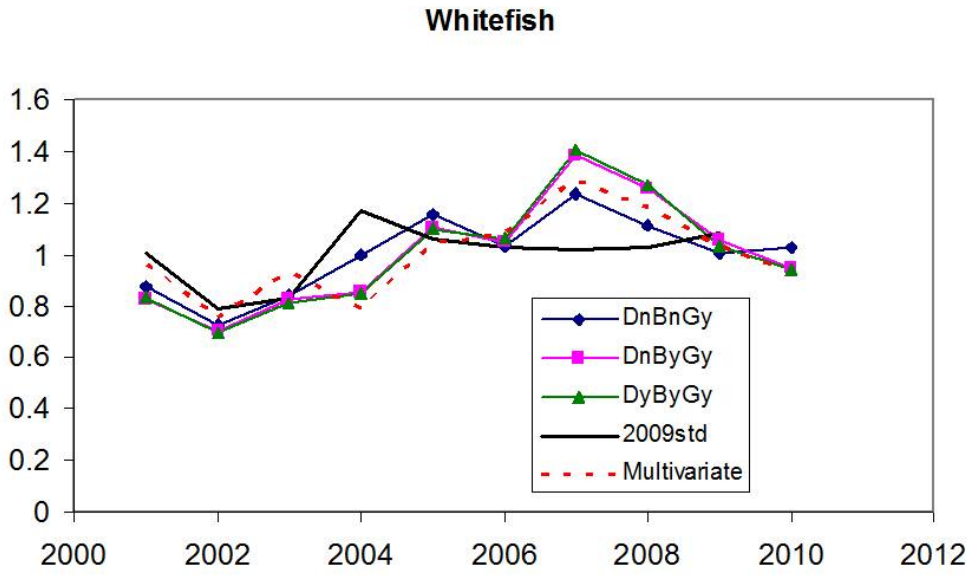
TOD is whether the operation was carried out fully at night, during the day, or a mix of day/night, **hours** is hours trawled

Component analyses

- A method of data filtering that uses a smoothed prediction of the area of occurrence of a species using a binomial generalised additive model (GAM) (d)
- Binomial GAM that models the probability of a species being caught in a shot as a function of lat, lon, depth and TOD (b)
- A GAM using a normal error distribution that models log(CPUE) as a function of lat, lon, depth, TOD, year (g)

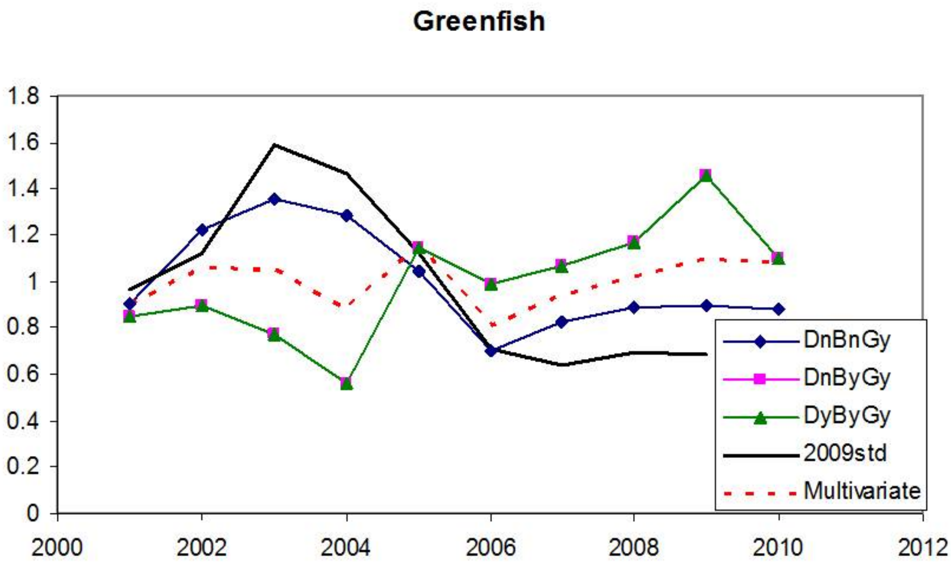
```
WhiteGAM1<-gam(IsWhite~s(Lat,Lon)+s(Depth)+as.factor(TOD),
         data=play,family=binomial)

play$WFprob <- predict(WhiteGAM1,play,type = "response")
WFDF<-play[(play$WFprob>0.3)&(play$Hours>0),]

WhiteGAM2<gam(CPUE~s(Lat,Lon)+s(Depth)+as.factor(TOD)+as.factor(Year),
         data=WFDF[WFDF$Whitefish>0,])
```

Results: Whitefish



CSIRO. Non-target

Results: Greenfish



CSIRO. Non-target

17.1.6 Simulation of Catch Rate data – Malcolm Haddon & Eva Plaganyi

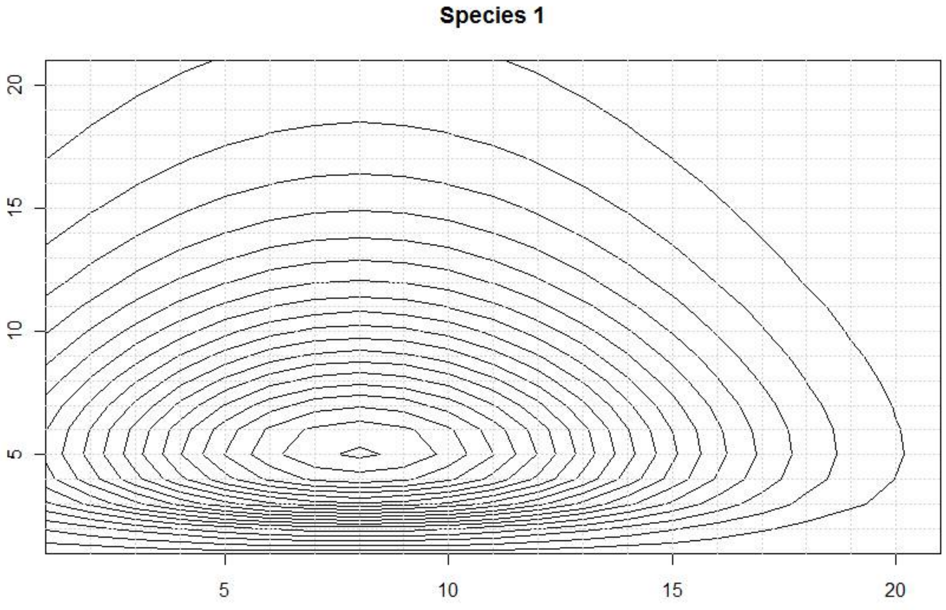
General Questions Addressed

- Catch rate standardization – does the addition of zeros affect outcomes?
- Spatial detail – how effective is the use of coarse scale at capturing fine scale information?
- Pre-selection of data:
- hot-spot analysis – identification of best areas
- Other forms of pre-selection (minimum catch per year, minimum number of years, etc.)
- Simulation of Fisheries Data – for simulation testing.

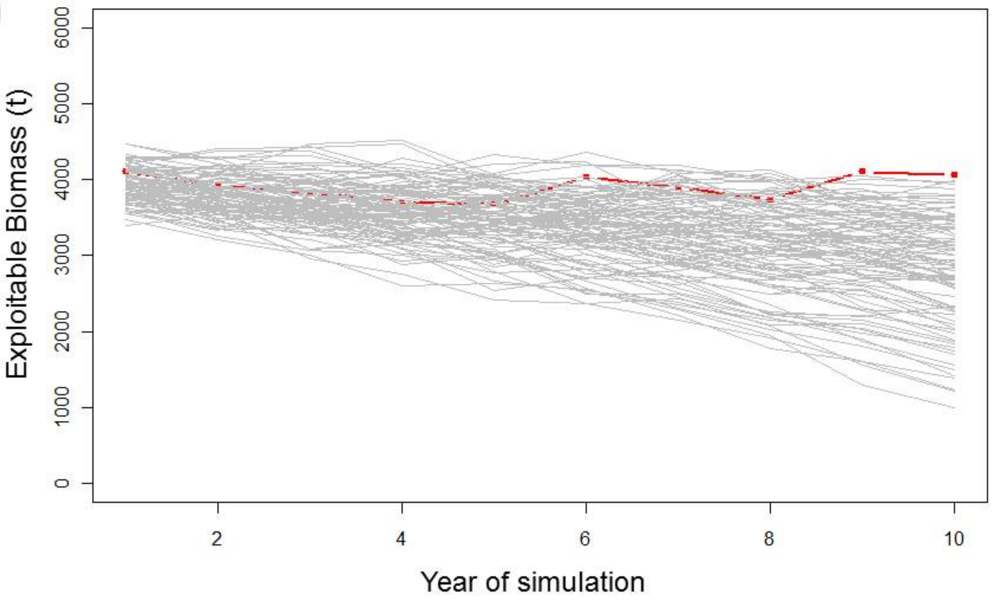
Simulation of Catch Rates

- Developed an algorithm in pseudocode
- Population dynamics simulated by surplus production models.
- Biomass was distributed according to species specific preferences (*sps1*).
- Simulated movement by modelling $q \alpha Mth + Dpth$
- Distribution of effort α *trunc(sps1 + error)*
- Need to add vessel details and daily records (plus lots of other things especially the bycatch species)

Hypothetical distribution of Target Species



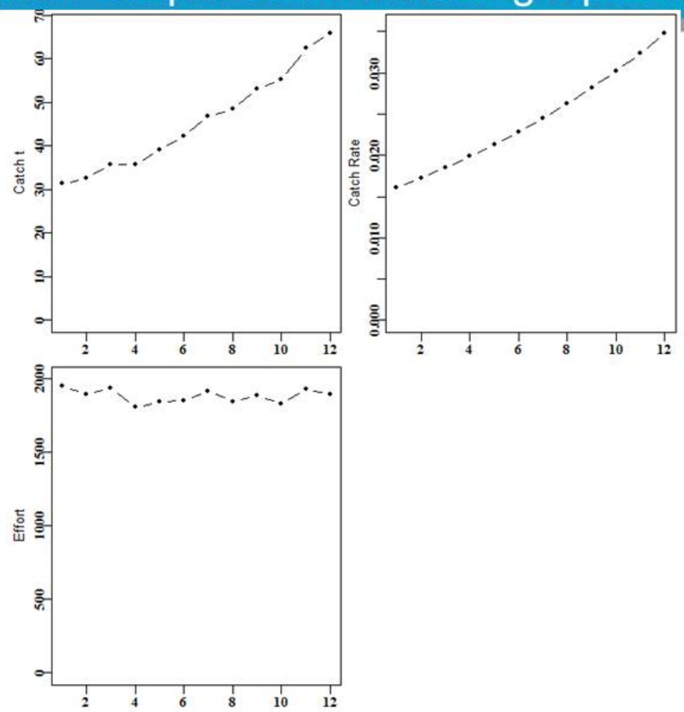
Typical Population Dynamics in Absence of Space



Typical catch distribution

	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]	[,7]	[,8]	[,9]	[,10]	[,11]	[,12]	[,13]	[,14]	[,15]	[,16]	[,17]	[,18]	[,19]	[,20]	[,21]
[1,]	NA	NA	0.13	0.15	0.13	0.14	0.28	0.20	0.14	0.05	0.11	0.09	0.07	NA	NA	NA	NA	NA	NA	NA	NA
[2,]	NA	0.12	NA	0.28	0.35	0.25	0.43	0.21	0.18	0.20	0.18	0.11	0.06	NA	0.09	0.09	NA	NA	NA	NA	NA
[3,]	NA	0.10	0.15	0.30	0.36	0.26	0.42	0.35	0.30	0.18	0.19	0.13	0.13	0.10	0.07	0.08	0.06	NA	NA	NA	NA
[4,]	NA	0.11	0.34	0.48	0.53	0.21	0.28	0.21	0.36	0.17	0.06	0.12	0.16	0.12	0.10	0.07	NA	NA	0.06	NA	NA
[5,]	NA	0.10	0.34	0.56	0.67	0.31	0.20	0.57	0.45	0.33	0.24	0.31	0.06	0.14	0.09	0.09	NA	0.06	0.07	NA	NA
[6,]	NA	0.21	0.36	0.64	0.61	0.68	0.59	0.77	0.48	0.29	NA	0.26	0.17	0.22	0.17	0.07	0.08	0.07	0.06	0.09	NA
[7,]	NA	0.11	0.49	0.73	0.74	0.25	0.68	0.51	0.42	0.23	0.37	0.19	0.16	0.20	0.15	0.09	NA	NA	NA	NA	NA
[8,]	NA	0.17	0.38	0.11	1.03	0.57	0.72	0.62	0.59	0.39	0.16	0.36	0.21	0.08	0.11	0.08	0.13	0.05	0.07	NA	0.06
[9,]	NA	0.15	0.32	0.89	1.06	0.70	0.52	0.72	0.52	0.45	0.34	0.17	0.21	0.12	0.17	0.12	0.14	NA	0.10	0.08	NA
[10,]	NA	0.23	0.56	0.78	0.50	0.40	0.75	0.68	0.24	0.50	0.24	0.21	0.21	0.14	0.16	NA	0.11	0.06	NA	NA	NA
[11,]	NA	0.16	0.49	0.83	0.58	0.72	0.51	0.56	0.50	0.25	0.32	0.17	0.11	0.19	NA	0.12	0.08	0.09	0.06	NA	NA
[12,]	NA	0.08	0.19	0.66	0.21	0.41	0.22	0.50	0.39	0.31	0.32	0.18	0.14	NA	0.10	0.10	0.08	NA	0.06	NA	NA
[13,]	NA	0.10	0.32	0.59	0.40	0.34	0.38	0.43	0.26	NA	0.13	0.18	0.14	0.15	0.15	0.08	0.08	0.05	NA	NA	NA
[14,]	NA	0.12	0.30	0.18	0.30	0.23	0.06	0.11	0.12	0.16	NA	0.12	0.10	0.07	0.08	NA	0.07	NA	NA	NA	NA
[15,]	NA	0.10	0.31	0.37	0.29	0.28	0.16	0.23	0.14	0.11	0.17	0.07	0.09	NA	NA	0.09	NA	NA	NA	NA	NA
[16,]	NA	0.06	NA	0.15	0.28	0.14	0.06	0.11	0.09	0.13	0.06	0.07	0.10	NA	NA	NA	NA	NA	NA	NA	NA
[17,]	NA	NA	0.07	0.11	0.16	0.07	0.07	0.14	0.11	0.08	0.09	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA
[18,]	NA	NA	0.13	0.06	0.07	0.09	0.11	0.09	0.07	0.06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
[19,]	NA	NA	NA	0.07	NA	0.08	NA	0.06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
[20,]	NA	NA	NA	NA	NA	0.06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
[21,]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Typical Output so far Including Space.



Catch of Bycatch Species

- Selectivity altering between species
- Different catchability across species

Contact Us

Phone: 1300 363 400
+61 3 9545 2176

Email: enquiries@csiro.au

Web: www.csiro.au

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