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Identification of climate-driven species shifts and adaptation options for recreational fishers

learning general lessons from a data rich case

Daniel Gledhill, David J. Welch, Alistair Hobday, Stephen Sutton, Adrian Jeloudev, Matt Koopman, Matthew Lansdell, Adam Smith and Peter Last

A Marine NARP Project

FRDC-DCCEE 2010/524

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JAMES COOK UNIVERSITY AUSTRALIA

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1 Non technical summary

FRDC-DCCEE 2010/524: Identification of climate-driven species shifts and adaptation options for recreational fishers: learning general lessons from a data rich case

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OBJECTIVES:

1. Examine change in the distribution of coastal fishes in eastern Australia over the past four decades and establish correlation of these to changes in environment, such as warming sea surface temperatures,
2. Investigate the perceptions of the representative group of recreational fishers regarding climate-induced change and effects this may have on the distribution and abundance of coastal fishes, and identify potential adaptation options,
3. Develop and test a process model for engagement and development of climate change adaptation options suitable for deployment to other fishing sectors and user groups, including commercial fishers.

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED TO DATE

- An engagement model for working with community-based groups has been successfully developed and implemented with a representative recreational fishing group - spearfishers. Members are ready and enthusiastic for greater involvement in, and recognition for, proactive research and management of their target species. This project represents a positive step in improved spearfisher engagement with science, particularly given prominence of recent climate-related media and political attention. The project has developed a positive and productive relationship with key spearfishing bodies in Australia that could lay the foundation for further science-stakeholder collaborations.
- Results from a social survey, covering a broad assessment of experience, attitudes and beliefs held by spearfishers, provide pertinent data on fisher attitudes to science, management, human-induced climate change, and their willingness for deeper engagement.
- Through a partnership approach, a long-term fishing dataset was made available for high priority science, delivering the first quantitative multi-decadal, multispecies examination of climate induced change on Australian coastal fishes.
- Results from this project improve understanding of range extensions by coastal fishes in south-eastern Australia, the plasticity of range-edges and the timeframes involved. These data will contribute to improved prediction, and fostering of recreational fisher adaptation to change.
- Improved understanding of self-implemented autonomous and directed adaptation mechanisms within a discrete community of recreational fishers, and with potential for broader application in the fishing sector and beyond.

Australia's south-east region is recognised as a global hotspot for rising sea surface temperatures. Impacts from this rapid change have already been recorded for coastal marine species, but with sparse decadal-scale, high quality datasets available, we remain poorly informed as to the detail of how change unfolds and which species may be affected. Further, these rapid changes are already proving challenging for fishery management, from both a scientific and engagement perspective.

This project would have been impossible without a significant investment of time and effort on behalf of spearfishers and spearfishing clubs. Likewise, scientists gaining access to spearfishing club datasets will depend on spearfishers trusting scientists to engage with clubs, to make appropriate use of those data, and to best ensure outcomes from associated projects don't negatively affect data owners. One objective of the project was to gain a better understanding of how engagement for effective partnerships should occur and to develop a process model for engagement and development of climate change adaptation options.

Through a partnership approach we successfully developed and implemented an engagement model aimed at improving such activities with community groups. This model contains elements suitable for broader application to other fishing groups and beyond the fishery sector. Importantly, the process also identified many of the challenges that need to be overcome in such engagement. Some 150 members of spearfishing clubs participating in this project were also surveyed to gain a better understanding of their attitudes and beliefs on engagement with fisheries science and management, as well as their observations regarding climate change and potential impacts on the marine environment.

Most respondents agreed that spearfishers and scientists (69% of respondents), and spearfishers and resource managers (59%) have common goals concerning the management and conservation of marine resources. However, most respondents disagreed that scientists (68%) and managers (79%) have a good understanding of spearfishers and spearfishing, and few (30%) reported having a good understanding of how scientific information is used in resource management. Likewise, few respondents reported having high levels of trust in resource managers to do what is best for the conservation of marine resources (13%) or to consider the concerns of spearfishers in decision-making (10%). Few respondents agreed that they are well informed about how their interests are considered in decision-making (22%), that they are adequately consulted about management decisions (6%), or that they receive fair treatment in the decision-making process (3%).

Similarly, the social survey has provided improved understanding of the beliefs among the target group regarding human induced climate change. Most (74%) respondents indicated that they believe there has been substantial change to earth's climate over the past 25 years and that humans are partially (41%) or largely (33%) responsible for those changes. Most respondents reported being moderately concerned about climate change in general (57%) and moderately (59%) or very (31%) concerned about the potential negative effects of climate change on the fisheries resources that they use. Most respondents also believed it to be moderately (41%) or very (47%) necessary to take steps to reduce greenhouse gas emissions that are thought to cause climate change.

The survey highlighted species that may have experienced population changes that could provide a basis for further investigation. These data also improve our understanding of spearfisher perceptions of the benefits and costs of engaging with scientists and provide a basis for further development of a general engagement model for marine resource user climate-change adaptation. They also challenge us to more positively and actively engage with spearfishers, and other member groups in future activities.

Spearfishing clubs provided records from some 730 competitions dating from the 1960's to the present, of which some 600 competitions (267 Victorian and 335 New South Wales), were analysed. A database has been developed to store these data and will be returned to clubs to enhance their own capabilities for ongoing monitoring and engagement. The earliest competition dates from 1961 in NSW, with consistent data available from late 1960s until 2011. Data were from competitions held at 43 sites in Victoria and 50 in NSW, ranging from Coffs Harbour in NSW to near Portland in western Victoria, representing >19,000 'diver days', nearly 130,000 individual fish and >150 species.

These 'fish' data represent the most comprehensive, multi-decadal digitised records based on recreational fisher activities in Australian waters from which to measure climate-based impacts. Quantitative analyses demonstrate a ‘tropicalisation’ effect (increasing percentage of tropical species) and a change in trophic level among fish communities from NSW waters.

The 50 most common species from NSW catches underwent a statistically significant shift toward a more tropical community, and this effect was robust across ‘summer’ and ‘winter’ periods. Examining the top 25 and top 26–50 species as separate units demonstrated the complexity of change occurring, with varying responses over different seasonal periods. Victorian records demonstrated no discernible change in the tropicalisation index for the 50 most common species, possibly resulting from the scoring criteria used.

Examination of Victorian species for trophic-level change among the top 20 or top 50 species since 1970 detected no change. Restricting analyses to the top 21–40 most common species, did however record a change, with species from lower trophic levels becoming more common. Examination of the trophic-level index for NSW species shows a significant increase in the index for the top 50 species across both ‘summer’ and ‘winter’ periods, with an apparent increase in higher trophic-level species (e.g. piscivores) in combination with a tropicalisation effect. Higher trophic level species may be of higher value to many spearfishers than lower trophic level species, changes in these ratios might therefore have a positive effect on their fishing experience.

Some species also show evidence of range extension in southeastern Australia, while others appear to have increased in abundance within the southern limits of their previously recorded range. These data demonstrate the complexity of changes occurring in natural communities, providing new understanding of ranges, range shifts, and movement, and aid in ongoing engagement with spearfishers as they seek to understand the impacts of climate change on their recreational activities.

Spearfishers have a history of adaptation, for example, to new fishing practices, the impacts of fishing, and to changing community attitudes. They are likely to continue to be reactive in adapting to change, many of which are considered positive, at least in the short term. Positive changes include the appearance of novel species, and the likely extension of the Victorian fishing season, currently limited during the cooler months. This history will likely serve them well in short term adaptation, but broader changes expected in the medium to longer-term may prove more challenging.

Spearfishers can be valuable observers of biological change in the ocean, and as such can provide information that can underpin increased societal awareness and galvanise actions to reduce the impacts of climate change through mitigation and widespread adaptation efforts. Spearfishers partnering on the project have requested further scientific examination of their data to better understand localised change from both environmental and human impacts (including commercial fishing, urbanisation and flooding). It is apparent that this engagement partnership, using data owned by the community group, is a powerful approach to developing adaptation options.

Following the extensive investment — both from spearfishers and researchers — to build this relationship, there is an opportunity to further explore these data to investigate questions raised by spearfishers during the engagement activity, and to better understand change currently occurring. There is potential to investigate more complex interactions between species-level change, environmental signals, and anthropogenic impacts including both commercial and recreational fishery management. Additional recreational-fisher data could be digitised to fill gaps, and clubs could be supported in continuing to populate electronic databases which may assist measuring and interpreting change into the future - a resource that would benefit greatly from ongoing technical support. Such a dataset could be revisited every five years, building an ongoing long-term resource for monitoring a range of impacts on coastal species.

The success of this project rests on the foundation and development of a successful partnership which now offers considerable opportunity, both as an ongoing engagement activity, and to further interrogate these novel data. But these relationships will falter without ongoing research projects and regular interactions to sustain them.

KEYWORDS: fish, species range extension, climate variability, climate change, engagement model, spearfishing, recreational fishing, climate hotspot, climate adaptation

2 Acknowledgements

The research team wishes to extend their appreciation to spearfisher competitors past and present from New South Wales, Victoria and Tasmania, who have directly and indirectly contributed to this project.

We thank the current executive and members of the Southern Freedivers (SFD), the Underwater Skindivers and Spearfishermen's Association (USFA) and affiliated clubs, and the Australian Underwater Federation (AUF). We wish to specifically thank members of the SFD executive Clint Engel (President), Leigh Elliot (past President), Paul Crane, Chris Monaghan, Murray Peterson, Andrew Vibert and Nia Vu, and from USFA, Darren Higgins, Peter Saunders, Bob McComb and Adrian Wayne.

Longstanding spearfishers, Mel Brown, Lee Dalli and Dallas Davies (NSW), and Brett Illingworth and Rob Torelli (Vic), gave valued assistance with interpreting data and shared historic perspectives on the sport. We also thank members who participated in the social survey, and the clubs and members who hosted and attended project information nights: The Southern Freedivers, Newcastle Neptunes, Living Water Free Divers, Sans Souci Dolphins, South Coast Skindiver's, St George, Revesby Workers.

CSIRO staff members Toni Cracknell, Tanya Fisher and Mina Brock provided valuable assistance with data entry, and Toni in particular went to considerable effort to ensure data-entry targets were achieved. The design of the database and improvements to its structure and operation benefited from the advice and guidance kindly provided by Scott Cooper (CSIRO).

Data used for the environment-based habitat classification were sourced from a range of providers detailed in the SDODE data libraries, and from publicly available sources and unpublished CSIRO data.

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3 Background

Fishing is an important recreation activity for over 3.4 million Australians annually (NRIFS, 2003), an activity that is likely to become increasingly complex to manage due to changes induced by global warming. Geographic extensions of species ranges are, for example, already being recorded for recreationally targeted species in Australian waters (Last et al. 2010), and State fisheries policies and legislations need to incorporate flexibility to be able to adapt to these changes.

Australia's south-east region is recognised as a hotspot for rising sea surface temperatures resulting from anthropogenic climate change. Over recent decades, Australia's south-east marine waters have warmed at almost four times the global average rate (Ridgway 2007). This increase is largely a result of a southward extension of the East Australian Current (EAC), which flows southward along the edge of the continental shelf, carrying tropical water south before turning towards New Zealand (Ridgway and Dunn 2003). Analyses of output from global climate models indicate that the south-east Australia hotspot (Figure 1) will remain one of the fastest warming in the world (Hobday and Lough 2011; Hobday and Pecl, in review).

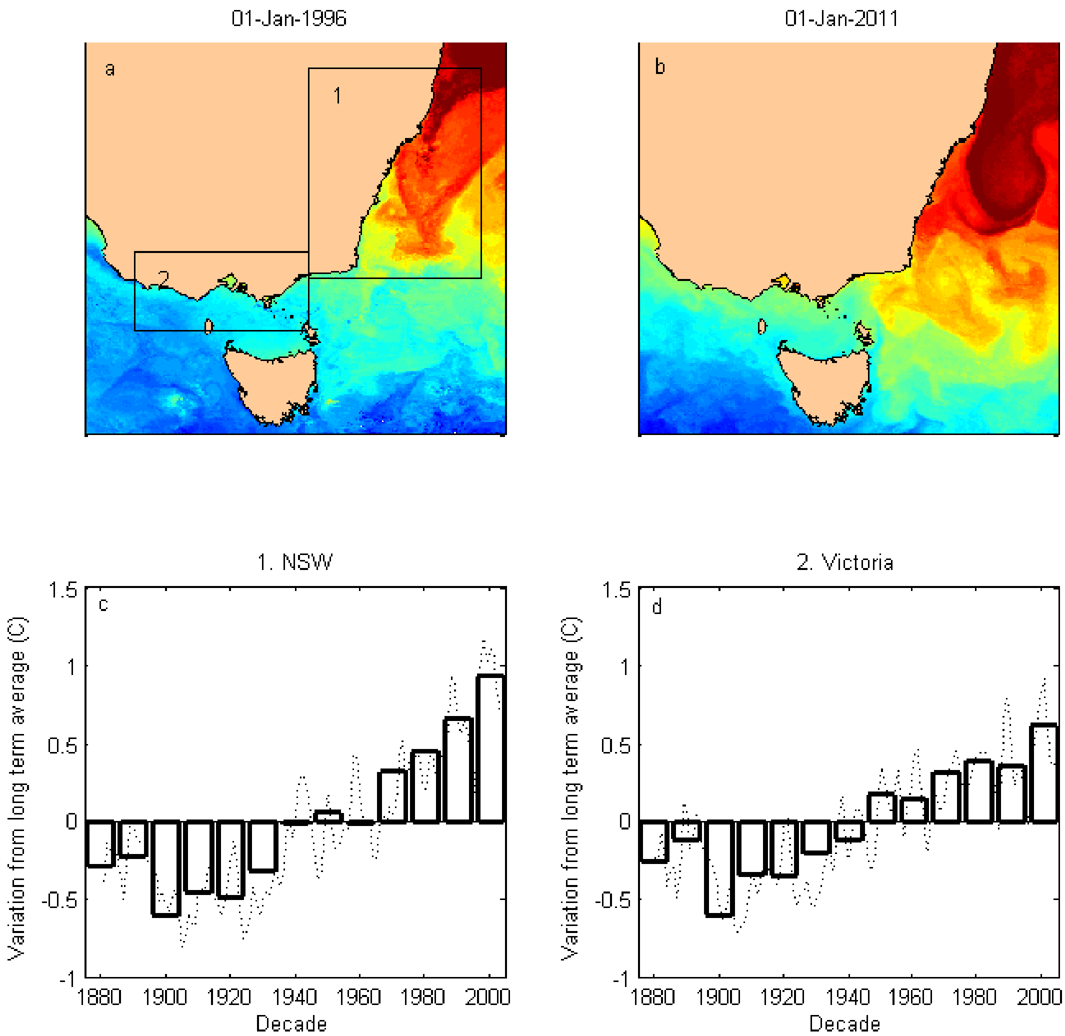


Figure 1. Sea surface temperature (SST) in southeastern Australia: a and b, examples of recent cool (1996) and warm (2011) summer ocean conditions (red = warm SST, blue = cooler SST); c and d, annual average temperature is depicted as variarion from the long term average for both New South Wales and Victoria, for the boxes shown on (a).

Biological changes have been reported at most trophic levels in south-eastern Australia, with poleward range shifts for 50% of intertidal invertebrates (Pitt et al. 2010), the sub-tidal urchin *Centrostephanus rodgersii* (Ling et al. 2009), coastal fish species (Last et al. 2011), phytoplankton (Thompson et al. 2009, Hallegraff 2010) and zooplankton (Johnson et al. 2011) reported. Changes at higher trophic levels are not as well established, but based on their dependence on marine foodwebs, seabirds and marine mammals will also likely be affected by marine climate change in this region.

There is limited understanding of how these changes will impact on the fishing experience of recreational fishers. During the preparation of a manuscript examining shifts in the distributions of coastal marine fishes in south-eastern Australia (Last et al. 2010), it became evident that the 1980s were a pivotal period for change in species distribution in the region. The rarity of long-term, statistically robust datasets on marine organisms makes it difficult to examine the timing and mechanisms by which these changes have occurred. For example, improved knowledge of the rate and timing of range extension, which species are most greatly affected, and the main drivers/correlations with environmental variables would provide great insight into how species and communities may continue to change and adapt to rapid warming.

With a paucity of long-term traditional scientific datasets, scientists are increasingly turning to historic (e.g. Hawkins et al. 2013) and non-traditional data to investigate historical change in biological communities (e.g. Gartside et al. 1999, Lloyd et al 2012, McClenachan 2008). Recreational fishers, including line anglers and spearfishers, have a long history of running competitions in Australia (Gartside *et al*. 1999), during which detailed catch records are often collected. Datasets held by recreational spearfishers were therefore recognised as representing one of the few such sources of long-term data for Australian coastal waters. Many of these records however, have been lost or discarded, but significant quantities of data were known to have been retained and curated.

Longstanding spearfishers were subsequently approached to determine the availability of historic data from spearfishing competitions held on Australia’s central and south-east coast since the 1970s. Members expressed a high level of interest to collaborate on such a project, and this support presented a unique and opportunity to collaborate with a proactive, organised and well-defined group of recreational fishers.

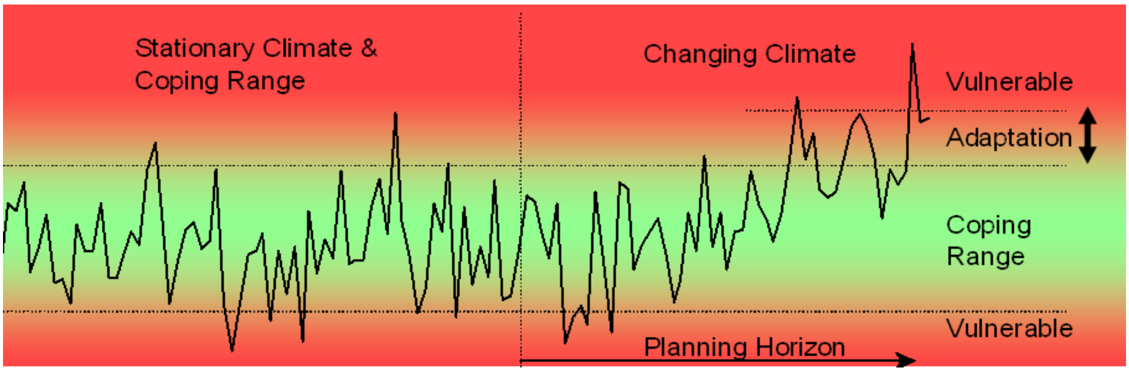
Importantly, spearfishing clubs have a long history of adaptation and marine stewardship. Current members are proud of these activities, and many also recognise their role as curators and custodians of datasets handed down from earlier generations. Having collected these records, members are likely to retain a high level of trust for results that may come from examining these data. Self regulation among spearfishers has occurred through changes to the competition scoring systems (e.g. when species have become rarer, or more common in the catch), and by the removal of vulnerable species from competition score sheets. Spearfishers are cautious about external parties using these historical data, with concerns their existing record of proactive adaptation may be overshadowed by any misinterpretation or misuse of aspects of the data.

The project represented an opportunity to better understand change in the marine environment utilising a truly unique dataset, to investigate adaptation options for a representative recreational group, and to develop a model that may assist engagement with the broader community.

Box 1. What is adaptation in the context of climate change?

Two general responses to climate change can occur – mitigation and adaptation. The focus of the international community and national government has been on policies aimed at reducing atmospheric greenhouse gas concentrations in an attempt to avoid dangerous climate change (mitigation). There is however, now increasing recognition of the need simultaneously to adapt to the impacts of unavoidable climate change (adaptation). One goal of this project is to raise the awareness of the spearfishing community regarding their adaptation options, and to initiate such thinking to maintain or enhance the benefits derived from this recreational activity.

Adaptation has been used to refer to both genetic change (evolution) by species to cope with a new environment, and to societal responses to minimise the impacts of climate change. Natural and human systems are likely to have limited capacity to adjust to the rate of climate change and so as the climate changes, some form of adaptation (natural or human-assisted) is needed to increase the coping range.



Source: Jones and Mearns 2005

A key question in predicting the ecological effects of climate change is whether species will be able to adapt fast enough to keep up with their changing environment. In the case of spearfishers, the results presented in this project show that some species are becoming more common, while others are moving south, or becoming less common. The maximum rate of adaptation will set an upper limit to the rate at which ocean temperatures can increase without leading to a decline in, say, abundance of a local fish species.

In this project, we have focussed on the adaptation options for the spearfishing sector, not on the species they harvest. In this context, adaptation research focuses on providing information to reduce the vulnerabilities of this recreational fishing sector to risks and increase the capacity to cope with and even benefit from change (See Section 7.5).

4 Need

There is consistent and increasing evidence that global warming, and associated increases in sea surface temperatures, are driving recent changes in the distribution and local abundance of a broad range of marine species (e.g. Hiddink and Hofstede 2008; Poloczanska et al., 2008). Changes often manifest as poleward extensions of species ranges, resulting in geographically extensive invasions and displacements (Walther et al. 2002). How these changes will impact fisheries and fisher behaviour is poorly understood. Perhaps the most readily measurable impact for recreational fishers is the increasing abundance of previously uncommon (or non-existent) but valuable target species. The appearance of novel and desirable species represent for many fishers, a positive impact of warming. However, the medium to long-term impact of broad-scale upheaval in coastal marine communities, through rapidly introduced species and habitats, may be negative for fisheries and the industries that rely on them. Such broad-scale and rapid shift may require unorthodox or new management practices.

Recreational fishers, around 3.4 million Australians annually (NRIFS 2003), are often the largest group impacted by fisheries management policy (Li et al. 2010) and therefore their support will be instrumental to successful management (Granek et al. 2008). Recreational fishers have become increasingly engaged in resource management, from the grass roots to the political level, and attempts to adapt to climate change effects may be hindered if recreational fishers are disengaged and unsupportive. Improved engagement of fishers in the development of adaptation strategies and policy decisions is therefore essential to ensuring timely and adequate response to the changes already occurring in marine biota.

Spearfishers, as a well organised, discrete group of recreational fishers, are ideal to engage to examine adaptation options. This project will assess how existing climate induced change may have already impacted recreational fishers and investigates how we might better engage recreational fishers (and other community groups). The project addresses priority questions 1, 6, 7 and 8 for the Commercial and Recreational Fishing sector within the NARP by determining sensitivity of target species to environmental change, and by engaging fishers in determining the need for adaptation strategies.

5 Objectives

Three core objectives were identified prior to undertaking the project. These reflected the initial data requirements to locate long-term datasets for investigation of change relating to increasing sea surface temperatures, and objectives reflecting needs for improved engagement and collaboration between science, management and end users in the broader community. The objectives were to:

1. Examine change in the distribution of coastal fishes in eastern Australia over the past four decades, and establish correlation of these to changes in environment, such as warming sea surface temperatures,
2. Investigate the perceptions of the representative group of recreational fishers regarding climate-induced change and effects this may have on the distribution and abundance of coastal fishes, and identify potential adaptation options,
3. Develop and test a process model for engagement and development of climate change adaptation options suitable for deployment to other fishing sectors and user groups, including commercial fishers.

6 Methods

6.1 A partnership approach

From initiation, to the successful completion of this project, collaboration with recreational spearfishers was fundamental to accessing and analysing historic catch data. This collaboration was started prior to project development between key project researchers and David Welch and Adam Smith, both of whom are long-standing spearfishers and members of the Australian Underwater Federation (AUF), a body representing spearfishers nationally, as well undertaking fish and fisheries research.

Table 1. Summary of core meetings and engagement activities. Project attendees – initials refer to report authors.

Date	Activity	Project attendees
November 2008	Initial contact with national spearfishing body (AUF); continued liaison among clubs/AUF/USFA and researchers until project commencement	DG, PL, DW, & AS
January 2011	Project start	
February 2011	Initial researcher Team meeting, Hobart	Refer to Appendix D
April 2011	Attend SFD Club meeting, Melbourne – Project introduction; continued extensive negotiation of data use over the ensuing 5 months	DG & DW
June 2011	Meeting with USFA executive, Sydney – Project introduction	DW
August 2011	Meeting with USFA executive, Sydney – Follow-up discussion; continued extensive negotiation of data use over the ensuing 5 months	DG & DW
September 2011	Data use agreement signed with SFD	
October 2011	SFD data collation and inventory	DG
April 2012	USFA data collation and inventory	DG
February 2012	Data use agreement signed with USFA	
May 2012	Meeting with SFD president, Melbourne	DG
October 2012	Final researcher Team meeting, Hobart	Refer to Appendix D
November 2012	Attend SFD Club meeting, Melbourne – Discuss results	DG & DW
November 2012	Attend Newcastle Neptunes Club meeting, Charlestown – Discuss results	DG & DW
November 2012	Attend meeting for Sydney metro clubs, Sydney – Discuss results	DG & DW
November 2012	Attend South Coast Skindivers club meeting, Wollongong – Discuss results	DG & DW
November 2012	Follow-up meeting with Brett Illingworth (SFD) for additional species-level feedback	DG
June 2013	Follow-up meeting with Brett Illingworth (SFD) to discuss draft final report	DG
June 2013	Follow-up meeting with Dallas Davies and Steve Elias (Newcastle Neptunes, USFA) to discuss draft final report	DG
June 2013	Follow-up meeting with Mel Brown (South Coast Skindivers, USFA) to discuss draft final report	DG

6.1.1 INITIAL CONSULTATION

Early discussions were undertaken to assess the extent and current availability of remaining data, and the preparedness of members to collaborate on such a project. In Victoria, a number of clubs that previously existed (eg. Bulldogs, Mako's, Dandenong, Kew, Warrnambool) have ceased, mostly around the late 1980s. Since 1994 the Southern Freedivers (SFD) — a member of the national spearfishing representative body the Australian Underwater Federation (AUF) — has represented Victorian spearfishers and curate the *Victorian Spearfishing Archives,* an extensive collection of competition records. These include data from national, state and club-level competitions held since the 1970s. In New South Wales (NSW), clubs ranging from the Central Coast to the south coast are represented by the state-based Underwater Skindivers and Fishermen's Association (USFA). As a state, the NSW member clubs also hold a significant body of records, called the *USFA Index*, with records dating from 1961.

Prior to funding being requested, extensive consultation secured in-principal support from key spearfisher representatives in NSW and Victoria to collaborate on the project.

6.1.2 FORMAL INTRODUCTORY MEETINGS

Following a successful project funding application via the competitive marine NARP, researchers held a team workshop in Hobart during February 2011 to determine: project tasks and timeframes; schedule of club engagement; roles and responsibilities of team members; and to prepare a publication plan for manuscripts and the final report. Workshop attendees are listed in Appendix D.

To assist with this aspect of the project, researchers attended a club meeting held by SFD in April 2011, and met with members of the USFA executive in June, and again in August 2011.

These initial meetings were to:

- Explain the project rationale and objectives,
- Discuss climate-associated environmental change in marine waters, and the observed and likely impacts of these changes, the need for data to inform on these impacts, and the importance of fishers being better prepared to adapt to these changes in the future,
- Establish a relationship with club executive and members to encourage support for the engagement process, and for the use of club data,
- Discuss details of a data agreement to be signed by both parties, and
- Discuss incentives for clubs to be involved. These include: active participation in novel research; collation and inventory of remaining historic data (previously dispersed, and much has been lost), a database of digitised records to be returned to clubs, and small development grants to assist club activities.

6.1.3 DATA AGREEMENTS

Formal data agreements were recognised as beneficial to both spearfishers and researchers to clearly describe the intended use of the data, and the conditions regarding the return of data. Development of data agreements required extensive consultation to ensure sensitivities around the historic data were addressed, and to build relationships between researchers, club executives and members. Members were generally willing to participate in the proposed project and were broadly supportive of using these data to better inform scientific management of target species. Despite this readiness, there was some reluctance of members to cooperate due to mistrust of science and management that resulted from some past bad experiences. Those members felt their needs and concerns were not adequately recognised in those past engagements, or in some cases were betrayed. There was also widely held concern that if the data became publically available, it may be selectively used to misrepresent and discredit spearfishers.

Following extensive consultation, a data agreement was signed with SFD in September 2011 and with USFA in February 2012. Data agreements formalised the intended uses of the data, a time period for which the data would be made available to researchers, and the formats and timing relating to how data would be returned to respective clubs. A scientific liaison was also appointed to the research team from each state — Matt Koopman (SFD) and Adrian Jeloudev (USFA) — to serve as representatives of their respective bodies, and contributing directly to research decisions and authorship.

6.1.4 ONGOING CONSULTATION

Following signing of agreements, a project researcher (DG) met with the club liaison in each state to create an inventory of data available, and to decide which data were to be sent to Hobart for further assessment and selective digitisation. All Victorian data available at that point were sent to Hobart, and 80% of located NSW data were also sent for selective digitisation. Throughout the digitisation process and initial analyses, club liaisons were the primary contact for the project, and relayed updates to club members and the executive. Additional interactions with club executive and members were also undertaken as required — for example to match and validate species common-names used during competitions.

6.1.5 FINAL MEETINGS

Following analyses of digitised data, researchers held a final team workshop in Hobart in October 2012 to discuss project results, refine the engagement process model, plan for final extension activities, and discuss reporting of results (Figure 2). Workshop attendees are listed in Appendix D.

Figure 2. Second team workshop, October 2012.

Researchers (DG & DW) met with members again in November 2012 with visits to SFD in Melbourne, Newcastle Neptunes, South Coast Skindivers, Wollongong, and a combined meeting for Sydney metro clubs. At each meeting results were presented to the 20-30 members in attendance. Feedback on the data analyses and on specific points requiring clarification and interpretation was sought. Members were very interested in results and offered many suggestions and queries regarding the data, along with valued discussion and broad support for the project and results to-date. These comments and insights were taken into consideration during further analyses, and also greatly improved our understanding of mechanisms contributing to changes to catches through time. The presentations also highlighted the availability of some limited, but greatly needed, Victorian data from recent years. Following these meetings, these additional Victorian data were sent to Hobart and digitised at CSIRO.

In June 2013 DG met with longstanding spearfishers Brett Illingworth (SFD), Dallas Davies and Steve Elias (Newcastle Neptunes, USFA) and Mel Brown (South Coast Skindivers, USFA) to discuss the draft final report (this document) and seek further feedback and comment prior to final submission. Considerable additional detail and insight was gained through these visits, greatly improving the final document.

Figure 3. David Welch delivering project results to members of Sydney metro spearfishing clubs, November 2012.

6.1.6 ONGOING ENGAGEMENT

Ongoing engagement activities are principally aimed at communicating results to members and ensuring continuity in the relationships that have been built. Activities will include the circulation of 'information sheets' summarising the results of the project, recognising the importance of the datasets that divers hold, and the potential of these to better inform current science and the sustainable management of target species.

Club liaisons and project collaborators will also meet with key members from each state over coming months to discuss results, and liaisons will present results to club meetings directly. Popular articles are also planned for publication in diving and/or fishing magazines, and a media release is planned following the finalisation of the project. These activities not only promote results of the project, but the role of the clubs, the importance of their data, and the successful collaboration and engagement activities undertaken.

6.2 Social survey design & analyses

6.2.1 SURVEY DEVELOPMENT

A survey of spearfishing club members was designed by the project team to collect the following information about club members': 1) beliefs and actions regarding engagement in fisheries decision-making; 2) beliefs and attitudes towards sharing of spearfishing club data with scientists; 3) beliefs and attitudes about climate change and its potential effects on the marine environment; and 4) observations of past changes in the marine environment and beliefs about the causes of those changes. A draft of the survey was reviewed by the executive of the spearfishing body in each state and resubmitted after revision to each executive for approval before being implemented. The NSW survey is included in Appendix E (the VIC survey was identical to the NSW survey except for references to the name of the club being surveyed in the introduction and Question #10). The survey was conducted under James Cook University Human Ethics Approval Number H4079.

6.2.2 SURVEY ADMINISTRATION

The survey was administered to spearfishing club members using the on-line survey tool SurveyMonkey. In Victoria, the e-mail addresses of all active club members (n = 83) were provided by the club executive and used to automate the survey administration through SurveyMonkey. An introductory e-mail inviting club members to participate in the survey was sent to each e-mail address in October 2012, followed by a reminder e-mail to non-respondents approximately 3 and 6 weeks later. A total of 32 responses were received from VIC club members. After accounting for non-valid e-mail addresses (n = 5), the response rate to the VIC survey was 41%.

In New South Wales, introductory and reminder e-mails were sent to active club members by the club executive on behalf of the survey team. The e-mail invitation included a hyperlink to the survey website; however, it was not possible to collect information on which club members had responded to the survey because individual e-mail addresses were not entered into SurveyMonkey. Therefore, reminder e-mails sent 3 and 6 weeks after the initial invitation were sent to all club members. A notice about the survey (including the survey hyper-link) was also included on the members-only page of the NSW club's website. A total of 133 survey responses were received from NSW club members. The NSW club executive reported to the project team that e-mail invitations were sent to approximately 500 members, giving a response rate of approximately 27% for the NSW club survey.

6.2.3 ANALYSIS

All survey questions (except the open-ended question collecting details about observed changes in the marine environment) were tested for differences between NSW and VIC club members using ANOVAs for continuous variables and Kruskal-Wallis tests for categorical variables. Because only a small number of differences were found between NSW and VIC club members, results have been presented for the pooled sample and significant differences between NSW and VIC noted when they occurred.

Responses to the open-ended question about observed changes in the marine environment were analysed for content and separated into individual observations (i.e., when an individual respondent made multiple different observations of environmental change, the individual observations were used as the unit of analysis rather than the respondent's entire response). Observations of environmental change were then categorized according to the species/species group mentioned in the observation, the direction of observed change (positive environmental change vs. negative environmental change) and the cited cause for the observed change (human cause vs. environmental cause).

6.3 Digitisation of historic data

Data collation activities discovered more data than could be digitised within the time available for the project. Data were therefore selected for digitisation to ensure maximum temporal and spatial coverage from each state. Many Victorian competition records included a summary sheet with total weights and counts for that competition. All Victorian summary data were entered. For both NSW and Victoria competitions, those selected for complete digitisation were entered in their entirety. Additional data also became available later in the project and were also selectively digitised to ensure maximum possible spatial and temporal coverage. Three national competition events held in Tasmania in 1984 were also located and digitised. A limited amount of previously digitised data was available from southern NSW competitions, and a significant amount of data from off Sydney was previously digitised by NSW liaison (AJ).

Clubs recorded data using standardised scoresheets (examples are included in Appendix F & Appendix G). Even the earliest competition records available — held by the Newcastle Neptunes Spearfishing Club in 1961 — were recorded on pre-printed scoresheets containing the club name and emblem and a listing of around 55 species. Numerous versions of scoresheets arose over the recording period, with variation both within and between clubs, creating considerable challenges for data entry. Regional and temporal changes in the use of common names also provided challenges, resulting in numerous requests to clubs for clarification. Where multiple species were captured under a single common-name group, e.g. 'Salmon', these were upgraded to the species-level identification, in this case Eastern Australian Salmon (*Arripis trutta*), where these related almost entirely to a single species. Other 'group' names represent a mix of species, and therefore have been retained.

6.4 Database design

A relational database system has been developed to store data pertaining to the typical catch of spearfishing-caught species as recorded in historic score sheets. The database holds details of fishers, catch measurements, and spatial and environmental data relating to their capture. Centralising the data storage has allowed flexibility in data access, quality control, exploration and analysis.

Historically, a wide range of data has been collected for spearfishing competitions. Prior to this project, much of that data remained in paper form – that is, the original competition score sheets. Whilst in the past decade clubs have modernised their data recording practices and digitised some competition data, there remains substantial variation in practices and detail recorded.

For effective analysis of historical data a comprehensive and cohesive data recording structure was needed into which all records, both paper-based scoresheets and semi-digitised competition data, could be entered. The solution aims to provide readily accessible data over a wide temporal and spatial period to permit scientific analysis of trends over time in relation to spearfishing practices and catch results.

In this section the development, structure and contents of a database developed to hold all spearfishing catch and event data is described.

6.4.1 RATIONALE BEHIND THE DESIGN

The database was designed with a relatively flat structure as there were relatively few fields and an effective structure could be achieved with just 3-4 database tables to link the data (Figure 4).

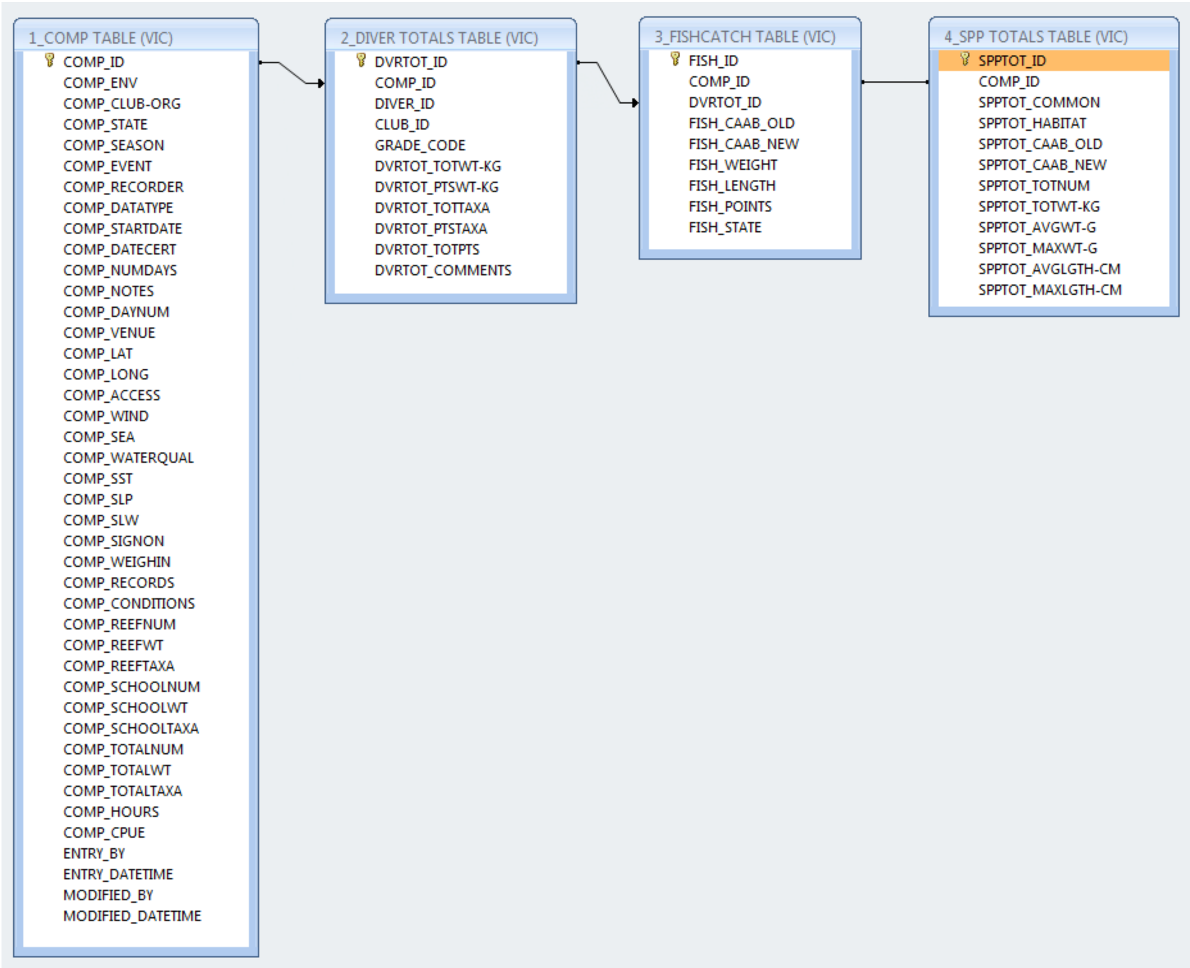


Figure 4. Diagram illustrating the relational design between key data entry tables for the Victorian Spearfishing Database. A similar structure was used for NSW.

The basic premise of the database is to store information of the competition event and catch data. Additionally, provision has been made within the database for additional environmental data (e.g. sea surface temperature, ocean colour, sea height) to be added from the resources available to CSIRO via the Spatial Dynamics Ocean Data Explorer database (SDODE; Hobday et al, 2006). It is thought that this additional data, matched to catch records by date and position, may assist in later analyses of trends in catch over time in relation to ocean temperature and current changes.

The process for which key data needs to be captured and stored is as follows:

- A spearfishing competition is set for a certain date and location, with environmental conditions on the day being recorded (wind, sea conditions, water quality) together with the means of diving access (shore dive, boat, etc.), in-water time and the number of divers signing on and weighing in. This data is stored in the COMP (Competition) table.
- A diver brings ashore their catch and this is recorded, being total weight of the catch, total points-weight of the catch (where undersize taxa are excluded), total number of taxa, total points-taxa (where undersize taxa are excluded) and total points earned by the diver based upon the type and size of fish and the points calculation system in effect for the competition. This data is stored in the DVRTOT (Diver Totals) table.
- The identity and weights of individual fish are recorded. For certain species, the length is recorded rather than the weight (e.g. longtoms, garfish), although there has been some variation over time and between states in which species this has been applied to. For consistency in identification purposes we used CSIRO's CAAB (Codes for Australian Aquatic Biota; http://www.marine.csiro.au/caab/) codes as a unique identifier for species (Rees et al., 1999).

Individual fish point-values may also be entered. This data is stored in the FISHCATCH (Fish Catch) table.

- Most Victorian competitions had a summary sheet attached, this recorded total catch for each species for that competition day. All available summary datasheets were entered for Victorian competitions, resulting in a few Victorian competitions where only the 'Summary Sheet' data was entered, as opposed to individual score sheets. An additional table was created to capture these summary data. For each species, the total number captured, total weight, average weight, maximum weight, average length (where applicable, for length-measured fish) and maximum length (where applicable, for length-measured fish) were recorded. For the Victorian Spearfishing Database only, this data is stored in the SPPTOT (Species Totals) table.

A number of additional reference tables have been created to support the content of the key data tables and provide a lookup facility for coded data (Figure 5). These tables have been designed with the intent that spearfishing clubs can customise and expand these to continue to capture member data as required. These include –

- CAAB Codes Fish Lookup table (Vic & NSW) – a reference table that provides a detailed taxonomic hierarchy of fish species from Australian waters, together with scientific name (genus and species) and accepted common name.
- Clubs Profile table (Vic only) – a shell table only, set up to accommodate the contact details of spearfishing clubs and their office-bearers. Can be expanded to include more fields for contact information if required.
- Codes Lookup table (Vic & NSW) – a reference table to translate between code descriptions and their full meaning where a coded entry (e.g. category value) has been used in a table rather than a text descriptive. This lookup table also details where in the key data tables coded values have been used.
- Divers Profile table (Vic only) – a shell table only, set up to accommodate the personal details of divers who are members of a spearfishing club. Can be expanded to include more fields for diver information if required.
- Diver-Club-Grade-Season Lookup table (Victoria only) – a reference table that creates a link between a diver, the club they are a member of, their grade and the season in which they last participated at that level or for that club. Created where adequate data permitted for Victorian data only from 1970 to 2000 only.
- Fish Metadata Table (Vic & NSW – not shown) – a reference table currently used for scientific analysis of data, contains metadata from other database sources relating to aspects of individual species such as trophic level, distribution, biome and reference notes.

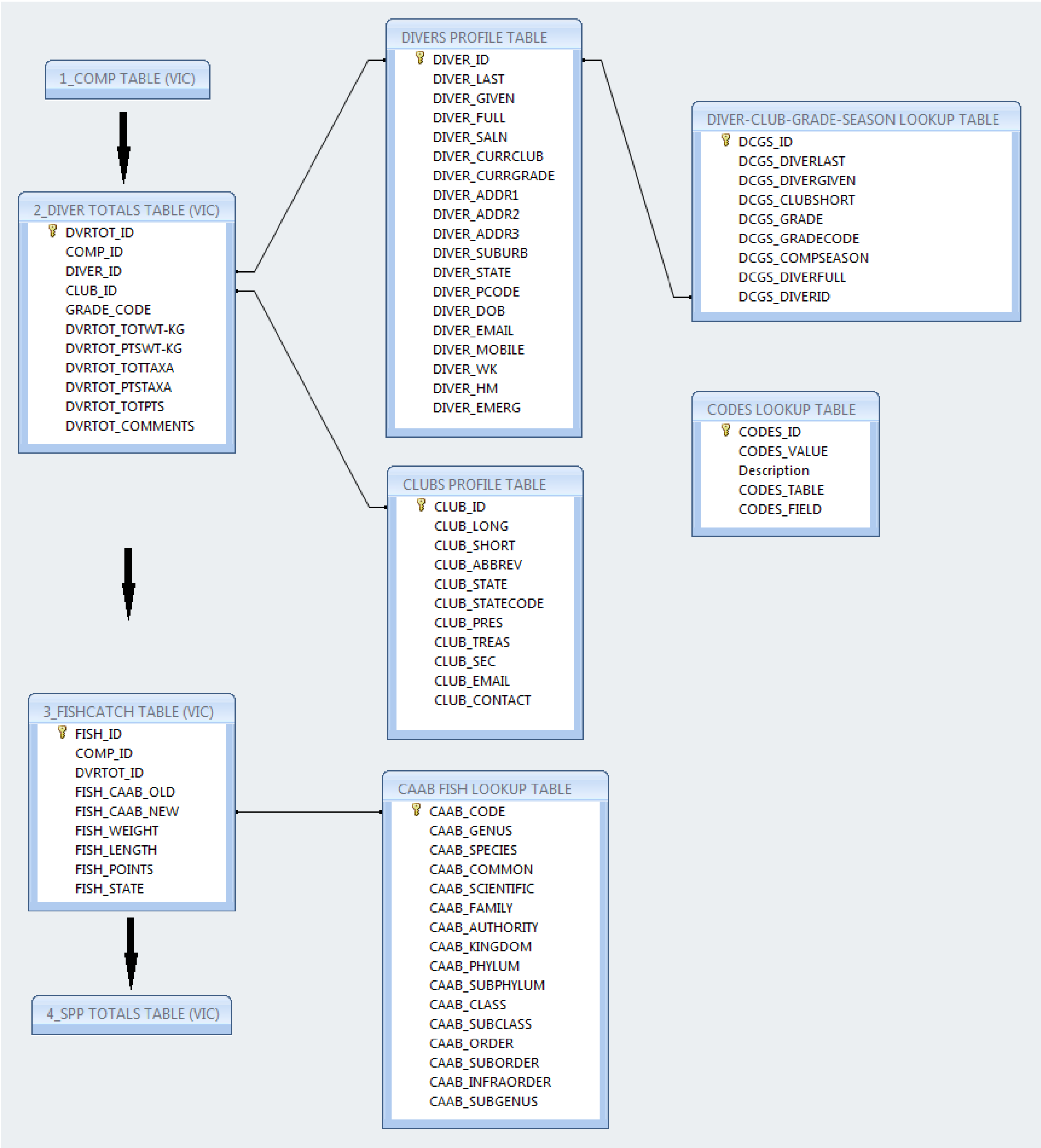
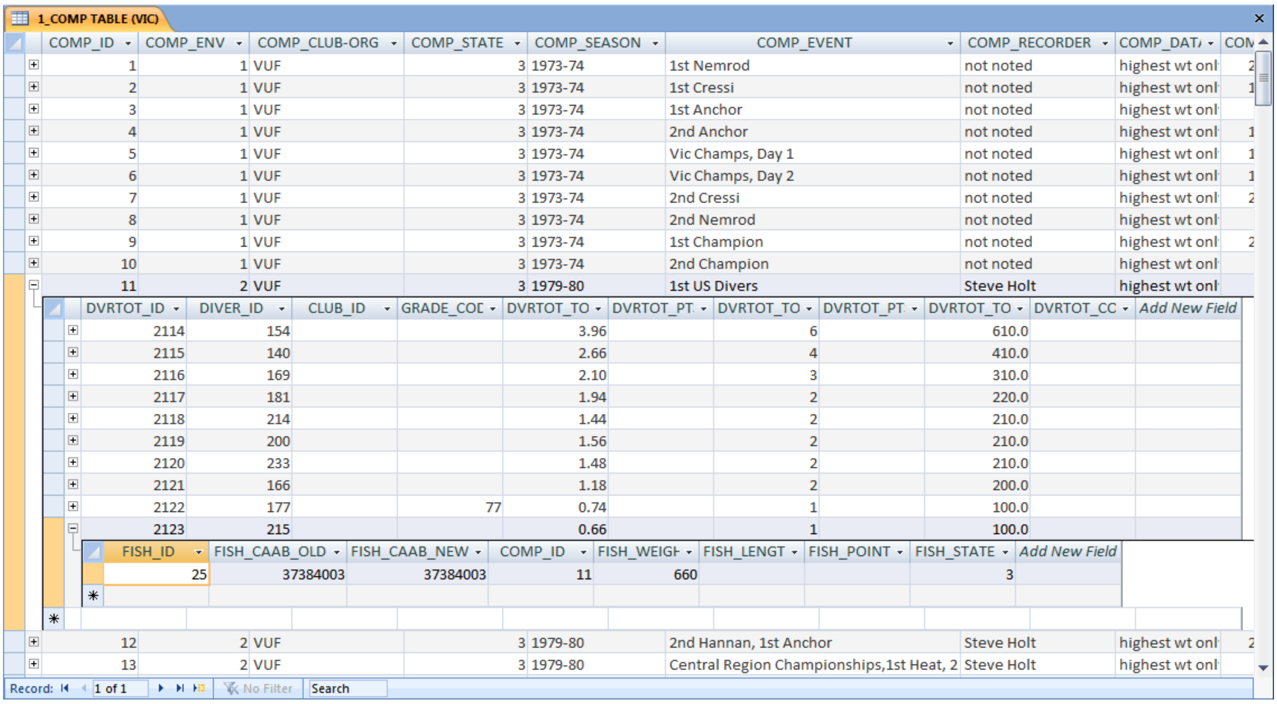


Figure 5. Diagram illustrating the supporting relational design between lookup and reference tables and the key data entry tables (1-4), in this instance, for the Victorian Spearfishing Database.

The Spearfishing database delivers a simple but easy method for entering data into a central storage area that can be accessed by club officials and permitted personnel to manage and enquire upon their data records. At this time the relational database design exists only as a Microsoft Office Access database without the creation of a front-end design using standard forms for entering data. Data is entered directly into the tables (Figure 6).

User defined reports can provide results for key queries in quick time. The Victorian database currently holds data for over 260 competition days across 40+ dive sites with more than 29,000 fish catch records. The New South Wales database currently holds data for over 320 competition days across 45+ dive sites with more than 97,000 fish catch records. This substantial collection of recreational spearfisher catch data is enabling detailed studies over a wide temporal and spatial period of the trends in relation to spearfishing practices and catch results, together with the impacts of ocean temperature and current changes upon spearfisher-targeted species.



1_COMP TABLE (VIC)

	COMP_ID	COMP_ENV	COMP_CLUB-ORG	COMP_STATE	COMP_SEASON	COMP_EVENT	COMP_RECORDER	COMP_DAT/	COM
⊞	1	1	VUF	3	1973-74	1st Nemrod	not noted	highest wt onl	2
⊞	2	1	VUF	3	1973-74	1st Cressi	not noted	highest wt onl	1
⊞	3	1	VUF	3	1973-74	1st Anchor	not noted	highest wt onl	
⊞	4	1	VUF	3	1973-74	2nd Anchor	not noted	highest wt onl	1
⊞	5	1	VUF	3	1973-74	Vic Champs, Day 1	not noted	highest wt onl	1
⊞	6	1	VUF	3	1973-74	Vic Champs, Day 2	not noted	highest wt onl	1
⊞	7	1	VUF	3	1973-74	2nd Cressi	not noted	highest wt onl	2
⊞	8	1	VUF	3	1973-74	2nd Nemrod	not noted	highest wt onl	
⊞	9	1	VUF	3	1973-74	1st Champion	not noted	highest wt onl	2
⊞	10	1	VUF	3	1973-74	2nd Champion	not noted	highest wt onl	
⊟	11	2	VUF	3	1979-80	1st US Divers	Steve Holt	highest wt onl	

	DVRTOT_ID	DIVER_ID	CLUB_ID	GRADE_COD	DVRTOT_TO	DVRTOT_PT	DVRTOT_TO	DVRTOT_PT	DVRTOT_TO	DVRTOT_CC	Add New Field
⊞	2114	154			3.96		6		610.0		
⊞	2115	140			2.66		4		410.0		
⊞	2116	169			2.10		3		310.0		
⊞	2117	181			1.94		2		220.0		
⊞	2118	214			1.44		2		210.0		
⊞	2119	200			1.56		2		210.0		
⊞	2120	233			1.48		2		210.0		
⊞	2121	166			1.18		2		200.0		
⊞	2122	177		77	0.74		1		100.0		
⊟	2123	215			0.66		1		100.0		

	FISH_ID	FISH_CAAB_OLD	FISH_CAAB_NEW	COMP_ID	FISH_WEIGH	FISH_LENGT	FISH_POINT	FISH_STATE	Add New Field
	25	37384003	37384003	11	660			3	
*									

	COMP_ID	COMP_ENV	COMP_CLUB-ORG	COMP_STATE	COMP_SEASON	COMP_EVENT	COMP_RECORDER	COMP_DAT/	COM
⊞	12	2	VUF	3	1979-80	2nd Hannan, 1st Anchor	Steve Holt	highest wt onl	2
⊞	13	2	VUF	3	1979-80	Central Region Championships,1st Heat, 2	Steve Holt	highest wt onl	

Record: 1 of 1 No Filter Search

Figure 6. Screen shot illustrating how individual data records are entered via a nested-table type of database structure. The record highlighted in orange shows fish captured (1 x 37384003 weighing 660g) by 'DIVER_ID' number 25 for 'COMP_ID' number 11. Data input extends to the right of the screen-grab shown and is accessed by a scroll-bar at the bottom of the screen, or by using the <Tab> key to move from one field to the next. This is a basic, first-generation data entry structure which will be enhanced for the user by a future front-end form input screen.

6.4.2 FUTURE DEVELOPMENT AND USING THE SPEARFISHING DATABASE

Further development of a basic front-end form solution is planned to be implemented before the completed database is delivered to Victoria and NSW bodies. For simplicity of user data entry, the design of this input form will replicate the layout of currently used club paperwork. The creation of these forms will permit data to be entered easily, consistently and can be further enhanced with input rules for error checking. Other enhancements may include the development of a limited set of standard reports or search queries accessible by form input to allow for user searching of the data. Clubs will be provided with both open and locked versions of the database. The open version will permit ongoing data entry, for both historic and current competitions, and the locked version will be read-only. Provision of a read only version will allow clubs to quote data (e.g. species and competition numbers and trends) from a database where all data have been entered by CSIRO staff, not by club members.

Once competition, diver, species and measurement data is collected, the next task is to address the question "what do we want to do with the data?". Of importance for clubs might be the need to easily produce a summary report after each competition, or extract all-time information on diver performance, or record-fish catches, and the like. Of importance for scientific analysis is the ability to easily compare collected data with published values. Accordingly, some refinement and massaging of the data usually needs to be undertaken to enable some comparison over different temporal or spatial scales.

At the owners' discretion, the Spearfish Database could become an important active repository of recreational spearfishing activity. With the inclusion of relevant environmental variables, such as sea surface temperature (SST) and sea surface colour (SSC, a measure of chlorophyll in surface waters), further reports could be produced that summarise the catch species and compare changes in response to these variables. Using the database to automatically run these calculations and allowing the user to choose the variables means these reports can be run and repeated very quickly. Output from these reports could also be exported to database formats such as Microsoft Office Excel to permit further data exploration or analysis.

This method of producing standardised reports using forms greatly simplifies comparisons between species and multiple variable options as the database runs the numerous base queries for the user.

6.4.3 DATA SECURITY

As presently designed, the Spearfishing Database will reside on the hard disk drive of a single host PC. As such it is vitally important that only the database manager has full unsecured access to the database to prevent accidental partial or full loss of data. It is equally important that regular backups of the database are made onto at least one alternate storage medium (e.g. a thumb drive or DVD data disk) and stored offsite in a secure, fire-proof location from the primary host pc.

6.5 Supplementary data

Data were compiled for the fifty most common species from each state, as represented in the catch data, to record their trophic level (largely from an unpublished CSIRO database), and to classify them as predominantly tropical or temperate. Demersal continental shelf provinces as defined by IMCRA (2006) were used. The coastal waters of central NSW lie within the Central Eastern Shelf Province, extending from just south of Coffs Harbour to Wollongong in the south, and consisting of a mixture of warm temperate and subtropical species. To the north lies the Central Eastern Shelf Transition Zone, extending to the southern Great Barrier Reef near Bundaberg, and centred around the NSW/Queensland border. The cooler Victorian waters are dominated by temperate species.

The fifty most common species from each state were classified as being predominantly tropical (range restricted largely to the north of the NSW border, or temperate (including warm temperate). A number of species classes could not be classified in his simplistic manner, either they were broad ranging across zones, or they represented a mix of species within a family or genus, resulting in a combined broad geographic range. Distribution maps and range extents were accessed from a range of sources, including FishMap (http://fish.ala.org.au/), the Catalog of Fishes (http://research.calacademy.org/ichthyology/catalog), FishBase (http://fishbase.org) and a number of publications. Data are presented with results in chapter seven.

6.6 Analysis of historic data

Data on fish records were available as (i) competition summaries, noting the total number and weight for each species captured in each competition, along with some measures of effort and (ii) for individual competitions, representing the size and frequency of fish, and the identification of the divers in the competition. Analyses presented here were based on the competition summaries.

Some analyses were completed for all data combined (NSW and Vic) and then refined for analysis at a state level. This state level analysis is appropriate in most cases due to geographic location of the competitions, varying temporal coverage, and as the relative abundance of the suite of species recorded in each state differs. All analyses were completed using Matlab and a range of visualizations produced.

The analyses were for the following broad categories:

1. Preliminary data exploration, including the spatial and temporal distribution of competitions for each state, the number of divers participating over time, geographic location of competitions over time, and the pattern of species numbers reported, was undertaken to understand potential biases in subsequent analyses.
2. Temporal trends in each species over time were considered using several metrics (Table 2). Abundance was represented by (i) frequency of occurrence of the species in each competition

which represents the most robust measure of occurrence in a site[1], (ii) the average catch per diver per competition (a measure of catch against diver effort), and (iii) the rank of each species over time. In this latter case, a species could be the most commonly reported species in 1998, 3rd most common in 1999 and so on. Thus, relative trends in species commonness could be assessed, on an annual or seasonal (summer Nov-Apr; winter May-Oct) timescale. In each case, linear trends over time were examined for significance and direction (increase or decrease). Finally (iv), size changes over time were explored using the mean size of fish for each competition, again with linear regression.

3. Patterns in community metrics, including (i) Tropicalisation Index (ii) mean trophic level of top ranking species, (iii) functional group changes over time and (iv) diet group changes over time. In this report we examine only the first two, tropicalisation and trophic level changes. To perform these analyses the top ranking species were coded according to biogeographic affinity (temperate or tropical) and trophic level (see section 6.5). The mean value by year was then plotted and tested with linear regression.

   Geographic subdivision was explored in several of the above categories (e.g. division of the NSW coastline into three zones) but differences between competition location and species resolution over time led to biases in patterns that are difficult to resolve. These may be explored in more detail using individual competition data in future analyses after the conclusion of this project.

[1] For analysis, changes in the catch (i.e. local availability) of individual species could be calculated using a number of metrics, including: (i) total weight or total number caught per competition, (ii) presence across all competitions over a time period (commonness), and (iii) catch relative to diver effort (a crude assessment of Catch Per Unit Effort, CPUE). We used the latter two methods, as the first is biased by a number of factors including diver numbers, skill and competition rules. The chosen methods will reveal changes in the frequency of a species' occurrence through time. Frequency of occurrence ('commonness') score measures a species occurrence in competitions irrespective of numbers caught, while the mean catch per diver per competition (Catch Per Diver, ACPD) provides a measure of relative abundance when averaged over a time period (i.e. calender year). Frequency of occurrence was assessed across all competitions within a year, and species ranked using the frequency score. A high species ranking reflects capture of at least one individual in most (sometimes all) competitions in that year, while a low ranking results when individuals of that species are caught in only a few competitions each year.

Table 2 . Abundance measures used to determine patterns in individual species over time for NSW and Vic spearfishing data

Abundance measure	What	Strength and weakness for the key question
Frequency of occurrence (annual measure)	Frequency of Occurrence (FoO) in competition for the year. For example, a species captured in 9 of 10 competitions in the year 1976 will have a FoO of 90%.	A robust measure of changes in relative abundance over time. Insensitive to changes in diver numbers or abundance Insensitive to the total number of fish captured in each competition.
Catch rate (competition or annual measure)	A measure of catch per unit effort, but related to the total number of each species Calculated as the number of individuals for the species captured per diver per competition – can also be then averaged for all competitions each year if needed.	Will be sensitive to the addition of "less skilled" divers as number of divers per competition increases. Standardises fish numbers caught with the level of effort in each competition.
Species rank (annual measure)	Rank of that species in frequency of occurrence per year	A robust measure of changes in relative abundance over time. Insensitive to the total number of fish captured in each competition. A relative measure, so may be insensitive to changes for particular species.
Size measure		
Mean size (competition or annual measure)	Total weight per competition divided by the total individuals of that species reported. Calculated for each competition – can also be then averaged for all competitions each year if needed.	Subject to some biases, including competition size limits and potentially high grading. As such it should represent the average "largest" fish captured by each diver in the competition.

7 Results/discussion

7.1 Engagement Process

During the earliest discussions the project team recognised this would be an ambitious undertaking and that the challenges were extensive, complicated and ongoing. Aside from the real and considerable risk that available data may not be sensitive or extensive enough to record species and community level change previously demonstrated (Last et al, 2010), there were considerable challenges relating to data access and use. With the lack of high quality historic data for Australian marine coastal marine biota predating the 1980s, these risks and challenges were considered worthwhile, and the project was initiated. We have described the engagement model developed for this project in the following sub-sections. A diagrammatic representation of why an engagement process might be considered is depicted in Figure 7. Following a choice to engage with stakeholders, investigators enter a second pathway, collaborating with stakeholders to build a collaborative project (Figure 8).

The biggest challenges faced by the project team and by spearfishers included an initial scepticism around the scientific interest in the data and lack of trust regarding outcomes. These concerns were broad-based, and included a lack of trust for various levels of government and management, and for an unbiased scientific process. These concerns stem from earlier attempts by spearfishers to work with scientists and management, here and overseas, and the feeling that previous engagement had at best been a waste of time, and at worst had been damaging to spearfishers. Many members were enthusiastic to see their data valued and utilised, but were also genuinely concerned it wouldn't be treated in a sensitive manner, or that it could be misused and results skewed to portray recreational fishing in a negative manner.

Developing and maintaining trust was therefore the largest and most enduring challenge the project faced.

7.1.1 ASPECTS OF THE ENGAGEMENT PROCESS

A primary aspect of this engagement model was the inclusion of long-standing members of the spearfishing community (DW & AS) in the project research team from the outset. Extensive planning and discussion was undertaken to assess the scope and likely success of such a project before any development or broader discussions were undertaken. This ensured the project was developed with consideration of the sensitivities involved, including previous engagement histories that were considered unsuccessful.

During early scoping activities to assess the availability of remaining data, researchers also investigated the willingness of the broader spearfishers community to work on such a project. These initial activates aimed to reduce the very real risk of initiating a project that was inherently impossible to undertake, as well as beginning the collaborative nature that was followed throughout the project.

Of similar importance, was the later inclusion of representatives from SFD and USFA (MK & AJ) as club liaisons. This aspect was vital, as bringing members of the representative bodies into the project team ensured full transparency through their contribution to analyses, interpretation and authorship. Liaisons were also the direct conduit for reporting back to club executive and members, which helped to develop a true partnership rather than a one-way consultation.

In recognition of the sensitivities surrounding competition data, investigators ensured this matter was recognised in the project application. A condition of undertaking the project was that clubs would retain ownership of all data (hard copy and digitised), and neither CSIRO nor the funding organisation would retain copies of club data after final data-handover. The importance of this aspect of the project was reflected in the inclusion of these points in the project contract.

Face to face meetings with club executive and members was also an essential element of engagement. These meetings were undertaken to introduce the project and to discuss data agreements, but importantly, were also opportunities to ask for diver feedback and suggestions regarding results and the project methods. By travelling to meet with members, we were also able to demonstrate our commitment to the project, and that we valued the experience and opinions of the members. There is no substitute for such meetings to build trust, but also to directly communicate our intent and recognition of spearfisher concerns, especially regarding previously failed engagement activities.

It was also important to communicate our recognition that knowledge of past spearfishing practices (e.g. changes to competitions and technology) was essential to being able to interpret the data. An understanding of the limitations also demonstrated our commitment to building and maintaining trust throughout the project, as interpretation of any results would be impossible without their knowledge. Once results were available we returned to clubs to report these results, to ask for assistance with interpretation, and to hear of potential sources of bias and error. A number of critical points, such as developing data-use agreements, could not have progressed without these face-to-face discussions.

A related and equally important activity was the use of surveys to directly record member experience with past engagement activities, experience of changes they had noted in their fishing experience, and to record concerns they may have about data sharing and data use. The survey was initially met with some concern and resistance from executive members in each state, largely reflecting the negative perceptions following previous engagement activities, and also out of concern to protect the privacy of members. Extensive interaction was undertaken to communicate the goal of the survey and to better explain the intent of certain questions. These interactions and the subsequent modification of some questions for the sake of clarity, improved the survey design, and resulted in both a highly satisfactory response rate and extensive experience being contributed by members (discussed below).

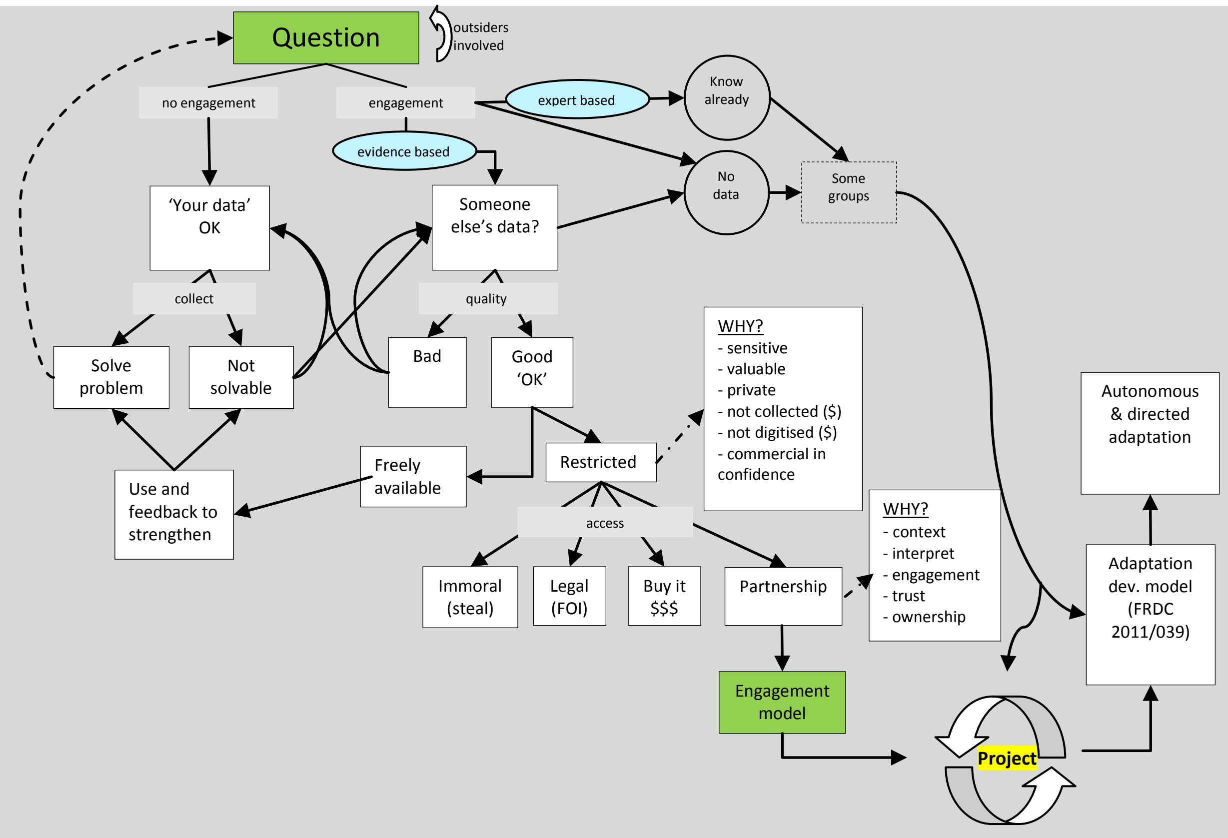


Figure 7. A process for engagement, phase 1: assessment of data sources and engagement options.

Engagement is continuing, and results will be directly disseminated to members through electronically correspondence, and by the research team directly reporting to key members. Popular articles and a media release will also be used to promote the success of the partnership, as well as the importance these data hold for informing our understanding of present day species occurrence and trends.

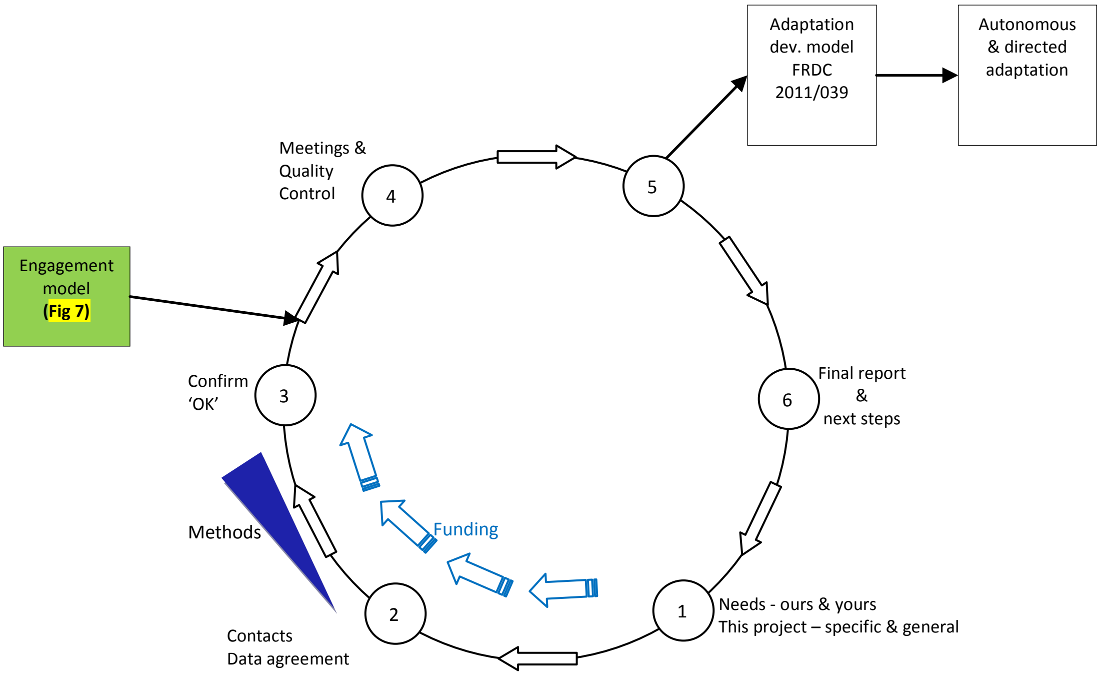


Figure 8. A process for engagement, phase 2: a simplified diagram of engagement activities as followed in this project. Step 1 represents the beginning of the engagement, prior to project funding being secured, but after a relationship is established. This could also follow completion of previous activities (Step 6).

7.1.2 CHALLENGES FOR ENGAGEMENT ACTIVITIES

A number of practical challenges were faced throughout the project, many of these were foreseen but were not able to be avoided. Estimating resources (time, travel, number of meetings) required for successful engagement is a considerable issue, and not one that can be negated. These activities were recognised as a critical aspect of the project, but despite all efforts the time required was still underestimated.

The project would have benefitted from additional time and resources available for further face-to-face meetings and more regular interactions with members, especially during the early phase while data agreements were being developed. The process for formalising agreements extended well beyond our maximum estimates, both in terms of time-delays and the investment required. Ensuring that particulars were dealt with in detail and that consideration was being given to the complexities, were essential to finalising data agreements. Despite the best efforts of all parties, negotiations extended to a point where project continuation and completion were jeopardised.

These delays almost wholly result from the extensive time required to build trust in the relationships we were developing. Developing the project with long-term and well known spearfishers in the research team, and later inclusion of club liaison members, accelerated this process, but considerable time and effort were still required.

Continuation of the relationship beyond project completion is also a challenge. The funding models for scientific projects create significant difficulties to maintaining trust for a long-term engagement plan. There is no way to remove this constraint, the project team have communicated our desire to develop additional projects that will benefit from the new relationship as well as the data, but we have also been at pains to manage expectations regarding the timing and mechanisms that may limit or delay these ongoing collaborative activities. Despite this, the data and the relationship offer considerable opportunity for ongoing development, both as an engagement activity, and to further interrogate the data.

7.1.3 BROADER APPLICATION

Many of the challenges encountered in this study are likely to be encountered when engaging other community groups. Similarly, the process and some of the key principles employed here with great success are broadly applicable and could be adapted to a wide range of engagement activities. Understanding the desire to engage, the advantages for each party as well as their concerns and any previous history are essential in early planning (Figure 7), which can lead to an engagement activity (Figure 8).

With researchers increasingly turning to non-traditional data sources, and the increase in citizen science activities being used to generate and vet data, proven engagement pathways are likely to become increasingly explored. An advantage of these activities is the potential to extend engagement beyond the core activity to broader engagement with management and the decision making process.

7.2 Social survey

7.2.1 DEMOGRAPHIC AND EXPERIENTIAL PROFILE OF RESPONDENTS

Survey respondents were predominantly male (98%), had a mean age of 36.9 years (NSW=37.9 years; VIC=32.3 years; p=0.04), and were educated at a tertiary (49%) or trade/technical (40%) level. Most respondents reported that spearfishing is their most important (83%) or second most important (9%) outdoor recreation activity. Respondents reported an average of 17.3 years of spearfishing experience, and participating in spearfishing an average of 39 days in the 12 months prior to the survey. On average, respondents had been a member of a spearfishing organization for 10.1 years (NSW=11.0; VIC=5.8; p=0.04).

7.2.2 ENGAGEMENT IN FISHERIES CONSULTATION

Spearfishers' responses to a series of statements about fisheries science and their engagement in fisheries management are presented in Table 3. Most respondents agreed that spearfishers and scientists (69%), and spearfishers and resource managers (59%) have common goals concerning the management and conservation of marine resources. However, most respondents disagreed that scientists (68%) and managers (79%) have a good understanding of spearfishers and spearfishing, and few (30%) reported having a good understanding of how scientific information is used in resource management. Likewise, few respondents reported having high levels of trust in resource managers to do what is best for the conservation of marine resources (13%) or to consider the concerns of spearfishers in decision-making (10%). Few respondents agreed that they are well informed about how their interests are considered in decision-making (22%), that they are adequately consulted about management decisions (6%), or that they receive fair treatment in the decision-making process (3%).

When asked about their level of engagement in fisheries consultation, 45% of respondents reported that they have attended a public meeting, 57% reported having made a submission to a government agency, and 30% reported having contacted their government representative about a fisheries related issue. Marine parks/fisheries closures were the issue most frequently cited as the reason for attending a public meeting (23% of respondents), making a submission to a government agency (32%), or contacting a government representative (13%). Other issues cited included grey nurse shark protection measures in NSW (public meeting = 6%; submission = 4%; contact government representative = 1.2%) and blue groper protection measures in Victoria (public meeting = 2%; submission = 6%; contact government representative = 1.2%).

Table 3. Survey respondents' level of agreement with statements about fisheries science and engagement in fisheries management

Statement	Level of Agreement (%)				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Spearfishers and scientists have many common goals concerning the management and conservation of marine resources.	4	8	19	42	27
Compared to other groups, spearfishers receive fair treatment in marine resource management decisions.	44	45	8	2	1
Spearfishers and resource managers have many common goals concerning the management and conservation of marine resources.	5	15	21	35	24
I trust resource managers to do what is best for conservation of marine resources.	28	35	24	11	2
I have a good understanding of how information collected by scientists is used in marine resource management.	5	25	34	25	11
Scientists have a good understanding of spearfishing and spearfishers.	21	47	19	12	1
Resource managers have a good understanding of spearfishing and spearfishers.	35	44	17	3	1
I trust resource managers to consider the concerns of spearfishers when making decisions about management of marine resources.	39	38	13	5	5
Spearfishers are well informed about how or interests are considered in decisions regarding management of marine resources.	18	42	18	18	4
Spearfishers are adequately consulted about marine resource management decisions.	29	49	16	4	2

7.2.3 BELIEFS ABOUT SHARING SPEARFISHING DATA WITH SCIENTISTS

Respondents were asked to rate their level of agreement with a series of statements aimed at understanding their beliefs about the value of spearfishing clubs' data and how that data should or should not be used (Table 4). Most respondents (94%) agreed that it is important to include information collected from resource users in marine resource decision-making, and most (83%) disagreed that spearfishers' data is not useful because it is not scientific. Most respondents agree that long-term data collected by spearfishers can help understand and describe changes that may be occurring in the marine environment (89%) and educate the general public about marine resource use, management, and conservation issues (89%). Likewise, most respondents believed that sharing spearfishing data with scientists will lead to a better relationship between spearfishers and scientists (81%) and a better relationship between spearfishers and resource managers (70%).

Fifty percent of the respondents agreed that they could trust scientists to honour agreements made with spearfishers about how spearfishers' data can be used; however, only 39% agreed that scientists can be trusted to consider the interests of spearfishers when using data shared by spearfishing clubs. Despite these low levels of trust, most respondents (79%) agreed that spearfishers' data should be shared with scientists if that data can benefit marine conservation. However, 72% also agreed that when spearfishers' data is shared with scientists, spearfishers must maintain control over how the data is used, and 42% agreed that spearfishers should only share data about spearfishing activity when they can be assured that the data will be used to benefit spearfishers. Likewise, 71% of spearfishers (NSW = 68%; VIC = 78%; $p = 0.03$) believed that when spearfishing data is shared with scientists there is a risk that those data could be used against them.

Table 4. Survey respondents' level agreement with statements about the value of spearfishing club data and how that data should or should not be used.

Statement	Level of Agreement (%)				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I trust scientists to consider the interests of spearfishers when using the data we share with them	9	15	37	24	15
It is important to include information collected from resources users (such as spearfishers) in marine resource management decisions	0	1	5	36	58
Data collected by spearfishers will not be very useful to scientists because it is not scientific	40	43	12	3	2
Sharing our data with scientists will help improve the engagement of spearfishers in decisions that affect us	2	3	19	52	24
If spearfishers have data that can be beneficial for marine conservation, we should share it freely with scientists	2	7	12	48	31
When spearfishers share data about our activities with scientists, there is a risk that our data will be used against us	3	8	18	43	28
Long-term data collected by spearfishers can help educate the general public about marine resource use, management, and conservation issues	1	1	9	43	46
Sharing our data with scientists will lead to a better relationship between spearfishers and scientists	1	2	16	43	38
Sharing our data with scientists will lead to a better relationship between spearfishers and marine resource managers	2	5	23	46	24
When spearfishers share our data about our activities with scientists, we must be sure that we maintain control over how that data is used	0	9	19	34	38
I trust scientists to honour agreements they make with us about how our spearfishing data can and cannot be used	7	14	29	29	21
Long-term data collected by spearfishers can help understand and describe changes that may be occurring in the ocean environment over time	2	1	8	46	43
Spearfishers should only share data that we collect about our activities when we are assured that our data will be used to benefit spearfishers	5	30	23	19	23

7.2.4 CLIMATE CHANGE BELIEFS

Survey respondents were asked a series of questions to understand their beliefs about climate change, their level of concern about climate change, and its potential impacts on fisheries resources. Most (74%) respondents indicated that they believe there have been substantial change to earth's climate over the past 25 years and that humans are partially (41%) or largely (33%) responsible for those changes (Table 5). Most respondents reported being moderately concerned about climate change in general (57%) and moderately (59%) or very (31%) concerned about the potential negative effects of climate change on the fisheries resources that they use (Figure 9). Most respondents also believed it to be moderately (41%) or very (47%) necessary to take steps to reduce greenhouse gas emissions that are thought to cause climate change (Figure 11).

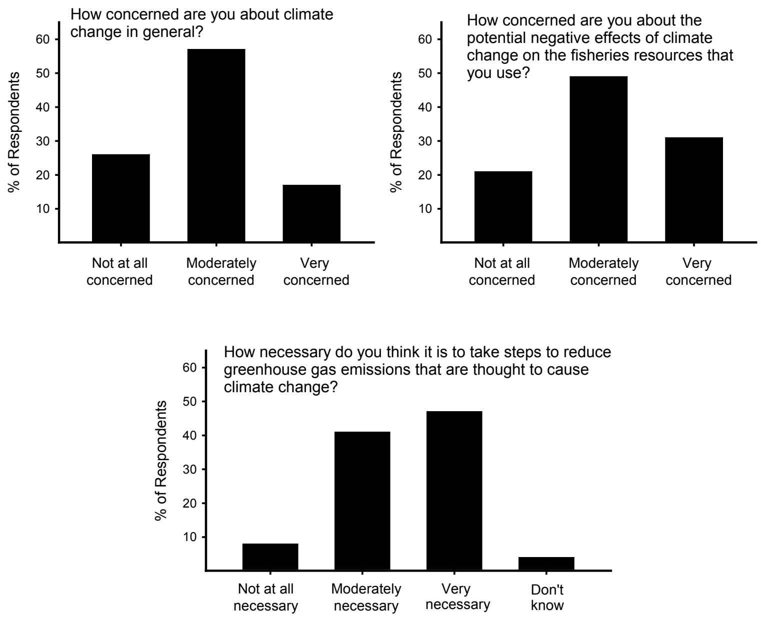
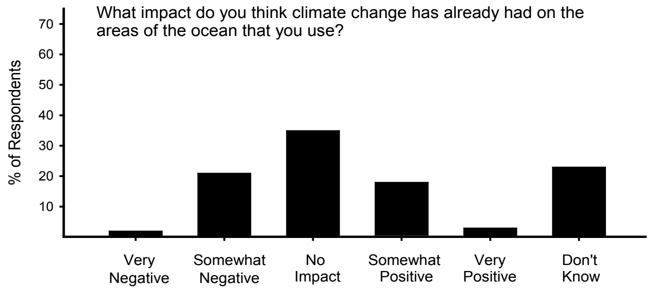


Figure 9. Respondents' level of concern about climate change and belief about necessity of taking action to reduce greenhouse emissions: (a) general concern; (b) concern about direct impacts; and (c) necessity for taking personal action to reduce climate change effects.

Respondents were evenly split between believing that climate change has already had a negative impact (23%) versus a positive effect (21%) on the areas of the ocean that they use (Figure 10). Most respondents (71%) believed that climate change will have no impact on the fisheries resources they use over the next 12 months. Respondents were evenly split between believing that climate change will have a negative impact (23%) versus a positive effect (20%) on fisheries resources over the next 5 years, whereas more respondents believe that climate change will have a negative impact (44%) versus a positive impact (19%) over the next 25 years.



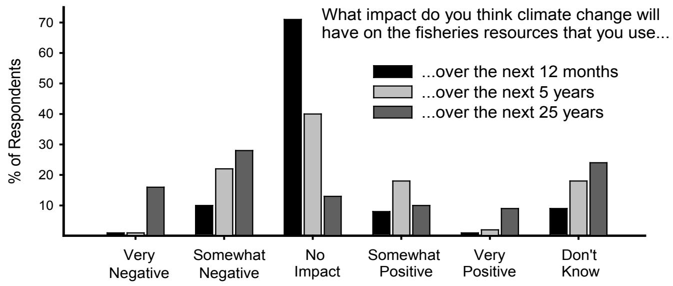


Figure 10. Respondents' beliefs about current and future impacts of climate change on the marine environment: (a) existing impacts on waters used by respondents; and (b) perceived future impact on resources respondents use.

Most respondents reported being moderately (52%) or very (21%) interested in being involved in developing local strategies to help reduce the negative impacts of climate change on the fisheries resources that they use (not at all interested = 27%). However, only 19% reported being aware of actions that they can take to reduce the impact of climate change on fisheries resources. When respondents were asked to describe the climate change actions they were aware of, the most commonly cited actions (cited by 13 respondent) were related to reducing individual carbon footprint (e.g., buy energy efficient appliances for the household, use 4 stroke motors, use energy efficient transportation, etc.). A small number (n=4) of respondents also mentioned reducing or minimizing fisheries harvest as a climate change reduction action.

Table 5. Distribution of respondents' selection of the statement that best summarizes their belief about climate change and humans' influence on it.

Climate change belief statement	% of Respondents
There have been substantial changes to the Earth's climate over the past 25 years, but humans are not responsible for those changes	4
There have been substantial changes to the Earth's climate over the past 25 years; humans are partially responsible for those changes, but some of the changes are also due to natural factors	41
There have been substantial changes to the Earth's climate over the past 25 years, and humans are largely responsible for those changes	33
I do not believe that there have been substantial changes to the earth's climate over the past 25 years	14
I have no opinion/do not know if there have been substantial changes to the Earth's climate over the past 25 years.	7

Table 6. Frequency of causes cited as reasons for negative and positive species changes observed by respondents to the survey

Cause	Species Response	NSW Count	VIC Count	Total Count
Environmental	Positive	7	2	9
	Negative	8	4	12
Human	Positive	27	4	31
	Negative	28	9	37
No cause cited	Positive	76	14	90
	Negative	72	19	91
Totals	**Positive**	**110**	**20**	**130**
	Negative	**108**	**32**	**140**
	Total	**218**	**52**	**270**

7.2.5 OBSERVATIONS OF ENVIRONMENTAL CHANGE

Responses to the open-ended question asking spearfishers to describe changes that they have observed in the marine environment are presented in Appendix J and Appendix K . Most respondents (68%) provided information on observed changes in the marine environment. In total, respondents provided 270 discrete observations of environmental change, which consisted of 130 observations of positive changes and 140 observations of negative changes (Table 6). Of the 270 observations of environmental changes provided, 21 (8%) were attributed to environmental causes, 68 (25%) were attributed to human causes, and no cause was attributed to the remaining 181 (67%) observations (Table 6).

A summary of the most commonly cited human and environmental causes of observed environmental changes is given in Table 7. Human causes for positive environmental changes generally involved improved/stricter fisheries management and/or reduction of commercial fishing pressure, whereas environmental causes for positive changes related to natural cycles and changes in prey availability. Likewise human causes for negative environmental changes generally related to overfishing by commercial and/or recreational fishers whereas environmental causes of negative changes related to declining environmental quality or disease. It should be noted that many of the environmental causes of observed changes (e.g., declining water quality, erosion) cited by respondents could have underlying human causes; however, these causes were considered to be environmental unless human activity was specifically mentioned by the respondent.

Aquatic species/species groups most frequently mentioned by respondents in their observations of marine environmental change are presented in Table 8. The most commonly mentioned species were kingfish (mentioned by 37 respondents), mulloway/jewfish (14 respondents), salmon (13 respondents), groper/blue groper (13 respondents), and grey nurse shark (12 respondents). With the exception of mulloway/jewfish, observations of these species by spearfishers indicated increasing numbers and/or sizes of these species over time, largely attributed to decreasing commercial fishing pressure (e.g., trap ban for kingfish) or increased species protection (e.g., grey nurse shark protection measures, no-take provision for blue groper). Few respondents provided explanations for changes in salmon and mulloway/jewfish numbers; however, five respondents who observed declines in mulloway/jewfish suggested that the decline was due to too much fishing pressure.

Table 7. Frequency of specific environmental and human drivers cited as reasons for negative and positive species responses observed by respondents to the survey.

	NSW Count	VIC Count	Total Count
Positive Response			
Human Driver			
Reduced commercial fishing pressure	18	3	21
Protected species status	4	0	4
Stricter size limits	2	0	2
Protected areas	0	1	1
Reduced recreational fishing pressure	1	0	1
Reduced pollution/environmental degradation	2	0	2
Environmental Driver			
Increased prey species	3	0	3
Natural cycles	2	1	3
Warming water	1	1	2
Floods	1	0	1
Negative Response			
Human Driver			
Commercial fishing	15	3	18
Recreational fishing (incl. spearfishing)	6	2	8
Overfishing (non-specific)	5	2	7
Dredging	1	2	3
Urban run off	1	0	1
Environmental Driver			
Erosion	2	0	2
Water quality decline	1	1	2
Sea urchin/seastar /Caulerpa overpopulation	2	1	3
Disease	2	0	1
Natural cycles	1	1	2
Warmer water	0	1	1

Table 8. Species or species groups most frequently mentioned by survey respondents when asked to describe changes that they have noticed in the marine environment. Positive species responses refer to observations of increased size, abundance, or catchability. Negative species responses refer to observations of decreased size, abundance, or catchability. Species or species groups cited fewer than three times are not included in the table.

Species [1]	Species Response	NSW Count	VIC Count	Total Count
Kingfish	Positive	26	6	32
	Negative	4	1	5
Grey nurse shark	Positive	12	0	12
	Negative	0	0	0
Salmon	Positive	11	0	11
	Negative	0	2	2
Mulloway/Jewfish	Positive	3	0	3
	Negative	11	0	11
Groper/Blue Groper	Positive	12	1	13
	Negative	0	0	0
Sharks	Positive	8	0	8
	Negative	0	0	0
Flathead	Positive	1	0	1
	Negative	3	3	6
Crayfish	Positive	3	0	3
	Negative	0	2	2
Lobster	Positive	2	0	2
	Negative	3	0	3
Black cod	Positive	4	0	4
	Negative	2	0	2
Bream	Positive	1	0	1
	Negative	3	1	4
Sea grass	Positive	1	1	2
	Negative	1	1	2
Abalone	Positive	2	1	3
	Negative	3	0	3
Wobbegong	Positive	3	0	3
	Negative	0	0	0
Snapper	Positive	0	2	2
	Negative	2	1	3
Banded morwong	Positive	0	0	0
	Negative	3	0	3

[1] Species groups were defined based on words used in the open-ended responses to the survey and therefore may not be mutually exclusive.

7.2.6 SYNTHESIS

Engagement

Engaging recreational fishers in fisheries management and conservation can, among other things, help foster stewardship of resources, increase trust in the management process, provide valuable information about resources and resource use and generally lead to increased management success (Lundquist and Granek 2005; Granek et al. 2008; Sullivan 2003; Arlinghaus 2006; Grey 2012). Spearfishing club members from New South Wales and Victoria report investing significant effort in engaging in fisheries-related decision-making through public meetings, formal submissions programs, and direct contacts with government representatives. However, despite this significant level of engagement, club members have low levels of trust in decision making and generally feel that spearfishers are not well consulted about decisions and do not receive fair treatment in the decision-making process. These results suggest that there is scope to improve the engagement of spearfishers and spearfishing clubs in fisheries decision-making.

This project represents a novel and potentially more meaningful method of engaging recreational fishing clubs in management and conservation that could provide valuable information in support of decision-making. The success of such arrangements will depend on spearfishing clubs' willingness to share data and maintain on-going participation in data analysis and interpretation, which in turn will likely depend on spearfishers realizing positive outcomes from their participation. Results of the survey indicate that spearfishers perceive a range of positive outcomes from sharing their data with scientists (e.g., improved relationships with scientists and managers, improved engagement in decision making, public education, etc.) and believe that their data is useful and should be shared. However, results also indicate that spearfishers recognize the potential for their data to be used in ways that may not benefit spearfishers, and they have not yet developed high levels of trust in scientists to use spearfishing data in appropriate ways. We suggest that future collaborative efforts such as this one need to pay particular attention to building and maintaining trust between resource users and scientists, and ensuring that the outcomes expected by those sharing their data are met. We hope that the engagement model and formal data sharing agreements developed here will provide useful guidance for future efforts in this area.

Climate change

Spearfishers were able to provide detailed information about changes that they've observed in the marine environment. Although respondents attributed human causes to many of these observed changes, few respondents attributed these changes directly to climate change, despite strong recognition that climate change has occurred and the belief by almost half of respondents (44%) that climate change has already affected (positively or negatively) the fisheries resources that they use. These results suggest that spearfishers are either not making a clear link between observed environmental changes and their beliefs about climate change, or that they are more likely to notice and report changes caused by other factors. In designing the survey, we chose to ask spearfishers to report any environmental changes that they've noticed (not just those related to climate change), because we were interested in exploring the extent to which fishers can provide information about environmental change in general. Further exploration of spearfishers' ability to document and report climate related environmental changes will likely require direct questioning of spearfishers about observed environmental changes they believe to be related to climate change.

Survey respondents were generally knowledgeable about the human cause of climate change, significantly concerned about climate change and its potential negative impacts on fisheries resources, and expected significant climate induced environmental change in the future. These results are generally consistent with the results of other studies showing high levels of climate change awareness and concern in Australia and elsewhere (van Riper et al., 2013; Lorenzoni and Pidgeon, 2006). However, it should be noted that a substantial proportion (~20%) of respondents believe that climate change is having (and will continue to have) a positive impact on the fisheries resources that they use. Indeed, from a spearfishing perspective, an increase in the size, abundance, or catchability of valued species would likely have a positive impact on the benefits that spearfishers derive from the activity. Clearly, we should not expect all individuals to view climate change in a negative light, or be responsive to messages aimed at engaging them in climate change reduction or mitigation actions.

7.3 Competition-data and single species trends

Data were digitised from a total of 607 historic spearfishing competitions, 267 of these competitions were held in Victoria and 335 in NSW. Results from two additional competitions with geographic location only coarsely known and three national events held in Tasmania were eliminated from subsequent analyses. The earliest competition dates were from 1961 in NSW, with consistent data collection from late 1960s until 2011 (Figure 11a). Competitions were held at 43 sites in Victoria and 50 in NSW, and ranged from Coffs Harbour in NSW to near Portland in western Victoria, representing >19,000 'diver days', nearly 130,000 individual fish and >150 species.

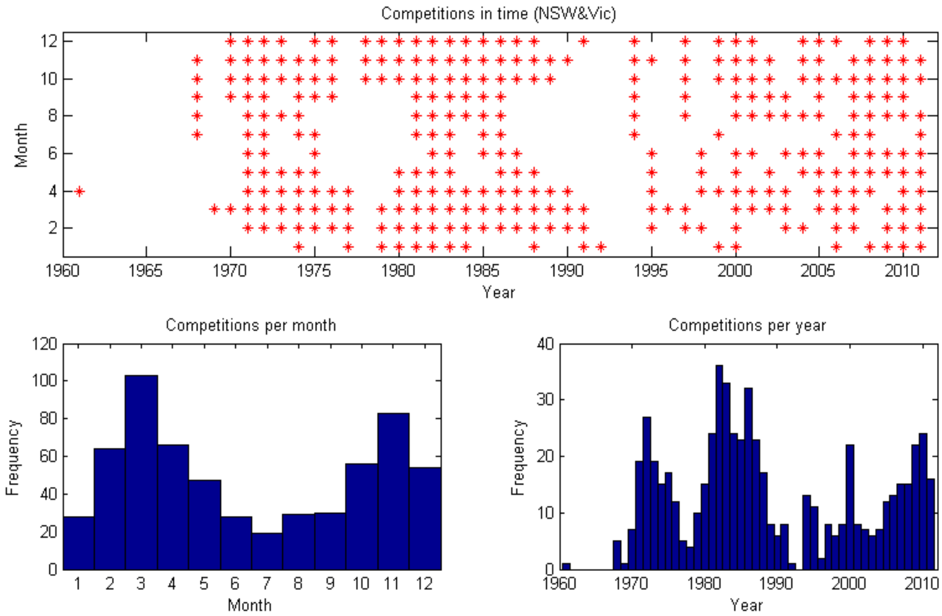


Figure 11. Temporal extent of digitised competition data from Victoria and New South Wales: (a) temporal distribution of data; (b) frequency of competitions by month; and (c) frequency of competitions per year. Note these represent data that were digitised, not all data sourced could be digitised, and large amounts of data have been lost or destroyed.

Combined data summarising results from both states are depicted in Figure 11 & Figure 12. Gaps in sampling represent both missing competition data, and our inability to digitise all available data (see Methods). The number of competitions peak in March (Figure 11b), with a reduction during winter associated with cooler waters and weather conditions that are poorer for diving. Competitions increase again in November with increased competition activity over the summer/autumn months. A dip in January may be due to a lack of competitions coinciding with the xmas holiday season.

Species frequency across all competitions (Figure 12a) shows the most common species (e.g. top 10) were captured in more than half the competitions. Some 130 species are uncommon in the dataset, being captured in less than 20% of competitions. This is also reflected in the species accumulation curve (Figure 12b), with some 25 competitions required per year to sample around 80% of species across both states.

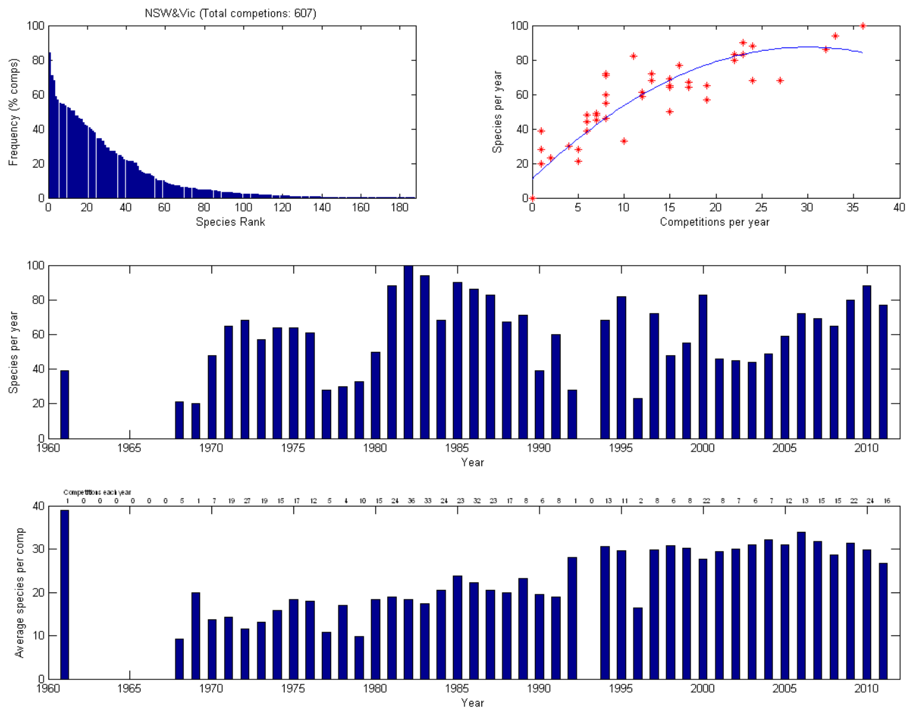


Figure 12. Summaries of digitised data combined for Victoria and New South Wales: (a) species rank as a percentage of occurrence across all competitions; (b) species accumulation curve; (c) number of species caught per year; and (d) the average number of species represented in each competition for each year.

The number of species caught per year and the average number caught per competition (Figure 12c & d) will be affected by competition and competitor numbers (sampling effort) for any particular year. In Figure 12c, troughs in the numbers of species captured per year in the late 1970s and again from around 1992 onwards correlate with reduced numbers of competitions digitised from those periods (Figure 11).

Reported changes to the scoring system in Victoria during the 1970s (and some NSW clubs) may also affect these results. Divers report the earlier scoring system strongly rewarded capture of large specimens, whereas the present system strongly rewards the capture of a broader range of species, with bonus points for weight. This reportedly changed diver strategy, from trying to get the biggest fish from a small number of species, to attempting to capture a larger variety of species. For example during historical competitions, a large Zebrafish might have attracted double the points of an average sized specimen, while with today's scoring system the bonus weighting for size is greatly reduced.

These changes may also have reduced the practice of 'high-grading', where a specimen caught early in a competition may later be substituted by a larger one of the same species. As divers may only weigh in a single specimen per species, there is a theoretical advantage in seeking the largest representative of each species. However, competitive fishers report that targeting an additional species is a better and more common strategy than chasing increasingly larger 'additional' specimens. The practice of high-grading may therefore be more opportunistic, rather than a common or chosen strategy.

It should also be noted that a number of species have been removed from competition eligibility, restricted for capture only by beginners, or the minimum size increased to a point where capture is uncommon. These changes will also affect results. Examples of such species can be seen in a number of summary figures (Appendix L & Appendix M), and include Black Cod and Eastern Blue Groper in NSW, and Old wife, Herring Cale and Toothbrush Leatherjacket in Victoria.

7.3.1 VICTORIAN DATA

Competition datasets from Victoria were digitised for years ranging from 1970 – 2011 (Figure 13). Data from 290 competitions were located, of which 267 (>90%) were digitised for analyses. Victorian data that were not digitised were largely those not suitable for entry due to lacking site or data details. These numbers also include additional data for a few recent competitions that were not located in time for inclusion in the analyses. Digitised data from 43 Victorian sites represent nearly 6,000 'diver days', and recorded 30,000 individual fish, ~100 species, and weigh over 26,000 kg.

Large gaps exist in data located for the period since the 1990s. Effort to fill this gap resulted in the location and digitisation of additional competitions, but gaps remain and are apparent in Figure 13a, & c. The seasonal reduction in competitions during cooler months is evident in Figure 13a & b, resulting from both reduced water temperatures, inclement weather and reduced availability of target species. Reduction in competitions during the colder months is of interest, as the continuation of warming coastal waters is expected to raise minimum winter sea-surface temperatures (Hobday and Lough 2011), potentially extending the spearfishing competition season into the winter months, more similar to the NSW competition season (below).

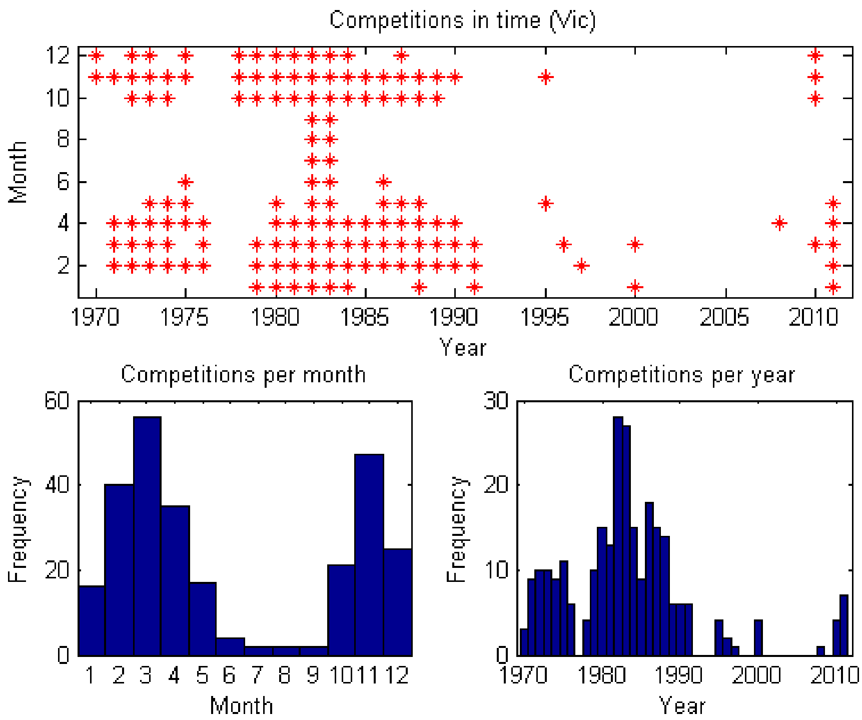


Figure 13. Temporal extent of digitised competition data for Victoria: (a) temporal distribution; (b) frequency of competitions by month; and (c) frequency of competitions per year.

Digitised Victorian data extends geographically from near Portland in western Victoria to Wilsons Promontory in the east, with data concentrated around the outer reaches of Port Phillip Bay between 144 and 146 degrees of longitude (Figure 14). Data gaps are depicted here for eastern Victoria, extending from east of Wilsons Promontory to the NSW border, representing the lack of suitable spearfishing locations, limited access, and increased distance from major population centres. The coastline for much of the area consists of sandy beaches, with a lack of rocky headlands, rocky shoreline or near shore, shallow reefs. Further, long stretches of the coastline have no boat access. Closer to the NSW border (East of Marlo), rocky coast and near shore reefs increase in occurrence, however much of that coastline has limited vehicular access, limited services, and is a long way from Melbourne. Temporal gaps discussed earlier are also evident, these reflect inability to locate additional data during the project. Further data are in existence, but were not physically obtainable or assessable from the respective data holders within the project period.

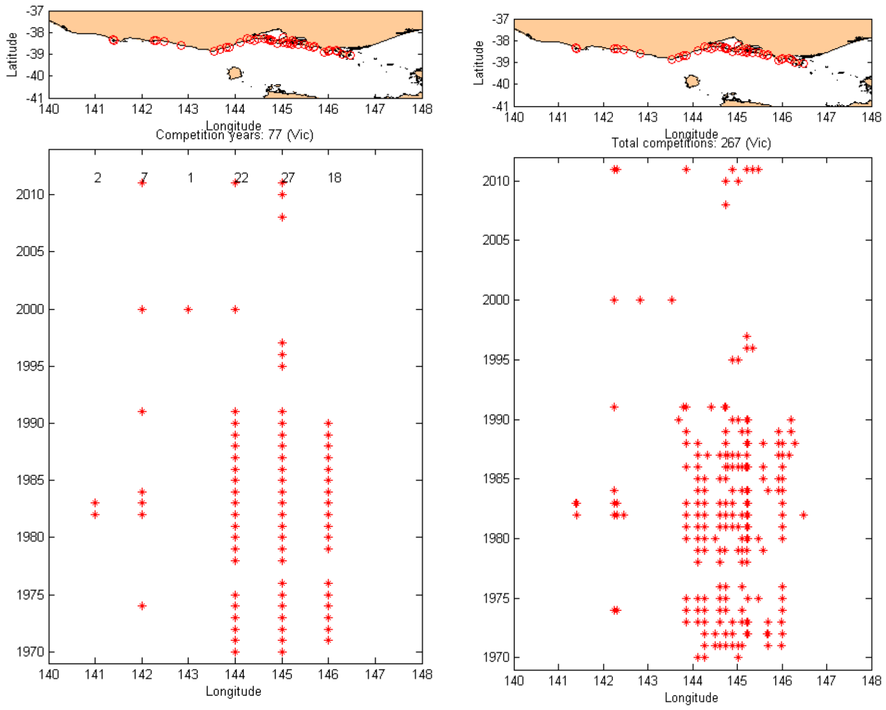


Figure 14. Geographic and temporal distribution of digitised Victorian competition data: (a) years represented within the dataset in longitudinal bins of 1 degree; and (b) total number of competitions by longitude.

The most commonly represented species in Victorian data appeared in almost 100% of digitised competitions, with some 10 species appearing in over 80% of competitions (Figure 15a), and >75% of species occurring in fewer than 30 competitions. This is also depicted in the species accumulation curve (Figure 15b), with a maximum number of species being represented from ca. 10–15 competitions per year.

Data gaps for Victoria are likely responsible for apparent drops in number of species caught per year from 1990 onwards (Figure 15c), from Figure 13c, we can see that digitised competition data has remained below 10 competitions per year since the late 1980s, below the number required to sample a majority of species. Our data display a drop in participation in Victorian competitions, variation in diver participation (Figure 16 & Figure 17a) may reflect the variety of competitions held (local club events, regional championships and national competitions), or the limited selection of competitions from recent decades that we were able to access and digitise.

Despite an apparent decrease in the number of divers, the number of species sampled per competition has been relatively stable, throughout the period (Figure 15d & Figure 17b–d). From the 267 competitions examined, in excess of 50 fish were commonly weighed in per competition, and competitions commonly returned over 75 kilograms of fish (Figure 17b & c) representing 15–25 species.

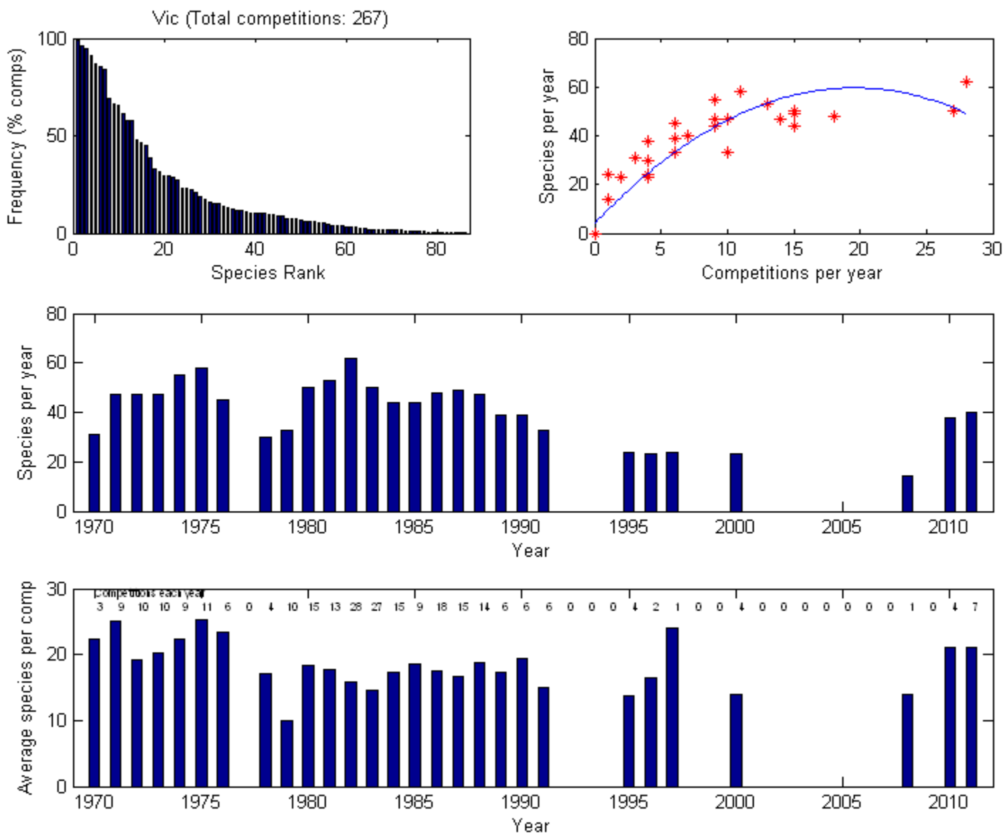


Figure 15. Summaries of digitised data for Victoria: (a) rank of the most common species (as a percentage occurrence across all competitions); (b) species accumulation curve; (c) number of species caught per year, depicted as a percentage of maximum catch (1982); and (d) the average number of species represented in each competition for each year.

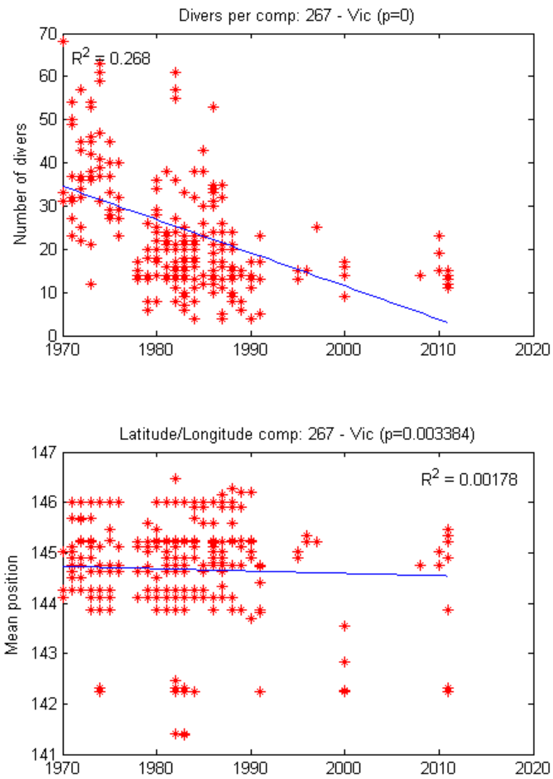


Figure 16. Temporal patterns in competitions: (a) number of divers participating in each competition; and (b) and longitudinal range of competition locality through time.

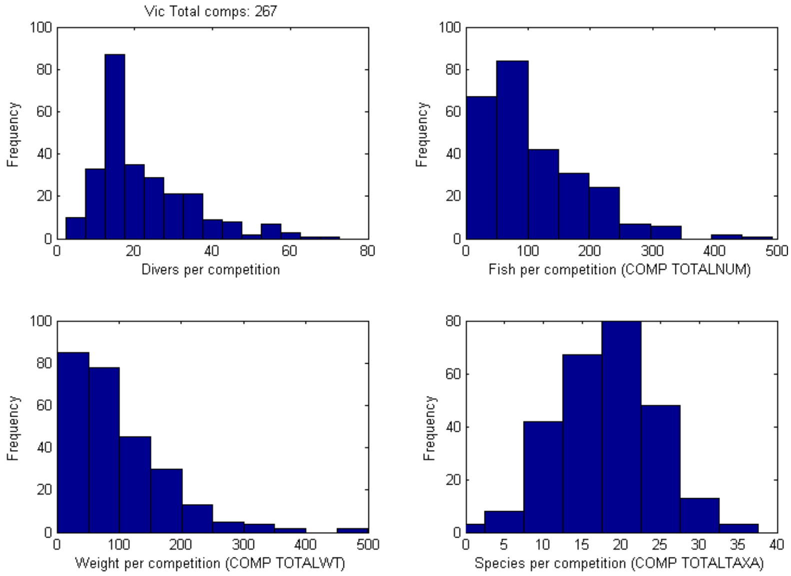


Figure 17. Frequency measures of catch components from 267 digitised Victorian competitions: (a) divers participating per competition; (b) number of fish caught; (c) weight of fish caught (kg); and (d) number of species caught in each competition.

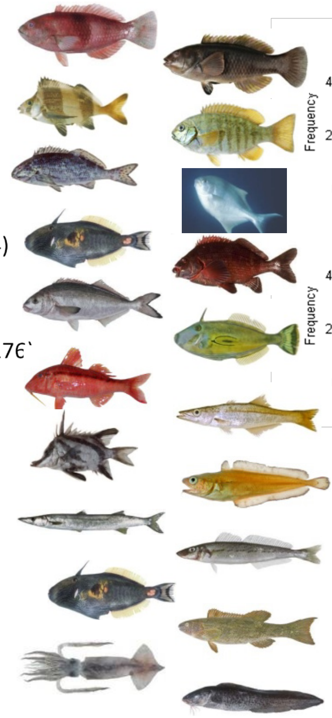
The 20 most commonly represented species across all Victorian competitions are depicted in Figure 18. The most commonly represented species from Victoria is the Bluethroat Wrasse (*Notolabrus tetricus*), which was recorded at least once in close to 100% of competitions digitised (Figure 15a & Figure 18a).

Changes in occurrence data for the top 50 Victorian species are also presented (Figure 18b). Of these, 25 species decreased in occurrence (10 significantly) and 25 increased in occurrence over the period (3 significantly) ($P<0.05$). Mean size (weight) decreased significantly for 7 species while none increased significantly in size. The average count of individual species per competition decreased for more species than increased, although this measure is biased by the number of divers in a competition, and is not used further in this report.

These measures all represent change relative to the sample population, and will be influenced by changes to other elements of the catch, numbers of species available to catch, and the number of divers participating in each competition. To avoid some of these biases, we also examined the catchability of each species, Annual Catch Per Diver (ACPD), and found some 3 species were significantly decreasing in catchability, or becoming harder to catch, while about 8 were significantly increasing in catchability over the period (Figure 18b).

Examining seasonal trends in Victorian data by comparing the top twenty most common species caught in Summer and Winter months (for simplicity, “Summer” months ranged Nov–Apr and “Winter” months ranged May–Oct) shows little seasonal pattern for these species (Figure 19). The seven most common species are shared across both Summer and Winter competitions, with a total of only six novel species out of a possible 40 from the list.

1 37384003: Bluethroat Wrasse (n=264)
2 37384021: Purple Wrasse (n=256)
3 37377001: Magpie Perch (n=252)
4 37361008: Zebrafish (n=244)
5 37377005: Dusky Morwong (n=232)
6 37361004: Sea Sweep (n=228)
7 37465036: Sixspine Leatherjacket (n=224)
8 37377006: Banded Morwong (n=184)
9 37378002: Bastard Trumpeter (n=178)
10 37465004: Horseshoe Leatherjacket (n=176`
11 37355000: Mullet (goatfish) (n=163)
12 37327002: Longfin Pike (n=155)
13 37367003: Longsnout Boarfish (n=155)
14 37224003: Bearded Rock Cod (n=127)
15 37382002: Snook (n=124)
16 37330001: King George Whiting (n=121)
17 37465903: Leatherjacket spp (n=104)
18 37385001: Herring Cale (n=89)
19 23615000: squid (n=84)
20 37228008: Rock Ling (n=79)



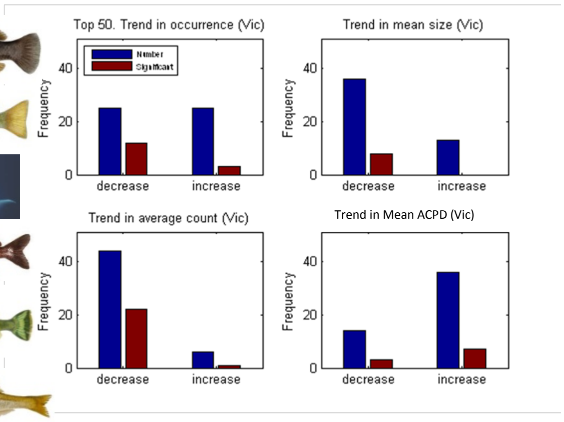


Figure 18. (a) Twenty most commonly caught species as represented in digitis ed Victorian data, measured as occurrence across all competitions, and (b) changes in basic biological and fishery data for the 50 most common species over the period. Numbers are presented in Blue, significant results in red.

Top 20 species: Summer
1. 37384003: Bluethroat Wrasse (n=217)
2. 37377001: Magpie Perch (n=210)
3. 37384021: Purple Wrasse (n=208)
4. 37361008: Zebrafish (n=203)
5. 37377005: Dusky Morwong (n=197)
6. 37361004: Sea Sweep (n=190)
7. 37465036: Sixspine Leatherjacket (n=189)
8. 37377006: Banded Morwong (n=156)
9. 37378002: Bastard Trumpeter (n=153)
10. 37465004: Horseshoe Leatherjacket (n=152)
11. 37327002: Longfin Pike (n=139)
12. 37367003: Longsnout Boarfish (n=136)
13. 37355000: Mullet (goatfish) (n=135)
14. 37382002: Snook (n=114)
15. 37330001: King George Whiting (n=105)
16. 37224003: Bearded Rock Cod (n=103)
17. 37465903: Leatherjacket spp (n=89)
18. 37385001: Herring Cale (n=76)
19. 37465035: Yellowstriped Leatherjacket (n=70)
20. 23615000: squid (n=69)

Top 20 species: Winter
1. 37384021: Purple Wrasse (n=48)
2. 37384003: Bluethroat Wrasse (n=47)
3. 37377001: Magpie Perch (n=42)
4. 37361008: Zebrafish (n=41)
5. 37361004: Sea Sweep (n=38)
6. 37377005: Dusky Morwong (n=35)
7. 37465036: Sixspine Leatherjacket (n=35)
8. 37355000: Mullet (goatfish) (n=28)
9. 37377006: Banded Morwong (n=28)
10. 37378002: Bastard Trumpeter (n=25)
11. 37224003: Bearded Rock Cod (n=24)
12. 37465004: Horseshoe Leatherjacket (n=24)
13. 37367003: Longsnout Boarfish (n=19)
14. 37067007: Southern Conger (n=17)
15. 37327002: Longfin Pike (n=16)
16. 37330001: King George Whiting (n=16)
17. 37465034: Gunn's Leatherjacket (n=16)
18. 23615000: squid (n=15)
19. 37465903: Leatherjacket spp (n=15)
20. 37228008: Rock Ling (n=13)

Figure 19. The twenty most common species for digitised Victorian competitions from summer and winter months.

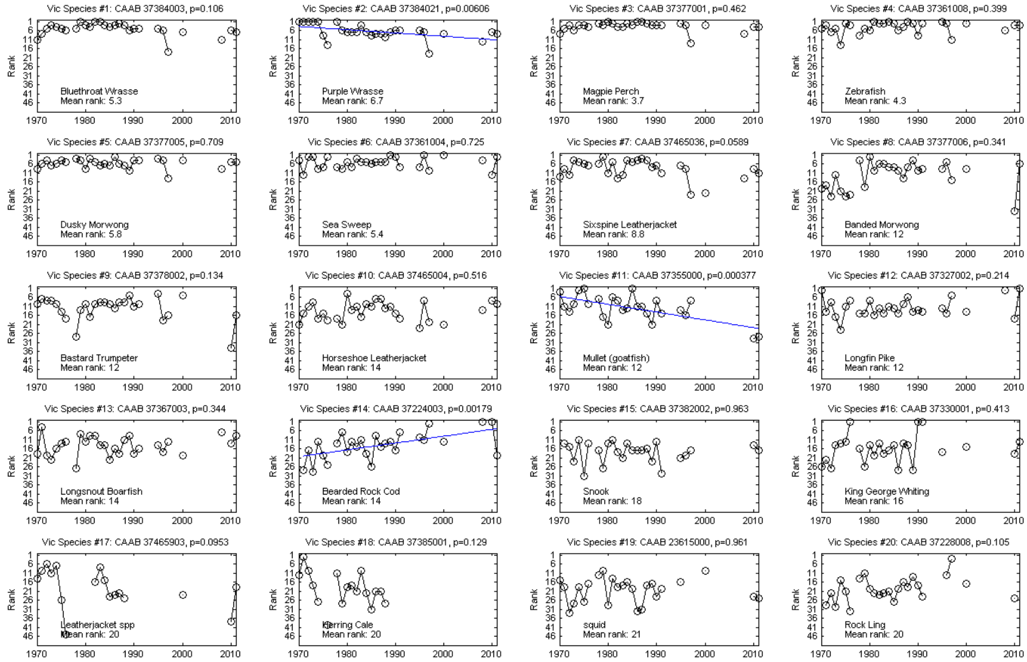


Figure 20. Rank through time for twenty most common Victorian species. Significant trends indicated by regression line on plot.

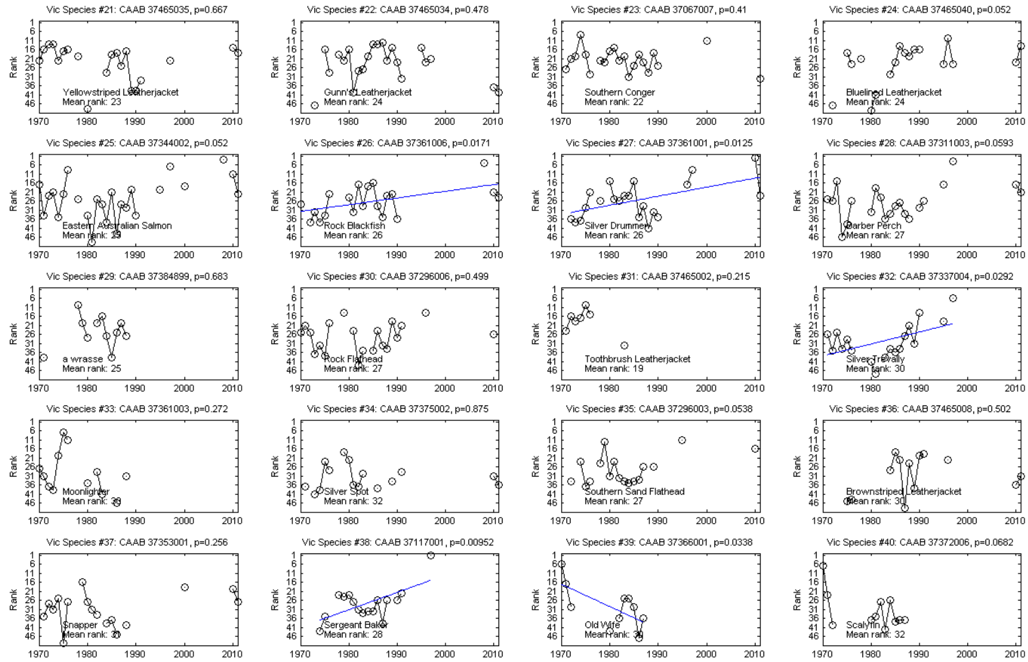


Figure 21. Rank through time for 21st to 40th most common Victorian species.

The ranking (measure of commonness) of most Victorian species has fluctuated over time (Figure 20 & Figure 21). Despite this variability, the top 10 species each remain relatively stable (mean rank) for the period examined, suggesting these common species are relatively consistent within the catch.

For each species ranked in the top 50, we examined four measures of species-level change within the period. These were frequency (from which commonness 'rank' was derived), mean size (weight in grams), average number caught per competition each year, and a measure of catch-rate ACPR (Average Catch Per Diver, per competition, per year). Results for each of the fifty most common species are presented in Appendix I & Appendix L .

For the most common species in Victorian competitions, Bluethroat Wrasse (*Notolabrus tetricus*), the frequency of occurrence was close to 100% (at least one specimen caught in almost every competition) for each year, and there was no change in mean size, with fish averaging around 1 kg (Figure 22). There is a significant drop in mean number caught per competition each year, but as discussed above, this measure will be heavily influenced by changes in the average number of competitors in each competition, which we have seen decrease for digitised Victorian competitions (Figure 16a). The catch rate per diver is seen to be stable across the time period examined, which is not surprising given how common this species has remained. This species has been fished commercially in Victoria since the 1990s (Smith et al, 2003), but these data tell little of the impact of the fishery given the gaps in data since the 1990s.

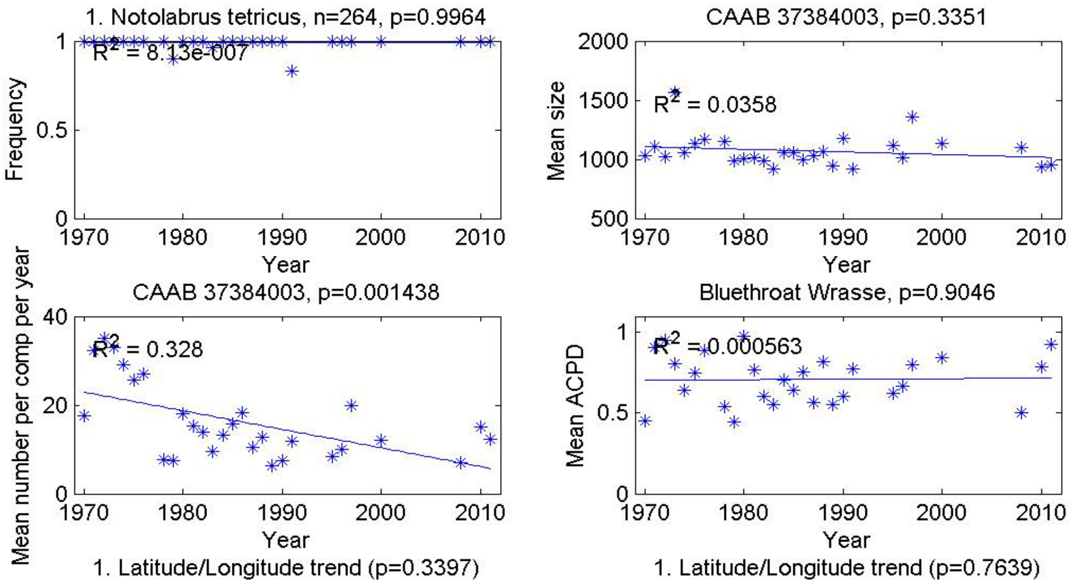


Figure 22. The most commonly caught species in Victorian competitions, measured by likelihood of occurring at least once per competition, is the Bluethroat Wrasse (*Notolabrus tetricus*). Data are presented for: (a) frequency (measured by 'commonness' across competitions); (b) mean size; (c) mean number caught in each competition per year; and (d) Annualised Catch Per Diver, (ACPD).

Examination of biological and catch data for the 50 most commonly caught species (Appendix L) shows a number of common patterns. Zebrafish (*Girella zebra*), the fourth most common species, displayed a stable frequency, increasing catchability, but decreasing mean size (Figure 23). This pattern could reflect decreasing numbers of large fish, accompanied by an increase in the number of smaller fish in coastal habitats, however this pattern could also have been influenced by the change in focus of competitions from targeting large fish to targeting more species. Anecdotal reports from fishers support the predominance of smaller fish, with fewer large specimens sighted.

The eleventh ranked species, a grouping of goatfishes (Mullidae, predominantly Bluespotted Goatfish, *Upeneichthys vlamingii*), displays a significant decrease both in frequency and mean size, yet maintains a relatively stable catchability (Figure 24). This shows that the species was less frequently encountered in competitions (frequency of occurrence declines) but when it was encountered, fishers captured similar numbers (around one fish every five fishers). Goatfishes are predominantly caught in bays, rather than on exposed coasts, and these results may reflect the lack of competitions held in bays in recent years.

A number of species were removed from scoresheets, these include Herring Cale (rank 18), Toothbrush Leatherjacket (rank 31), and Scalyfin (rank 40).

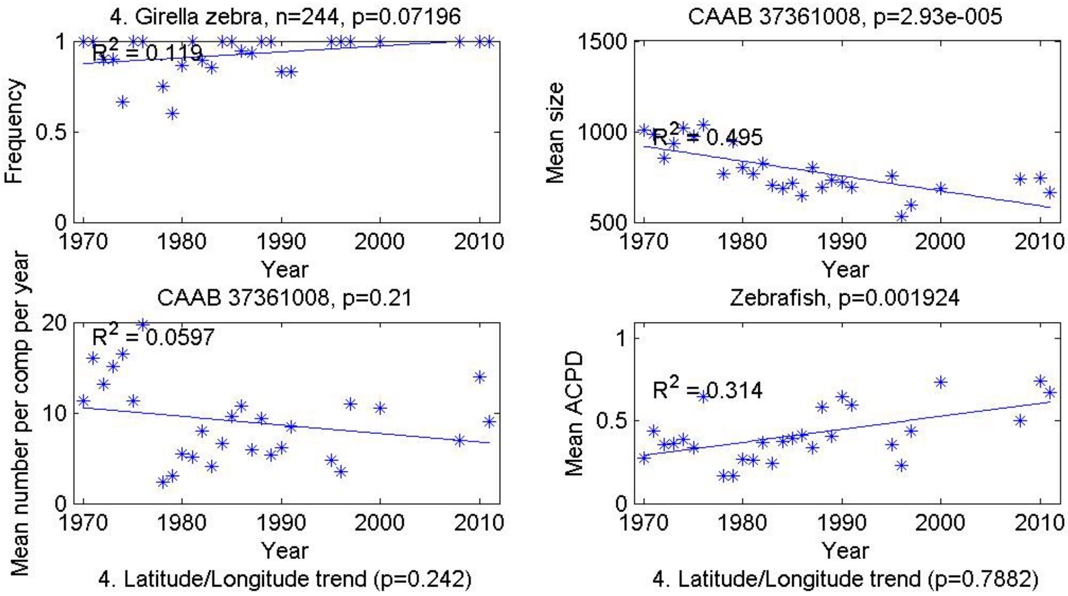


Figure 23. Catch data for fourth most common species, Zebrafish (*Girella zebra*). Data are presented for: (a) frequency (measured by 'commonness' across competitions); (b) mean size; (c) mean number caught in each competition per year; and (d) Annualised Catch Per Diver, (ACPD).

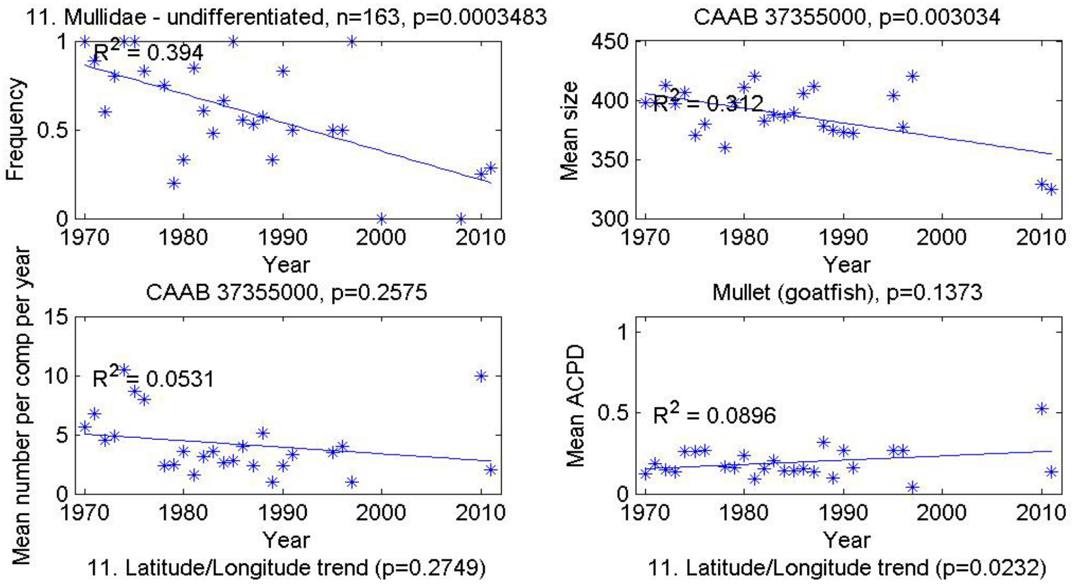


Figure 24. Catch data for eleventh most common species, Goatfishes (predominantly Bluespotted Goatfish, *Upeneichthys vlamingii*). Data are presented for: (a) frequency (measured by 'commonness' across competitions); (b) mean size; (c) mean number caught in each competition per year; and (d) Annualised Catch Per Diver, (ACPD).

7.3.2 NEW SOUTH WALES DATA

Located competition datasets from NSW dated from 1961 to 2011. Data from 440 competitions were made available, of which 335 (>75%) were included in analyses. Digitised data from 50 NSW sites represent over 13,000 'diver days' and recorded 98,000 individual fish representing ~150 species, and weighing around 108,000 kg.

Gaps exist in data digitised from the 1990s (Figure 25a) and for the southern coastline prior to 1980 (Figure 26). These gaps represent missing data, some of which have since been located by clubs. Comparing these Figures with Victorian data (Figure 13 & Figure 14), there is less of a seasonal effect in NSW, with winter competitions exceeding those held over December (Figure 25b). Gaps in the number of records digitised for each year (Figure 25c) reflect both our inability to locate historic data for all years, and that we were unable to digitise all data located.

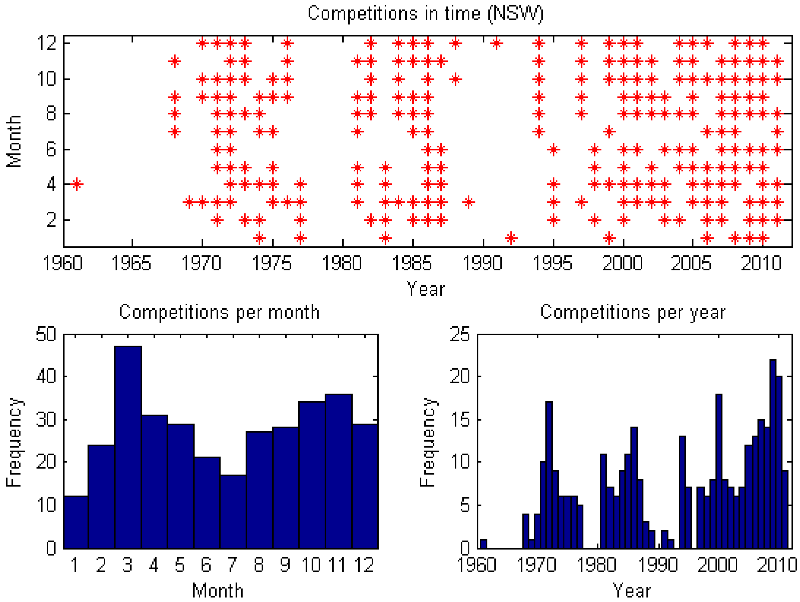


Figure 25. Temporal extent of digitised competition data for NSW: (a) temporal distribution; (b) frequency of competitions by month; and (c) frequency of competitions per year.

Digitised NSW data extend from near Coffs Harbour in the north to near Eden, near the Victorian border in the south (Figure 26). Data from the far northern coast are limited, and consistent coverage was only available from the central coast southwards. Gaps are also evident from the southern coastline prior to the 1980s. These large geographic gaps reflect inability to locate additional data during the project and/or a lack of competitions held in certain regions. Limited additional data has since been located, but was not available in time for digitisation and inclusion.

The most commonly represented species in NSW digitised data appeared in over 90% of competitions, with nearly 25 species appearing in over 50% of competitions (Figure 27a). The high percentage of uncommon species is also depicted in the species accumulation curve (Figure 27b), with most species being sampled after some 15 competitions per year. New South Wales competitions take more species than Victorian competitions, ~100 versus ~60, largely reflecting the broader latitudinal range of the coastline. The amount of effort required to reach an asymptote in the species accumulation curve is similar for each state.

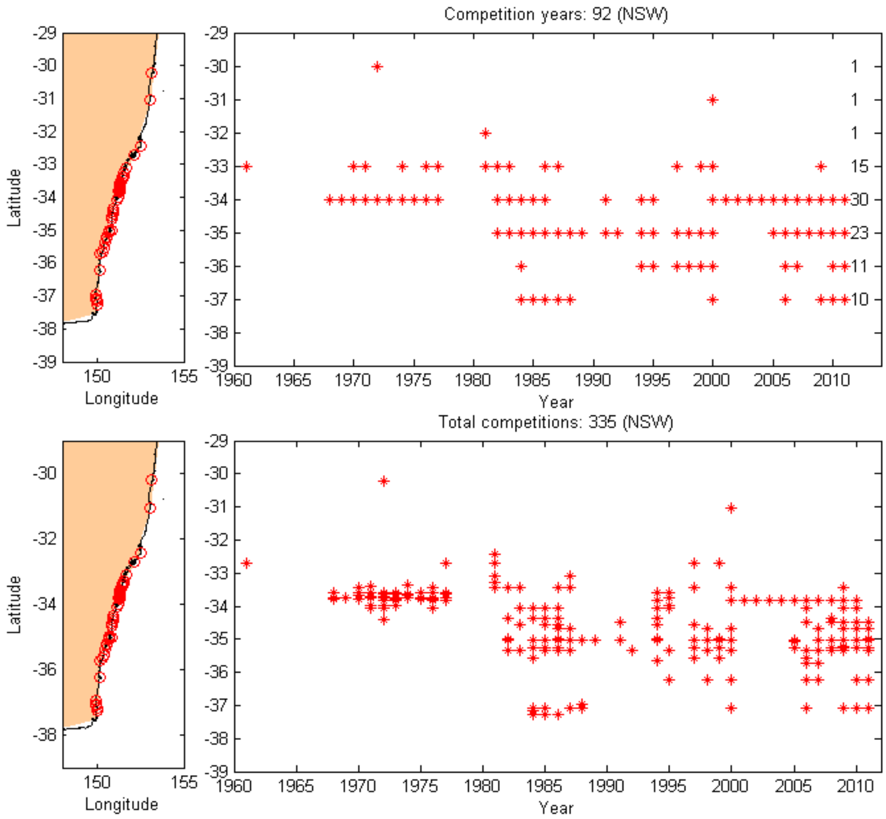


Figure 26. Geographic and temporal location of digitised NSW competition data: (a) years represented within the dataset; and (b) total number of competitions.

The number of species caught per year and average number caught per competition (Figure 27 c & d) will be affected by sampling effort — the number of divers competing in each competition and the number of competitions digitised for any particular year. The data from 1961 provides an example, with data available only from a single large competition held in April at Shoal Bay. Datasheets for competitions held in the late 1960s and early 1970s are from smaller, local club events, some with only half a dozen participants.

Anecdotal reports suggests these data under represent the number of active divers from the period, perhaps resulting from the surviving data from this period largely being from smaller clubs. From the 1980s onwards, competitions were regularly attended by between 20 and 60 members, with extremes reaching around 100 for popular competitions (Figure 28a).

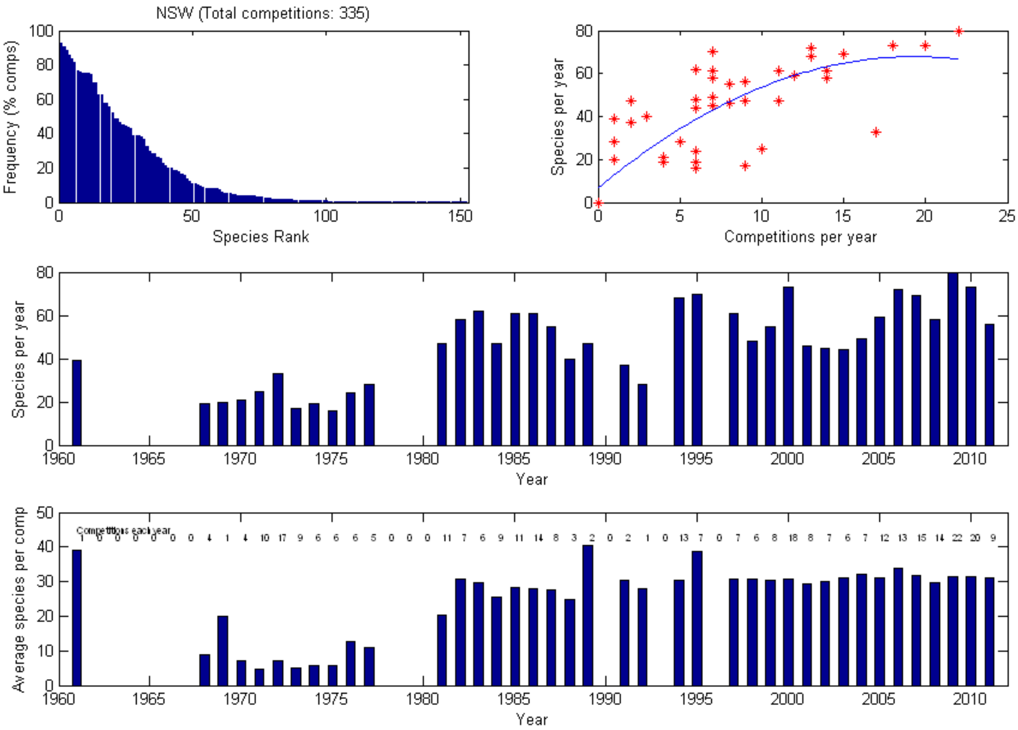


Figure 27. Summaries of digitised data for NSW: (a) rank of the 40 most common species (as a percentage occurrence across all competitions); (b) species accumulation curve; (c) number of species caught per year, depicted as a percentage of maximum catch (1982); and (d) the average number of species represented in each competition for each year.

The low number of species captured per competition, and per year, through the 1970s (Figure 27c & d) is likely to reflect the low numbers of competitors in each competition that were available for digitisation. From the data we have available, we can see the number of species being caught increased greatly from the 1970s to the 1980s and has remained relatively stable until the present. There is no indication from these data that the spearfishing experience has declined in NSW.

Spearfishers have suggested the notable increase in species captured during the early 1980s is likely a result of a combination of factors, including:

- Surviving data available for digitisation from the 1960s and 70s are largely from small clubs. This will artificially reduce the reported number of divers participating each year, as well as the number of species caught per year, and the average number caught per competition.
- In the 1970s there was more of a focus on the social aspects of competitions and on catching large fish than on winning. Rule changes in the 1970s (discussed above) are also likely to result in a broader range of species being caught in some clubs since that period.
- There were a range of gear changes around this time, including better fins and wetsuits, and these becoming cheaper and more accessible allowed divers to stay in the water longer, and cover more ground and habitats within a competition.
- More divers started to regularly dive deeper. Divers have attributed increases in catches of species such as the Sixspine Leatherjacket during the early 1980s to increased diver ability.
- There was also an increase in the range of locations for competitions combined with the increase in boat competitions in NSW. These resulted in fishers covering a broader range of habitats, within single dives, and across each year. This could be as extensive as covering grounds that might have been previously covered only over several competitions. There has also been a reported trend to larger, faster boats able to cover more area within a competition period.
- Divers also report that around the late 1970s to early 1980s it became more common to have a ‘boatie’ to assist during a dive, making previously inaccessible locations dive-able and also meaning divers could cover more ground as they didn’t have to return to the entry point.

- Increasing affordability and availability of GPS and depth sounding technologies have assisted divers that would have once struggled to find offshore dive grounds, to quickly find these areas. This also reduced the gap between novice and older/experienced divers who previously relied on years of dive experience and accumulated knowledge to locate dive spots.

Factors such as these, combined with the targeting of new species (as some species have been removed from scoresheets), may have also contributed to the stability in catches seen since the 1980s.

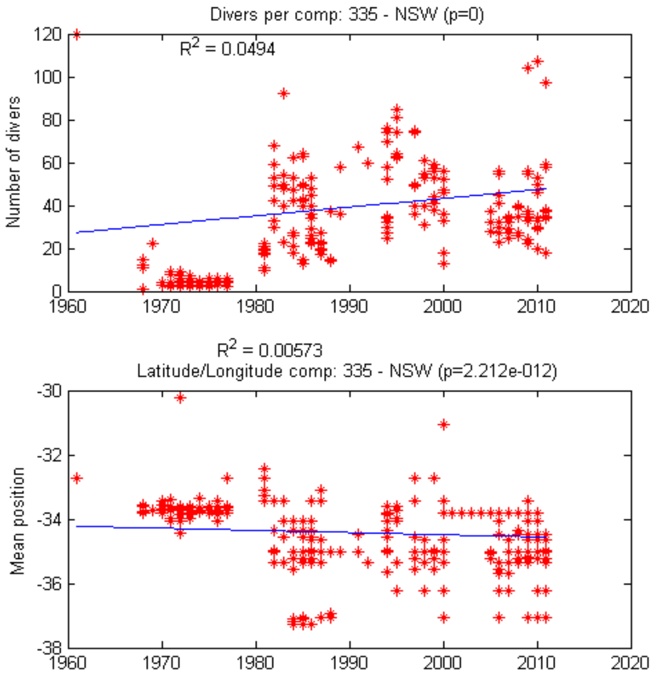


Figure 28. Temporal patterns in NSW competitions: (a) number of divers participating in each competition; and (b) change in competition location (by latitude) over time.

Competition locality through the sampling period (Figure 28b) can be seen to have undergone a minor shift southwards. In the absence of any climate induced, southwards range extensions (leading to increased tropicalisation of the catch), the southern shift in competitions would likely create a minor 'temperate' signal in the dataset (discussed below).

The 20 most commonly represented species across all NSW competitions are depicted in Figure 29. Not all captures are recorded at the level of species, in Figure 29, for example, the 13th most common 'species' represents a grouping of undifferentiated Ling (family Moridae) reported as predominantly consisting of the Largetooth Beardie (*Lotella rhacina*), but also likely to include other species such as Rock Ling (*Genypterus tigerinus*) in the south of the state.

Changes in basic biological and occurrence data for the top 50 species are also presented, with statistically significant changes (P<0.05) depicted in red (Figure 29b). For the top 50 species there was one species that underwent a significant decrease in occurrence and 39 underwent a significant increase in occurrence over the period. The mean size (weight) of nine species has statistically decreased, and increased for two species. The average count for each species per competition has also significantly increased for 30 species, while decreasing for one species.

These measures represent change relative to the sample population, and will be influenced by numbers of species available to catch, relative number of other species caught, and the number of divers participating in each competition. To avoid some of these biases, we also examined change in the annual catchability of each species, Annualised Catch Per Diver (ACPD) and found some eight species were becoming harder to catch, while about 15 were easier to catch over the period. Summary data for top 50 NSW species are presented in Appendix H and summary graphs for top 73 species in Appendix M .

Assessing for seasonal trends in NSW data by comparing the top twenty most common species caught in Summer and Winter months, shows little pattern for these species (Figure 30). Of the top 20 species, the top 17 remain the same for summer and winter, and only total of two species differ out of 40 possible.

Comparing the 20 most common species from each of Victoria and NSW (Figure 21), shows little overlap between faunal compositions, with only three species common to both lists: Sixspine Leatherjacket, Longfin Pike and Bastard Trumpeter. This is not unexpected given that central NSW represents a warm temperate province and southern NSW an associated transition zone, while Victorian data come from a temperate province and associated transition zone to the west (IMCRA 2006).

The ranking of NSW species as a measure of commonness through time shows even the most 'stable' species have high variability in commonness, with species in the top ten having changed rank by as much as 30 positions (Figure 32 & Figure 33). A number of species, including the temperate Eastern Australian Salmon (#20) and Eastern King Wrasse (#21), and the Spotted Sawtail (#23) have risen in commonness rank over the study period. A number of species have had a reduction in rank, including the temperate Crimson Banded Wrasse (#24) and Rock Cale (#27).

1 37377009: Red Morwong (n=311)
2 37361007: Luderick (n=303)
3 37361006: Rock Blackfish (n=297)
4 37465036: Sixspine Leatherjacket (n=287)
5 37465039: Black Reef Leatherjacket (n=281)
6 37117001: Sergeant Baker (n=274)
7 37361009: Silver Sweep (n=258)
8 37287066: Eastern Red Scorpionfish (n=257)
9 37327002: Longfin Pike (n=254)
10 37465003: Mosaic Leatherjacket (n=253)
11 37465059: Yellowfin Leatherjacket (n=252)
12 37378002: Bastard Trumpeter (n=249)
13 37228899: Ling (n=244)
14 37377004: Blue Morwong (n=234)
15 37361001: Silver Drummer (n=232)
16 37337004: Silver Trevally (n=222)
17 37437035: Australian Sawtail (n=210)
18 37311090: Eastern Wirrah (n=194)
19 37465007: Rough Leatherjacket (n=194)
20 37344002: Eastern Australian Salmon (n=186)

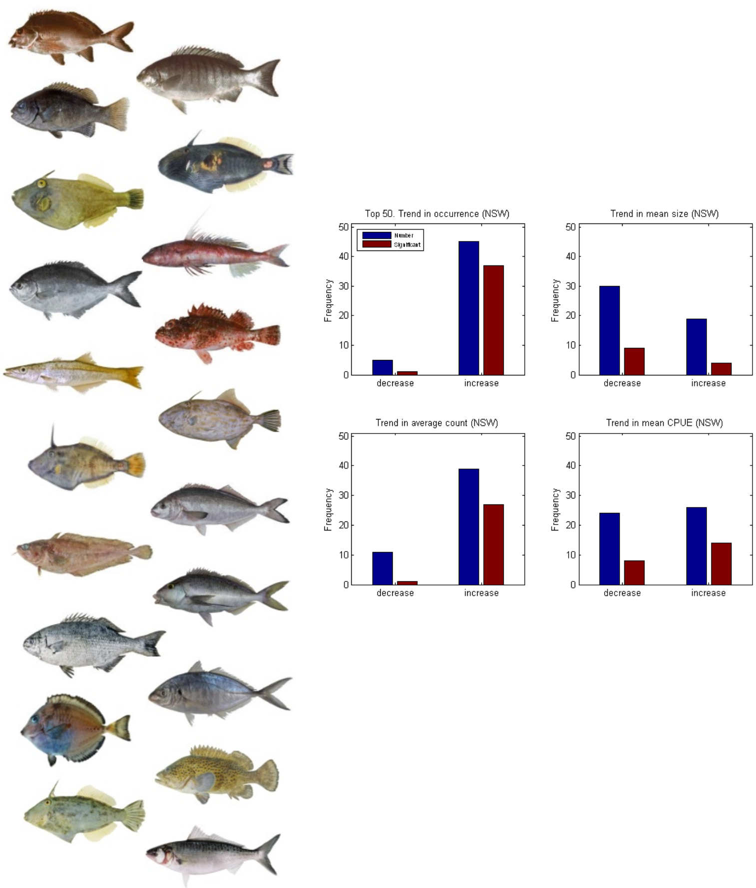


Figure 29. (a) Twenty most commonly caught species as represented in digitised NSW data, measured as occurrence across all competitions, and (b) changes in basic biological and fishery data for the 50 most common species over the period. Numbers are presented in Blue, significant results in red.

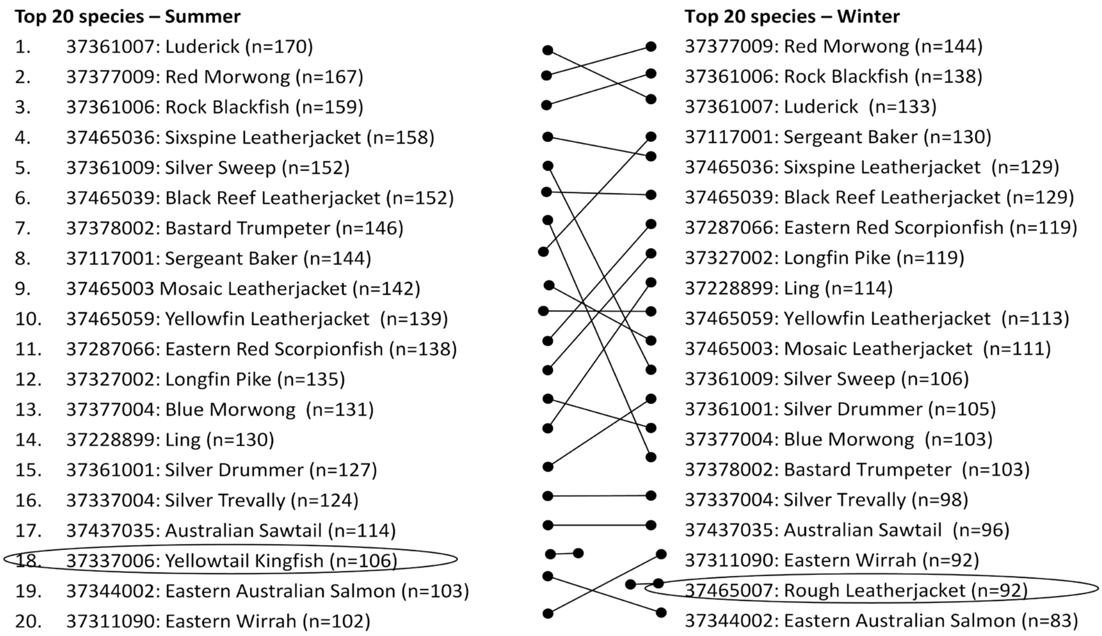


Figure 30. Top twenty most common species for digitised NSW competitions from summer and winter months.

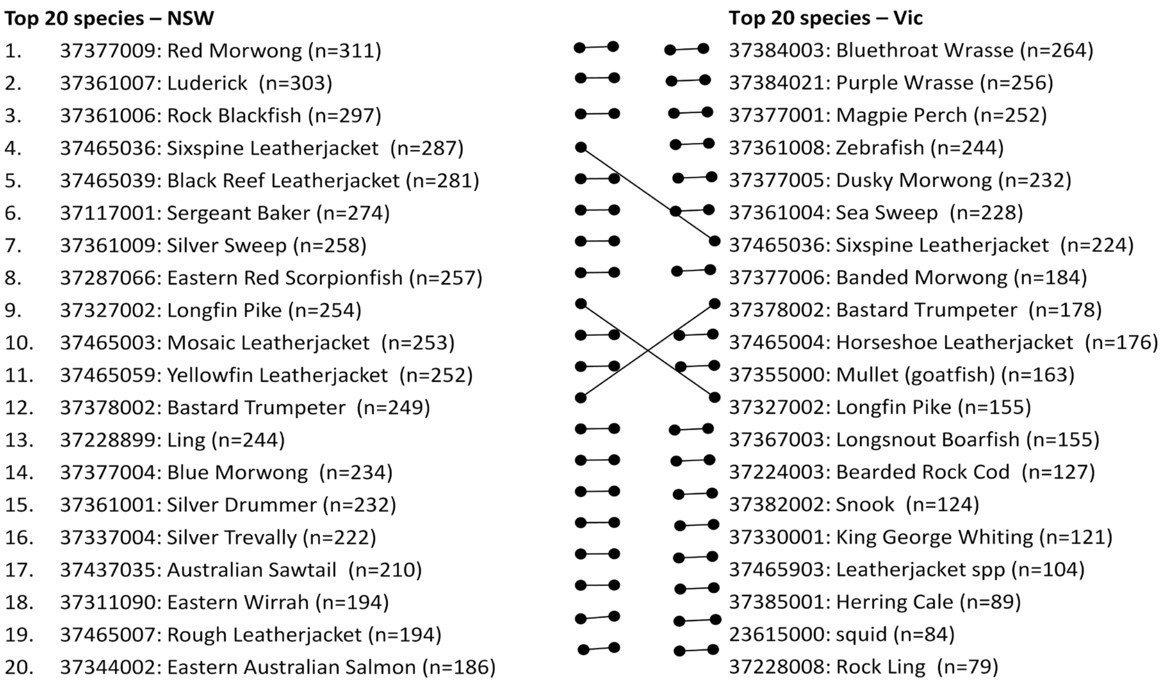


Figure 31. Comparison of top 20 species for Vic & NSW catches. The top 20 species (appearance at a competition) show only 3 species in common between the two states.

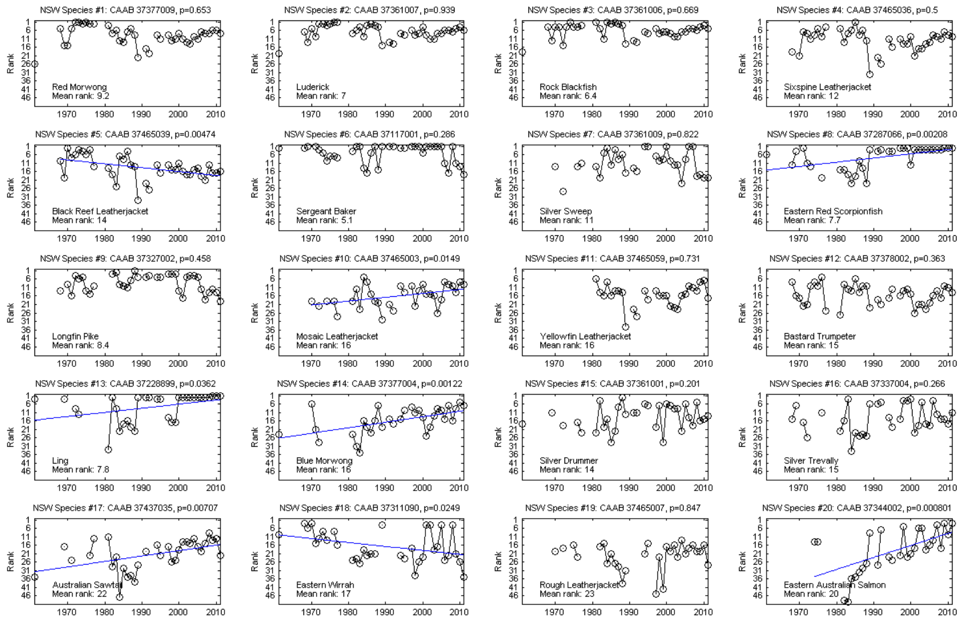


Figure 32. Rank through time for twenty most common NSW species. Significant trends indicated by regression line on plot.

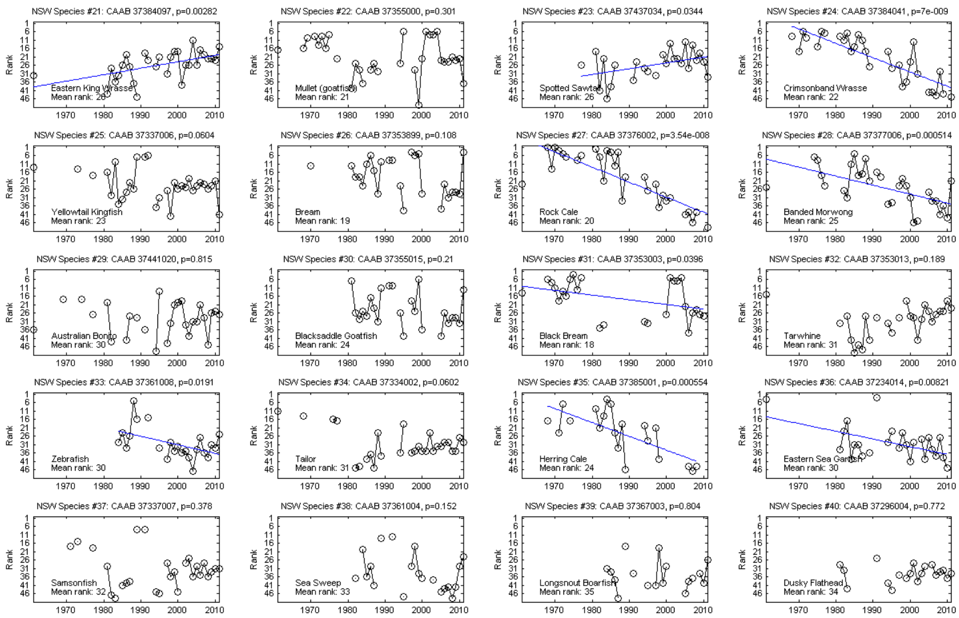


Figure 33. Rank through time for 21st to 40th most common NSW species. Significant trends indicated by regression line on plot.

For each species ranked in the top 50, we examined four measures of species-level change within the period. These were frequency (from which 'rank' was derived), mean size (weight in grams), average number caught per competition each year, and the mean catch per diver per competition (Annual Catch Per Diver, ACPD). Results for each of the 50 most common NSW species are presented in Appendix M .

The most common fish across all competitions digitised from NSW is the Red Morwong (*Cheilodactylus fuscus*), caught in over 90% of competitions each year (Figure 34). Each of the four measures show a statistically significant increase over the study period. There has been an increase in the mean size of this species from around 1 kg, to around 1.2 kg over the period, and the number caught per competition and the mean catch per diver per competition (Catch Per Diver, ACPD) have both also increased.

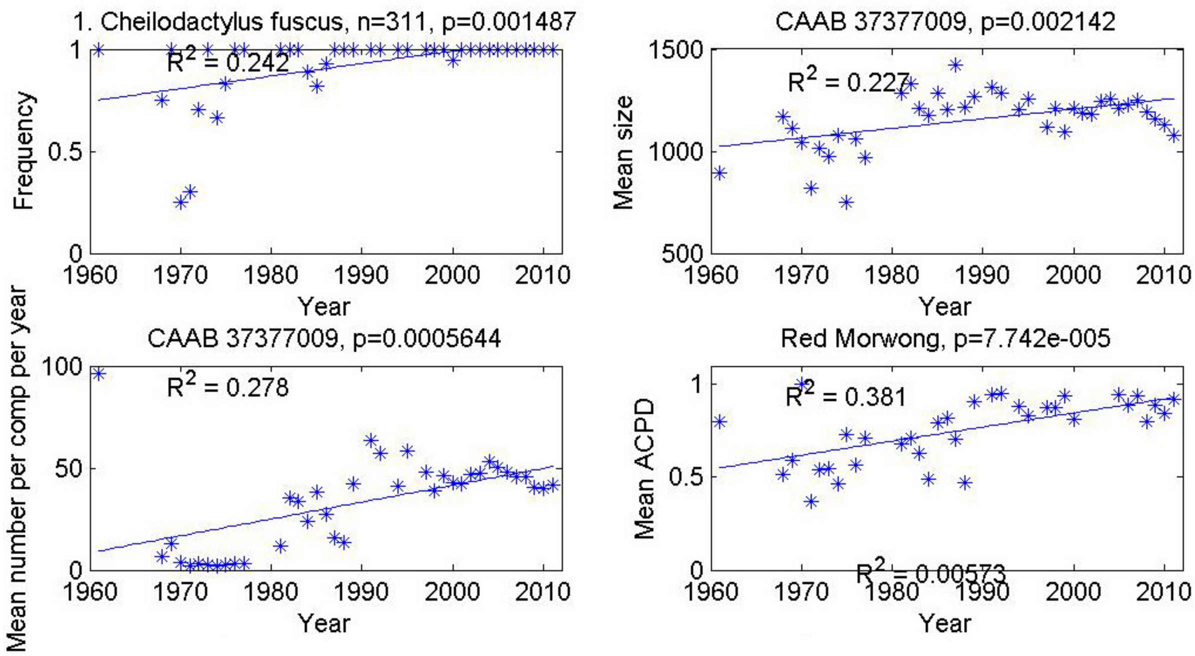


Figure 34. The most commonly caught species in NSW competitions, measured by likelihood of occurring at least once per competition, is the Red Morwong (*Cheilodactylus fuscus*). Data are presented for: (a) frequency (measured by 'commonness' across competitions); (b) mean size; (c) mean number caught in each competition per year; and (d) mean catch per diver (ACPD).

Results for both the Black Reef Leatherjacket (#5, Figure 35) and Silver Drummer (#15, Figure 36) display a statistically significant increase in each of frequency, mean number caught per competition and ACPD, while also displaying a decrease in mean size, from ~650 g to ~600 g, and ~550 g to 450 g respectively. Given the increase in catch rate and ACPD, these figures suggest a reduction in large individuals within the population. Anecdotal reports suggest Silver Drummer are commonly encountered, but are never 'abundant'. They are also reportedly difficult to spear in open water, more commonly targeted in large caves, the increasing 'ease of capture' may in part reflect a change in practice and technique to target this species.

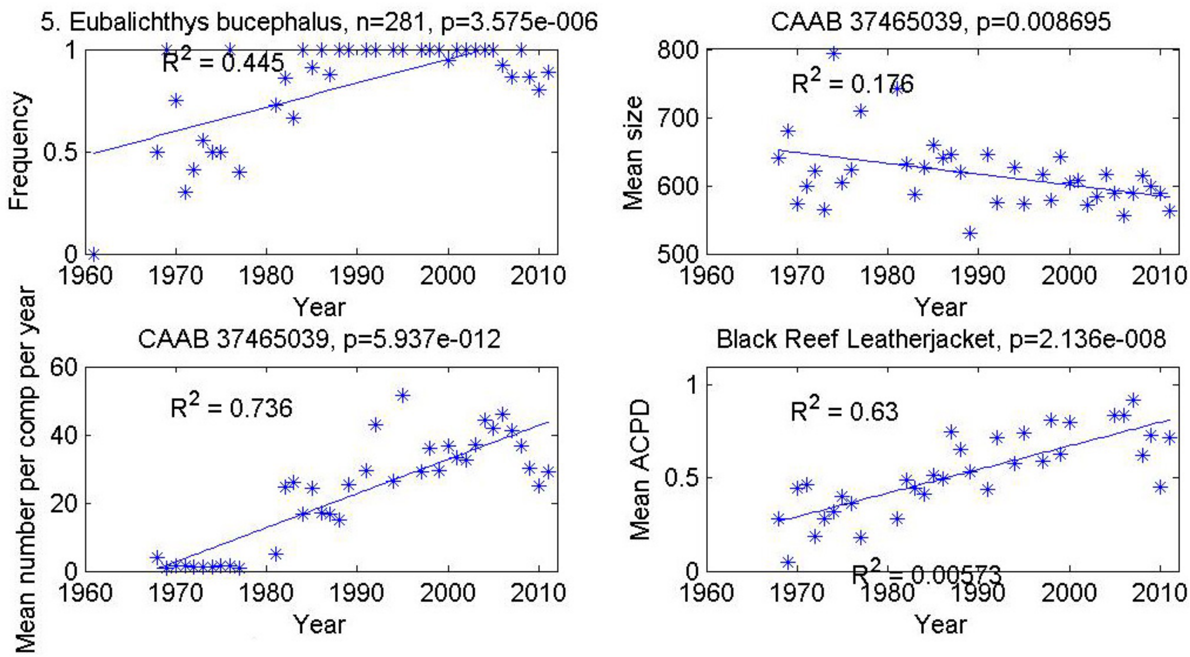


Figure 35. Fifth most common species in the NSW catch, the Black Reef Leatherjacket (*Eubalichthys bucephalus*). Data are presented for: (a) frequency (measured by 'commonness' across competitions); (b) mean size; (c) mean number caught in each competition per year; and (d) mean catch per diver (ACPD).

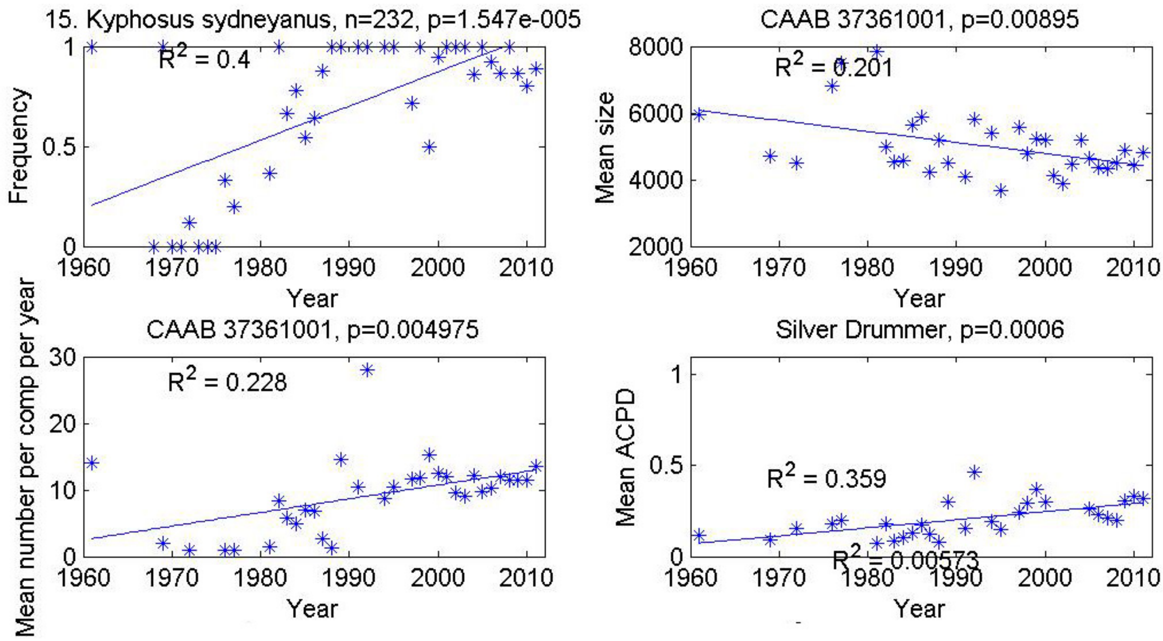


Figure 36. Fifteenth most common species in the NSW catch, Silver Drummer (*Kyphosus sydneyanus*). Data are presented for: (a) frequency (measured by 'commonness' across competitions); (b) mean size; (c) mean number caught in each competition per year; and (d) Annualised Catch Per Diver, (ACPD).

7.4 Community-level change

7.4.1 TROPICALISATION

Datasets were examined for evidence of 'tropicalisation' — an index assessing the ratio of temperate versus tropical within the 50 most common species from the catch within each state. As described in the methods, the transition zone at the New South Wales (NSW) and Queensland border was used as the cut-off for this analysis, with those predominantly distributed within provinces to the north classed as tropical, and those primarily distributed in provinces to the south classed as temperate. This classification was chosen to examine change along the NSW border, but is coarser than desired for examining change among Victorian species. Those species that could not be scored in this simplistic manner were ignored for these analyses.

New South Wales

Since the 1970s, there has been considerable change among the 50 most common NSW species, resulting in a significant change in the tropicalisation index toward a more tropical fauna. This is consistent across all seasons, and for both 'summer' and 'winter' (for simplicity, split into summer months, Nov–Apr and winter, ranged May–Oct) periods (Figure 37a).

Restricting analyses to the 25 most common species (Figure 37b) showed significant tropicalisation signal across all months and for the summer period, but significant change was not recorded in the winter months. Restricting the analyses to the 26–50th most common species (Figure 37c) demonstrated significant tropicalisation for both summer and winter, but not for the whole year combined. The results demonstrate the complexity of species interactions, and the inconsistent effects on species within the catch.

As there were apparent differences in the catches from the 1970s (fewer species caught, fewer divers etc, see above), we also assessed the tropicalisation signal for a restricted set of data, from 1980 until 2011. Data were again assessed across all seasons, as well as being limited to 'summer' and 'winter' (Figure 38). The tropicalisation signal for the top 50 species was retained for all seasons, as well as for summer and winter periods, despite the reduced data and time period being analysed. The tropicalisation signal is however lost for the top 25 and the top 26–50 species, with the exception of the 26–50th for winter only (Figure 38c). This loss of signal may suggest that there were changes happening prior to this period, and/or may reflect the limited data from the period of most change (1970–80). Alternatively the limited range of species available for the 1970s period may have had an undue influence on the analyses.

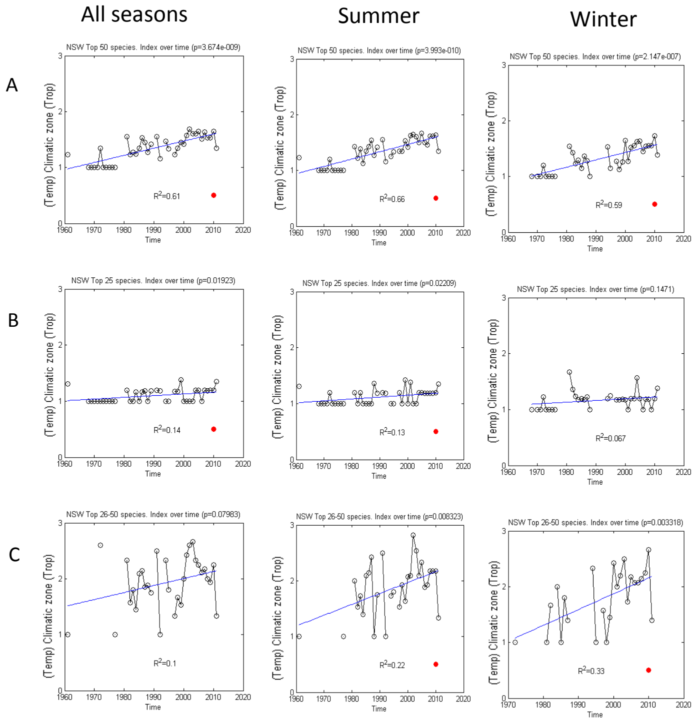


Figure 37. Tropicalisation of NSW species during the sampling period, 1961–2011, presented for: all seasons, Summer (November to April), and Winter (May to October). Data are also presented for: (A) 50 most common species; (B) limited to 25 most common species; and (C) limited to the 26–50 most common species. The index ranges from 1, temperate to 5, tropical, red dots indicate statistically significant change.

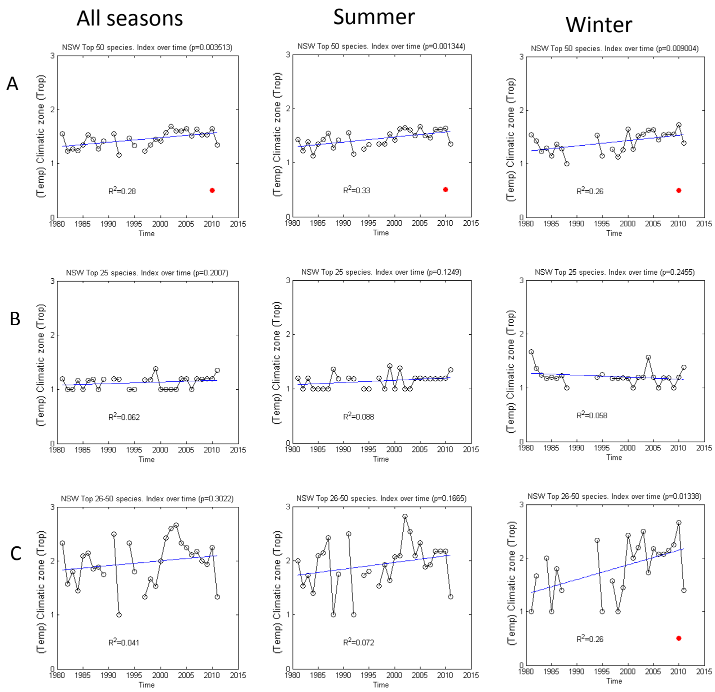


Figure 38. Tropicalisation of NSW species limited to the sampling period 1980–2011, presented for: all seasons, Summer (November to April), and Winter (May to October). Data are also presented for: (A) 50 most common species; (B) limited to 25 most common species; and (C) limited to the 26–50 most common species. The index ranges from 1, temperate to 5, tropical, red dots indicate statistically significant change.

To better understand which species were influencing the change in the index, we examined the member species from two year periods, 1982 and 2010. We ignored data pre-dating 1981 as there were large gaps from southern NSW prior to this period, and 1982 is the first year with a consistently high number of species caught (Figure 27c). Data from 2010 were chosen for the most recent year, as the 2011 season was incomplete and had a lower number of species recorded than years immediately prior (Figure 27c).

Comparison of the 20 most common species for the two seasons (Table 9) displays the predominance of temperate species commonly caught in the catch, with 21 species from 1982 and 20 from 2010 being classed as primarily temperate. Four species from each period were not classified, and only a single tropical species was recorded, this being Tarwhine in 2010. Despite apparent stability in the overall biogeographic influences in the top 25 species, there is considerable species turnover, five drop out of the top 50, three drop down into the 26–50 list, seven rise from the bottom 25 to the top 25, and the single predominantly tropical species is a new entry into the top 50.

The 26–50 most common species for NSW (Table 10) has greater change and diversity. Of the species recorded in 1982, 13 were classified as temperate, two as primarily tropical and ten were not classified (Table 10). The 2010 season records an additional three tropical species, eleven temperate species and nine unclassified.

It must be noted that examining two years in isolation will not show all species responsible for change in the tropicalisation index, and additionally, selection of differing years could well have shown fewer or greater species undergoing change. For example, 1981 appears to have been a particularly ‘tropical’ year, and 2011 appears to have been unusually ‘temperate’ (Figure 38a). Selection of these two, incomplete years would have demonstrated less difference than presented in these tables. The tropicalisation index is therefore a more robust method of examining the extent of change over the period.

Table 9. Comparison of the 20 most common species for each of the 1982 and 2010 NSW seasons. Species classed as predominantly tropical are scored '5' and shaded yellow, predominantly temperate species are scored '1' and shaded blue. Categories representing a combination of species, or representing wide-ranging species, are coded 'NA'.

1982				2010			
Rank	Common Name	Index	Change	Rank	Common Name	Index	Change
1	Sergeant Baker	1	•	1	Ling[1]	1	•
2	Ling[1]	1	•	2	Eastern Red Scorpionfish	1	•
3	Longfin Pike	1	•	3	Rock Blackfish	1	•
4	Silver Drummer	1	•	4	Luderick	1	•
5	Rock Blackfish	1	•	5	Blue Morwong	1	↑
6	Luderick	1	•	6	Red Morwong	1	•
7	Rock Cale	1	→	7	Yellowfin Leatherjacket	1	•
8	Red Morwong	1	•	8	Mosaic Leatherjacket	1	•
9	Bastard Trumpeter	1	•	9	Sixspine Leatherjacket	1	•
10	Southern Maori Wrasse	1	→	10	Eastern Australian Salmon	1	↑
11	Crimsonband Wrasse	1	→	11	Bastard Trumpeter	1	•
12	Mosaic Leatherjacket	1	•	12	Australian Sawtail	NA	↑
13	Sixspine Leatherjacket	1	•	13	Sergeant Baker	1	•
14	Yellowfin Leatherjacket	1	•	14	Longfin Pike	1	•
15	Eastern Red Scorpionfish	1	•	15	Silver Drummer	1	•
16	Silver Trevally	1	•	16	Rough Leatherjacket	1	•
17	Rough Leatherjacket	1	•	17	Black Reef Leatherjacket	1	•
18	Black Reef Leatherjacket	1	•	18	Silver Trevally	1	•
19	Bream[2]	NA	↓	19	Tarwhine	5	←
20	Silver Sweep	1	•	20	Silver Sweep	1	•
21	Herring Cale	1	→	21	Yellowtail Kingfish	NA	↑
22	Estuary Cobbler	NA	→	22	goatfish[3]	NA	•
23	Eastern Sea Garfish	NA	↓	23	Eastern King Wrasse	1	↑
24	Eastern Wirrah	1	↓	24	Spotted Sawtail	NA	↑
25	goatfish[3]	NA	•	25	Australian Bonito	1	↑

5	tropical species	1	mainly Largetooth Beardie
1	temperate species	2	mainly Yellowfin Bream
↑	moved up into top 20	3	mainly Blue Spotted Goatfish
NA	Not classifiable &/or widespread		
↓	moved down into bottom 21-40		
→	dropped out of top 40		
←	new addition to top 40		
•	stayed within top 20		

Table 10. Comparison of the 26–50 most common species for the 1982 and 2010 NSW seasons. Species classed as predominantly tropical are scored '5' and shaded yellow, predominantly temperate species are scored '1' and shaded blue. Categories representing a combination of species, or representing wide-ranging species, are coded 'NA'.

1982				2010			
Rank	Common Name	Index	Change	Rank	Common Name	Index	Change
26	Blacksaddle Goatfish	5	•	26	Eastern Wirrah	1	↓
27	Banded Morwong	1	•	27	Tailor	NA	•
28	Eastern King Wrasse	1	↑	28	Black Bream	1	•
29	Australian Sawtail	NA	↑	29	Bream[1]	NA	↓
30	Yellowtail Kingfish	NA	↑	30	Sea Sweep	1	•
31	Blue Morwong	1	↑	31	Samsonfish	1	•
32	Dusky Flathead	1	•	32	Blacksaddle Goatfish	5	•
33	Black Rockcod	NA	→	33	Zebrafish	1	←
34	Snapper	1	•	34	Whiting[2]	NA	←
35	Black Bream	1	•	35	Amberjack	5	←
36	Mulloway	1	→	36	Fanbelly Leatherjacket	5	←
37	Sea Sweep	1	•	37	Dusky Flathead	1	•
38	Blue Drummer	NA	→	38	Snapper	1	•
39	Giant Boarfish	1	→	39	Unicorn Leatherjacket	5	←
40	Eastern Kelpfish	1	→	40	Longsnout Boarfish	1	←
41	Spotted Sawtail	NA	↑	41	Sea Mullet	NA	←
42	rabbitfishes	5	•	42	rabbitfishes	5	•
43	Australian Bonito	1	↑	43	Banded Morwong	1	•
44	John Dory	NA	→	44	Bluethroat Wrasse	1	←
45	Tailor	NA	•	45	Eastern Sea Garfish	NA	↓
46	remoras	NA	•	46	remoras	NA	•
47	Samsonfish	1	•	47	Highfin Amberjack	NA	←
48	trevallies	NA	→	48	Black Rabbitfish	NA	←
49	Eastern Australian Salmon	1	↑	49	mullets	NA	←
50	Goldspotted Sweetlips	NA	→	50	Snook	1	←

5	tropical species	1	mainly Yellowfin Bream
1	temperate species	2	mainly Sand Whiting
NA	Not classifiable &/or widespread		
↑	moved up into top 25		
↓	moved down into bottom 25-50		
→	dropped out of top 50		
←	new addition to top 50		
•	stayed within top 25		

Victoria

The 50 most common Victorian species are dominated by temperate species. This is expected given Victoria's location within temperate and cool temperate demersal-shelf provinces. Using the scoring employed here, there was no discernible change in the tropicalisation index for Victoria when the 50 most common species were considered as a whole, or when splitting the catch into common and less common components. There is also little recent Victorian data, this gap that may further reduce a tropicalisation signal. The data warrants a more detailed analysis to further examine finer-scale variation.

7.4.2 TROPHIC-LEVEL CHANGES

Changes in the trophic level of the 50 most common species were examined annually to detect change which may result from species extending their ranges southwards (tropicalisation index, above). Species were scored for trophic level and an index was created. High trophic level species were scored as four, lower levels as one.

New South Wales

Since the 1970s, the 50 most common NSW species displayed a significant change in the index for trophic-level change, representing an increasing ratio of higher trophic-level species across all seasons, and for both 'summer' and 'winter' (for simplicity, split into summer months, Nov–Apr and winter, ranged May–Oct) periods (Figure 39a).

Restricting analyses to the 25 and 26–50 most common species (Figure 39b & c) showed no significant signal across all months, or for the summer period, but an increase in the index was recorded in the winter months for the less common species (Figure 39c).

Similar to the tropicalisation index (above), we also restricted analyses to only those species caught since 1980. We detected an increase toward higher trophic level species for the summer and winter months for all of the top 50 species combined (Figure 40a). Splitting the top 50 species resulted in significant change for all seasons and in summer months for the top 25, and significant change for the bottom 25 species only in winter months.

For NSW, we appear to be seeing an increase in higher trophic-level species (e.g. piscivores), which may be of higher value to spearfishers than fish at the lower trophic levels, and changes in these ratios might therefore affect their fishing experience.

Example species composition and their classification for the top 50 are provided for the years 1982 and 2010 (Table 11 & Table 12).

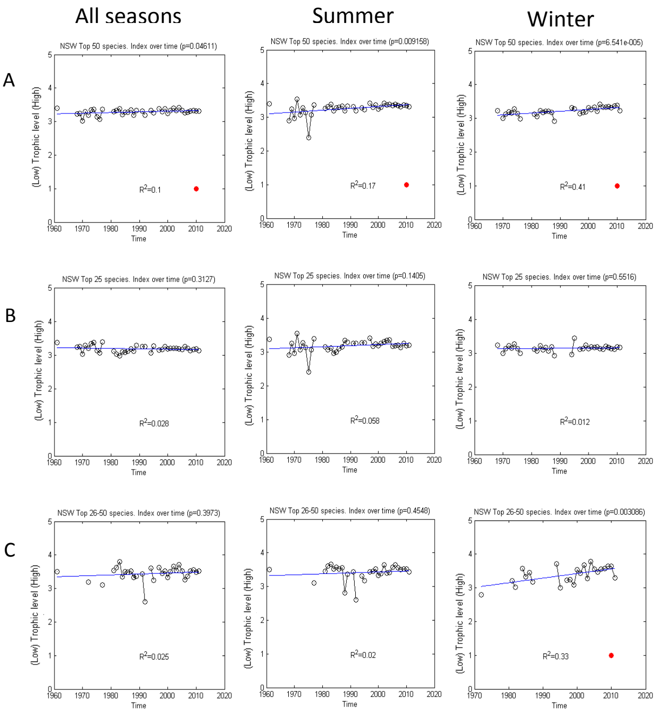


Figure 39. Change in Trophic level for the 50 most common species from the NSW dataset during the sampling period, 1961–2011, presented for: all seasons, Summer (November to April), and Winter (May to October). Data are also presented for: (A) 50 most common species; (B) limited to 25 most common species; and (C) limited to the 26–50 most common species. Red dots indicate statistically significant change.

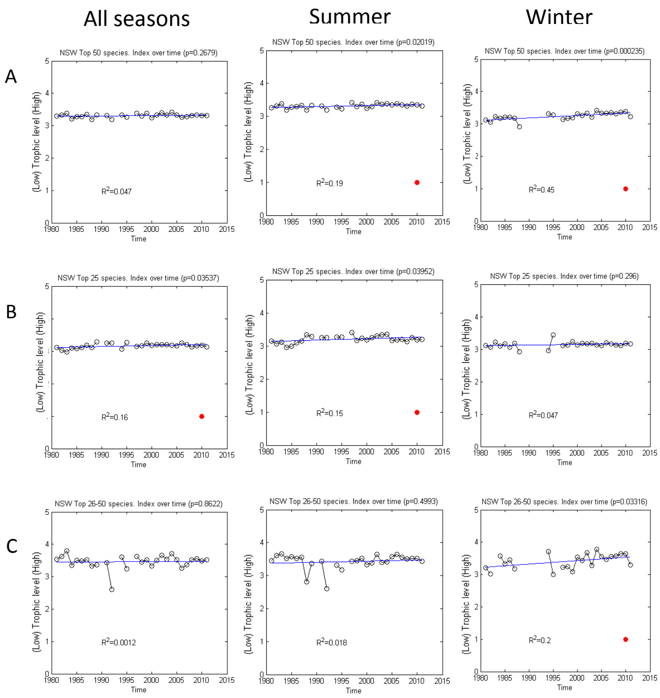


Figure 40. Change in Trophic level for the 50 most common species from the NSW dataset restricted to the sampling period 1980–2011, presented for: all seasons, Summer (November to April), and Winter (May to October). Data are also presented for: (A) 50 most common species; (B) limited to 25 most common species; and (C) limited to the 26–50 most common species. Red dots indicate statistically significant change.

Table 11. Trophic-level data for the 25 most common NSW species. Those classed as predominantly tropical are in yellow, those scored as predominantly temperate are in blue.

1982				2010			
Rank	Common Name	Trophic Role	Change	Rank	Common Name	Trophic Role	Change
1	Sergeant Baker	piscivore	•	1	Ling[1]	piscivore	•
2	Ling[1]	piscivore	•	2	Eastern Red Scorpionfish	invertebrate carnivore	•
3	Longfin Pike	piscivore	•	3	Rock Blackfish	omnivore	•
4	Silver Drummer	herbivore	•	4	Luderick	omnivore	•
5	Rock Blackfish	omnivore	•	5	Blue Morwong	invertebrate carnivore	↑
6	Luderick	omnivore	•	6	Red Morwong	invertebrate carnivore	•
7	Rock Cale	herbivore	→	7	Yellowfin Leatherjacket	omnivore	•
8	Red Morwong	invertebrate carnivore	•	8	Mosaic Leatherjacket	invertebrate carnivore	•
9	Bastard Trumpeter	invertebrate carnivore	•	9	Sixspine Leatherjacket	omnivore	•
10	Southern Maori Wrasse	invertebrate carnivore	→	10	Eastern Australian Salmon	piscivore	↑
11	Crimsonband Wrasse	invertebrate carnivore	→	11	Bastard Trumpeter	invertebrate carnivore	•
12	Mosaic Leatherjacket	invertebrate carnivore	•	12	Australian Sawtail	herbivore	↑
13	Sixspine Leatherjacket	omnivore	•	13	Sergeant Baker	piscivore	•
14	Yellowfin Leatherjacket	omnivore	•	14	Longfin Pike	piscivore	•
15	Eastern Red Scorpionfish	invertebrate carnivore	•	15	Silver Drummer	herbivore	•
16	Silver Trevally	piscivore	•	16	Rough Leatherjacket	invertebrate carnivore	•
17	Rough Leatherjacket	invertebrate carnivore	•	17	Black Reef Leatherjacket	invertebrate carnivore	•
18	Black Reef Leatherjacket	invertebrate carnivore	•	18	Silver Trevally	piscivore	•
19	Bream[2]	invertebrate carnivore	↓	19	Tarwhine	invertebrate carnivore	←
20	Silver Sweep	invertebrate carnivore	•	20	Silver Sweep	invertebrate carnivore	•
21	Herring Cale	herbivore	→	21	Yellowtail Kingfish	piscivore	↑
22	Estuary Cobbler	invertebrate carnivore	→	22	goatfish[3]	invertebrate carnivore	•
23	Eastern Sea Garfish	omnivore	↓	23	Eastern King Wrasse	invertebrate carnivore	↑
24	Eastern Wirrah	not defined	↓	24	Spotted Sawtail	herbivore	↑
25	goatfish[3]	invertebrate carnivore	•	25	Australian Bonito	piscivore	↑

(yellow)	tropical species
(blue)	temperate species
↑	moved up into top 20
NA	Not classifiable &/or widespread
↓	moved down into bottom 21-40
→	dropped out of top 40
←	new addition to top 40
•	stayed within top 20

1 mainly Largetooth Beardie
2 mainly Yellowfin Bream
3 mainly Blue Spotted Goatfish

Table 12. Trophic data for the 26–50 most common NSW species. Those classed as predominantly tropical are in yellow, those scored as predominantly temperate are in blue.

1982				2010			
Rank	Common Name	Trophic Role	Change	Rank	Common Name	Trophic Role	Change
26	Blacksaddle Goatfish	invertebrate carnivore	•	26	Eastern Wirrah	not defined	↓
27	Banded Morwong	invertebrate carnivore	•	27	Tailor	piscivore	•
28	Eastern King Wrasse	invertebrate carnivore	↑	28	Black Bream	invertebrate carnivore	•
29	Australian Sawtail	herbivore	↑	29	Bream[1]	invertebrate carnivore	↓
30	Yellowtail Kingfish	piscivore	↑	30	Sea Sweep	invertebrate carnivore	•
31	Blue Morwong	invertebrate carnivore	↑	31	Samsonfish	piscivore	•
32	Dusky Flathead	invertebrate carnivore	•	32	Blacksaddle Goatfish	invertebrate carnivore	•
33	Black Rockcod	piscivore	→	33	Zebrafish	omnivore	←
34	Snapper	invertebrate carnivore	•	34	Whitings[2]	invertebrate carnivore	←
35	Black Bream	invertebrate carnivore	•	35	Amberjack	piscivore	←
36	Mulloway		→	36	Fanbelly Leatherjacket	omnivore	←
37	Sea Sweep	invertebrate carnivore	•	37	Dusky Flathead	invertebrate carnivore	•
38	Blue Drummer	omnivore	→	38	Snapper	invertebrate carnivore	•
39	Giant Boarfish	invertebrate carnivore	→	39	Unicorn Leatherjacket	invertebrate carnivore	←
40	Eastern Kelpfish	invertebrate carnivore	→	40	Longsnout Boarfish	invertebrate carnivore	←
41	Spotted Sawtail	herbivore	↑	41	Sea Mullet	omnivore	←
42	rabbitfishes	herbivore	•	42	rabbitfishes	herbivore	•
43	Australian Bonito	piscivore	↑	43	Banded Morwong	invertebrate carnivore	•
44	John Dory	piscivore	→	44	Bluethroat Wrasse	invertebrate carnivore	←
45	Tailor	piscivore	•	45	Eastern Sea Garfish	omnivore	↓
46	remoras	invertebrate carnivore	•	46	remoras	invertebrate carnivore	•
47	Samsonfish	piscivore	•	47	Highfin Amberjack	piscivore	←
48	trevallies	omnivore	→	48	Black Rabbitfish	herbivore	←
49	Eastern Australian Salmon	piscivore	↑	49	mullets	omnivore	←
50	Goldspotted Sweetlips	invertebrate carnivore	→	50	Snook	piscivore	←

(yellow)	tropical species	1	mainly Yellowfin Bream
(blue)	temperate species	2	mainly Sand Whiting
NA	Not classifiable &/or widespread		
↑	moved up into top 25		
↓	moved down into bottom 25-50		
→	dropped out of top 50		
←	new addition to top 50		
•	stayed within top 25		

Victoria

There was no evidence of a change in the trophic index for the top 20 or top 50 Victorian species (Figure 41a & b). Restricting analyses to the top 21–40 most common species however, showed a significant change in the index, with species representing lower trophic levels becoming more common (Figure 41c). Digitised Victorian data from recent competitions are sparse, for example some species in the top 21–40 bracket may be represented by few specimens in any given year. Breaking this data into annual component species is therefore of limited value.

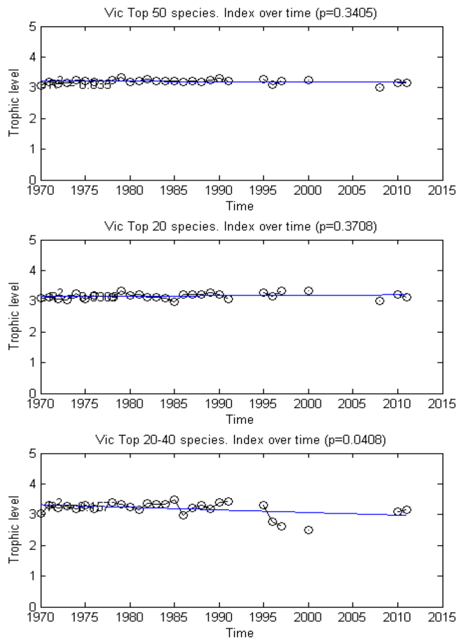


Figure 41. Change in Trophic level in the 50 most common species from the Victorian dataset: (a) 50 most common species; (b) limited only to 20 most common species; and (c) limited to only the 21–40 most common species. The trophic level score ranges from high level carnivores (4) to lower level species (1).

7.4.3 RANGE EXTENSION

The distributional range limits of marine fishes are difficult to establish and may correlate with a range of variables, including: geographic, depth, temperature and salinity ranges and habitat availability. The first two of these have been the most commonly recorded for fishes, and are often used as surrogates for other variables. Spatial occupancy is also important for fishes, a simplified classification may recognise those species living in association with the bottom (demersal), or freely in the water column (pelagic and/or neritic).

Where data are available, distributional ranges can often be further subdivided to recognise 'breeding range' (where conditions allow viable reproduction), a larger 'core range' (where species may commonly occur), and a more extensive 'extra-limital range' (where a species may infrequently occur, perhaps following a chance event). The edges of these ranges are plastic and therefore not clearly definable in a robust scheme, and could for example fluctuate with annual changes in water temperature. Minimal winter temperatures may for example be the limiting factor governing the ability to survive year-round at the southern range extent for many fishes (core and breeding range).

Estimating the extent of any species' range is therefore difficult, especially for poorly known species or where range-edges occur in areas with little human activity. When recorded, these ranges often relate to the core range, or combination of this with extra-limital data. Establishing a baseline (or historic) range edge is therefore difficult, making range-extensions particularly difficult to establish for mobile marine biota.

Our discussion of range extensions is therefore undertaken with full recognition of these limitations.

To assess change, we've therefore looked for both an increasing abundance within the southern limits of a species previously recorded range, as well as any apparent extension of the previously recorded range. To establish southern limits we've referred primarily to specialist literature, and to FishMap (fish.ala.org.au) which has established ranges from available, verifiable data (including specialist publications, species descriptions and reviews, and museum specimens). A number of tropical species recorded within the historic spearfishing data do appear to be extending their ranges and/or frequency in NSW, some of these are discussed below.

The predominantly tropical Rabbitfish, are recorded in the catch as Black Rabbitfish (*Siganus fuscescens*), ranked 58, and a grouping of mixed rabbitfish species ranked 46 (anecdotally this grouping is reported as mainly consisting of Black Rabbitfish, with some additional species likely included). Despite the extensive spearfishing data from off Sydney since the 1970s, rabbitfishes only appear in catches from the early 1980s, and are commonly caught off Sydney from 2000 (Figure 42 & Figure 43). The southern limit for Black Rabbitfish was previously recognised as the NSW/Qld border (Figure 44), and of the 15 other rabbitfish species occurring in Australia, only the Spotted Rabbitfish (*Siganus punctatus*) is recognised as extending into northern NSW waters. Species within this genus, including Black Rabbitfish appear to be extending their southern range-limit. No species from this family were recorded in the digitised Victorian data.

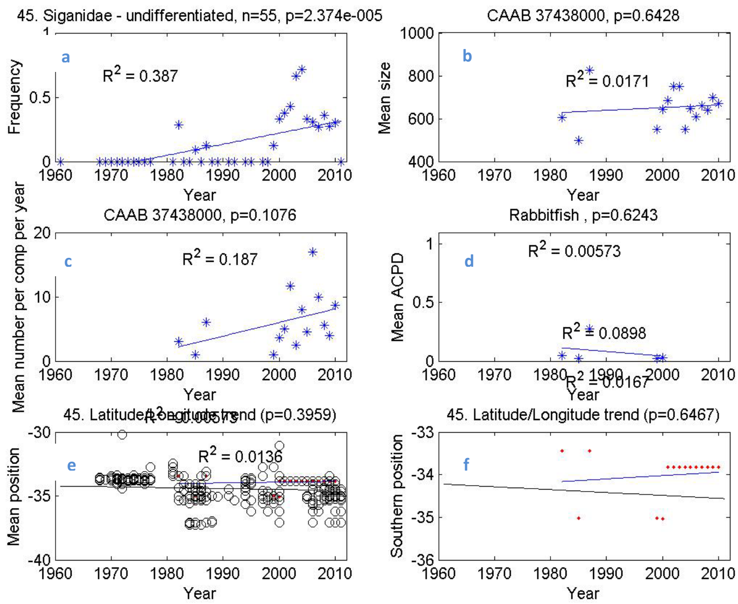


Figure 42. Catch data for Rabbitfish (undifferentiated species, family Siganidae): (a) frequency in competition data; (b) mean size; (c) catch per competition per year; (d) catch rate per fisher, per competition; (e) mean location of NSW competitions per year, open circles represent competition location, red closed circles represent catches of this species; and (f) southern-most catch record for the species in each year, the black trend-line in (e) & (f) depicts the mean competition location.

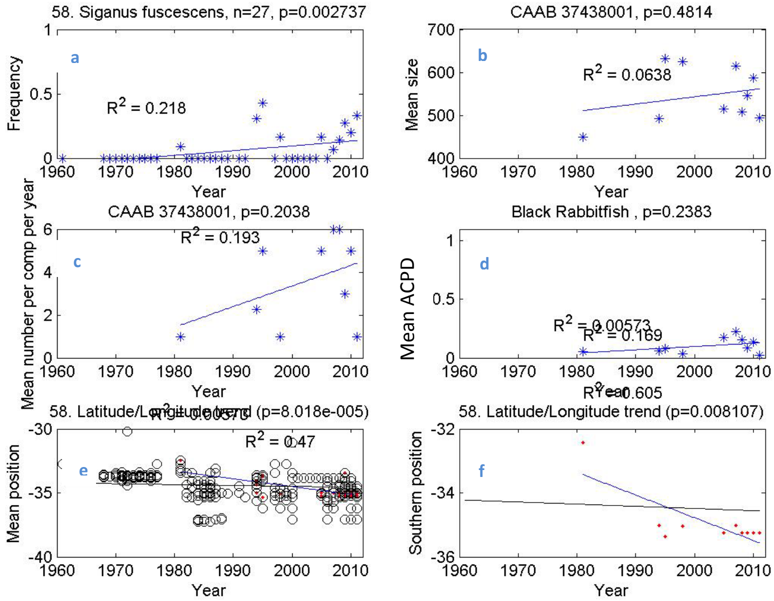


Figure 43. Catch data for Black Rabbitfish (*Siganus fuscescens*): (a) frequency in competition data; (b) mean size; (c) catch per competition per year; (d) catch rate per fisher, per competition; (e) mean location of NSW competitions per year, open circles represent competition location, red closed circles represent catches of this species; and (f) southern-most catch record for the species in each year, the black trend-line in (e) & (f) depicts the mean competition location.

Figure 44. Previously established Australian distribution for Black Rabbitfish (*Siganus fuscescens*). Source: FishMap (fish.ala.org.au), accessed May 21, 2013.

The Fanbelly Leatherjacket (*Monacanthus chinensis*), a widespread but predominantly tropical species which occurs throughout northern Australia extends southwards on the east coast to the southern NSW border. From the catch data, this species appears to be becoming increasingly common in southern NSW over the sampled period. The species was infrequently recorded off Sydney prior to 2000 (Figure 45), but appears to be becoming increasingly common in central and southern NSW over the last two decades. Anecdotal reports from fishers suggest the increase in this species may also be assisted by the reduction in netting in estuaries over the period. This species has not been recorded in the digitised Victorian data.

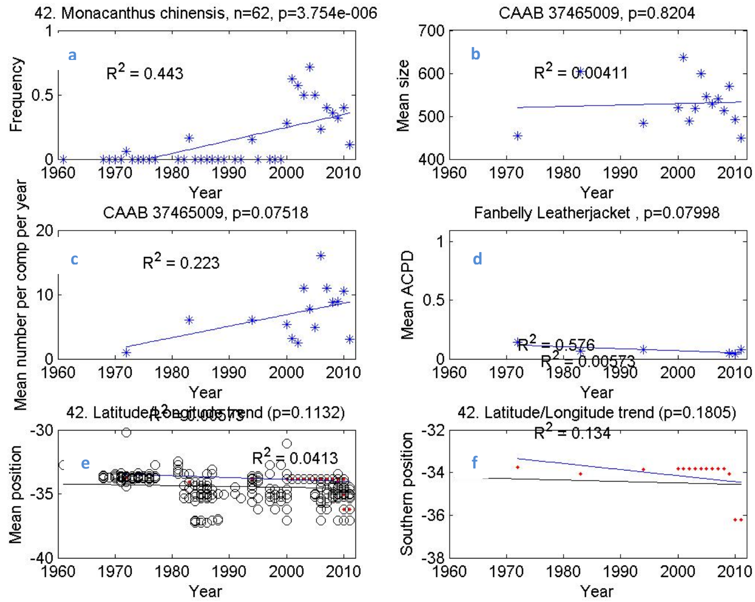


Figure 45. Catch data for Fanbelly Leatherjacket (*Monacanthus chinensis*): (a) frequency in competition data; (b) mean size; (c) catch per competition per year; (d) catch rate per fisher, per competition; (e) mean location of NSW competitions per year, open circles represent competition location, red closed circles represent catches of this species; and (f) southern-most catch record for the species in each year, the black trend-line in (e) & (f) depicts the mean competition location.

The Spotted Sawtail, the 23rd most common NSW species, has been a common component of the catch off Sydney since the 1980s (Figure 46) and appears to be becoming more frequent in southern NSW with the southern-most catches off Narooma since 1999. The species is previously recognised as occurring southwards to around Jervis Bay (Figure 44), and appears to be becoming increasingly common in the southern limits of its range. It has not been recorded in the digitised data from Eden or from Victoria.

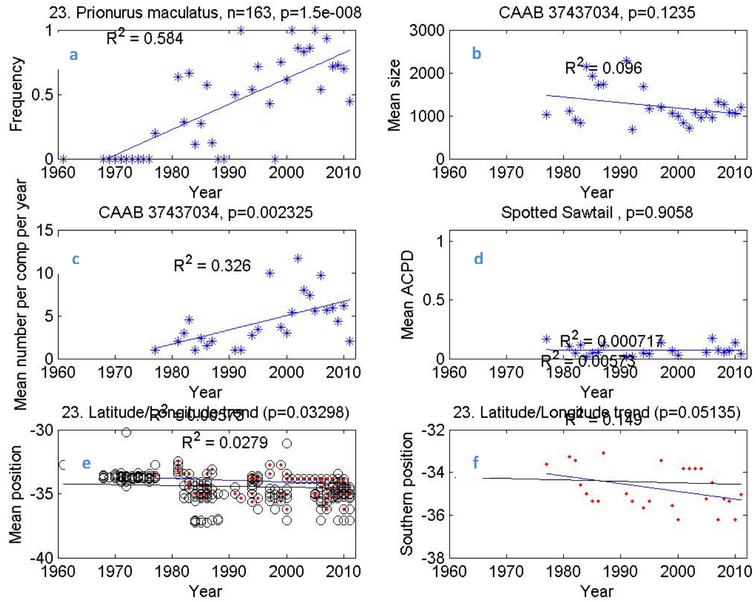


Figure 46. Catch data for Spotted Sawtail (*Prionurus maculatus*): (a) frequency in competition data; (b) mean size; (c) catch per competition per year; (d) catch rate per fisher, per competition; (e) mean location of NSW competitions per year, open circles represent competition location, red closed circles represent catches of this species; and (f) southern-most catch record for the species in each year, the black trend-line in (e) & (f) depicts the mean competition location.

Figure 47. Previously established Australian distribution for Spotted Sawtail (*Prionurus maculatus*). Source: FishMap (fish.ala.org.au), accessed May 21, 2013.

Barred Longtom (ranked 66) are a tropical and subtropical species, previously recorded in eastern Australia as far south as the central coast of NSW. These have only been recorded in the catch data since the late 1990s and have been caught more commonly off Sydney in recent years. Spearfishers report that this species requires the targeting of particular habitats, and the increase in records from southern NSW may therefore reflect changes in fishing practice, rather than warming waters.

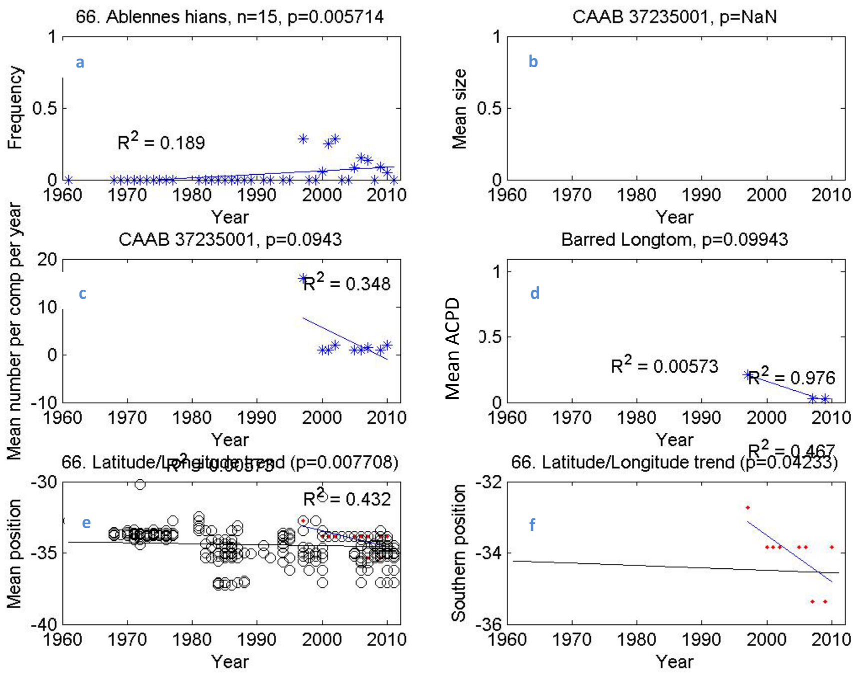


Figure 48. Catch data for Barred Longtom (*Ablennes hians*): (a) frequency in competition data; (b) mean size; (c) catch per competition per year; (d) catch rate per fisher, per competition; (e) mean location of NSW competitions per year, open circles represent competition location, red closed circles represent catches of this species; and (f) southern-most catch record for the species in each year, the black trend-line in (e) & (f) depicts the mean competition location.

7.5 Climate-induced change?

Establishing changes in abundance, communities and range extensions for marine species is difficult, complicated by limited historic data from which to establish baselines against which change can be measured. Here we have established changes in the composition of the competition catch data in both NSW and Victoria over the period examined. Changes are apparent in the percentage of tropical and temperate species, with warm-water associated species becoming more common in the catch, this has also led to changes in the trophic level of species caught, with an apparent increase in higher trophic-level species in NSW, and lower trophic-level species in Victoria. There are also apparent extensions to the southern range-limit for some species, and for other species, an increasing frequency of occurrence within previously documented southern range limits.

Some caution is recommended here, as collection bias and/or loss of fine scale data may influence the results. These may include changes in the fishing location, range of locations fished (for example, from increased boat range) during a competition, changes in the scoring system, adding or removing species from score sheets, or even fish behaviour in response to spearfishing. The lumping of species within 'catch-all' groupings may also hide fine-scale detail, for example Black Rabbitfish are often recognised and recorded as such, while on other occasions are simply recoded as 'rabbitfish'. Such cases represent a loss of fine-scale catch data, and may be hiding species-level responses.

None of these potential interactions and issues can be assessed here, but need to be considered. Additionally, the mean location of NSW competitions has undergone a minor shift southwards, in the absence of any tropicalisation signal, this effect alone could be expected to create a decrease in the tropicalisation (toward a more temperate community). This shift may be partially offsetting the increase in the tropicalisation index reported here, suggesting we're under reporting this effect.

Despite these limitations, the results reported improve our knowledge of species-level effects, and more broadly improve our understanding of how range-shifts may be occurring. There are however large gaps in our understanding of the finer scale changes taking place, partially reflecting the gaps in historic data available. Digitisation of further data to fill geographic, temporal and seasonal holes in the data would greatly assist in answering some of these questions. Improved data breadth would allow closer comparison of patterns with for example, previously reported range limits and seasonal fluctuations.

7.6 Spearfisher adaptation

What is adaptation?
The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as: "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"
(IPCC 2007)

The goal of this project in regard to climate change adaptation was to raise awareness with spearfishers about the ways in which they could respond to the biological changes in the species they value for the recreational experience. It is apparent from discussions with club members that a range of adaptation options exist. The focus of this section is to illustrate some of the historical flexibility demonstrated by spearfishers, and to illustrate where future adaptation might occur.

Past changes indicate that this group of recreational fishers have been responsive to environmental or societal changes. Spearfishers have a documented history of responsive custodianship over a number of decades through changing competition rules to protect species that were apparently vulnerable to recreational and commercial fishing. The earliest competition for which we have data, the Australian Pacific Coast Spearfishing championships held in April 1961, excluded species of sunfish, crustacea, sharks and rays, and had a daily bag limit of two groper per diver, only one of which could be weighed-in. All surplus fish from the competition were auctioned at end of the event with monies raised being donated to charity.

Changing regulations also provide examples of past responsiveness: fisher concern resulted in Black Cod and Blue Groper being banned from competition catches, followed by public lobbying for broader protection. Spearfishers also responded to changes in public and member attitudes toward spearing certain species, for example those that were of poor eating quality or too easy to spear. In many cases these were removed from score sheets, minimum sizes drastically increased, or eligibility restricted to junior members. While not climate-related adaptation, these are examples of directed management actions, through committees or broad member recognition, where rules were changed to actively mange potential impact on these species.

Fishing takes place in a dynamic environment, and so fishers already consider themselves flexible in dealing with future climate change. In response to historical change, autonomous adaptation by spearfishers has occurred. Examples include changes in fishing techniques resulting from better, and more affordable, or more accessible equipment (for example GPS technology, faster boats, better wetsuits and fins), increased diver ability (e.g. diver training for deeper diving). These past changes demonstrate the preparedness of spearfishers to adapt to change, and suggest options for adaptation under climate change as spearfishers adjust to a new suite of species.

A vulnerability framework that explicitly links changes in the ecological system to the resource users can be used to explain the range of adaptation options (Figure 49). Exposure to climate change (e.g. warming east coast waters) and the sensitivity of the particular fish species (e.g. lower survival in warm waters) can lead to a potential impact. If the adaptive capacity of the species is low (e.g. little genetic flexibility) then the ecological vulnerability will be high. As a result, the resource users will see a decline (ecological vulnerability) in the resource, and if they are dependent on that resource (e.g. few other prized fish exist as alternatives), then they may be exposed to potential impacts. If the adaptive capacity is high, due to an ability to move competitions to new locations or target new species, then the "socioeconomic vulnerability" will be low.

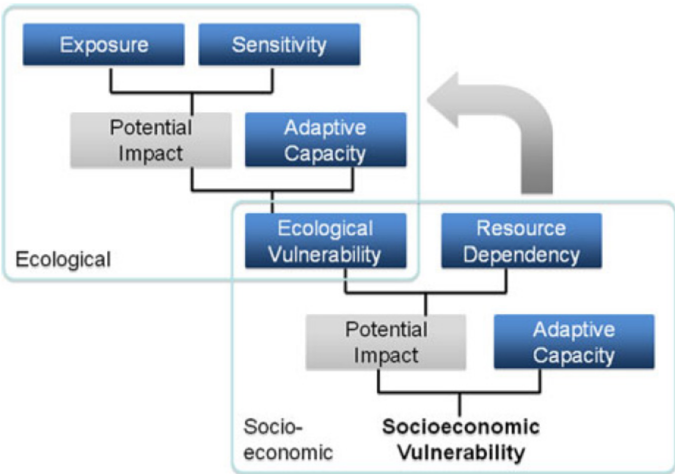


Figure 49. A conceptual framework for assessing vulnerability to climate change in climate-sensitive socio-ecological systems. The co-dependency of ecological and socio-economic subsystems means that their vulnerabilities are intrinsically linked. The ecological vulnerability enters the socio-economic sub-model as the equivalent of ecological exposure. Source: Marshall et al 2013.

With regard to adaptations that will reduce their vulnerability to climate change, three categories are possible (Figure 49). Fishers may reduce the ecological vulnerability (e.g. reduce the impacts of climate change on key species), reduce their resource dependency (e.g. target other species), and/or increase adaptive capacity (e.g. travel to new diving locations where species persist).

1. Reducing ecological vulnerability – while spearfishers may seem to have little to offer in this category, changes in rules and regulations can relieve pressure on species being heavily impacted by climate change (thus increasing the adaptive capacity of these species). Lending support to initiatives that preserve or restore critical fish habitat may also be of interest to spearfishing clubs, and in general demonstrate environmental stewardship. Fishers can also use the data generated in this project to engage with decision makers about the perceived changes in the marine environment. This engagement can positively improve the status of the ecological community on which this recreational sector depends.
2. Decrease resource dependency – while spearfishers do not depend on the availability of certain species for their livelihoods (as do commercial fishers), the spearfishing experience is enhanced by the presence of certain species (both for sport and competition scoring). Thus, changes in species distribution (e.g. range contraction to the south as waters warm) represent a vulnerability to the spearfishing groups. The resource dependency on the existing suite of species can be reduced by awareness regarding alternative species to target. Spearfishers are now targeting range extending species, including tropical species increasingly abundant at the southern limits of their range. Victorian spearfishers for example have recently begun an annual competition to target Yellowtail Kingfish, which are becoming more prevalent, and easier to predict with coastal water movements. The increasing availability of tropical species in southern waters is considered by many fishers as a positive effect of global warming, and autonomous adaptation to this opportunity is

already occurring. New fishing techniques may be employed to target tropical species (e.g. dolphin fish), such as increased use of fish aggregating devices (FADs), and blue water (offshore/deepwater) diving. Fishers should ensure that they are represented in discussions about the provision of new facilities (e.g. FADs and boat ramps) to ensure that the opportunities from climate change are realised, and offset some of the losses of traditional species.

3. Increase adaptive capacity – the impacts of climate change on spearfishers can be reduced by holding competitions at different times of year or in different locations. In this way, spearfishers may also offset the impacts of changed species distribution and abundance. They may also advocate for access to offshore FADs in a way that reduces the interference from line fishers. Dedicated spearfisher FADs may be one option for clubs to pursue.

In feedback sessions with clubs, we introduced this conceptual framework, and expect this to lead to additional suggestions and internal discussion for the future strategy to reduce the impacts of climate change on the spearfishing sector.

Overall, in the short-term, adaptation by spearfishers to the effects of climate change is likely to be reactive in response to the increasing commonness of some tropical species. Importantly for Victorian fishers, the warming waters will also likely extend their fishing season, currently limited during the cooler months. 'Winter' temperatures will contract to a shorter period. Medium to long term effects are more difficult to predict, but broad scale changes to species composition of communities and habitats could result in more dramatic changes in the species that are available to spearfishers. However, given that spearfishers are used to operating in a dynamic ocean, target a range of species, and are not dependent on critical species for food or livelihoods, the short-term impacts of climate change are not likely to lead to major disruptions to their recreational pursuits. Spearfishers can be valuable observers of the biological change in the ocean, and as such, provide information that can underpin increased societal awareness and galvanise actions to reduce the impacts of climate change through mitigation and widespread adaptation efforts.

8 Benefits and adoption

From the outset, this project aimed to improve recreational spearfisher engagement with scientific examination of the impacts of climate change, and the appreciation for the immense scientific value of spearfisher-collected data. This has been achieved through the development of a fruitful partnership between spearfishers and the research team, which has benefitted from visits to clubs to introduce the project, and again later to discuss results. These engagement activities are ongoing; this report will be delivered to participating clubs, information sheets will be developed for members, and club liaisons will deliver and explain results to their respective executive and members. A planned second media release and follow-on popular articles will promote the success of this partnership, and the proactive support from spearfishers for this collaboration.

This project has promoted the importance and relevance of data collected by recreation and non-specialist groups, and suitability for investigating pertinent and challenging issues. Additionally, the preparedness by spearfishers to self regulate, and to lobby for legislation where needed has been demonstrated and recorded.

The social survey has similarly raised these considerations amongst members, and the results demonstrate a grass-roots willingness and openness for increased engagement activities that recognise their potential contribution. Many members recorded a desire for greater and closer involvement in the scientific process, but also raise concerns that such process may have little understanding of their data. These results present both an invitation and a challenge to science and management to better tap and develop such potential partnerships.

Activities undertaken within the project have opened a pathway for continuing and expanding dialogue that must be progressed if such engagement is to succeed. The engagement model developed and successfully implemented here provides a baseline from which to expand, amongst recreational fishers, and more broadly in the community.

The benefits outlined above have already been demonstrated, and the uptake and adoption of the results will be promoted through the distribution of this report, a final media release and through associated popular articles. Three manuscripts are being prepared to also disseminate these results to the scientific community.

9 Further development

The data accessed and digitised during this project are truly unique, and an important scientific resource for studying multi-decadal change in Australian coastal marine communities. These data, curated and maintained by clubs, have proven the increasing importance of non-traditional data sources to put a temporal perspective on the change currently unfolding.

Following the extensive investment — both from spearfishers and researchers — to build this relationship, there is now a unique and time-sensitive opportunity to further explore these data to investigate questions raised by spearfishers during the engagement activity, and to better understand change currently occurring. There is potential to investigate more complex interactions between species-level change, environmental signals, and anthropogenic impacts including both commercial and recreational fishery management. Clubs are being provided electronic databases they can continue to populate, these may assist measuring and interpreting change into the future, and are a resource that would benefit greatly from ongoing technical support.

The engagement model developed and implemented here would also benefit from broader testing for transferability. This could be undertaken with alternative recreational fisher groups, or more broadly to better engage the community in natural resource management and in climate change adaptation.

Clubs have expressed a strong desire to undertake further collaborative projects, and we'll be looking for opportunities to develop these.

Further development could include:

- Digitisation of additional data. These could include remaining spearfishing competition data from Victoria and NSW (other states where available), and potential for inclusion of other recfisher datasets.
- Comparison of available data with other pertinent datasets, including: other recreational fisher data, state-based commercial fishery data, and oceanographic data.
- Explore changes noted in the spearfisher survey, and examine correlations with climate and other variables.
- Broader testing of the engagement model, this could be on another recreational group or community group, and could extend to a terrestrial or freshwater focus, and
- Continuation of the existing relationship could see an extension in the time series of data collected. Ongoing interaction from the research team could ensure these data are suitable for ongoing analyses.

10 Planned outcomes

While too early to measure many of the impacts that will result from this project, the following achievements against planned outcomes are noted:

- **Policy makers and managers better informed of current and likely future shifts in species ranges resulting from climate change.**

  This project represents the first quantitative multi-decadal, multispecies examination of climate induced change on coastal Australian fishes. Species-level data has helped quantify which species appear to be most affected, but have also better informed our understanding of the plasticity of expansion at range edges. Measures such as the 'tropicalisation index' also provide insight into how community-wide response is unfolding.

  Some data are coarse, and there are still temporal and geographic gaps in data, but ongoing engagement could see these refined, improving our understanding of change.

  Dissemination of these results will directly inform policy makers and managers, improving understanding of species and community level change in marine waters.

- **Recreational fishers and managers better positioned to respond adaptively to future climate change scenarios through an increased understanding of the elements of reef-fish communities that have been most impacted to-date, and**
- **Greater adaptive capacity of commercial fishers through being better informed on current and likely future changes in species distributions and catch composition.**

  As per above, results from this project along with the digitisation of the underlying data, form the first broad, quantitative examination of multi-decadal range-shifts in Australian coastal fishes. These data are already improving our understanding of mechanisms of change. The reporting of directed and autonomous adaptation undertaken by a sector of the recreational fisher community reveals historical adaption, and their readiness for ongoing adaptation. These mechanisms are of relevance to both commercial and recreational sectors, and will continue to inform management and the recreational and commercial fishery sectors.

- **Improved education of the recreational fishing community regarding the effects of climate change on target species.**

  Results from the social survey recorded most (74%) respondents believing there have been substantial change to earth's climate over the past 25 years and that humans are partially (41%) or largely (33%) responsible for those changes. Our presentations to clubs have included an overview of impacts on Australian marine biota, and likely impacts of continuing change. Dissemination of results will further inform fishers on the level of impacts occurring.

- **Improved dialogue between recreational fishers, scientists, and managers.**

  Extensive effort from all parties has resulted in significant improvements in the trust and relationship between fishers and researchers participating in the study. There is scope to further this through planned dissemination of results in popular publications, and potentially through additional follow-up engagement activities.

- **Improved process(es) for identifying climate change adaptation options for all fishery sectors.** Documenting adaptation options already employed by spearfishers has two main outcomes; it records the proactive adaptation activeties already in place; and suggests we need firstly consult with user groups about similar measures already in place. The engagement model devised and trialled here could be used for precisely this purpose.

11 Conclusion

This was a challenging project for all participants. The geographic scope of the project, a past history of unfavourable engagement and management experiences, the diversity of opinions and experience, and the sensitive nature of the data all conspired to test the resolve of members, club executive and researchers on numerous occasions. Through perseverance, and a genuine desire from spearfishers to have a greater role in the scientific and management process, the initial aims of this project have been achieved, and in many cases exceeded.

Project objectives:

1. Examine change in the distribution of coastal fishes in eastern Australia over the past four decades, and establish correlation of these to changes in environment, such as warming sea surface temperatures.

Data were digitised from a total of 607 historic spearfishing competitions, the earliest dating from 1961 in NSW. Competitions were held at 43 sites in Vic and 50 in NSW, and ranged from Coffs Harbour in NSW to near Portland in western Victoria, representing >19,000 'diver days', nearly 130,000 individual fish and >150 species.

From these data we found evidence of species extending their range further south, community-level change resulting in both a 'tropicalisation' of the catch and changes in the trophic composition. These changes are all consistent with warming sea surface temperatures recorded over recent decades.

Results from these analyses might be biased by changes in the fishing location, range of locations fished (for example, from increasing boat range) during a competition, changes in the scoring system, adding or removing species from score sheets, or even fish behaviour in response to spearfishing. The lumping of species within 'catch-all' groupings may also hide fine-scale detail, for example species of 'flathead' are often separated in the catch data, but in some cases species may be lumped into a single grouping. Such cases represent a loss of fine-scale catch data from the analyses and may be hiding species-level response.

None of these potential interactions and issues can be assessed here, but need to be considered when interpreting these results. Additionally, we detected a small southward shift in the mean location of NSW competitions, in the absence of any tropicalisation signal this effect alone would create a minor decrease in the index (toward a more temperate community). This shift may be partially offsetting the increase in the tropicalisation index reported here, suggesting we're under reporting this effect.

2. Investigate the perceptions of the representative group of recreational fishers regarding climate-induced change and effects this may have on the distribution and abundance of coastal fishes, and identify potential adaptation options.

Results from the social survey recorded most respondents (74%) believing there have been substantial change to earth's climate over the past 25 years and that humans are partially (41%) or largely (33%) responsible for those changes. Our direct presentations to clubs have included an overview of impacts on Australian marine biota, and likely impacts of continuing change. Dissemination of results will further inform fishers on the level of impacts occurring. For many fishers, these impacts are largely positive with the increase tropical species available in the catch.

The research team are cautious about such optimism — broad scale habitat and community level change over the medium to longer term may not be so positive.

We have also documented adaptation and self management measures undertaken by spearfishers since at least the 1960s. There is great a great opportunity to better engage recreational user groups on this level, through firstly acknowledging the stewardship previously shown, and encouraging further consideration as appropriate.

3. Develop and test a process model for engagement and development of climate change adaptation options suitable for deployment to other fishing sectors and user groups, including commercial fishers.

The process model for engagement developed and implemented during this project has proven successful. Key elements include having stakeholders as members of the research team, being generous in the time allowed for developing relationships based on trust, and seeking direct pathways to members and governing bodies. These and other mechanisms are likely to be adaptable to a wide range of engagement activities and would benefit from further testing and refinement.

It is too early measure the impact of this project, ongoing outreach and communication activities will play an important role in ensuring the results are incorporated into future management and research.

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Appendix A **Intellectual Property**

No conditions other than those specified in the contract, of which the most pertinent is that spearfishing clubs retain all existing Intellectual Property for their records.

Appendix B Project staff

Staff engaged on the project

CSIRO

Daniel Gledhill	Principal Investigator
Alistair Hobday	Data analysis, engagement model development
Peter Last	Biogeography of marine fishers, ex-spearfisher
Matt Lansdell	Database design and management
Toni Cracknell	Data entry
Tanya Fisher	Data entry
Mina Brock	Data entry

C2O Fisheries

David Welch	Engagement model development, member liaison, AUF member and spearfisher

James Cook University

Stephen Sutton	Social scientist

Spearfisher representatives

Adrian Jeloudev	Underwater Skindivers and Spearfishermen's Association (NSW)
Matt Koopman	The Southern Freedivers (Vic)
Adam Smith	Australian Underwater Federation (national)

Appendix C **Project publications and extension**

The project publication outputs include three papers in preparation for peer-reviewed journals, three popular articles, a media release which received print, online and radio coverage, and a conference presentation.

A.1 Journal papers – in preparation

Paper 1. Daniel Gledhill, Alistair J. Hobday, Matthew Lansdell, David Welch, Stephen Sutton, Adrian Jeloudev, Matt Koopman, Adam Smith and Peter Last (in preparation) Trends in abundance and distribution of coastal fishes determined from recreational spearfisher competition records.

Paper 2: Sutton et al, (in preparation) spearfishers perceptions of climate change, fishery science and management.

Paper 3. Daniel Gledhill, Alistair J. Hobday, David Welch, Stephen Sutton, Adrian Jeloudev, Matt Koopman, Adam Smith and Peter Last (in preparation) Developing and evaluating an engagement framework: a case study with recreational spearfishers.

A.2 Media release

Fishers and scientists examine the past to understand a changing marine environment
CSIRO media release: http://www.csiro.au/en/Portals/Media/Changing-marine-environment.aspx - 3 September 2012. The project team will prepare a second release to publicise results of the project as well as the successful and positive collaboration between fishers and researchers.

Fishers and scientists examine the past to understand a changing marine environment

Fishers and scientists will be better informed about the impacts of a changing climate on coastal fish species, thanks to a new partnership.

3 September 2012

Competition records collected by fishing clubs over the past 50 years will be used by CSIRO scientists in a new project which aims to detect changes to fish distributions along the south-east Australian coast in response to warming coastal waters.

CSIRO Ichthyologist (zoologist specialising in the study of fish) Daniel Gledhill said they hope to understand how these changes will impact on the experience of recreational fishers and to better develop adaptation strategies for coastal communities.

> "Recreational users of coastal waters are often in the best position to see changes occurring locally."
> Daniel Gledhill, CSIRO Ichthyologist

'As marine species and fishing communities adapt to climate change, fishers are facing increased challenges. Ensuring sustainable use and management of coastal waters is becoming increasingly complex,' Mr Gledhill said.

Scientists will review historic records from New South Wales, Victorian and Tasmanian fishing clubs from as early as the 1960s.

'Long-term, statistically robust datasets of marine species are rarely available, so scientists are turning to novel, high-quality datasets such as those from spearfishing clubs to fill this knowledge gap. Spearfishing competition data sheets are a historical "biodiversity inventory" for recreational fish species,' Mr Gledhill said.

'Recreational users of coastal waters are often in the best position to see changes occurring locally. These records will provide us with a precious insight into how fish populations have moved as the East Australian Current (EAC) pushes southwards.'

'Geographic extensions of species ranges are already being recorded for recreationally targeted species in Australian waters,' Mr Gledhill said.

Coastal waters off the east coast of Tasmania are warming at 3–4 times the global average, largely resulting from the intensification of the EAC. These changes are bringing sub-tropical species to the state that have not been seen previously and are having detrimental impacts, for example, on endangered giant kelp forests and associated species.

Member of the Melbourne-based Southern Freedivers spearfishing club Dr Matt Koopman says changes in species are already being seen in Victoria.

'There are a couple of species that have been caught in Port Phillip Bay in the past 10 years that I'd never heard of in coastal Victorian waters,' Dr Koopman said.

In contrast, Underwater Skindivers & Fishermen's Association's Mr Adrian Jeloudev said some New South Wales fishers have noticed 'less movement of northern species down the

Media resources

Click image for high resolution version.

Our own 'Diver Dan' Gledhill will research fishing competition records from as early as the 1960s to detect changes to fish distributions due to warming coastal waters.

Spearfisher Adrian Jeloudev with a Wahoo (Acanthocybium solandri), a pelagic species known to follow warmer waters southwards. Photo from Adrian Jeloudev.

Spearfisher Matthew Koopman with a Wahoo (Acanthocybium solandri), pelagic species known to follow warmer waters southwards. Captured around Coffs Harbour. Photo from Matthew Koopman.

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A selection of media coverage is presented below:

International

27 September

Fishers and Scientists Examine the Past to Understand a Changing Marine Environment along Australia's South-East Coast. **Ocean News & Technology**

3 September

Spearfishers help to prove a point over climate change. **Fishnewseu**

National

3 September

Fishing competition records give clues. **BoatPoint**

Science turns to fish records. **The Coffs Coast Advocate**

Fishers and scientists examine the past to understand a changing marine environment. **Noodls Australia**

4 September

Compere: Celine Foenander. News headlines: Scientists will study the records of local fishing clubs to learn more about how fish are adapting to climate change. The CSIRO study will investigate fish distributions in Vic, NSW and Tas. Daniel Gledhill, CSIRO Researcher, says fish populations are moving but it is not known why. **ABC Gippsland, Sale** (2 identical items: Mornings 9.29am and news headlines 10.31)

Compere: Newsreader: Scientists will study the records of fishing clubs on the far South Coast and East Gippsland to learn more about marine life and how they are adapting to climate change. Daniel Gledhill, Researcher, CSIRO says scientists and recreational fishers know populations are moving but don't know why. Interviewee: Daniel Gledhill, Researcher, CSIRO. **ABC South East NSW, Bega** (2 items: 12.33 & 5.33pm)

Fishers, Scientists Examine Past to Understand Marine Environment. **The Fish Site**

5 September

Fishos records help research. **Coffs Coast Advocate, Coffs Harbour**

Examine the past to understand change. **Get Farming.**

6 September

The CSIRO says the competition records of local fishing groups will be used to study how climate change is affecting fish populations. The CSIRO will look at records from Vic, NSW, and Tas. Interviewee Daniel Gledhill, marine researcher, CSIRO. **ABC South Western Victoria, Warrnambool** (syndicated to the following station: ABC Ballarat)

7 September

Climate scientists ask fishers for help. **Carbon News**

10 September

Buddy diving to explore changing marine environment. **ECOS Magazine**

Fishing club records help in climate study. ***Daily Examiner***

12 September

Spearfishers and scientists examine the past to understand changing fish stocks
Department of Primary Industries Fish-e-Fax Newsletter Issue 321, ***The Observer***

14 September

Evidence fish are adapting to climate change. **ABC Rural/ABC Gippsland**

15 September

Speared for science. ***Courier Mail***

17 September

Scientists have been looking through records of spearfishing clubs from the last 3 decades to track climate change's impact on fish populations. Daniel Gledhill, ichthyologist with CSIRO, says they discovered fish populations were moving south, and the records were standardised and ideal for their purposes. Gledhill says a colleague who used to be a spearfisher suggested approaching clubs, and contact was made with the Australian Underwater Federation and the USFA. **Vic Country Hour, ABC Ballarat** (syndicated to the following (7) station(s): ABC Central Victoria (Bendigo), ABC Gippsland (Sale), ABC Goulburn Murray (Wodonga), ABC Mildura Swan Hill (Mildura), ABC Shepparton (Shepparton), ABC South Western Victoria (Warrnambool), ABC Western Victoria (Horsham).

A.3 Popular articles

The project team published three popular articles during the implementation phase of the project. Follow-up articles are planned to publicise the results and the productive collaboration.

1. *Marine Adaptation Bulletin*, Spring 2012 (vol, 4 #3) - General project overview.

Fishing for Data: what can novel datasets tell us about climate impacts and rec-fisher adaptation?

Dr Daniel Gledhill, Adaptation Research Grant Project Principal Investigator and Matt Lansdell, Data Manager, CSIRO's Climate Adaptation Flagship, CSIRO Marine and Atmospheric Research, Hobart Tasmania. Project title: 'Identification of climate-driven species shifts and adaptation options for recreational fishers: learning general lessons from a data rich case'. Project number: 2010/524 FRDC-DCCEE.

Competition score-sheets compiled over the past 50 years by New South Wales (NSW) and Victorian spearfishing clubs are being analysed for fish species extending their ranges southwards in response to warming coastal waters. Range extensions have been previously recorded for recreationally targeted species in Australian waters, and we are hoping to better understand the extent of these changes and their impact on recreational fishers.

The information we analyse will help recreational fishers adapt to changing conditions. Adaptation can be either a natural or directed response to change. For example, fish may adapt to warmer waters, and not show any change in distribution, while others may move considerable distances. In this project we are particularly interested in helping 'adaptation' by fishers - and understanding the possible changes in their activities in response to warming marine waters. We already know that many fishers are already adapting, and the targeting of new fish species in private trips or competitions is but one example. Changing species observed along the coastline may also mean that some fish are becoming less common, so longer trips may be needed to catch these species now, and in the future. There may be changes in the availability of preferred species for eating – which may also impact on the recreational experience. Overall, by understanding changes along the coast, and adapting to them in a sustainable way, we hope to ensure that fishing continues to be enjoyed by many Australians.

This project (Adaptation Research Grant 2010/524 FRDC-DCCEE) is a partnership between recreational spearfishers and project scientists, with researchers working with club representatives to locate and collate records. Spearfishing competitions are held through the warmer months and may involve dozens of divers, with fish captures recorded on pre-printed score-sheets that specify target species, minimum sizes and points for each species. Competitions are hotly contested and species identifications and data integrity are therefore closely monitored to ensure points are awarded fairly. Like many community clubs, competitions rely on a dedicated core team of organisers, ensuring consistent record keeping and high quality species identifications.

There are few long-term, high quality recreational fishing data from which to compile a baseline of fish distributions prior to recent rapid change. The level of organisation, competition and consistency in identifications from spearfisher competitions therefore make these records highly valued for studying change over recent decades and will provide a baseline and 'sampling' for the period.

It is common to hear stories of data being lost, or thrown out, so finding and accessing data has been a challenging exercise. Having diver representatives as members of the research team has been essential to building relationships and gaining support for the project, as well as assisting with interpretation of results. Clubs have nominated a liaison officer to represent them in the project team who will also co-author papers and reports, ensuring involvement in analysis, interpretation and reporting.

The project team has been entering many years of spearfishing competition records from NSW and Victoria. Data from more than 250 competitions from each state has been entered. Researchers will meet with club members in November 2012 to report results and to seek assistance with interpretation. One of the great benefits to clubs and researchers will be that digitised data (along with the old competition score-sheets) are provided and future updates to the database can occur, making club record-keeping easier and more comprehensive.

We are also working to better understand the past experience of fishers working with management and scientists, and their perceptions of the rate and cause of change. Stephen Sutton, a James Cook University researcher, is leading these aspects of the project, and will survey members to better understand their experience.

The collaborative project between the CSIRO Climate Adaptation National Research Flagship, James Cook University and the Australian Underwater Federation, is working directly with spearfishing representative bodies, Southern Freedivers from Victoria, and the Underwater Skindivers & Fishermen's Association from New South Wales. The project is supported by funding from the Australian Government Fisheries Research and Development Corporation and the Department of Climate Change and Energy Efficiency. Results of the project are expected to be available in May 2013.

For more information regarding this article please contact: Daniel.Gledhill@csiro.au, or Matt.Lansdell@csiro.au.

Drowning in data: Matt Lansdell keeps track of data entry while surrounded by archive boxes containing historic catch records.

Spearfisher and project liaison Adrian Jeloudev with a Wahoo (*Acanthocybium solandri*), a pelagic species known to follow warmer waters southwards. Photo from Adrian Jeloudev.

Spearfisher and project liaison Matthew Koopman with a Wahoo (*Acanthocybium solandri*), captured around Coffs Harbour. Photo from Matthew Koopman.

Two

2. *Spearfishing Downunder* Oct-Nov 2012 (#39). Overview of the project and discussion of movement in marine biota.

Spearfishers partner with scientists to track changes in distributions of coastal fishes.

BY DANIEL GLEDHILL, DAVID WELCH AND ALISTAIR HOBDAY

Readers have probably heard reports of unusual tropical and subtropical fishes captured in southern waters. Or perhaps you've already landed a few?

But what do these reports mean, are these southward excursions becoming more common, or are they simply part of natural long-term cycles?

The Australian Underwater Federation (AUF) along with members of the Underwater Skindivers and Fishermen's Association (USFA), NSW and Southern Freedivers (SFD), Vic. have partnered with a team of scientists to help understand and interpret data from spearfishing competitions dating from the 1960's.

Compared to other regions of the world, there are few long-term datasets of marine species for Australia. Scientists are therefore increasingly turning to novel, high-quality datasets such as those from spearfishing clubs to fill this knowledge gap. These data can provide a historical "biodiversity inventory" for recreational fishes.

Additionally, recreational users of coastal waters, in particular spearfishers, are often in the best position to see changes occurring locally. These records will provide one of the few opportunities to assess changes that may be occurring in our coastal waters over this extended time period.

But so what, fish move all the time!

Fish are generally mobile, especially large pelagic species such as wahoo and mackerels, with well known seasonal movements. But most species don't live everywhere in the ocean - marine waters aren't all the same; properties such as water temperature, depth, salinity, and food availability all combine to restrict a species distribution around Australia. For bottom dwelling, or demersal species, availability of physical habitat and bottom substrate can also be important limiting factors.

Pelagic species

Open water species often have highly seasonal distributions and respond to ocean currents, such as the East Australian Current (EAC). Species may follow currents due to their own temperature requirements or to follow prey species. Currents may vary seasonally and annually, but we're recording significant long-term change in some currents. For example the southern limit of the EAC has extended southwards by about 350km since 1944, and over the last 100 years sea surface temperatures in south eastern Australia have warmed much faster (by ~2.3°C) than the global average rate (about 0.7°C). Warmer water currents and eddies can often carry species further south than commonly encountered. Given the variable nature of currents, long-term data are needed before we can try to understand change at these scales.

Demersal species

Bottom-associated species have also been recorded further south than anytime in recent history. For these species, the lowest winter temperatures may be what prevent species from establishing. So as coastal waters warm, we may see species surviving winters further south and establishing breeding populations in waters where they've not previously been recorded. New sightings of rocky-reef species have been recorded off Tasmania since the 1980s (see Redmap for examples: http://www.redmap.org.au/), and sightings in unusual locations are also being recorded in other states.

USFA's Environment Officer, Adrian Jeloudev with a Spanish Mackerel caught over shallow reef off Tweed Heads earlier this year. Large pelagics like this have been successfully speared off Terrigal and Sydney in recent seasons.

The project team have been entering many years of spearfishing competition records from NSW and Victoria and analyses of these data is underway. The results will be discussed with club members and one of the great benefits will be that digitized data from old competition score sheets will be provided to clubs and updates to this database can occur into the future, making club record keeping easier and more comprehensive.

What does adaptation mean?

This information we analyse will help recreational fishers adapt to changing conditions. Adaptation can be either a natural or directed response to change. For example, fish may adapt to warmer waters, and not show any change in distribution along the coast, while others may move considerable distances. In this project we're particularly interested in helping 'adaptation' by fishers - and understanding the possible changes in their activities in response to warming marine waters. We already know that many fishers are already adapting and the targeting of new fish species in private trips or competitions is but one example. Changing species along the coastline may also mean that some kinds of fish are less common and so longer trips may be needed to catch these species. Also fishers could adapt by altering point scoring systems in fishing competitions in response to both new and disappearing local species. Overall, by understanding the changes along the coast, and adapting to them, we hope to ensure that fishing continues to be a past-time safely enjoyed by many Australians.

Participants

The project is a collaboration between CSIRO's Climate Adaptation National Research Flagship, James Cook University and the Australian Underwater Federation, and is working directly with spearfishing clubs and representative bodies, the Southern Freedivers in Victoria and the Underwater Skindivers & Fishermen's Association in New South Wales. The project is supported by funding from the Fisheries Research and Development Corporation, and the Department of Climate Change and Energy Efficiency on behalf of the Australian Government. Results of the project are expected to be available in May 2013 so look out for the next article that will present what the data tells us.

If you would like further information you can contact:

Daniel Gledhill on (03) 6232 5222 or Dave Welch on 0414 897 490

Daniel and Alistair are from CSIRO's Climate Adaptation Flagship, CSIRO Marine and Atmospheric Research in Hobart, and David is the AUF representative on the project.

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3. *Australian Society for Fish Biology Newsletter* December 2012 (Vol 42 #2). Overview of the project and discussion data compilation and digitisation.

Working with recreational fishers to better understand future climate impacts and opportunities for adaptation

Daniel Gledhill and Matt Lansdell, CSIRO's Climate Adaptation Flagship, CSIRO Marine and Atmospheric Research, Hobart Tasmania.

Competition score-sheets compiled over the past 50 years by New South Wales (NSW) and Victorian spearfishing clubs are being analysed for evidence of fish species extending their ranges southwards in response to warming coastal waters.

Range extensions have been previously recorded for recreationally targeted species in Australian waters, and we are hoping to better understand the extent of these changes and their impact on recreational fishers.

The information we analyse will help recreational fishers adapt to changing conditions. Adaptation can be either a natural or directed response to change. For example, fish may adapt to warmer waters, and not show any change in distribution, while others may move considerable distances. In this project we are particularly interested in helping 'adaptation' by fishers - and understanding the possible changes in their activities in response to warming marine waters. We already know that many fishers are already adapting, and the targeting of new fish species in private trips or competitions is but one example. Changing species observed along the coastline may also mean that some fish are becoming less common, so longer trips may be needed to catch these species now, and in the future. There may be changes in the availability of preferred species for eating – which may also impact on the recreational experience. Overall, by understanding changes along the coast, and adapting to them in a sustainable way, we hope to ensure that fishing continues to be enjoyed by many Australians.

This project is a partnership between recreational spearfishers and project scientists, with researchers working with club representatives to locate and collate records. Spearfishing competitions are held through the warmer months and may involve dozens of divers, with fish captures recorded on pre-printed score-sheets that specify target species, minimum sizes and points for each species. Competitions are hotly contested and species identifications and data integrity are therefore closely monitored to ensure points are awarded fairly. Like many community clubs, competitions rely on a dedicated core team of organisers, ensuring consistent record keeping and high quality species identifications.

Spearfisher and project liaison officer Matthew Koopman with a Wahoo (*Acanthocybium solandri*) caught around Coffs Harbour. Photo by Matthew Koopman

A.4 Conference presentations

Project results relating to the engagement aspects of the project were presented at the NCCARF conference, June 2013.

Gledhill et al., (2013) **Developing and evaluating an engagement framework: a case study with recreational spearfishers**.

The impacts of climate change and the development of adaptation options can seem remote from many in the non-scientific community – and thus may represent a barrier to widespread engagement and action. Some community groups, however, collect high quality data for a range of reasons, and these data may be useful for detecting climate impacts and planning adaptation.

One leading example is high quality information collected as part of recreational spearfishing competitions which represents one of few long-term datasets available for Australian recreational coastal fisheries. These data, collected during competitions dating to the 1960s, could therefore provide further detail of species range extensions in response to warming waters in eastern Australia, as well as assist an active group of ocean users consider their options as fish change distribution and availability under a changed climate. However, accessing these data for scientific study is complicated by what is considered by many spearfishers as an unfavourable history of interaction with science and management. We engaged in an extensive consultation process with spearfishing representative bodies to assess data suitability and availability, and interest in conducting a collaborative research project. Each party could foresee benefit from a utilising the data, and importantly, the concerns and interests of each party could also be protected or mitigated to an acceptable level. After reaching an in-principal agreement to utilise data, we embarked on a project within the National Climate Change Adaptation Research Plan (NARP) framework in 2011.

We've used this often challenging project to develop a process model for engagement, which may be suitable with other community groups. Additionally we have documented autonomous adaptation measures previously undertaken within organised spearfishing competitions, and consider the suitability of autonomous versus directed adaptation using recreational spearfisher as an example community group.

Appendix D

Attendees at Hobart team workshops

Initial researcher team meeting, Hobart February 2011

Attendees	Organisation
Daniel Gledhill	CSIRO Marine & Atmospheric Research
David Welch	C2O Fisheries, & Australian Underwater Federation
Alistair Hobday	CSIRO Marine & Atmospheric Research
Stephen Sutton	James Cook University
Matt Lansdell	CSIRO Marine & Atmospheric Research
Barry Bruce	CSIRO Marine & Atmospheric Research
Apologies:	
Peter Last	CSIRO Marine & Atmospheric Research
Adam Smith	Australian Underwater Federation

Final researcher team meeting, Hobart October 2012.

Attendees	Organisation
Daniel Gledhill	CSIRO Marine & Atmospheric Research
David Welch	C2O Fisheries, & Australian Underwater Federation
Alistair Hobday	CSIRO Marine & Atmospheric Research
Stephen Sutton	James Cook University
Matt Koopman	The Southern Freedivers
Peter Last	CSIRO Marine & Atmospheric Research
Toni Cracknell	CSIRO Marine & Atmospheric Research
Apologies:	
Adam Smith	Australian Underwater Federation
Adrian Jeloudev	Underwater Skindivers and Spearfishermen's Association
Matt Lansdell	CSIRO Marine & Atmospheric Research

Appendix E NSW member survey

A survey of spearfishing club members was designed by the project team to collect information about club members': 1) beliefs and actions regarding engagement in fisheries decision-making; 2) beliefs and attitudes towards sharing of spearfishing club data with scientists; 3) beliefs and attitudes about climate change and its potential effects on the marine environment; and 4) observations of past changes in the marine environment and beliefs about the causes of those changes.

The NSW survey is included in here. The Victorian survey was identical to the NSW survey except for references to the name of the club being surveyed in the introduction and Question #10.

USFA Survey

11%

Welcome to the 2012 USFA Survey!

This survey is being conducted as part of a collaborative project involving the Australian Underwater Federation, CSIRO, James Cook University, the Underwater Skindivers & Fishermen's Association (USFA) in New South Wales, and Southern Freedivers in Victoria.

The project has two main aims:

1) To understand and highlight the value of spearfishing organizations' long-term fishing activity and catch datasets for informing and describing changes in the marine environment, including those resulting from warming waters as a result of climate change.

2) To demonstrate how collaborations between spearfishers and scientists can increase the capacity of the spearfishing community to become meaningfully involved in fisheries decisions that affect them.

You are being invited to participate in this survey because you are a member of the USFA. The purpose of this survey is to get a better understanding of spearfishers' beliefs and attitudes about climate change and its potential impacts, the value of spearfishers' data and personal observations for exploring climate change impacts, and issues surrounding the sharing of spearfishers' data with scientists. The results of this survey will be used to help improve opportunities for spearfishers to have a say in management decisions affecting the marine resources that they depend on.

Participation in this survey is voluntary and all the information you give us is strictly confidential. No names, addresses, or other identifying information is recorded on the questionnaire so your responses to questions cannot be traced to you. The information you provide will be used in reports and publications which will be provided to all of the collaborating spearfishing organizations. If you have any questions regarding this survey, please contact one of the people listed below:

Daniel Gledhill (CSIRO)
(03) 6232 5363
Daniel.Gledhill@csiro.au

Steve Sutton (JCU)
(07) 4781 5510
stephen.sutton@jcu.edu.au

Adrian Jeloudev (USFA)
adrian.jeloudev@gmail.com

If you have any questions or concerns regarding the ethical conduct of this survey, please contact Sophie Thompson, Human Ethics and Grants Administrator, James Cook University on (07) 4781 6575 or Sophie.Thompson@jcu.edu.au.

Next

1. In the last 12 months, approximately how many days did you do go:

Recreational fishing (all methods) [ ]

Spearfishing [ ]

2. Compared to other outdoor recreation activities that you participate in (such as boating, diving, swimming, tennis, etc.), would you say recreational fishing (including spearfishing) is:

- ◯ Your most important outdoor activity
- ◯ Your second most important outdoor activity
- ◯ Your third most important outdoor activity
- ◯ Only one of many outdoor activities you participate in

3. How many years have you been recreational fishing (all methods)?

Years recreational fishing [ ]

4. How many years have you been spearfishing?

Years spearfishing [ ]

5. We are interested in understanding and documenting any changes (positive or negative) that spearfishers have noticed in fisheries resources and/or the marine environment over time.

In the space below, please tell us about any changes you have noticed in the areas that you fish. These could be changes in the size, number, or availability of certain fish species, or other positive or negative environmental changes that you have noticed. We are particularly interested in finding out how long you have been noticing these changes, how they have affected your spearfishing activity, and what you believe the causes of these changes to be.

The following questions (6-9) are aimed at understanding spearfishers' opinions about their level of consultation in fisheries management decisions, their previous levels of involvement in consultation processes, and their levels of knowledge and trust regarding fisheries science and management. Your answers to these questions will help us gain a better understanding of how spearfishers' involvement in the decision making process can be improved.

6. Please indicate the extent to which you agree or disagree with each of the following statements:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Spearfishers and scientists have many common goals concerning the management and conservation of marine resources	○	○	○	○	○
Compared to other groups (e.g., commercial fishers, tourism), spearfishers receive fair treatment in marine resource management decisions	○	○	○	○	○
Spearfishers and resource managers have many common goals concerning the management and conservation of marine resources	○	○	○	○	○
I trust resource managers to do what is best for conservation of marine resources	○	○	○	○	○
I have a good understanding of how information collected by scientists is used in marine resource management	○	○	○	○	○
Scientists have a good understanding of spearfishing and spearfishers	○	○	○	○	○
Resource managers have a good understanding of spearfishing and spearfishers	○	○	○	○	○
I trust resource managers to consider the concerns of spearfishers when making decisions about management of marine resources	○	○	○	○	○
Spearfishers are well informed about how our interests are considered in decisions regarding management of marine resources	○	○	○	○	○
Spearfishers are adequately consulted about marine resource management decisions	○	○	○	○	○

7. Have you ever attended a public meeting about a fisheries-related issue?

○ No

○ Yes

If Yes, what issue(s)?

[   ]

8. Have you ever made a submission to a government agency (e.g., Fisheries New South Wales) as part of a formal consultation process about a fisheries-related issue?

- ◯ No
- ◯ Yes

If Yes, what issue(s)?

9. Have you ever contacted your government representative about a fisheries-related issue?

- ◯ No
- ◯ Yes

If Yes, what issue(s)?

10. As you may be aware, the Underwater Skindivers & Fishermen's Association has entered into an agreement to share the organization's data about its historical fishing activity and catches with scientists at the CSIRO. These scientists will analyze the data in close collaboration with representatives from the Underwater Skindivers & Fishermen's Association to look for climate change-related changes in the abundance and distribution of key fish species. This question is aimed at understanding your beliefs about the value of spearfishers' data, and your beliefs about how that data should or should not be shared and used.

Please indicate the extent to which you agree or disagree with each of the following statements about the use of spearfishers' data in support of marine resource research and management:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I trust scientists to consider the interests of spearfishers when using the data we share with them	○	○	○	○	○
It is important to include information collected by resource users (such as spearfishers) in marine resource management decisions	○	○	○	○	○
Data collected by spearfishers will not be very useful to scientists because it is not scientific	○	○	○	○	○
Sharing our data with scientists will help improve the engagement of spearfishers in decisions that affect us	○	○	○	○	○
If spearfishers have data that can be beneficial for marine management and conservation, we should share it freely with scientists	○	○	○	○	○
When spearfishers share data about our activities with scientists, there is a risk that our data will used against us	○	○	○	○	○
Long-term data collected by spearfishers can help educate the general public about marine resource use, management, and conservation issues	○	○	○	○	○
Sharing our data with scientists will lead to a better relationship between spearfishers and scientists	○	○	○	○	○
Sharing out data with scientists will lead to a better relationship between spearfishers and marine resource managers	○	○	○	○	○
When spearfishers share our data about our activities with scientists, we must be sure that we maintain control over how that data is used	○	○	○	○	○
I trust scientists to honor agreements they make with us about how our spearfishing data can and cannot be used	○	○	○	○	○
Long-term data collected by spearfishers can help understand and describe changes that may be occurring in the ocean environment over time	○	○	○	○	○
Spearfishers should only share data that we collect about our activities when we are assured that our data will be used to benefit spearfishers	○	○	○	○	○

One of the aims of this collaborative project is to assess the value of spearfishers' data for investigating the effects of climate change on the marine environment. The following questions (11-21) are aimed at gaining a better understanding of spearfishers' beliefs, attitudes, and knowledge about climate change and its potential effects on the marine environment. Your answers to these questions will help us understand whether participatio in this project has any effect on spearfishers' attitudes, beliefs and knowledge regarding climate change.

11. Most climate scientists now agree that there have been substantial changes to the Earth's climate over the past 25 years. Please select the statement below that best summarizes your beliefs about climate change and our (human) influence on it:

- ◯ There have been substantial changes to the Earth's climate over the past 25 years, but humans are not responsible for those changes
- ◯ There have been substantial changes to the Earth's climate over the past 25 years; humans are partially responsible for those changes, but some of the changes are also due to natural factors
- ◯ There have been substantial changes to the Earth's climate over the past 25 years, and humans are largely responsible for those changes
- ◯ I do not believe that there have been substantial changes to the Earth's climate over the past 25 years
- ◯ I have no opinion/do not know if there have been substantial changes to the Earth's climate over the past 25 years

12. How concerned are you about climate change in general?

- ◯ Not at all concerned
- ◯ Moderately concerned
- ◯ Very concerned

13. How necessary do you think it is to take steps to reduce greenhouse gas emission that are thought to cause climate change?

- ◯ Not at all necessary
- ◯ Moderately necessary
- ◯ Very necessary
- ◯ Don't know

14. How concerned are you about potential negative effects of climate change on the fisheries resources that you use?

- ◯ Not at all concerned
- ◯ Moderately concerned
- ◯ Very concerned

15. What impact do you think climate change has already had on the areas of the ocean that you use?

- ◯ Very negative
- ◯ Somewhat negative
- ◯ No impact
- ◯ Somewhat positive
- ◯ Very positive
- ◯ Don't know

16. Overall, what impact do you think climate change will have on the fisheries resources that you use...

	Very negative	Somewhat negative	No impact	Somewhat positive	Very positive	Don't know
... over the next 12 months	◯	◯	◯	◯	◯	◯
... over the next 5 years	◯	◯	◯	◯	◯	◯
... over the next 25 years	◯	◯	◯	◯	◯	◯

17. How interested are you in being involved in developing local strategies to help reduce the negative impact of climate change on the fisheries resources that you use?

- ◯ Not at all interested
- ◯ Moderately interested
- ◯ Very interested

18. Are you aware of any actions that you can take to reduce the negative impact of climate change on the fishery resources that you use?

- ◯ No
- ◯ Yes

If Yes, please describe. Which of these actions are you currently taking?

19. What is your age?

Years [ ]

20. Are you:

- ◯ Male
- ◯ Female

21. What is the highest level of education you have obtained?

- ◯ Primary
- ◯ Secondary
- ◯ Trade or Technical (including TAFE)
- ◯ Tertiary

22. How many years have you been a member of a spearfishing organization?

Years [ ]

23. Is there anything else that you would like to tell us?

Appendix F **Example score sheet from a Victorian championship held in November 1990.**

The sheet records target species and associated points, individual diver catch, and in this case, additional specimens retained. The competitor’s name has been removed. Note that species present on score sheets have been modified over time, and this example does not reflect current scoresheets.

DAY 1

VICTORIAN BRANCH

24-11-90

SCORE SHEET

NAME:

CLUB: DANDENONG

GRADE: A

COMPETITION: C.R. CHAMPS PYRAMID ROCK

TOTAL SCORE: 947.6

NO. OF SPECIES: 8

A SCALE 340g + 1 % WT	PTS	WT
BARBER PERCH	125	
BEARDIE	125	
BUTTERFLY PERCH	125	
DEEP BODIED LJ	125	
FLOUNDER	125	
GURNARD PERCH	125	
KING GEORGE WHITING	(125)	580
LJ OTHERS X S L M R	(125)	400
LONGFIN PIKE	125	
RED MULLET	125	
SAND MULLET	125	
SILVER SPOT COD	125	
TREVALLY	(125)	540
TRUE SWEEP	125	
YELLOW EYE MULLET	125	
A SCALE BONUS 340g + 1 % WT		
BLUE MORWONG	150	
BLACK BREAM	150	
JACKASS FISH	150	
SILVER DORY	150	
SOLE	150	
TOTAL PTS		
TOTALS 390.2		

B SCALE 400g + 1 % Wt	PTS	WT
BANDED MORWONG	100	
BEARDED ROCK COD	100	
BLACK DRUMMER	100	
BLACK PARROTFISH 360 X 360 X	100	
BLUE THROAT	(100)	910
HORSESHOE LJ	(100)	710
LING	(100)	3130
LONG SNOUT BOAR FISH	100	
MAGPIE PERCH	(100)	520
ROCK FLATHEAD	100	
SAND FLATHEAD	100	
SEA SWEEP	(100)	470
SIX SPINED LJ X 350	100	
SNOOK	100	
SOUTHERN GROUPER	100	
SQUID	100	
TRUMPETER	100	
ZEBRA FISH	100	
B SCALE BONUS 400g + 1 % Wt		
WAREHOU	125	
BARRACOUTA	125	
QUEEN SNAPPER	125	
SALMON	125	
SERGEANT BAKER	125	
SNAPPER	125	
C SCALE 1000g + 1 % Wt	PTS	
DUSKY MORWONG	100	
STARGAZER	100	
C SCALE BONUS 1000g + 1 % Wt		
KINGFISH	125	
MULLOWAY	125	
TUNA	125	
D SCALE 1000g + .5% Wt		
CONGER EEL	100	
PTS —		

Appendix G **Example summary score sheet from a Victorian competition held in February 1982.**

The sheet records totals for individual species and associated points. Note that species present on score sheets have been modified over time, and this example does not reflect current scoresheets.

3rd HANNAN
2ND CUMBERLAND.

DIVE SUMMARY

Date of Comp. 2/82

Location WALKERVILLE

Sign-on 13

Conditions GOOD. Vis-50'

BOAT COMP

Fish Speared	1st Day No. Fish	1st Day Av. Wt.	2nd Day No. Fish	2nd Day Av. Wt.	Total No. Fish	Total Av. Wt.	Total Wt.
* BARBER PERCH							
BEARDIE	1	500					500
BLUE MORWONG							
BLUE ROCK WHITING							
**BUTTERFLY PERCH	1	360					360
DEEP BODIED L.J.							
FLOUNDER							
GREY COD							
GROUPER							
GURNARD PERCH							
JACKASS FISH							
* K.G. WHITING	5	414					2070
* LONGFIN PIKE	1	660					660
* LUDERICK	2	500					1000
MOTTLED L.J.							
MOONLIGHTER							
RED MULLET	1	380					380
* SAND MULLET							
SILVER DORY							
SILVER SPOT COD							
SOLE							
* TREVALLY							
* TRUE SWEEP	1	430					430
WEED FISH							
* YELLOW EYE MUL.							
BANDED MORWONG	9	1380					12420
* BARRACOUTA							
BEARDED ROCK COD	2	725					1450
* BLACK DRUMMER	3	1003					3010
BLACK PARROT	7	675					4730
BLUETHROAT	9	1294					11650
HORSESHOE L.J.							
LING							
LONG SNOUT B/F	5	614					3070
MAGPIE PERCH	10	981					9810
QUEEN SNAPPER							
ROCK FLATHEAD							
* SALMON							
SAND FLATHEAD							
* SEA SWEEP	8	807					6460
SERGEANT BAKER							
* SILVER DRUMMER	1	1940					1940
SIX SPINED L.J.	5	1220					6100
* SNAPPER							
* SNOOK							
STARGAZER							
* SQUID							
* TRUMPETER	5	914					4570
* WAREHOU							
* ZEBRA FISH	8	754					6070
* DUSKY MORWONG	2	1300					2600.
* MULLOWAY							
* KINGFISH							
* TUNA	87						
CONGER EEL							
* GARFISH							

Appendix H

Summary data for 50 most common NSW species

Table displays significant changes for four variables measured: commonness; average size (grams); average number caught per competition per year; and average catch per diver (ACPD).

Rank	CAAB Code	Scientific name	Common name	# Comps	Occurrence	Size	Count	ACPD
1	37377009	*Cheilodactylus fuscus*	Red Morwong	311	incr	incr	incr	incr
2	37361007	*Girella tricuspidata*	Luderick	303	incr		incr	incr
3	37361006	*Girella elevata*	Rock Blackfish	297	incr		incr	incr
4	37465036	*Meuschenia freycineti*	Sixspine Leatherjacket	287	incr	incr	incr	incr
5	37465039	*Eubalichthys bucephalus*	Black Reef Leatherjacket	281	incr	decr	incr	incr
6	37117001	*Aulopus purpurissatus*	Sergeant Baker	274	incr		incr	
7	37361009	*Scorpis lineolata*	Silver Sweep	258	incr	decr		decr
8	37287066	*Scorpaena jacksoniensis*	Eastern Red Scorpionfish	257	incr		incr	incr
9	37327002	*Dinolestes lewini*	Longfin Pike	254	incr		incr	
10	37465003	*Eubalichthys mosaicus*	Mosaic Leatherjacket	253	incr		incr	incr
11	37465059	*Meuschenia trachylepis*	Yellowfin Leatherjacket	252	incr			
12	37378002	*Latridopsis forsteri*	Bastard Trumpeter	249	incr		incr	incr
13	37228899	Ling - group code	Ling	244	incr	incr	incr	incr
14	37377004	*Nemadactylus valenciennesi*	Blue Morwong	234	incr		incr	
15	37361001	*Kyphosus sydneyanus*	Silver Drummer	232	incr	decr	incr	incr
16	37337062	*Pseudocaranx dentex*	Silver Trevally	222	incr	decr	incr	
17	37437035	*Prionurus microlepidotus*	Australian Sawtail	210	incr		incr	
18	37311090	*Acanthistius ocellatus*	Eastern Wirrah	194		incr	incr	decr
19	37465007	*Scobinichthys granulatus*	Rough Leatherjacket	194	incr		incr	decr
20	37344002	*Arripis trutta*	Eastern Australian Salmon	186	incr		incr	
21	37384097	*Coris sandeyeri*	Eastern King Wrasse	175	incr	decr		
22	37355000	Mullidae - undifferentiated	goatfishes	163	incr		incr	decr
23	37437034	*Prionurus maculatus*	Spotted Sawtail	163	incr		incr	
24	37384041	*Notolabrus gymnogenis*	Crimsonband Wrasse	155				decr
25	37337006	*Seriola lalandi*	Yellowtail Kingfish	150	incr			
26	37353899	Acanthopagrus spp	Bream	149	incr	decr	incr	incr
27	37376002	*Aplodactylus lophodon*	Rock Cale	143	decr			decr
28	37377006	*Cheilodactylus spectabilis*	Banded Morwong	131			incr	
29	37441020	*Sarda australis*	Australian Bonito	131	incr			
30	37355015	*Parupeneus spilurus*	Blacksaddle Goatfish	129	incr	decr	incr	incr
31	37353003	*Acanthopagrus butcheri*	Black Bream	127			incr	
32	37353013	*Rhabdosargus sarba*	Tarwhine	122	incr			
33	37361008	*Girella zebra*	Zebrafish	99	incr		incr	incr
34	37334002	*Pomatomus saltatrix*	Tailor	95	incr			
35	37385001	*Olisthops cyanomelas*	Herring Cale	95				decr
36	37234014	*Hyporhamphus australis*	Eastern Sea Garfish	87				
37	37337007	*Seriola hippos*	Samsonfish	85	incr			decr
38	37361004	*Scorpis aequipinnis*	Sea Sweep	76	incr			
39	37367003	*Pentaceropsis recurvirostris*	Longsnout Boarfish	72	incr		incr	incr
40	37296004	*Platycephalus fuscus*	Dusky Flathead	66	incr		decr	
41	37384003	*Notolabrus tetricus*	Bluethroat Wrasse	66				
42	37465009	*Monacanthus chinensis*	Fanbelly Leatherjacket	62	incr			
43	37337025	*Seriola dumerili*	Amberjack	61	incr			
44	37384040	*Ophthalmolepis lineolatus*	Southern Maori Wrasse	60		decr		
45	37438000	*Siganidae - undifferentiated*	Rabbitfish	55	incr			
46	37353001	*Pagrus auratus*	Snapper	53	incr			
47	37354001	*Argyrosomus hololepidotus*	Mulloway	45				
48	37382002	*Sphyraena novaehollandiae*	Snook	40				
49	37367002	*Paristiopterus labiosus*	Giant Boarfish	36		decr		
50	37465022	*Aluterus monoceros*	Unicorn Leatherjacket	36	incr			

Appendix I Summary data for 50 most common Victorian species

Table displays significant changes for four variables measured: commonness; average size (grams); average number caught per competition per year; and average catch per diver (ACPD).

Rank	CAAB Code	Scientific name	Common name	# Comps	Occurrence	Size	count	ACPD
1	37384003	*Notolabrus tetricus*	Bluethroat Wrasse	264			decr	
2	37384021	*Notolabrus fucicola*	Purple Wrasse	256			decr	
3	37377001	*Cheilodactylus nigripes*	Magpie Perch	252			decr	
4	37361008	*Girella zebra*	Zebrafish	244		decr		incr
5	37377005	*Dactylophora nigricans*	Dusky Morwong	232			decr	
6	37361004	*Scorpis aequipinnis*	Sea Sweep	228				incr
7	37465036	*Meuschenia freycineti*	Sixspine Leatherjacket	224			decr	
8	37377006	*Cheilodactylus spectabilis*	Banded Morwong	184			decr	
9	37378002	*Latridopsis forsteri*	Bastard Trumpeter	178			decr	
10	37465004	*Meuschenia hippocrepis*	Horseshoe Leatherjacket	176				
11	37355000	Mullidae - undifferentiated	goatfishes	163	decr	decr		
12	37327002	*Dinolestes lewini*	Longfin Pike	155		decr	decr	
13	37367003	*Pentaceropsis recurvirostris*	Longsnout Boarfish	155			decr	
14	37224003	*Pseudophycis barbata*	Bearded Rock Cod	127	incr		decr	
15	37382002	*Sphyraena novaehollandiae*	Snook	124			decr	
16	37330001	*Sillaginodes punctata*	King George Whiting	121				incr
17	37465903	Monacanthidae - undifferentiated	leatherjacket	104	decr		decr	
18	37385001	*Olisthops cyanomelas*	Herring Cale	89	decr		decr	
19	23615000	Squid group code	squid	84	decr	decr	decr	
20	37228008	*Genypterus tigerinus*	Rock Ling	79				
21	37465035	*Meuschenia flavolineata*	Yellowstriped Leatherjacket	79			decr	
22	37465034	*Eubalichthys gunnii*	Gunn's Leatherjacket	77				
23	37067007	*Conger verreauxi*	Southern Conger	73	decr			incr
24	37465040	*Meuschenia galii*	Bluelined Leatherjacket	62	incr			
25	37344002	*Arripis trutta*	Eastern Australian Salmon	61				
26	37361006	*Girella elevata*	Rock Blackfish	60				
27	37361001	*Kyphosus sydneyanus*	Silver Drummer	56				
28	37311003	*Caesioperca rasor*	Barber Perch	50			decr	
29	37384899	*Notolabrus* spp.	wrasse	47		decr	decr	decr
30	37296006	*Platycephalus laevigatus*	Rock Flathead	42			incr	incr
31	37465002	*Acanthaluteres vittiger*	Toothbrush Leatherjacket	41	decr			
32	37337004	*Pseudocaranx georgianus*	Silver Trevally	40			decr	
33	37361003	*Tilodon sexfasciatus*	Moonlighter	36	decr			
34	37375002	*Chironemus maculosus*	Silver Spot	35				
35	37296003	*Platycephalus bassensis*	Southern Sand Flathead	34				
36	37465008	*Meuschenia australis*	Brownstriped Leatherjacket	32			decr	
37	37353001	*Pagrus auratus*	Snapper	31				
38	37117001	*Aulopus purpurissatus*	Sergeant Baker	30		decr	decr	
39	37366001	*Enoplosus armatus*	Old Wife	28	decr		decr	decr
40	37372006	*Parma victoriae*	Scalyfin	28	decr		decr	decr
41	37445901	*Seriolella punctata & brama*	Warehou	28	decr			incr
42	37460000	Mixed flounder	Flounder	28				
43	37224899	*Lotella sp*	Beardie	25	decr	decr		
44	37361009	*Scorpis lineolata*	Silver Sweep	25		decr		
45	37234001	*Hyporhamphus melanochir*	Southern Garfish					
46	37465003	*Eubalichthys mosaicus*	Mosaic Leatherjacket	23				
47	37337000	Carangidae - undifferentiated	trevallies	20	incr			
48	37361007	*Girella tricuspidata*	Luderick	19	decr			
49	37381001	*Aldrichetta forsteri*	Yelloweye Mullet	19				
50	37287899	Neosebastidae not defined	Gurnard Perch	18				

Appendix J Responses to open-ended survey question 5 indicating a negative change in environmental conditions

Table AS1. Comments received from survey question 5 (what changes have you noticed in the marine environment in the areas that you fish, and what do you believe the cause(s) of these changes to be?) indicating a negative change in environmental conditions. ID numbers 1-133 are from respondents to the NSW survey; ID numbers greater than 133 are from respondents to the VIC survey. Comments with the same ID number are from the same respondent.

ID	Comment indicating a negative change in environmental conditions	Species Mentioned	Driver Cited	Driver Type
4	More legal snapper were caught in when fishing the structured areas of broken bay such as Flint and Steel reef, lion Island and various other coves. Our best guess to the cause of this is that commercial netters are frequently seen in numbers out on the bay and the area may be overfished by them.	Snapper	Commercial fishing	Human
4	I have also frequently line fished a location on the mid north coast called Scotts head. Most of the fishing there has been in the form of beach fishing and in the past 2 years have noticed a decline in the population of pipis which are used for bait. A possible hypothesis to the disappearance of the pipis is due to coastal erosion as that beach and many other beach's in that area and on the NSW east coast have lost up to 50 metres in the riparian sand dune and many tonnes of sand and habitat.	Pipis	Erosion	Environment
4	I have only been spear fishing 3 years mostly based on the northern beach's and haven't noticed anything too much out of the blue only that the amount of yellowtail baitfish has dropped a little in this summer.	Yellowtail baitfish		
7	I have noticed, especially viewing club records, that the Jewfish numbers in Sydney have Severely declined. I truly believe this has to do with commercial fishing and the immense pressure this has put on Jewfish numbers.	Jewfish	Commercial fishing	Human
8	Negative: Rubbish in the water.	Rubbish		
11	The decline in fish in Pittwater and the Hawkesbury River/Broken Bay Region due to continued commercial fishing and decline in water quality. Primarily water quality in the upper sections of the Hawkesbury River. Also the widespread distribution Caulerpa Taxifolia in Pittwater has a negative impact by creating an invasive monoculture.	Fish	Commercial fishing Decline in water quality Caulerpa Taxifolia	Human Environment
12	Main change is reduced abundance of popular territorial target species at accessible sites around metropolitan Sydney. Examples include red morwong and rock blackfish. Large groups of red morwong were once often found in only 6- 8 metres of water in such areas. These groups are now scarce or absent, and the individual fish tend to be more secretive and are usually difficult to get at these depths. Only by diving deeper (12 metres or more) and/or by swimming a long way from the popular access points are decent sized (1 kg -plus) red morwong easily obtained. This change does not appear to have occurred in areas not heavily fished by spearfishers. Similarly, good-sized rock blackfish, once often found in shallow accessible areas have retreated to less accessible parts of the coastline. These changes have occurred over approximately 30 years. My spearfishing activity has been affected in terms of needing to swim further from the usual access points to get a feed of these sorts of fish. I believe the cause is localised spearfishing pressure. I don't believe that overall population levels for these species have been signifiantly affected - rather, I believe that the fish have been scared out/ rendered more flighty rather than 'wiped out' from these shallow areas. Any actual depletion would be very localised. A generous bag limit (5) for red morwong may have contributed to the changes.	Territorial species Red morwong Rock blackfish	Spearfishing	Human
14	Species decline- trevally, sweep, maori, seargos. Increased rec fishing and commercial netting Also species declines and fish number decline in marine parks- too many peiople in too small areas having pressure impacts	Trevally, Sweep, Maori, Seargos.	Recreational fishing Commercial fishing	Human
23	alot more small fish are being seen, there are terrible amounts of sea urchins around	Small fish Sea urchins		
23	there is alot of fishing tackle hanging round and alot of rubbish round out front of Avoca Beach this is due to the amount of people fishing off the rocks just leaving there rubbish in rock pools, ect.	Rubbish	People	Human
34	major lack of fish	Fish		
38	I have noticed a decline in red morwongs in the Ulladulla area (home bommy, north bommy) and at the rocks. I have spearfished those areas for the last 12 years and it is obvious to me that the fish stock in general has declined in recent years and that the size of the fish seems to be getting smaller. It is my opinion that spearfishing is impacting on fish stocks on reef areas which are easily accessible to divers without a boat. I have noticed that the fish stocks are more abundant on reef areas which are	Red morwong	Spearfishing	Human

	difficult to reach without boat transport. I think that many people are taking up spearfishing without understanding the fishing rules and who are ignorant to the size and bag limits and who would not know which fish are protected.			
40	Most demersal species have decreased over the 12 years I have been spearfishing Broadly, I believe fish stock levels are significantly more impacted by commercial fishing than recreational fishing	Demersal species	Commercial fishing	Human
44	Jewfish seem to be a fish that is becoming harder and harder to find. This would be especially so in the Sydney metro area where it is now very uncommon for spearo's to take Jewies.	Jewfish		
44	The number of slimey mackerel (bait fish) seems to be in decline. This type of bait is normally a very good indicator of pelagic fish. This has been more noticed on off shore reefs such as the banks (Currarong).	Slimey mackerel		
44	Big bream have become scarce in areas where the pro's trap. There are a few spots around Cronulla where big bream were consistently found up until a few years ago.	Bream	Commercial fishing	Human
46	We used to see far more large bream than we do now. Bream used to be quite common in sizes 30cm+ whereas a fish that size now is more of a rarity. When schooling we used to see bigger ones amongst the school, now we look through the school and the big ones are hardly ever there.	Bream		
46	Big Tarwine are not that common either but we don't feel that their numbers have dropped in the same regard as the Bream.	Tarwine		
46	Big Mulloway used to be caught off the local beaches and large ones frequently caught in certain spots around the local estuaries, as well as just off-shore. Some holes / caves which used to guarantee a decent fish have been empty for years. Catching Big Mulloway off the beaches is now virtually unheard of and rare around the estuaries. Smaller fish can be seen and caught on occasion from these locations, more often around the 40-60cm range.	Mulloway		
46	We very rarely see Snapper now and if we do they are nearly always under 40cm. My father used to talk of seeing schools of Snapper locally, the likes of which I have only seen in New Zealand.	Snapper		
46	We don't see as many Blue Morwong as we used to.	Blue morwong		
46	We recall seeing huge schools of Mullet swimming through the waves whilst surfing which we don't get anywhere near as often now.	Mullet		
46	We have noticed a significant drop in the number of whiting, especially anything over 20cm.	Whiting		
46	It is a lot less common for us to see flathead over 40cm	Flathead		
46	Leatherjacket (Reef, Six-spine and Deepbody) have all dropped in average size, as has the Silver Trevally.	Reef leatherjacket Six spine leatherjacket Deepbody leatherjacket Silver trevally		
46	Silver Drummer numbers seem to have stayed constant; Black Drummer numbers seem to have stayed almost as constant but their average size has dropped significantly from around 4kg to around 2kg.	Silver drummer Black drummer		
46	It is very, very hard to find legal Abalone now. On occasions I have regretfully taken the last Abalone from places where I know there to have been some left, these legally sized abalone have been / were the same in number and size (I assume the same abalone) for several years. Although I still find baby abalone in the shallows, no larger ones have replaced or joined the remaining few in the usual spots we check.	Abalone		
46	Lobsters used to be easy pickings in the 1990's, every special occasion we could have lobster. Now I cannot find any at the coastline closest to us, and when we have found some they have been undersize.	Lobster		
46	The quantity of shellfish / molluscs on the rock platforms has dropped significantly over the last 20yrs.	Shellfish/mollusks		
46	We used to see a lot more small tropical reef species (baby angelfish, damsels, etc) in the shallows during the warm current months than we do now.	Tropical reef species		
46	We used to be able to get a few kilos of prawns out of the local lake, but in recent	Prawns		

	years surfers and council have repeatedly let the lake out to the sea and interrupted the prawns life cycle so that now you would be lucky to get a handful of prawns for a nights prawning.			
47	Two trophy species, Mulloway and Yellowtail Kingfish have declined in density dramatically over the last 20 years. When I first started spearfishing in Sydney in 1990 I would regularly take Mulloway and Kingfish up to 25Kg (A couple of times per month) Kingfish wre more abundant than Mulloway. Commercial Kingfish trapping decimated the population in the late 1990s and I do not believe that stocks of this species have yet recovered. We only see the occasional Kingfish upto maybe 12Kg weighed in during our competitions these days. I Have not even seen a Mulloway in Sydney for several years, although spearfishermen with specific location knowledge do still take them in Sydney. I have no idea why their numbers seem to have plummeted so dramatically.	Mulloway Yellowtail kingfish	Commercial fishing	Human
48	Not much. but i have noticed around the cronulla area there have been less and less fish while spearfishing	Fish		
49	All other species have maintained healthy numbers over the 40 years I have been spearfishing with the exepction of black cod	Black cod		
50	A reduction in the amount of jewfish captured due to over fishing of commercial operators.	Jewfish	Commercial fishing	Human
56	The only noticeable decrease is Mulloway which has decreased thru fishing pressure.	Mulloway	Fishing pressure	Human
58	port kembla Wollongong has been declining in fish numbers for some years to the point my son and I don't spearfish there anymore, this is one area that is over fished (line fishing) you really need to go south of Kiama before you start to find good fish.	Fish		
59	Reduction of green sea grass at freshwater beach. In 2008-10 there used to be plenty on the northern end. It used to provide an ideal habitat for juvenile lobsters, however I think due to big swells in 2011-13 most of it has been destroyed and now sand and rocks cover that area. I don't find nearly as many lobster anymore	Sea grass Lobster	Big swells	Environment
64	fish numbers have declined	Fish		
68	availablitiy of fish declining. I spearfish in Darwin, NT. Over the last 3 years there has been a huge decline in fish numbers as well as the variation of species. For example Coral trout have seemd to decline in recent years from the places that we dive. We dive ship wrecks and coral reef structure which i personally see as having changed in what i have mentioned above.	Coral trout		
69	since the closer have noticed that everyone is either diving or fishing in the same spot week after week which means it is harder to catch or spear fish what they should of done is open area for so long then close it then open another area which wold mean that the fish stocks could be replemished	Fish	Fishing pressure	Human
69	have also noticed a lot more sharks then normal	Sharks		
73	There are less of the more common species in the shallower more easily accessible locations. I feel this is due the increase in spearfisher numbers but also an ease of access to decent equipment and all the technologies that can speed up the learning rate to go from absolute beginner to a moderate level of competency, YouTube videos forum sites etc.	Common species	Spearfishing	Human
77	Numbers of and size flathead found whilst line fishing Off shore has dropped. possibly over fishing by professionals with nets and or large bag limits taken by amateurs	Flathead	Commercial fishing Recreational fishing	Human
78	I have seen less jewfish where I spear. I believe this is due to professional fishing that degrades the environment & takes the juvenile & also the breeding stock. An example of the effect of pro fishing can be seen in both Botany Bay & Sydney Harbour. Since pro netting was banned the amount and variety of fish found in both places is astounding. I fished both areas before and after the ban, you could not come to any other conclusion other than the netting of the bottom affected the fish numbers and size. Also pollution and siltation are problems, just have to look at the shallow inlets on the Northern Beaches of Sydney. Manly, Curl Curl & Dee Why lagoons all suffering terribly from siltation and urban run off	Jewfish	Commercial fishing Urban runoff	Human
79	I have found a lot less seaweed cover in the last few years due to sea urchin over population on the far south coast of NSW.	Seaweed	Sea urchins	Environment
	I have also seen a decrease in population and catching of traglin in my area. I think all fishing party's should be held accounted for these changes.	Teraglin	Fishing pressure	Human

	Over a period of 40+ years a reduction of fish numbers and size due to both commercial and population pressures has been fairly clear.	Fish number and size	Commercial fishing Population pressure	Human
85	Some resident Black Cod have disappeared from South Maroubra.	Black cod		
85	There appears to be less Kingfish of legal size in Maroubra and Malabar.	Kingfish		
93	One thing I have noticed is the absence of rat kingfish in the areas that I dive. The availability of the kingfish is highly dependent on the baitfish being present. This season (2012-2013) has seen a distinct lack of bait in most of the areas that I dive and hence no kingfish.	Kingfish		
101	I have noticed a decline in numbers of large mulloway over the last 8 years	Mulloway		
101	A big decline in abalone in northern waters perhaps due to perkensis disease and warmer water. Very warm water 25C+ this season from mid december and weaker NE seabreezes	Abalone	Perkensis	Environment
103	Decrease in bonito, this is bad as i like eating them	Bonito		
103	Decrease in bream and tarwine, again bad, good eating fish, also seem overall size has dropped	Tarwine		
106	Over all the years of fishing (all types) fish stocks have seemed to have lowered (Bream, flatty etc - all the commercially harvested fish). I believe this is due to all the trawling etc of the Hawkesbury river - my local area. When my father was around my age, he used to fish in a local club (before bag limits). They would have no problem filling an esky with bread and butter species. These days people seem to be only able to line catch a couple. I do not see any abundance of these species while diving either. Commercial fishing I believe is the main reason for depleted stocks.	Commercially harvested fish Bream Flathead	Commercial fishing	Human
110	I have especially noticed a decline in Eastern Rock Lobster at Boat Harbour and Cronulla. I believe poaching is partly responsible. I believe the dredging of the Hacking River and dumping of sand out the front of Cronulla has filled many of the Lobster hole with sand.	Eastern rock lobster	Poaching Dredging	Human
111	There may be a reduction in size of shallow reef species but this is subjective.	Shallow reef species		
112	Silver drummer don't appear to be as prolific in the large schools, unsure as to why given they are rarely if at all targeted by recco' or commercial.	Silver drummer		
112	Bait fish are under severe pressure from commercial harvest such as for tuna pens where entire populations can be cleaned out and shipped for feed (alive). The main area I have witnessed this is Latitude Rock, Forster NSW.	Bait fish	Commercial fishing	Human
112	The visitations of Bonito and Kingfish are therefore drastically reduced.	Bonito Kingfish		
114	Banded Morwong are not as common as they once were.	Banded morwong		
114	Bastard Trumpter are less common on the South Coast , Ulladulla Jervis area,	Bastard trumpter		
116	In the Wollongong area have noticed very little change. Except for a lack of Mullaway where 20 years ago were a reasonably common catch. Now a very rare catch.	Mulloway		
116	Also a lack of Abalone. Possible due to the disease that affected them a few years ago.	Abalone	Disease	Environment
123	I've noticed that the water is dirter than years ago. But I think this is cyclic like the fish we have just come out of our longest drought we're the years were on a7 year cycle	Dirty water	Natural cycle	Environment
126	No one in our club thinks there are ANYWHERE near the number of fish as when they were kids. The unanimous consensus is commercial fishing is responsible. Any political noise about recreational fishing and spearfishing having an impact is misguided when you look at the total quantity of fish taken by each group.	Fish	Commercial fishing	Human
129	Since 1985 I have kept catch records and have seen a reduction in mulloway due to overfishing	Mulloway	Overfishing	Human
129	There are fewer rainbow runner sighted than two decades ago.	Rainbow runner		
129	I have also noticed long nose boarfish and unicorn leatherjacket are no longer a frequent sighting and do not know why this is so.	Long nose boarfish Unicorn leatherjacket		

131	Mulloway have reduced dramatically over the past 30 years & must be further protected.	Mulloway		
131	I have observed a decline in fish that were considered well out of their territory to us.Fish such as purple rock cod,mangrove jack,rainbow runners,sampson fish,dusky morwong,bluefish,cobia,spangled emporer,various sweetlip,giant barracuda,Spanish mackerel were all taken at various times off Sydney however the occurrence appears to be much less today.The good warm water season was dec to April & appears to have moved back to jan to July off central Nsw.	Purple rock co Mangrove jack Rainbow runner Sampson fish Dusky morwong Bluefish Cobia Spangled emperor Sweetlip Giant barracuda Spanish mackerel		
131	Wobbygong are scarcer… than 50 years ago	Wobbygong		
131	I believe the commercial take coupled with modern electronic equipment for recreationals & commercials are making it to easy to find & take fish.We are now exploiting the very deep water species with electric reels,disastrous Bag & size limits are to generous & have been for years . Our water conditions ie: temp,currents,seasons are changing & we are overfishing.	Fish	Recreational fishing Commercial fishing	Human
132	South Coast area - banded morwong are considered to be rare now,	Banded morwong		
132	sargent baker - lately in the last say 2 years I've noticed they are getting harder to find, even though my strategy for finding them (certain locations, burley etc) hasn't changed.	Sargent baker		
132	Eden area - banded morwong definitely not as plentiful, one only taken on the competition day now.	Banded morwong		
136	At some of my local dive places in Corio bay professional netting is causing damage to weed beds and making the area void of fish life, especially the species I target (flounder, Flathead, bream) it is very frustrating.	Weed beds Flounder Flathead Bream	Commercial fishing	Human
137	as for fish life i have seen change in the past few years there is not as many and not as big. i believe that this has happened to the pros netting and longlineing closer to land and in the areas where alot of people dive.	Fish	Commercial fishing	Human
137	i found that the places that i used to dive are getting reacked by other divers and they are doing the wrong thing by shooting unsize fish, using abs for burley, and leaving rubbish on the beach and under the water	Places wrecked	Spearfishing	Human
138	flounder are now rare, flathead are now becoming less frequent i believe flounder and flathead are on the decrease because of changes to the environment ie. pest species like the pacific seastar	Flounder Flathead	Pacific seastar	Environment
138	trumpeter seem to be less frequent, crays are harder to find. trumpeter and crayfish are less frequent maybe due to high fishing pressure	Trumpeter Crayfish	Fishing pressure	Human
138	scallops area seems to have moved further south ie. from the edge of mornington they now start at rye i think the differences are occurring because the water temperature is more favourable to the northern temperate species.	Scallops	Warmer water	Environment
139	In the areas of PPB that I fish, I have noticed that some years are better than others in specific areas when it comes to species such as snapper, kingfish or even large salmon. Some years I have seen large poputations of beardies (bearded rock cod) and gurnard over sand/mud terrain and then never seen them in plagues since. Some years I have had good catches of snotty nose trevalla and then none. I believe that these are seasonal changes, like weather/climate it is constantly changing from day to day, year to year. I also believe that certain species that enter the bay such as snapper, kingfish or southern calamari either find their way in or they don't resulting in either exceptional, average or low quantities. The average size of the individual fish within schools may also vary from year to year.	Snapper Kingfish Salmon Bearded rock cod Gurnard Snotty nose trevalla	Natural variability	Environment
147	Portsea pier region is also now being smashed by swell, What used to be a pleasent safe and flat dive site for spearfishing, snorkelling and scubadiving is now undiveable	Environment	Dredging	Human

	quite often. I believe this is due to the dredging of the bay.			
148	Have spread of Northern pacific sea star through out the bay, especially the mornington - mt martha region. I first started noticing the sea star spreading about 1-2 years ago when they starting turning up at some of the spots i dive regularly. Along with this i have noticed what appears to be a decrease in visibility in these reef systems where they sea stars are. Im not sure if this is associated, but it has occured during the same time frame.	Pacific sea star	Water quality	Environment
148	The only large noticeable change is in the distribution and abundance of Flathead (all bay species) and Gurnards. I have speared regularly on the east of the bay from Sandringham to Sorrento, however there has been a noticeable decrease in said sand species. I would easily see / catch these species most dive most of the time year round, however they seem very rare In particular, the sand flathead is largely rarer than it was three years ago. Rock flatheads have only decreased slightly in sightings	Flathead Gurnards		
148	Notable is the lack of Gurnards also seen while diving, i used to see 2 - 3 a year around Frankston - Dromana however i have not seen them for the past three years.	Gurnards		
150	some areas in PPB not as fishy as others, I believe caused by over professional fishing. Nets from pro's in PPB and Corio Bay do not discriminte.	Fish	Commercial fishing	Human
154	The squid have totally dissapeared from daveys bay, not sure why.	Squid		
154	I would say the most important change in Port Phillip Bay I have noticed would have to be a drop in visibility. This has occured only since channel dredging commenced.	Visibility	Dredging	Human
156	Hi, I fish mostly in Port Phillip Bay and from the Heads west to Apollo Bay. I see the biggest change in our fishery being the increased pressure on the environment and fish stocks by a huge popullation increase over the last 30years. More and more people own boats, with fantastic technology for finding fish. They have more disposable income and take the time to fish. Most boat ramps in summer have become amost unusable for the crowds and the time it takes to launch and retrieve. Recently I witnessed about 50 boats fishing in Lonsdale Bight inside Port Phillip for squid. A few squid were taken but I personally gave up for the rediculous amount of boat traffic. The squid have been punished this season by an alarming amount of rec. fishermen. Size limits should be increased and catch limits decreased across all species.	Fishery Squid	Fishing pressure	Human
156	I see a distinct lack of numbers of all fish in areas close to home.	Fish		
156	In Corio bay when I was in my late teens it was possible to spear large Gar fish near the city of Geelong. I have not seen a large Gar for a long time.	Gar		
156	I have noticed less Crayfish in the last year or so in the stretch of coast between Point Lonsdale and Lorne. Every time I go out in the boat I see Cray pots and try my best to pick the weather to allow me to dive on areas of reef which the Pro fishermen can't Pot. Scuba divers also have a nasty effect on the cray population in certian areas. I am sure that some shore dive locations are hammered by scuba divers chasing crayfish. It seems less cray are found in areas where scuba can be carried from the carpark to a dive location. If I walk 2kms down the beach the cray are more prevalant on similiar reef.	Crayfish	Scuba divers	Human
163	Lack of sea grass beds near portarlinton/ queenscliffe.	Sea grass		
163	Distroyed whitting grounds	Whiting		
163	Less aus salmon in the rip area	Australian salmon		
164	I have seen the reef areas I fished 30 years ago completley covered by sand and recently some other areas now plagued by very dirty water and current.	Reef		

Appendix K Responses to open-ended survey indicating a positive change in environmental conditions

Table AS2. Comments received from survey question 5 (what changes have you noticed in the marine environment in the areas that you fish, and what do you believe the cause(s) of these changes to be?) indicating a positive change in environmental conditions. ID numbers 1-133 are from respondents to the NSW survey; ID numbers greater than 133 are from respondents to the VIC survey. Comments with the same ID number are from the same respondent.

ID	Comment indicating a positive change in environmental conditions	Species Mentioned	Driver Cited	Driver Type
4	I have frequently line fished inside and just offshore from Broken bay mostly and have definitely noticed a slight increase in days where many legal size flathead would be caught when drifting just off Lion Island, Patonga, Barrenjoey Head and palm beach.	Flathead		
4	However the positive changes observed for fishing in broken bay is that there has been a noticeable increase in pelagic species such as legal Taylor and Australian salmon frequenting the area quite often and often have come home with many legal Salmon and Taylor.	Taylor Salmon		
5	An increase in the number of Grey Nurse Sharks seen as well as an increase in the number of Kingfish and Australian Salmon. The changes have been happening of the past few years. I believe the increase in shark activity is due to the fact that more food source eg. australian salmon is closer into the coast and the sharks have moved in from the outer reefs to take advantage of it.	Grey nurse shark Kingfish Salmon	More food for sharks	Environment
8	Positive: Large numbers of blue groper found off majority of headlands School species such as blackfish and salmon are becoming more common in big schools Certain areas fished seem to have a building number of fish in the last 4 years. I have noticed these changes over the last 5 years and more so in the last two since I started spearfishing/freediving I believe these changes have occured due to an increasing population of line fisherman participating in catch and release methods along with better treatment of surrounding areas	Blue groper Blackfish Salmon	More catch and release Better treatment of areas	Human
9	Increased numbers of kingfish in the JB/Currarong areas since the introduction of increased size limits.	Kingfish	Size limits	Human
10	if anything ,i`ve only noticed the fish stocks getting better.	Fish stocks		
11	The increase in fish and diversity of species in sydney harbour which I believe is a direct result of the banning of commercial fishing and increase in water quality and less pollution in the harbour.	Fish and diversity of species	Reduced commercial fishing Less pollution	Human
11	An overall increase in kingfish stocks since the banning of kingfish traps.	Kingfish	Trap ban	Human
12	While I have encountered a number of tropical species around Sydney over the years (spotted mackeral, barramundi cod, clown trigger fish, spangled emporer etc.), I have not noticed any general trend in their abundance through time.	Tropical species Spotted mackerel Barramundi cod Clown trigger fish Spangled emperor		
16	I have noticed that fish numbers and sizes have been in the increase in the general lake macquarie area. .	Fish number and size		
16	I have also noticed a slight increase in lobster numbers in the Broughton island area	Lobster		
17	Since the trapping of Kingfish etc had been banned, I've noticed more schools of Kingfish to be greater in number during my outings.	Kingfish	Trap ban	Human
22	when fishing in Lake Macquarie, for many years we found it hard to get a good feed of fish. The 70"s were good and since pro-fishing has ceased the lake is returning to it good old self.	Fish numbers	Reduced commercial fishing	Human
22	I do beleive that in recent years I have seen more jewfish.	Jewfish		
26	I have noticed an increase in the numbers of Grey Nurse sharks. HAve found them lately in places i had never seem them before.	Grey nurse shark		
39	Fish such as Australian Salmon are increasing in numbers	Salmon		
40	yellowtail kingfish have been appearing in better numbers in NSW over the past 3 years	Kingfish		
40	- Eastern rock crayfish had remained in good numbers in NSW	Crayfish		
44	A few years back there seemed to be a resugence in the Australian salmon. There are regions where this fish is quite thick.	salmon		

46	In my experience Kingfish have become more plentiful in recent years as have schools of Australian Salmon. Although the Kingfish tend to be undersized more often than not.	Kingfish Salmon		
46	*It is my impression that the number of sea urchins has grown if not stayed the same.	Sea urchin		
46	There is a bright green ribbon-like / smooth seagrass which blanketed over large sections of the rocky shallows towards the end of the dry period (approx 4-6yrs ago) which wasn't there previously	Sea grass		
46	There is way more Groper than there used to be, they are Everywhere! Especially Green Groper. At some local beaches all you see under the water is Groper and Kelp Fish.	Groper Green groper		
46	There are so many more Wobbygong Sharks than there used to be! Every decent hole / cave we look in now houses one! Some places they are a nuisance because every time you spear a fish they come in to check out the fish.	Wobbegong		
46	Similarly, Grey Nurse Sharks show up to 50% of our dives. Small to medium sized Bronze Whalers come around about 30% of the time. (My father tended not to talk bout sharks he saw so this is my recent experience only).	Grey nurse shark Bronze whaler shark		
47	I have clearly seen cycles in the population density of particular species over time. Even common species such as Bream, Luderick, Rock Blackfish and Red Morwong have had seasons of scarcity and seasons of plenty over the last 20 years. We appear to be recording catch results currently which are equally as good if not better than 20 years ago. To a small degree the improvement in Spearfishing ability, technique and equipment could account for this but I do not believe there has been any decline in the numbers of common species targeted by spearfishers other than the aforementioned seasonal cycles.	Bream Luderick Rock blackfish Red morwong	Seasonal cycles	Environment
47	I would like to point out that the recently purported idea that Grey Nurse Sharks are endangered is a total crock, particularly the idea that there may only be 300 left alive. I have personally witnessed more than 300 Grey Nurse Sharks surrounding Big Seal Rock within the last few years and there continue to be multiple sightings all along the Sydney coastline.	Grey nurse shark		
49	The Yellowtail Kingfish population suffered terribly with the introduction of floating kingfish traps. This specie has made a slow recovery with more fish sighted over the past 10 years	Kingfish	Trap ban	Human
50	An increase I kingfish average size since the removal of kingfish traps.	Kingfish	Trap ban	Human
55	There are more grey nurses at my local diving spots year after year!!! And contrary to people's belief of them living in the same gutter or on the same reef they must travel as I've seen on atleast 20 occasions a nurse varying from 1m-2.5m in a spot I've never seen one before and then never see them there again. As well as that I've seen a "school", I guess, of nurses up to 10 in the school turn up to the same sand/weed patch for about 2 months than disappear again until about the same time next year 3 years in a row. Often when I see nurses in these bigger groups (up to 30) there are always big ones with bite marks on there backs and whenever I've seen ones with the bites the group of nurses seem to be a lot more aggressive! Charging you from behind while on the bottom and literally bumping you with there noses! I've also seen nurses become increasingly aggressive at my local spots when there are fish on the float rope. Often having my fish hit by the shark even when they're being pulled along the surface. (I live at port Stephens)	Grey nurse shark		
56	I have seen more fish in the last few years but I may put that down to my skill level increasing.	Fish		
56	Kingfish have certainly increased in the last few years but I put that down to the banning of the Kingfish traps.	Kingfish	Trap ban	Human
57	Since the netting of Yellowtail Kingfisdh has been discontinued in NSW I have noticed a strong growth in the numbers and sizes of these near Apex predators.	Kingfish	Net ban	Human
59	Stronger presence of black cod- possibly due to effective protection techniques.	Black cod		
59	A lot of abalone at freshwater beach nowadays. See them pretty often. This is most likely due to the restrictions placed on them in the past years.	Abalone		
59	In 6 years diving at freshwater I've noticed a steady increase in rock cale, cale herring, and blue groper - possibly because these are not targeted, however they are in plague proportions. larger luderick and black drummer now	Rock cale Cale herring	Species not targeted	Human

	frequent the area after big swells. Possibly a lot of food for them.	Blue groper Luderick Black drummer	More food	
60	The number of groper around is incredible over the past gew years. There are more groper than any other species due to legislastion prohibiting the capture of the species particularly over the past 2 years or so.	Groper	Protected species	Human
60	Wobbegongs are in abundance, seen atleast a couple every dive in summer.	Wobbegong		
61	I think that the size and amount of fish have gotten greater in and around Sydney in particular Botany Bay. I also fish alot at Merries Reef and Boat Harbour which now seems alot cleaner and the fishlife is fantastic there. Often it has the biggest fish and the most species of fish compared to other areas in Sydney that I fish	Fish		
63	I have noticed a roughly 10 - 12 year cycle with the average water temperature during the cooler and warmer months of the year in the Sydney through to mid/north coast NSW region and believe I have recognized that few fish / shark species of note seem to cooincide with these patterns. Of particular note is the GNS shark. ~12 years ago I could promise to show a fellow diver visiting Sydney GNS sharks at 6 regular locations. Over the preceding 3 years the numbers dropped slowly at these locations untill you could almost promise not to find any in Sydney except on occassion at 2 locations. Certain green groups had marine scientists claim that their numbers were distinctly dropping yet when we went up the coast we found their numbers vastly increased at sights like Seal rocks. (Up to 70 sharks at one location on one visit). And now roughly 12 years later in 2013 I can find GNS at the same 6 locations in Sydney once again. A recent point of interest that cooincides with this time frame; a juvenile Marlin aggregation on the Mid north coast that was typical for a few years, 12 years ago.	Grey nurse shark	Natural cycles	Environment
67	Increase in Grey nurse sharks and other shark species.	Grey nurse shark		
67	Increase in Eastern Blue Groper populations. Obviously the increases are due to the protected status of these fish.	Blue groper	Protected status	Human
69	have also noticed a lot more sharks then normal	Sharks		
71	I've found that recently the larger kingfish are back around Sydney a bit more than the previous years.	Kingfish		
73	I have definitely noticed an increase in water temp, and a slight lengthening of warm water period, the "summer" is lasting longer. It also seems to have started a little later in the year, although this isn't as definite.	Water temperature		
75	I have noticed a lot more divers in the water in the areas i frequent, without a drop in species	More divers		
76	Increased number of bonito seen in the last 4 years. (Sydney)	Bonito		
76	Increased number of sawtail, (Sydney)	Sawtail		
76	Off the continental shelf, spearfisherman have seen an increase in Marlin number catches, for club based members. (Due to good warm water currents down the EAC. Last 3 years summer water has risen in temperature,	Marlin	Warm EAC	Environment
77	numbers of salmon has increased since cannery at Eden was closed	Salmon	Commercial fishing reduced	Human
77	Number of sharks sighted seems to have increased maybe due to more salmon ?	Sharks	More salmon	Environment
79	But on the plus I have seen and speared fish like Samson fish , seen black cod, and the population explosion of groper in my area.	Samson fish Black cod Groper		
80	King fish were once plentiful, then the population seemed to disappear. They are now making a welcome comeback. Some changes to commercial practices such as kingfish trapping and Wobbygong fishing have seen a steady recovery in those species	Kingfish Wobbegong	Commercial fishing reduced	Human
80	Blue groper are one of three species I will be guaranteed of seeing in great numbers per dive which is positive.	Blue groper		

80	Water ways that were once heavily polluted are much cleaner and fish life has returned some areas that were once barren.	Less pollution		
80	Fish populations may not be high as they once were but the recovery is noticeable where I frequent.	Fish populations		
84	The major change I have seen over the past decade if the increasing number and size of Yellowtail Kingfish.	Kingfish		
85	I am spearing Maroubra and Malabar on a weekly basis and in the last 12 month I noticed that the numbers of Abalone are increasing. The average size would be around 100 mm with the occasional big one above that. Though I have only been able to take 4 Abalone of legal size in 2012 and none for the years 2006 to 2011	Abalone		
85	I also think that the numbers of Bastard Trumpeter have increased in the last 12 month from the occasional sighting to regular catches.	Bastard trumpeter		
85	The average size of Black Spot Goatfish has certainly increased wih fish of 450 mm and above having been taken and sighted regularly by me.	Black spot goatfish		
86	increase in kingfish numbers over the past decade	Kingfish		
86	increase in the number of shark encounters over the past 2-3 years, both Bull sharks, whalers and Grey nurses. The grey nurses have been turning up in the last year or so in areas I have Never seen them before that I have consistently dived.	Bull shark Grey nurse shark Whaler shark		
86	Also, the increase in Black Cod sightings although they have been all under 2-3 kg max	Black cod		
91	water temps are begining to bring in different kinds and species of fish. currents and tides are also changeing and bringing in different species.	Water temperature, Current changes		
93	one of the biggest changes i have seen has been the increase in numbers of eastern blue groper. these fish are extremely common now. I have not done any counts but i see them every dive in all sizes. The large blues in the 7-10kg range are also very common and i Often see 10-20 of these fish with their entourage of females on a single rockop in Sydney. They would have to be the only large fish that I See regularly.	Blue groper		
93	Kingfish numbers and average size have been on the increase in the Sydney region over the last 5 or so years. I am encountering large schools (100+ Fish) in the 8-15kg range with a few 20+kg models sighted as well.	Kingfish		
93	Grey nurse sharks are being encountered in areas previously not seen. These sharks are the most common sharks sighted by spearfishermen. There appears to be alot more juvenile sharks now and I often sight small sharks either singly or in pairs. I believe that this shark is alot more common than the public has been led to believe. I personally counted 200 sharks on 1 reef including 90 sharks in one gutter one one days diving on the mid north coast of N.S.W.	Grey nurse shark		
101	Big increase in eastern rock lobster population and big increase in number of large lobsters over 18cm carapace length. I think that is due to maximum size limit and improved stock management.	Lobster	Max size limit Improved management	Human
101	Expansion of tropical species south-I have shot 1 kg coronation trout at South West Rocks and seen 2 juveniles. I have photographed 30cm blue spot trout in Nambucca River. More tropical species like Chaetodonts seem to be surviving the winter and regular sightings of Coral Cod south of Coffs harbour.	Tropical species Coronation trout Blue spot trout Coral cod Chaetodon		
101	My main area of diving is between Coffs harbour and South West Rocks. Last year there was a massive recruitment of teraglin with schools of 500+ fish around 20cm long in several areas	Teraglin		
101	a massive recruitment of juvenile mulloway in the last 3 years-I believe that this is flood related.	Mulloway	Flood related	Environment
102	Not sure for how long but, rock cale are extremely prolific, like every where.	Rock cale		
102	Also female groper are probably the 2nd most seen species on a dive.	Groper		
103	Increase in salmon numbers, seen this over the last 5 years or so. This is a good thing, i dont target them, but they are often seen in large schools which is pleasurable to dive with	Salmon		

104	steady increase in kingfish numbers and average size on NSW south coast over past ~5 years due to banning of floating traps	Kingfish	Trap ban	Human
107	Have seen an increase in kingfish numbers and size. I believe this was due to the banning of commercial kingfish floating traps.	Kingfish	Trap ban	Human
107	Blue Groper numbers have increased to plague proportions.	Blue groper		
109	Increase in the number of Kingfish and Australian Salmon in the Central Coast region. I assume as a result of reduced commercial pressure.	Kingfish Salmon	Reduced commercial pressure	Human
114	Since the King fish trapping ha been banned i am now seeing large healthy King Fish rerturn in numbers	Kingfish	Trap ban	Human
114	the same again with Australian Salmon.	Salmon		
114	Seals are making a strong comeback, a mixed blessing.	Seals		
114	Whales are in larger numbers ..	Whales		
114	Black Cod, i am seeing much more often, one aroun the 10 kg most around 1-3kg.	Black cod		
114	Bastard Trumpter are more common around Wollongong, quite often in large schools.	Bastard trumpeter		
114	Seeing larger cray fish for the first time.	Crayfish		
115	There would seem to be more northern species taken in southern waters these days or maybe we are just more aware I'm not sure, social media has put peoples catches out in the public domain where in days gone by such catches were kept to ones self and especially the place it was taken from.	Northern species		
115	Blue bar parrotand spangled emporer something you may encounter in warmer months in Coffs Harbour now seem to be showing up in the Port stephens area	Blue bar parrot Spangled emperor		
115	The greatest change I have noticed in recent years is the return of the yellowtail kingfish although for how long I do not now they cop a fair flogging by professionals and rec fishers alike over the christmas period in Eden.	Kingfish		
116	Sea turtles are now a common encounter in my area.	Turtles		
119	last 5 years some increase . eg kingfish spanishmack and jews	Kingfish Spanish mackerel Jewfish		
124	Increased numbers and size of Yellowtail Kingfish, last couple of years, perhaps from recovery of ceasing trapping.	Kingfish	Trap ban	Human
125	lots of sharks, always see grey nurse sharks when diving- headlands or solitary islands nsw	Shark Grey nurse shark		
126	The next most noticeable thing has been the steady increase number and size of King Fish. They have made a great comeback and this by all accounts directly from the banning of traps not long before I arrived.	Kingfish	Trap ban	Human
126	There does seem to be a higher concentration of reef fish in marine sanctuaries. Snorkeling these areas I do see a greater range of species and of bigger sizes. This does not hold for Palagics.	Reef fish		
127	The main change would be a large increase in the grey nurse population, and an increase in the areas which I see them.	Grey nurse shark		
128	More kings, biggers kings	Kingfish		
128	More crays.	Crayfish		
128	Increase sightings of fish that usually accompany warmer waters eg spangled emperor, parrotfish, mangrove jacks and starting to see them earlier in the warm seasons and later in the warm season.	Warm water fish Spangled emperor Parrotfish Mangrove jack		
128	More sharks!!	Shark		

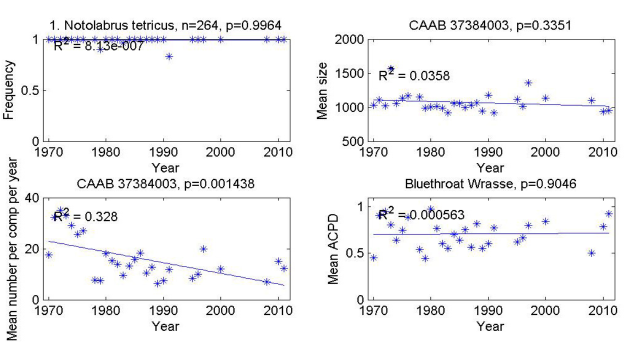
129	I have noticed a increase in the number of mangrove jack sighted between seals rocks and swansea.	Mangrove jack		
131	During my time I noticed a decline on some species in the 60's mainly groper & cod,blue devil's ect. All of these fish were removed from spear competition & by fisheries later to be fully protected.these species have since rallied.	Groper Cod Blue devil	More protection	Human
131	The same can be said for grey nurse sharks which are now the most commonly seen shark by Spearo's.	Grey nurse shark	More protection	Human
131	Since trapping was banned kingfish have come back but nowhere near the abundance of the 60's	Kingfish	Trap ban	Human
131	salmon have rallied dramatically since becoming a recreational only specie.	Salmon	Recreational only species	Human
131	great whites more common than 50 years ago	Great white shark		
132	kingfish are definitely coming back but some limitations on number taken could assist their recovery.	Kingfish		
136	The recovery of green-lip Abalone off the Queenscliff-Lonsdale bite is a positive, this area should be opened up again to recreational take as they are quite clearly the dominate grazers there now, much more so then blacklip.	Green lip abalone		
138	blue groper are becoming larger and more frequent	Blue groper		
138	people are catching queen snapper trevally are definatley more frequent as before there was not many	Queen snapper Trevally		
138	luderick, black drummer and silver drummer are on the increase of sightings and catches	Luderick Black drummer Silver drummer		
138	kingfish especially in the last few years are on the increase	Kingfish		
138	bonito were unheard of off inverloch but last year were common	Bonito		
138	i think the other differences are occurring because the water temperature is more favourable to the northern temperate species.	Northern species	Water temperature	Environment
139	There was a stage some 10 years ago that the reefs that I frequent were becoming barron with a similar appearance to the south coast of NSW. Most of the algae was dying off or dead, however these days those reefs are very healthy and most of the algae has recovered. I believe that these are seasonal changes, like weather/climate it is constantly changing from day to day, year to year.	Reefs Algae	Seasonal changes	Environment
142	Return of seagrass beds due to withdrawal of scallop boats!	Sea grass	Reduced commercial fishing	Human
151	The amount of kingfish in Victorian waters may have increased in the last 5 years, the amount speared has definitely increased. Apparently commercial fishing of kingfish has been reduced in southern NSW in the last 10 years and I believe this has resulted in more kingfish in Victoria	Kingfish	Trap ban	Human
151	Bluefin tuna have been landed in huge numbers in the last few years by line fisherman around western Victoria, with some bluefin being speared for the first time also. As with kingfish, it is difficult to know whether the reason for this is because more people are targeting these fish which have always been there. Or because of another reason such as a change in current patterns bringing the bluefin closer to shore in Victoria. I believe it is a bit of both.	Bluefin tuna	More people targeting Change in environmental conditions	Environment
152	I have seen a significant increase in Yellow Tail Kingfish in the past probably 4-5 years in Victorian waters	Kingfish		
153	Over the last 3 years I have sighted Yellow Tail Kingfish on several occassions which I have never ssen in the past.	Kingfish		
155	Main difference is the amount of yellowtail kingfish in the central regions of Vic in the last 5 years. From Wilsons Prom through to Port-phillip Bay.	Kingfish		

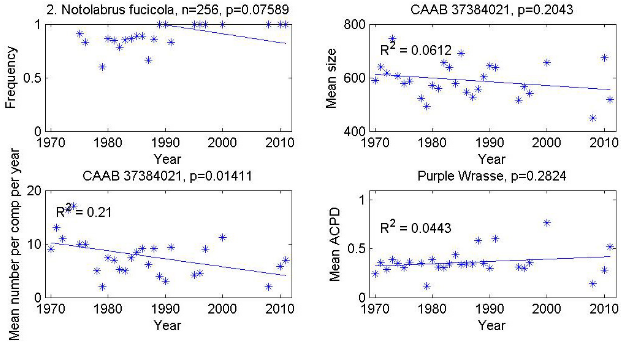
156	The Bay has however I believe recovered a great Snapper fishery which I personally believe to be largely due to the removal of Scallop dredging in Port Phillip through the 80's-90's. The environment in which the snapper feed and spawn has had time to recover and in the last 6-8 years good Snapper catches are common.	Snapper	Reduced commercial fishing pressure	Human
156	The introduction of marine parks (namely Swan Bay) seems to have improved the fishing around that area.	Fishing	Marine protected areas	Human
156	I have had a lot more frequent sighting of King Fish in Victoria.	Kingfish		

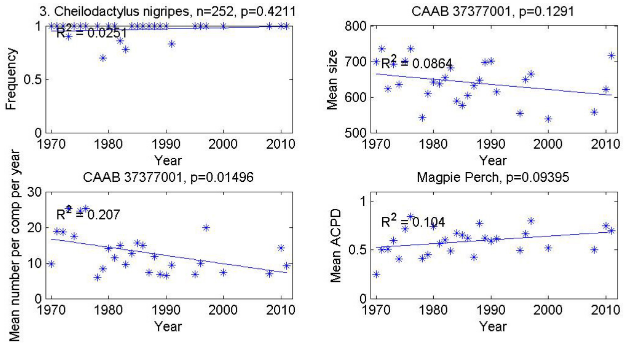
Appendix L

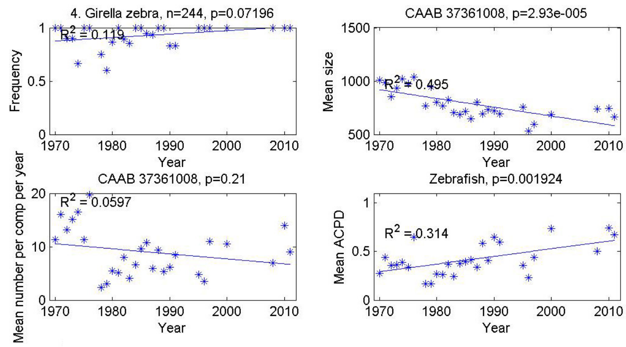
Fifty most common Victorian species

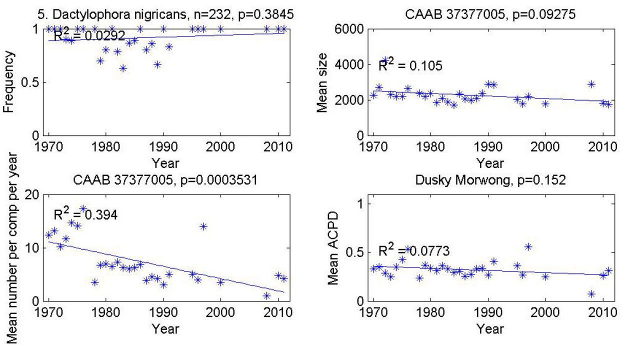
Figures display four parameters: commonness in competition data; mean size (weight in grams); catch per competition per year; annual catch rate per diver per year (ACPD).

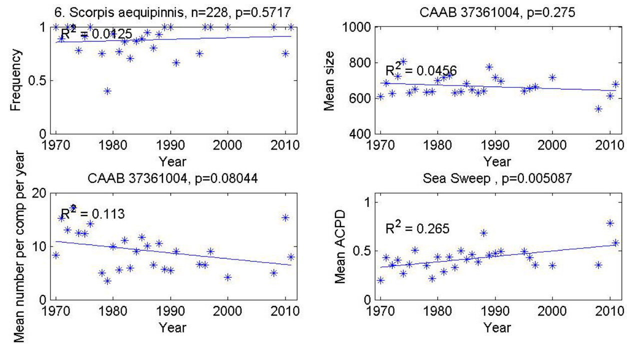

1. Notolabrus tetricus, n=264, p=0.9964
R2 = 8.13e-007
Frequency
Year
CAAB 37384003, p=0.3351
R2 = 0.0358
Mean size
Year
CAAB 37384003, p=0.001438
R2 = 0.328
Mean number per comp per year
Year
Bluethroat Wrasse, p=0.9046
R2 = 0.000563
Mean ACPD
Year

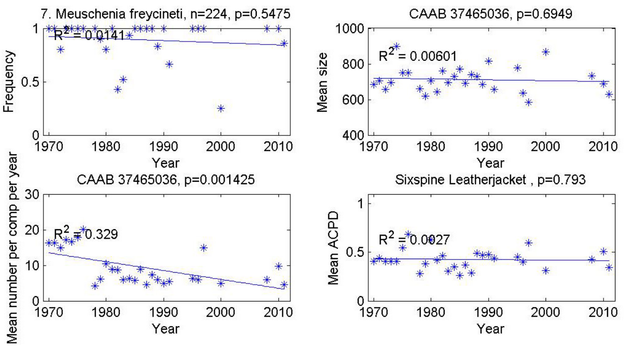

2. Notolabrus fucicola, n=256, p=0.07589
Frequency
Year
CAAB 37384021, p=0.2043
R2 = 0.0612
Mean size
Year
CAAB 37384021, p=0.01411
R2 = 0.21
Mean number per comp per year
Year
Purple Wrasse, p=0.2824
R2 = 0.0443
Mean ACPD
Year

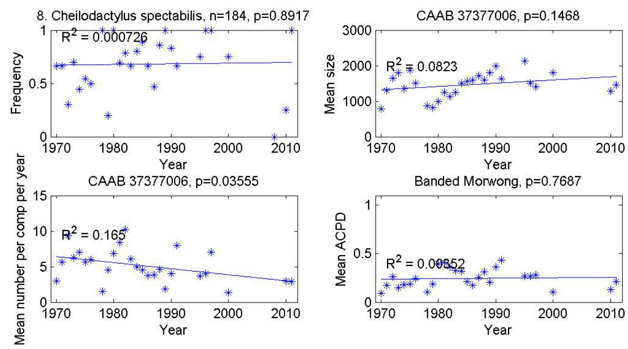

3. Cheilodactylus nigripes, n=252, p=0.4211
R2 = 0.0251
Frequency
Year
CAAB 37377001, p=0.1291
R2 = 0.0864
Mean size
Year
CAAB 37377001, p=0.01496
R2 = 0.207
Mean number per comp per year
Year
Magpie Perch, p=0.09395
R2 = 0.104
Mean ACPD
Year

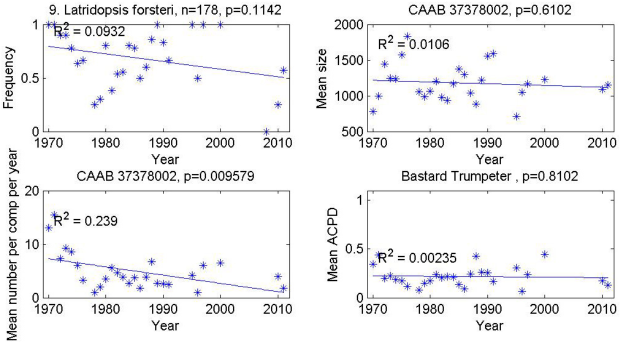

4. Girella zebra, n=244, p=0.07196
R2 = 0.119
Frequency
Year
CAAB 37361008, p=2.93e-005
R2 = 0.495
Mean size
Year
CAAB 37361008, p=0.21
R2 = 0.0597
Mean number per comp per year
Year
Zebrafish, p=0.001924
R2 = 0.314
Mean ACPD
Year

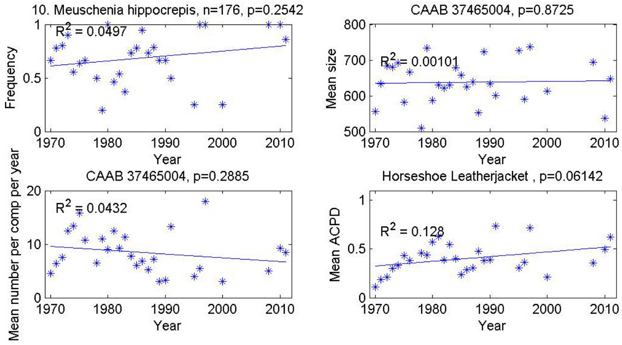

5. Dactylophora nigricans, n=232, p=0.3845
R2 = 0.0292
Frequency
Year
CAAB 37377005, p=0.09275
R2 = 0.105
Mean size
Year
CAAB 37377005, p=0.0003531
R2 = 0.394
Mean number per comp per year
Year
Dusky Morwong, p=0.152
R2 = 0.0773
Mean ACPD
Year

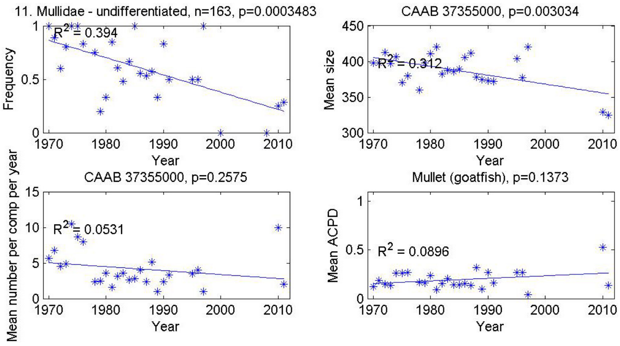

6. Scorpis aequipinnis, n=228, p=0.5717
R2 = 0.0125
Frequency
Year
CAAB 37361004, p=0.275
R2 = 0.0456
Mean size
Year
CAAB 37361004, p=0.08044
R2 = 0.113
Mean number per comp per year
Year
Sea Sweep , p=0.005087
R2 = 0.265
Mean ACPD
Year

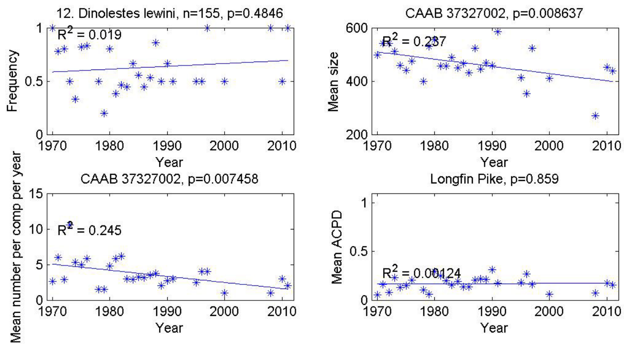

7. Meuschenia freycineti, n=224, p=0.5475
R2 = 0.0141
Frequency
Year
CAAB 37465036, p=0.6949
R2 = 0.00601
Mean size
Year
CAAB 37465036, p=0.001425
R2 = 0.329
Mean number per comp per year
Year
Sixspine Leatherjacket , p=0.793
R2 = 0.0027
Mean ACPD
Year

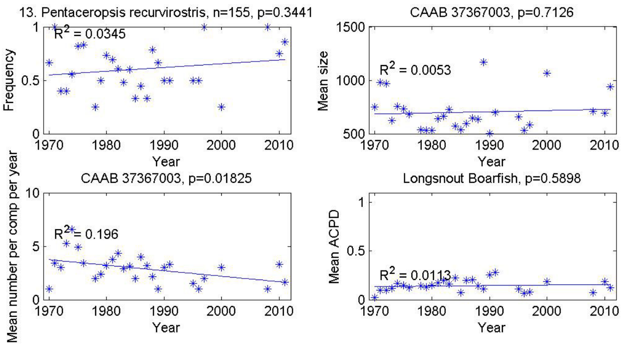

8. Cheilodactylus spectabilis, n=184, p=0.8917
R2 = 0.000726
Frequency
Year
CAAB 37377006, p=0.1468
R2 = 0.0823
Mean size
Year
CAAB 37377006, p=0.03555
R2 = 0.165
Mean number per comp per year
Year
Banded Morwong, p=0.7687
R2 = 0.00352
Mean ACPD
Year

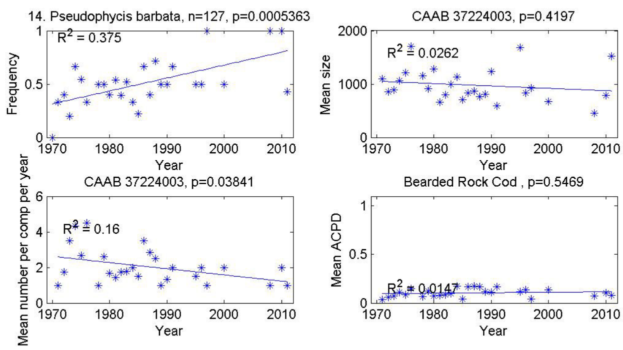

9. Latridopsis forsteri, n=178, p=0.1142
R2 = 0.0932
Frequency
Year
CAAB 37378002, p=0.6102
R2 = 0.0106
Mean size
Year
CAAB 37378002, p=0.009579
R2 = 0.239
Mean number per comp per year
Year
Bastard Trumpeter , p=0.8102
R2 = 0.00235
Mean ACPD
Year

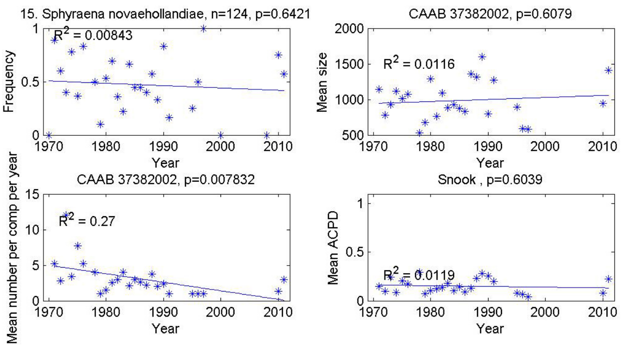

10. Meuschenia hippocrepis, n=176, p=0.2542
R2 = 0.0497
Frequency
Year
CAAB 37465004, p=0.8725
R2 = 0.00101
Mean size
Year
CAAB 37465004, p=0.2885
R2 = 0.0432
Mean number per comp per year
Year
Horseshoe Leatherjacket , p=0.06142
R2 = 0.128
Mean ACPD
Year

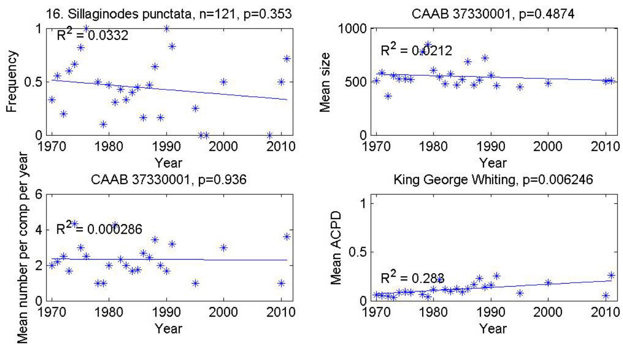

11. Mullidae - undifferentiated, n=163, p=0.0003483
R2 = 0.394
Frequency
Year
CAAB 37355000, p=0.003034
R2 = 0.312
Mean size
Year
CAAB 37355000, p=0.2575
R2 = 0.0531
Mean number per comp per year
Year
Mullet (goatfish), p=0.1373
R2 = 0.0896
Mean ACPD
Year

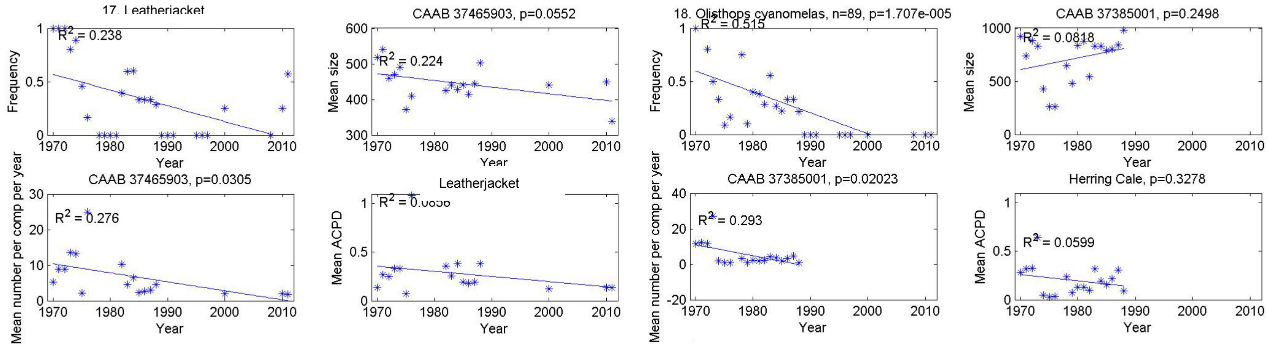

12. Dinolestes lewini, n=155, p=0.4846
R2 = 0.019
Frequency
Year
CAAB 37327002, p=0.008637
R2 = 0.237
Mean size
Year
CAAB 37327002, p=0.007458
R2 = 0.245
Mean number per comp per year
Year
Longfin Pike, p=0.859
R2 = 0.00124
Mean ACPD
Year


13. Pentaceropsis recurvirostris, n=155, p=0.3441
R2 = 0.0345
Frequency
Year
CAAB 37367003, p=0.7126
R2 = 0.0053
Mean size
Year
CAAB 37367003, p=0.01825
R2 = 0.196
Mean number per comp per year
Year
Longsnout Boarfish, p=0.5898
R2 = 0.0113
Mean ACPD
Year

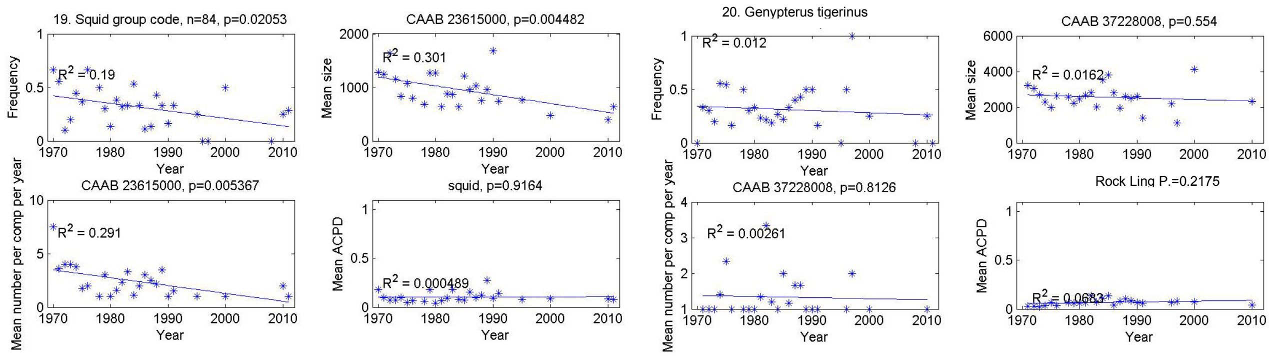

14. Pseudophycis barbata, n=127, p=0.0005363
R2 = 0.375
Frequency
Year
CAAB 37224003, p=0.4197
R2 = 0.0262
Mean size
Year
CAAB 37224003, p=0.03841
R2 = 0.16
Mean number per comp per year
Year
Bearded Rock Cod , p=0.5469
R2 = 0.0147
Mean ACPD
Year


15. Sphyraena novaehollandiae, n=124, p=0.6421
R2 = 0.00843
Frequency
Year
CAAB 37382002, p=0.6079
R2 = 0.0116
Mean size
Year
CAAB 37382002, p=0.007832
R2 = 0.27
Mean number per comp per year
Year
Snook , p=0.6039
R2 = 0.0119
Mean ACPD
Year

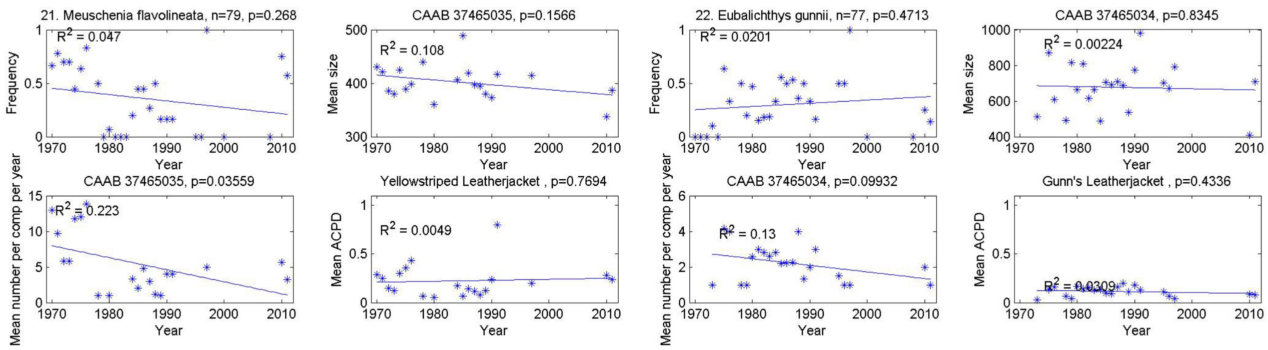

16. Sillaginodes punctata, n=121, p=0.353
R2 = 0.0332
Frequency
Year
CAAB 37330001, p=0.4874
R2 = 0.0212
Mean size
Year
CAAB 37330001, p=0.936
R2 = 0.000286
Mean number per comp per year
Year
King George Whiting, p=0.006246
R2 = 0.288
Mean ACPD
Year



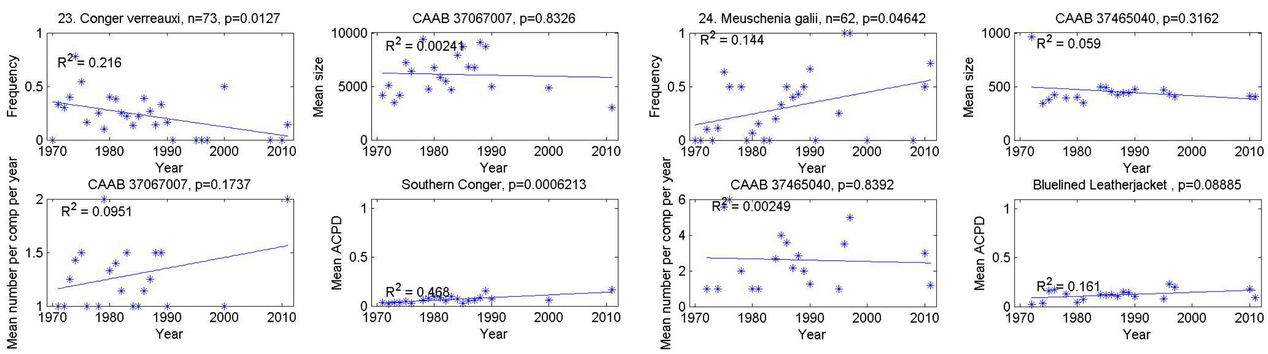
17. Leatherjacket
R^2 = 0.238
CAAB 37465903, p=0.0552
R^2 = 0.224
18. Olisthops cyanomelas, n=89, p=1.707e-005
CAAB 37385001, p=0.2498
R^2 = 0.0818
CAAB 37465903, p=0.0305
R^2 = 0.276
Leatherjacket
CAAB 37385001, p=0.02023
R^2 = 0.293
Herring Cale, p=0.3278
R^2 = 0.0599
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Year



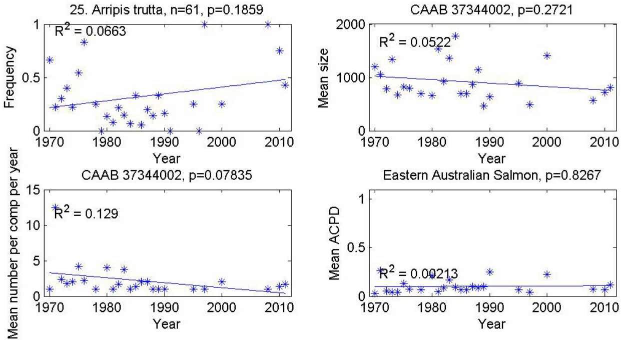
19. Squid group code, n=84, p=0.02053
R^2 = 0.19
CAAB 23615000, p=0.004482
R^2 = 0.301
20. Genypterus tigerinus
R^2 = 0.012
CAAB 37228008, p=0.554
R^2 = 0.0162
CAAB 23615000, p=0.005367
R^2 = 0.291
squid, p=0.9164
R^2 = 0.000489
CAAB 37228008, p=0.8126
R^2 = 0.00261
Rock Ling P.=0.2175
R^2 = 0.0683
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Year

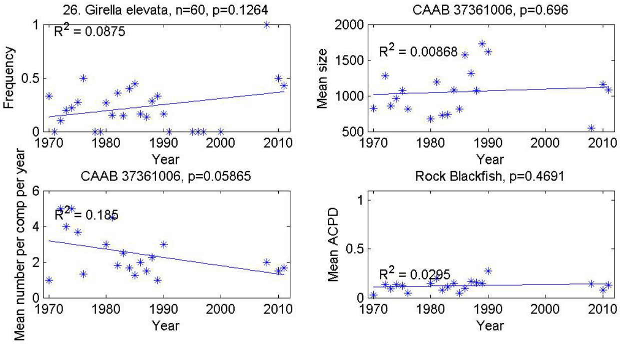


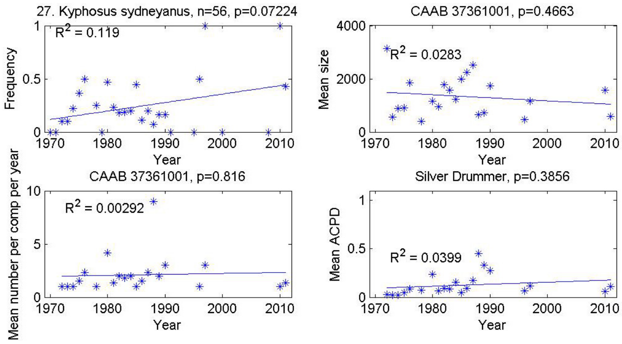
21. Meuschenia flavolineata, n=79, p=0.268
R^2 = 0.047
CAAB 37465035, p=0.1566
R^2 = 0.108
22. Eubalichthys gunnii, n=77, p=0.4713
R^2 = 0.0201
CAAB 37465034, p=0.8345
R^2 = 0.00224
CAAB 37465035, p=0.03559
R^2 = 0.223
Yellowstriped Leatherjacket , p=0.7694
R^2 = 0.0049
CAAB 37465034, p=0.09932
R^2 = 0.13
Gunn's Leatherjacket , p=0.4336
R^2 = 0.0309
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Year

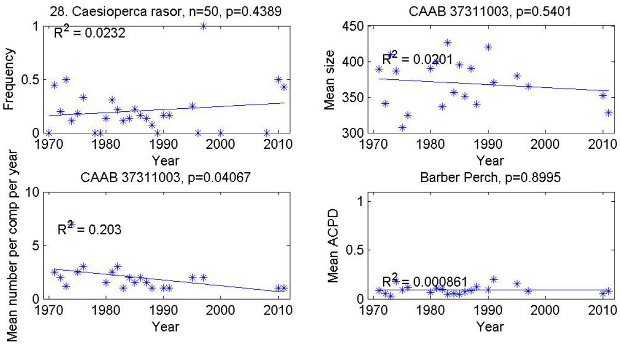


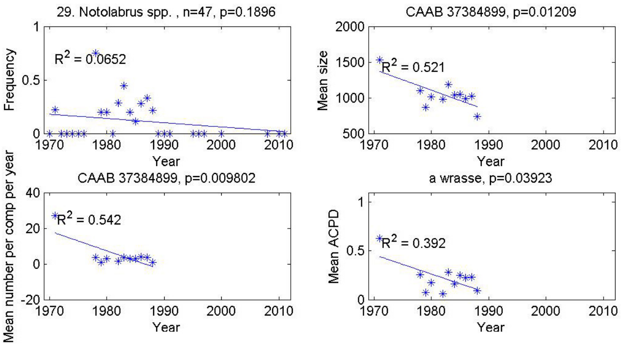
23. Conger verreauxi, n=73, p=0.0127
R^2 = 0.216
CAAB 37067007, p=0.8326
R^2 = 0.00241
24. Meuschenia galii, n=62, p=0.04642
R^2 = 0.144
CAAB 37465040, p=0.3162
R^2 = 0.059
CAAB 37067007, p=0.1737
R^2 = 0.0951
Southern Conger, p=0.0006213
R^2 = 0.468
CAAB 37465040, p=0.8392
R^2 = 0.00249
Bluelined Leatherjacket , p=0.08885
R^2 = 0.161
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Year

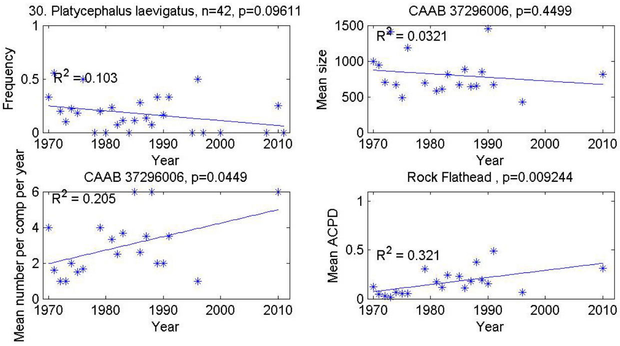

25. Arripis trutta, n=61, p=0.1859
R2 = 0.0663
Frequency
Year
CAAB 37344002, p=0.2721
R2 = 0.0522
Mean size
Year
CAAB 37344002, p=0.07835
R2 = 0.129
Mean number per comp per year
Year
Eastern Australian Salmon, p=0.8267
R2 = 0.00213
Mean ACPD
Year

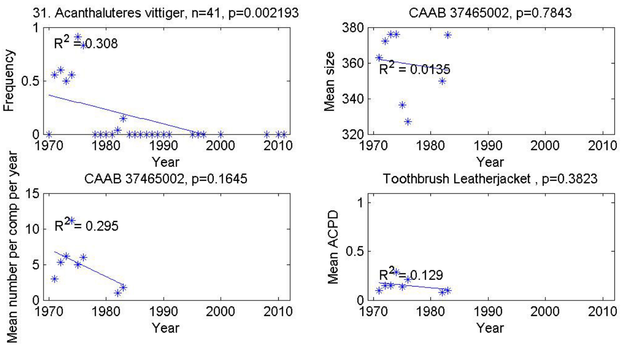

26. Girella elevata, n=60, p=0.1264
R2 = 0.0875
Frequency
Year
CAAB 37361006, p=0.696
R2 = 0.00868
Mean size
Year
CAAB 37361006, p=0.05865
R2 = 0.185
Mean number per comp per year
Year
Rock Blackfish, p=0.4691
R2 = 0.0295
Mean ACPD
Year

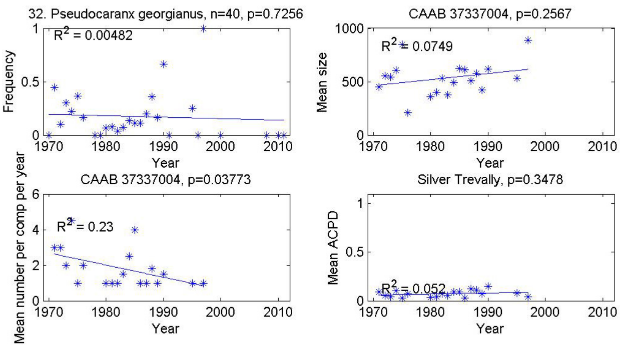

27. Kyphosus sydneyanus, n=56, p=0.07224
R2 = 0.119
Frequency
Year
CAAB 37361001, p=0.4663
R2 = 0.0283
Mean size
Year
CAAB 37361001, p=0.816
R2 = 0.00292
Mean number per comp per year
Year
Silver Drummer, p=0.3856
R2 = 0.0399
Mean ACPD
Year

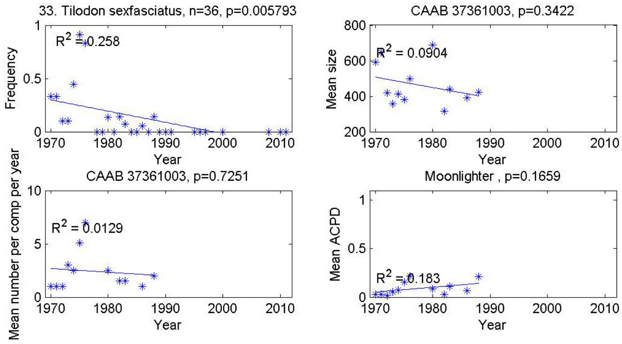

28. Caesioperca rasor, n=50, p=0.4389
R2 = 0.0232
Frequency
Year
CAAB 37311003, p=0.5401
R2 = 0.0201
Mean size
Year
CAAB 37311003, p=0.04067
R2 = 0.203
Mean number per comp per year
Year
Barber Perch, p=0.8995
R2 = 0.000861
Mean ACPD
Year

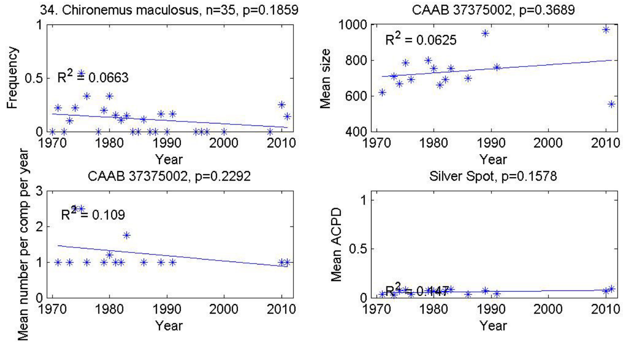

29. Notolabrus spp. , n=47, p=0.1896
R2 = 0.0652
Frequency
Year
CAAB 37384899, p=0.01209
R2 = 0.521
Mean size
Year
CAAB 37384899, p=0.009802
R2 = 0.542
Mean number per comp per year
Year
a wrasse, p=0.03923
R2 = 0.392
Mean ACPD
Year

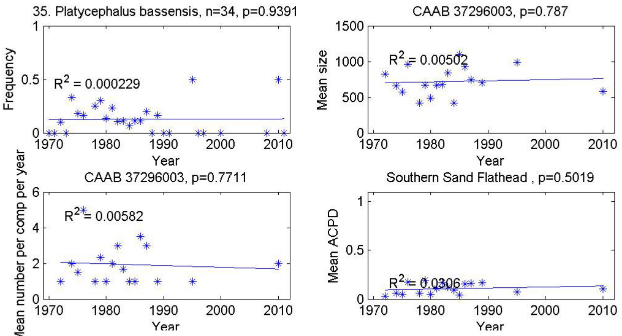

30. Platycephalus laevigatus, n=42, p=0.09611
R2 = 0.103
Frequency
Year
CAAB 37296006, p=0.4499
R2 = 0.0321
Mean size
Year
CAAB 37296006, p=0.0449
R2 = 0.205
Mean number per comp per year
Year
Rock Flathead , p=0.009244
R2 = 0.321
Mean ACPD
Year

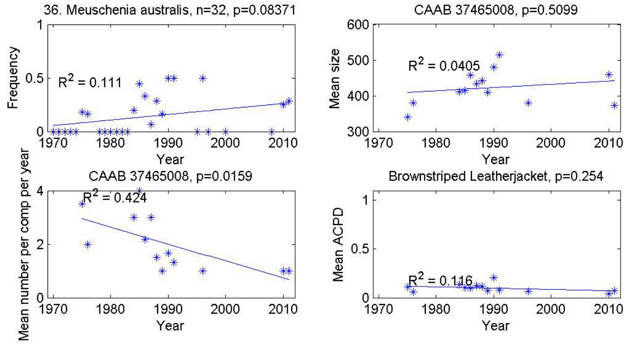

31. Acanthaluteres vittiger, n=41, p=0.002193
R2 = 0.308
Frequency
Year
CAAB 37465002, p=0.7843
R2 = 0.0135
Mean size
Year
CAAB 37465002, p=0.1645
R2 = 0.295
Mean number per comp per year
Year
Toothbrush Leatherjacket , p=0.3823
R2 = 0.129
Mean ACPD
Year

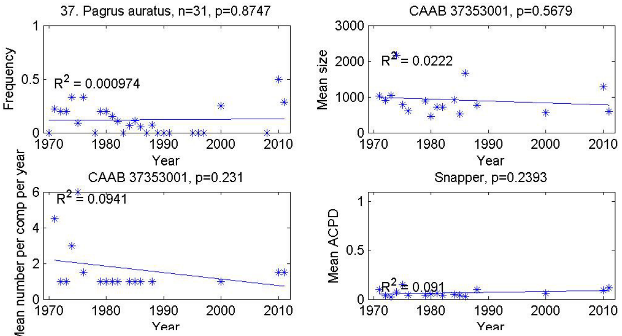

32. Pseudocaranx georgianus, n=40, p=0.7256
R2 = 0.00482
Frequency
Year
CAAB 37337004, p=0.2567
R2 = 0.0749
Mean size
Year
CAAB 37337004, p=0.03773
R2 = 0.23
Mean number per comp per year
Year
Silver Trevally, p=0.3478
R2 = 0.052
Mean ACPD
Year

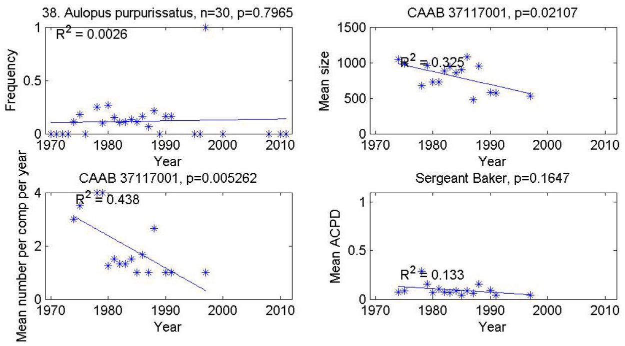

33. Tilodon sexfasciatus, n=36, p=0.005793
R2 = 0.258
Frequency
Year
CAAB 37361003, p=0.3422
R2 = 0.0904
Mean size
Year
CAAB 37361003, p=0.7251
R2 = 0.0129
Mean number per comp per year
Year
Moonlighter , p=0.1659
R2 = 0.183
Mean ACPD
Year

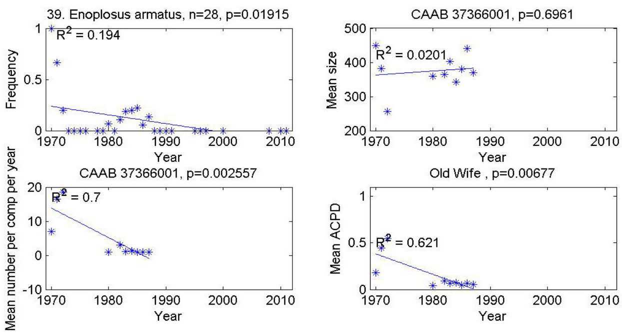

34. Chironemus maculosus, n=35, p=0.1859
R2 = 0.0663
Frequency
Year
CAAB 37375002, p=0.3689
R2 = 0.0625
Mean size
Year
CAAB 37375002, p=0.2292
R2 = 0.109
Mean number per comp per year
Year
Silver Spot, p=0.1578
R2 = 0.147
Mean ACPD
Year

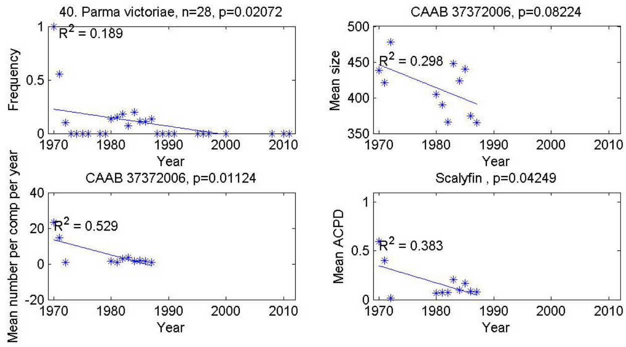

35. Platycephalus bassensis, n=34, p=0.9391
R2 = 0.000229
Frequency
Year
CAAB 37296003, p=0.787
R2 = 0.00502
Mean size
Year
CAAB 37296003, p=0.7711
R2 = 0.00582
Mean number per comp per year
Year
Southern Sand Flathead , p=0.5019
R2 = 0.0306
Mean ACPD
Year

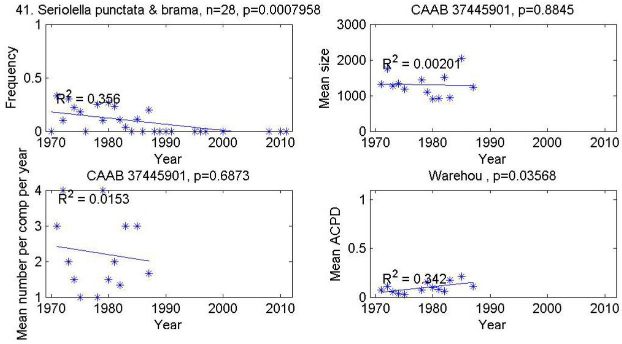

36. Meuschenia australis, n=32, p=0.08371
R2 = 0.111
Frequency
Year
CAAB 37465008, p=0.5099
R2 = 0.0405
Mean size
Year
CAAB 37465008, p=0.0159
R2 = 0.424
Mean number per comp per year
Year
Brownstriped Leatherjacket, p=0.254
R2 = 0.116
Mean ACPD
Year

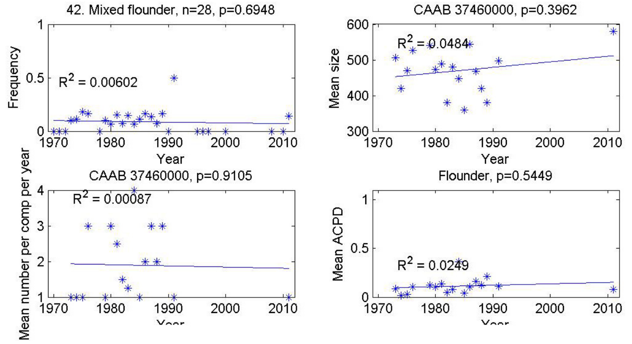

37. Pagrus auratus, n=31, p=0.8747
R2 = 0.000974
Frequency
Year
CAAB 37353001, p=0.5679
R2 = 0.0222
Mean size
Year
CAAB 37353001, p=0.231
R2 = 0.0941
Mean number per comp per year
Year
Snapper, p=0.2393
R2 = 0.091
Mean ACPD
Year

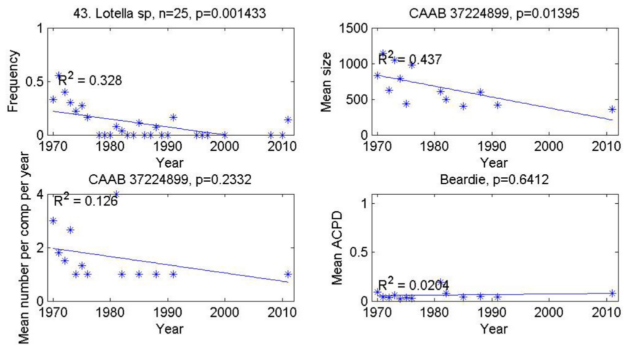

38. Aulopus purpurissatus, n=30, p=0.7965
R2 = 0.0026
Frequency
Year
CAAB 37117001, p=0.02107
R2 = 0.325
Mean size
Year
CAAB 37117001, p=0.005262
R2 = 0.438
Mean number per comp per year
Year
Sergeant Baker, p=0.1647
R2 = 0.133
Mean ACPD
Year

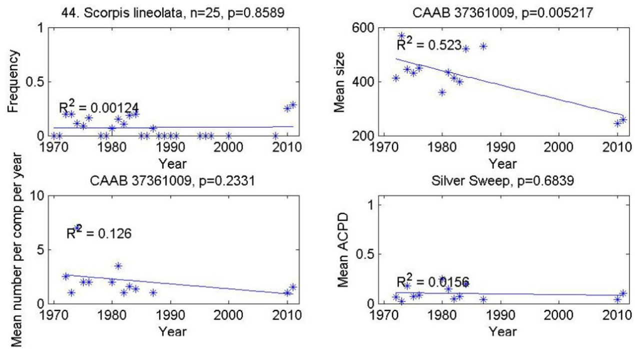

39. Enoplosus armatus, n=28, p=0.01915
R2 = 0.194
Frequency
Year
CAAB 37366001, p=0.6961
R2 = 0.0201
Mean size
Year
CAAB 37366001, p=0.002557
R2 = 0.7
Mean number per comp per year
Year
Old Wife , p=0.00677
R2 = 0.621
Mean ACPD
Year

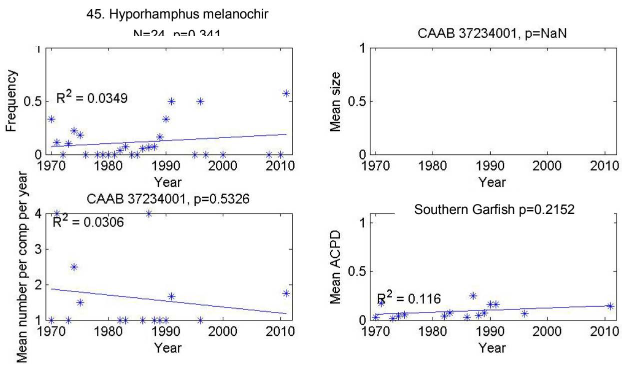

40. Parma victoriae, n=28, p=0.02072
R2 = 0.189
Frequency
Year
CAAB 37372006, p=0.08224
R2 = 0.298
Mean size
Year
CAAB 37372006, p=0.01124
R2 = 0.529
Mean number per comp per year
Year
Scalyfin , p=0.04249
R2 = 0.383
Mean ACPD
Year

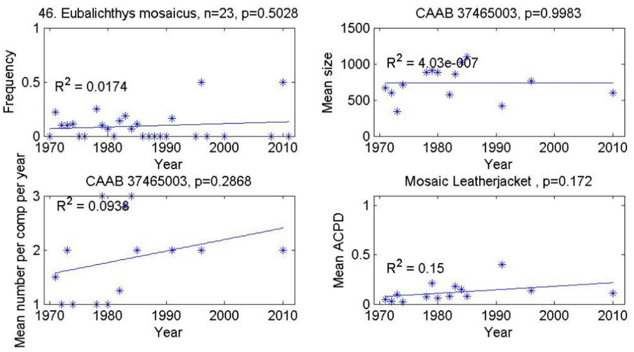

41. Seriolella punctata & brama, n=28, p=0.0007958
R2 = 0.356
Frequency
Year
CAAB 37445901, p=0.8845
R2 = 0.00201
Mean size
Year
CAAB 37445901, p=0.6873
R2 = 0.0153
Mean number per comp per year
Year
Warehou , p=0.03568
R2 = 0.342
Mean ACPD
Year

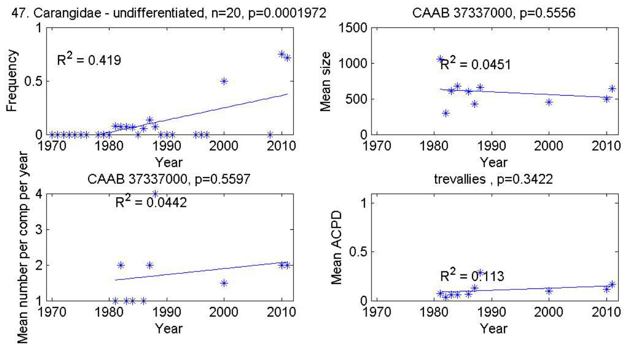

42. Mixed flounder, n=28, p=0.6948
R2 = 0.00602
Frequency
Year
CAAB 37460000, p=0.3962
R2 = 0.0484
Mean size
Year
CAAB 37460000, p=0.9105
R2 = 0.00087
Mean number per comp per year
Flounder, p=0.5449
R2 = 0.0249
Mean ACPD

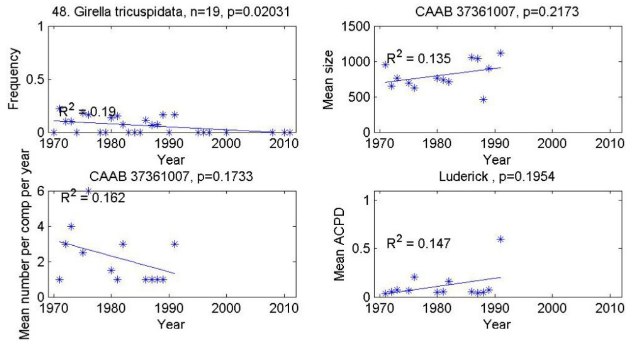

43. Lotella sp, n=25, p=0.001433
R2 = 0.328
Frequency
Year
CAAB 37224899, p=0.01395
R2 = 0.437
Mean size
Year
CAAB 37224899, p=0.2332
R2 = 0.126
Mean number per comp per year
Year
Beardie, p=0.6412
R2 = 0.0204
Mean ACPD
Year

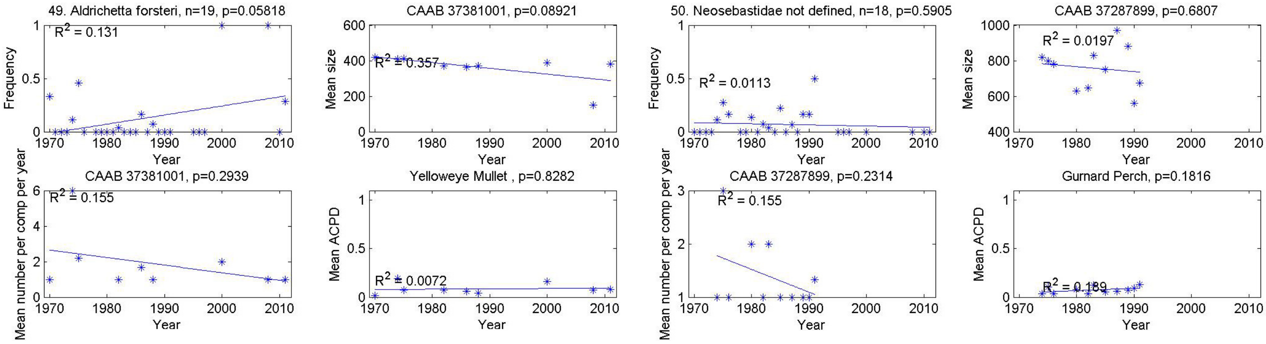

44. Scorpis lineolata, n=25, p=0.8589
R2 = 0.00124
Frequency
Year
CAAB 37361009, p=0.005217
R2 = 0.523
Mean size
Year
CAAB 37361009, p=0.2331
R2 = 0.126
Mean number per comp per year
Year
Silver Sweep, p=0.6839
R2 = 0.0156
Mean ACPD
Year


45. Hyporhamphus melanochir
R2 = 0.0349
Frequency
Year
CAAB 37234001, p=NaN
Mean size
Year
CAAB 37234001, p=0.5326
R2 = 0.0306
Mean number per comp per year
Year
Southern Garfish p=0.2152
R2 = 0.116
Mean ACPD
Year


46. Eubalichthys mosaicus, n=23, p=0.5028
R2 = 0.0174
Frequency
Year
CAAB 37465003, p=0.9983
R2 = 4.03e-007
Mean size
Year
CAAB 37465003, p=0.2868
R2 = 0.0938
Mean number per comp per year
Year
Mosaic Leatherjacket , p=0.172
R2 = 0.15
Mean ACPD
Year


47. Carangidae - undifferentiated, n=20, p=0.0001972
R2 = 0.419
Frequency
Year
CAAB 37337000, p=0.5556
R2 = 0.0451
Mean size
Year
CAAB 37337000, p=0.5597
R2 = 0.0442
Mean number per comp per year
Year
trevallies , p=0.3422
R2 = 0.113
Mean ACPD
Year

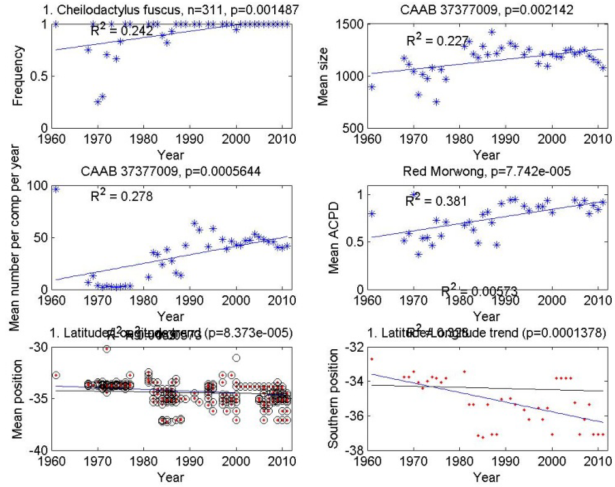

48. Girella tricuspidata, n=19, p=0.02031
R2 = 0.19
Frequency
Year
CAAB 37361007, p=0.2173
R2 = 0.135
Mean size
Year
CAAB 37361007, p=0.1733
R2 = 0.162
Mean number per comp per year
Year
Luderick , p=0.1954
R2 = 0.147
Mean ACPD
Year

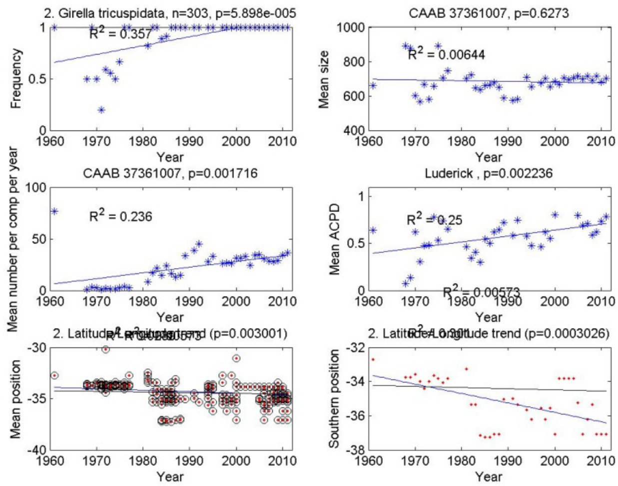

49. Aldrichetta forsteri, n=19, p=0.05818
R2 = 0.131
Frequency
Year
CAAB 37381001, p=0.08921
R2 = 0.357
Mean size
Year
50. Neosebastidae not defined, n=18, p=0.5905
R2 = 0.0113
Frequency
Year
CAAB 37287899, p=0.6807
R2 = 0.0197
Mean size
Year
CAAB 37381001, p=0.2939
R2 = 0.155
Mean number per comp per year
Year
Yelloweye Mullet , p=0.8282
R2 = 0.0072
Mean ACPD
Year
CAAB 37287899, p=0.2314
R2 = 0.155
Mean number per comp per year
Year
Gurnard Perch, p=0.1816
R2 = 0.189
Mean ACPD
Year

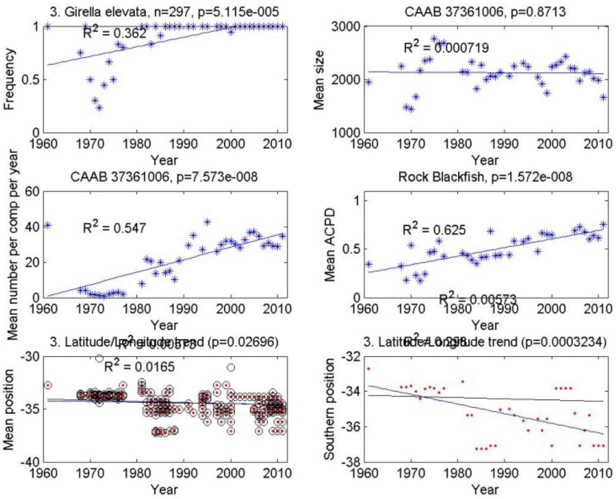
Appendix M

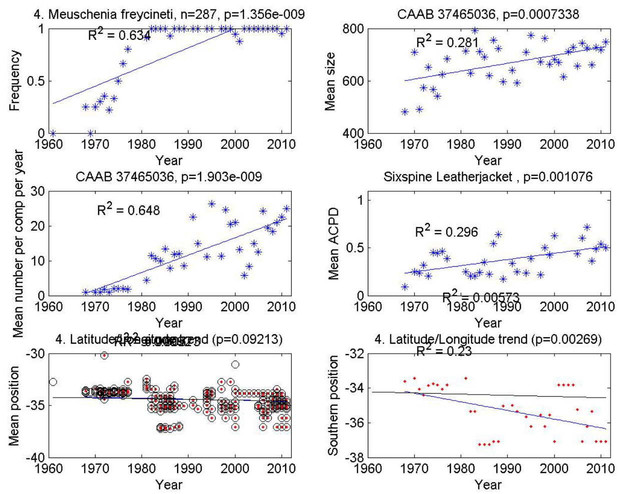
Fifty most common NSW species

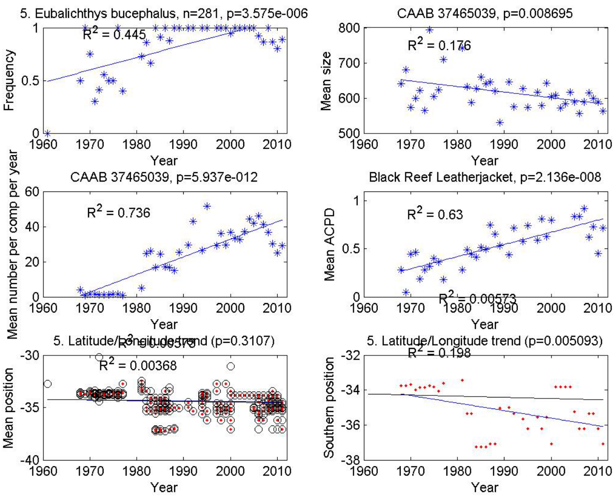
Figures display six parameters: commonness in competition data; mean size (weight in grams); catch per competition per year; catch rate per fisher, per competition; mean location of NSW competitions per year, open circles represent competition location, red closed circles represent catches of this species, and black trend-line in depicts the mean competition location; and the southern-most catch record for the species in each year, the black trend-line depicts change in the mean competition location.

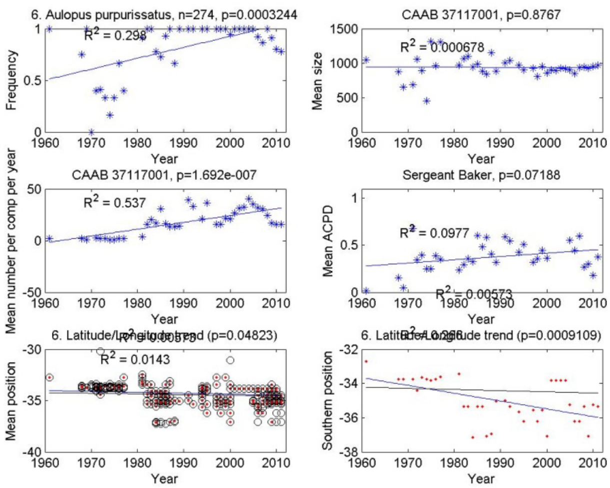

1. Cheilodactylus fuscus, n=311, p=0.001487
R2 = 0.242
Frequency
Year
CAAB 37377009, p=0.002142
R2 = 0.227
Mean size
CAAB 37377009, p=0.0005644
R2 = 0.278
Mean number per comp per year
Red Morwong, p=7.742e-005
R2 = 0.381
Mean ACPD
1. Latitude/Longitude trend (p=8.373e-005)
Mean position
1. Latitude/Longitude trend (p=0.0001378)
Southern position

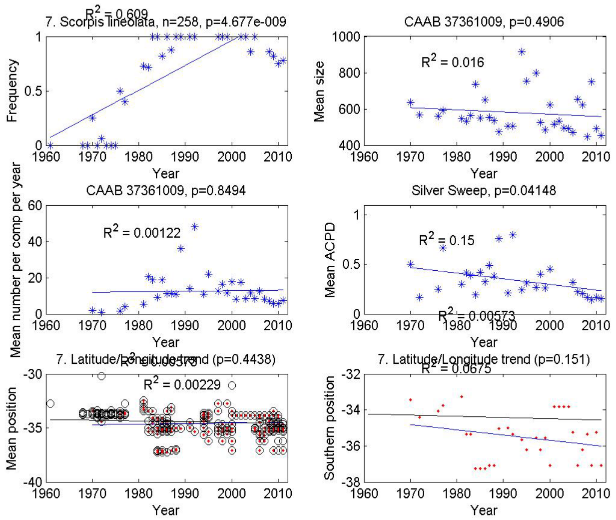

2. Girella tricuspidata, n=303, p=5.898e-005
R2 = 0.357
Frequency
Year
CAAB 37361007, p=0.6273
R2 = 0.00644
Mean size
CAAB 37361007, p=0.001716
R2 = 0.236
Mean number per comp per year
Luderick , p=0.002236
R2 = 0.25
Mean ACPD
2. Latitude/Longitude trend (p=0.003001)
Mean position
2. Latitude/Longitude trend (p=0.0003026)
Southern position

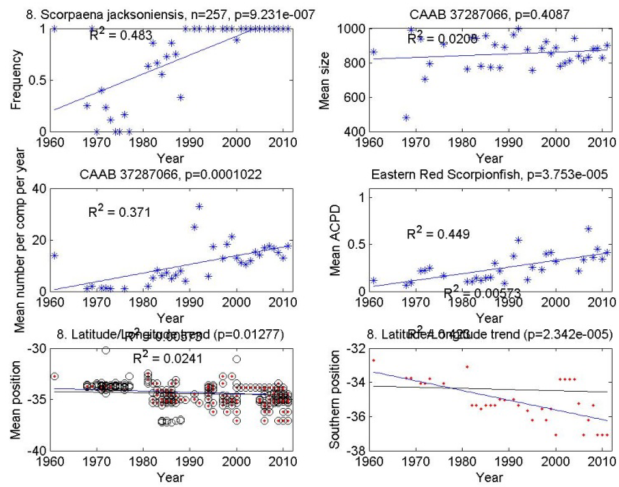

3. Girella elevata, n=297, p=5.115e-005
R2 = 0.362
Frequency
Year
CAAB 37361006, p=0.8713
R2 = 0.000719
Mean size
CAAB 37361006, p=7.573e-008
R2 = 0.547
Mean number per comp per year
Rock Blackfish, p=1.572e-008
R2 = 0.625
Mean ACPD
3. Latitude/Longitude trend (p=0.02696)
R2 = 0.0165
Mean position
3. Latitude/Longitude trend (p=0.0003234)
Southern position

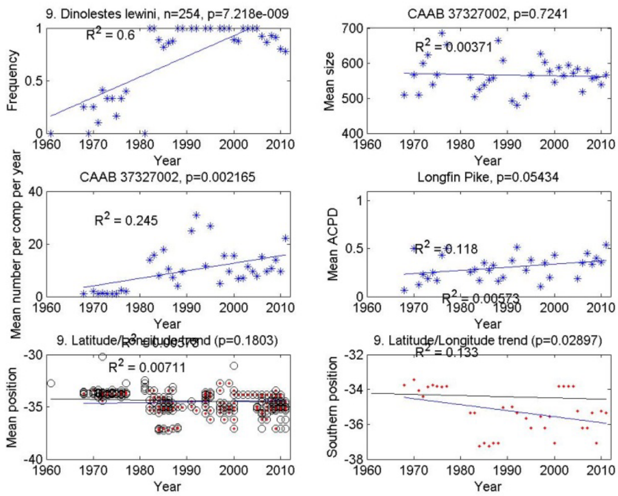

4. Meuschenia freycineti, n=287, p=1.356e-009
R2 = 0.634
Frequency
Year
CAAB 37465036, p=0.0007338
R2 = 0.281
Mean size
CAAB 37465036, p=1.903e-009
R2 = 0.648
Mean number per comp per year
Sixspine Leatherjacket , p=0.001076
R2 = 0.296
Mean ACPD
4. Latitude/Longitude trend (p=0.09213)
Mean position
4. Latitude/Longitude trend (p=0.00269)
R2 = 0.23
Southern position

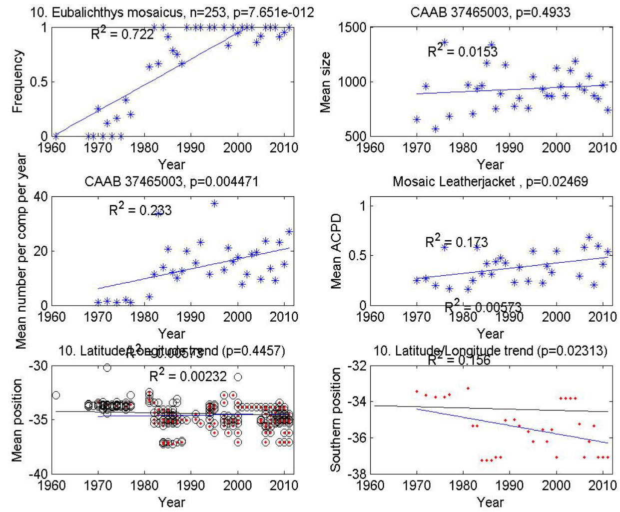

5. Eubalichthys bucephalus, n=281, p=3.575e-006
R2 = 0.445
Frequency
Year
CAAB 37465039, p=0.008695
R2 = 0.176
Mean size
CAAB 37465039, p=5.937e-012
R2 = 0.736
Mean number per comp per year
Black Reef Leatherjacket, p=2.136e-008
R2 = 0.63
Mean ACPD
5. Latitude/Longitude trend (p=0.3107)
R2 = 0.00368
Mean position
5. Latitude/Longitude trend (p=0.005093)
R2 = 0.198
Southern position

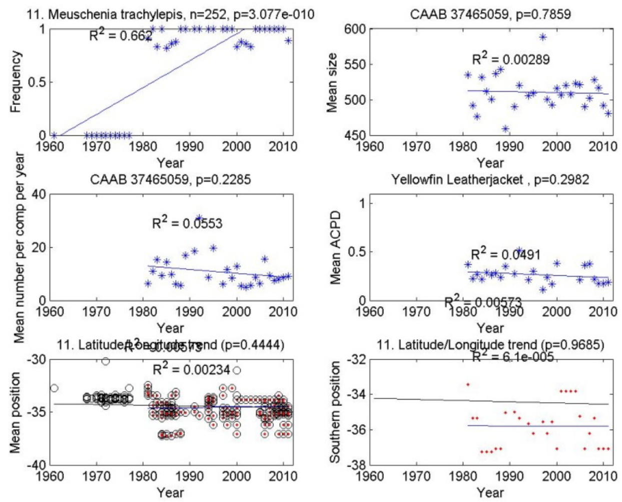

6. Aulopus purpurissatus, n=274, p=0.0003244
R2 = 0.298
Frequency
Year
CAAB 37117001, p=0.8767
R2 = 0.000678
Mean size
CAAB 37117001, p=1.692e-007
R2 = 0.537
Mean number per comp per year
Sergeant Baker, p=0.07188
R2 = 0.0977
Mean ACPD
6. Latitude/Longitude trend (p=0.04823)
R2 = 0.0143
Mean position
6. Latitude/Longitude trend (p=0.0009109)
Southern position

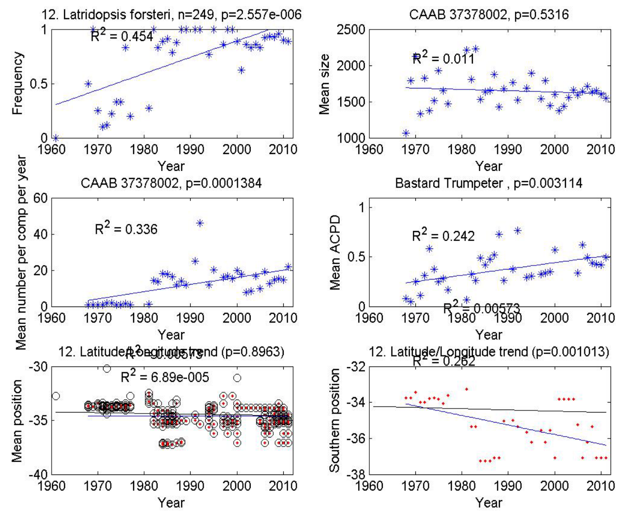

7. Scorpis lineolata, n=258, p=4.677e-009
R^2 = 0.609
Frequency
CAAB 37361009, p=0.4906
R^2 = 0.016
Mean size
CAAB 37361009, p=0.8494
R^2 = 0.00122
Mean number per comp per year
Silver Sweep, p=0.04148
R^2 = 0.15
Mean ACPD
7. Latitude/Longitude trend (p=0.4438)
R^2 = 0.00229
Mean position
7. Latitude/Longitude trend (p=0.151)
R^2 = 0.0675
Southern position
Year

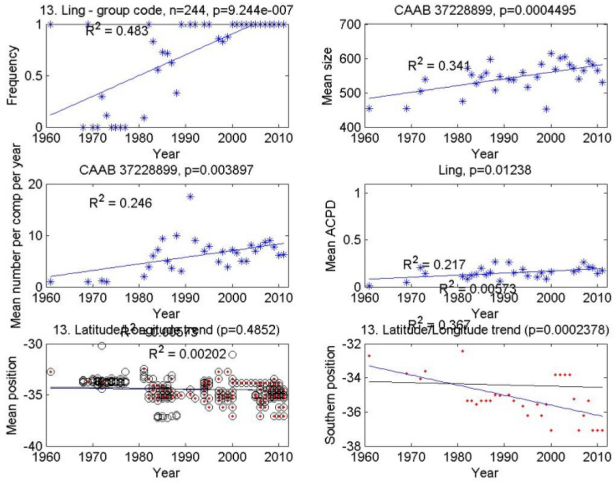

8. Scorpaena jacksoniensis, n=257, p=9.231e-007
R^2 = 0.483
Frequency
CAAB 37287066, p=0.4087
R^2 = 0.0208
Mean size
CAAB 37287066, p=0.0001022
R^2 = 0.371
Mean number per comp per year
Eastern Red Scorpionfish, p=3.753e-005
R^2 = 0.449
Mean ACPD
8. Latitude/Longitude trend (p=0.01277)
R^2 = 0.0241
Mean position
8. Latitude/Longitude trend (p=2.342e-005)
Southern position
Year

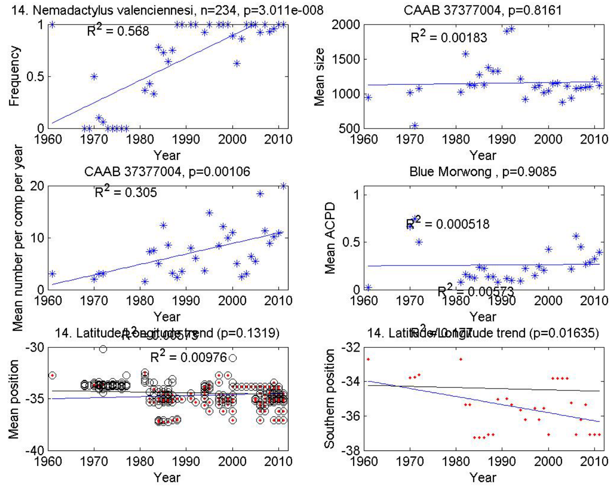

9. Dinolestes lewini, n=254, p=7.218e-009
R^2 = 0.6
Frequency
CAAB 37327002, p=0.7241
R^2 = 0.00371
Mean size
CAAB 37327002, p=0.002165
R^2 = 0.245
Mean number per comp per year
Longfin Pike, p=0.05434
R^2 = 0.118
Mean ACPD
9. Latitude/Longitude trend (p=0.1803)
R^2 = 0.00711
Mean position
9. Latitude/Longitude trend (p=0.02897)
R^2 = 0.133
Southern position
Year

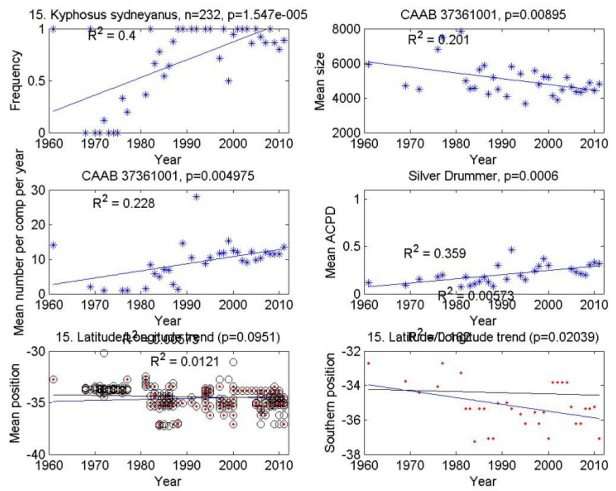

10. Eubalichthys mosaicus, n=253, p=7.651e-012
R^2 = 0.722
Frequency
CAAB 37465003, p=0.4933
R^2 = 0.0153
Mean size
CAAB 37465003, p=0.004471
R^2 = 0.233
Mean number per comp per year
Mosaic Leatherjacket , p=0.02469
R^2 = 0.173
Mean ACPD
10. Latitude/Longitude trend (p=0.4457)
R^2 = 0.00232
Mean position
10. Latitude/Longitude trend (p=0.02313)
R^2 = 0.156
Southern position
Year

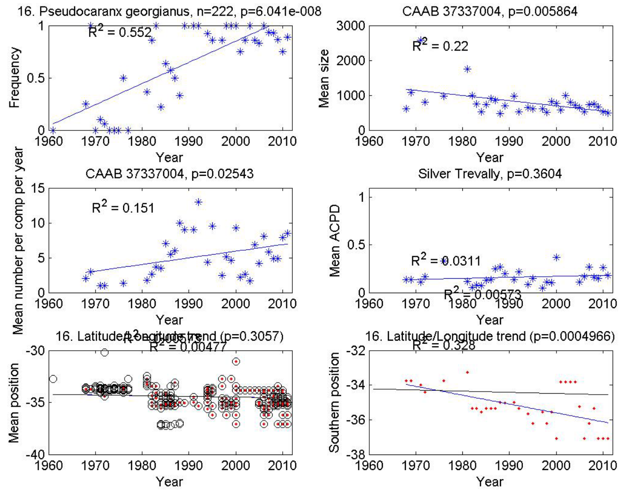

11. Meuschenia trachylepis, n=252, p=3.077e-010
R^2 = 0.662
Frequency
CAAB 37465059, p=0.7859
R^2 = 0.00289
Mean size
CAAB 37465059, p=0.2285
R^2 = 0.0553
Mean number per comp per year
Yellowfin Leatherjacket , p=0.2982
R^2 = 0.0491
Mean ACPD
11. Latitude/Longitude trend (p=0.4444)
R^2 = 0.00234
Mean position
11. Latitude/Longitude trend (p=0.9685)
R^2 = 6.1e-005
Southern position
Year

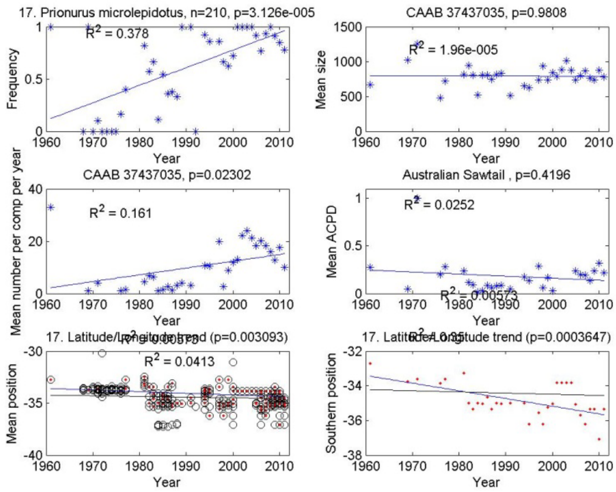

12. Latridopsis forsteri, n=249, p=2.557e-006
R^2 = 0.454
Frequency
CAAB 37378002, p=0.5316
R^2 = 0.011
Mean size
CAAB 37378002, p=0.0001384
R^2 = 0.336
Mean number per comp per year
Bastard Trumpeter , p=0.003114
R^2 = 0.242
Mean ACPD
12. Latitude/Longitude trend (p=0.8963)
R^2 = 6.89e-005
Mean position
12. Latitude/Longitude trend (p=0.001013)
R^2 = 0.262
Southern position
Year

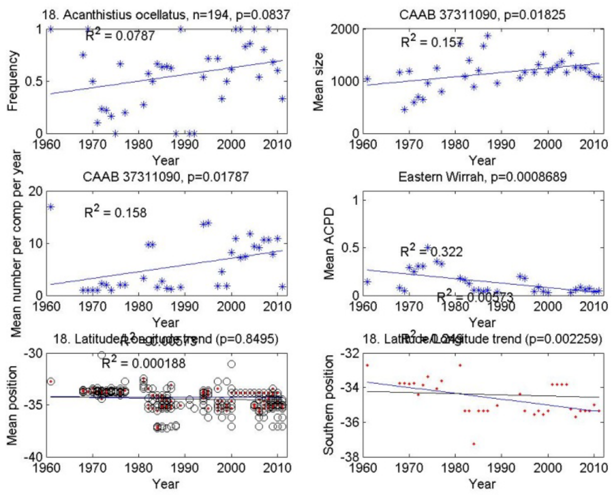

13. Ling - group code, n=244, p=9.244e-007
CAAB 37228899, p=0.0004495
CAAB 37228899, p=0.003897
Ling, p=0.01238
13. Latitude/Longitude trend (p=0.4852)
13. Latitude/Longitude trend (p=0.0002378)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

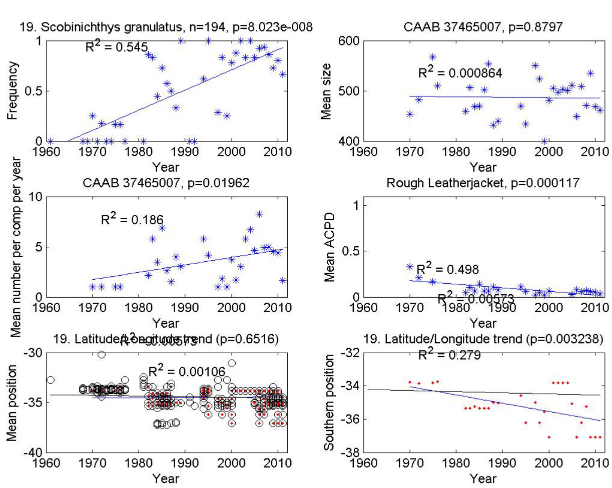

14. Nemadactylus valenciennesi, n=234, p=3.011e-008
CAAB 37377004, p=0.8161
CAAB 37377004, p=0.00106
Blue Morwong , p=0.9085
14. Latitude/Longitude trend (p=0.1319)
14. Latitude/Longitude trend (p=0.01635)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

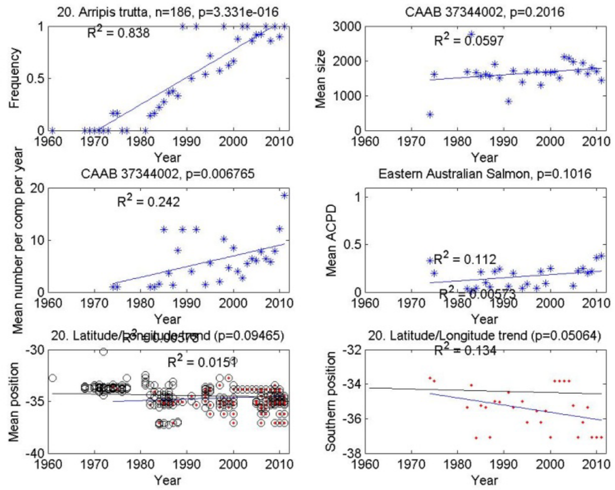

15. Kyphosus sydneyanus, n=232, p=1.547e-005
CAAB 37361001, p=0.00895
CAAB 37361001, p=0.004975
Silver Drummer, p=0.0006
15. Latitude/Longitude trend (p=0.0951)
15. Latitude/Longitude trend (p=0.02039)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

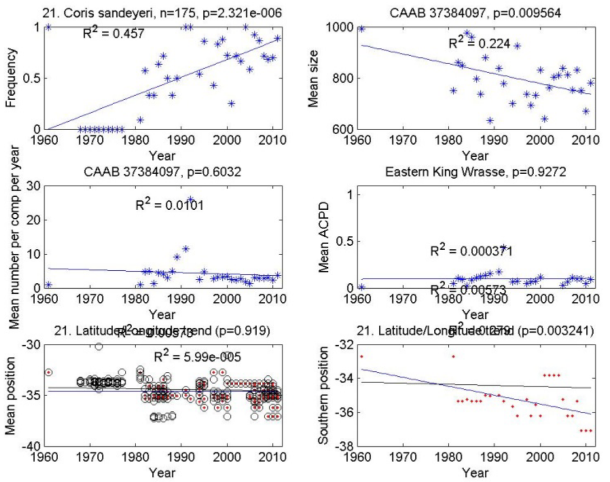

16. Pseudocaranx georgianus, n=222, p=6.041e-008
CAAB 37337004, p=0.005864
CAAB 37337004, p=0.02543
Silver Trevally, p=0.3604
16. Latitude/Longitude trend (p=0.3057)
16. Latitude/Longitude trend (p=0.0004966)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

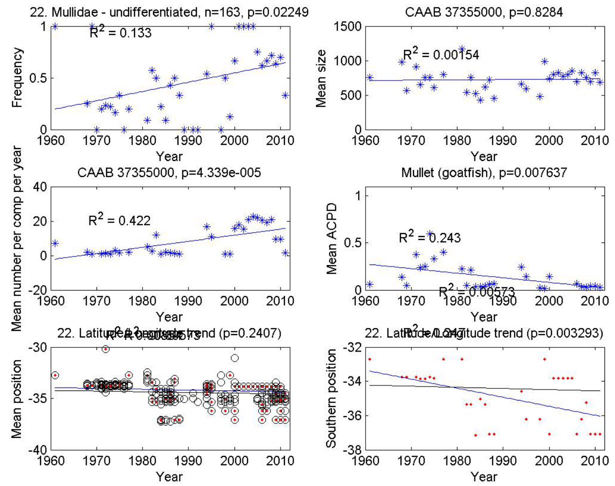

17. Prionurus microlepidotus, n=210, p=3.126e-005
CAAB 37437035, p=0.9808
CAAB 37437035, p=0.02302
Australian Sawtail , p=0.4196
17. Latitude/Longitude trend (p=0.003093)
17. Latitude/Longitude trend (p=0.0003647)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

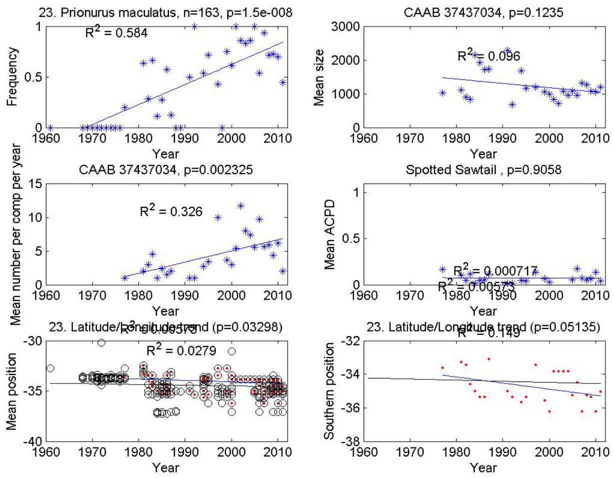

18. Acanthistius ocellatus, n=194, p=0.0837
CAAB 37311090, p=0.01825
CAAB 37311090, p=0.01787
Eastern Wirrah, p=0.0008689
18. Latitude/Longitude trend (p=0.8495)
18. Latitude/Longitude trend (p=0.002259)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

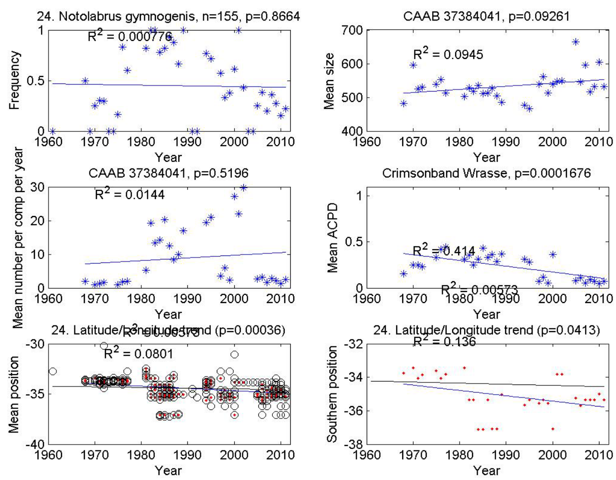

19. Scobinichthys granulatus, n=194, p=8.023e-008
R² = 0.545
Frequency
Year
CAAB 37465007, p=0.8797
R² = 0.000864
Mean size
CAAB 37465007, p=0.01962
R² = 0.186
Mean number per comp per year
Rough Leatherjacket, p=0.000117
R² = 0.498
Mean ACPD
19. Latitude/Longitude trend (p=0.6516)
R² = 0.00106
Mean position
19. Latitude/Longitude trend (p=0.003238)
R² = 0.279
Southern position

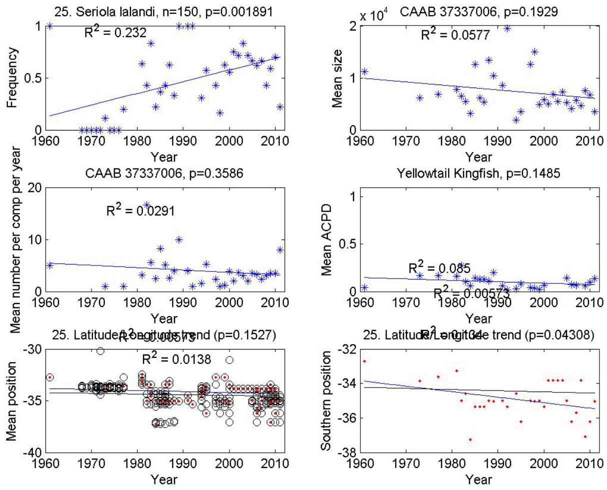

20. Arripis trutta, n=186, p=3.331e-016
R² = 0.838
Frequency
Year
CAAB 37344002, p=0.2016
R² = 0.0597
Mean size
CAAB 37344002, p=0.006765
R² = 0.242
Mean number per comp per year
Eastern Australian Salmon, p=0.1016
R² = 0.112
Mean ACPD
20. Latitude/Longitude trend (p=0.09465)
R² = 0.0151
Mean position
20. Latitude/Longitude trend (p=0.05064)
R² = 0.134
Southern position

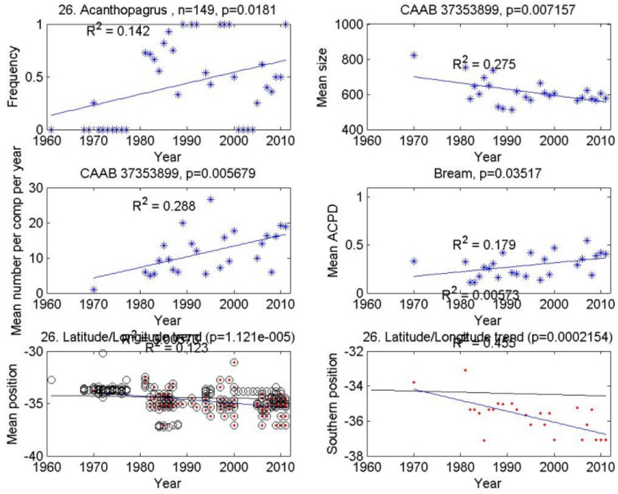

21. Coris sandeyeri, n=175, p=2.321e-006
R² = 0.457
Frequency
Year
CAAB 37384097, p=0.009564
R² = 0.224
Mean size
CAAB 37384097, p=0.6032
R² = 0.0101
Mean number per comp per year
Eastern King Wrasse, p=0.9272
R² = 0.000371
Mean ACPD
21. Latitude/Longitude trend (p=0.919)
R² = 5.99e-005
Mean position
21. Latitude/Longitude trend (p=0.003241)
Southern position

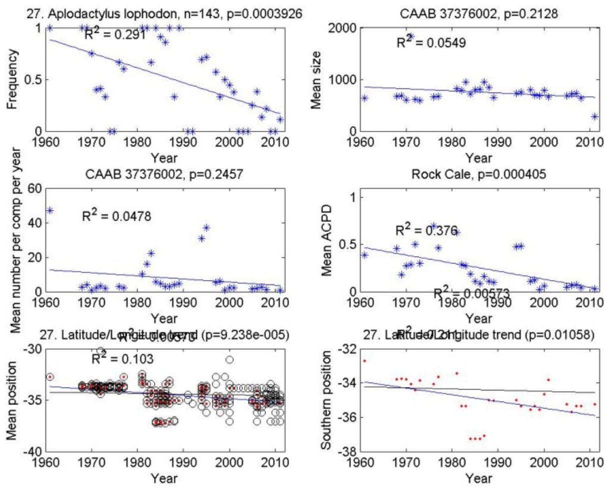

22. Mullidae - undifferentiated, n=163, p=0.02249
R² = 0.133
Frequency
Year
CAAB 37355000, p=0.8284
R² = 0.00154
Mean size
CAAB 37355000, p=4.339e-005
R² = 0.422
Mean number per comp per year
Mullet (goatfish), p=0.007637
R² = 0.243
Mean ACPD
22. Latitude/Longitude trend (p=0.2407)
Mean position
22. Latitude/Longitude trend (p=0.003293)
Southern position

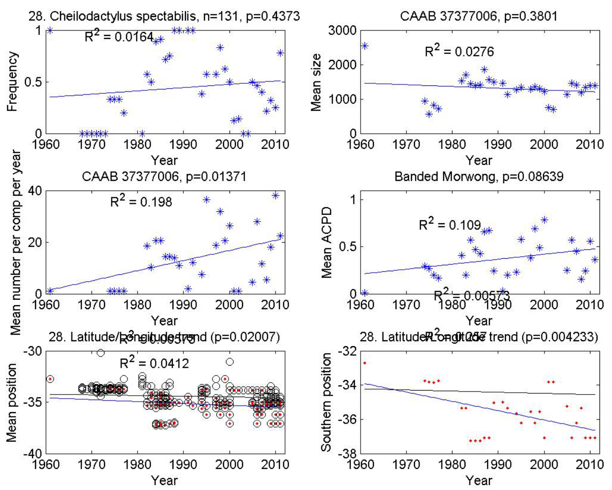

23. Prionurus maculatus, n=163, p=1.5e-008
R² = 0.584
Frequency
Year
CAAB 37437034, p=0.1235
R² = 0.096
Mean size
CAAB 37437034, p=0.002325
R² = 0.326
Mean number per comp per year
Spotted Sawtail , p=0.9058
R² = 0.000717
Mean ACPD
23. Latitude/Longitude trend (p=0.03298)
R² = 0.0279
Mean position
23. Latitude/Longitude trend (p=0.05135)
R² = 0.149
Southern position

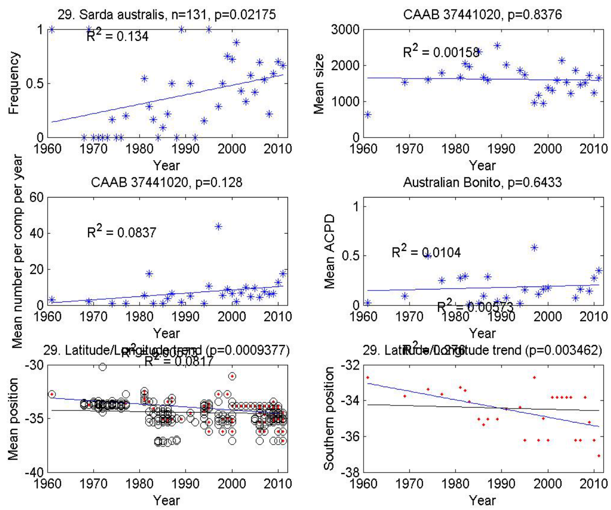

24. Notolabrus gymnogenis, n=155, p=0.8664
R² = 0.000776
Frequency
Year
CAAB 37384041, p=0.09261
R² = 0.0945
Mean size
CAAB 37384041, p=0.5196
R² = 0.0144
Mean number per comp per year
Crimsonband Wrasse, p=0.0001676
R² = 0.414
Mean ACPD
24. Latitude/Longitude trend (p=0.00036)
R² = 0.0801
Mean position
24. Latitude/Longitude trend (p=0.0413)
R² = 0.136
Southern position

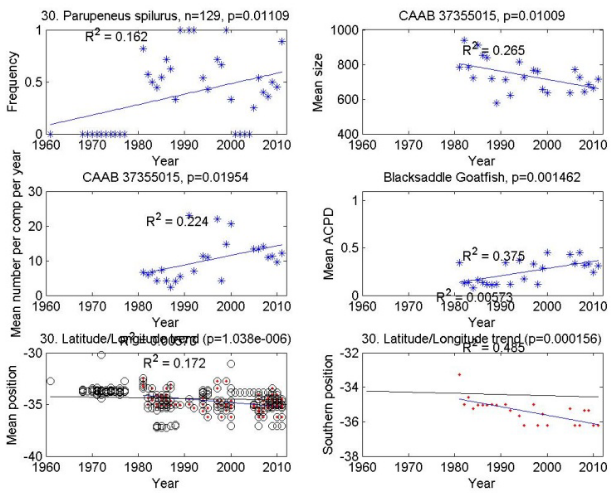

25. Seriola lalandi, n=150, p=0.001891
R² = 0.232
CAAB 37337006, p=0.1929
R² = 0.0577
CAAB 37337006, p=0.3586
R² = 0.0291
Yellowtail Kingfish, p=0.1485
R² = 0.085
25. Latitude/Longitude trend (p=0.1527)
R² = 0.0138
25. Latitude/Longitude trend (p=0.04308)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

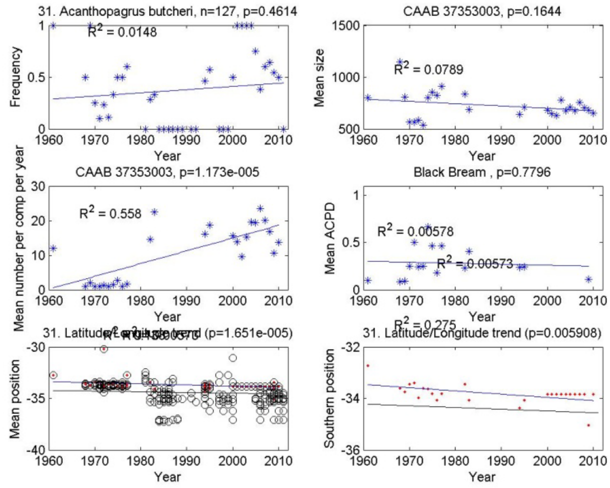

26. Acanthopagrus , n=149, p=0.0181
R² = 0.142
CAAB 37353899, p=0.007157
R² = 0.275
CAAB 37353899, p=0.005679
R² = 0.288
Bream, p=0.03517
R² = 0.179
26. Latitude/Longitude trend (p=1.121e-005)
R² = 0.123
26. Latitude/Longitude trend (p=0.0002154)
R² = 0.455
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

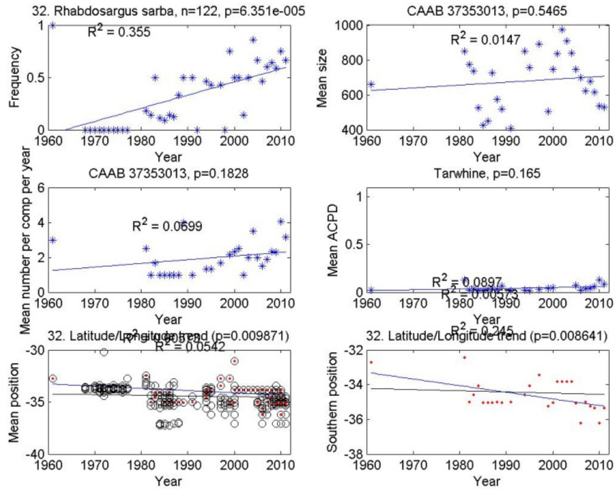

27. Aplodactylus lophodon, n=143, p=0.0003926
R² = 0.291
CAAB 37376002, p=0.2128
R² = 0.0549
CAAB 37376002, p=0.2457
R² = 0.0478
Rock Cale, p=0.000405
R² = 0.376
27. Latitude/Longitude trend (p=9.238e-005)
R² = 0.103
27. Latitude/Longitude trend (p=0.01058)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

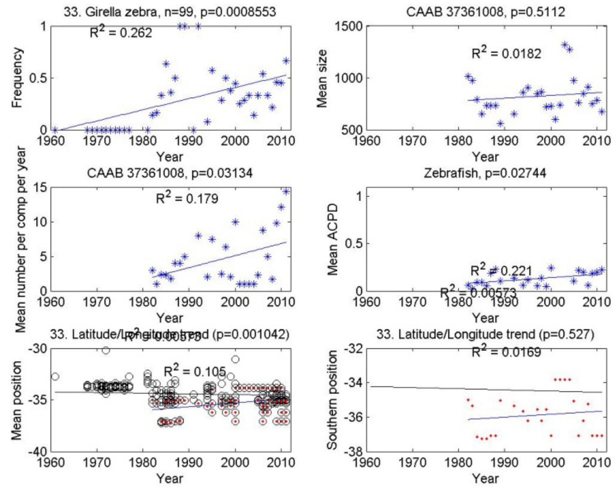

28. Cheilodactylus spectabilis, n=131, p=0.4373
R² = 0.0164
CAAB 37377006, p=0.3801
R² = 0.0276
CAAB 37377006, p=0.01371
R² = 0.198
Banded Morwong, p=0.08639
R² = 0.109
28. Latitude/Longitude trend (p=0.02007)
R² = 0.0412
28. Latitude/Longitude trend (p=0.004233)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

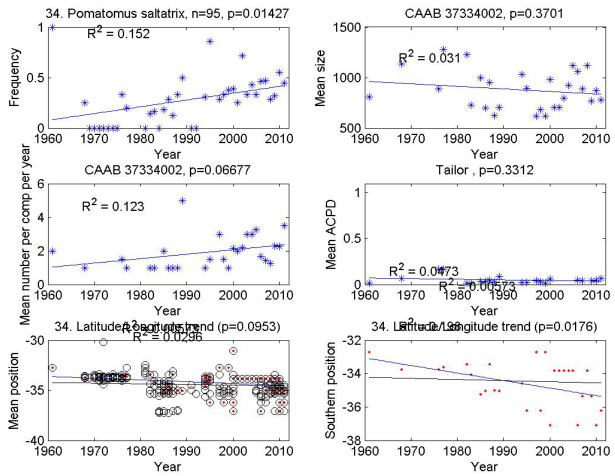

29. Sarda australis, n=131, p=0.02175
R² = 0.134
CAAB 37441020, p=0.8376
R² = 0.00158
CAAB 37441020, p=0.128
R² = 0.0837
Australian Bonito, p=0.6433
R² = 0.0104
29. Latitude/Longitude trend (p=0.0009377)
R² = 0.0817
29. Latitude/Longitude trend (p=0.003462)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

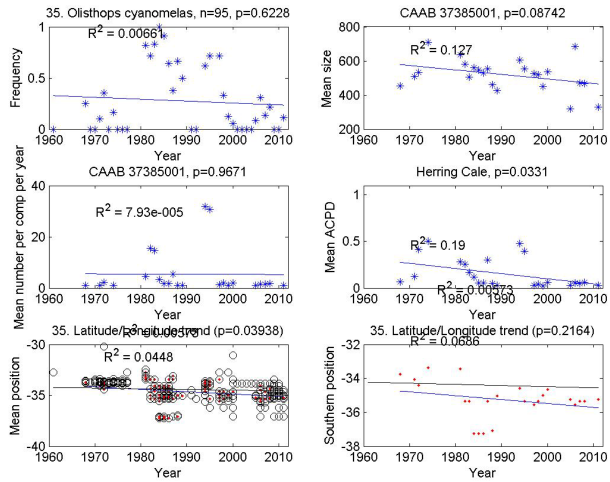

30. Parupeneus spilurus, n=129, p=0.01109
R² = 0.162
CAAB 37355015, p=0.01009
R² = 0.265
CAAB 37355015, p=0.01954
R² = 0.224
Blacksaddle Goatfish, p=0.001462
R² = 0.375
30. Latitude/Longitude trend (p=1.038e-006)
R² = 0.172
30. Latitude/Longitude trend (p=0.000156)
R² = 0.485
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

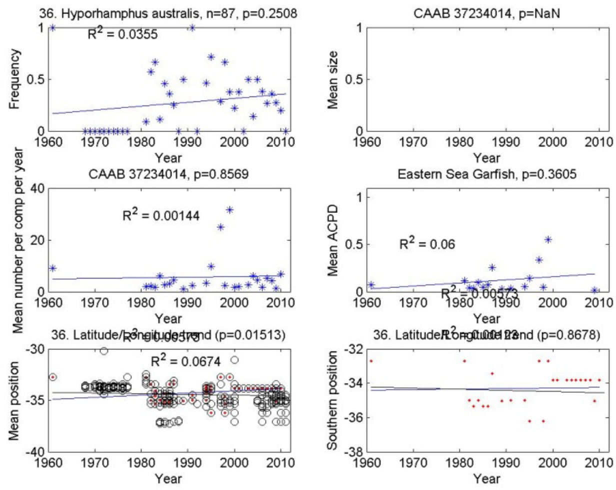

31. Acanthopagrus butcheri, n=127, p=0.4614
CAAB 37353003, p=0.1644
CAAB 37353003, p=1.173e-005
Black Bream , p=0.7796
31. Latitude/Longitude trend (p=1.651e-005)
31. Latitude/Longitude trend (p=0.005908)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

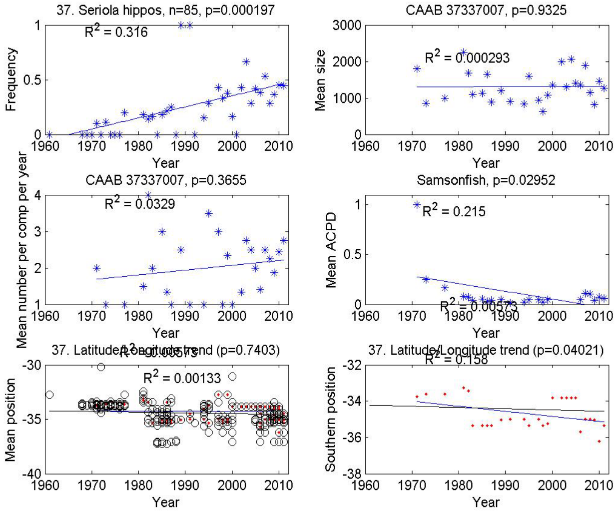

32. Rhabdosargus sarba, n=122, p=6.351e-005
CAAB 37353013, p=0.5465
CAAB 37353013, p=0.1828
Tarwhine, p=0.165
32. Latitude/Longitude trend (p=0.009871)
32. Latitude/Longitude trend (p=0.008641)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year


33. Girella zebra, n=99, p=0.0008553
CAAB 37361008, p=0.5112
CAAB 37361008, p=0.03134
Zebrafish, p=0.02744
33. Latitude/Longitude trend (p=0.001042)
33. Latitude/Longitude trend (p=0.527)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

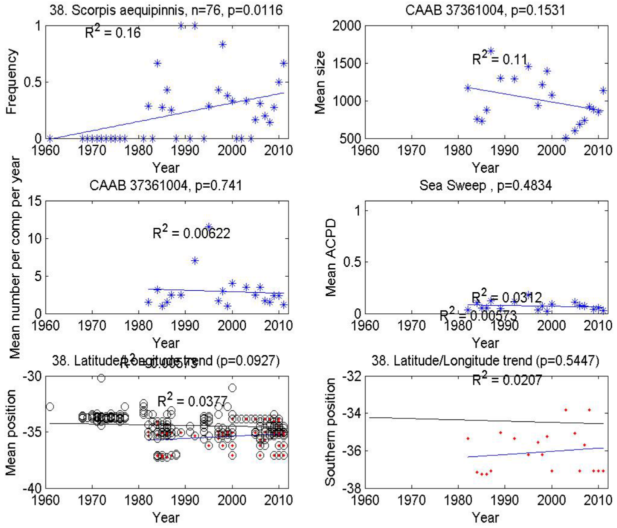

34. Pomatomus saltatrix, n=95, p=0.01427
CAAB 37334002, p=0.3701
CAAB 37334002, p=0.06677
Tailor , p=0.3312
34. Latitude/Longitude trend (p=0.0953)
34. Latitude/Longitude trend (p=0.0176)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year


35. Olisthops cyanomelas, n=95, p=0.6228
CAAB 37385001, p=0.08742
CAAB 37385001, p=0.9671
Herring Cale, p=0.0331
35. Latitude/Longitude trend (p=0.03938)
35. Latitude/Longitude trend (p=0.2164)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

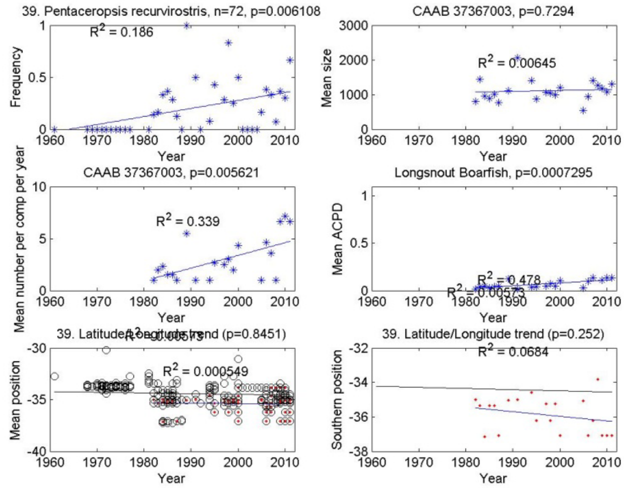

36. Hyporhamphus australis, n=87, p=0.2508
CAAB 37234014, p=NaN
CAAB 37234014, p=0.8569
Eastern Sea Garfish, p=0.3605
36. Latitude/Longitude trend (p=0.01513)
36. Latitude/Longitude trend (p=0.8678)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year



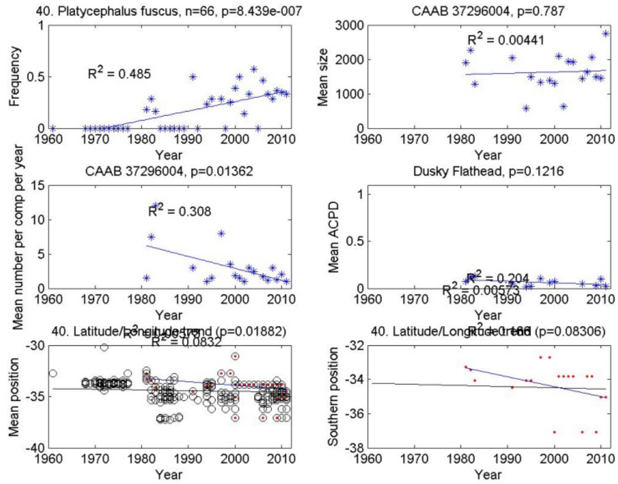
37. Seriola hippos, n=85, p=0.000197
CAAB 37337007, p=0.9325
CAAB 37337007, p=0.3655
Samsonfish, p=0.02952
37. Latitude/Longitude trend (p=0.7403)
37. Latitude/Longitude trend (p=0.04021)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year



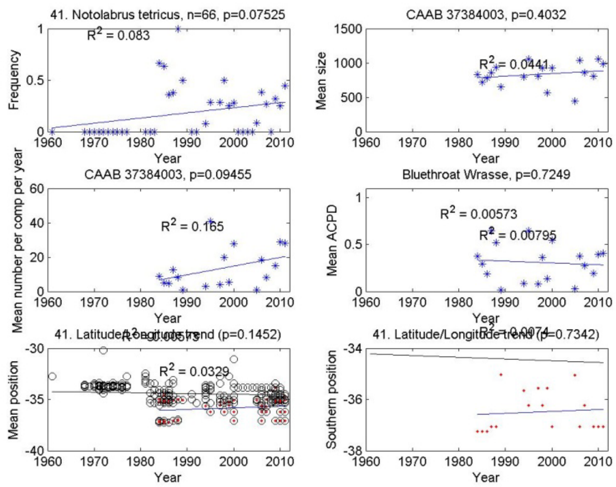
38. Scorpis aequipinnis, n=76, p=0.0116
CAAB 37361004, p=0.1531
CAAB 37361004, p=0.741
Sea Sweep , p=0.4834
38. Latitude/Longitude trend (p=0.0927)
38. Latitude/Longitude trend (p=0.5447)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year



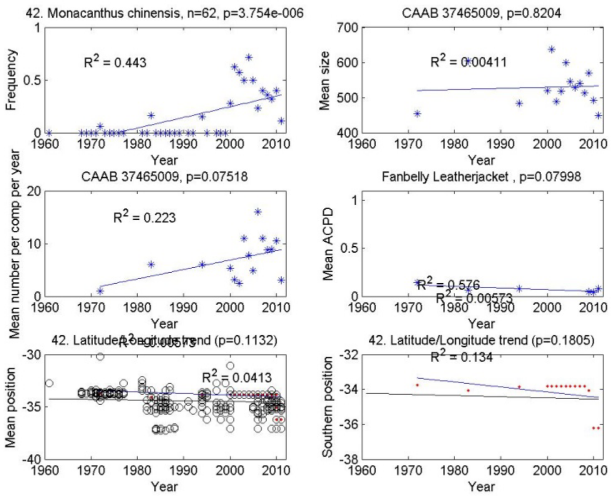
39. Pentaceropsis recurvirostris, n=72, p=0.006108
CAAB 37367003, p=0.7294
CAAB 37367003, p=0.005621
Longsnout Boarfish, p=0.0007295
39. Latitude/Longitude trend (p=0.8451)
39. Latitude/Longitude trend (p=0.252)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year



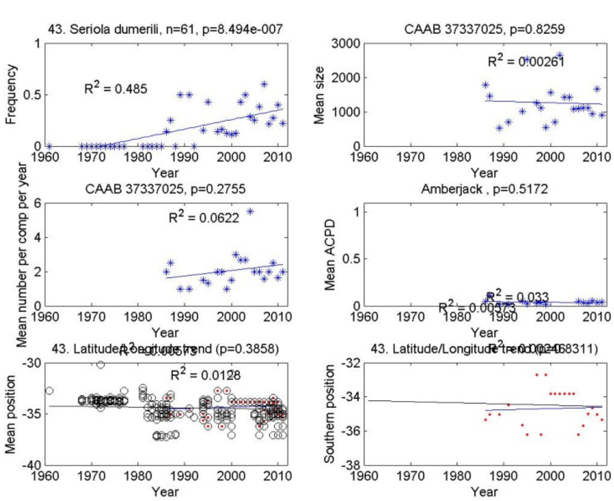
40. Platycephalus fuscus, n=66, p=8.439e-007
CAAB 37296004, p=0.787
CAAB 37296004, p=0.01362
Dusky Flathead, p=0.1216
40. Latitude/Longitude trend (p=0.01882)
40. Latitude/Longitude trend (p=0.08306)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

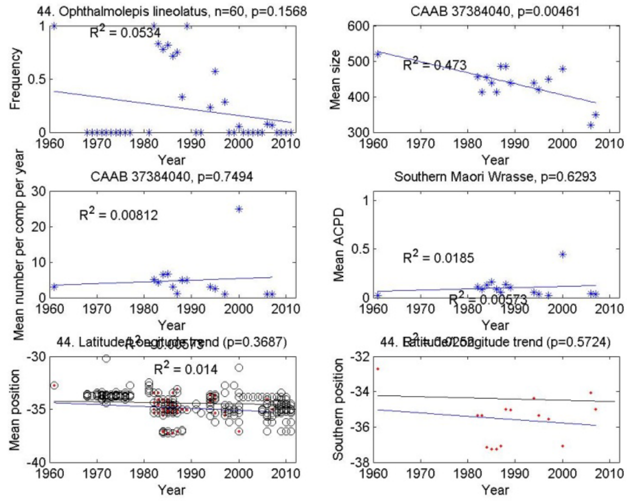


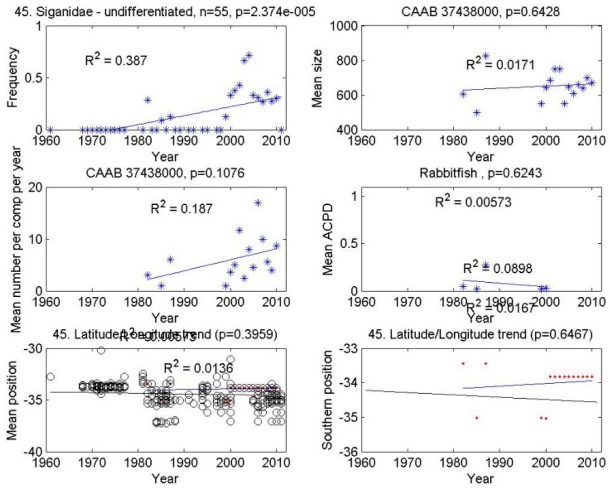
41. Notolabrus tetricus, n=66, p=0.07525
CAAB 37384003, p=0.4032
CAAB 37384003, p=0.09455
Bluethroat Wrasse, p=0.7249
41. Latitude/Longitude trend (p=0.1452)
41. Latitude/Longitude trend (p=0.7342)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

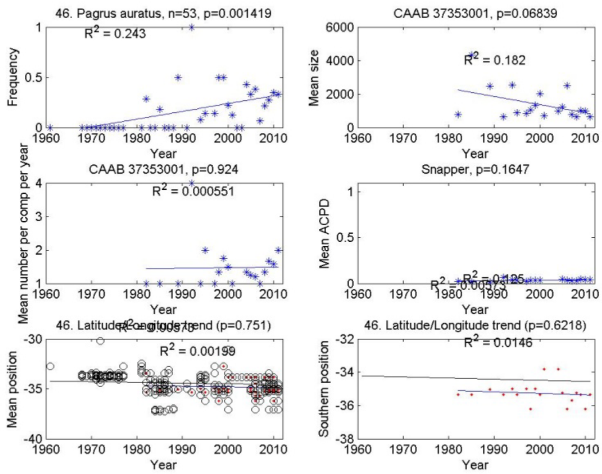


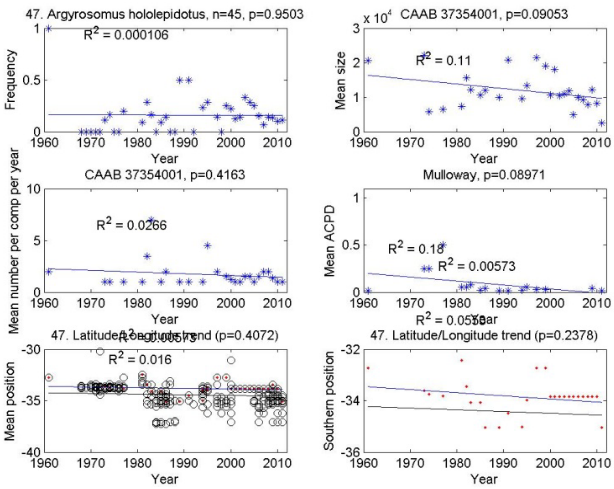
42. Monacanthus chinensis, n=62, p=3.754e-006
CAAB 37465009, p=0.8204
CAAB 37465009, p=0.07518
Fanbelly Leatherjacket , p=0.07998
42. Latitude/Longitude trend (p=0.1132)
42. Latitude/Longitude trend (p=0.1805)
Frequency
Mean size
Mean number per comp per year
Mean ACPD
Mean position
Southern position
Year

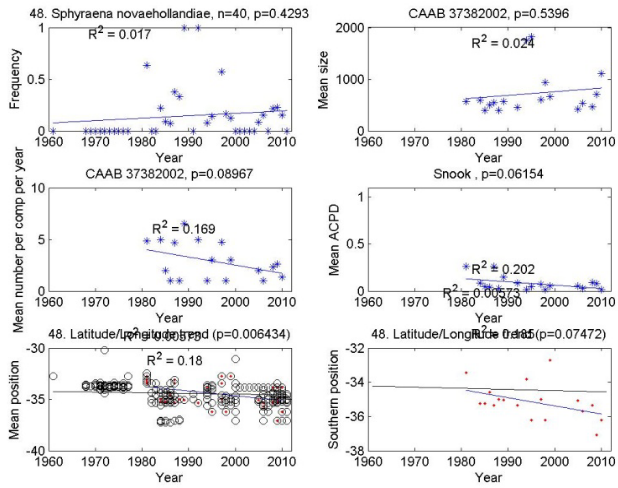

43. Seriola dumerili, n=61, p=8.494e-007
CAAB 37337025, p=0.8259
CAAB 37337025, p=0.2755
Amberjack , p=0.5172
43. Latitude/Longitude trend (p=0.3858)
43. Latitude/Longitude trend

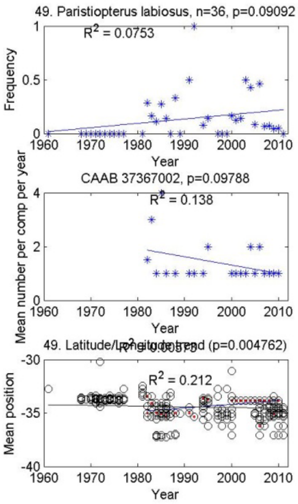

44. Ophthalmolepis lineolatus, n=60, p=0.1568
CAAB 37384040, p=0.00461
CAAB 37384040, p=0.7494
Southern Maori Wrasse, p=0.6293
44. Latitude/Longitude trend (p=0.3687)
44. Latitude/Longitude trend (p=0.5724)


45. Siganidae - undifferentiated, n=55, p=2.374e-005
CAAB 37438000, p=0.6428
CAAB 37438000, p=0.1076
Rabbitfish , p=0.6243
45. Latitude/Longitude trend (p=0.3959)
45. Latitude/Longitude trend (p=0.6467)

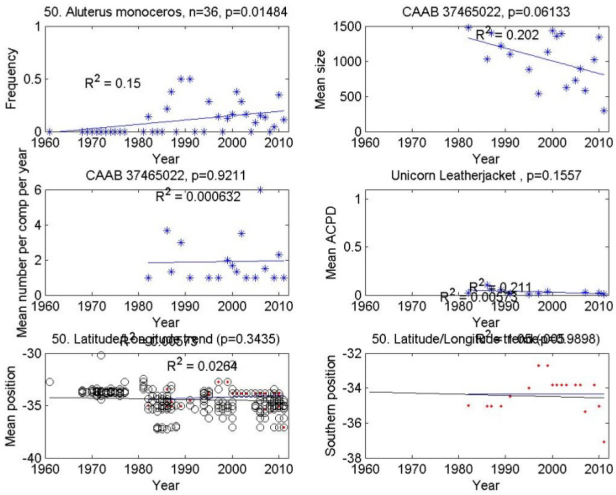

46. Pagrus auratus, n=53, p=0.001419
CAAB 37353001, p=0.06839
CAAB 37353001, p=0.924
Snapper, p=0.1647
46. Latitude/Longitude trend (p=0.751)
46. Latitude/Longitude trend (p=0.6218)


47. Argyrosomus hololepidotus, n=45, p=0.9503
CAAB 37354001, p=0.09053
CAAB 37354001, p=0.4163
Mulloway, p=0.08971
47. Latitude/Longitude trend (p=0.4072)
47. Latitude/Longitude trend (p=0.2378)


48. Sphyraena novaehollandiae, n=40, p=0.4293
CAAB 37382002, p=0.5396
CAAB 37382002, p=0.08967
Snook , p=0.06154
48. Latitude/Longitude trend (p=0.006434)
48. Latitude/Longitude trend (p=0.07472)



49. Paristiopterus labiosus, n=36, p=0.09092
R^2 = 0.0753
Frequency
Year
CAAB 37367002, p=0.02155
R^2 = 0.248
Mean size
Year
CAAB 37367002, p=0.09788
R^2 = 0.138
Mean number per comp per year
Year
Giant Boarfish , p=0.5379
R^2 = 0.0391
Mean ACPD
Year
49. Latitude/Longitude trend (p=0.004762)
R^2 = 0.212
Mean position
Year
49. Latitude/Longitude trend (p=0.09015)
R^2 = 0.144
Southern position
Year



50. Aluterus monoceros, n=36, p=0.01484
R^2 = 0.15
Frequency
Year
CAAB 37465022, p=0.06133
R^2 = 0.202
Mean size
Year
CAAB 37465022, p=0.9211
R^2 = 0.000632
Mean number per comp per year
Year
Unicorn Leatherjacket , p=0.1557
R^2 = 0.211
Mean ACPD
Year
50. Latitude/Longitude trend (p=0.3435)
R^2 = 0.0264
Mean position
Year
50. Latitude/Longitude trend (p=0.9898)
Southern position
Year

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