Paper 6: Past, present and future research of Abalone management and assessment RD&E investment (2002 – 2018)

Background

This paper provides a summary of FRDC research, development and extension (RD&E) projects invested between 2002 and 2018. These projects reflect a combination of investment from the Abalone Council of Australia (ACA), State-based RACs (formerly FRABs), Tactical Research Funding (TRFs; now defunct) and other FRDC Subprograms (e.g. the FRDC's Aquatic Animal Welfare and Subprogram).

Over this period (2002-2018), there has been 80+ projects and approximately $18.5 million invested in the wild Abalone resource (Table 1). This considerable body of RD&E investment encompasses projects that investigated all aspects of the biology & ecology, and management of both the sustainability and biosecurity of the resource. In addition, there has been substantial investment into the development of markets for and trade in wild caught Abalone; namely, through the Seafood CRC. Refer to the ACA website for a partial list of Abalone related research projects (https://www.abalonecouncil.com.au/research-development/abalone-related-research-projects/).

Table 1. Overview of FRDC RD&E investment into wild Abalone between 2002 and 2018 (this is not exhaustive). Total investment ($) has been partitioned into three 5-year periods, and is split across a number of research categories. The per cent of projects in each research category (%) is shown for each 5-year period.

	2002-2005		2009-2013		2014-2018	
Research Category	$	%	$	%	$	%
Capacity & diver welfare	$334,356	8	$6,000	2		
Centrostephanus	$828,553	8	$483,581	7	$439,712	12
Climate change			$795,163	5		
Community & consumer support			$143,400	5	$168,800	4
Customary issues	$207,395	8			$510,390	4
Disease / pathogens / biosecurity	$344,133	8	$1,280,745	17	$2,493,998	24
General	$426,819	25	$820,451	7		
Markets & trade			$1,164,552	17	$436,500	8
Planning, review & conferences	$20,000	8	$449,844	7	$899,528	16
Recruitment & translocation	$18,500	8	$671,630	12	$887,192	20
Stock assessment & management	$1,081,393	25	$1,823,198	14	$993,606	12
Value adding			$771,070	7		
GRAND TOTAL	$3,261,149		$8,409,633		$6,829,726	

It is worth noting that this summary does not take into account the considerable investment made by Abalone industry groups/individuals as well as State fishery management and research agencies. It should be acknowledged that this work forms the cornerstone for much of the stock assessment and management of Australia's wild Abalone stocks. For an excellent synopsis of 50-years of Australian Abalone fisheries research refer to Mayfield et al. (2012), which provides a holistic picture

of the body of literature and its use in the assessment and management of Australian Abalone fisheries.

In addition, there is a considerable body of Abalone RD&E from the aquaculture sector through the Australian Abalone Growers' Association (AAGA) and others. This research is likely of relevance to and/or directly transferable to wild caught Abalone and the ACA. These projects have not been included here; however, should be considered as part of future reviews into Abalone biosecurity and/or molecular applications to enhance productivity.

This paper aims to highlight those (completed) FRDC projects that address issues and/or provide advancements in the monitoring, assessment and management of Australian Abalone stocks. It also lists projects that have yet to report. This has been done by aligning completed projects to the relevant categories of the '*Four Box*' framework for collection and use of finer scale data in assessment and management decision-making (Table 2).

The Four Box framework was developed at the 2010 Abalone Fisheries Management Research Workshop and partitioned the monitoring, assessment and decision making into sequential components – namely:

1. *Data recording technology (all types)* – i.e. manual & automated data collection, historic & current catch data
2. *Database & analytical tools* – i.e. databases that are secure, tools to interrogate databases
3. *Indicators & performance measures* – i.e. catch rates, length distributions
4. *Harvest strategies/ management decisions* – i.e. tools to present performance indicators to inform harvest strategies and management decision-making processes

Based on the alignment of completed projects to the Four Box framework (Table 2), it is evident that there has been considerable research and development at all stages (or boxes). However, what is not readily evident from Table 2, is that projects are largely undertaken on a State-by-State basis (again refer to Mayfield et al. 2012), with evidently few instances of multi-jurisdictional uptake (e.g. 2006-029 *Using GPS technology to improve fishery dependent data collection in Abalone fisheries*). This has likely contributed in the separation among how States about how they are approaching their acquisition of key data to inform harvest strategies and partly explains differences in processes for assessment and decision-making.

The State-based approach to Abalone RD&E projects is, in part, reflective of the fact that research priorities were set by State-based RACs / FRABs, who until recently (mid-2018), had wild catch Abalone funds contributing to their budgets. The ACA IPA now has carriage for *all* of the wild catch Abalone funds provided to the FRDC. This necessitates that the ACA has the lead role in providing over-arching guidance and resourcing to address both the tactical needs of individual jurisdictions, while progressing strategic and/or common priorities at a national level. This therefore requires that consistent and structured systems be in place with input from all jurisdictions to discuss, prioritise and agree upon common RD&E needs for the assessment and management of Australian Abalone fisheries.

The prioritisation of RD&E needs at a national scale can also facilitate the further collaboration among research providers, managers and industry, such that there is a pooling of complementary arears of expertise that may exist in one State but is absent in another. The objective of this collaboration should be to ensure that co-investigators complement each other skills rather than

compete with one another or duplicate research effort. Moreover, such collaborative arrangement will also enable the transfer of research outputs among jurisdictions at all stages of the project (e.g. from project development, at key milestones, to project finalisation).

The period from 2002 to 2018 also saw considerable research investment to understand the impacts of external (non-commercial fishing) factors on the sustainability of wild Abalone stocks; e.g. disease outbreaks, urchin barrens, temperature increases. Similarly, there has been investment into exploring a range of approaches to recover and enhance the productivity of wild stocks. Given that commercial fishing has a cumulative affect with these external factors on Abalone stocks, it is suggested that the Four Box framework be complemented with the '*+Two Box*' framework to account for these external factors (Table 3). As above, completed projects were aligned to the relevant impact or recovery boxes of the new +Two Box framework (Table 3).

To assist in the interrogation of the projects highlighted in Tables 2 & 3, this paper provides an abridged catalogue of those FRDC projects (both active and completed) that focus on:

- stock assessment
- fisheries management
- diver observational data
- stock translocation
- recruitment
- the management of *Centrostephanus*

Projects focused on these research areas comprises a considerable component of the FRDC's and the ACA's RD&E investment portfolio – between 40 and 50% of the total number of projects funded, and approximately $1.5 to 2 million worth of investment in any five-year period (Table 1). Please note that this catalogue is not exhaustive. Each project has been summarised using a standardised approach:

Title	• *The FRDC project number* • *The project title*
Research provider	• *The Principle Investigator* • *The administrative organisation*
Budget	• *The project budget*
Objectives	• *The stated project objectives*
Outputs	• *A comment on the key outputs that were generated from the project (where possible – e.g. the project might still be 'active')*
Final report (project site)	• *The link to the FRDC project specific site (where available – e.g. project might be deemed 'commercial in confidence')* • *The link to the project final report (where available – e.g. the project might not be finalised)*
Outcomes (adoption)	• *A comment on the key outcomes that resulted from the adoption of the project outputs (where possible)*

It is worth noting that while many aspects of the project summary are relatively easy to collate; for example the project budget and stated objectives. Interpreting the key outputs of the project as well as the outcomes of project was harder to achieve. Ultimately, this was done subjectively (in part based on the final reports provided) and requires considerable input from those actively/directly involved in the research, assessment and management of Australian wild Abalone stocks. As such, the commentary provided here is from the perspective of an author removed from the active monitoring, assessment and management of Australian Abalone stocks.

This paper should be considered a 'living document', whereby further input, particularly in expanding the catalogue of projects as well as the provision of more comprehensive assessments of the key outputs and outcomes of projects as they are completed will considerable enhance the value of such a document.

In addition to strategic planning of future RD&E priorities, there is a need to consolidate what has been achieved from past investments, review barriers to adoption, and how they might be overcome (this can also be informed by revisiting instances where RD&E adoption has been achieved). Revisiting some projects to see if they can be integrated and built upon, rather than 'reinventing the wheel' (e.g. due to recent technology development) is a worthwhile exercise with the potential to deliver benefits from modest investments. The extension by IMAS of the juvenile collectors developed in Tasmania (2014-010) to trialling them in eastern Victoria (2017-049) is a recent example of adding value to a contemporary project. It is also acknowledged that (opportunities for) adoption can be premature, resulting in valuable outputs from past projects that are yet to be utilised to best advantage for Abalone fisheries. Revisiting such projects will add value to previous investment whilst saving funds for the emerging priorities.

Nevertheless, to achieve true technology transfer and adoption among jurisdictions there is likely a need to spread the research effort among States so that the work can be replicated and tested under varying local conditions, and/or using data from different jurisdictions. This has occurred to some extent with several projects – for example:

- 2010-013 *Towards understanding Greenlip Abalone population structure* – conducted between Tasmania and South Australia
- 2007-020 *Identification and evaluation of performance indicators for Abalone fisheries* – which encompassed all south-eastern Australian abalone fisheries
- 2006-029 *Using GPS technology to improve fishery dependent data collection in abalone fisheries*

Fortunately, the biological variability among abalone populations means that projects conducted exclusively in one State will likely have at least partial relevance to application in another, implying that the reason for a lack of interstate transfer and adoption are institutional not ecological.

Table 2. The 'Four Box' framework for collection and use of finer scale data in assessment and management decision making. The projects shown in blue address the assessment and management needs of the respective boxes (note that some projects overlap multiple boxes).

Data recording technology (all types)	Database & analytical tools	Indicators & performance measures	Harvest strategies/ management decisions
Support current & new methods used in jurisdictions	• Regional capability, methods and tools • Freely accessible and usable • Use inputs from variety of data loggers and traditional information sources • Re-package data into required space/time blocks • Calculate indicators and performance measures used in different jurisdictions		Support current & new methods used in jurisdictions • Including current & evolving workshop approaches • Practical use of finer scale data in assessment and management
• 2002-079 Video survey • 2002-083 Towards an industry-based abalone fishery monitoring program • 2006-029 Use of GPS loggers • 2008-077 Assessment of AVG reefs • 2008-097 Cost effective monitoring	• 2004-019 Optimising spatial scale • 2005-024 Local assessment by industry • 2006-029 GPS for data collection & assessment • 2007-020 Identification and evaluation of performance indicators • 2008-077 Assessment of AVG reefs • 2008-097 Cost effective monitoring • 2009-746 Use of size-based measures • 2011-201 Implementing geo-referenced diver data • 2013-200 Using spatial performance measures • 2014-010 Use of recruitment plates • 2015-017 Using biological indicators to inform fishing		• 2002-083 Towards an industry-based abalone fishery • 2004-019 Optimising spatial scale • 2005-024 Industry involved in management • 2008-097 Cost effective monitoring • 2013-200 Testing HS for setting TACs & LMLs • 2012-236 TAC setting post-AVG

Table 3. The '+Two Box' framework is an expansion on the 'Four Box' framework above. The '+Two Box' framework highlights those non-commercial fishing factors that impact (both negatively & positively) the productivity and sustainability of wild Abalone stocks. Corresponding projects are shown in blue.

Adapting management to account for impacts	Recovering productivity
Adapting management to account for • *Centrostephanus* incursions • Climate impacts • Disease outbreak • Recreational & indigenous catch	Support current & new methods used in jurisdictions
• 2007-045 Management options to minimise impacts of Centro • 2007-066 Data & management needs to respond to AVG • 2008-077 Assessment of AVG reefs • 2009-075 Susceptibility of remnant populations previously exposed to AVG • 2012-236 TAC setting process post-AVG	• 2008-076 Evaluating rehabilitation approaches post-AVG • 2010-710 Stock enhancement evaluation • 2010-782 Habitat enhancement • 2011-087 Targeted Centro harvesting • 2011-762 Stock translocation • 2012-220 Sea ranching trials • 2014-214 Evaluation of sea ranching

Project Summaries

Active Projects

Title	2017-099 Survival and growth rate of ranched greenlip abalone off South Australia
Research provider	Owen Burnell SARDI
Budget	$199,631
Objectives	1. Quantify rates of survival and growth of greenlip abalone at sea ranches in South Australia 2. Quantify the influence of abiotic (i.e. tide, swell, temperature) and biotic (i.e. feed availability, predator activity) conditions on survival and growth of greenlip abalone at sea ranches in South Australia 3. Monitor the prevalence of the Perkinsus infection in greenlip abalone at sea ranches and in nearby wild populations 4. Determine the reproductive state of greenlip abalone from sea ranches 5. Compare and contrast the survival and growth of greenlip abalone from sea ranches in South Australia with those from replicated studies in Western Australia
Outputs	Active
Final report (project site)	http://frdc.com.au/project/2017-099

Title	2017-049 Monitoring abalone juvenile abundance following removal of *Centrostephanus* and translocation
Research provider	Jaime McAllister IMAS
Budget	$67,916
Objectives	1. Test Tasmanian designed juvenile abalone collectors on Victorian Eastern Zone reef systems 2. Use juvenile collector methods to assess effect of translocation on population recovery 3. Consider broader application of juvenile collectors as a recruitment monitoring tool
Outputs	Active
Final report (project site)	http://frdc.com.au/project/2017-049

Title	2017-026 Can spatial fishery-dependent data be used to determine abalone stock status in a spatially structured fishery?
Research provider	Craig Mundy IMAS
Budget	$562,128
Objectives	1. Characterise the statistical properties, coherence, interpretability and assumptions of spatial and classic indicators of fishery performance 2. Develop methods for inclusion of fine-scale spatial data in CPUE standardisations 3. Identify methods for detecting hyper-stability in CPUE 4. Determine feasibility of spatial data based stock status determination in spatially structured fisheries
Outputs	Active
Final report (project site)	http://frdc.com.au/project/2017-026

Title	2016-213 Building economics into fisheries management decision making - to utilise a suite of SA case studies
Research provider	Julian Morison Econsearch
Budget	$158,500
Objectives	1. The development of cost effective techniques to incorporate economic considerations into harvest strategies. 2. The preparation of a check list/self-assessment tool to guide fisheries managers in determining whether or not a fishery is suitable for economic modelling using one of the cost effective techniques developed as part of the project. 3. The development of a practical User Guide for fisheries managers that contains a set of steps to develop a cost effective economic model, adjust the model, collect necessary data, and generate results for practical application in relevant fishery's harvest strategy.
Outputs	Active
Final report (project site)	http://frdc.com.au/project/2016-213

Title	2014-224 Rebuilding abalone populations to limit impacts of the spread of urchins, abalone viral ganglioneuritis and other external impacts
Research provider	Harry Peeters Western Abalone Divers Association
Budget	$340,000
Objectives	1. Identify and prioritise sites and strategies for assessment to recover shallow reef habitat and productive abalone populations 2. Assess strategies for recovery of shallow reef habitats and productive abalone populations. 3. Develop a business plan to guide ongoing future actions and strategies to extend the project outputs and rebuild abalone populations
Outputs	Active
Final report (project site)	http://frdc.com.au/project/2014-224

Title	2013-026 Can commercial harvest of long-spined sea urchins reduce the impact of urchin grazing on abalone and lobster fisheries?
Research provider	John Keane IMAS
Budget	$301,581
Objectives	1. Determine spatial location and extent of overlap between *Centrostephanus* and existing fisheries 2. Application of coastal exposure indices for identifying potential urchin harvest locations 3. Determine dive profile strategies to enable safe harvest of urchins at depths greater than 15m
Outputs	Active
Final report (project site)	http://frdc.com.au/project/2013-026

Title	2011-201 Implementing a spatial assessment and decision process to improve fishery management outcomes using geo-referenced diver data
Research provider	Craig Mundy IMAS
Budget	$864,251

Objectives	1. To introduce geo-referenced fishery-dependent data collection using the Digital Toolbox across the fishing fleets in South-Eastern Australia 2. To develop, test and implement an objective decision making framework using geo-referenced fishery-dependent data 3. To adapt advances in spatial fishery management from other jurisdictions into the decision framework 4. Extension of geo-referenced data decision systems to Tasmanian industry and other abalone jurisdictions underpinned by robust management science 5. Develop and provide an E-resource to enable individual fishers with access to their data
Outputs	Active

Completed Projects

Title	2015-025 Patterns of interaction between habitat and oceanographic variables affecting the connectivity and productivity of invertebrate fisheries
Research provider	Daniel Ierodiaconou Deakin University
Budget	$270,000
Objectives	1. Integrate commercial catch and survey data with LiDAR-derived seafloor structure information to identify the spatial structure and patch-level productivity of reef systems, potential abalone fishable habitat extent and map important source reefs of abalone larvae. 2. Development of a high resolution hydrodynamic model for Victorian coastal waters that allows the modeling of larval dispersal between individual reef complexes throughout state waters. 3. Development of a biophysical larval dispersal model to map the probable dispersal pathways for H. rubra and SRL across Victorian reef complexes. 4. Determine if recruitment across the respective fisheries is influenced by adaptive genetic factors
Outputs	• Identification of important larval source reefs, dominant dispersal pathways and the role of genomic selection on population recruitment processes • Repository of high-resolution maps of coastal habitat overlaid with oceanographic and biological factors that influence population structure and fisheries productivity for Abalone and Southern Rock Lobster
Final report	http://frdc.com.au/project/2015-025 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2015-025-DLD.pdf
Outcomes (adoption)	• This study provides industry with substantial long-term benefits relating to assessments of stock viability and implementation of management strategies that optimise sustainable • Improved understanding of relationships between stock productivity and environment

Title	2015-017 Maximise yield or minimise risk in the Blacklip Abalone fishery: using biological data to direct harvest strategies
Research provider	Ben Stobart SARDI
Budget	$272,978
Objectives	1. Quantify the seasonal and spatial variation in the blacklip abalone shell size/whole weight/meat weight ratios

	2. Incorporate the biological data into the existing greenlip model and apply under the monthly fishing scenarios developed in consultation with Industry 3. Provide model outputs from each fishing scenario that detail the number of abalone harvested and their value. This information will allow Industry and managers to maximise the efficiency of their blacklip fisheries.
Outputs	• Identified optimum months to harvest Blacklip Abalone to maximise yield based on natural variation in meat yield
Final report (project site)	http://frdc.com.au/project/2015-017 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2015-017-DLD.pdf

Outcomes (adoption)	• Confirmed seasonal fishing strategies to harvest Blacklip was optimised
	• Fishers can be selective in the fishing to either:
	  ○ harvest fewer Blacklip for the same total TACC taken, or
	  ○ adopt a co-management strategy where they harvest the current number of abalone that are heavier and thus allowing a higher TACC.

Title	2014-214 Investigating critical biological issues for commercial Greenlip Abalone sea ranching in Flinders Bay, Western Australia
Research provider	Roy Melville-Smith Curtin University
Budget	$152,790
Objectives	1. To understand the source and seasonal movements of drift-algae across the aquaculture lease in Flinders Bay and relate it to local wind-wave climate 2. To evaluate the seasonal variations in the biomass, species composition and functional properties of the drift algal species that form the main food source for greenlip abalone on the lease site 3. To evaluate the health status of ranched greenlip abalone by using various physiological stress indicators and use this status to predict future health/condition of the greenlip abalone
Outputs	• Identified optimal (local) conditions to maximise the health status of Greenlip Abalone
Final report (project site)	http://frdc.com.au/project/2014-214 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2014-214-DLD.pdf
Outcomes (adoption)	• Findings supported and optimised ranching in Flinders Bay

Title	2014-010 Understanding recruitment collapse of juvenile abalone in the Eastern Zone Abalone fishery – development of pre-recruitment monitoring, simulation of recruitment variation and predicting the impact of climate variation
Research provider	Craig Mundy IMAS
Budget	$141,656
Objectives	1. Optimise collector module design for quantifying abundance of juvenile abalone across a range of habitat types 2. Determine links between juvenile abundance observed on modules and abalone in surrounding habitat 3. Estimate expected juvenile abundance on collectors in a 'normal' recruitment year using published natural mortality data and known abundance
Outputs	• "Abalone Recruitment Modules" shown to be suitable for monitoring recruit abundance at key indicator sites
Final report (project site)	http://frdc.com.au/project/2014-010 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2014-010-DLD.pdf
Outcomes (adoption)	• Abalone Recruitment Modules provide a potential measure of recruitment abundance • Abalone Recruitment Modules being trialled in Eastern Victoria (see project 2017-049)

Title	2013-200 Testing abalone empirical harvest strategies, for setting TACs and associated LMLs, that include the use of novel spatially explicit performance measures
Research provider	Malcolm Haddon CSIRO Oceans and Atmosphere
Budget	$185,630
Objectives	1. Review objectives and logic of having and setting Legal Minimum Lengths in abalone fisheries and how these interact with TAC levels. 2. Conduct Manager/Industry workshops to inform, identify issues, and to select LML/TAC scenarios within particular harvest strategies for testing by Management Strategy Evaluation. 3. Develop new modules for the present Abalone MSE Framework for testing LML/TAC harvest strategies containing multiple empirical performance measures (MCDA) that use spatially explicit PMs 4. 4. Use the modified MSE framework to test new Multi-Criteria Decision Analysis Abalone Harvest Strategy under development in FRDC 2011-201

Outputs	• Effective management requires TACs set no higher than or below current productivity • And that the LML is set at a level that will protect at least a minimum mature biomass • MCDA was able to combine different performance measures to established harvest
Final report (project site)	http://frdc.com.au/project/2013-200 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2013-200-DLD.PDF
Outcomes (adoption)	• Results are used in the development of formal harvest strategy within the Tasmanian abalone fisheries. • The MCDA process enable Tasmania to produce repeatable and defensible management advice

Title	2012-236 Tactical Research Fund: Developing the decision process for setting the TAC for abalone in Victoria, particularly with reference to recovery of AVG-impacted reefs
Research provider	Harry Peeters Western Abalone Divers Association
Budget	$85,000
Objectives	1. Facilitate a workshop to consolidate existing data, review analysis, interpretation and use as performance indicators in the TAC setting process, including development of a future monitoring plan. 2. Implement the short-term outcomes of the workshop, particularly related to development of the performance indicators, their use in updating population model scenarios of recovery, and combination in the TAC Setting process
Outputs	• MSE was used to examine the performance of potential Harvest Control Rules for calculating TAC for the Western Zone Fishery (post-AVG)
Final report (project site)	http://frdc.com.au/project/2012-236 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2012-236-DLD.pdf
Outcomes (adoption)	• Outputs supported current fishing practices that aim to recover stocks post-AVG • Basis for a draft biomass harvest strategy currently applied for TACC setting in the Western Zone Fishery

Title	2012-220 Tactical Research Fund: Sea ranching trials for commercial production of greenlip (*Haliotis Laevigata*) abalone in Western Australia

Research provider	Brad Adams Ocean Grown Abalone
Budget	$40,000
Objectives	1. To have sampling methods used in the enhancement trial independently validated 2. For data collected by the trial to be analysed and presented in a report suitable for peer review
Outputs	• Provided proof of concept of abalone sea ranching in Western Australia • Survival rates can be reduced to suitable levels and growth rates are comparable with wild & ranched abalone
Final report (project site)	http://frdc.com.au/project/2012-220 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2012-220-DLD.pdf
Outcomes (adoption)	• These results have seen the expansion of abalone sea ranching in the WA and trials in SA (see project 2017-099)

Title	2012-058 Tactical Research Fund: Limiting impacts of the spread of urchins by rebuilding abalone populations
Research provider	Geoff Ellis Eastern Zone Abalone Industry Association
Budget	$42,000
Objectives	1. Facilitate a workshop to coordinate existing research findings among jurisdictions, and plan further development and extension. 2. Implement the short-term outcomes of the workshop, particularly related to development of a survey to monitor spread of *Centrostephanus*
Outputs	
Final report (project site)	http://frdc.com.au/project/2012-058
Outcomes (adoption)	• Commercial urchin and abalone divers are now employed in the Eastern Zone to specifically cull urchins • Ongoing development of industry-based monitoring protocols for assessing effectiveness of culling

Title	2012-016 Demographic Performance of Brownlip Abalone: Exploration of Wild and Cultured Harvest Potential

Research provider	Lachlan Strain DPIRD WA
Budget	$299,436
Objectives	1. Determine the growth and natural mortality of wild brownlip abalone populations. 2. Determine growth rates and mortality of cultured brownlip abalone. 3. Habitat identification to determine release mortality, growth, survival and recapture parameters for potential brownlip abalone stock enhancement. 4. Develop fishing size limits and optimal market sizes based on size distribution and growth to examine the harvest potential of the total industry. 5. Preliminary integrated length-based model and harvest/fishing sizes determined
Outputs	• Evaluation of Brownlip Abalone biology and fisheries assessment methods • Provided estimates of natural and fishing mortality, size composition and the first to model growth throughout all stages of life
Final report (project site)	http://frdc.com.au/project/2012-016 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2012-016-DLD.pdf
Outcomes (adoption)	• Data and models established are used in annual TACC setting and provide industry with information on optimising harvest strategies

Title	2011-762 Seafood CRC: Recovering a collapsed abalone stock through translocation
Research provider	Anthony Hart DPIRD WA
Budget	$175,096
Objectives	1. To establish founder populations of roe's abalone in areas of mass mortality 2. To evaluate the genetic structure of existing and founder populations 3. To compare natural and assisted recovery rates of roe's abalone populations 4. To evaluate the genetic contribution of existing and founder populations to stock recovery
Outputs	
Final report (project site)	http://frdc.com.au/project/2011-762
Outcomes (adoption)	

Title	2011-087 Tactical Research Fund: Trial of an industry implemented, spatially discrete eradication/control program for *Centrostephanus rodgersii* in Tasmania
Research provider	Sean Tracey IMAS
Budget	$133,200
Objectives	1. Determine the effectiveness of divers physically destroying urchins in situ to either eradicate or control spatially discrete aggregations to allow the re-establishment of native flora and fauna 2. Determine the cost effectiveness of objective 1 in regard to lost production for commercial, recreational and customary harvests
Outputs	• Culling shown to significantly reduce *Centro* densities in discrete areas • A cost benefit model of implementing a culling strategy at a range of spatial scales
Final report (project site)	http://frdc.com.au/project/2011-087 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2011-087-DLD.pdf
Outcomes (adoption)	• Findings support culling as a viable method to control *Centro*

Title	2011-046 Tactical Research Fund - Aquatic Animal Health Subprogram: Disease risk assessment for abalone stock enhancement program
Research provider	Richard Stevens WAFIC
Budget	$67,000
Objectives	1. Independent risk assessment of the raw biosecurity risks posed by the commercial scale abalone stock enhancement 2. Independent risk assessment of the residual biosecurity risks posed by the commercial scale abalone stock enhancement, following staged implementation of risk mitigation measures
Outputs	• A range of risk control measures would enable the stocking of abalone • Biosecurity conditions and quality management systems are outlined
Final report (project site)	http://frdc.com.au/project/2011-046 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2011-046-DLD.pdf
Outcomes (adoption)	• Understanding of risks and control measures associated with biosecurity to safeguard natural resources

Title	2011-033 Spatial patterns, landscape genetics and post virus recovery of blacklip abalone, *Haliotis rubra* (Leach), in the Western commercial fishing zone of Victoria
Research provider	Daniel Ierodiaconou Deakin University
Budget	$73,500
Objectives	1. Investigate methodologies to integrate commercial catch data with LiDAR-derived seafloor structure information to identify spatial connectivity of reef systems and abalone habitat suitability. 2. Conduct a population genetic assessment of H. rubra in the Western Zone to determine stock population structure and assess the impact of AVG on genetic diversity and recruitment. 3. Integrate population genetics, landscape ecology and spatial analyses to elucidate how genetic variation in H. rubra is affected by landscape and environmental variables at the broad (Western Zone) and fine (Port Fairy to Warrnambool) spatial scales
Outputs	• Geospatial and genetic approaches provided information on potential habitat availability and fisheries productivity (reflecting stock structure) • Genetic assessment of stock spatial connectivity, genetic diversity and recruitment
Final report (project site)	http://frdc.com.au/project/2011-033 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2011-033-DLD.pdf
Outcomes (adoption)	• Estimates of the areal extent of suitable fishing grounds – links to revised scaling from density to total biomass in project 2008-077 • Patterns of change in spatial allocation of fishing effort (from diver GPS) • Impacts of AVG on genetic diversity and population structure across the Western Zone fishery • Understanding of spatial patterns of larval recruitment across reef complexes

Title	2010-013 Towards understanding greenlip abalone population structure
Research provider	Stephen Mayfield SARDI
Budget	$447,515
Objectives	1. Quantify greenlip abalone population genetic structure within key fishing areas

	2. Assess genetic connectivity within and among greenlip abalone populations in key fishing areas
Outputs	• Population structure and connectivity determined for greenlip and blacklip abalone (noting patterns are species specific)
Final report (project site)	http://frdc.com.au/project/2010-013 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2010-013-DLD.pdf
Outcomes (adoption)	• Spatial stock structure incorporated into South Australian management planning in a species specific manner

Title	2009-746 Seafood CRC: Could harvests from abalone stocks be increased through better management of the size limit / quota interaction?
Research provider	David Tarbath University of Tasmania
Budget	
Objectives	1. Quantify density-dependent effects on wild abalone growth and meat quality 2. Develop a statistical tool for classification of shell age 3. Use length-based models to test the adequacy of shell age performance measures 4. Use length-based models to determine the sustainability and cost-effectiveness of an LML that optimises the proportion of 'old' shell within 5mm of the LML
Outputs	• No density effects were found on growth • Developed a morphological model to estimate size at maturity and age (however, imprecise)
Final report (project site)	http://frdc.com.au/project/2009-746 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2009-746-DLD.pdf
Outcomes (adoption)	• Findings informed LML decision making in Tasmania • Model imprecision hindered adoption

Title	2009-714.30 Seafood CRC: Economic management guidance for Australian abalone fisheries
Research provider	Klaas Hartmann University of Tasmania
Budget	$84,140

Objectives	1. Define baseline economic performance of participating abalone fisheries 2. Produce bio-economic analysis tools in abalone fisheries 3. Determine optimal management strategies using stock and economic information including seasonal / size / catch combinations 4. Promote and drive management change to capture opportunities identified at (3). 5. Define baseline economic performance of participating abalone fisheries
Outputs	• Used economic survey data to develop an economic baseline for Abalone fisheries in NSW & Tas
Final report (project site)	http://frdc.com.au/project/2009-714_30 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2009-714.30-DLD.pdf
Outcomes (adoption)	• Economic factors could be integrated into management planning to maximise the economic yield of the fishery • The project was discontinued at the end of Objective 1

Title	2009-710 Seafood CRC: Bioeconomic evaluation of commercial scale stock enhancement in abalone
Research provider	Anthony Hart DIPRD WA
Budget	$209,430
Objectives	1. To estimate long-term growth and survival of enhanced greenlip abalone 2. Undertake a bioeconomic analysis of large scale stock enhancement in greenlip abalone 3. To evaluate appropriate wild-stock management protocols that facilitate stock enhancement 4. Develop biosecurity protocols for stock enhancement
Outputs	• Evaluated the ecological, biosecurity and economic components of the enhancement • Manual developed for commercial enhancement programs • Developed WA policy for stock enhancement
Final report (project site)	http://frdc.com.au/project/2009-710 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2009-710-DLD.pdf
Outcomes (adoption)	• Established feasibility and the general principles to guide successful commercial-scale enhancement of Greenlip Abalone is feasible • There has been subsequent Abalone enhancement in WA

Title	2008-097 Tactical Research Fund: Developing the use of existing technology in cost-effective and reliable Industry-based structured fishing surveys to urgently replace more costly methods and advise finer-scale management of abalone populations
Research provider	Duncan Worthington Abalone Council of NSW
Budget	$75,000
Objectives	1. Train commercial divers in the use of GPS loggers to record observations of the abundance of under-size abalone. 2. Assess the reliability of logged observations by commercial divers through comparison within and among divers, and with estimates from surveys completed independent of fishing. 3. Develop a cost-effective and targeted program to measure the lengths of abalone being landed in the Structured Fishing Program and compare with existing methods of estimating the size of abalone landed. 4. Improve the existing survey design for structured fishing, by developing the database of sampling sites, standardised techniques and historical information for estimating changes in abalone stocks.
Outputs	• Developed a detailed spatial information collection, management and analysis system for delivering fine scale spatial information about fishing and stocks in the NSW abalone fishery
Final report (project site)	http://frdc.com.au/project/2008-097 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2008-097-DLD.pdf
Outcomes (adoption)	• The continued use of GPS loggers by all divers in NSW • The application of diver based performance indicators in NSW Abalone fishery management • Adoption requires some means of interpreting this proxy against direct measures of biomass; e.g. biomass surveys developed in project 2008-077

Title	2008-077 Tactical Research Fund: Developing cost-effective and reliable Industry-based surveys to advise re-opening and conservative management of abalone populations on AVG-affected reefs
Research provider	Harry Peeters Western Abalone Divers Association
Budget	$105,000
Objectives	1. Develop a robust sampling design and implement an Industry-based, pre-fishing survey of AVG-affected abalone populations on reefs near Port Fairy, and compare with DPI-based survey results.

	2. Estimate the harvestable biomass of abalone from the area sampled near Port Fairy and possible catches for a more extensive structured commercial fishing survey 3. Using results from the pre-fishing surveys, develop and implement a structured commercial fishing survey of AVG-affected abalone populations on reefs near Port Fairy 4. Develop and refine options for a broadly-applicable and cost-effective harvest strategy to inform short- and medium-term management goals.
Outputs	• Biomass estimate for the Port Fairy Spatial Management Unit in 2009
Final report (project site)	
Outcomes (adoption)	• Baseline input for current draft harvest strategy in determining harvestable biomass as a fraction of the total. Incorporated into the MSE component of project 2012-236

Title	2008-076 Tactical Research Fund: Cost-benefit analysis of implementing alternative techniques for rehabilitating reefs severely depleted by Abalone Viral Ganglioneuritis epidemic
Research provider	Harry Peeters Western Abalone Divers Association
Budget	$43,010
Objectives	1. Synthesis available data on reseeding, translocation and natural rebuilding of abalone 2. Construct a quantitative economic and population dynamics model of reseeding, translocation and natural rebuilding for blacklip abalone reefs and use it to analyse the likely costs and benefits of alternative techniques of rehabilitating the Kilarney reef code in the Victorian western zone 3. Prepare and present a written and audio-visual report to WADA at their October 2008 and February 2009 reef assessment workshops detailing modelling methods, underlying assumptions and results of evaluating alternative rehabilitation techniques
Outputs	• Cost benefit analysis demonstrated that the natural rebuilding of stocks is likely to be the most cost effective approach to recovery
Final report (project site)	http://frdc.com.au/project/2008-076 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2008-076-DLD.pdf
Outcomes (adoption)	• Passive rebuilding was undertaken via conventional management of TACC applied at sub-zone scale and a higher LML of 130 mm • Western Zone have since implemented a translocation activities (see project 2014-224)

Title	2007-066 Tactical Research Fund: Rapid response to abalone virus depletion in western Victoria - information acquisition and reef-code assessment models
Research provider	Harry Gorfine University of Melbourne
Budget	$70,000
Objectives	1. Conduct the scientific surveys at the DPIR reef-code sites, using the Victorian survey methods, augmented by genetic sampling and extended survey of the extent of aggregations. 2. Develop a long-term monitoring strategy for continued assessment of reef-stock status and management options. 3. Use existing models to broadly illustrate the likely impacts of the outbreaks. 4. Compile existing information on the outbreaks in an accessible, informative form, develop reef-code growth, maturity and abundance trajectories, and agreed catch histories. 5. Develop and apply a quantitative model that is spatially resolved to the scale of reef-codes, and use this to assess the status of populations and inform the Total Allowable Catch setting process
Outputs	• Modelling indicates that resumption of fishing in areas of moderate disease related mortality undermines recovery
Final report (project site)	http://frdc.com.au/project/2007-066 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2007-066-DLD.PDF
Outcomes (adoption)	• Provided models to assess population status and examine management options for specific reef-codes • Model was used by CSIRO to develop a MSE model for project 2012-236 to determine the effects of varying harvest fractions of exploitable biomass on rebuilding in western VIC

Title	2007-045 Rebuilding Ecosystem Resilience: assessment of management options to minimise formation of 'barrens' habitat by the long-spined sea urchin (*Centrostephanus rodgersii*) in Tasmania
Research provider	Craig Johnson University of Tasmania
Budget	$828,551
Objectives	1. To assess the effectiveness of translocating large rock lobsters (=135 mm CL) en masse as means of preventing formation of incipient barrens and rehabilitating incipient and extensive barrens. 2. To assess the effectiveness of a range of management options (e.g. imposing upper size limits and spatial management) in building the

	biomass of large (=135 mm CL) rock lobsters to levels sufficient to limit C. rodgersii populations. 3. To assess the effectiveness of killing or removing sea urchins by abalone divers during the conduct of their fishing activity, as a means of preventing formation of incipient barrens and rehabilitating incipient and extensive barrens
Outputs	• Rock lobsters suggested to be effective in minimising impacts of Centro • Harvesting was considered an effective method to control Centro
Final report (project site)	http://frdc.com.au/project/2007-045 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2007-045-DLD.pdf
Outcomes (adoption)	• Ministerial support given for a 10 year strategy to rebuild rock lobster stocks in eastern Tas. This was expected to have indirect benefits to reducing Centro barrens formation • Tas Abalone divers permitted to cull urchins while fishing

Title	2007-020 Identification and evaluation of performance indicators for abalone fisheries
Research provider	Craig Mundy University of Tasmania
Budget	$449,845
Objectives	1. Determine, document and review the Performance Indicators (PIs), related stock assessments and fishery management objectives used in the abalone fisheries of Australia and similar fisheries worldwide. 2. Identify in close collaboration with abalone Industry, Management, and researchers, a suite of fishery assessment PIs that facilitate assessments against the management objectives for abalone fisheries. 3. Where possible, evaluate the fishery assessment PIs against known fishery performance. 4. Develop a National Management Strategy Evaluation framework that can be adapted to represent different abalone fisheries from the various jurisdictions in southern Australia. 5. Identify, using the PIs determined in Objective 1, a suite of Management Strategies (i.e. unique combinations of data, PIs and decision rules) that aim to achieve the fishery objectives identified in objective 1). 6. Use the Management Strategy Evaluation framework (from objective 4), to assess the relative effectiveness of the alternate Management Strategies (from Objective 5) to achieve the fishery objectives, in the face of multiple sources of uncertainty and spatial variation in data availability and quality.
Outputs	• Performance indicators for management of abalone fisheries were reviewed • Developed a MSE simulation framework for testing specific performance measure and harvest control rule strategies

	• Interactions and the assumed trade-offs between the TAC and LML explored using MSE
Final report (project site)	http://frdc.com.au/project/2007-020 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2007-020-DLD.pdf
Outcomes (adoption)	• The MSE can be adapted for different jurisdictions, or to test specific scenarios of interest to management

Title	2006-040 Understanding the ecological role of abalone in the reef ecosystem of Victoria
Research provider	Gregory Jenkins DEDJTR VIC
Budget	$313,809
Objectives	1. To determine whether any components of the reef ecosystem are dependent on abalone by monitoring the reef ecosystem in areas of predictable change in abalone abundance 2. To investigate the possible dependencies of predatory fish on abalone prey 3. To identify whether there are ecological indicators of abalone depletion that potentially could be used to detect ecological impacts 4. To assist Fisheries Victoria in implementing Ecosystem Based Fisheries Management (EBFM) policy in Victoria 5. To provide ecological information that will satisfy the Commonwealth requirements for this export industry
Outputs	• Demonstrated minor and spatially inconsistent impact of that removal of abalone through fishing has on Victorian reef ecosystems
Final report (project site)	http://frdc.com.au/project/2006-040 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2006-040-DLD.pdf
Outcomes (adoption)	• Sustainable management of Abalone is sufficient to achieve broader ecological sustainability without the need to incorporate broader ecological performance indicators • Research contributed to the Victorian Abalone Fishery Management Plan's inclusion of ecological considerations • Important information now that urchin culling has been underway for several years in VIC & TAS • Cessation of enumeration of other biota in fishery independent surveys of abalone abundance, except for urchins in Eastern VIC

Title	2006-029 Using GPS technology to improve fishery dependent data collection in abalone fisheries

Research provider	Craig Mundy University of Tasmania
Budget	$450,862
Objectives	1. Develop protocols and/or tools to automate conversion and interpretation of high resolution data. 2. Develop and test technology derived indicator variables. 3. Evaluate high resolution data for assessment of spatially-structured abalone populations. 4. Commence mapping commercially productive abalone populations 5. Preliminary investigations of spatial dynamics of abalone fisheries. 6. Incorporation of electronically derived indicator variables into the Tasmanian Abalone Management Plan.
Outputs	• Development of management and storage platform for GPS and depth logger data • Identification of spatial performance indices and spatial analyses of use in • management of abalone dive-fisheries • Analysis of spatial fishery-dependent data from abalone diver fisheries
Final report (project site)	http://ecite.utas.edu.au/81136/1/Final%20Report2006_029%20Final.pdf
Outcomes (adoption)	• Use of the AbTrack database in Tasmania, SA, Victoria and NSW • GPS and Depth data loggers are a mandatory component of fishery-dependent data reporting in Tasmania • GPS and depth data loggers being used in NSW, SA and Central & Western Zones in VIC

Title	2005-024 Abalone Industry Development: local assessment and management by industry
Research provider	Rob Day University of Melbourne
Budget	$525,531
Objectives	1. Develop, evaluate and document the Reef Assessment approach in Victoria, South Australia and NSW. 2. Test and validate the biological assumptions underlying the Reef Assessment Workshops. 3. Establish base-line (Year 0) measurements that provide a basis for predictions, and will provide the basis for a powerful long term (10-20 year) study of the level of parental breeding stock required to optimize long term production 4. Specify an Internet site template that provides industry with a facility for timely access to information and an avenue for feedback that reduces the

	delay between observations of reef-scale events and required adjustments in management strategy. 5. Build a simulation framework based on selected reef stocks, which will facilitate consistency in the synthesis and analysis of the performance of individual reefs 6. Facilitate, develop and document local scale co-management by industry organizations through collaborative workshop processes. 7. Develop and test a training syllabus for abalone divers, covering abalone biology and stock dynamics, the use of indicators, and how they relate to stock assessment.
Outputs	• Reef assessment was refined • Reproductive parameters determined for model parameterisation • A suite of tools were developed to assist industry in working towards co-management
Final report (project site)	http://frdc.com.au/project/2005-024 http://frdc.com.au/Archived-Reports/FRDC%20Projects/2005-024-DLD.pdf
Outcomes (adoption)	• Reef assessments initially adopted by industry, now conducted at an intermediary spatial management unit (sub-zone) scale • Biological data used to inform model parameterisation • Co-management arrangement have been explored and implemented in some fisheries • VIC poised to implement a co-management trial in whereby WADA will manage the fishery under an MOU with Fisheries (as of early 2019)

Title	2002-083 Towards an industry-based abalone fishery monitoring program
Research provider	Ross McGowan Seafood Industry Victoria
Budget	$334,356
Objectives	1. Facilitate acquisition of data via industry including tagging for growth, size at maturity and length frequency of the catch. 2. Promote industry self-sufficiency in data collection including the training of deckhands and divers in sampling, measuring and recording techniques. 3. Develop appropriate management protocols to support on-going voluntary data collection by industry.
Outputs	• Restocking of juvenile hatchery-reared blacklip abalone at depleted sites at The Passage reef close to Portland Harbour and The Patches reef adjacent to Port Fairy lighthouse. • Facilitated commercial abalone divers' exploration of 25 km of reefs fished for southern rock lobster east of Wilsons Promontory – located six blacklip abalone, but obtained useful habitat data

	• Onboard observation and recording of detailed data during abalone diving including wet weight of individual bags of catch and precise location and time of effort
Final report (project site)	
Outcomes (adoption)	• Establishment of voluntary micro-management strategies in terms of higher minimum sizes, catch caps and daily boat limits for individual reefs • Intervention by industry to rehabilitate depleted reefs • Improved access to seldom fished stocks via new management arrangements • Better informed catching sector with respect to abalone biology and assessment • Foundation for future self-governance by Australia's abalone industry

Title	2002-079 Digital video techniques for assessing population size structure and habitat of greenlip and Roe's abalone
Research provider	Anthony Hart DPIRD WA
Budget	$288,213
Objectives	1. 1. Determine the reliability and usefulness of in-water digital video in getting cost effective, fishery independent counts and measures of abalone (as an alternative to traditional manual techniques). 2. To provide a comparison of abundance and stock structure information (between and within years) for main fishing areas videoed. 3. Develop a time (cost) efficient computer program to extract (frame grab) and measure (within frame) abalone on videotape, and a database where images and data from video can be stored, accessed and interrogated
Outputs	• Diver video surveys were comparable to FIS for assessing abundance • Video can measure pre-recruits abundance, but only samples a small proportion of juveniles
Final report (project site)	http://www.frdc.com.au/project/2002-079 http://www.frdc.com.au/Archived-Reports/FRDC%20Projects/2002-079-DLD.PDF
Outcomes (adoption)	• A scaled up program was providing alternate data to stock assessment and management planning in WA • Not adopted interstate as abalone frequently well camouflaged and therefor difficult to discern