Tactical Research Fund: Developing cost-effective and reliable Industry-based surveys to advise reopening and conservative management of abalone populations on AVG-affected reefs.

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Australian Government

Fisheries Research and Development Corporation

Project No. 2008/077

(Note, this copy of the report does not include the previously released SARDI Prefishing survey report)

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FRDC Project – 2008-077
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May 2010
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CONTENTS

NON TECHNICAL SUMMARY

2008/077 Tactical Research Fund: Developing cost-effective and reliable Industry-based surveys to advise reopening and conservative management of abalone populations on AVG-affected reefs.

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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
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.

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED TO DATE

- Development of a process for the re-opening and conservative management of depleted abalone populations, such as those affected by AVG.
- Development, training and implementation of an Industry-based, pre-fishing survey of AVG-affected abalone population on reefs near Port Fairy, which produced estimates of the the harvestable biomass and possible catches of abalone.
- Development, training and implementation of an Industry-based, structured fishing survey of AVG-affected abalone population on reefs near Port Fairy, to extend knowledge of abalone populations and develop options for a cost-effective harvest strategy.
- Extension and use of the AbTrack database framework to the Western Zone Victoria abalone fishery.
- Conservative re-opening of commercial fishing for abalone on AVG-affected reefs.

Abalone Viral Ganglioneuritis (AVG) was first observed causing catastrophic mortality of abalone in western Victoria during May 2006, and has continued to spread. Reefs around Port Fairy were the first impacted, and have been closed to fishing for periods approaching four years in early 2010. As a direct consequence, there have already been large reductions in TAC and GVP of the. Further, the

AVG-related mortality has led to great uncertainty about the status of the abalone populations (e.g. depletion) and their future productive ability (e.g. catch).

The Western Zone Abalone Divers Association have proposed a conservative harvest strategy, based on low catches and high size limits, that seeks to rebuild stocks and progressively regain access to the abalone resource. As one of its goals, this strategy looks to reduce the information-burden and cost required by more exploitative harvest strategies. As such, the harvest strategy proposes to rely on information, such as Industry-based surveys and shell morphology, collected at a finer spatial scale.

Several recent developments have increased the ability of Industry to be involved, cooperatively with management and research agencies, in increasing knowledge of abalone resources. In particular, this includes the development of GPS-enabled loggers and a spatial information management system, based on the AbTrack database and GIS. Further, by structuring fishing to enable valid comparisons among different areas or through time, data produced by GPS-enabled loggers will be most informative.

A Pre-fishing survey, with no catch of abalone, was designed to provide the first assessment of populations of abalone on many of the reefs in the Port Fairy area. The primary intent of the survey was to inform an appropriate level of commercial catch that could be taken in a Structured Fishing survey to further extend information about the populations. The Pre-fishing survey built on the existing available information (i.e. MAFRI-based survey, past catch records and WADA workshop process), particularly through the attempted repetition of exactly the same methods used by the MAFRI-based survey, facilitating direct comparison.

The survey area and past productive strata (i.e. 72 ha of reef) were defined at an intital workshop with Industry divers. A Pre-fishing survey was designed to provide estimates of the density and sizes of abalone, and was completed in May 2009. The survey enabled calculation of the biomass of abalone above several possible minimum length limits, and uncertainty about those estimates. A total of about 80 t of abalone $\geq$ 120 mm, or 34 t of abalone $\geq$135 mm, was estimated in the sampled strata only (i.e. 55.6 ha), with most biomass in the Crags Reef code.

Results from the Pre-fishing survey and a further Workshop and Steering Committee meeting were used to plan the design and catch of a Structured Fishing survey. The intent of the survey was to use a small commercial catch, spread appropriately across the sampling area, to increase the information available about the abalone population. Further, implementation of the structured fishing was intended to increase the capcity of Industry to implement cost-efficient survey methods, for potential use in a future harvest strategy.

The average catch rate of abalone was high at over 50 kg.h^{-1}, with some sites $\geq$100 kg.hr^{-1}, and others <20 kg.hr^{-1}, distributed throughout the survey area. Observations of under-size abalone were also completed by the divers at all sites, and were related to the density of pre-recruits from the Pre-fishing survey. The design of the survey also enabled comparisons of survey indicators among areas to answer questions about the design of both surveys and their use. Catch rates in

sampled strata from the Pre-fishing survey were lower than those in unsampled strata or even outside strata, suggesting it may be appropriate to extend density estimates from the Pre-fishing survey. With the full survey area including up to 350-400 ha, or more than 7 times the area of reef included in the original biomass estimate, if the Pre-fishing survey density estimates were extrapolated across the full survey area, this would suggest a biomass of abalone about 7 times higher, or over 500 t of abalone $\geq$120 mm with over 200 t of abalone $\geq$135 mm.

Successful completion of the Structured Fishing survey, and comparison of the results with those from the Pre-fishing survey, demonstrated the potential of structured fishing surveys as part of a future harvest strategy.

Relationships between the morphology of abalone shells and biological parameters (e.g. growth and reproduction) have been documented in most abalone fisheries. Similarly, relationships between growth in length, weight and the corresponding SPR (Spawning Potential Ratio) may also be common. These relationships provide the opportunity for Industry to monitor shell characteristics of the landed catch and use them as indicators of a population's SPR, and so cost-effectively produce fine-scale estimates of SPR and improve estimates of depletion.

This project has developed and implemented several cost-efficient and Industry-based options for monitoring, and advice about catch setting, for use in a harvest strategy for the Victorian Western Zone fishery, and these options now need to be developed futher and extended in consultation with Stakeholders. Such a harvest strategy, and particularly monitoring, also appears to be developing in many other Australian abalone fisheries.

KEYWORDS: Abalone, AVG, reopening, survey, Industry, training, structured fishing, harvest strategy.

ACKNOWLEDGMENTS

This project was developed and implemented with the support and cooperation of the Abalone Industry in Western Zone Victoria and Fisheries Victoria, particularly with the intent to investigate the potential of again fishing commercially for abalone on AVG-affected reefs.

The involvement of commercial divers, including Jason Ciavola, David Forbes, Rod Harris, Peter Riddle, Rob Torelli, Glen Plummer and Phil Plummer, was essential to the project's success and the outcome of commercial catches from these AVG-affected reefs. This included particularly their contribution to design, training and data collection, including operation of GPS and measuring loggers.

A Project Steering Committee guided strategic implementation of the project, and contributed significantly to its success. Members included, Dallas D'Silva, Harry Gorfine (MAFRI), Stephen Mayfield (SARDI), Rick McGarvey (SARDI), Jeremy Prince, Keith Sainsbury and Duncan Worthington.

Craig Mundy and Peter Walsh (TAFI) provided support to the extension and development of the AbTrack logger database, as part of FRDC project 2006/029.

I also wish to acknowledge the efforts of Dr Duncan Worthington, in contributing to many aspects of the project, and in particular for developing the interactive graphic displays of survey data. These data formats will greatly enhance the ability to readily provide meaningful feedback to licence holders, divers, managers and other stakeholders in the fishery.

BACKGROUND

Abalone Viral Ganglioneuritis (AVG) was first observed causing unprecedented, catastrophic mortality of abalone in western Victoria during May 2006, and has continued to spread. As a direct consequence, there have already been large reductions in TAC with consequent reductions in the GVP of the Industry and its profitability. Further, the AVG-related mortality has led to great uncertainty about the status of the abalone populations (e.g. depletion) and their future productivity (e.g. catch). Areas where populations have been affected by AVG, including adjacent to Port Fairy, have now been closed to fishing for periods approaching four years in early 2010, and as a result, little or no information is available about abalone populations in many of these areas. What information that is available has come from costly fishery-independent surveys completed by MAFRI in a limited number of areas, and anecdotal information from Industry divers at a finer-scale for a broader selection of areas.

NEED

There is now a strong need to develop cost-effective and reliable surveys of the AVG-affected abalone populations, to provide information and support decisions about possible re-opening and conservative management of the stocks and fishery. Industry-based surveys and structured fishing have the potential to provide a cost-effective and reliable method of collecting more, finer-scale information about the status and productivity of populations, and to also allow an audit of the resource to enable Industry to fish-to-market within the agreed conservative management guidelines. Both these aims will influence the future profitability of the Industry. Further, finer-scale and more representative information about the stocks, that is possible through the use of more cost-efficient Industry-based surveys, and a cost-efficient and conservative harvest strategy, will also be fundamental to better assessment and management of the populations to ensure sustainability for all stakeholders.

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
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.

METHODS, RESULTS AND DISCUSSION

Project Context

It is important to understand this project and methods used in the context of the harvest strategy proposed by WADA. WADA have proposed a fundamentally conservative harvest strategy, based on low catches and high size limits, that seeks to rebuild stocks and progressively regain access to the abalone resource. As one of its goals, this strategy looks to reduce the information-burden and cost required by more exploitative harvest strategies. As such, the harvest strategy proposes to rely on information, such as surveys of abundance or biomass and shell morphology and fouling, collected cost-efficiently by Industry at a finer spatial scale.

Within this context, the project planned to:

- Contribute to understanding of the current abalone stocks, and the strengths and weaknesses of the current stock assessment and management process;
- Develop the capacity of divers and WADA to implement reliable surveys of abalone populations at a finer spatial scale.
- Rebuild stocks through a precautionary harvest strategy that progressively regains access to the resource;
- Complement the current project dealing with Performance Indicators and strategies for resumption of harvesting following catastrophic losses of abalone;
- Develop and begin to refine a broadly-applicable harvest strategy for obtaining data to inform short- and medium-term management decisions in the Western Zone fishery; and
- Build on the WADA Finer Scale Management strategies, developed before the AVG-related mortalities, to establish a more appropriate stock assessment and harvest strategy for finer-scale management of the fishery.

Project Leadership

While WADA led and was responsible for completion of the project, the project was implemented with the broad involvement of all co-investigators through a Steering Committee. The Steering Committee, Chaired by Harry Peeters (Executive Officer of WADA), included Dallas D'Silva, Harry Gorfine, Stephen Mayfield, Rick McGarvey, Jeremy Prince, Keith Sainsbury and Duncan Worthington, guided strategic implementation of the project. Support from Fisheries Victoria, MAFRI and SARDI was possible through significant cash and in-kind contributions from Fisheries Victoria. Stephen Mayfield and Rick McGarvey were responsible for development of the Pre-fishing survey. Jeremy Prince was responsible for SPR development and analyses. Duncan Worthington provided support across the project, and particularly in the design and analysis of structured fishing.

Progress against Objectives

Three stand-alone reports were prepared to specifically address the Objectives of the project (see Appendix 3a-c). A brief summary of those reports and progress against Objectives is presented here.

1. Industry-based, pre-fishing survey

A Pre-fishing survey, with no catch of abalone, was designed to provide the first assessment of populations of abalone on many of the reefs in the Port Fairy area. The primary intent of the survey was to inform an appropriate level of commercial

catch that could be taken in a Structured Fishing survey to further extend information about the populations. The Pre-fishing survey built on the existing available information (i.e. MAFRI-based survey, past catch records and WADA workshop process), particularly through the attempted repetition of exactly the same methods used by the MAFRI-based survey, facilitating direct comparison.

The survey area and past productive strata (i.e. 72 ha of reef) were defined at an intital workshop with Industry divers. Commercial divers, inexperienced in such surveys, were trained to complete the surveys, and estimates of density produced by commercial divers were compared to estimates from Research divers, used by MAFRI and with experience completing the surveys. Four, 30 m^2 survey transects were completed at 40 sites (i.e. a sampling fraction of 0.86% of the sampled strata), counting 2009 abalone, with 56% classified as pre-recruits $\geq$80 and <120 mm in length, 40% recruits $\geq$ 120 mm and 4% juveniles <80 mm. The shell length of 1995 abalone were also measured. Densities of abalone averaged 0.39 m^{-2} (se = 0.07), ranged among sites from 0 to 1.4 m^{-2} and were highest in the Crags and Lighthouse Reef codes.

2. Estimate of harvestable biomass and possible catch

Harvestable biomass was estimated from information collected during the Pre-fishing survey. This included estimates of density and size-structure from systematically selected sites within strata identified in the survey area. This information was combined with estimates of the relationship between size and weight to produce estimates for each strata of the biomass of abalone above several possible minimum legal lengths. Because of differences among experienced and inexperienced survey divers, only density estimates from experienced divers were used in estimating biomass. Variances of biomass estimates were calculated using a stratified, non parametric bootstrap. A total biomass of 79.9 t (se = 13.9 t) of abalone $\geq$ 120 mm was estimated in the sampled strata only (i.e. 55.6 ha), with most biomass in the Crags Reef code. Biomass estimates were then incorporated into harvest decision tables for four assumed minimum legal lengths of 120, 125, 130 and 135 mm SL.

3. Structured fishing survey

Results from the Pre-fishing survey and a further Workshop and Steering Committee meeting were used to plan the design and catch of a Structured Fishing survey. The intent of the survey was to use a small commercial catch, spread appropriately across the sampling area, to increase the information available about the abalone population. Further, implementation of the structured fishing was intended to increase the capcity of Industry to implement cost-efficient survey methods, for potential use in a future harvest strategy.

The Structured Fishing survey was designed to enable future comparisons, and current comparisons among different areas of the survey. These included comparisons with the Pre-fishing survey and the strata defined during that survey, including among sampled and unsampled strata and among areas inside and outside strata. To complete the Structured Fishing survey, 7 t of catch and 92 planned sites selected to the design were allocated to divers in proportion to units in the fishery they were associated with. At each site, divers collected up to about 100 kg of abalone and were required to operate GPS- and shell measuring-loggers

and fish above a minimum size limit of 135 mm, with catch and effort reported for each site.

In total, 6.693 t of abalone (i.e. about 13 000 individuals or over 6 times more than counted in the Pre-fishing survey) were caught in 163 bins from 95 sites. On average, 82 kg of abalone were caught at each site, with the diver spending 74 minutes fishing and swimming 104 m, while catching abalone at 57 $kg.hr^{-1}$(se = 4.0). A total 10 572 abalone were measured with a GPS-enabled measuring board during the survey. Length structures were calculated for 15 areas, with some substantial differences in size structure among adjacent areas.

While average catch rates were 57 $kg.hr^{-1}$, 11 of 95 sites had catch rates $\geq$100 $kg.hr^{-1}$, with one of those $\geq$150 $kg.hr^{-1}$ (i.e. 100 kg in 35 min) and another $\geq$250 $kg.hr^{-1}$ (i.e. 80 kg in 19 min), and these were distributed throughout the survey area rather than being concentrated in any area. No catch was collected from four sites visited, and an additional 7 sites had catch rates <20 $kg.hr^{-1}$ and these were also distributed throughout the survey area. Observations of under-size abalone were also completed by the divers at all sites, and were related to the density of pre-recruits from the Pre-fishing survey.

The design of the survey enabled several comparisons of survey indicators among different areas. Catch rates at sites corresponding to Pre-fishing survey sites were lower than those at sites selected in the design as Structured Fishing sites and Supplementary sites, or sites selected by the divers. Catch rates in sampled strata from the Pre-fishing survey were lower than those in unsampled strata or outside strata. This suggests it may be appropriate to extend density estimates in the Pre-fishing survey from only sampled strata, on which the original biomass estimate was based, to unsampled strata and even all survey areas outside strata. With the full survey area including up to 350-400 ha, or 7 times the area of reef included in the original biomass estimate, if the Pre-fishing survey density estimates were extrapolated across the full survey area, this would suggest a biomass of abalone about 7 times higher, or over 500 t of abalone $\geq$120 mm with over 200 t of abalone $\geq$135 mm.

Successful completion of the Structured Fishing survey, and comparison of the results with those from the Pre-fishing survey, demonstrated the potential of structured fishing surveys as part of a future harvest strategy.

4. Development of a cost-effective harvest strategy

The need for finer spatial scale assessment, combined with a practical scale of management, is now widely acknowledged in Australia's abalone fisheries. It is not possible to replicate the currently-used, broad-scale assessment processes, based on government-based surveys, at a finer spatial scale because of obvious cost constraints. Industry-based surveys combined with conservative harvest strategies, such as those based on their Spawning-Potential-Ratio (SPR), provide an opportunity for both greater cost-efficiency and information at a fine spatial scale, which can be used to both direct fishing to market and ensure sustainability.

Relationships between the morphology and fouling of abalone shells and biological parameters (e.g. growth and reproduction) have been documented in many

abalone fisheries. Similarly, relationships between growth in length, weight and the corresponding SPR, may also be common. These relationships provide the opportunity for Industry to monitor shell characteristics of the landed catch and use them as indicators of a population's SPR, and so cost-effectively produce fine-scale estimates of SPR and improve estimates of the depletion of the stock.

Using a meta-analysis of available data about the relationship between shell morphology, biological parameters and SPR, it is possible to suggest appropriate size limits corresponding to various levels of SPR. For example, using estimates of the shell length at which 50% of individuals are mature, and its relationship to growth in length and SPR, it is possible to calculate minimum length limits that correspond to certain levels of SPR. For data from Western Zone Victoria, size limits that maintain an estimated 35% of the population SPR, ranged among areas from 133-154 mm, with 141 mm at the Crags and 150 mm at Watertower.

Once appropriate minimum size limits are set, a more complete harvest strategy would also require definition of a combination of specific monitoring data and strategies (e.g. GPS loggers, structured fishing, shell measuring) and a catch control rule based on this information. Again, ongoing monitoring data could be used to calculate an annual SPR or change in the stock, which in turn could be used to determine the next year's catch through the relationship of SPR to estimates of fishing mortality, or decision rules. This project has developed several cost-efficient options for monitoring, and advice about catch setting, for use in a harvest strategy for the Victorian Western Zone fishery, and these options now need to be developed futher in consultation with Stakeholders. Such a cost-efficient harvest strategy, and particularly monitoring, also appears to be developing in many other Australian abalone fisheries.

BENEFITS AND ADOPTION

This project has provided a range of outputs and outcomes to all Stakeholders in the Victorian Western Zone abalone fishery, as well as developing processes and strategic information that, if applied, will benefit other abalone fisheries. Principal among these is the development of Industry's capacity to work with fishery managers and researchers in designing and implementing surveys of the abalone stock to provide greater information about management of the fishery.

Stakeholders in the Victorian Western Zone abalone fishery will benefit, in particular, from greater knowledge of the current and ongoing recovery of abalone stocks on AVG-impacted reefs. The project also delivered outcomes that directly benefit Divers, Licence holders and WADA, through the development of capacity to train divers, design and implement Industry-based Pre-fishing surveys and Structured Fishing surveys of abalone populations, and place them within a cost-efficient harvest strategy.

This project has also demonstrated the capacity of the abalone industry to cooperatively manage, with government fishery managers and researchers, the development and application of cost-effective technologies to collect large, fine scale spatial data sets to contribute to the assessment and management of abalone stocks and their fisherys. The success of this project in Western Zone Victoria, and its similarity to developments in other states, demonstrates the

potential of a standard approach to fine scale spatial data collection and analysis, and its use in managing Australia's abalone fisheries. The benefits of such a system should be developed further and extended throughout all abalone fisheries.

WADA, Industry and Fisheries Victoria will continue to develop the monitoring and harvest strategy options, and other outcomes, developed in this project. As such, the project's outcomes will continue to deliver benefits for all Stakeholders of a more cost-effective and auditable method of collecting finer-scale information about the status and productivity of abalone populations in Western Zone Victoria, for use in their managment.

FURTHER DEVELOPMENT

Several directions are important to the ongoing development of the capacity and processes established during this project, and assessment and management of the abalone fishery in Western Zone Victoria. These include:

- A commitment to fund further development of the capacity and processes developed in this project.
- Continued collection and use of fine scale spatial data, through Structured Fishing and other information collection methods, to further increase knowledge of fishing and abalone stocks at this scale.
- Extension of methods and processes developed in this project to other areas impacted by AVG with very limited information about abalone stocks (e.g. Warrnambool).
- Continued development of the spatial information collection, management and analysis system, based around AbTrack, to futher automate calculation of key fishery performance indicators.
- Continuation of WADA workshop processes, with divers and Licence holders, to consider fine scale spatial data and better inform fine scale assessments for TAC setting and catch planning.
- Further development of simple catch control rules, such as SPR, to establish a formal harvest strategy for the fishery.

PLANNED OUTCOMES

This project has delivered a range of outcomes to Stakeholders in the Victorian Western Zone abalone fishery, as well as other abalone fisheries. Principal among these will be the development of more cost-effective and finer-scale techniques for the assessment of abalone populations, their implementation to AVG-impacted reefs near Port Fairy, and their proposed development throughout the fishery.

Stakeholders in the Victorian Western Zone abalone fishery have and will continue to benefit from greater knowledge of the recovery and future change of abalone populations, and how they respond to future management. The project has also delivered outcomes that directly benefit Divers, Shareholders and WADA, through the development of capacity to train divers and implement Industry-based surveys and Structured Fishing surveys of abalone populations.

The outcomes delivered by this project can continue to provide benefits of a more cost-effective and auditable method of collecting finer-scale information about the status and productivity of abalone populations, and as such deliver improvements

in profitability. Potential development and application in other state's abalone fisheries could deliver similar benefits.

CONCLUSION

This project has developed the capacity of Industry, working with fishery managers and researchers, to develop and implement Pre-fishing and Structured Fishing surveys, to provide information about stocks of abalone. This information will provide a valuable baseline for future comparison, as well contributing to further development of a harvest strategy for the fishery, including simple and cost-efficient methods of data collection and catch setting, such as SPR.

WADA has clearly stated Industry's position supporting development of a conservative, simple and cost-efficient harvest strategy for the fishery. Such a harvest strategy will be based on a high size limit and full coverage of GPS-enabled loggers, structuring fishing to provide data to inform specific questions about management of the fishery, and a simple and cost-efficient harvest strategy based on SPR. While this project has provided much information to develop this approach, and helped facilitate commencement of fishing on AVG-impacted reefs, much still remains to be developed before the harvest strategy can be fully implemented.

The continued development of the fishery's harvest strategy, involving continued development of Industry's capacity to implement Pre-fishing and Structured Fishing surveys, and development of the use of shell morphology in SPR catch controls, is likely to provide a valuable data series for evaluating these emerging, cost-effective techniques for collecting and using fine scale data in managing Australia's abalone fisheries.

APPENDIX 1: INTELLECTUAL PROPERTY

The intellectual property developed through this project is for general publication.

APPENDIX 2: STAFF

Harry Peeters

APPENDIX 3A: PRE-FISHING SURVEY AND ESTIMATION OF BIOMASS REPORT (REMOVED FROM THIS VERSION). BIOMASS OF BLACKLIP ABALONE (*HALIOTIS RUBRA*) BETWEEN PT FAIRY AND THE CRAGS IN THE WESTERN ZONE OF THE VICTORIAN ABALONE FISHERY. S. MAYFIELD, R. MCGARVEY, H.K. GORFINE, P. BURCH & S. SHARMA

Biomass of blacklip abalone (*Haliotis rubra*) between Pt Fairy and the Crags in the Western Zone of the Victorian abalone fishery

Report for the Western Abalone Divers Association

S. Mayfield, R. McGarvey, H.K. Gorfine, P. Burch & S. Sharma

August 2009

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APPENDIX 3B: A STRUCTURED FISHING SURVEY OF ABALONE ON REEFS NEAR PORT FAIRY. DUNCAN WORTHINGON, HARRY PEETERS AND HARRY GORFINE.

A report as part of FRDC Project TRF 2008/077

Background

As part of the WADA TRF 2008/077 Project, a Structured Fishing survey of abalone on reefs near Port Fairy was completed between December 2009 and March 2010. Following a pre-fishing survey completed in mid-2009 (Appendix 3), the WADA TRF Steering Committee recommended implementation of the Structured Fishing survey with a catch of 7 t of abalone $\geq$ 135 mm. The intent and Objectives of the Structured Fishing survey are summarised in Steering Committee Workshop notes and discussion papers in the Appendix.

Briefly, the intent of the Structured Fishing survey was to extend the Pre-fishing survey to areas unable to be sampled, and by enabling comparisons of survey indicators among areas, to provide additional information to further increase knowledge of stocks of abalone recovering from AVG on reefs near Port Fairy. This report attempts to both summarise the databases developed during the survey, and summarise the information collected during the Structured Fishing survey. Interpretation of the potential use of these databases and the information collected within them, in further developing the harvest strategy for the fishery, will occur in the WADA TRF Final Report.

Methods

Structured Fishing survey design

On the basis of the biomass estimates provided by the Pre-Fishing survey, a Structured Fishing survey involving a catch of 7 t was discussed and supported at the second Steering Committee Meeting. The Structured Fishing survey was designed to enable several specific comparisons of survey indicators among sites. These included comparisons with the Pre-fishing survey and the strata defined during that survey, including among sampled and unsampled strata and among areas inside and outside strata. The primary intent of the Structured Fishing survey was to train WADA and its divers in the implementation of a cost-effective survey method, and to enable a baseline for comparisons of future changes in stocks,

To complete the Structured Fishing survey, 7 t of catch and 92 planned sites (i.e. chosen by SARDI to the design specified, plus additional sites able to be selected by divers) were allocated to divers in proportion to units in the fishery they were associated with. At each site used in the Structured Fishing survey, divers collected up to about 100 kg of abalone, implying a minimum number of 70 sites in the survey (i.e. compared to 38-40 in the Pre-fishing survey). With catches below 100 kg possible at some sites, additional sites were also pre-selected to enable distribution of any additional catch within the 7 t limit.

Divers were provided a series of GPS points (see Appendix 3), in proportion to their identified catch entitlement, and were required to enter the water at the identified site and search for commercial quantities of abalone. If commercial quantities of abalone were not immediately obvious, divers recorded the time taken to locate them, prior to fishing. Once commercial quantities were located, divers commenced fishing until 3, 30 kg bags of abalone were full (i.e. about 100kg) or they had moved a maximum of about 500 m from the site they entered the water.

As the planned GPS points provided to divers were selected using a GIS by SARDI, it was possible that the sites selected may have had inappropriate habitat for abalone (e.g. no reef, but sand). If divers found inappropriate habitat for abalone at a planned site, they were required to move their boat towards the nearest identifiable reef and reposition the survey site. Relatively few sites were repositioned in this way, and the vast majority of sites where fishing was reported to occur were adjacent to planned sites. There was one significant exception to this, involving sites selected within the deeper water strata off the Crags,

as sites in the strata were all identified with inappropriate habitat (i.e. sand), and were all repositioned into slightly shallower water closer to shore (e.g. compare Appendix 3 and 4).

At all times, divers were required to operate GPS- and shell measuring-loggers and fish above a minimum size limit of 135 mm, with total catch and effort reported for each site. Divers were also required to fill in an extensive data sheet for each site, including details of the abalone catch and under-size observations, habitat, weather conditions, and other observations. Primary survey indicators included the diver's search time (min), catch (kg), effort (h), catch area (m^2, e.g. based on the area of the GPS-logger track buffered by 100 m), catch rate ($kg.hr^{-1}$ and $kg.m^{-2}$) and size structure of the abalone population at each site.

Results and Discussion

Structured Fishing data

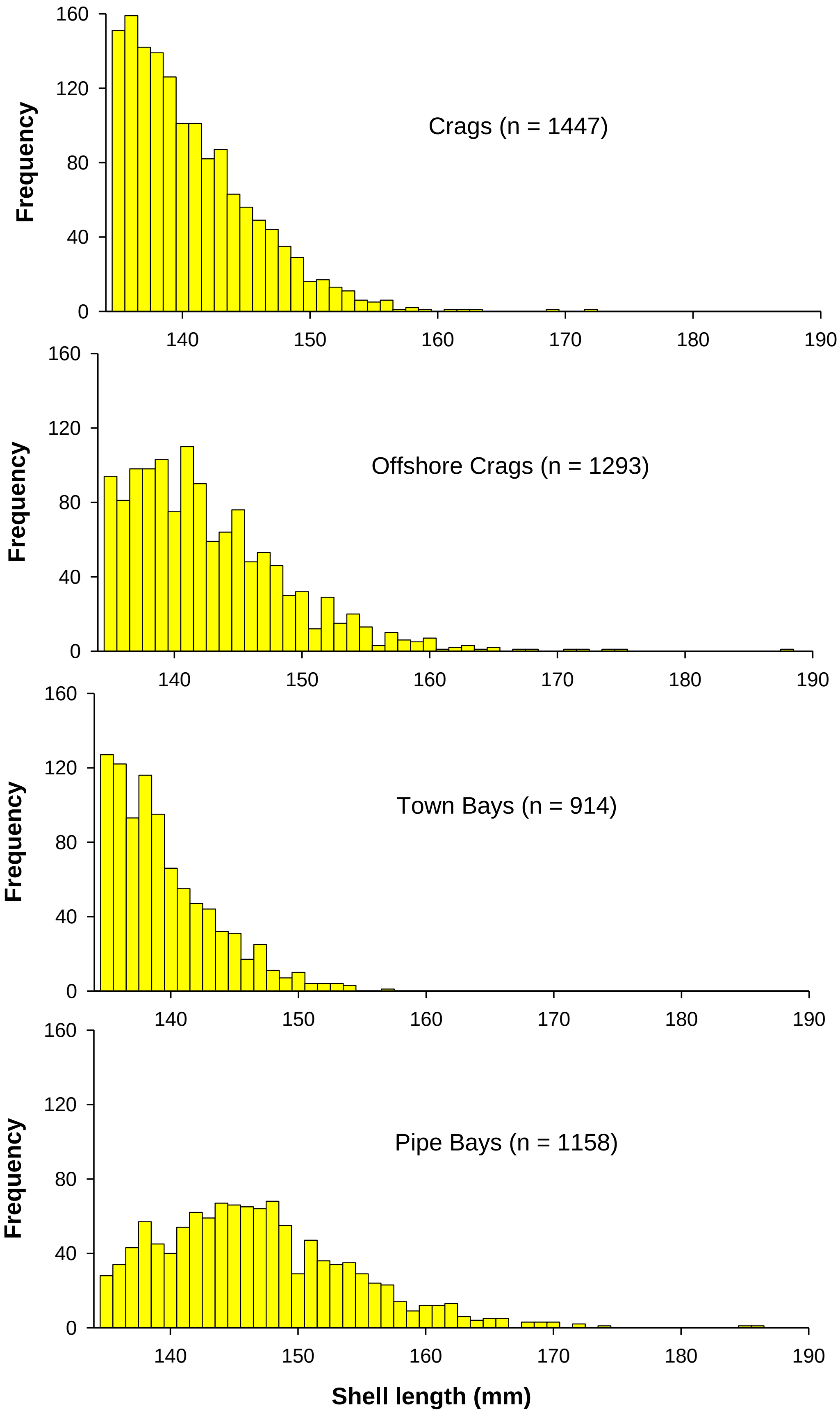
A Structured Fishing database (i.e. MS Access) was developed with records for 95 separate sites fished to the survey protocol, including fields describing the abalone catch, effort and under-size observations, habitat, weather conditions, and other observations. Specific fields referred to the Site number, Reef code, Logger number, Date, Observer, Location, Depth, Latitude, Longitude, Arrival time, Departure time, Wind speed, Wind direction, Swell height, Swell direction, Site description, Water visibility, Surge, Current, Water temperature, Geology, Sand patches, Relief/terrain, Juvenile abalone abundance, Cryptic habitat, Kelp cover, Pink coralline algae, Bottom overgrowth, Sea-stars, Periwinkles, Sea urchins, Wrasses, Crayfish, Crabs, Comments, Data module number, Sensus DTS Number, Start time, Finish time, Start latitude, Finish latitude, Start longitude, Finish longitude, GPS explanation, Time swum, Distance covered, Additional comments, Total Minutes and Total Catch.

In total, 6.693 t of abalone were caught in 163 bins, as reported to DPI Victoria, and 6.666 t of abalone were caught according to the Structured Fishing database. On average, 82 kg of abalone were caught at each site, with the diver spending 74 minutes fishing and swimming 104 m, while catching abalone at a rate of 57 $kg.hr^{-1}$(se = 4.0). All data from GPS loggers and GPS-enabled measuring board loggers were entered in to the AbTrack SqlServer 2008 database, and spatial queries and links have been developed to create maps in Manifold GIS of all data and summaries.

Length data

A total 10 572 abalone were measured with a GPS-enabled measuring board during the survey, providing a spatial map of the distribution of abalone of different sizes. A total of 2883 of the 10 572 abalone (i.e. 27%), were measured within strata from the Pre-fishing survey, with a mean length of 143 mm (SE = 0.1) and 431 (i.e. 15%) individuals $\geq$ 150 mm in length. Of the 7092 abalone measured outside the Pre-fishing strata with a mean length of 141.4 mm (se = 0.1), 1036 (i.e. 15%) individuals $\geq$ 150 mm in length. Length structures were calculated for 15 areas, with some substantial differences in size structure among adjacent areas. For example, the size structure of abalone measured in the Town Bays was much smaller than most other areas, including the adjacent Pipe Bays, which had some of the largest abalone measured (Figure 1). Manifold GIS layers and queries have been developed and are available for calculation of sampled length structures in any selected area of reef.

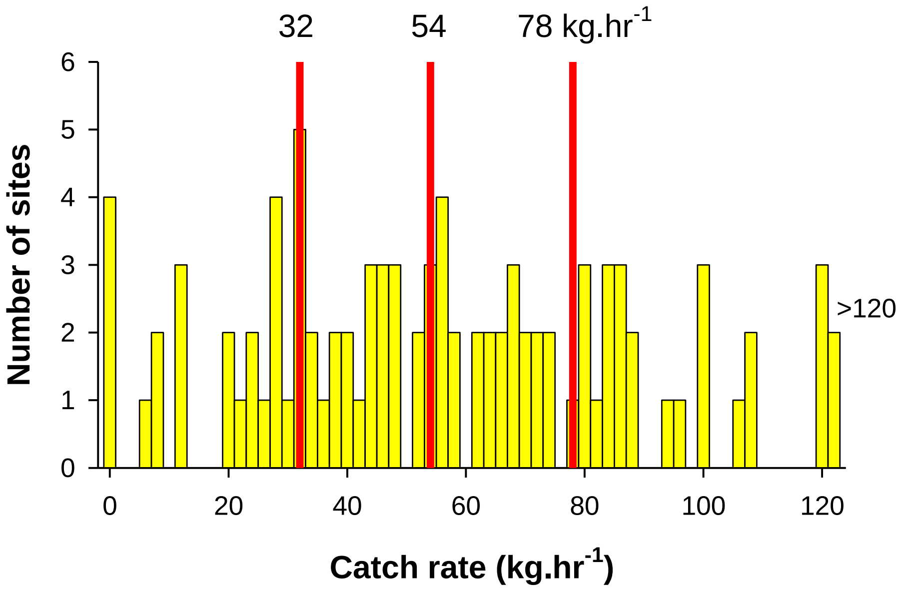
Figure 1. Length structure of abalone measured with GPS-enabled measuring boards and landed during the Structured Fishing survey, at 4 of 15 broad areas near Port Fairy.



Catch rate data

Catch rates of abalone across all sites were 57 kg.hr^{-1}(se = 3.6), with 11 of 95 sites producing catch rates ≥100 kg.hr^{-1}, with one of those ≥150 kg.hr^{-1} (i.e. 100 kg in 35 min) and another ≥250 kg.hr^{-1} (i.e. 80 kg in 19 min), and these were distributed throughout the survey area rather than being concentrated in any area (Figure 2). No catch was collected from four sites visited, and an additional 7 sites had catch rates <20 kg.hr^{-1} and these were also distributed throughout the survey area. There were differences in catch rate among divers (i.e. range 26-82 kg.hr^{-1}), although as some divers only sampled a few sites, and others sampled many sites (i.e. range 5-32 sites), differences among divers were confounded with any differences among sites.

Figure 2. Frequency distribution of catch rates during the Structured Fishing survey at 95 sites near Port Fairy, with 25%, 50% and 75% quantiles of observations shown as red lines.



The design of the survey enabled several comparisons of survey indicators among different areas, although only comparisons of catch rate and size structures are presented here. Catch rates varied among the Reef codes in the survey area (Figure 3), with higher catch rate in the Crags (60 kg.hr^{-1}, se = 4.1) than Burnet's (59 kg.hr^{-1}, se = 11.9), Water Tower (51 kg.hr^{-1}, se = 5.1) and Lighthouse (52 kg.hr^{-1}, se = 13.7). These differences among Reef codes are similar to the differences in density estimated in the Pre-fishing survey for combined counts. There were also differences in catch rate among the different type of sites (Figure 4). Catch rates at sites corresponding to Pre-fishing survey sites (52 kg.hr^{-1}, se = 5.2), were lower than those at sites selected in the design as Structured Fishing sites (58 kg.hr^{-1}, se = 6.4) and Supplementary sites (58 kg.hr^{-1}, se = 8.2), or sites selected by the divers (59 kg.hr^{-1}, se = 7.3).

Figure 3. Catch rate (+ se) in the four reef codes during the Structured Fishing survey, with 95% Confidence Interval of the survey average catch rate shown as red lines. Reef codes refer to the Crags, Burnets, Watertower and Lighthouse.

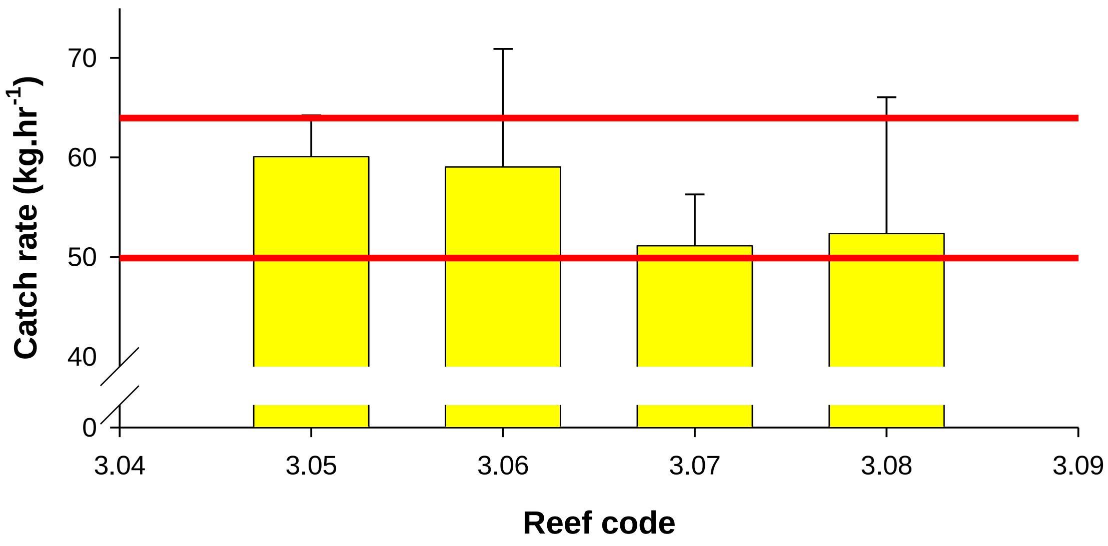
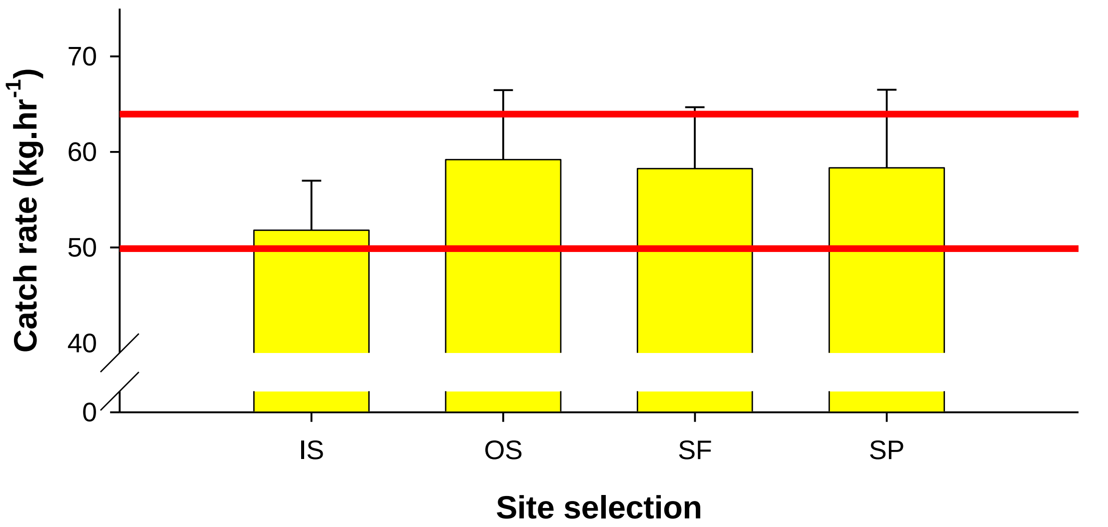


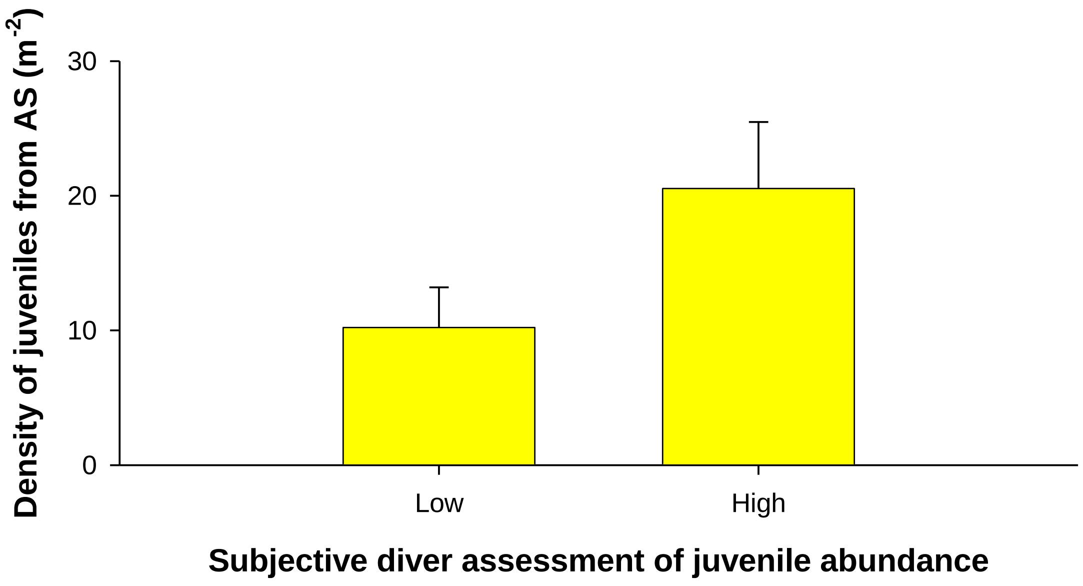
Figure 4. Catch rate (+ se) in the four different types of sites during the Structured Fishing survey, with 95% Confidence Interval of the survey average catch rate shown as red lines. Sites were selected corresponding to the Pre-fishing Survey (IS), diver chosen sites (OS), and the Structured Fishing (SF) design, with Supplementary sites (SP).



Observations of under-size abalone were also completed by the divers at all sites, allowing a comparison with pre-recruits from the Pre-fishing survey. Diver observations were combined into Low (i.e. none-low) and High (i.e. medium-high) categories at the Pre-fishing survey sites sampled in the Structured Fishing, and compared to the density of pre-recruits estimated in the Pre-fishing survey (Figure 5). Density of pre-

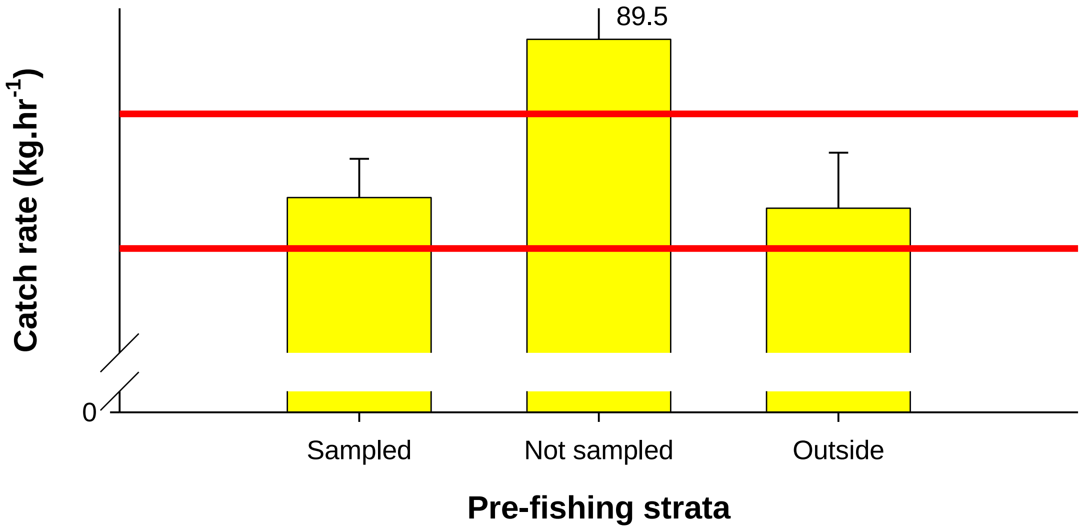
recruits in the Pre-fishing survey were higher at sites where divers reported observing High abundance of juveniles (20.5 30.m^{-2}, se = 4.9), than where Low abundance was reported by divers (10.2 30.m^{-2}, se = 3.0).

Figure 5. Density of pre-recruits in the Pre-fishing survey (± se) at sites where divers observed Low and High abundance of juveniles in the Structured Fishing survey.



Catch rates were very similar across all areas in the Structured Fishing survey (Figure 6). Catch rates in sampled strata from the Pre-fishing survey were 54 kg.hr^{-1}(se = 5.8), which was lower than those in unsampled strata at 71 kg.hr^{-1}(se = 17.8), and outside strata 55 kg.hr^{-1}(se = 4.1). This suggests it may be appropriate to extend density estimates in the Pre-fishing survey from only sampled strata, on which the original biomass estimate was based, to unsampled strata and even all survey areas outside strata. Such results are also consistent with comments by divers at the Port Fairy Workshop in August 2009, that they estimated 50% of the abalone biomass was outside strata at Burnetts, 30% at Watertower and 20% at the Crags. The original SARDI biomass estimate was based on sampled strata only, which included about 55.6 ha of reef. The full survey area could include up to 350-400 ha, or 7 times the area of reef included in the original biomass estimate. If Pre-fishing survey density estimates were extrapolated across the full survey area, as suggested by similar catch rates in the Structured Fishing survey, this would suggest a biomass of abalone about 7 times higher than the original SARDI estimate of 79.3 t of abalone ≥120 mm, or over 500 t. Extrapolating the Pre-fishing survey estimate of the biomass of abalone ≥135 mm of 34 t by the same amount would suggest a biomass of over 200 t across the full survey area.

Figure 6. Catch rate (+ se) inside sampled strata, inside unsampled strata and outside strata during the Structured Fishing survey. Note strata were defined in the Pre-fishing survey, and the upper standard error bar extends to 89.5 for Not Sampled strata.



GIS layers
In addition to the figures presented above, a series of layers have been created in Manifold GIS, and are likely to be particularly useful for summary and extension of results to Industry through the WADA Workshop process. These layers range from the design and results of the Pre-fishing survey, through to design and results of the Structured Fishing survey. Additional layers also allow comparisons with historical data and MAFRI survey sites. Layers created for comparison of Structured Fishing survey information are include (see also figures in Appendix):

Pre-fishing survey

- Sites sampled
- Density of abalone at sites
- Size structure at sites
- Survey strata

Structured Fishing survey

- Sites provided to divers
- Sites sampled
- Catch, catch rate and other observations at sites
- GPS of boat while diver underwater
- GPS of abalone length measurements
- Full survey area and Structured Fishing areas

Summary
The Pre-fishing and Structured Fishing surveys have enabled collection of the first detailed information about abalone stocks, and the first catch of abalone, from reefs near Port Fairy following the major AVG event. The broad participation of Industry and Researchers made possible by the FRDC TRF project, enabled development of a well-informed design and cost-efficient implementation of both surveys. Information collected, particularly during the Structured Fishing survey, demonstrates high catch rates of ≥

135 mm abalone at many sites throughout the survey area. Sites with lower catch rates were often associated with areas where divers recorded comments of good abalone abundance, with few appearing to grow to the high minimum length limit.

The Structured Fishing survey generated information about abalone stocks from 95 sites, and enabled structured comparisons among sites in different area to provide further information about stocks. This was achieved through the cooperation of Industry and researchers, very cost-efficiently. WADA estimates that the total resources used to complete the structured Fishing survey at less than $30 000, in addition to the in-kind support provided by divers and the proceeds from landing abalone. Further, a process for the re-opening of AVG impacted reefs has been developed by developing the capacity of Industry to work with Fisheries Victoria and Researchers, and implement Pre-fishing and Structured Fishing survey to cost-efficiently provide information about stocks.

At the project Steering Committee meeting in August 2010, the Committee discussed the way forward for development of structured fishing and collection of further information about AVG-impacted abalone stocks on reefs near Port Fairy, and new areas towards Warrnambool. WADA hopes to extend the Structured Fishing survey at Port Fairy, and develop it on reefs toward Warrnambool, from late 2010. In addition to providing information about stocks impacted by AVG, these surveys will also form an important baseline against which future changes in abalone stocks can be assessed. As Pre-fishing and Structured Fishing surveys are further developed the capacity of Industry and WADA to develop and implement the surveys will also increase.

Appendix 1. First Structured Fishing Discussion paper.
Using Structured Fishing Surveys to assess stocks of abalone in western zone Victoria

Background

At the first Steering Committee workshop of the WADA TRF Survey Project, it was agreed to develop a discussion paper about the use of Structured Fishing Surveys in assessing stocks of abalone in western zone Victoria.

Information provided by surveys has been used in the past, and is likely to be needed and used in the future, to advise decisions about appropriate catch levels. The limited spatial coverage and high cost of scientific surveys has encouraged investigation of alternatives in Western Zone Victoria, and most other abalone fisheries. Several aspects of the design of Scientific Surveys have provided confidence in their outputs to users of the information. In particular, the ability of Scientific Surveys to resample specific sites with the same method has provided the ability to detect serial depletion or spatial contraction of the population. By re-fishing specific sites with the same or very similar method, Structured Fishing Surveys provide the opportunity to avoid many of the pitfalls of CPUE data from routine commercial fishing, and to collect data very similar to that from Scientific Surveys. If Structured Fishing Surveys can be integrated in some way with routine commercial fishing to reduced costs, a much greater amount of fine scale and informative data could be collected.

Structured Fishing Surveys aim to give cost-efficient and repeatable information about stocks, and there are a range of possible survey designs that could deliver such information. This paper will discuss design considerations for the Structured Fishing Survey proposed as part of WADA's TRF project, in the context of other information sources and the broad management strategy proposed for the fishery by WADA. The objectives of the TRF project relate particularly to the development, training and investigation of Industry-based Scientific and Structured Fishing Surveys, and the feasibility of using shell measurements to indicate depletion, and to allow these options to be considered within a broader management strategy for the fishery.

WADA vision

WADA have identified a vision for a more conservative, and less costly, management strategy for the fishery. The management strategy would utilise information from a range of sources at a fine spatial scale, to develop advice about catch levels also at a fine spatial scale, and calculate a TAC for the zone from a bottom-up spatial approach. Information sources would include some combination of Scientific Surveys by Industry divers, Structured Fishing Surveys, biological and shell measuring, would include the ability for independent audit, and would not be repeated in full each year. Annual catch levels would be determined at a fine spatial scale through tested empirical decision rules, with their performance checked less frequently.

Assessment data streams

Current assessment

There are several data streams currently used and combined to provide an assessment of stocks and advice about catch levels in the fishery. These include:

Table 1. Data used and combined to provide an assessment of stocks and advice about catch levels.

Data	Use	Frequency	Limitation	Cost
Count of abalone per m at surveys sites	Indicator of reef code/zonal abundance	Annual	Limited spatial coverage	High
Sizes of abalone at survey sites	Indicator of reef code/zonal size structure	Annual	Limited spatial coverage	Medium
Sizes of abalone caught with GPS	Indicator of reef code/zonal size structure	Continuous/ annual	Information only on legal-sized stock, not a clear link to site of catch	Low
Biological data	Model dynamics	As available	Limited spatial coverage	High
Zonal Population Model	Combine zonal data sources to estimate population trajectory to advise catch levels and test decision rules	Annual	As per data limitations plus zonal structure	Low

Structured Fishing Survey

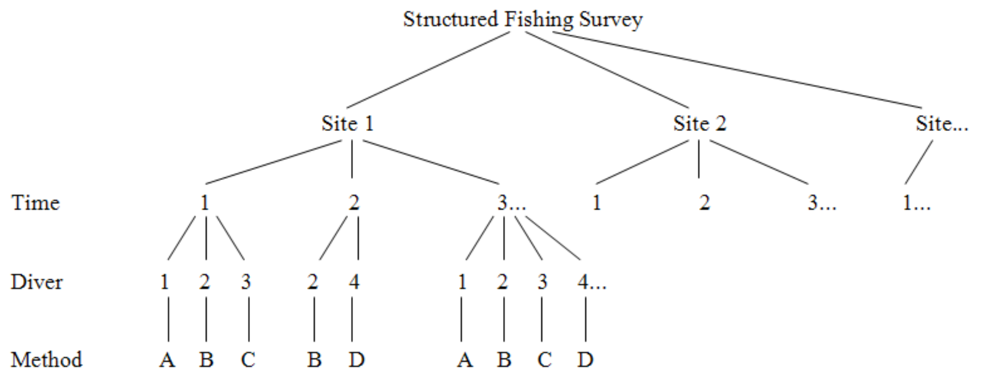
Several additional data streams could be produced from Structured Fishing Surveys, where consistent and repeatable methods are used by the same divers, at the same survey sites through time, as is done by the current Scientific Survey. These include:

Table 1. Additional data streams from Structured Fishing Survey for use in assessment of stocks and advice about catch levels.

Data	Method	Use	Frequency	Limitation	Cost
Catch of abalone per hour or estimated area at survey sites	Identified catch related to GPS/Depth logger record	Indicator of abundance at survey site/strata	Variable (repeat regularly, or as needed)	Repeatability	Low
Size of abalone caught with GPS at survey site	Identified catch related to GPS measuring device records	Indicator of size structure at survey site/strata	Continuous and ongoing	Information only on legal-sized stock	Low
Observed abundance of under-size abalone at survey sites	Quantitative or semi-quantitative estimate of abundance from observation in fixed area	Indicator of under-size abundance and future recruitment at survey site/strata	Variable (repeat regularly 1-5 yr, or as needed)	Extra cost to fishing, and high habitat related variation	Low-Med
Reef-code or finer-scale population models	Finer-scale application of population model	Combine data sources to estimate population trajectory, advise catch levels and test decision rules	Infrequent (5 years, to test progress with ongoing decision rules)	Data at a fine scale	Low

Structured Fishing Survey general design

There are a range of possible designs for both Scientific and Structured Fishing Surveys. There was broad agreement at the WADA workshop that a fundamental component of a Structured Fishing Survey was the ability to compare data, collected using the most consistent and repeatable methods possible, at the same survey site through time, as is done by the current Scientific Survey. For a Structured Fishing Survey, this requires the ability to standardise and control the Method used by divers as much as possible, and to ensure they revisit and fish the same site at some future times. Further, with the intent to integrate any Survey as much as possible with routine commercial fishing, there also likely to be some unbalanced replication of Divers and Methods at Sites each Time. A Structured Fishing Survey where sites are revisited through time, when possible by a diver, and re-fished with the same method which is unique to each diver and site, is summarised below.



More specific design considerations

While the above figure describes a generalised design for a Structured Fishing Survey, several considerations remain about the specifics of the design. For example:

Spatial coverage	How many sites, and per reef code?
Temporal coverage	How frequently are sites sampled, and before analysis/presentation?
Site selection	How important is the site and/or is it representative of a broader area?
Method selection	How consistent and easy to replicate are the Methods for each diver?
Development	How many sites now, and how many added later?
Diver coverage	How many sites does each diver sample?
Audit coverage	How many sites do divers repeat of others?

Further, several logistical considerations remain about the design of any Structured Fishing Survey used to advise catch levels in the fishery. For example, these include whether the catch taken during any Structured Fishing Survey is considered part of the TAC for the zone, or if a separate allocation is provided. Resources and expertise would also be needed to develop a database of survey sites and methods specific to each diver used in the survey, and the database should also include historic observations or estimates of abundance for comparison.

Methods from TRF Proposal

The TRF proposal included an indicative design for a preliminary Structured Fishing Survey. That is, divers would fish 42 sites from within strata already identified in the initial workshop and adjacent to the TRF Scientific Survey sites. From these 42 sites, 14 sites were proposed to be re-fished where the initial diver had fished, and 14 sites re-fished by a different diver adjacent to where the initial diver had fished. At each site, a maximum of 100 kg of abalone would be removed, and would be within an overall catch allocation. Such a survey should provide information about the feasibility of developing methods, training and managing divers, provide a baseline comparison with the TRF Scientific Survey and potentially some comparison with historical observations, a comparison of results among divers and the ability of sites to be re-fished.

Appendix 2. Steering Committee Meeting Notes

12 August 2009

Senior Citizens' Hall, Port Fairy

Attendees

Keith Sainsbury	(KS)	*CSIRO*
Rick McGarvey	(RM)	*SARDI*
Stephen Mayfield	(SM)	*SARDI*
Jeremy Prince	(JP)	*Biospherics*
Duncan Worthington	(DW)	*Ambrad Consulting*
Bruce Taylor	(BT)	*PIRVic*
Dallas D'Silva	(DD)	*Fisheries Victoria*
Melissa		*Fisheries Victoria*
Sasha Ruff		*Fisheries Victoria*
Harry Peeters	(HP)	*Executive Officer, WADA*
Rob Day	(RD)	*University of Melbourne*
Patrick Gilmour		*University of Melbourne*
Jason Ciavola		*WADA*
Peter Riddle		*WADA*
Philip Plummer		*WADA*
David Fenton		*WADA*

Action Items

- DW to write a revised discussion paper on structured fishing, to be circulated to steering committee members within 2 weeks. Steering committee to be given 1 week for comments before broader circulation to divers *etc.*

- RD and JP to run further scenarios for the Crags and the other areas to explore what is the best split between the areas – is it 135 mm at the Crags and 130 mm at the others? These can be incorporated into DW's structured fishing discussion paper.

- Rick to scale up estimates for incorporating into JP's program

- HP to look at adding 3 or 4 more annual sites for collecting juvenile data and possibly density measurements (this would bolster the PIRVic data. These could be on sites surveyed in the current project

Introduction

HP introduced the workshop, and emphasised that the aim of this project is to come up with a cost-effective method of diver surveys. Such surveys will provide data for decisions about when to restart commercial fishing and potential harvest quantities.

It was noted that some of the divers had questions and comments about why there were differences between the 'research-diver' and the 'commercial-diver' surveys. It was noted that the source of these concerns needed to be discussed and addressed constructively.

Points raised for discussion included:

- The biomass estimates and how they relate to pre-virus biomass
- Juvenile condition (what recruitment is likely to occur in coming years)
- Design of structured fishing program (which will provide more robust data on when/where commercial fishing can restart)

SARDI Report (SM/RM)

SM outlined the stages involved in production of the assessment report that had been circulated to the workshop attendees:

- Worked with divers to map areas of high productivity in the Port Fairy area
- Designed a sampling protocol and implemented using commercial and survey divers
- Used survey results (including length-frequency and length-weight data) to make calculations of biomass
- Place this information in context (*e.g.* comparison of densities to previous surveys by Harry Gorfine's team, to data from South Australia etc)
- The ultimate outcome was the production of harvest decision-tables. This was biomass levels above different size limits and with different levels of confidence.

It was noted that the tables were produced from research-diver data.

SM noted that comparisons were also made between commercial divers and research divers. The methods were similar with the exception of:

- Commercial divers collected (and measured) all abalone on their transect
- Research divers counted all available abalone on their transect (into three size categories)

It was noted that the information supplied by the commercial divers was invaluable and of very high quality:

- Only 2 out of 40 locations did not have any abalone
- Individual estimates of sustainable catch from different areas were very consistent between divers

It was noted that because the expert knowledge of the divers had been confirmed, one could have a high degree of confidence in scaling up the biomass estimates (taken across 75% of the 'high productivity' area) to the remaining 25% of the 'high productivity' area.

Discussion about differences between commercial and research divers

Workshop participants discussed some of the potential sources of differences between research- and commercial-divers' results.

Differences in method

Research divers counted abalone into three size-categories. Commercial divers collected all abalone they could from their transects. It was noted that commercial divers therefore had a more quantitative measure of biomass.

However, differences in the number of recruits were still noted. It was suggested that because the growth morphology could have changed, research divers may not be making accurate assessments of whether abalone are recruits or pre-recruits. BT suggested this is unlikely, given the extensive experience of the research divers, the rigorous training, the fact they regularly dive across areas of different growth and that they calibrate/ground-truth their estimates.

It was suggested that research-divers may be counting more pre-recruits than commercial divers because they are able to count individuals that are unable to be collected. This point was later disputed by the research divers, who clarified that their approach is to only count those individuals that would be available for collection.

Adherence to transect

It was noted that the transect is a 1 m wide strip but, as this strip is not measured, there is the potential for surveyors to collect/count abalone from a wider transect. It was suggested, however, that the difference between commercial- and research-divers could not be explained solely by 'wide' transects.

Another possible source of variation was suggested to be the straightness of the survey line and how well it adhered its intended bearing.

SM noted there is evidence of research divers in S.A. deviating from 'strict' transects. In that case, density-estimates from transects run perpendicular to a surface-laid transect were approximately 11% higher than from the transect laid from the surface. This indicates that even in highly trained divers, some unintended sampling bias can emerge.

Ways to reduce variation
South Australian researcher noted three things that reduced variation in their own diver-surveys:

1. Transect lines laid from the surface
2. A 1 m 'calibration' stick to help ensure the transect is only 1 m wide
3. A decision rule that the peak of the abalone spire must be within the transect to be counted

Key learnings
There are differences between the methods – the real aim is to explore the source of these differences and try to ensure results can be as consistent as possible through time.

Also, envisaging commercial-diver-based surveys as a way forward, there needs to be a way of tying back their results to the historical data. One solution to this is to 'calibrate' the different methods against each other and the divers—*i.e.* get the research divers to harvest abalone along transects, and get commercial divers to count the abalone along transects. This cross-over experiment would also test the hypothesis of mis-categorisation by research-divers. The hypothesis of mis-categorisation could also be tested by looking in more detail at the length-frequency distributions across the 40 sites.

DW summarised that in the current project, some of the learning outcomes have been displaced by a greater focus on getting more precise estimates of biomass.

HP noted that comparisons to historical data were good, but the historical survey sites are spread thinly in some areas. It is these areas that are of interest and industry-based surveys are essentially giving a new baseline-measurement. Sites that had been historically surveyed will continue to be surveyed using the research-diver methods.

Discussion about historical biomass levels

To check the estimates of biomass against historical levels, it was suggested that historical biomass could be calculated from:

- Catch levels
- Estimates of the proportion of the catch of the available biomass

It was noted that the average catch from the Crags from 1988-2000 was approximately 30 t. Following changes to size limits and effort distribution, this reduced to 23 t.

JP estimated that 30 tonne average represented close to 100% of the available legal biomass (above 120 mm). He noted that at this time industry was expressing serious concerns about the health of the stocks in that area. JP noted that from the length-frequency data, there was very little catch over 140 mm at this time, meaning a very high exploitation rate.

This suggests, conservatively, that the total available legal biomass (above 120 mm) was somewhere in the order of 40 t.

JP suggested that, ignoring the problem of pre-recruit mortality, the survey results suggest the biomass of the stocks is approximately similar to the biomass just prior to starting Fine-Scale Management (FSM).

There was general agreement that the stocks (at the Crags) were in approximately the same 'ballpark' state as from where they had been recovered previously (an acknowledged position of stress).

SM noted this sort of 'back-calculation' also needs to be done for the other reefs.

History of FSM in the Crags

- Area of agreed concern between Portland and Port Fairy divers

- Effort increasing because of declines in the Portland end of the fishery
- Size limit increased to 125 mm
- Size limit increase meant fishing was harder, so pushed effort into other areas
- This movement of effort was then controlled using catch caps
- Eventually the size limit was stepped up to 125 and 130 (in two different areas of the Crags)

JP explained that the catch cap was 22 t in 2004. KS noted that the drop in catch from the long-term average of 30 t meant a drop in the harvest fraction. KS noted that it would be good to calculate how this harvest fraction changed as an indicator of what was done to recover the stocks.

JP also noted that the underlying philosophy had been to ensure the size limit was the conservative 'backstop' to preserve breeding. He noted that the informal/qualitative nature of what they were doing relied on a conservative size limit, rather than exploitation rates.

It was noted that in recent surveys Harry Gorfine had observed that most shells were flat and clean – apparently fast-growing. Workshop participants were later informed by other divers and JP that the Crags also had shells that appeared flat and clean before AVG, consistent with it being fished relatively heavily down towards the size of maturity, and WADA's long policy of increasing the size limits for the area.

Pre-recruit year-classes

Workshop participants examined surveys of recruits and pre-recruits to explore potential changes in egg production.

SM noted the survey results showed:

- 50 % of the sample above 120 mm was 120-130mm
- 15% bigger than 140 mm
- These figures are similar to the commercial catch in earlier years

KS questioned whether before the virus impact, the number of new recruits was constant or falling. SM noted that across the reef-codes, there was 26% above 140 mm in the commercial catch. Post-virus, there is 14% above 140 mm. KS noted that this is lower, but not grossly lower. This is a drop of approximately 50%. JP noted that this size-class is not likely to have had as much 'accumulation' of smaller animals growing into it, so will therefore be more reflective of changes to the smaller size-classes.

There was discussion about the apparent rise in recruitment in the early 2000's and whether this was natural variation or not. Out of session, this was later confirmed as an artefact of the data—new sites had been added to the data set and not standardised.

Workshop participants noted that the smaller size classes show a larger impact than the larger size classes, which have had three years to accumulate. Two main issues were noted:

- The number of juveniles growing through in the next few years looks to be approximately 30% of previous levels. This coincides with initial estimates of 70% mortality at the Crags. This will mean 1or 2 more years of low levels of recruitment to the fishery.
- The potential for recruitment to be depressed further because of decreases in the breeding population (because of the virus). This means there may be a more persistent decrease in recruitment to the fishery (beyond the 1 to 2 years noted above). The effects of this will not be apparent for another 2-3 years.

KS questioned the level of depletion of the stocks pre-virus. JP estimated 40% - not heavily depleted, but not robust. Considering the virus reduced the spawning stock by approximately 50%, this would have left only 20% - KS noted this is a population level at which one could expect some effect on recruitment levels.

Coincidental environmental impacts

Workshop participants also noted that there was a decrease in recruitment at Lady Julia Percy at approximately the same time as the virus was affecting other reefs. This suggests that the virus impact may

coincide with an environmentally-driven decrease in recruitment. As a result, the impact may be worse than the virus-mortality alone. Recovery efforts should, therefore, be conservative.

Other potential post-virus changes

RM expressed concern that stocks at the Crags seemed to be maintained at a very high level of exploitation.

JP noted that 120 mm did not represent the cut-off for breeding – there is some level of breeding below this size limit. There was growth-overfishing at the Crags, but it's less clear that there was recruitment overfishing.

RM noted, however, that growth rates may have changed (because of reductions in density). This may also mean a higher size of maturity. New size limits, post-virus, should therefore be even more conservative.

Cost-effectiveness

JP noted that into the future, the surveys are important in the short to medium term for exploring biomass levels *etc*. However, in the long-term, less elaborate methods of monitoring, such as measuring shells in processors, could be used. These will also be more cost-effective.

HP asked if there is the potential for improving the cost-effectiveness of the current system (perhaps not having to go to SARDI for instance)?

SM noted that now the system is setup, it will be much less of an effort (and expense) in the future. RM estimated that for future analysis, his time would be perhaps 25% of that required in the current project. SM noted that it remains valuable, however, to compile all of the information (historical data, *etc*) into one place.

DD queried how extensively this method has/is used in South Australia. SM noted that at the moment it is a small, but increasing fraction. Timed-surveys are being phased-out.

It was suggested that because of the quality of the stratification, it may be possible to do less sampling – perhaps 50% instead of 75%.

HP reiterated that the question of cost-effectiveness has not been answered. Three points were noted:

- The structured fishing will provide more information and allow for comparisons which will allow decisions to be made about whether surveys can be scaled-back, *etc*.
- The cost of the reporting/analysis will be reduced in future exercises
- Sampling can be at a lower rate (cover more areas for the same effort) in future exercises because of the quality of the stratification in the current exercise.

Discussion of survey results with divers

Differences between research and commercial divers

HP introduced the session noting that everyone here is a commercial diver. Two are also survey divers for MAFRI.

Questions were raised by divers concerning:

- Why are commercial divers apparently overestimating abundance when the total numbers are the same

SM noted, firstly, the huge value of the commercial-diver data-set. He noted that the biomass could not have been calculated without the length-frequency data from the commercial divers. Only the abundance data has not been used in biomass calculations because of very large differences in the legal density.

He noted possible explanations include:

- Research-divers mis-estimating size-classes, though given the experience of the research-divers this is unlikely

- The relatively un-prescribed nature of the method (relative to S.A. methods) means there is potential for some 'straying' to occur. There is evidence of this in S.A. research divers, so it is not surprising that there is at least some differences between divers

A diver questioned what the difference was and if it could be simply the result of the patchiness of the abalone.

SM noted that the difference is approximately 70%. Differences between patchy abalone should be averaged out across all the sites, but, the commercial divers were consistently higher.

DF noted that the differences appeared to reduce through the day, possibly as a result of increased experienced. He also noted that differences could relate to the unintended enthusiasm of commercial divers and their skills and experience as commercial divers.

HP noted that none of this is a reflection on the commercial divers, but part of the learning and training exercise.

There was a discussion about why the transects need to cover areas randomly and not just where the abalone are in high densities. JP explained that while divers will generally fish/see areas of abalone in much higher densities than they did when they were surveying, it is too hard to 'scale-up' those smaller, denser areas. Therefore, the surveys are done over a broader ground and scaled up across that broader ground – thus you have lower than 'commercial' densities, but this is multiplied by a much bigger area than would normally be fished.

It was noted that statistical, random sampling will always lead to feelings that the area may not have been properly surveyed or represented. However, JP and SM emphasised that overall, the high level of sampling done by the commercial and research divers has ensured that these sorts of issues are averaged out when the results are combined and scaled-up.

It was also noted that the random survey sites will only be used for the initial biomass estimates – monitoring in the future will happen on the more consistently fished areas.

With regards to sampling location position, DF noted that they had devised a rule for if the site was inaccessible (too shallow, *etc*) — 50 m south, if not, 50 m west, if not 50 m north, *etc*.

JP recounted how impressed the scientists have been with the knowledge and expertise evident in the current project.

Discussions about biomass

JP reviewed the discussion about the virus impact and the biomass at the Crags:

- By 2005, the fishing areas around Port Fairy were relatively sustainable – assumption that things were more or less sustainable

- Crags was under lots of pressure though, with almost all of the biomass above the size limit being taken each year

- Gives a measure of what was there over the size limit

- We can then assume that this is somewhere in the order of 10-25% of the total **breeding** biomass

- Thus, the pre-virus **breeding** biomass represents about 5 times the catch

- Assumed that fishing 30 t from crags represented about 75% of **legal** biomass
- Thus the 30 t catch was supported by probably 40 t of **legal** biomass
- From the survey, the biomass above 125 mm is (with 50% confidence) about 43 t in total
- Thus, roughly back to the lower-end of when the Crags was under stress

Also noted:

- There are several years of weak recruitment coming
- There are possibly some changes to the growth dynamics (faster, bigger maturity)

It was noted that Burnetts and Water Tower had a lower biomass, relative to the old average catch. This indicates either a larger impact from the virus, but alternatively a slower recovery. Slower recovery was noted as most plausible because of observations of higher mortality at the Crags and known higher growth rates.

There was some discussion about the actual proportion of the historical catch, relative to the legal biomass. However, KS clarified that even if there are differences in the order of 80% compared to 50%, the result is still in the same order of magnitude – the biomass at the Crags is somewhere around half of what it was historically.

TAC setting

Given these results, there was a question about what the TAC would be set at. SM noted that in S.A., would take the 80% confidence estimate of biomass and harvest 10% of that. JP noted that in the current case, would probably work up in the range of 90% confidence and 135 mm. HP clarified that these tables are not being used to discuss quota – only to discuss how to do structured fishing (which may then provide additional information on calculating harvestable catch).

Sub-legal abalone

KS noted that while the legal-sized abalone do not look in a dire position, the effects on the sub-legal abalone also need to be considered. He noted that the survey suggest there has been quite a major reduction – somewhere in the order of 70% (similar to initial estimates of mortality).

- This depressed recruitment can be expected to continue for at least a couple more years
- There is also the potential for continued depressed recruitment because of lower levels of breeding stock – this needs to be watched in the coming years. Long-term sustainability will depend on what is coming through in the pre-recruits.

SM noted that there are also some environmental effects there at work – seen in the reduction at Lady Julia Percy as well. It was also suggested that ecosystem changes are perhaps an issue, though a diver noted they had seen little change in the Port Fairy region.

Structured Fishing

KS emphasised that as part of the structured fishing, or separate, there needs to be monitoring of pre-recruits as a leading indicator of recruitment into the fishery.

DW noted that structured fishing can take a range of forms, so we need to be specific about the sorts of questions we want to answer, *e.g.*:

- Opening areas to commercial fishing?
- Ongoing monitoring?

In the TRF project brief, there were initial thoughts about the design of the structured fishing:

- 42 sites
- In the order of 500 kg per licence
- To answer questions raised by the survey:
    - Structured fishing in and out of surveyed areas
    - Inside surveyed areas, adjacent to and away from survey sites
    - Sites selected by divers
    - Re-fishing comparisons (how they re-fish through time)
    - Test further the biomass survey – how good was it

1st question - what is the questions we want to answer

2nd question - how do we then use those priorities to select sites

There was discussion about the need to get further certainty about the state of the resource, issues with recruitment, *etc.* This is also about the opportunity to setup a process of monitoring by industry that can be used in management going forward. Potentially a more cost-effective way of surveying and monitoring into the future.

It was noted that it is important to communicate the realities of structured fishing to the industry members not present here.

DD asked, firstly, if there is the information to go ahead with structured fishing or if it is worth leaving it longer. This was noted to balance against the value of getting divers in the water collecting data. HP clarified that structured fishing should occur such that it does not impede recovery in any way.

JP suggested that, in working towards a proposal, we could conservatively use the biomass estimates of **135 mm (at 90% confidence) which gives 28 t**. There is a margin of safety in this because not all of the bottom was surveyed. The assumption, theoretically, would be that without the virus, you could fairly safely catch 28 t sustainably because enough biomass would be secured by the size limit. However, because of the issues of the virus we could conservatively reduced this to somewhere between 25-50% of 28 t without doing harm. KS added that the problem of the pre-recruit abalone should mean that you should be more careful over the next 2 or 3 years in particular. JP agreed this is good justification for 25% - which equates to spreading the **28 t over 4 years**. This allows some cost-effective monitoring to occur and something that can be adjusted over time as necessary – *i.e.* if there was indications that the 28 t was the only biomass available, then the structured fishing can be stopped. This also returns to the original proposals of approximately **500 kg per licence**.

There was discussion about how to collect information on sub-legal abalone. KS again emphasised the importance of collecting data on these size-classes. It was noted that 100 mm abalone would be sufficient for this sort of sampling. Also, this sampling does not have to happen in perpetuity.

A separate survey of sub-legal abalone was discussed as a separate exercise to structured fishing:

- Fewer issues with permits, etc
- Possibly better random sampling
- Fewer logistical problems
- Can still be done on MAFRI sites
- No issues with commercial-take of undersized abalone

JP noted that in the future, GPS loggers will also provide useful indicators to complement structured fishing/survey exercises – indicators such as area-based catch rates, area-swept, etc. This may also complement the more qualitative workshop-assessment process. KS noted that this method, however, still misses a leading indicator.

DW reiterated four points about the questions structured fishing should answer:

1. Comparing inside and outside blue-circle (high productivity) areas
2. How areas 're-fish' through time
3. Survey sites versus diver 'free-selection'
4. Testing the survey – *e.g.* is the mortality really worse at Lighthouse than the Crags

Once these questions have been prioritised, then the structured fishing can be designed in more detail.

DW to write a revised discussion paper on structured fishing, to be circulated to steering committee members within 2 weeks. Steering committee to be given 1 week for comments before broader circulation to divers *etc.*

HP noted that the details can be discussed in the next session before being presented to WADA later in the afternoon.

HP asked if there was any disagreements with the original proposition of 500 kg per licence, which corresponds to JP's suggestion of 25% of the available biomass above 135 mm.

SM suggested that it perhaps should be done on time, rather than quantity. HP noted that logistically, this would not work because of the problem of dividing catch between licences, *etc.* HP reasoned that if 7 tonnes could not be safely taken off now, then nothing should be done. JP noted that other rules could be used to spread this quantity appropriately.

There was discussion about whether to have fixed, continually monitored sites, random allocation, divers' favourites, *etc*. Justification for diver selected sites is that they could provide a good site for continued monitoring in the fishery.

AbaSIM demonstration

KS summarised that:

- The 'best'-case scenario is a 70% mortality
- The other scenario is that there has also been a knock-down of breeding stock from the virus and a change in the size at maturity—meaning a delay in return to average recruitment

He noted that the two scenarios have different results. JP explored these scenarios briefly using AbaSIM II. KS noted that these scenarios should be explored more formally to test the sensitivity of different courses of action to different assumptions.

JP noted that, under scenario 1 (10-year-old size limit [~135 mm], catch of 5 tonnes):

- It does recover, but there is a small flat area at the start indicating the effects of catch and recruitment lag
- A similar scenario is evident with a 3 t catch
- With 0 catch, there is still some delay (flat-spot) from the recruitment lag
- With 20 t catch – 20 t is caught in the first year but the recovery is less rapid and you are not able to meet the 20 t catch each year

KS noted that this indicates the 'best-case' scenarios discussed before lunch are not unreasonable.

RD and JP to run further scenarios for the Crags and the other areas to explore what is the best split between the areas – is it 135 mm at the Crags and 130 mm at the others? These can be incorporated into DW's structured fishing discussion paper.

KS noted this would also provide some assurance that the current proposal for structured fishing is reasonable.

There was discussion about the relative biomass inside and outside the blue, stratified areas. Divers noted that in addition to the surveyed areas (outside the bounded areas with the survey points):

- At Burnetts there is 50% more biomass than contained within the surveyed, bounded areas
- There is 30% more than surveyed in Watertower
- There is 20% more than surveyed at the Crags

KS suggested using these values to scale-up by table 1.

Rick to scale up estimates for incorporating into JP's program

KS noted that although accurate models haven't been built for all the areas, the simulation modelling is a good logic-check of the reasoning discussed here.

Structured Fishing Design

HP noted that the current session needs to provide DW with some design dot-points for writing a structured-fishing discussion paper.

Site selection

DW reiterated four points about the questions structured fishing could answer:

1. Comparing inside and outside blue-circle (high productivity) areas
2. How areas 're-fish' through time
3. Survey sites versus diver 'free-selection'
4. Testing the survey – *e.g.* is the mortality really worse at Lighthouse than the Crags

He suggested that with a starting point of 72 sites – how many devoting to each of the questions?

DW noted there are three key areas to potentially split effort across:

- Blue areas that have been surveyed
- Blue areas that have not been surveyed
- Outside of blue areas

Suggestions that it could be 80% effort into blue areas versus 20% outside blue areas. All agreed that some effort at least should be put outside blue areas.

Participants discussed several options, agreeing on a split of effort of 40:40:20 (blue surveyed : blue unsurveyed : outside of blue)

DW clarified the reasons for doing diver-selected sites:

- Setting up sites to monitor through time – not a one-off question, but a through-time comparison
- These will be on precisely the same sites into the future
- The data will not be used in any way to 'scale-up'

It was noted that choosing highly preferred sites can be a dangerous strategy – thus, those preferred sites must be used in the context of a broader sampling program. It was suggested these diver-preferred sites should perhaps be 10-20% of the total number of sites.

JP noted the point is to simply force some sort of spread of effort across the area which then forms the start point for further surveys in the future (with such a small amount of catch, without some sort of structuring no useful data will be collected).

KS noted that it is worth going through the formal structures/design/indicators – then looking for the strengths and weaknesses. Also need to look how it would be calibrated with historical data and biomass calculations.

DW to write a revised discussion paper on structured fishing, to be circulated to steering committee members within 2 weeks. Steering committee to be given 1 week for comments before broader circulation to divers *etc.*

DW asked if there was interest in assessments of re-fishing. JP contended that this sort of information will emerge through normal fishing patterns. It's use as a leading indicator was also discussed, but it was agreed that surveys of undersize will be more informative.

JP proposed a model for how structured fishing may work:

- 45 odd sites dispersed between the areas in 40:40:20 ratio (blue surveyed : blue unsurveyed : outside blue)
- Sites spread through these areas
- Divers constrained by effort-based rules (*e.g.* 30 minutes/50 kg)
- Will get size-structure, fishing track, area swept
- Sets up measure that can be used as monitoring tool into the future
- Also has rough relative value for comparing between known (surveyed) and unknown (unsurveyed) areas

SM noted that he was uncomfortable with relying on diver-selected sites only. JP acknowledged this would be good, but there are problems with sand patches *etc* – this will upset the results into the future if someone has to swim 50 m before they find an abalone.

The solution agreed on was to a two-stage process: randomly assigned sites with decision rules (*e.g.* if on sand, swim south to reef). When reef is encountered (and fishing begins) this is the site that is marked and used in perpetuity.

A diver noted that a 50 kg limit per drop works out to be 10 drops per diver for the 500 kg quota—this works out to be 140 drops. Is this oversampling? It was agreed that perhaps 100 kg per drop was perhaps more appropriate.

Indicators of pre-recruits

It was suggested that animals down to 100 mm could be collected as a leading indicator of recruitment. Two issues were raised:

- There may be problems in getting a representative sample
- There are logistical issues in terms of permits, *etc*

Though it was agreed that it would be more efficient for pre-recruits to be sampled during the structured fishing exercise, participants agreed that it would be easier and more reliable to do this as a separate exercise.

JP suggested the full value of the PIRVic survey system was not be being captured by the flavor of the current discussion and that continuing them provided the best means of monitoring recruitment trends through the next few years.

HP to look at adding 3 or 4 more annual sites for collecting juvenile data and possibly density measurements (this would bolster the PIRVic data. These could be on sites surveyed in the current project

Summary for Licence Holders

JP summarised the results from the earlier discussions:

- There were differences between research and commercial diver results, but these differences are to be expected considering the slightly different methods, the fact that there was less training of commercial divers and so on
- These variations can be explored and reduced in future surveys – possibly using more prescribed methods
- The quality of the diver input has been of exceptionally high quality
- The stocks of recruits (legal-size abalone) at the Crags are lower, but in roughly the same realm as when fine-scale management was initiated
- This was checked several ways, such as through AbaSIM simulations, historical catch/biomass levels, *etc*.
- Juveniles appear to be approximately 30% of their abundance pre-virus, indicating (and supporting early estimates) of 70% viral mortality
- In combination, the adults are at pre-FSM levels, though the next few year classes coming into the fishery are relatively weak – this means a high level of vulnerability over the next few years
- There is a strong need to monitor the new recruits into the fishery to look for depressed levels of recruitment over the next few years

JP noted that biomass estimates are given in Table 7 of the report. He noted that they are for different size limits and for different levels of confidence. At 90% confidence (a conservative level appropriate for the current situation), there is approximately 28 t of stock above 135 mm. These numbers are reasonable when put into the context of other data about the fishery and its history – probably used to be fishing the catch from the Crags from a biomass of 40-90 tonnes. Now, there is 31 t, which is about half to one third.

Some areas look like they have been affected more, such as Burnetts and Watertower. However, these areas may have been impacted by the virus less, but because they grow slower, are recovering slower.

JP was questioned on why the commercial divers are underestimating the pre-recruits. JP recounted some of the reasons discussed earlier in the day. He concluded that regardless of the source of the variation, it was important to err on the side of caution.

In terms of structured fishing:

- At 90% confidence, 28 tonnes are present above 135 tonnes
- With the aim of getting people in the water, looking, gathering data on recovery, there is some justification for harvesting some of this 28 tonnes as part of a structured fishing program
- Given the dip in recruitment coming through, and potential of depressed recruitment for the next few years, the argument has been to take 25% of the 28 tonnes each year
- This gives the opportunity to see what is going on, to watch recruitment *etc*, without 'dipping' into smaller size classes
- It also gives the option of pulling back if the worst-case scenario eventuates
- The assessment model gives similar results
- The end result is a justification for a 7 tonne catch, to be used for structured fishing, without any unacceptable risk.

JP noted the other risk is that the size of maturity may have increased (because of decreases in density and increases in growth rate). 130 mm may be now what 120 mm used to be.

KS noted there are three problems/uncertainties suggesting recruitment won't jump up to where it was straight away and therefore we should be precautionary:

1. Increase in size of maturity
2. Environmental coincidence (as shown by the decline in recruitment at Julia Percy Island where the virus did not affect)
3. Decrease in stock enough to negatively impact on recruitment

An industry member added there may be an entire missing year class as well because the virus could have stressed the surviving abalone sufficiently to prevent reproduction for one season.

JP/RD noted that there is value in also gathering length-structured sampling to look at size of maturity across the zone, from which the ideal size of harvest (50% of maximum fertility) could be picked.

JP discussed the nature of structured fishing, noting:

- We do not want to catch the quota without getting more information
- We want to spread the effort round

- It could be potentially somewhere in the order of 500 kg per licence, broken into 5 drops of 100 kg
- These drops would be split over three areas in 40:40:20 ratio (surveyed zones, unsurveyed zones, and outside zones)
- Divers would be given a starting point (that they can move if they're on sand, *etc*.)
- Would monitor things like:
    - Area swept (could do approximate scale-up of biomass from areas with biomass estimates)
    - Trends through time
    - Size data
- There is unlikely to be enough for both structured and 'free-fishing'
- Over time this is anticipated to change as more quota becomes available

After discussion with other divers, JP confirmed that it would be most appropriate to have a 135 mm size limit across the entire Port Fairy area.

It was noted that further areas can now be assessed using the same sort of method. Firstly, from Lighthouse to Lady Bay. However, because the stratification (selection of high-productivity areas) was so successful, it is likely that larger areas could be assessed for the same effort. Similarly, continued monitoring through PIRVic will be very valuable in keeping an eye on recruitment. HP noted that they would fund a few more of these sites to bolster the pre-existing data in this area.

HP closed the meeting.

Appendix 3. Second Structured Fishing Discussion paper

Design of a Structured Fishing survey to assess stocks of abalone in western zone Victoria

Background

At the second Steering Committee workshop of the WADA TRF Survey Project, it was agreed to develop a discussion paper about the design of a Structured Fishing survey to assess stocks of abalone in western zone Victoria. A draft of this paper was circulated to the Steering Committee on 18 August, and changes made in response to comments received. The Objectives of the WADA TRF Project are:

Objectives of WADA TRF Project

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.

The TRF Project has Objectives relevant to short-, medium- and long-term goals for the fishery. Short-term goals that have already been progressed within the TRF project include the development of a Pre-fishing survey sampling design, implementation of a survey, comparison of results among survey methods, estimation of biomass and consideration of possible catches for a more extensive Structured Fishing survey. Project objectives more relevant to medium and longer-term goals for the fishery involve the development of a cost-effective harvest strategy with some combination of information from Structured Fishing and interpretation of shell morphology.

Objectives and design of a Structured Fishing survey were discussed at the second Steering Committee Meeting. These include the short-term need to develop and implement a cost-effective process to reopen AVG-impacted reefs to fishing, and the medium- to long-term need to establish a baseline of information for possible future comparison. With these goals in mind, the Structured Fishing Survey to be completed as part of the TRF project has the following Objectives:

Objectives of TRF Structured Fishing survey

1. Compare results from a Structured Fishing survey to the Pre-fishing survey, and extend the Structured Fishing Survey to areas unable to be sampled in the Pre-fishing survey.

2. Commence development of a cost-efficient Structured Fishing survey that can be used for future comparison.

Structured Fishing protocol

On the basis of the biomass estimates provided by the Pre-Fishing survey, a Structured Fishing survey involving a catch of 7 t was discussed and supported at the second Steering Committee Meeting. This level of catch would be allocated in proportion to units held in the fishery.

At each site used in the Structured Fishing survey, divers would collect up to 100 kg of abalone, implying a minimum number of 70 sites in the survey (i.e. compared to 38-40 in the Pre-fishing survey). With catches

below 100 kg possible at some sites, more sites may be needed to complete the survey and would be pre-selected.

Divers will be provided a series of GPS points, in proportion to their identified catch entitlement, and will enter the water at the identified site and search for commercial quantities of abalone. If commercial quantities of abalone are not immediately obvious divers will record the time taken to locate them. Divers will continue fishing until 3, 30 kg bags of abalone are full (i.e. approximately 100kg) or they have moved a maximum of 500 m from the site they entered the water.

At all times, divers will run GPS- and shell measuring-loggers and fish to a size limit of 135 mm, and total catch and effort will also be reported for each site. GPS records will enable calculation of some survey indicators, and enable the opportunity for divers in future fishing surveys to follow a similar direction from the GPS entry point. Survey indicators will include the diver's search time (min), catch (kg), effort (h), catch area (m^2, e.g. based on the area of the GPS-logger track buffered by 100 m), catch rate ($kg.hr^{-1}$ and $kg.m^{-2}$) and size structure (and samples of shell/gonad?) of the abalone population at each site.

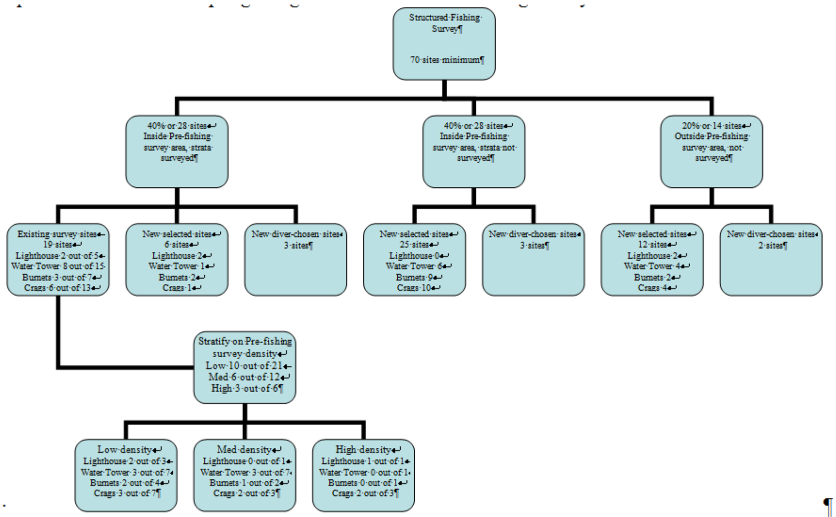
Structured Fishing survey design

The Steering Committee Meeting considered the priority of several factors in the design of the Structured Fishing survey, including the limited resources available to the TRF project. It was agreed, consistent with the Objectives of the TRF project, to concentrate the design of the survey on comparison and calibration with the Pre-fishing survey, the extension of the Structured Fishing survey to sites unable to be sampled in the Pre-fishing survey, and development of a Structured Fishing design for future comparison, involving mostly randomly-selected and some diver-chosen sites.

With these Objectives in mind, a Structured Fishing design was developed to reflect the estimated relative importance of different Pre-fishing survey areas (i.e. inside sampled Pre-fishing survey strata 40%, inside un-sampled Pre-fishing survey strata 40%, and outside Pre-fishing survey strata 20%), existing Pre-fishing survey sites (50% of Pre-fishing sites sampled, 50% sites avoided) stratified by density of recruits estimated in the biomass survey (i.e. to aid calibration and retention of a representative selection of un-fished sample sites), new selected sites in strata with lower sampling fractions in the biomass survey, and an even distribution of diver-chosen sites (90% randomly selected, 10% diver-chosen) across the survey areas. GPS co-ordinates for these sites will be selected from within the identified strata using the maps and process developed by SARDI in selection of Pre-fishing survey sites. A rule to relocate a site to new GPS points for application in the field also needs to be finalised, for use when selected GPS points are inappropriate.

To allow a direct comparison, it was agree to make the catch from the Structured Fishing survey proportional to the Pre-fishing survey, and the prior estimates of biomass on which they were based, rather than output estimates of biomass from the survey. MAFRI Survey sites will not be selected for fishing, and calibration of these past surveys to Structured Fishing surveys will be achieved through comparison with the Pre-Fishing survey. For future surveys, diver-selected sites should remain fixed, while randomly selected sites may include a combination of fixed and re-randomised sites, and additional sites of both types may be added.

It was agreed by the Steering Committee that the Structured Fishing survey would not attempt to collect information about abalone below the minimum size limit. Information about undersize abalone was considered a high priority by the Steering Committee, but its collection will be funded separately. A visual representation of the sampling design for the Structured Fishing survey is shown below:



Structured Fishing survey proposed comparisons

The Structured Fishing survey design described above will enable several comparisons to progress the Objectives of the TRF project and address goals of the fishery. Each of the comparisons described below could be made for each of the sampled indicators described above. The most direct comparisons between the Pre-fishing and Structured Fishing surveys will be possible among estimates of absolute biomass density (i.e. $kg.m^{-2}$) from the two surveys. Relative change in measures from the Structured Fishing survey will also be able to be compared among sites and eventually, with subsequent data, through time. For example, this could include estimates of relative change in biomass density, from one sample to another of the Structured Fishing survey (or some component), enabling an updated absolute biomass estimate through combination with the previous Pre-fishing survey estimate.

Possible comparisons among indicators derived from the Pre-fishing and Structured Fishing surveys are described below.

Abbreviations

Survey – PF = Pre-fishing, SF = Structured Fishing
Pre-fishing survey strata – A = sampled, B = un-sampled, C = outside strata
Site selection – r = randomly-selected, d = diver-selected

1. How consistent are survey measures among randomly-selected sites in the different surveys? Calibration of Pre-fishing survey, and historic MAFRI surveys, with Structured Fishing survey. Density, biomass and size-structure of abalone at sites in the Pre-fishing survey could be compared to estimates of catch rate (kg.hr and $kg.m^{-2}$), biomass and size-structure at the same sites in the Structured Fishing Survey.

   PF(Ar) v SF(Ar), for each site/strata, 19 and/or 38 v 19 sites.

2. How consistent are survey measures among randomly-selected sites in the Pre-fishing survey sampled area to other productive unsurveyed areas, and unproductive unsurveyed areas? Extension of Pre-fishing survey to un-sampled areas by the Structured Fishing survey. Estimates of catch rate (kg.hr and $kg.m^{2}$), biomass and size-structure in the Structured Fishing survey could be compared among sites sampled within strata, un-sampled within strata and outside strata from the Pre-fishing survey.

   SF(Ar) v SF(Br) v SF(Cr), for each site/strata, 25 v 25 v 12 sites.

3. How consistent are survey measures among randomly-selected and diver-chosen sites, and among diver-chosen sites in different strata of the Pre-fishing survey? Comparison of site-selection methods. Estimates of catch rate (kg.hr and kg.m^2), biomass and size-structure in the Structured Fishing survey could be compared among randomly-selected and diver-chosen sites, and among diver-chosen sites, in each strata.

   SF(Ar) v SF(Ac), SF(Br) v SF(Bc), SF(Cr) v SF(Cc), 25 v 3, 25 v 3, 12 v 2 sites.
   SF(Ac) v SF(Bc) v SF(Cc), for each site/strata, 3 v 3 v 2 sites.

4. Establishment of baseline for future comparisons of how consistent are survey measures through time at randomly-selected and diver-chosen sites? Baseline for future comparisons through time. Estimates of catch rate (kg.hr and kg.m^2), biomass and size-structure in the Structured Fishing survey could be compared among randomly-selected and diver-chosen sites through time, and among diver-chosen sites through time, in each strata. Sites will ideally be sampled by the same diver through time.

   SF(As and Bs), SF(Cs) through time, 25+25+12 sites v future sampling.
   SF(Ac and Bc), SF(Cc) through time, 3+3+2 sites v future sampling.

Table 1. Summary of design and results from Pre-fishing survey, and the proposed design of Structured Fishing survey. In the Structured Fishing survey, 19 existing sites (10 low, 6 medium and 3 high density) and 6 new sites will be sampled within the existing sampled strata, 25 new sites will be sampled within un-sampled strata, 12 new sites will be sampled outside sampled strata, and 8 diver-chosen sites will sampled (3 in sampled strata, 3 in un-sampled strata and 2 outside strata).

Survey block	Mean catch (t)	% of catch	Area (km^2)	No. samples	Biomass (no.m^{-2})	Biomass density (kg.m^{-2})	Biomass (t)	Existing sites inside sampled strata	Breakdown of existing sites into density strata			New sites inside sampled strata	New sites inside un-sampled strata	New sites outside sampled strata
									Lo	Med	Hi			
1	5.3	8.8	0.061	5	0.42	0.158	9.5	3	2		1	1		2
2	1.4	2.3	0.004	0	-	-	-						2	
3	0.8	1.4	0.018	0	-	-	-						1	
4	1	1.6	0.002	0	-	-	-						1	
5	2.5	4.1	0.009	3	0.36	0.128	1.1	1		1				4
6	1.5	2.5	0.003	2	0.15	0.047	0.1	1	1					
7	5.3	8.8	0.057	5	0.17	0.059	3.4	2	2			1		
8	2	3.3	0.013	2	0.19	0.071	0.9	1		1				
9	1.4	2.4	0.002	0	-	-	-						2	
10	2.6	4.3	0.029	3	0.61	0.227	6.6	1		1				
11	2.2	3.6	0.048	2	0.23	0.085	4.1	1		1		1		
12	1.5	2.5	0.018	2	0.43	0.145	2.6	1	1					
13	4.3	7.1	0.029	0	-	-	-						7	2
14	1	1.6	0.008	0	-	-	-						2	
15	2.5	4.1	0.021	2	0.35	0.122	2.5	1	1			1		
16	3.8	6.3	0.081	0	-	-	-						6	
17	13.7	22.5	0.265	8	0.48	0.178	47.3	4	1	1	2	2		
18	3.3	5.5	0.024	3	0.06	0.023	0.6	2	2					
19	1	1.6	0.005	0	-	-	-						1	4
20	1.7	2.9	0.01	2	0.37	0.139	1.4	1		1				
21	0.2	0.3	0.005	0	-	-	-						1	
22	1.5	2.5	0.008	0	-	-	-						2	
Total	60.5	100	0.72	39			80.1	19	10	6	3	6	25	12

Table 2. Same as Table 1 sorted by estimate of biomass from the Pre-fishing survey, and then estimates of prior catch.

Survey block	Mean catch (t)	% of catch	Area (km^2)	No. samples	Biomass ($no.m^{-2}$)	Biomass density ($kg.m^{-2}$)	Biomass (t)	Existing sites inside sampled strata	Breakdown of existing sites into density strata			New sites inside sampled strata	New sites inside un-sampled strata	New sites outside sampled strata
									Lo	Med	Hi			
17	13.7	22.5	0.265	8	0.48	0.178	47.3	4	1	1	2	2		
1	5.3	8.8	0.061	5	0.42	0.158	9.5	3	2		1	1		2
10	2.6	4.3	0.029	3	0.61	0.227	6.6	1		1				
11	2.2	3.6	0.048	2	0.23	0.085	4.1	1		1		1		
7	5.3	8.8	0.057	5	0.17	0.059	3.4	2	2			1		
12	1.5	2.5	0.018	2	0.43	0.145	2.6	1	1					
15	2.5	4.1	0.021	2	0.35	0.122	2.5	1	1			1		
20	1.7	2.9	0.01	2	0.37	0.139	1.4	1		1				
5	2.5	4.1	0.009	3	0.36	0.128	1.1	1		1				4
8	2	3.3	0.013	2	0.19	0.071	0.9	1		1				
18	3.3	5.5	0.024	3	0.06	0.023	0.6	2	2					
6	1.5	2.5	0.003	2	0.15	0.047	0.1	1	1					
13	4.3	7.1	0.029	0	-	-	-						7	2
16	3.8	6.3	0.081	0	-	-	-						6	
22	1.5	2.5	0.008	0	-	-	-						2	
2	1.4	2.3	0.004	0	-	-	-						2	
9	1.4	2.4	0.002	0	-	-	-						2	
4	1	1.6	0.002	0	-	-	-						1	
14	1	1.6	0.008	0	-	-	-						2	
19	1	1.6	0.005	0	-	-	-						1	4
3	0.8	1.4	0.018	0	-	-	-						1	
21	0.2	0.3	0.005	0	-	-	-						1	
Total	60.5	100	0.72	39			80.1	19	10	6	3	6	25	12

Appendix 4. Structured Fishing planned sites.

Note, sites corresponding with Pre-fishing survey sites are labelled as numbers, while sites are also labelled SF for Structured Fishing and SUP for Supplementary sites.

				Longitude		Latitude	
Label	**Diver**	**Longitude**	**Latitude**	**Deg**	**Minutes**	**Deg**	**Minutes**
02	Torelli	142.2539161	-38.3932951	142	15.2350	38	23.5977
03	Ciavola	142.2522799	-38.3937687	142	15.1368	38	23.6261
05	Riddle	142.2510364	-38.3960302	142	15.0622	38	23.7618
07	Forbes	142.2119065	-38.3951133	142	12.7144	38	23.7068
09	Riddle	142.209379	-38.3945005	142	12.5627	38	23.6700
13	P Plummer	142.2066227	-38.3963067	142	12.3974	38	23.7784
15	Ciavola	142.2049186	-38.394991	142	12.2951	38	23.6995
16	G Plummer	142.1865754	-38.3938904	142	11.1945	38	23.6334
19	G Plummer	142.1825573	-38.3924579	142	10.9534	38	23.5475
21	G Plummer	142.1745942	-38.3927527	142	10.4757	38	23.5652
24	Torelli	142.1709454	-38.3933494	142	10.2567	38	23.6010
27	Riddle	142.1482316	-38.3926497	142	8.8939	38	23.5590
28	Riddle	142.141295	-38.3876057	142	8.4777	38	23.2563
29	Harris	142.1407423	-38.3892682	142	8.4445	38	23.3561
31	Ciavola	142.1388508	-38.3884498	142	8.3310	38	23.3070
35	P Plummer	142.1361419	-38.3840406	142	8.1685	38	23.0424
36	Ciavola	142.1355827	-38.3851881	142	8.1350	38	23.1113
38	Ciavola	142.1337642	-38.3833736	142	8.0259	38	23.0024
40	Ciavola	142.1316853	-38.3809453	142	7.9011	38	22.8567
SF 01	Harris	142.2554921	-38.3911823	142	15.3295	38	23.4709
SF 02	Riddle	142.2518051	-38.3943219	142	15.1083	38	23.6593
SF 03	Ciavola	142.2463863	-38.3982442	142	14.7832	38	23.8947
SF 04	Ciavola	142.2399561	-38.3949551	142	14.3974	38	23.6973
SF 05	Forbes	142.2395075	-38.3948891	142	14.3705	38	23.6933
SF 06	Ciavola	142.231546	-38.3942369	142	13.8928	38	23.6542
SF 07	Riddle	142.228517	-38.3948774	142	13.7110	38	23.6926
SF 08	Riddle	142.2220305	-38.3942233	142	13.3218	38	23.6534
SF 09	Riddle	142.220511	-38.3958529	142	13.2307	38	23.7512
SF 10	P Plummer	142.2180488	-38.3959776	142	13.0829	38	23.7587
SF 11	Riddle	142.2073016	-38.3943759	142	12.4381	38	23.6626
SF 12	Ciavola	142.1938354	-38.3969487	142	11.6301	38	23.8169
SF 13	G Plummer	142.1845392	-38.3938579	142	11.0724	38	23.6315
SF 14	Torelli	142.1846789	-38.3936017	142	11.0807	38	23.6161
SF 15	G Plummer	142.1733035	-38.3920174	142	10.3982	38	23.5210
SF 16	Harris	142.167023	-38.3929436	142	10.0214	38	23.5766
SF 17	Torelli	142.1635878	-38.3929636	142	9.8153	38	23.5778
SF 18	Riddle	142.1625058	-38.3927903	142	9.7503	38	23.5674
SF 19	Ciavola	142.1607584	-38.3926236	142	9.6455	38	23.5574
SF 20	Ciavola	142.1587005	-38.3921627	142	9.5220	38	23.5298
SF 21	P Plummer	142.1567915	-38.3920117	142	9.4075	38	23.5207
SF 22	P Plummer	142.1551384	-38.3921129	142	9.3083	38	23.5268
SF 23	Torelli	142.1542115	-38.3926458	142	9.2527	38	23.5587
SF 24	P Plummer	142.1497589	-38.3920242	142	8.9855	38	23.5215
SF 25	Harris	142.1493468	-38.3932599	142	8.9608	38	23.5956

SF 26	Riddle	142.14855	-38.3917813	142	8.9130	38	23.5069
SF 27	P Plummer	142.1454996	-38.39225	142	8.7300	38	23.5350
SF 28	Forbes	142.1380422	-38.3949981	142	8.2825	38	23.6999
SF 29	Harris	142.1365051	-38.3933285	142	8.1903	38	23.5997
SF 30	Torelli	142.1350098	-38.3920264	142	8.1006	38	23.5216
SF 31	Riddle	142.1337716	-38.3910617	142	8.0263	38	23.4637
SF 32	Ciavola	142.1324578	-38.3898569	142	7.9475	38	23.3914
SF 33	P Plummer	142.1308929	-38.3886971	142	7.8536	38	23.3218
SF 34	P Plummer	142.1388997	-38.3865953	142	8.3340	38	23.1957
SF 35	Ciavola	142.1364554	-38.3867039	142	8.1873	38	23.2022
SF 36	Forbes	142.1313536	-38.3824781	142	7.8812	38	22.9487
SF 37	Ciavola	142.1295615	-38.381731	142	7.7737	38	22.9039
SF 38	Riddle	142.1289827	-38.3793656	142	7.7390	38	22.7619
SF 39	Riddle	142.1233075	-38.3786981	142	7.3985	38	22.7219
SF 40	Torelli	142.1193714	-38.3765133	142	7.1623	38	22.5908
SF 41	Forbes	142.1143234	-38.3745087	142	6.8594	38	22.4705
SF 42	Torelli	142.1095517	-38.3729119	142	6.5731	38	22.3747
SF 43	Ciavola	142.1088047	-38.3734569	142	6.5283	38	22.4074
SUP 01	Ciavola	142.253712	-38.391894	142	15.2227	38	23.5136
SUP 02	Harris	142.249073	-38.397658	142	14.9444	38	23.8595
SUP 03	P Plummer	142.244243	-38.398097	142	14.6546	38	23.8858
SUP 04	Riddle	142.241929	-38.396763	142	14.5157	38	23.8058
SUP 05	Forbes	142.237779	-38.395717	142	14.2668	38	23.7430
SUP 06	Ciavola	142.234346	-38.393972	142	14.0607	38	23.6383
SUP 07	Ciavola	142.230185	-38.393437	142	13.8111	38	23.6062
SUP 08	Riddle	142.225981	-38.394300	142	13.5589	38	23.6580
SUP 09	Ciavola	142.215628	-38.395564	142	12.9377	38	23.7338
SUP 10	Torelli	142.200500	-38.396708	142	12.0300	38	23.8025
SUP 11	Riddle	142.197396	-38.396521	142	11.8438	38	23.7912
SUP 12	Riddle	142.191580	-38.396504	142	11.4948	38	23.7902
SUP 13	G Plummer	142.189844	-38.394868	142	11.3906	38	23.6921
SUP 14	Riddle	142.180073	-38.393737	142	10.8043	38	23.6242
SUP 15	Ciavola	142.168591	-38.392996	142	10.1155	38	23.5797
SUP 16	Torelli	142.165263	-38.392896	142	9.9158	38	23.5737
SUP 17	Ciavola	142.152196	-38.393175	142	9.1317	38	23.5905
SUP 18	P Plummer	142.143222	-38.390927	142	8.5933	38	23.4556
SUP 19	Ciavola	142.126248	-38.378020	142	7.5749	38	22.6812
SUP 20	Ciavola	142.120809	-38.377910	142	7.2485	38	22.6746
SUP 21	Ciavola	142.117513	-38.375727	142	7.0508	38	22.5436
SUP 22	Forbes	142.111822	-38.373818	142	6.7093	38	22.4291
SUP 23	Ciavola	142.138164	-38.393776	142	8.2899	38	23.6266
SUP 24	Harris	142.136457	-38.394696	142	8.1874	38	23.6818
SUP 25	Riddle	142.136380	-38.392198	142	8.1828	38	23.5319
SUP 26	Forbes	142.134632	-38.390514	142	8.0779	38	23.4308
SUP 27	Ciavola	142.134631	-38.392892	142	8.0778	38	23.5735
SUP 28	Ciavola	142.132346	-38.388699	142	7.9408	38	23.3219
SUP 29	P Plummer	142.132233	-38.391244	142	7.9340	38	23.4747
SUP 30	Torelli	142.098635	-38.386135	142	5.9181	38	23.1681

Appendix 5. Steering Committee summary, August 2010.

Summary of 3rd WADA TRF Steering Committee Meeting

Crowne Hotel, Melbourne, 17 August 2010

The meeting was presented with a summary of results from TRF Project, including Structured Fishing (note a GIS was not available, so see additional figures for reference below)

Discussion and agreement on way forward included...

- Need to enter GPS and measuring data into AbTrack
- Finalise analysis (site selection to design) and summary of SF for draft final report
- Estimate full survey reef area and extend biomass estimate (to outside strata, SARDI?)
- Investigate comparisons for next SF design (Number of SF sites to be resampled, see below)
- Confirm specific data required and circulate proposal for SPR calculation and use (Jeremy)
- Finalise draft TRF Final Report (end September?)
- Develop proposal for continuation (Port Fairy, Warrnambool)

The SC discussed various options to collect further information about stocks through a further structured fishing catch. This included a discussion of the benefits of fixed sites (i.e. as used in the previous SF design), which provided little information through GPS loggers as divers simply anchored at the site and swam on average about 100m, and sites with a fixed starting point, but allowing divers to swim 4-500 m both to cover more area and generate a more informative GPS track likely to be more representative and comparable to future fishing patterns. The SC discussed a combination of fixed sites (i.e. as used in the previous SF design) and fixed starting point sites, as part of a further structured fishing catch at Port Fairy.

The SC also discussed progress against Objective 4 of the TRF, and specifically how results from the past and future surveys would be used in making management decisions. This included discussion of the potential of extrapolating within-sampled-strata biomass estimates, to unsampled-strata and all reef areas adjacent to Port Fairy. There was also discussion of the data required for calculation of SPR-based methods of estimating catch, and the need for further detail about how the SPR-based methods will be used

Port Fairy way forward

Plan Presentation of results to date to divers/DPI, October 2010
Plan to start next Structured Fishing design pre-xmas
14 fixed sites (i.e. those with higher catch rate in 09/10) refished @ 100kg, ≥135 mm
14-28 new sites selected for ~500 m structured fishing @ up to 200-400 kg, ≥135 mm

Warrnambool way forward

Plan presentation of extension to Warrnambool to divers/DPI, October 2010
Plan to start Abundance Survey and Structured Fishing design pre-end of March
Stratify core areas with divers, October 2010
Complete proposed abundance survey, Jan-Feb 2011
Design and complete SF survey, Mar 2011

Number of SF sites to be resampled at Port Fairy

In the meeting, the SC discussed and requested information on the number of 2009/10 SF sites that could be resampled, and that may provide information about the size of declines in catch rate at higher catch rate sites, as an indicator of possible low-level recruitment to the fishery. The table below shows the number of

highest catch rate sites, their average catch rate and lower 95% CI in the 2009/10 SF survey, with simulated binomial reductions of 0.15, 0.2, 0.25 and 0.3 and corresponding upper 95% CI from 5 independent simulations. For example, to detect a change (by non-overlapping CI) of a 0.15 reduction, more than 42 sites were required to be sampled to provide an Upper 95% CI below the Lower 95% CI of 79.3 from the 2009/10 SF survey. In comparison, to detect a change (by non-overlapping CI) of a 0.2 reduction in catch rate, 14 sites were required to be sampled to provide an Upper 95% CI of 97.7, below the Lower 95% CI of 99.3 from the 2009/10 SF survey. This suggests the intent of resampling about 14 sites, consistent with the logistics supported by WADA, can provide a good ability to detect declines in catch rate of about 20%.

			Binomial % reduction			
			0.15	0.2	0.25	0.3
No. sites	Average catch rate	Lower 95% CI	Upper 95% CI			
7	122.8	106.1	119.7	112.4	103.6	98.5
14	110.6	99.9	103.9	97.7	91.0	85.8
21	102.0	93.2	94.9	89.3	83.3	78.3
28	96.1	88.4	88.8	83.5	78.0	73.2
35	90.8	83.7	83.7	78.7	73.6	69.1
42	86.1	79.3	79.4	74.7	69.9	65.6

Associated standard errors

			Binomial % reduction			
			0.15	0.2	0.25	0.3
No. sites	Average catch rate	Standard error	Standard error			
7	122.8	8.4	6.7	6.9	6.8	5.6
14	110.6	6.1	4.6	4.6	4.5	3.3
21	102.0	5.2	3.8	3.8	3.6	3.0
28	96.1	4.9	3.3	3.3	2.9	2.7
35	90.8	5.0	3.1	3.1	2.7	2.4
42	86.1	5.6	2.9	2.9	2.5	2.4

Additional Figures showing WADA TRF GIS layers

Figure 1. Survey strata identified by divers at Port Fairy

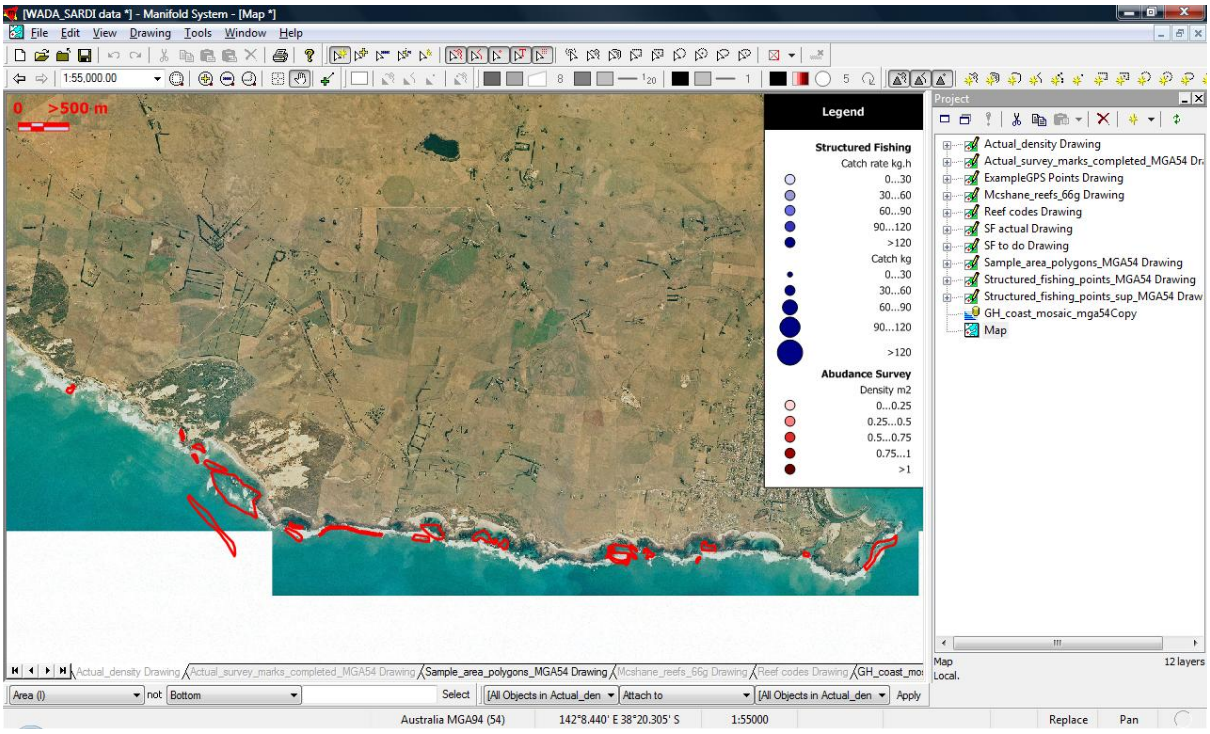


Figure 2. Survey strata with Abundance survey sites coloured by density >120 mm (see Legend).

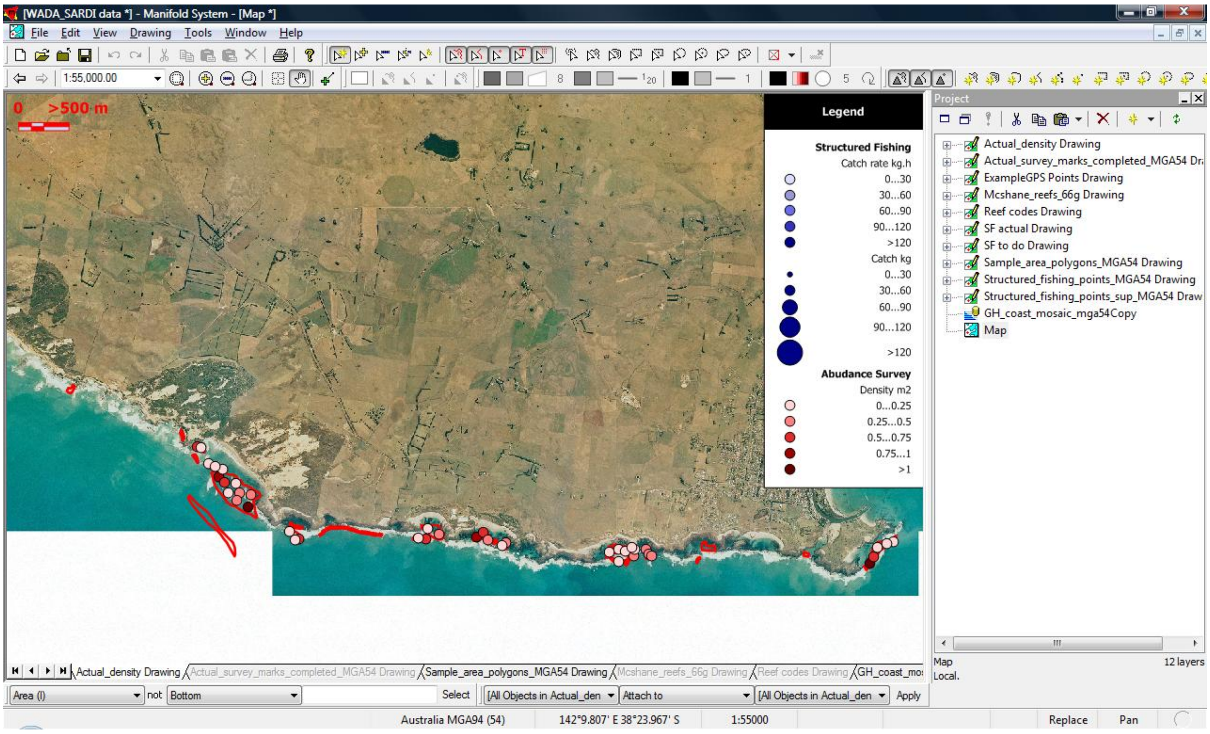


Figure 3. Survey strata with proposed Structured Fishing sites (blue) and Supplementary SF sites (yellow).

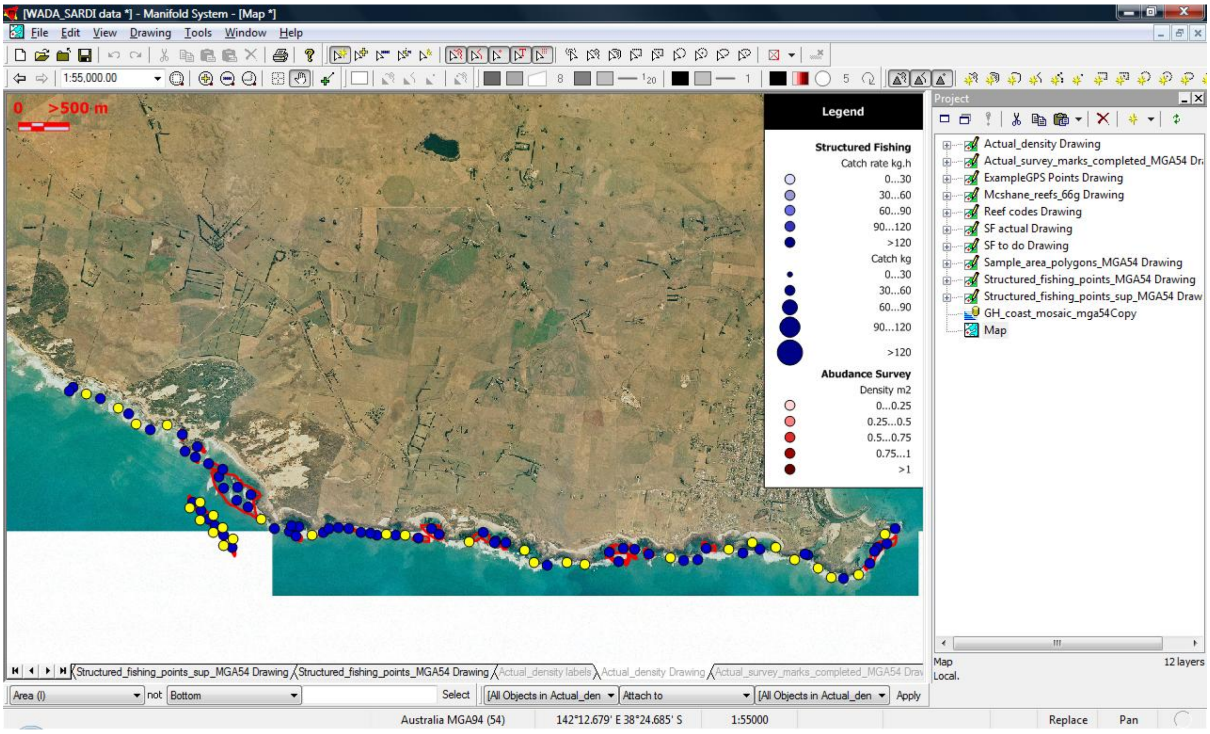


Figure 4. Structured fishing catch (size of circle) and catch rates (intensity of blue) at all sites fished (see Legend).

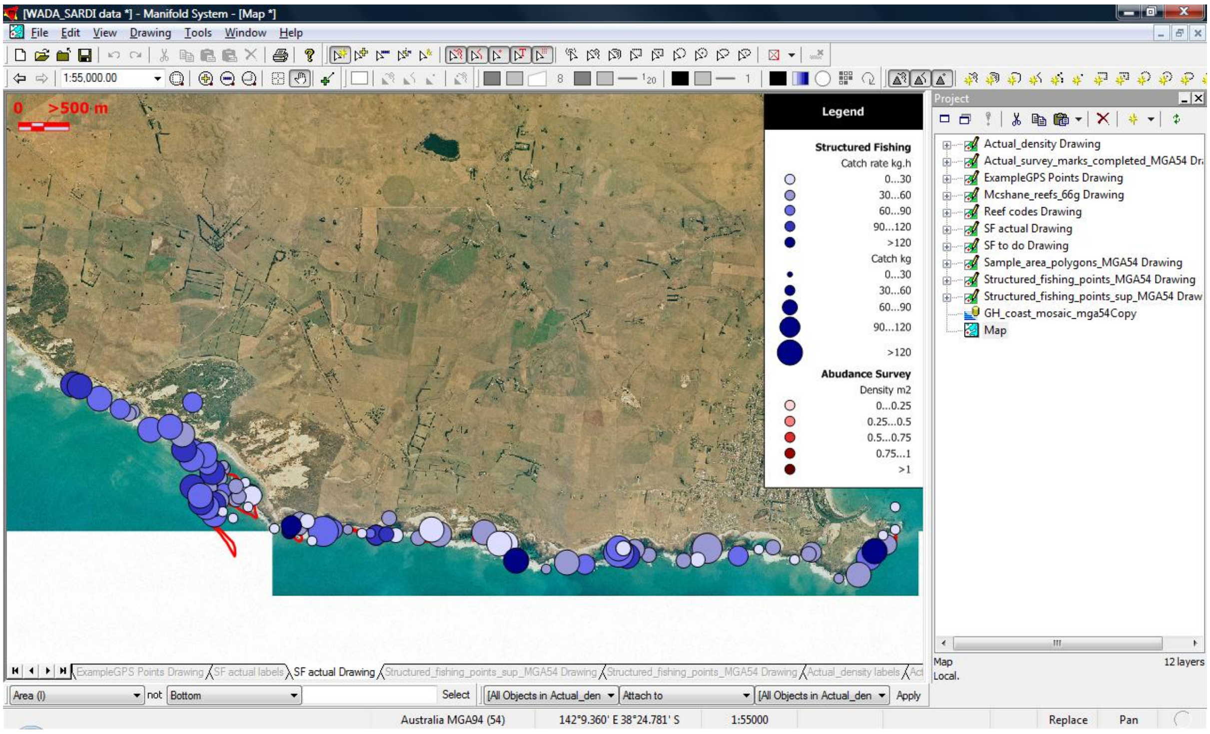
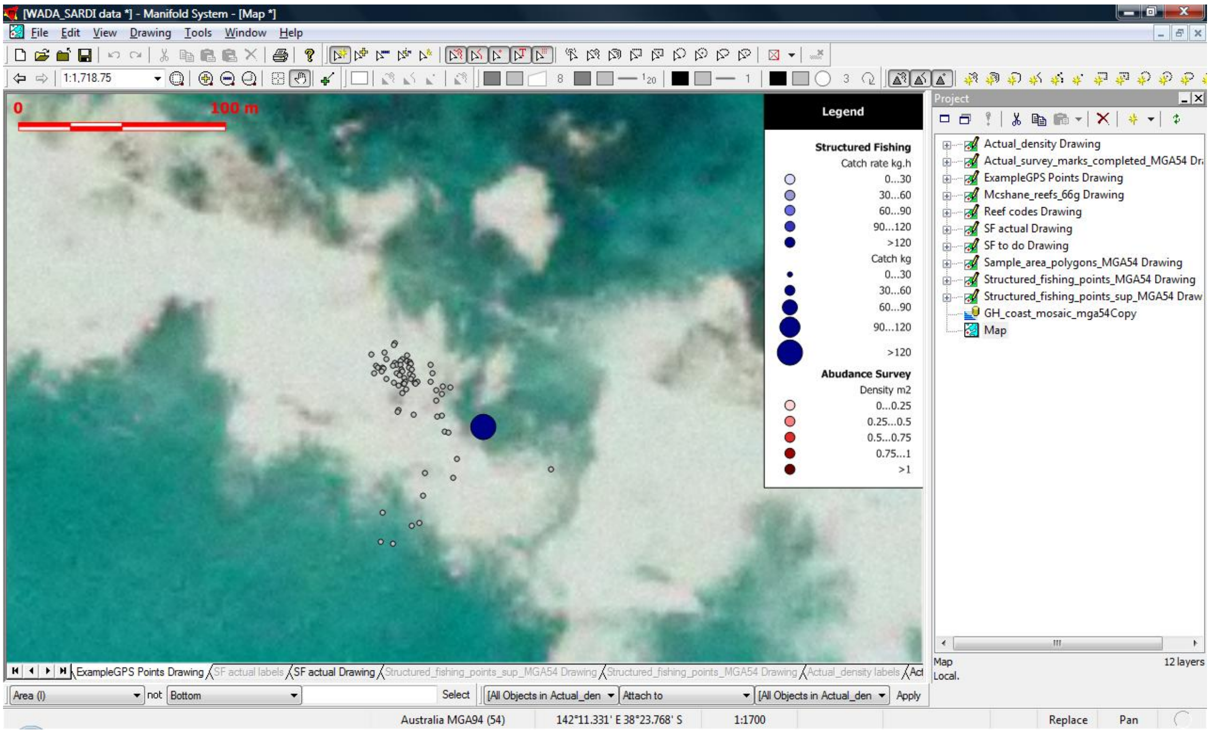


Figure 5. Example of GPS logger points from a boat adjacent to a site during the 2009/10 SF survey.



Appendix 6. Additional Manifold GIS layers.

Figure 1. Planned Structured Fishing survey sites (labelled SF # with pink cross) and Supplementary sites (labelled SUP # with yellow star), with Pre-fishing survey strata shown in red, at Watertower and Lighthouse.

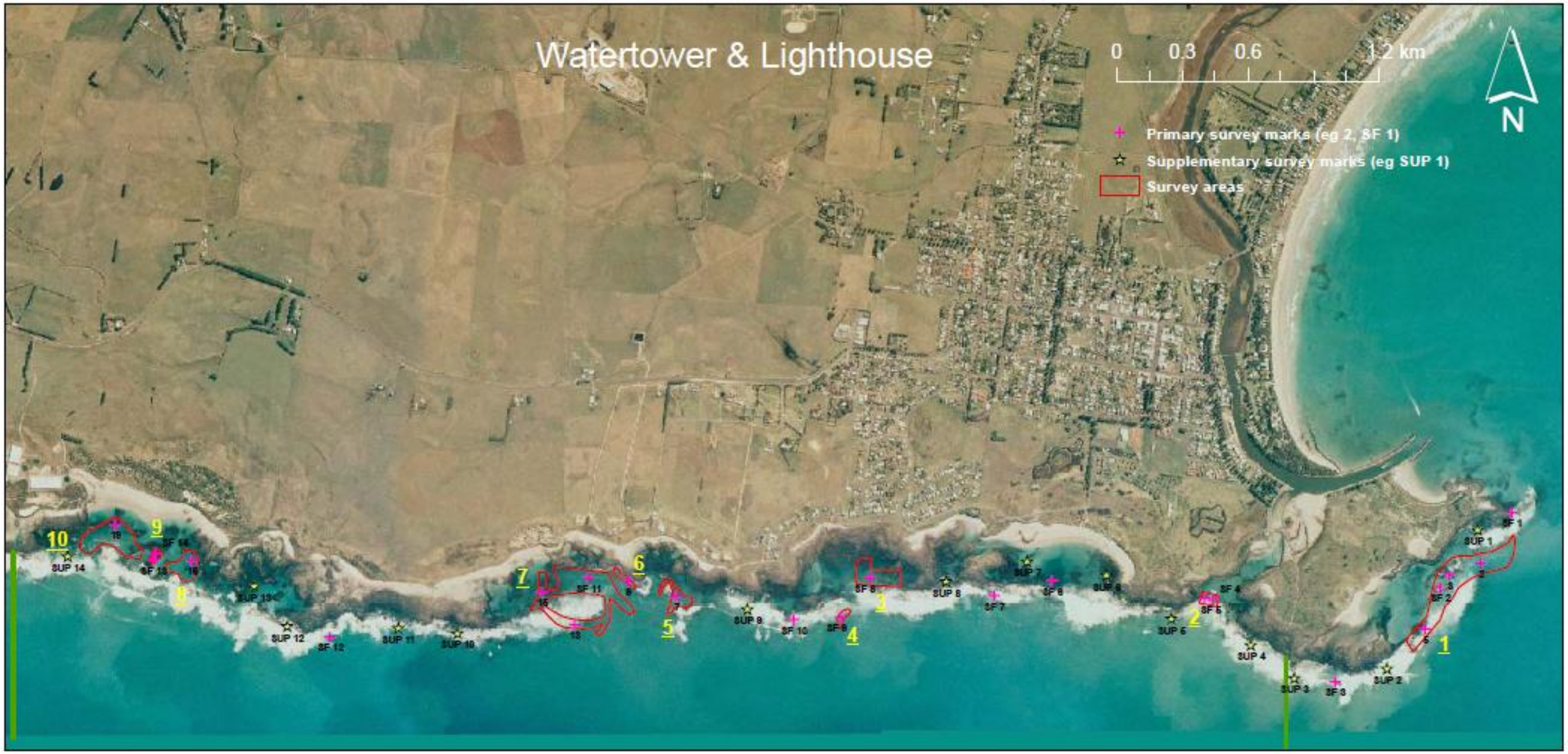


Figure 2. Planned Structured Fishing survey sites (labelled SF # with pink cross) and Supplementary sites (labelled SUP # with yellow star), with Pre-fishing survey strata shown in red, at Crags and Burnets.

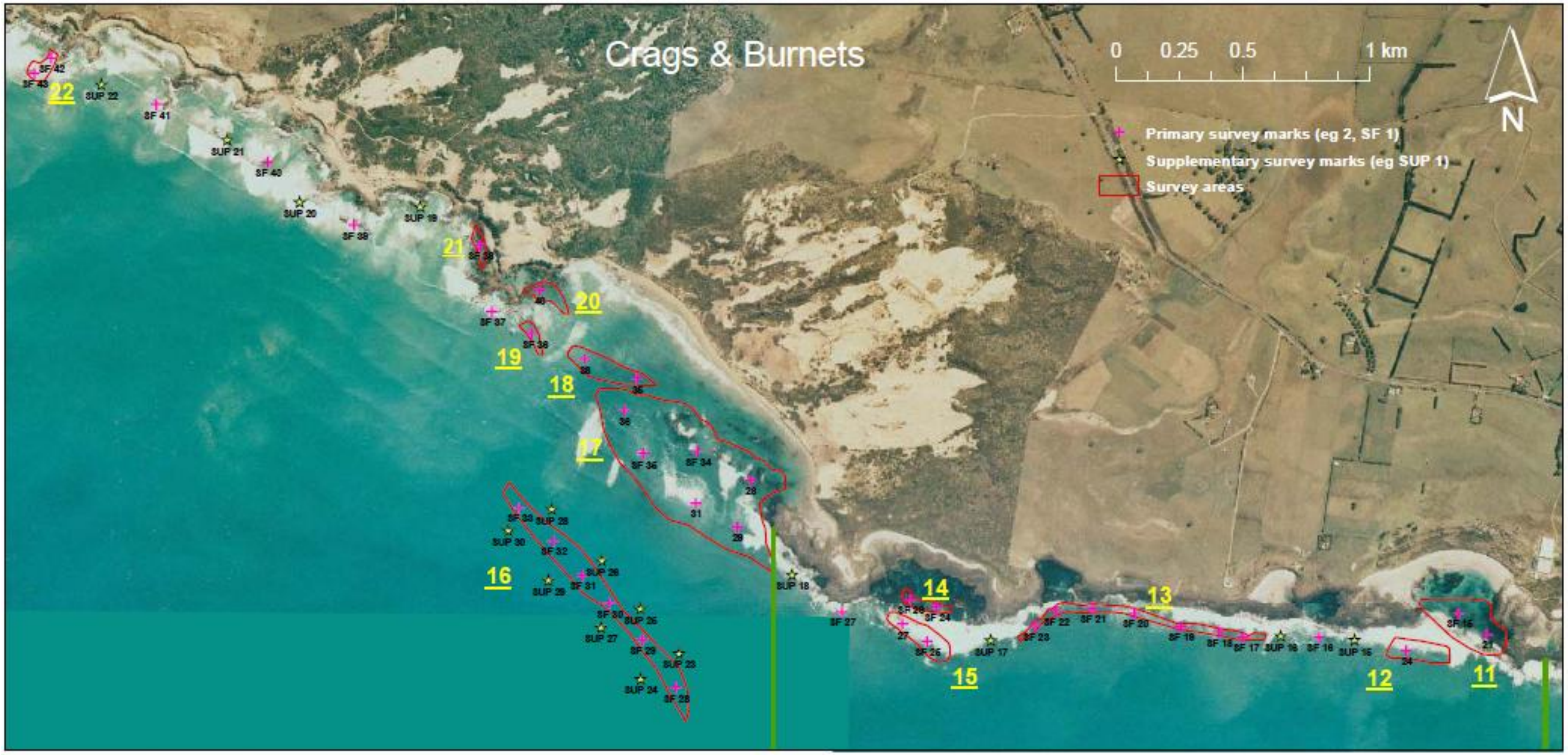


Figure 3. Actual Structured Fishing survey sites, with catch proportional to size of circle and catch rate related to colour (see legend) at Watertower and Lighthouse.

Figure 4. Actual Structured Fishing survey sites, with catch proportional to size of circle and catch rate related to colour (see legend) at Crags and Burnets.

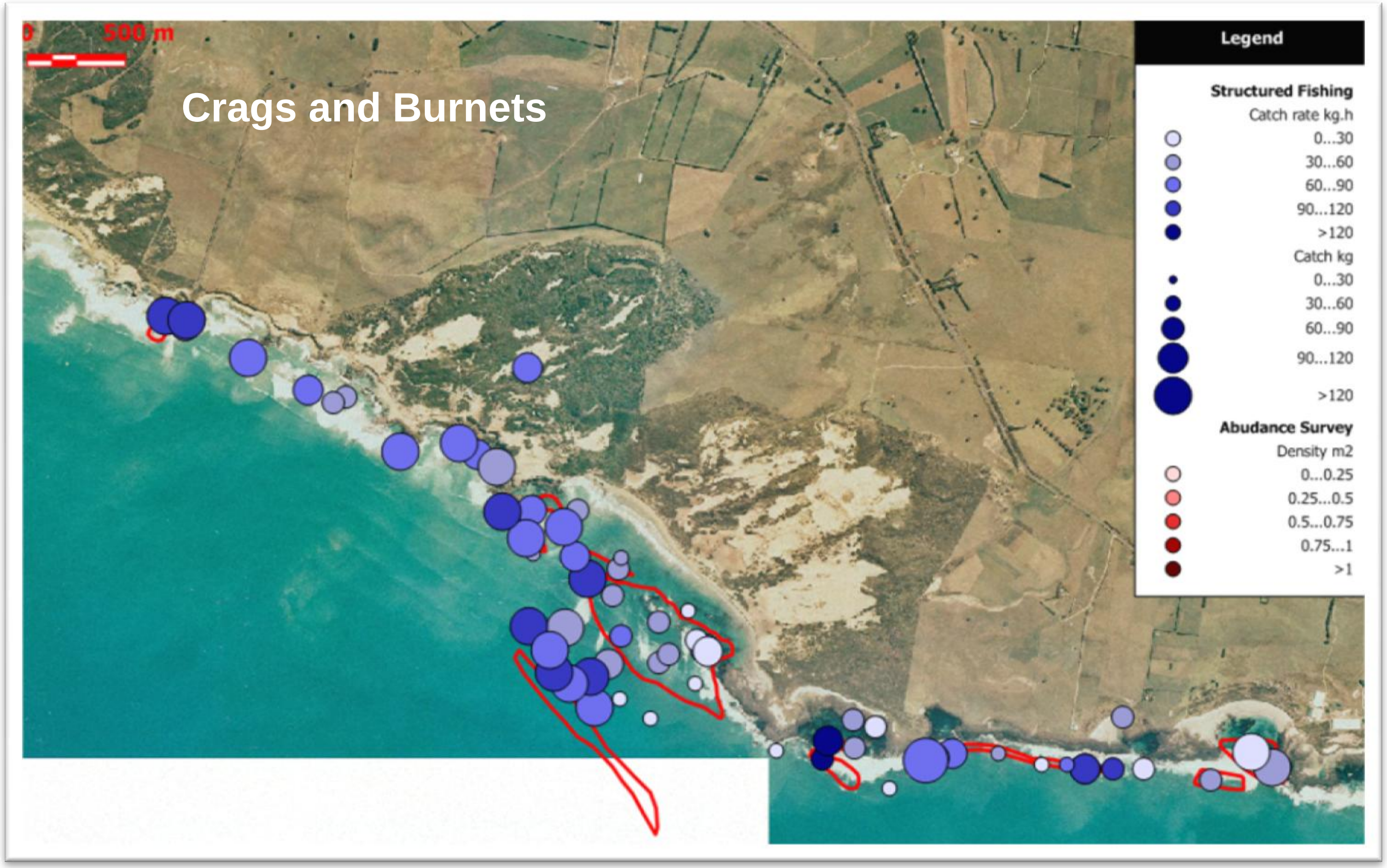
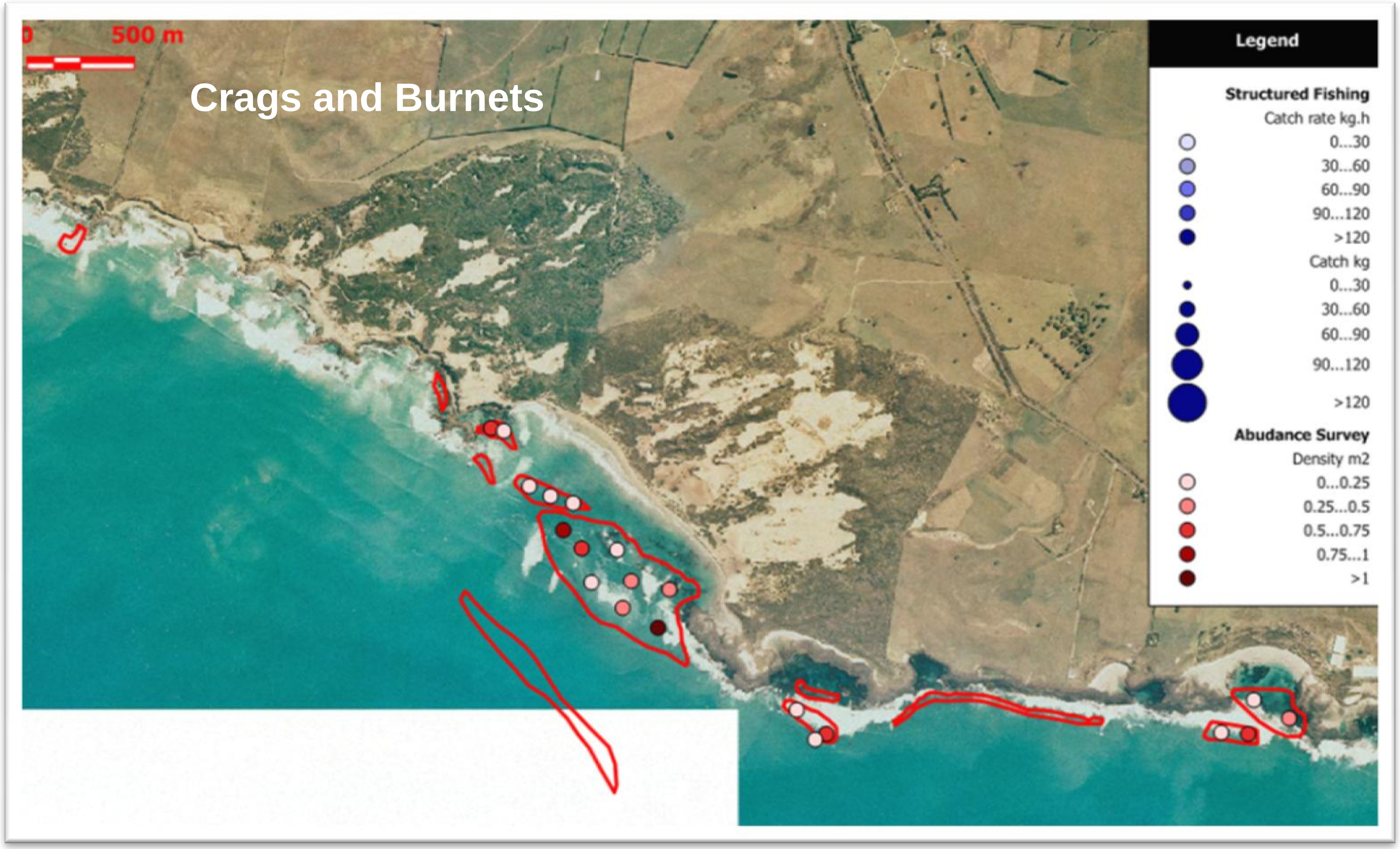


Figure 5. Actual Pre-Fishing survey sites, with density related to colour (see legend) at Watertower and Lighthouse.

Figure 6. Actual Pre-Fishing survey sites, with density related to colour (see legend) at Crags and Burnets.



APPENDIX 3C: SETTING LML'S FOR THE WESTERN ZONE USING EMPIRICAL TECHNIQUES. JEREMY PRINCE.
A report as part of FRDC Project TRF 2008/077
September 2010

Introduction
This document begins developing a methodology for empirically setting LMLs in the Victorian Western Zone, the aim being to develop new size limits for reef codes that are being re-opened after the AVG epidemic, and to develop this nascent empirical approach.

Spawning Potential Ratio (SPR) is commonly defined as the proportion of unfished spawning potential, which is being conserved by the fishery (Walters & Martell 2004). The central of this approach is to develop simple length based indicators of SPR which can be used to assess the size structure of the catch from each reef. The size composition of the catch would be assessed against the size structure expected if the target level of SPR is being conserved. In this situation LML's can be set on the basis of the SPR they conserve, and manipulated along with reef code catch levels to manage the size structure of the catch so that target levels of SPR are conserved in each reef code. The size structure information for each reef code is already being collected by WADA's universal use of the data loggers.

The outcomes of the two (SA & Vic) longer term FRDC projects just completed suggest that estimates of SPR at size can be estimated by the ratio of length & height of the shell, and with differing levels of precision from shell morphology and scarring. However, the methodologies that those findings suggest have not yet been developed to a level that can be applied right at this time. This last summer I had a student begin preparing an analysis of whether the connection that has been established between SPR and body shape for abalone can be found more widely. We have compiled a database which currently has 100+ species (prawns, sharks, marine mammals, blacklip abalone, short, medium & long-lived teleosts) of populations of marine resource for which we could find length weight regressions and develop SPR models.

We can show that the very same relationship between SPR and body shape seen in abalone is seen consistently across marine resources. If one can conceptualize the upward curving length-weight curve for each species over its life span, then we have found that all the species reach the same level of SPR at the same distance or angle (tangent) around their own length-weight curve. That means that across species levels of SPR will be attained at the same proportion of the average maximum size ($L_{infinity}$).

Our development of this analysis is still in its early phases and the results shown here are based on the first 70+ species. However, our reading of the literature so far shows that the observation we are making here is entirely new for international fisheries science, but sits within a very rich context. In many ways our finding has been anticipated and so that it is entirely consistent with a broad body of fisheries assessment science known as the Beverton & Holt Life History Invariance by which rates of growth and natural mortality in bony fish (teleosts) are known to be linked, which parallel bio-energetic modeling shows is because teleost species all make the

same trade-off between somatic growth and reproductive output in their life strategies.

Despite this context, we appear to be the first to have noticed that the Beverton-Holt Life History Invariants actual suggest our finding that previously modeled estimates of SPR can be empirically estimated from the average maximum size a species attains without fishing. Furthermore, accepting that we have re-confirmed Beverton-Holt Life History Invariance then from that body of work we also know that size of maturity is also related in some way to average maximum size, and so logically size at any SPR reference point might also be estimated from size of maturity.

What needs to be made at explicit at the outset here is the very preliminary nature of the approach being advanced here. On the basis of the meta-analysis conducted to date we are very confident that principles we have just established, and the general approach being advanced here is sound, however the exact techniques by which we are applying those principles, and the initial estimates made must be regarded as very preliminary, and will no doubt be subject to some level of revision through further analysis.

Methodology

Applying the Beverton-Holt invariance implies that across many species size based SPR reference points (length and weights) can be estimated on the basis of both the size of maturity and the average maximum size ($L_{infinity}$) attained in a population.

Stressing again that our analysis, understanding and use of these data and principles is still very preliminary, we proceed to try and make here the first experimental application of this principle.

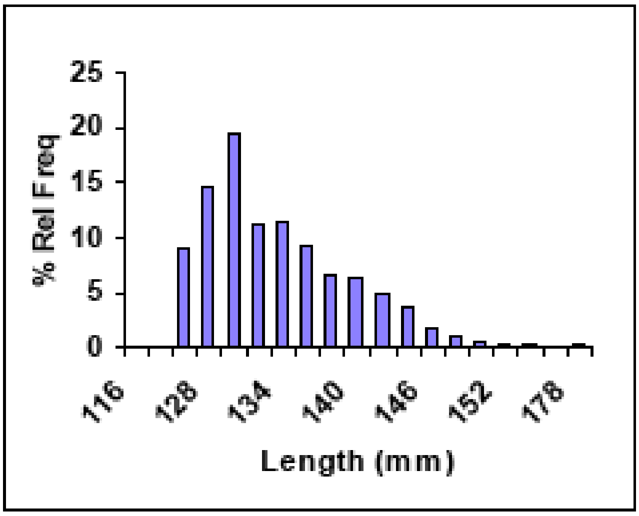
Data

The data available to me at this time are:

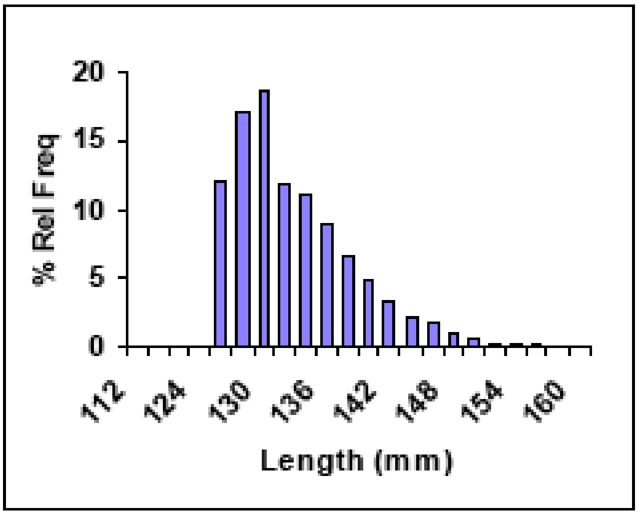
1. Size data collected by industry from their catch from the Craggs in 2004 and 2005 (Figure 1).
2. The length-frequency histograms for recent survey samples made available by Duncan Worthington (Figure 2).
3. Estimates of the size at which 50% of the abalone have attained maturity (L_{50}) from across the zone reported to me by Harry Gorfine (Table 1).

Site	5% CI (mm)	L50(mm)	95% CI (mm)
South Cape Bridgewater	96.498	98.393	100.203
Whites	98.257	99.831	101.363
JP Island	99.303	101.527	103.681
The Craggs	103.231	104.569	105.913
Murrels	104.005	105.932	107.877
Inside Cape Nelson	107.255	109.113	110.901
Water tower	109.704	111.348	112.904
Inside Levies	112.228	113.944	115.574

Table 1. Estimates of 50% maturity L_{50} from across the zone reported by H Gorfine.



Year 2004 ***Count*** 2557



Year 2005 ***Count*** 10606

Figure 1. Catch composition from the Craggs in 2004 and 2005 prior to AVG.

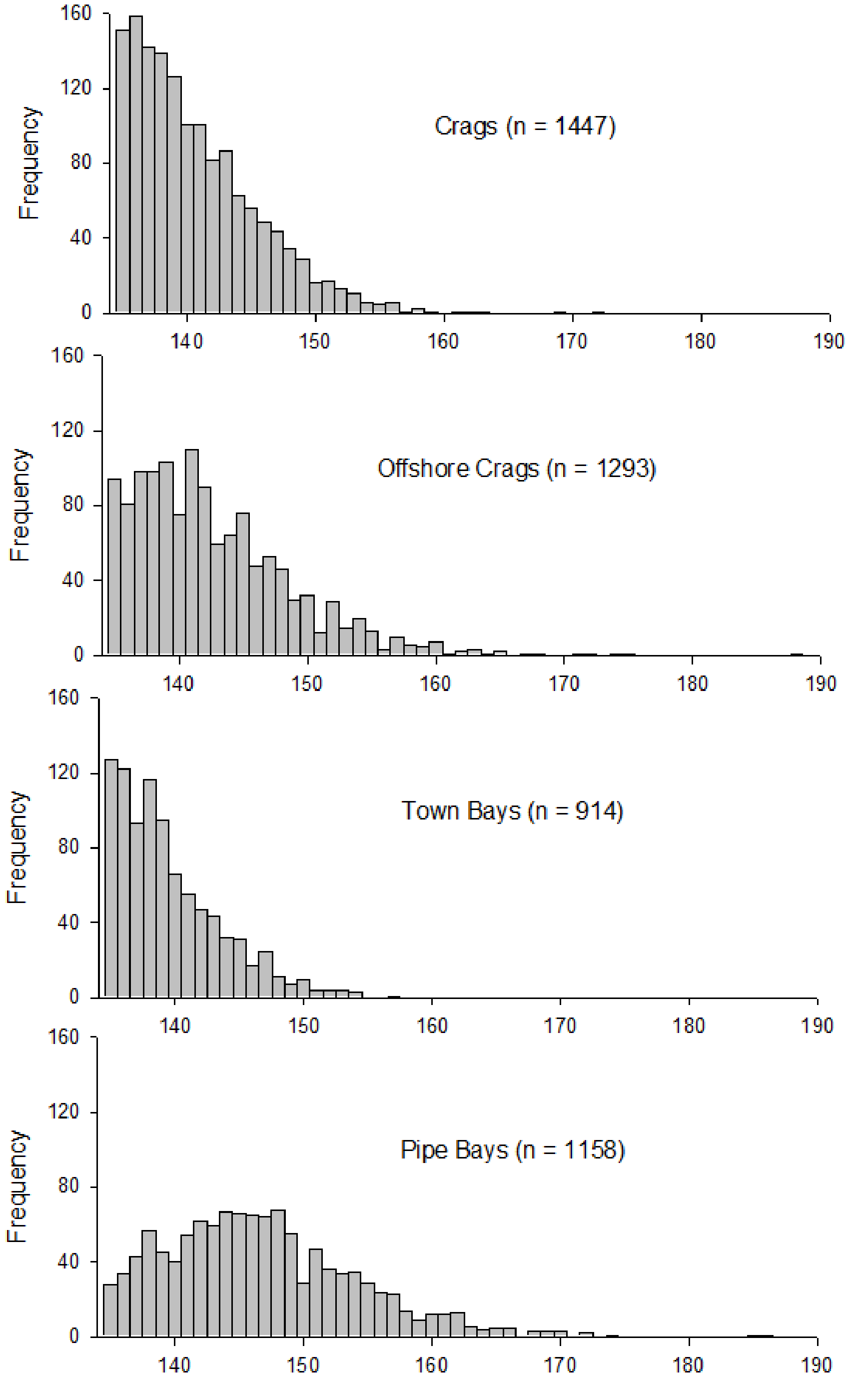


Figure 2. The aggregated length-frequency histogram for all survey samples in 4 areas from the report by Duncan Worthington.

Estimation of SPR Reference Points

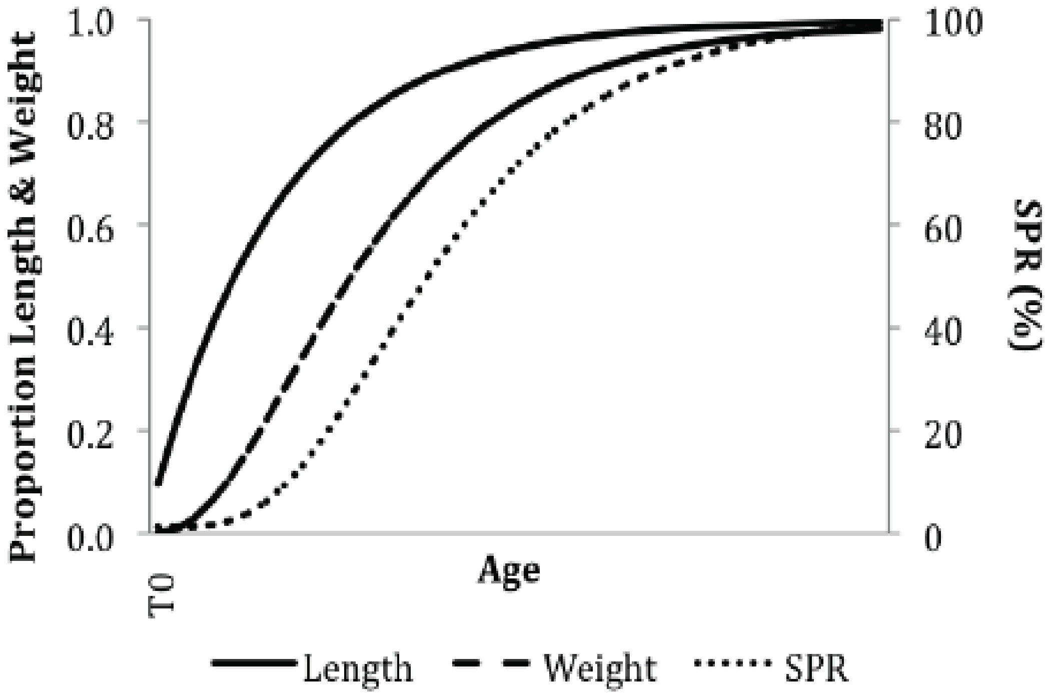


Figure 3. The average relationship between normalized length, weight, age and SPR estimated for 70+ diverse marine species and populations, including 9 Tasmanian blacklip abalone populations.

Figure 3 shows the average multi-species relationships estimated for the species in our analysis, suggesting that many, if not all marine species exhibit between normalized size, age and SPR. From these relationships SPR reference points can be visually equated to a proportion of maximum weight or length. The 9 Tasmanian blacklip populations drawn from Prince (1989) & Nash (1992) show a similar, but apparently, not identical relationship. At this early stage in this application we have used the average relationship estimated for the 9 blackip abalone populations, rather than the multi-species relationship shown in Figure 3. This decision needs review in the future. From these populations we derived an average relationship between normalized size (both length and weight) and SPR (Table 2) and also an initial estimate that L_{50} is equivalent to 3% of SPR. This schedule of SPR reference points expressed in length and assumption about the equivalence of SPR and L_{50} have been used in a preliminary fashion to evaluate the data presented above.

SPR (%)	Prop Lmax	Prop Wmax
0	0.25	0.02
3	0.48	0.11
10	0.60	0.22
15	0.68	0.31
25	0.75	0.43
35	0.81	0.54
45	0.86	0.63
55	0.89	0.72
60	0.92	0.78
80	0.97	0.91
90	0.99	0.97

Table 2. Schedule showing the relationship between SPR and proportion of maximum length and weight, that was computed using SPR models for 7 blacklip abalone populations.

Results

Estimating SPR Reference Points from Size of Maturity

In table 3 assuming initially that L_{50} approximates 3% SPR we apply our estimates of relative size at each SPR reference points (Table 2) to the estimates of L_{50} provided by Harry Gorfine (Table 1) to develop initial estimates of length at a range of SPR reference points for the various Western Zone reef codes. From the length frequency data for these areas (Figures 1 & 2) these initial estimates, starting with the estimated L_{Max} look very high, being some 40-50mm larger the biggest abalone in the samples. So it should be immediately noted that all the SPR reference points computed in Table 2, depend on our preliminary assumption that L_{50} is equivalent to 3% SPR. If however we assume that L_{50} is equivalent to 10% SPR alternative values can be estimated using the same approach which look much more reasonable (Table 4).

Site	L50 (mm)	Estimated Max Length	SPR 25	SPR 35	SPR 45	SPR 55
South Cape Bridgewater	98.4	205	154	166	176	182
Whites	99.8	208	156	168	179	185
JP Island	101.5	212	159	171	182	188
The Craggs	104.6	218	163	176	187	194
Murrels	105.9	221	166	179	190	196
Inside Cape Nelson	109.1	227	170	184	195	202
Water tower	111.3	232	174	188	199	206
Inside Levies	113.9	237	178	192	204	211

Table 3. Estimates of Maximum Length (mm) and length at various SPR reference points derived from estimates of L_{50} (Table 1), estimates of the proportion of maximum length at each SPR reference point (Table 2) and the assumption that L_{50} approximates 3% SPR.

Site	L50 (mm)	Estimated Max Length	SPR 25	SPR 35	SPR 45	SPR 55
South Cape Bridgewater	98.4	164	123	133	141	146
Whites	99.8	166	125	135	143	148
JP Island	101.5	169	127	137	146	151
The Craggs	104.6	174	131	141	150	155
Murrels	105.9	177	132	143	152	157
Inside Cape Nelson	109.1	182	136	147	156	162
Water tower	111.3	186	139	150	160	165
Inside Levies	113.9	190	142	154	163	169

Table 4. Estimates of Maximum Length (mm) and length at various SPR reference points derived from estimates of L_{50} (Table 1), estimates of the proportion of maximum length at each SPR reference point (Table 2) and the assumption that L_{50} approximates 10% SPR.

Estimating SPR Reference Points from Estimates of Maximum Size

An alternative way of applying this technique is to simply try and estimate the likely average maximum size ($L_{infinity}$) directly from our size data, and use this estimate with the estimates of relative SPR reference points in Table 2. With that in mind we turn to the length frequency histograms (figures 1 and 2) to see what the data imply about the average maximum length of these populations.

The first point to note here is that the average maximum size ($L_{infinity}$) is an average maximum size, and so in an unfished population it would be slightly smaller than the biggest (above average) animals seen in the population. Rather than being indicated by the largest specimens in an unfished population the average maximum size would lie inside the descending right hand limb of the main mode of adult animals, rather than by the extreme largest animals. On the other hand in a fished population animals maybe fished before ever reaching their potential maximum size, so that few if any animals attain the average maximum size. In our situation we are looking at a relatively heavily fished population in figure 1, and a population in which the largest animals have had three years without fishing to grow back towards their average maximum size in figure 2.

Taking the size composition of the catch from the Crags in 2004 and 2005 (Figure 1) we see a mode skewed to the left at around 132 mm, and the right hand tail of the histogram coming to an end at slightly less than 150 mm, but with a scatter of individual out to 160+mm. Turning to the survey data for inshore and offshore Crags (Figure 2) we see size distributions that have significantly shifted to the right with 3 years of no harvest. Inshore at the Crags the modal length now seems to have shifted to 136 mm while offshore Crags the mode is about 142 mm. The right hand descending limb of the histogram now stretches out to just below 160 mm at the inshore Crags and >160 mm at the offshore Crags, with a few animals being >170 mm.

The difference between the pre-AVG and post-AVG size distributions shows that there has been a considerable change in size structure since fishing stopped,

supporting the idea that prior to AVG fishing pressure in the area was quite heavy so that the size structure was truncated, however, with only 3 years of re-growth, it is uncertain how much further the size structure would shift to the right if it remained unfished. In this circumstances $L_{infinity}$ could conceivably be as low 150-155 mm at the Crags (larger offshore), but at the other extreme it could also be as high as 170-175 mm. This higher estimate would be consistent with the idea that the Craggs had been heavily fished pre-AVG and after only 3 years closure the size structure still has some potential to grow towards its maximum potential size and shift the right hand tail of the distribution further to the right. For the sake of this analysis we will assume $L_{infinity}$ for the Crags is approximately 160 mm, between these two extremes.

Max Length	SPR 25	SPR 35	SPR 45	SPR 55
145	109	117	125	129
150	113	122	129	134
155	116	126	133	138
160	120	130	138	142
165	124	134	142	147
170	128	138	146	151
175	131	142	151	156
180	135	146	155	160

Table 5. Contains the length (mm) based SPR reference points estimated for a range of possible maximum sizes (145 -180 mm).

Table 5 contains the length (mm) based SPR reference points estimated for a range of possible maximum sizes (145 -180 mm) from this it can be seen that depending on whether maximum size at the Craggs is taken to be 150-155 or 170-175mm the estimated SPR reference points would also vary by about 20mm. If the average maximum size is taken as 160 mm this would suggest an LML of 130-138 mm would preserve 35-45% of SPR.

Discussion

How should we interpret this initial empirical analysis of SPR reference points based upon measures of L_{50} and estimates of average maximum size?

Firstly given this techniques' early state of development any of these estimates should really only be considered as starting estimates, and liable to be changed as the R&D process on this topic continues.

Secondly, at this point in time it appears that using the estimates of L_{50} and our estimates of how L_{50} corresponds with our SPR models is producing estimates of average maximum which are too large. Conceivably this could be a reflection of statements by the original divers that in the early days when they began fishing all the abalone were very large and that through fishing down that biomass and the 'shifting baseline syndrome' we have over time forgotten how large the abalone were. If this scenario is correct it would imply both that the Western Zone stocks were held at very low levels of SPR for a considerable period of time, and that the potential long

term yield from this area under optimal management is considerably higher than the TAC levels prior to the AVG outbreak.

On the other hand the means by which we have linked the L_{50} measurements to our SPR models is still very ad-hoc being based on just a few SPR models for Tasmanian blacklip abalone, and I would be reluctant to place too much faith in this at this time.

On the other hand our estimation of $L_{infinity}$ directly from the size data is clearly relatively imprecise giving a range of some 20mm, from which I selected a middle value of approximately 160mm for the Craggs.

The third, point about interpretation of these analyses to be considered is that at this time we have no precise basis for establishing what is the optimal level of SPR to conserve in abalone fishery. Previously while working with qualitative indicators we have loosely used 50% SPR as a conservative level, and across a wide range of fisheries this is considered to be very conservative. In most contexts 30-45% of SPR is considered likely to be where optimal long term yields are delivered.

Clearly this first attempt to apply these techniques to empirically estimating SPR reference points indicates the need for further development, analysis, and to gather a broader base of the existing data together for these reef codes. However, in the interest of providing some firm if preliminary input to WADA's discussions and processes I suggest that the best interpretation of this analysis would be to use the 35% SPR values estimated in Table 4 as a basis for setting minimum size limits for reef codes. This suggestion uses estimates of average maximum size based on the measured L_{50} 's, which while appearing somewhat too large, are not entirely inconsistent with the size data presented here. It also uses a level of SPR (35%) which while lower than the level we have been nominally discussing is still considered broadly by the fisheries community to be likely to optimize long term yields.

References

Walters, C. and S.J.D. Martell. 2004. 'Fisheries Ecology and Management.'

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