Tactical Research Fund: Developing the use of existing technology in cost-effective and reliable Industry-based structured fishing surveys to urgently replace more costly methods and advise finer-scale management of abalone populations

Dr D. Worthington

Abalone Council of NSW

Australian Government

Fisheries Research and Development Corporation

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Duncan Worthington, Abalone Council of NSW

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Abalone Council of NSW
133 Blencowes Lane
Wildes Meadow NSW 2577

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2008/097 Tactical Research Fund: Developing the use of existing technology in cost-effective and reliable Industry-based structured fishing surveys to urgently replace more costly methods and advise finer-scale management of abalone populations.

PRINCIPAL INVESTIGATOR: Dr D. Worthington
ADDRESS: Abalone Council of NSW
PO Box 263
Northbridge NSW 2063
Telephone: 02 4858 0506 Fax: 02 4886 4445

OBJECTIVES:

1. Train commercial divers in the use of GPS loggers to record observations of the abundance of under-size abalone.
2. Assess the reliability of logged observations by commercial divers through comparison within and among divers, and with estimates from surveys completed independent of fishing.
3. Develop a cost-effective and targeted program to measure the lengths of abalone being landed in the Structured Fishing Program and compare with existing methods of estimating the size of abalone landed.
4. Improve the existing survey design for structured fishing, by developing the database of sampling sites, standardised techniques and historical information for estimating changes in abalone stocks.

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED TO DATE

- Development of existing technology to produce and facilitate the cost-efficient collection of fine-scale spatial data about abalone stocks.
- Implementation of a detailed spatial information collection, management and analysis system, with full uptake by all divers in the NSW fishery.
- Summary of fine-scale spatial data about abalone stocks to inform Industry-based decision-making and better advise management decisions.
- Development and demonstration of capacity within the abalone Industry to train and be involved in fine-scale spatial data collection, development, interpretation and advice to improve management of the fishery.

FRDC Project 2006/029 developed GPS and Depth logger technology, and database tools, to collect and use fine scale spatial information about fishing. This information has the potential to better inform stock assessments for spatially structured populations, such as abalone. In particular, the technology enables collection of data to allow comparisons of fishing patterns of commercial divers and their catch information at a fine spatial scale through time. Anecdotal evidence suggests changes in such fishing patterns and catches at a fine spatial scale may precede any changes at broader spatial scales, and hence provide earlier indications of change in stocks. While fine scale fishing patterns can now be monitored in NSW, there

remains a strong need to collect the GPS and Depth logger technology over several years to observe and understand its relationship to changes in abalone stocks.

This project attempted to extend the use of GPS and Depth logger technology to produce more cost-efficient and reliable information about stocks of abalone at a fine spatial scale in NSW, to better inform Industry-based decision-making and advise management decisions. Past large reductions in TAC and Beach Price had made previous assessment methods unaffordable, and established an urgent need for a replacement.

Outputs and outcomes were achieved relevant to all project objectives, but particularly in achievement of the roll out, training and uptake of the voluntary use of GPS and Depth loggers by all divers in the NSW Abalone Fishery. NSW is the only abalone fishery that has achieved full uptake to date.

All divers in the fishery have now been trained to operate GPS and Depth loggers to record their fishing effort and enter observations about the stock, with confidentiality and release agreements about provision and use of their information in assessment of stocks. The 30 sets of GPS and Depth loggers are managed using the purpose built AbTrack database, which also holds and facilitates analysis of the large amounts of data produced.

The framework developed by FRDC project 2006/029 for handling data from the loggers, including download, archive, handling, analysis and summary of large amounts of detailed spatial information, has been successfully implemented and is operational for the NSW Fishery. In particular, this includes integration of AbTrack, SQL Server 2008, Manifold GIS and R statistical software in summarizing the spatial data. Spatial data enables direct comparisons of catch information at a fine spatial scale (e.g. catch rate of the same diver at the same site), avoiding much of the confounding of such comparisons, and is presented in grid-based and dive event-based summaries.

Because of the greater level of resources devoted to roll out and training of GPS loggers to all divers, and slower than expected uptake of recording undersize observations, comparisons of observations within and among divers were limited to undesigned comparisons, although formal comparisons are planned when uptake and reporting of undersize observation is more consistent, which should occur with ongoing development.

A further important component of the use of GPS loggers involves entering the position that bins of abalone are filled to link or geo-reference information associated with bin-based logbook catch records. While this information is being successfully related in many cases, small errors in incorrectly reporting the number of bins within the day can significantly reduce correct geo-referencing. Changes to logbook catch reporting have been implemented to facilitate correct geo-referencing.

A cost-efficient length measuring program has been developed, using GPS-enabled measuring loggers operated by staff in processors or deckhands on boats, and able to be linked to bin-based catch statistics and GPS loggers operated while fishing. This program has provided estimates of the length-structure of abalone from the

sensitive Region 2, and confirmation of a strong relationship with the sizes of abalone estimated from bin-based catch statistics. Ongoing development of the program is proposed with a commitment to purchasing more loggers.

Five SQL Server databases have been created for use in further development of the Structured Fishing Program. These include AbTrack (GPS and depth logger information), Catch (diver's bin based logbook catch records), NSW Features (reference geometry of coastline and grids), Outputs (such as dive-event KUD geometry and grid summaries and other results of analysis/linking other databases) and Structured Fishing sites (reference geometry and historical information about sites identified with productive abalone populations for potential use in future Structured Fishing programs). Over 100 sites were identified as suitable for inclusion in structured fishing designs, and interviews with past and current divers and other historical information about sites was included in the database. TSQL Queries and views were developed to interrogate and link these databases to provide summary information

This project has developed a detailed spatial information collection, management and analysis system for delivering fine scale spatial information about fishing and stocks in the NSW abalone fishery. The continued use of GPS loggers by all divers in NSW, and the further development and application of derived performance indicators in fishery management, is likely to provide a valuable data series for evaluating these emerging, cost-effective techniques. There is now a strong need to ensure the continuation of development and automation of methods of analysis of this spatial data to allow monitoring over several years to demonstrate which measures derived from the GPS logger data are more responsive fishery performance indicators. Use of the tools developed in this project, together with an ongoing commitment to resource and implement appropriate structured fishing designs, will be able to better inform fine scale assessments for TAC setting and catch planning through a process with strong Industry involvement that is currently being developed in the fishery. Development and application of cost-effective technologies to collect large, fine scale spatial data sets can contribute to the assessment and management of all state's abalone stocks and their fisherys. Extension and development of capacity to achieve this cooperatively with government fishery management agencies, as demonstrated by this project, is a priority.

KEYWORDS: Abalone, GIS, spatial, assessment, Industry, training, fine scale, TAC.

ACKNOWLEDGMENTS

The involvement and commitment of the NSW Abalone Industry, including Shareholders, divers and processors has been central to the development and implementation of GPS loggers and structured fishing to spread catch and provide information about abalone stocks in NSW.

This support has included a significant financial and in-kind contribution from many in the Industry, particularly those contributing directly to the Abalone Council of NSW, at a difficult financial time in its history. This contribution was driven by a commitment from the Industry to change what had occurred. While the support was not always

unanimous, there is now a single-minded intent within the Industry to ensure a better outcome.

Industry members of the fishery's Management Advisory Committee provided formal support for development and funding of the Industry-based research and this project.

Ian Cartwright and Keith Sainsbury provided important support for development and funding of the project.

Craig Mundy provided very important support to the development of the GPS logger program in NSW, as part of FRDC project 2006/029. Without that support progress with GPS loggers in NSW would not have advanced as quickly.

Gerald Verdouw from Scielex provided support to the technical development and provision of GPS loggers.

Cameron Westaway and Doug Ferrell provided support during development and implementation of the Industry-based research and this project. The Department of Industry and Investment also facilitated an Industry contribution to this project from all Shareholders in the fishery.

BACKGROUND

From the late 1980s, it appears that stocks of abalone were significantly reduced on the NSW Central Coast through mortality related to the protistan parasite, Perkinsus olseni. Observed mortality commenced around Sydney in the late 1980s and had spread ~400 km north to Port Stephens and south to Jervis Bay by the early 2000s. In response to the reported declines, and because of uncertainty about the productivity of stocks, a large section of coast (i.e. ~350 km) was closed in 2001. Since then there have been a series of closures to commercial and recreational fishers throughout the area known as Region 1 and 2 (i.e. ~700 km) that previously produced over 100 t of abalone per year. With no fishery-dependent information, the only information about stocks of abalone was available from expensive fishery-independent surveys which were only possible at a very low number of sites leading to uncertainty about how representative they were of the broader area.

For several years, the TAC Setting and Review Committee has emphasized the need to investigate more cost-effective, Industry-based fishing surveys to provide greater information about stocks in Region 1 and 2 of the fishery. Following review by the Ministerial Special Abalone Recovery Group and MAC, the Minister recommended development and implementation of an Industry-based Structured Fishing Program in May 2008, to increase knowledge of stocks throughout Region 1 and 2 of the fishery. With the decline in TAC, and necessary reduction in investment in fishery independent abundance surveys, more cost-efficient methods, such as GPS loggers and structured fishing programs, will be essential to maintain and expand information about the fishery. The intent was to develop a more cost effective system, and enable it to be run in conjunction with the previous system, to allow calibration. Unfortunately, this direct calibration was not possible because of limited resources, and subsequent data has demonstrated the difficulties of such calibration.

The Structured Fishing Program developed by the Department of Industry and Investment (DII) and Industry commenced in September 2008, and provided the tactical opportunity to leverage existing resources devoted to the program by further developing the use of more cost-effective approaches and technology to the collection of fine scale information about stocks. A project was developed by the Abalone Council of NSW, in conjunction with fishery divers and Shareholders and DII, and was supported by members of the Management Advisory Committee and TAC Committee, identified in the DII Strategic Research Plan as a high priority, and formally supported by DII.

Two previous FRDC projects also contributed significantly to the development of this project: FRDC Project 2006/029, “Using GPS technology to improve fishery dependent data collection in abalone fisheries” and FRDC Project 2005/024, “Abalone Industry Development: local assessment and management by industry”. Support was provided by Craig Mundy (Tasmanian Aquaculture and Fisheries Institute) as part of FRDC 2006/029, which initially developed the GPS logger technology and was essential to the development in NSW of a desire and capacity to use the technology in the fishery. Rob Day (University of Melbourne) and the Steering Committee of FRDC 2005/024 contributed to development of the concept of Structured Fishing surveys completed by Industry. As a result, development of methods to improve the design of Structured Fishing was a high priority to the fishery

in NSW, and this project extends the benefits and outcomes of the FRDC Finer-Scale Management and GPS Technology projects.

At commencement of the Structured Fishing Program in September 2008, an agreement of responsibilities was jointly signed by DII and commercial divers who proposed to fish in Region 1 and 2 as part of the program. Industry had originally invested in several GPS/Depth loggers and with other units (from Craig Mundy, TAFI) had access to 9 GPS loggers. An additional 6 GIS loggers and 15 Depth loggers purchased with Industry funding by DII were provided to the Abalone Council of NSW prior to the commencement of the Structured Fishing Program in September 2008. No further funding was available for Industry or the Abalone Council of NSW until the project received support from the Tactical Research Fund of the FRDC in May 2009, and DII in August 2009. This meant a proposal to provide greater spatial control of catches at selected sites did not proceed. In May and July 2009, additional GPS and Depth loggers were purchased by DII with Industry funding and provided to the Abalone Council of NSW, enabling the provision of loggers for all commercial divers in the fishery in late 2009. As a direct result of this project, all commercial divers in NSW have now been trained and voluntarily operate GPS loggers while fishing, and have signed formal release agreements about provision and use of the information in assessment of stocks in Region 1 and 2, and throughout the fishery.

NEED

Surveys completed independent of fishing are used to advise management of abalone fisheries in some states, although they are often expensive and struggle to provide a representative description of stocks throughout a fishery. Although such surveys have been completed in NSW for over 10 years, it has not been possible to collect representative information throughout the fishery because of their prohibitive cost. Very limited information is available about stocks in northern areas of the fishery, and following Perkinus-related mortality, a series of closures were introduced from 2001, so that by 2007 over 1000 km of coast was closed to fishing and some closures remain in 2010.

In recent years, there have been large reductions in Total Allowable Catch, GVP and profitability of the commercial abalone Industry in NSW, as well as large reductions in recreational bag limits. One consequence of these changes was a reduced ability to contribute to the cost of independent surveys of abundance outsourced by DII, in addition to uncertainty about how representative the surveys were of the changes in stock that had occurred. These independent surveys of abundance were not continued from July 2009. The cessation of these surveys, together with very little other information available to assess stocks in the closed areas of the fishery, led to an urgent need to develop more cost-efficient methods of the assessment of stocks throughout the fishery, and particularly at a fine spatial scale.

Following development of a Structured Fishing Program by DII, an Industry-based survey of the previously closed area was commenced in September 2008. The program involved a system of catch targets and caps for different areas to ensure the appropriate distribution of catch, and a Memorandum of Understanding and Strategic Research Plan, to ensure representative information about stocks was collected. Following the cessation of independent surveys of abundance, there was also a need to extend development of such cost-efficient methods of collecting information about

stocks throughout the fishery. Such methods have the potential to improve profitability of the Industry, by providing a more cost-effective and reliable method of collecting finer-scale information about stocks.

OBJECTIVES

1. Train commercial divers in the use of GPS loggers to record observations of the abundance of under-size abalone.
2. Assess the reliability of logged observations by commercial divers through comparison within and among divers, and with estimates from surveys completed independent of fishing.
3. Develop a cost-effective and targeted program to measure the lengths of abalone being landed in the Structured Fishing Program and compare with existing methods of estimating the size of abalone landed.
4. Improve the existing survey design for structured fishing, by developing the database of sampling sites, standardised techniques and historical information for estimating changes in abalone stocks.

METHODS

Project Context

The recent FRDC projects 2006/029 (GPS Technology) and 2005/024 (Finer-scale Management) have demonstrated and highlighted the need for finer scale data collection and assessment, and where possible, management to all states abalone fisheries. To achieve this, there is a need for further development and support for cost-efficient technologies to allow collection of the fine scale information (e.g. GPS loggers, underwater video), and the development of methods to maximise the return on investment in such technologies, including the role that structured fishing can play in extending the types of information able to be provided by the technologies.

The Structured Fishing Program in NSW was designed to provide basic information about stocks from fishing distributed throughout Region 1 and 2 of the fishery. This project took a tactical approach by using the opportunity of the Structured Fishing Program to develop the use of cost-effective data collection technologies, and maximise the value of information collected from the investment in development of the technologies and implementation of the Program. In addition, following the cessation of the independent abundance surveys throughout the fishery, the project was also able to respond by extending use of the GIS technology throughout the fishery, to enable collection of information about stocks that would be valuable in designing future structured fishing programs and informing assessments of the stock for management advice.

An original application to the FRDC Tactical Research Fund in mid 2008 was timed to coincide with the commencement of the Structured Fishing Program, but was unsuccessful. A subsequent application in early 2009 was funded in May 2009. Several changes in management of the fishery occurred during this time and throughout the project, and required or enabled a revised approach to this project. First, the independent surveys outsourced by DII were no longer repeated in July 2009, complicating direct comparisons of results from the independent survey with those recorded in GPS loggers by commercial divers. Second, the Structured Fishing Program commenced in September 2008 and was completed in Region 2 which was then closed to fishing in February 2009, and completed in Region 1 in

June 2009, while funding of this project commenced in May 2009. Region 2 was re-opened in July 2009, but Region 1 South remained closed throughout 2010. Third, with support and funding from fishery Shareholders, by July 2009 DII purchased and supplied to the Abalone Council of NSW sufficient GPS and depth loggers for extension to all divers in the fishery. As a consequence, considerably more of the project's resources than planned were spent on rolling out the new loggers and training divers in their use as part of Objective 1.

The GPS technology and AbTrack database were developed as part of FRDC project 2006/029. In addition, that project also developed a range of fishery performance indicators that may be suitable for use in TAC setting and catch planning. Two main types of Performance Indicators have been developed and were applied by this project to the data collected from Region 1 and 2. First, grid-based performance indicators were calculated, which involve summing or averaging measures (e.g. such as effort, catch, catch rate, depth, mean size of abalone) within grids of a specific size. In Appendix 1, information is summarised in 100 m (i.e. 1 ha) and 500 m hexagon grids and in the subzones and Regions used for logbook catch reporting. The second type of performance indicators developed involve consideration of dive events. These involve summary of a dive event by a Kernel Utilisation Distribution (KUD), which involves a spatial model-based representation of each dive event. Bivariate normal distributions are fitted to each GPS point in a dive, and an estimate of the spatial density of points in the dive event is calculated. Contours of the model's estimate of the spatial density of points in the dive event then provide a simple and easily manipulated summary of the dive event for use in subsequent analyses. In all cases, the privacy of diver's fine scale data is retained by not presenting the specific location of GPS data or adjacent coastline to avoid identification. While personal privacy will continue to be retained, specific location information will be available as part of the process being developed with Industry and DII for consideration of the data in TAC allocation and catch planning.

Train commercial divers in the use of GPS loggers.

At the commencement of the project 9 GPS loggers, of several different models, were being used by divers in the NSW abalone fishery. Shortly after the project commenced, 30 GPS and Depth loggers became available for use by divers in the fishery. All 30 GPS loggers purchased also had the ability to record events associated with pressing of two buttons on the logger unit that could insert additional information into the GPS stream.

Changes in abundance of undersize abalone may predict likely changes in the fishery before they occur, allowing the TAC or other management to be adjusted appropriately. Surveys by DII of undersize abalone have shown some ability for this prediction, and both the TAC Committee and Special Abalone Recovery Group have emphasized the importance of such information. GPS loggers able to record commercial diver observations about the abundance of undersize abalone provide the opportunity to collect this information more cost-effectively.

New firmware was developed and installed in all GPS loggers to provide the necessary functionality to two available buttons. One button was enabled to record the entry of a semi-quantitative score (i.e. 1-5) related to observations of undersize abalone when selected by the diver. This information should provide a spatial map of

observations and changes in the undersize abalone population. The second button was enabled to record a character in the GPS data stream when pressed coincident with the filling of a bin of abalone. This information should provide a spatial map of the position bins of abalone are filled for association with bin-based logbook catch records.

GPS logger firmware was also modified to facilitate coordination of reporting with changed logbook reporting requirements introduced by DII in July 2009. New reporting requirements required divers to enter latitude and longitude to the nearest decimal of a degree for each bin landed in the fishery on the paper-based logbook. To support and facilitate divers reporting this information, logger firmware was modified and installed in GPS loggers to display the current latitude and longitude, as well as storing a waypoint in memory when the button associated with filling a bin of abalone was pressed. In this way, divers could access a record of the latitude and longitude their bins were filled at the end of the day when they were filling in their paperwork.

As well as visiting all divers individually to introduce and train them in the use of the loggers, three small workshops were arranged to facilitate consideration and discussion about progress with implementation of the loggers. Divers were also visited individually as needed to arrange download of data from GPS and Depth loggers, and receive further advice and training in using the loggers. During the project, several GPS and Depth loggers either required maintenance or were destroyed (1 depth logger) or lost (1 depth logger). GPS loggers were returned to Scielex for maintenance, while lost or destroyed loggers were replaced.

Assess the reliability of logged observations by commercial divers.
To interpret observations of undersize abalone made by commercial divers and recorded to loggers, it will be essential to understand the reliability and sources of variation among observations. This information can be collected by comparing repeated observations within and among divers, and by comparison to changes in abundance estimated in independent surveys.

Comparisons of observations within and among divers, and to abundance estimated in independent surveys were complicated by several factors. First, after the project commenced, it became clear that independent surveys of abundance outsourced by DII would no longer proceed from July 2009. Second, while there was broad uptake across divers in attempting to report undersize observations, the intensity of observations being recorded was considerably less than expected. To some extent, this reduced recording of observations was associated with uncertainty about the recording process and recording rates continue to increase through time with further training. With recording rates increasing and divers continuing to learn and improve their understanding of what should be recorded, it was decided to delay formal comparisons among divers until recording and learning rates had stabilised. This decision was also impacted by the larger proportion of resources devoted to Objective 1 and the roll out of more loggers and training of more divers than expected. As a result, comparisons within and among divers are limited to informal comparisons that occurred haphazardly as divers fished and recorded in similar areas.

Develop a cost-effective and targeted program to measure the lengths of abalone being landed.

The size of abalone being landed is central to an understanding of changes in abalone stocks and their response to management changes, such as finer scale size limits. Extensive information about the average weight of abalone being landed is already collected routinely throughout the fishery and has been repeated for almost 10 years. Further, large numbers of abalone were measured using callipers by scientific staff prior to 2000. Despite that, apart from limited Industry initiatives to address specific questions, no broad-scale program measuring the length of abalone has occurred in NSW since 2000. As a result, there has been limited information about the length of abalone being landed, particularly in reference to implemented or planned minimum length limits.

A cost-efficient length measuring program was developed by coordinating divers and processors to enable the association of individual bins measured by the processor or diver, with bin-based catch information reported in the logbook and recorded in the GPS logger. In addition, this revealed the potential of the Scielex measuring logger and consideration of the hardware and firmware options required for the proposed purchase of further Scielex measuring boards. Throughout this project, these procedures were developed with one processing company receiving the vast majority of abalone from Region 2 in the fishery. In addition, the measuring logger was also trialed on one diver's boat for several days in Region 2. In total, over 100 slats or 39 bins of abalone were measured by the processors, with abalone targeted from the sensitive Region 2. Each bin was also associated with catch statistics to allow a comparison of the mean length of abalone measured in each bin with the mean weight of abalone that is reported on logbook catch reporting.

Improve the existing survey design for structured fishing by developing databases.

Data collected during this project will improve the design of future structured fishing programs. The fundamental aim of structured commercial fishing is to spread the commercial catch appropriately across abalone stocks, and to provide representative information about changes in those stocks. While the recent Structured Fishing Program spread catch across Region 1 and 2 at the scale of subzones, the design could have been improved by controlling some fishing at a finer spatial scale. A proposal was put forward by the Abalone Council of NSW to achieve this, but it was not funded.

Future Structured Fishing Program designs could be improved by concentrating sampling at pre-selected and more specifically defined sites at a fine scale, where fishing is most repeatable and feasible, and comparable fine-scale historic information can be collected. For example, a pool of structured fishing sites could be linked to local characteristics of the reef and existing diver habits and operations, such as a standardized swim along a point or the searching of a well-defined area of productive reef. These sites would be small enough to enable direct comparison of catch and effort information within them (e.g. the size of a diver event, 100-300 m), and could be monitored in addition to full GPS logger coverage. The reduced spatial scale of structured fishing sites, compared to full GPS logger coverage, would

improve the ability to standardize methods of fishing (i.e. effort) that would benefit the repeatability both within and among divers and facilitate audit processes.

Five SQL Server databases have been created for use in further development of the Structured Fishing Program designs. These include AbTrack (GPS and depth logger information), Catch (diver's bin based logbook catch records), NSW Features (reference geometry of coastline and grids), Outputs (such as KUD geometry and grid summaries and other results of analysis/linking other databases) and Structured Fishing sites (reference geometry and historical information about selected sites). Transact SQL Queries and views were developed to interrogate and link these databases to provide summary information.

The GPS and depth information held in AbTrack can be used to identify localised areas with productive abalone populations for inclusion in a pool of sites for selection within structured fishing designs. Sites with documented fishing activity, and others without recent activity, were identified in Manifold GIS and their spatial extent recorded as a geometry instance in a SQL Server database. Other information stored in the database also includes all available information about the site, including any anecdotal historical information collected during interviews. Over 350 separate dive events have been recorded to date in Region 1 and 2, and over 100 sites have been selected and are currently held in the database. More sites have also been selected throughout the rest of the fishery.

RESULTS AND DISCUSSION

Roll out of loggers across the fleet

Following commencement of the project and consistent with the project application, it became clear there was an opportunity to extend roll out, training and implementation of GPS and Depth loggers across all divers in the NSW abalone fishery. Thirty GPS and Depth loggers were purchased by DII, fishery Shareholders and the Abalone Council of NSW. Twenty-eight GPS and Depth loggers, and training in their use, have been provided to endorsed divers in the fishery, enabling full coverage of all divers or dive-teams, and the retirement of several older logger versions. For example, some divers who work together were provided a shared GPS logger and individual Depth loggers. As part of release of the loggers to divers, they were required to sign confidentiality agreements with the Abalone Council of NSW detailing appropriate use of the data, and privacy releases which were provided to DII to enable release of private logbook catch information for association with GPS records. Firmware was initially standardised across all new loggers to enable recording of undersize and the filling of bins. Logger firmware was then extended to allow display of current latitude and longitude, and extended again to enable display of bin filling waypoints at the end of the day to facilitate logbook reporting.

Currently, NSW is the only fishery with full uptake of the GPS and Depth loggers. While it is expected there will be some data loss, through issues related to loss/charging/damage to loggers, there appears now to be an intent from all divers to run loggers at all times. There also appears now to be an intent within Industry and DII to appropriately fund the GPS logger program as a core responsibility of the fishery, including maintenance, ongoing training, download, archiving and reporting.

Information from Region 1 and 2

Information summarised from data collected from Region 1 and 2 are presented as examples and in summary form below and in Appendix 1. As mentioned previously, privacy of information will be retained in public documents by removing coastlines or displaying summary information at a broad scale. Fine scale spatial data enables direct comparisons of catch information at a fine spatial scale (e.g. catch rate of the same diver at the same site), avoiding much of the confounding of such comparisons, but only summary information is presented here and used in workshops for catch planning and TAC allocation. Grid-based summary information is presented in a draft report prepared for DII in Appendix 1 that was also sent to all Shareholders for comment and input to the TAC Setting process. Dive-event summary information is presented below.

Dive-event data are summarised here using Kernel Utilisation Distributions (KUDs), which have been extensively developed for common use in animal home range studies. A KUD is a model that is fitted to the observed GPS points from a dive-event by combining two-dimensional normal densities fitted to each GPS point in the dive event, to describe an estimated density of GPS points throughout the area of the dive event (Figure 1). Contours enclosing different proportions of the estimated distribution of points can then be calculated (Figure 1 and 2).

The KUD of a dive event can then be simply summarised by the shape of different contours. For example, here 50% and 90% contours are used, which are calculated to include the minimum area that encloses 50% or 90% of the GPS points or fishing effort from a dive event (Figure 2). These contours are easily stored as a polygon in a shapefile or a geometry instance, which is easily retrieved and used as a convenient and simple description of a single dive event, or by overlapping multiple dive events, for use in workshops with divers. By overlapping KUD from all dive events in an area, it can become clear how much of a reef is fished and productive, and for a productive area of reef how much has been fished in a given time period. This can then influence decisions made in workshops about appropriate catch planning and allocation for TAC setting. KUD have been calculated for all dive events from Region 1 and 2.

Figure 1. GPS points associate with one dive event, showing the estimated KUD (colour gradient) and associated contours (coloured lines). These summarise how the KUD model provides an estimate of the spatial density of GPS points from a dive. Note coastline is not shown to retain privacy

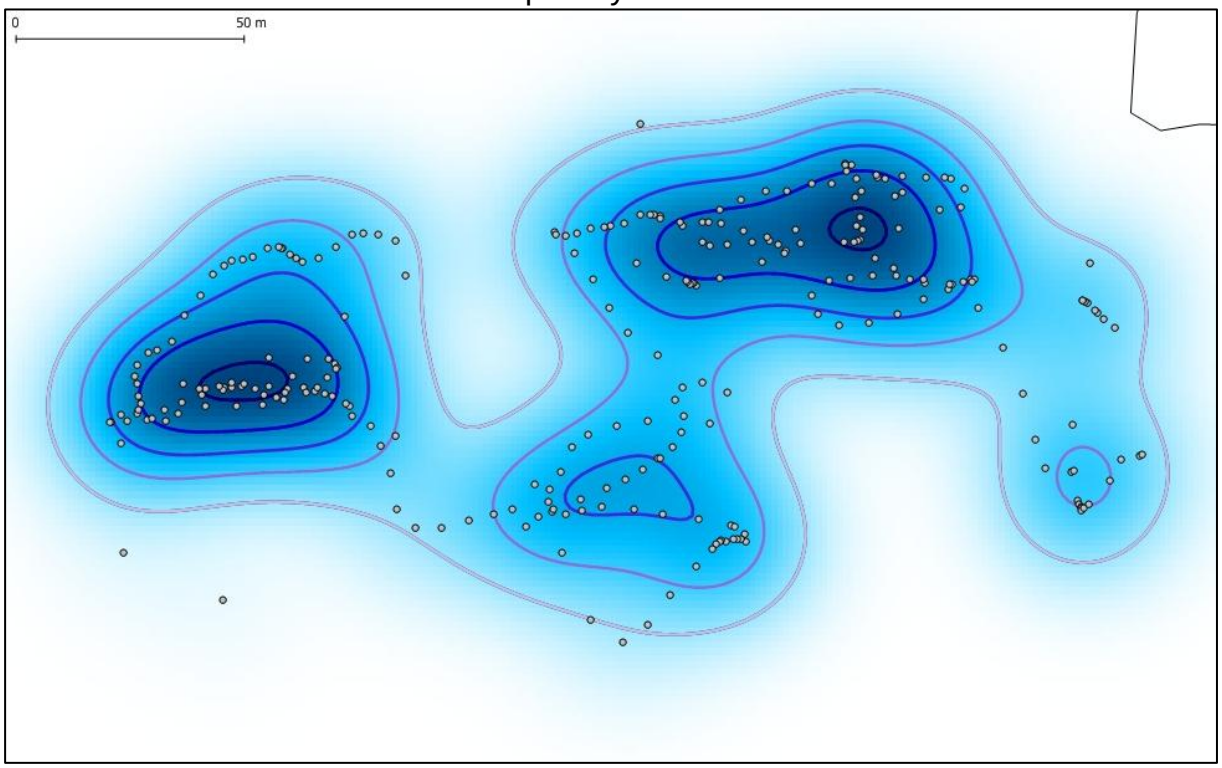


Figure 2. GPS points associated with two dive events, and area of 50% (inner dark blue) and 90% (larger light blue) contours of the KUDs. These show the areas estimated to enclose 50% or 90% of the GPS points from each dive, based on the KUD model's estimate of point density. Note, coastline is not shown to retain privacy.

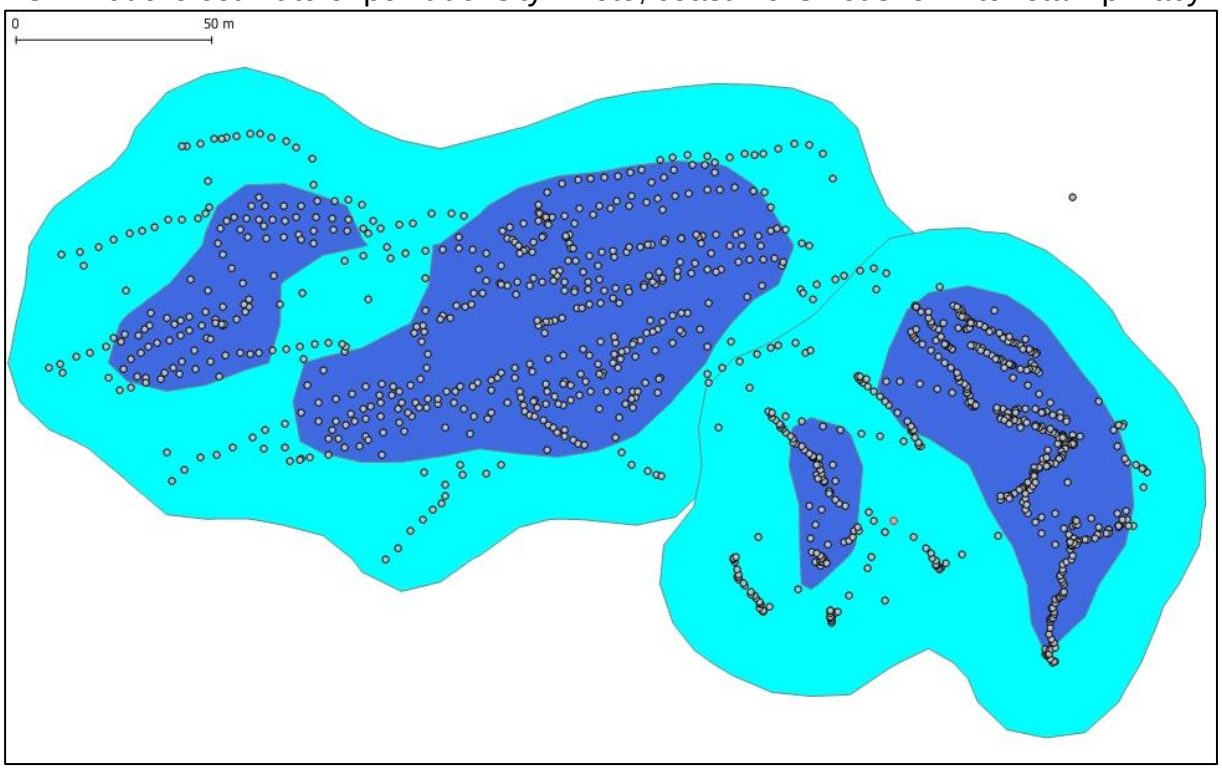
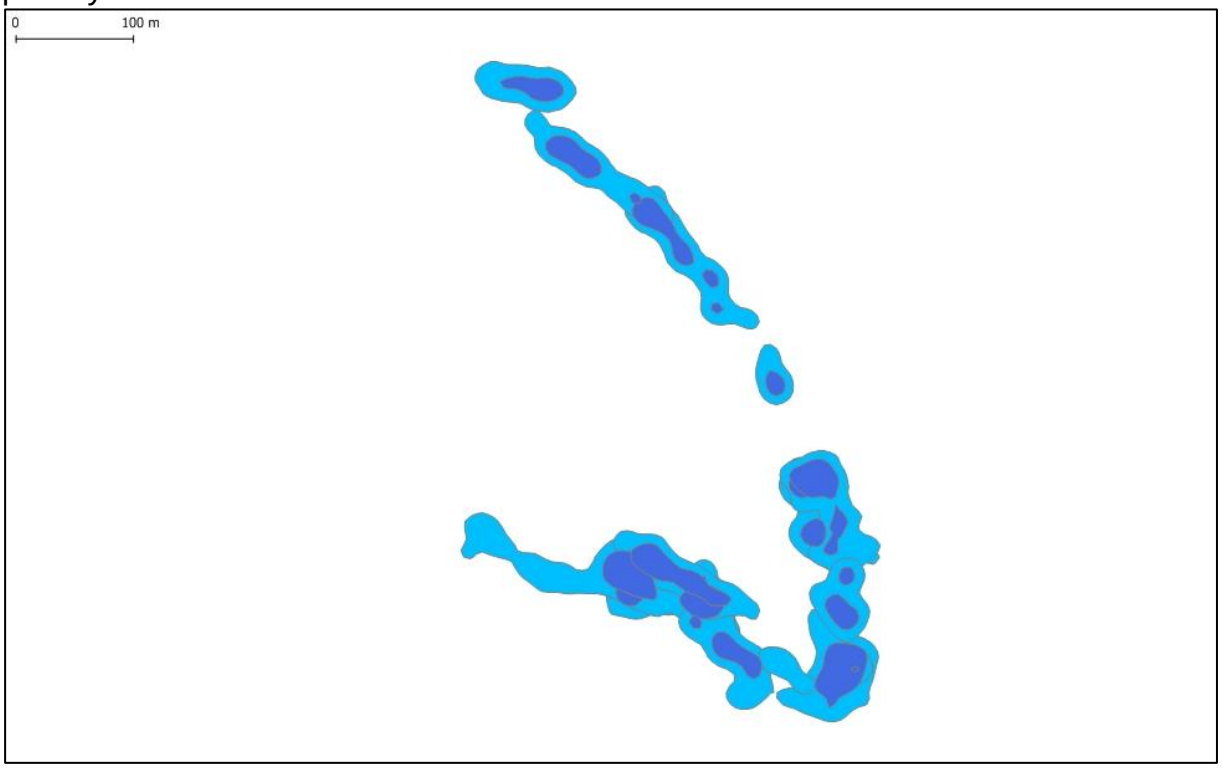


Figure 3. Both 50% and 90% contours of the KUD for 9 dive events in 2008-09 around a point in Region 2. These demonstrate the areas of productive abalone populations fished by divers within the year. Note, coastline is not shown to retain privacy.



Summary information about KUDs of dive events by 7 divers in Region 1 and 2 are presented in Table 1. While total effort and catch varied significantly among the divers, and there was relatively little directly comparable data where different divers fished in the same place, there are clearly some major differences among the divers in their pattern of fishing effort that are consistent with expectations. Some divers cover much larger distances within each dive event, while others can have many more, shorter dive events. Divers with smaller (i.e. shorter maximum distance) dive events also tend to have KUD contours with a higher perimeter to area ratio. While these differences among divers are confounded with spatial differences, they demonstrate the ability of GPS loggers and dive event KUD to detect differences in fishing patterns that may occur as abalone stocks change, and spatial patterns in fishing effort of divers respond, through time. Apparent differences among divers also emphasize the need to better understand individual diver's spatial patterns in fishing effort, and how they might change in response to a variety of influences including changes in the stock, to allow some form of standardisation when using the information to monitor changes in the stock, particularly when a low number of divers has fished in an area (e.g. Region 1 and 2).

Summary information about KUDs of dive events in selected subzones within Region 1 and 2 are presented in Table 2. As with comparisons among divers, there is also considerable confounding of comparisons among subzones, and limited opportunities to compare the same diver in different subzones or areas. Despite that, there are clearly some major differences in fishing patterns among subzones that are consistent with expectations. For example, dive events in subzones D1-D2 are smaller (i.e. smaller maximum distance), consistent with known, isolated patches of

abalone in the area. Dive events through subzones J and K are larger, consistent with a diver that had not fished in the area before and was more generally searching the reef. These differences again demonstrate the ability of GPS loggers and dive event KUD to detect differences in fishing patterns that may occur as abalone stocks change, and spatial patterns in fishing effort of divers respond, through time. These differences also highlight the ability of changes in fishery management to influence the spatial patterns in fishing effort of divers, which could confound temporal comparisons being used to monitor changes in the stock. The snapshot of patterns in fishing effort presented here, following opening of the closures in Region 1 and 2, will be important for reference in future years.

Table 1. Average (with SD) measures of dive events recorded on GPS loggers by 7 divers in Region 1 and 2. Maximum distance refers to the maximum distance between any two points within a dive event. Divers are not identified to respect privacy.

Diver	Dive events	Maximum distance m	90% KUD polygons per dive event	50% KUD Area m^2	90% KUD Area m^2	90% KUD Perimeter:Area Index
AD001	36	193 (194)	1.6 (1.1)	952 (618)	3583 (1892)	0.17 (0.03)
AD002	10	290 (182)	2.5 (1.7)	2533 (1569)	10977 (5252)	0.16 (0.04)
AD004	14	216 (205)	1.8 (1.1)	749 (621)	3308 (3036)	0.19 (0.03)
AD006	64	165 (125)	1.4 (0.7)	709 (339)	3076 (1491)	0.18 (0.01)
AD007	63	310 (213)	2.6 (1.6)	2007 (1235)	6974 (4190)	0.15 (0.04)
AD023	72	472 (274)	4.1 (2.4)	2376 (1466)	8627 (5203)	0.17 (0.02)
AD024	92	67 (102)	1.2 (0.5)	470 (415)	1870 (1679)	0.22 (0.04)
All		220 (226)	2.1 (1.8)	1300 (1236)	4884 (4374)	0.18 (0.04)

Table 2. Average (with SD) measures of dive events recorded on GPS loggers for subzones in Region 1 and 2, selected with a large number of dive events during the Structured Fishing Program.

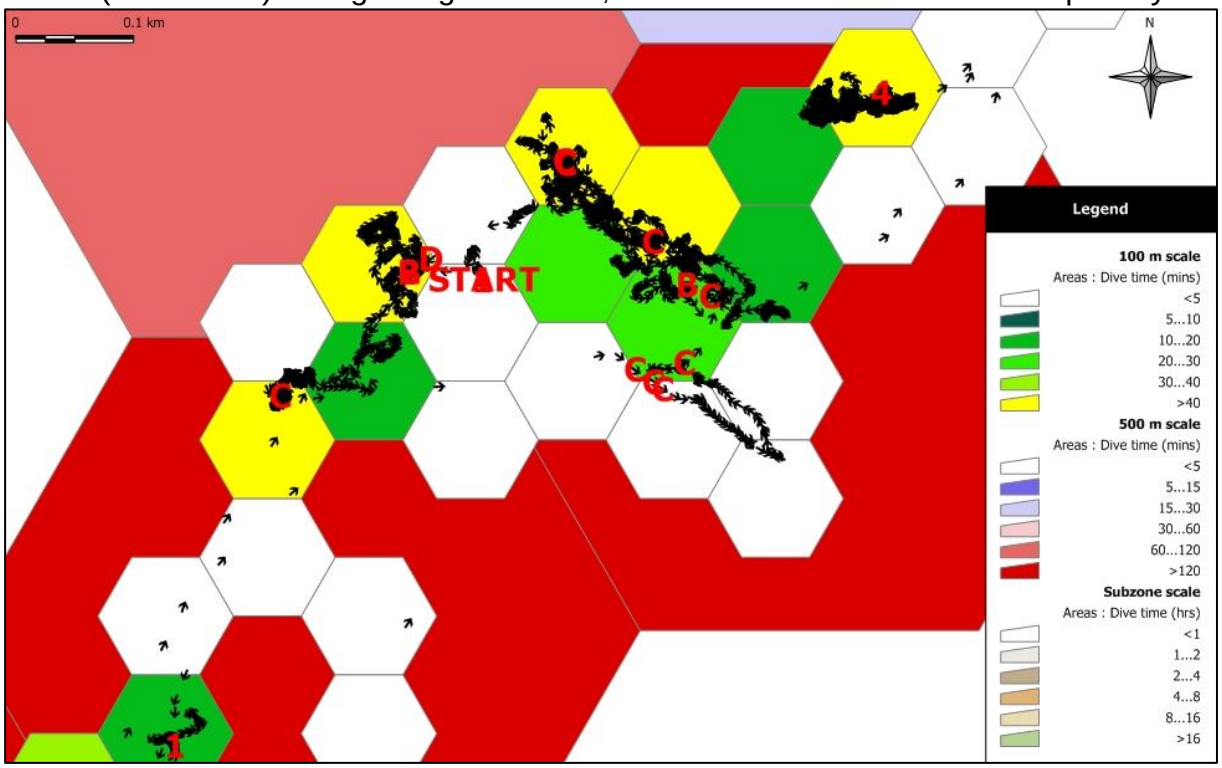
Subzone	Dive events	Maximum distance m	50% KUD Area m^2	90% KUD Area m^2	50% KUD : 90% KUD Index
D1	37	110 (135)	533 (461)	2097 (2175)	0.26 (0.04)
D2	29	28 (41)	354 (376)	1425 (1593)	0.26 (0.02)
F1	13	122 (89)	668 (439)	2943 (2024)	0.25 (0.06)
J3	25	509 (284)	2523 (1621)	9121 (5565)	0.27 (0.03)
J4	12	354 (185)	2215 (1264)	7934 (4385)	0.28 (0.03)
K2	10	434 (328)	2898 (1956)	10464 (7434)	0.28 (0.03)
K3	19	464 (321)	2036 (1306)	7622 (4628)	0.26 (0.04)
N1	18	305 (250)	1610 (1448)	5718 (4781)	0.28 (0.06)
N2	18	149 (156)	618 (316)	4172 (4233)	0.20 (0.07)
P1	22	294 (249)	1350 (910)	4924 (3034)	0.27 (0.05)
P2	75	233 (185)	1380 (1140)	4967 (3771)	0.27 (0.06)
P3	24	223 (185)	1292 (686)	5304 (2761)	0.25 (0.06)
R1	10	209 (190)	1704 (1564)	6059 (5425)	0.28 (0.03)

Currently, NSW is the only fishery with full uptake of the GPS and Depth loggers. There appears now to be an intent from all divers to run loggers at all times, and an intent within Industry and DII to appropriately fund the GPS logger program as a core responsibility of the fishery. The continued use of GPS loggers by all divers in NSW, and the application of derived performance indicators in fishery management, is likely to provide a valuable data series for evaluating these emerging, cost-effective techniques. There is now a strong need to continue the further development and automation of methods of analysis of this spatial data to allow monitoring over several years to demonstrate which measures derived from the GPS logger data are more responsive fishery performance indicators.

Supplementary information from loggers

While there are comparisons within and among divers in their observations of undersize abalone, they are not extensive enough to provide summary information. Further, because of the ongoing training and uptake of reporting undersize observations, the limited number of comparisons downloaded to date and the need to retain privacy, only an example of comparisons is possible here (Figure 4). In total, about 200 observations of undersize have been reported, downloaded and analysed to date. In contrast, most divers have been regularly reporting the position that bins of abalone were filled, with over 1000 positions reported equivalent to about 25 t of abalone. Positions that bins of abalone were filled were often concentrated in similar areas, potentially because of both the position of productive abalone populations and the habit of filling bins in areas not exposed to more exposed weather. Positions that bins of abalone were filled as recorded on GPS loggers were also consistent with the reported latitude and longitude grids required for logbook reporting.

Figure 4. GPS points (black arrow showing direction) from Region 2, with associated undersize observations by divers (1 bottom left, and 4 top right) and indication of bins filled (B, C or D), with summed fishing effort in 100 m (green to yellow, overlaid) and 500 m (blue to red) hexagonal grids. Note, coastline is not shown to retain privacy.



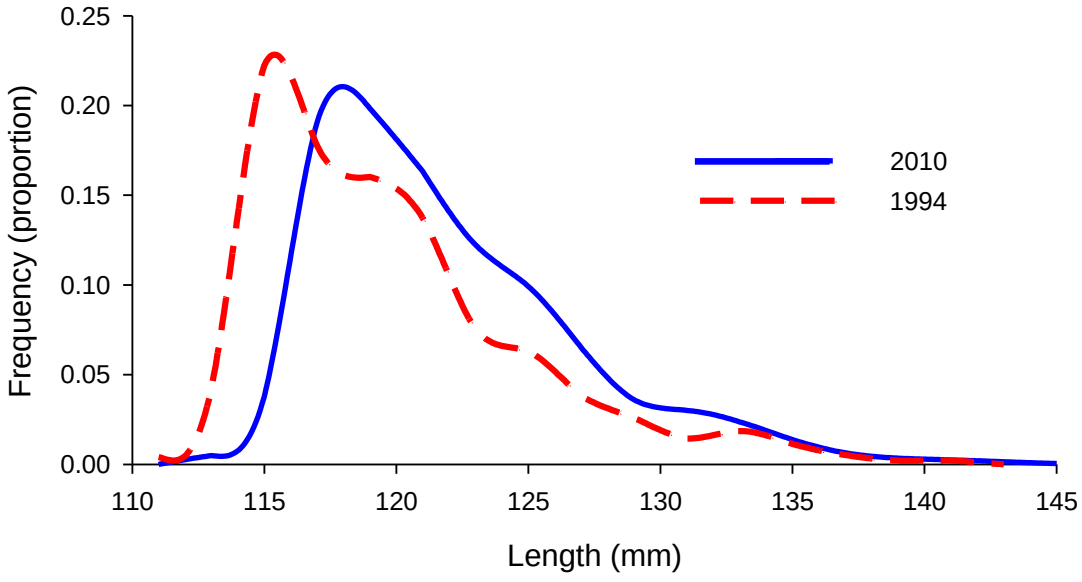
There is a need to continue to develop, encourage and train divers in the reporting of undersize abalone. The fishery in NSW appears likely to continue to be strongly influenced by the progression of cohorts of undersize abalone, and observations of the abundance of undersize should enable some predictive ability about changes in stock size. While training all divers to report undersize observation has proved difficult, it may perhaps be more cost-effective to concentrate training and encourage uptake by key, informed and dependable divers. Revision of the approach to reporting the position that bins were filled could also liberate deckhands to enable a greater uptake of undersize reporting.

Length measuring program

Information on the length of abalone landed was collected throughout the fishery until 2000. In 1999, extensive measuring of the length of landed abalone was completed in an attempt to calibrate a newer method of monitoring the mean weight of abalone within bins. The intent of this project was to develop a cost effective measuring program that could provide information on the length-structure of landed abalone, and be linked with logbook catch reporting to fine scale spatial information from GPS loggers. This could provide a spatial map of the length of abalone landed. While this could most easily be achieved through operation by deckhands on boats, this is not always possible and a much greater coverage will be possible in processors.

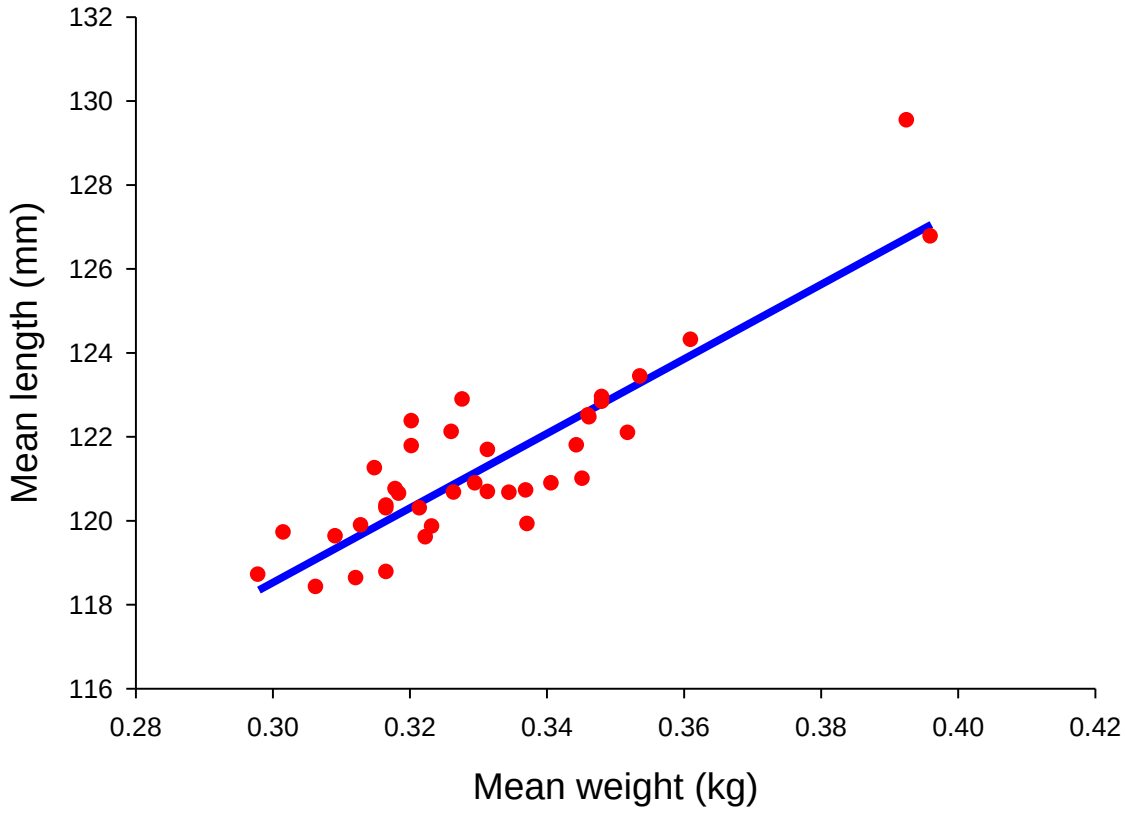
The size structure of landed abalone was estimated in Region 2 from a sample of 2027 abalone measured from January-March 2010. Sampling effort was concentrated in Region 2 because of the sensitivity of the area and the proximity of a processor. Most abalone landed were close to the minimum legal length of 117 mm, and the largest abalone landed was 145 mm (Figure 5). Larger abalone (i.e. 117-135 mm) were generally more frequent in the sample of the landed catch from 2010 when catch rates were over 30 kg/hr, compared to 1994 (i.e. the reference year from the fishery Management Plan) when catch rates were about 18 kg/hr.

Figure 5. Shell length-frequency estimated within Region 2 from 2027 abalone measured with a GPS-enabled measuring logger in 2010 (solid line) when catch rates were 31.4 kg/hr, and 968 abalone measured using callipers in 1994 (dashed line) when catch rates were 18.1 kg/hr.



There was a strong linear relationship between the mean length of individual abalone measured and the mean weight of abalone calculated from the weight and number of abalone per bin (Figure 6). Variation in length among abalone within bins was also linearly related to mean length and weight. Together, these relationships suggest monitoring of the mean weight of abalone provided for every bin landed in the fishery through logbook catch reporting, can provide a good indicator of the length of abalone being landed, and with the associated GPS logger information, a spatial map of the sizes of abalone that were landed.

Figure 6. Relationship between the mean length of landed abalone measured from bins of abalone collected in Region 2, and the mean whole weight of abalone from the same bins. A linear relationship is fitted suggesting the mean whole weight of abalone calculated from figures provided for all bins landed as part of logbook catch records is closely related to the mean length of abalone within the bin



While there is a long history of information about the length of abalone landed in the NSW fishery, no routine measuring has been completed since 2000. Despite that, information from logbook catch records about the mean weight of abalone landed is likely to be a good indicator of the length of abalone landed during this period. This project developed a process where individual lengths of landed abalone are measured, and able to be associated with logbook catch records and GPS logger information, to provide a spatial map of the length and weight of abalone landed. It is proposed to invest further in the purchase of GPS-enabled measuring loggers, and their use in processors and on boats as a core responsibility of the fishery targeting specific questions (e.g. size limits) and sensitive areas.

Structured Fishing Database development

Five databases have now been developed to facilitate the further development of Structured Fishing surveys in NSW. In addition to the databases themselves, there now exists a series of views and queries in TSQL to interrogate and summarise the databases, and add additional data as it becomes available, particularly through the interaction with Manifold GIS. Outputs from each of these databases have been summarised throughout this report. The databases include:

- AbTrack - the raw GPS and Depth logger data downloaded from all loggers, including that collected in the Structured Fishing Program in Region 2.
- Catch - data owned by DII but released to the Abalone Council of NSW describing logbook data of bin based catch records.
- NSW Features - geometry of coastline and reference grids of different sizes and shapes.
- Outputs - KUD geometry and grid summaries and other results of analysis and linking other databases.
- Structured Fishing sites - geometry and historical information about sites identified with productive abalone populations for potential use in development and application of structured fishing designs.

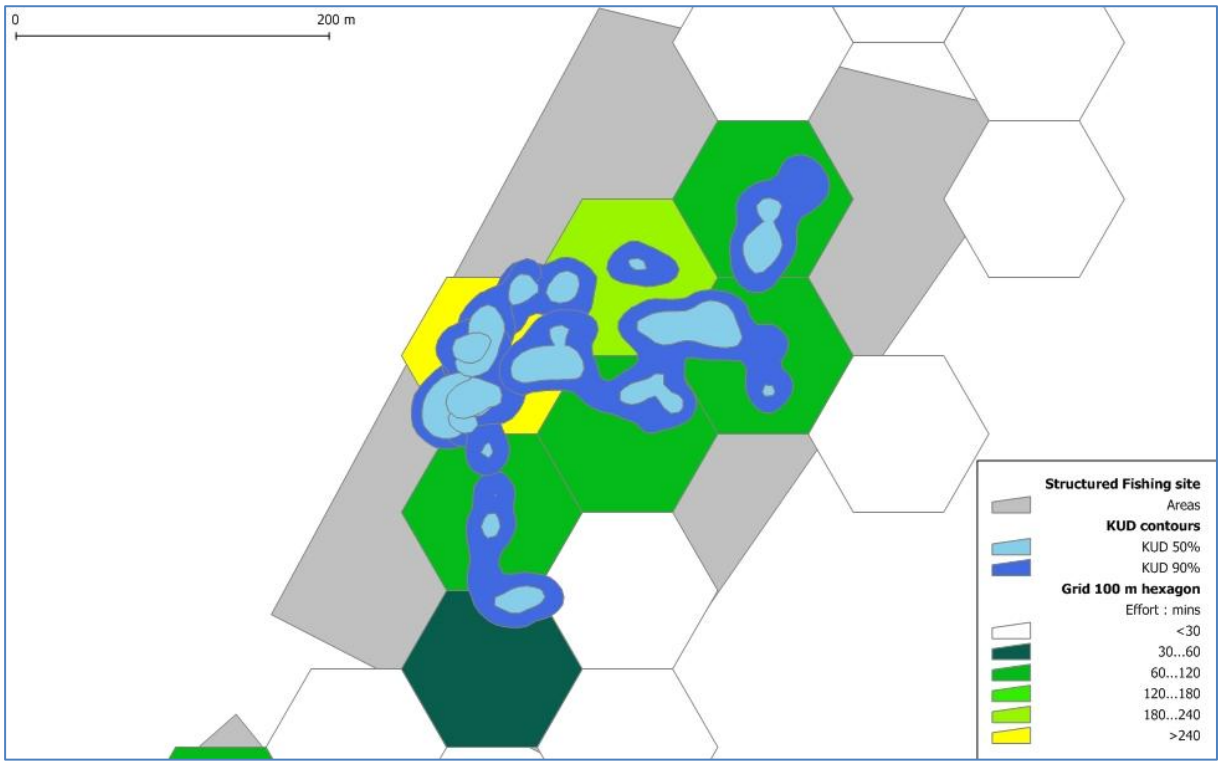
Sites with documented fishing activity, and others without recent activity, were identified in Manifold GIS and their spatial extent recorded as a geometry instance in a SQL Server database. Other information stored in the database also includes all available information about the site, including any anecdotal historical information collected during interviews. Over 350 separate dive events have been recorded to date in Region 1 and 2, and over 100 sites have been selected for addition to a pool of sites suitable for structured fishing designs (Table 3 and Figure 5), with more sites being added, and existing sites modified, as more information from loggers and interviews becomes available. Further sites have also been selected throughout the rest of the fishery.

Table 3. Number of sites, and average site area, with logged fishing activity for subzones in Region 1 and 2, documented in the Structured Fishing sites database with supplementary information.

Subzone	Number of sites	Average site area (ha)
D1	5	40
D2	4	7
E2	4	10
F1	3	9
F2	1	12
G2	3	21
J2	3	30
J3	5	23
J4	4	17
K2	5	18
K3	9	13
M1	2	17
M2	5	14
N1	6	21
N2	7	13

N3	1	13
P1	7	11
P2	23	9
P3	10	9
Q5	1	24
R1	1	24

Figure 5. Map showing an area of 12.1 ha defined as a Structured Fishing site (grey polygon), overlaid with KUD contours of dive events (blue) and 1 ha grid summary of GPS points (green to yellow) from a site within Region 2. Note, coastline is not shown to retain privacy.



In addition, late in the project it has also been possible to work further with FRDC project 2006/029 to develop the AbTrack database to include the historical and recently-collected information on abalone lengths, and coordinate any future length information from the GPS-enabled measuring logger in NSW.

While this project has commenced the development of databases for management of fine scale spatial information about fishing and stocks, data collected at this scale has only been collected for a few years. While the information collected by this project will contribute to the future design and interpretation of information from commercial fishing, this benefit will increase significantly through time as more information is collected and used. There is a strong need to maintain and further extend the databases developed by this project, as a core responsibility of the fishery.

BENEFITS AND ADOPTION

This project has provided a range of outputs and outcomes to all Stakeholders in the NSW abalone fishery, as well as delivering strategic information and potential benefits to other abalone fisheries. Principal among these is the development and implementation of more cost-effective technology for the collection of fine spatial scale information for assessment of abalone populations. These were initially implemented in Region 1 and 2 of the fishery, and then developed and extended throughout the fishery.

Stakeholders in the NSW fishery will benefit from greater knowledge of the current recovery and future change of abalone populations in NSW, which has already flowed to better inform management of the fishery. The project will also deliver outcomes that directly benefit Divers, Shareholders and the Abalone Council of NSW, through the development of capacity to train divers and implement Industry-based surveys and structured commercial fishing surveys of abalone populations.

This project had also demonstrated the capacity of the abalone industry to cooperatively manage, with government fishery management agencies, the development and application of cost-effectively technologies to collect large, fine scale spatial data sets to contribute to the assessment and management of abalone stocks and their fishery. The success of this project in NSW, with technology mostly developed in Tasmania, demonstrates the potential of a standard spatial data collection and analysis system throughout Australia's abalone fisheries. The benefits of such a system should be developed further and extended throughout all abalone fisheries.

DII, Industry and the Abalone Council of NSW will continue to develop the monitoring and 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 NSW, for use in their management.

FURTHER DEVELOPMENT

Several directions are important to the ongoing development of the resources established during this project, and assessment and management of the abalone fishery in NSW. These include:

- A commitment to fund further development of all resources developed by this project as a core responsibility of the fishery.
- Continued collection and use of fine scale spatial data to further increase background knowledge of fishing and abalone stocks at this scale.
- Continued development of the spatial information collection, management and analysis system, based around AbTrack, to further automate calculation of key fishery performance indicators.
- Development of workshop processes, with divers and Shareholders, to consider fine scale spatial data and better inform fine scale assessments for TAC setting and catch planning.
- Full fishery application and testing of GPS logger based fishery Performance Indicators as abalone stocks change through time.

The continued use of GPS loggers by all divers in NSW, and the application of derived performance indicators in fishery management, is likely to provide a valuable

data series for evaluating these emerging, cost-effective techniques. There is now a strong need to continue the further development and automation of methods of analysis of this spatial data to allow monitoring over several years to demonstrate which measures derived from the GPS logger data are more responsive fishery performance indicators.

PLANNED OUTCOMES

Describe how the project's outputs will contribute to the planned outcomes identified in the application. Describe the planned outcomes achieved to date.

This project has delivered a range of outcomes to Stakeholders in the NSW 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, and their implementation in Region 1 and 2 of the fishery, and then development throughout the fishery.

Stakeholders in the NSW fishery have and will continue to benefit from greater knowledge of the recovery and future change of abalone populations in NSW and their future management. The project will also deliver outcomes that directly benefit Divers, Shareholders and the Abalone Council of NSW, through the development of capacity to train divers and implement Industry-based surveys and structured commercial fishing surveys of abalone populations.

These outcomes will continue to deliver benefits of a more cost-effective and auditable method of collecting finer-scale information about the status and productivity of populations, and improvements in profitability. Potential development and application in other state's abalone fisheries could deliver similar benefits.

CONCLUSION

The information collected in GPS and Depth loggers clearly provides detailed information about patterns of fishing effort, observations about stocks, and through links to logbook catch reporting, related catch. Anecdotal evidence from past fluctuations in abalone stocks in several fisheries suggests change in diver's fine-scale patterns of effort, catch and observations, often precede broader-scale (e.g. zone, region) changes when a stock declines.

GPS and Depth loggers provide a very cost-efficient method of collection of fine-scale information about fishing and the stock, thanks particularly to the very significant in-kind contribution by Industry to their operation. All resources developed in the project received significant in-kind support by Industry to produce cost-efficient outcomes respected by the Industry because of their involvement. Despite being a potentially very useful measure of the stock, uptake of recording of observations of undersize by divers was initially slow, but with ongoing training and logistical changes appears and should increase, producing very cost-effective information that can not be replaced by independent surveys without enormous expense.

This project has developed a detailed spatial information collection, management and analysis system for delivering fine scale spatial information about fishing and stocks in the NSW abalone fishery. There is now a strong need to continue the development and automation of methods of analysis of this spatial data to allow

monitoring over several years to demonstrate which measures derived from the GPS logger data are more responsive fishery performance indicators. Use of the tools developed in this project, together with an ongoing commitment to resource and implement appropriate structured fishing designs, will be able to better inform fine scale assessments for TAC setting and catch planning through a process with strong Industry involvement that is currently being developed in the fishery.

The continued use of GPS loggers by all divers in NSW, and the application of derived performance indicators in fishery management, is likely to provide a valuable data series for evaluating these emerging, cost-effective techniques like GPS loggers. There is now a strong need to continue the further development and automation of methods of analysis of this fine scale spatial data to allow monitoring over several years to demonstrate which measures derived from the GPS logger data are more responsive fishery performance indicators.

REFERENCES

APPENDIX 1: INTELLECTUAL PROPERTY

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

APPENDIX 2: STAFF

Dr Duncan Worthington
Consultants and staff from Ambrad Consulting and Southern Ocean Seafoods.

APPENDIX 3: DRAFT REPORT

Structured Fishing Program in Region 1 and 2

A draft report for public release prepared by the Abalone Council of NSW, January 2010

Background

Commercial fishing can be structured to provide more information about abalone stocks from the data collected while fishing. Structured fishing can take a range of forms from heavily structured designs with extensive spatial regulation of fishing, through to less regulated fishing with very simply structured spatial designs. The level of structuring and regulation used in any design should be closely related to the intent and questions attempted to be answered by the fishing. Both the structure and intent of any structured fishing design, and hence the information about stocks available from it, will also be influenced by the resources available.

In April 2008, the Minster approved the introduction of a structured fishing program in Regions 1 and 2 for the commercial harvest of abalone. The intent of the Structured Fishing Program was described by IINSW "to provide information about changes in abalone stocks and to spread the commercial catch appropriately". Further detail about the Structured Fishing Program is found in the IINSW advice to Industry in Appendix 1 and 2.

The TAC Committee have also made a series of recommendations about new information and analyses to be provided. In particular, the TAC Committee recommended that structured fishing be used to "address the extent of stock depletion, the relative abundance of sub-legal abalone and calibration ... (with the past) fishery independent surveys". Further detail about the Committee's recommendations can be found in Appendix 3 and their annual determination.

The Structured Fishing Program currently in place in Region 1 and 2, and being extended throughout the fishery, attempts to provide the information recommended by the TAC Committee, within the bounds of the resources available to the fishery from IINSW and Industry. Because of the limited resources available to the fishery, and because of other factors such as temporal variation in stocks, the program will not provide answers to all recommended questions in the short term. Rather, to best address the recommendations of the TAC Committee, the program is planned to run for several years, and is likely to become an ongoing part of the commercial fishery.

This report, which was required as part of the commitment necessary for funding support from IINSW, will summarise background, implementation and information gathered from the Structured Fishing Program, and Region 1 and 2, with the vast majority of data available until December 2009. The report presents summary data, but procedures for handling, analysis and presentation of the data are still being developed. In addition to this report, which contains a summary of all available catch information at a 500 m scale, a further report for public release has also been prepared without this information to protect the privacy of the spatial data, while demonstrating the stage of development and potential of the information.

This data and report were only possible with funding provided by some Shareholders to the Abalone Council of NSW, the support of the Fisheries Research and Development Corporation, and Craig Mundy at the Tasmanian Aquaculture and Fisheries Institute in lending GPS loggers and providing database development and support to the Abalone Council of NSW. IINSW provided 6 GPS loggers and funding after the 2008-09 fishing was completed, and IINSW supplied and retains ownership of

logbook catch data in this report. Uncertainty about available resources continues to significantly limit progress in the use of loggers throughout the fishery.

Design

As described in the IINSW advice to Industry, there were two main components to the design of the Structured Fishing Program when it was established in October 2008. The first component was to spread the commercial catch appropriately across the extent of stocks in Region 1 and 2. To achieve the appropriate spread of catch, a catch plan based on historical catches and structured by sub-zone, including targets and voluntary caps, was prepared and agreed to by Industry and IINSW, and the distribution of actual catches were monitored through the year against the plan. As actual catches approached targets in an area, extensive communication within Industry was used in an attempt to control catch within the voluntary cap. Because of the time period between catch and reporting of catches, which can be several weeks, there can be some implementation error where catches can exceed caps prior to reporting, although such errors are generally small (e.g. <10%) and incorporated when setting caps. The catch plan also acknowledged the uncertainties of stock abundance and the most appropriate spread of catch, and the difficulties of weather and commercial logistics to the actual catching of abalone. A proposal to control the smaller-scale spatial distribution of catches, particularly to areas not chosen to be fished, was not implemented because of a lack of resources.

The second component of the Structured Fishing Program involved the collection of data about fishing, and the development of observations of under-size abalone populations, to provide information about stocks and their changes. This involves the voluntary collection of data in addition to the regulated requirements of completing the daily log-sheet. Most importantly, all commercial divers now have access and operate Global Positioning System (GPS) loggers that record the position of the boat every 10 seconds, and Depth and Temperature Sensing (DTS) loggers on the diver that also record every 10 seconds. In addition to recording position, the GPS loggers now enable recording of when a bin of abalone is filled and observations of the abundance of sub-legal or under-size abalone (i.e. when chosen, the ability to record abundance on a scale of 1-5 of abalone likely to recruit to the fishery over the next 1-2 years). The GPS loggers now also display the current latitude and longitude of the boat, and at the end of the fishing day cycle through the locations where it was recorded the bins of abalone were filled, to help facilitate correct recording of details on logbooks. Use of the loggers in this was has significantly improved logbook reporting, standardisation and encouraged use of the loggers.

The two data streams from GPS and DTS loggers are associated through the specific time of each record, and also linked to the daily logbook records required by regulation and maintained by IINSW. In this way, commercial divers contribute to information about a spatial map of abalone populations, that includes information about their size and productivity (e.g. catch, effort, catch rate), growth (e.g. mean size in catch) and recruitment (e.g. observations of under-size). In addition, information about the lengths of abalone caught is now being collected, and related to estimates of the mean weight of abalone caught for each bin.

During the Structured Fishing Program several different types of GPS loggers were initially used because of the limited resources available. Older loggers, with less reliability and a limited ability to record the filling of bins and other observations, were distributed initially to those most likely to fish in Region 1 and 2. Use of these older loggers resulted in some loss of GPS data from some divers and

loggers. Subsequently, as newer, more reliable and advanced loggers became available they were distributed to others likely to fish in Region 1 and 2. Finally, new loggers were purchased in mid-2009, and all divers now have the same style of logger available with the same firmware that enables recording of undersize abalone.

Data about the spatial distribution of fishing is covered by NSW Privacy legislation, including catch records from the daily logbook required by regulation and GPS/DTS records collected voluntarily. The Abalone Council of NSW arranged the necessary approval from all divers involved in the Region 1-2 Structured Fishing Program for release of logbook catch records from IINSW and the agreed use of GPS/DTS records. Spatial and personal information about catch will be limited in the public release of data (such as this report), while spatial information about catch released to IINSW will match and exceed that required by regulation in the catch logbook. In this report, all data currently available about Region 1 and 2 will be presented at a 500 m scale with identifying coastline, while some examples of data at a 100 m will be presented without the associated coastline (or other distinguishing features) to aid privacy. Since July 2009, the logbook data collected allows direct comparison with logger data at a finer spatial scale, and will enable regular audit of data collected based on comparison of the two independent data sets prior to association. Unfortunately, comparisons will be limited by the logistical difficulties of the logbook hand-paper based system of longitude and latitude reporting and the dangers of recording data by hand while navigating/diving. IINSW have expressed the potential for loggers to replace the requirement to report latitude and longitude on logbooks, and a more cost-efficient catch recording system could involve divers reporting the subzone and time of filling for each bin on logbooks, for subsequent association with logger records.

Results

General catch distribution

During the 2008-09 Structured Fishing Program, a voluntary plan for the spatial distribution of catch was agreed, and actual catch was monitored against the plan (Table 1). Actual catch approached the cap in areas of Region 1 south (i.e. F1-F2 and K1-K2) and Region 2 (i.e. P1-Q5), and extensive communication within Industry advised divers likely to fish in these areas to avoid further catches that would push catches above the caps. Actual catch did not exceed the agreed voluntary cap in any area.

Table 1. Spatial plan and actual distribution of catch (kg) as part of the 2008-09 Structured Fishing Program and TAC.

Area	Sub-zones	TAC Committee Recommendation 2008/09	Target catch (kg)	Cap (kg)	Actual catch (kg)
Region 1 North	**A-C2**		**250**	**500**	**177**
	D1		**1500**	**2000**	**522**
	D2		**1000**	**1500**	**158**
	E1-E4		**500**	**1000**	**265**
	Total	**5000**	**3250**		**1122**
Region 1 South	**F1-F2**		**250**	**500**	**354**
	F3-F4		**500**	**1000**	**100**
	G1-G2		**500**	**1000**	**160**
	G3-G4		**250**	**500**	**0**

	H1-H3		250	500	0
	J1-J5		750	1250	252
	K1-K2		250	500	461
	K3		1000	1500	293
	K4		1000	1500	629
	L1-L4		250	500	558
	Total	5000	5000		2806
Region 2	M1-M2		500	1000	260
	N1		750	1250	623
	N2-N3		250	500	260
	P1		750	1250	991
	P2		1250	2250	1689
	P3-P4		750	1250	900
	Q1-Q5		500	1000	921
	R1-R2		500	1000	229
	Total	5000	5000		5875
Region 3-4	S1-X2	40000			39241
Region 5-6	Y11-Z5	50000			54239
Total		105 000			103 283

Nine divers fished in Region 1 and 2 during the 2008-09 Structured Fishing Program, for a total of 398 hours over 100 days (Table 2). During this time, a total of 9.8 t of abalone were caught at an average of 24.6 kg/hr. Only 1 diver fished in Region 1 North, and catch in the area was well below the target, partly because the program did not cover the main late Winter fishing period for this area and other Industry logistic complications, but 1.1 t was caught over 11 days. Six divers fished in Region 1 South, with 2.8 t caught in 31 days, but generally very little overlap in the area fished by different divers, and catch limited by the program not covering the Winter fishing period and Industry logistics. Five divers fished in Region 2 and caught 5.9 t in 58 days. Only three of the nine divers fished in more than one of the three broad regional areas. The average size of abalone caught was largest in Region 1 North, partly because of individual fishing practices, and Region 1 South following extensive closure of the area over the past 10 years.

Table 2. Summary of information about catch and effort during the 2008-09 Structured Fishing Program in Region 1 North, Region 1 South and Region 2.

Measure	Diver									Total
	A	B	C	D	E	F	G	H	I	
Days	1	16	21	3	5	12	7	15	20	100
Hours	5	73	80	13	22	47	27	62	69	398
Hours/day	4.6	4.6	3.8	4.3	4.3	3.9	3.8	4.2	3.5	4.0
Catch	100	1475	2689	185	721	1611	477	1105	1438	9802
Catch/day	100	92	128	61	144	134	68	73	71	98
Catch/hr	21.7	20.1	33.6	14.2	33.5	34.2	17.7	17.7	20.7	24.6
Catch Region 1N		1122								1122
Days Region 1N		11								11
Hours Region 1N		48								48

Av. size Region 1N		**362**							**362**
Catch Region 1S	**100**	**354**	**1638**	**185**		**477**	**52**		**2806**
Days Region 1S	**1**	**5**	**14**	**3**		**7**	**1**		**31**
Hours Region 1S	**5**	**25**	**46**	**13**		**27**	**3**		**119**
Av. size Region 1S	**313**	**325**	**337**	**296**		**312**	**318**		**326**
Catch Region 2			**1051**		**720**	**1611**		**1054**	**1438**	**5875**
Days Region 2			**7**		**5**	**12**		**14**	**20**	**58**
Hours Region 2			**34**		**22**	**47**		**60**	**69**	**231**
Av. size Region 2			**319**		**291**	**302**		**297**	**297**	**301**

Catch rates varied among divers from 14-34 kg/hr, similar to variation among divers throughout the fishery. Because of the limited spatial overlap of areas fished by different divers, particularly within Region 1, it is unclear to what extent variation in catch rates at this scale can be attributed to differences among divers or among areas fished, although further information about this is available from the GPS loggers and historical catch rates of the divers involved (although these data were not made available by IINSW by the time of this report). Catch rates of individual divers during the 2008-09 Structured Fishing Program in Region 2 were generally much higher than previous catch rates in Region 2 (Table 3) and higher than catch rates in other regions of the fishery (Table 4). Catch rates in Region 1 and 2 generally increased through the 2008-09 Structured Fishing Program, as they did in all other regions of the fishery, and has been continued across all regions to 26.8 kg/hr in mid-December 2009.

Table 3. Catch rate (kg/hr) within Region 2 for the six divers involved in the 2008-09 Structured Fishing Program in Region 2, during three time periods.

Time period	**Diver**						**Total**
	C	**E**	**F**	**G**	**H**	**I**	
2006.08 – 2007.08	**25.5**	**22.2**	**20.2**	**24.0**	**14.6**	**14.6**	**17.1**
9 month closure							
2008.05 – 2008.06		**14.7**		**21.8**	**19.3**		**18.6**
2 month closure							
2008.08 – 2009.02	**31.2**	**33.5**	**34.2**		**17.6**	**20.8**	**25.4**

Table 4. Catch rate (kg/hr) for all divers in each Region of the fishery during three time periods.

Time period	**Region**						**Total**
	1	**2**	**3**	**4**	**5**	**6**	
2006.08 – 2007.08	**22.5**	**16.8**	**18.0**	**14.1**	**14.9**	**17.9**	**16.3**
9 month closure of Region 1-2							
2008.05 – 2008.06	**19.0**	**18.6**	**19.6**	**16.0**	**14.7**	**22.0**	**18.3**
2 month closure of Region 1-2							
2008.08 – 2009.08	**21.2**	**25.4**	**17.9**	**14.5**	**14.1**	**19.6**	**17.7**

Table 5. Catch rate (kg/hr) for all divers in each Region of the fishery coincident with the Structured Fishing Program in Region 1 and 2. Catch rate since June 2009 has further increased across all regions to 26.8 kg/hr in mid-December 2009.

Time period	Region						
	1	2	3	4	5	6	Total
2008.07			16.7	14.3	16.1	18.8	17.1
2008.08		44.0	12.8	13.2	12.6	20.1	16.6
2008.09	16.1	26.7	14.8	13.1	13.5	19.3	17.6
2008.10	42.2	23.2	19.1	13.8	13.1	17.7	16.5
2008.11	27.9	24.6	11.8	13.1	15.1	20.8	17.7
2008.12	28.7	18.4	21.5	16.4	14.4	21.3	19.2
2009.01		25.7	23.6	15.5	15.1	18.9	18.2
2009.02	20.7	26.8	21.0	20.3	17.4	18.6	20.0
2009.03	30.6		24.7	15.7	19.0	21.4	20.4
2009.04			25.1	20.0	19.3	23.8	22.2
2009.05	27.0		31.4	20.8	14.3	21.2	22.1
2009.06	31.0		34.8	22.0	14.8	19.8	22.9

Similar to differences in catch rate among divers, there were also differences in the mean size of abalone landed among divers (Table 6) and among areas (Table 7), although again because of limited spatial overlap of different divers it is unclear to what extent these differences can be attributed to differences among divers or among areas fished. Further information about this is available from the GPS loggers and historical catch rates of the divers involved (although these data were not made available by IINSW by the time of this report). The mean size of abalone caught during the Structured Fishing Program generally increased through time, and differences among regions remained very similar throughout the fishery despite the increase in size of abalone landed.

Table 6. Mean size of abalone (g) caught by each diver during the 2008-09 Structured Fishing Program in Region 1 and 2.

Time period	Diver									
	A	B	C	D	E	F	G	H	I	Total
2008.08						300				300
2008.09	313	331		296	299	311	312	298	303	309
2008.10			349		278	302		302	294	301
2008.11			349		283	261			288	322
2008.12		319	346			278		299		319
2009.01			316			317		294	304	310
2009.02			348			296		300	290	303
2009.03		386								386
2009.04										
2009.05		378								378
2009.06		349	312							326
Total	313	352	330	296	291	302	312	298	297	314

Table 7. Mean size of abalone (g) caught by all divers during the 2008-09 Structured Fishing Program in Region 1 and 2, and during periods before during and after in all regions of the fishery. Note also the change in state-wide minimum length limit from July 2008.

Time period	Region			
	1 North	1 South	2	All
2008.08			300	300
2008.09	360	313	304	309
2008.10		349	292	301
2008.11		349	280	322
2008.12	319	346	297	319
2009.01			310	310
2009.02		318	302	303
2009.03	386			386
2009.04				
2009.05	378			378
2009.06	349	312		326

	Region						
	1	2	3	4	5	6	Total
2006.01-06.2008	334	287	288	281	273	283	282
2008.07-2009.06	344	298	305	299	296	306	303

Fine-scale spatial information

There are currently over 500 000 records of GPS/DTS from 7 divers involved in the Region 1-2 Structured Fishing Program and 4 other divers fishing in areas further south. There are also over 500 records of where bins have been filled, equivalent to about 10 t of abalone. This data is currently stored in a password-secured SQL Server Database with the AbTrack Database Management system (regularly backed up on- and off-site) and queried through links from Manifold GIS. With the more extensive roll out of loggers from July 2009, with loggers now available to all divers, there are many more records currently in loggers, and a significant increase in the need for certainty of resources to download, maintain and analyse these records.

Several technical problems prevented the collection of all GPS/DTS records from the Structured Fishing Program, mostly related to problems associated with the operation of the older logger units (e.g. power supply, sticky buttons etc). In most cases where GPS data were lost by such technical problems, DTS data was retained demonstrating the intent to run the loggers. Some DTS data was lost from destruction of the units.

The simplest information available from the GPS loggers, includes the position and direction of the diver's boat every 10 seconds, together with the position that bins of abalone are filled (shown as B and C in Figure 1 over about 200 m). For each GPS position, a series of other data is also available, including the DTS depth, date and time of diving. For each position a bin of abalone is filled, there is also an associated record from the catch logbook database detailing the weight and number of abalone, and dive time (leading to estimates of mean size of abalone and catch rate) from the bin (Figure 1).

By combining the GPS logger information among divers, the spatial distribution of effort and catch by the fishery can be viewed and summarised at a range of spatial scales (Figure 2). To maintain the privacy of the information at very small spatial scales, and to enable efficient summary, the GPS records can be summarised in, for example, 100 m hexagons which can be coloured to demonstrate the level of dive effort (and other measures) within them (Figure 2c). In a similar way, the GPS records can also be summarised at a 500 m scale (Figure 2d), or at the subzone scale (Figure 2e). Further information, such as depth, catch rate, number of divers, mean abalone size per bin and undersize observations can then be overlayed on the histograms to provide spatial maps of these measures (e.g. Figure 2f). Technical procedures for summarising and presenting this additional information, and particularly associating the GPS/DTS and logbook databases, are currently being finalised and only some examples are presented here.

Figure 2 and 3 show the same area of coast at a range of scales. From the distribution of positions bins of abalone were filled, it is clear abalone stocks are aggregated on some areas of reef. For example, the GPS and bin full records on the far left of Figure 3c, and in the centre of Figure 3d, indicate an area where multiple divers filled bins of abalone on multiple days. Other areas of reef are fished and bins filled, but abalone stocks in some areas fill bins for multiple divers. This aggregation of areas where bins are filled is characteristic of the GPS records throughout the fishery.

All data from Region 1 and 2 at a scale of both 500 m and sub-zones are presented in Figure 3 (Note, only an example is shown in the report for public release). As well as showing the fine-scale spatial distribution of fishing effort, the GPS logger data has also highlighted some challenges for the existing logbook data. First, the GPS logger data provides a very detailed picture of the spatial distribution of fishing, which is not possible using the hand-paper spatial reporting in the logbooks. The impact of this difference is highlighted in Figure 3 with the map of fishing effort in sub-zone R1. At a scale of 500 m (and lower), it is clear only one headland has been fished, yet because of the position of the sub-zone border, this catch from one 500 m headland should apparently be reported to two, separate 15 km subzones. In this case, the increased fine scale spatial information from GPS loggers improves the understanding and interpretation of the logbook catch record. In a similar way, the GPS/DTS loggers provide a very detailed assessment of the amount of time spent by the diver in the water, which is not always possible for the 'dive time' reported on logbooks. A simple comparison of dive time recorded in these two ways makes clear there can be significant differences that influence logbook-based estimates of effort and catch rate. Again, the increased fine scale temporal information from GPS loggers improves the understanding and interpretation of the logbook catch record.

TAC Committee recommendations

The TAC Committee have made a series of recommendations over several years about fishing and information to be collected from Region 1 and 2. These recommendations are summarised in their determination report for 2009-10 (see Appendix 3). As well as analysis of past fishing data held by IINSW, they recommend analysis of the 2008-09 structured fishing data to "address the extent of stock depletion, the relative abundance of sub-legal abalone and calibration ... (with the past) fishery independent surveys".

A proposal to better address the extent of stock depletion by developing a database of historical information about fishing sites, and to control catch in an attempt to get information from those sites during the 2008-09 Structured Fishing Program, did not receive funding. A proposal to develop

the historical database did receive funding from the FRDC Tactical Research Fund after the 2008-09 Structured Fishing Program was completed, and the database is in the process of being developed to provide an improved ability to estimate stock depletion. Estimates of stock depletion compared to earlier years in the fishery's history will remain very problematic because of a variety of factors, including a lack of directly comparable data on catch and catch rates, including particularly limited spatial information. Currently, stock depletion can be estimated from the combination of estimates of the loss of productive reef area (e.g. from the Region 1 south survey) and reduction in stocks of abalone on still productive reef (e.g. proportional, in some way, to changes in commercial catch rates). Unfortunately, because of the limited spatial information about catch rates prior to the 1980's, comparisons of current catch rates, even with the current detailed GPS information about their position, can only be compared to broad-scale estimates of catch rates from the past. Moving forward, with the use of GPS loggers it will now be possible to compare detailed spatial catch rates through time, and remove the majority of spatial and diver confounding from the temporal comparison.

Depletion of abalone stocks in Region 1 and 2 can be estimated from the combination of estimates of the loss of productive reef area and reduction in stocks of abalone on still productive reef. Anecdotal estimates of the area of productive reef within Region 1 South, and those from the Region 1 South survey, suggest the loss of significant areas of productive abalone stocks, while there evidence for any significant loss in Region 1 North and Region 2 is limited. Reduction in stocks of abalone on still productive reef can be estimated by comparing catch rates as an indicator of stock biomass on still productive reef. Broad scale catch rates at sites where divers chose to fish during the Structured Fishing Program are approaching the highest on record, although catch rates at sites that that were not chosen by divers are not clear. Some individuals bins catch rates approached 90 kg/hr, and almost 1.7 t were caught at catch rates greater than 40 kg/hr. Catch rate can also be strongly influenced by rates of growth, with evidence of a strong growth of abalone throughout the fishery in 2009, so catch rates in the 10 months of the Structured Fishing Program are likely to have been influenced by this. Only with ongoing fishing over multiple years and growth trajectories will catch rates be more reflective of stock abundance.

Calibration of data from Structured Fishing and use of GPS loggers, with the past fishery independent surveys (FIS), will be possible to some extent. GPS records are able to identify catch records in close proximity to sites used in the FIS, and estimates of change in abundance in the FIS can be compared to changes in catch rates. For example, this includes several sites in F1, J2, K2-K3, N1 and P1-2, including FIS sites that had declined significantly or remained stable. It is clear from a brief review of the data that at a fine spatial scale there is considerable significant variation in the relationship between trends in abundance at individual FIS sites and subsequent local catch rates. For example, all 3 FIS sites in sub-zone P2 showed significant declines in abundance up to the final year of the surveys, while catch rates from areas within 100 m of those sites generally increased from before the final year of the surveys and are continuing to increase, in a pattern very similar to most other sites throughout Region 1 and 2, including those where abundances in the FIS were stable. In other words, at the fine spatial scale of individual sites, the abundance of under-size abalone in the FIS was not a good predictor of subsequent local catch rates. This analysis could be improved if the FIS survey data was released at such a fine spatial scale.

Estimates of the relative abundance of under-size abalone are difficult and often costly to collect, but can provide some prediction of future changes in the fishable stock. In an attempt to improve information about undersize abalone, GPS logger firmware was modified to enable divers to record observations of the abundance of under-size abalone. During the Structured Fishing Program, only 2 active loggers were able to record this information (i.e. older borrowed loggers were not), but since July 2009 all diver's loggers are able to record this information and comparisons will be made within and among divers in the consistency of observations. The value of this information in being able to predict subsequent changes in fishable stocks will not become clear until further information is collected and analysed, but the method appears to provide a cost-effective way of collecting a considerable amount of fine scale information.

Perhaps the most valuable use of the spatial catch information collected with the GPS logger during the Structured Fishing Program will be the ability to improve survey designs to improve estimates of depletion at a fine spatial scale. As is clear from the spatial information provided in this report, fishing generally occurs at a discrete set of productive abalone grounds separated by unproductive reef. The fine scale spatial information about fishing will enable the selection of a subset of areas that could act as representative survey sites in future structured fishing designs to estimate change in measures derived from catch data. Further, with historical information about those sites, this will also facilitate estimates of historical depletion.

While the fine spatial scale data collected on GPS loggers to date is mostly comprised of a snapshot of the spatial distribution of fishing in the 2008-09 Structured Fishing program, they do not yet provide significant fine scale information about change in stocks. While comparisons with broad-scale catch rate and FIS abundances from the past can be made, much of the value of the GPS logger information will occur moving forward. The snapshot of the spatial distribution of fishing will be important in designing a better structured fishing program to enable for the first time direct comparisons of catch rate of the same diver in the same local area. Confounding of temporal comparisons of catch rate across divers and among sites has been a major cause of problems in the interpretation of catch rates in abalone and other fisheries. Removing such confounding from the interpretation of catch rates with a spatially structured design made possible with GPS loggers is the key to gaining the most information about stocks from fishing.

Future

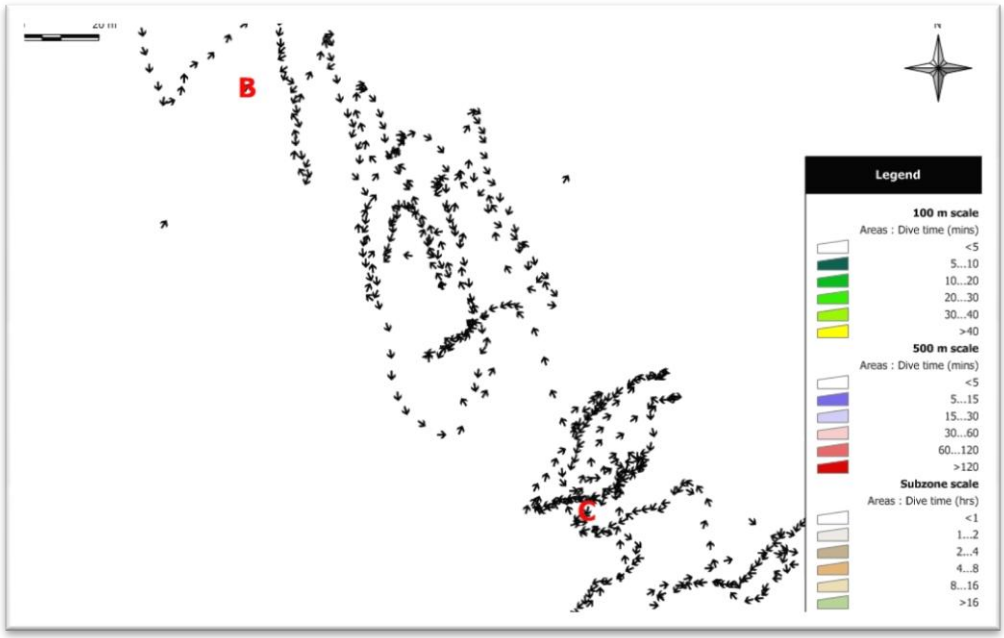
A range of issues remain to be addressed about the Structured Fishing Program and the use of GPS/DTS loggers to provide fine spatial scale information about changes in abalone stocks, that could be used in TAC setting. While there is an intent to generate information for use in TAC setting, there is also a need to approach questions about changes in stock over a longer term than the 2008-09 Structured Fishing Program, as much because of available resources as the ongoing shorter term fluctuations in the stock. The ongoing development of the Structured Fishing Program in Region 1 and 2, and the greater use of GPS/DTS logger data in fine scale assessment of abalone stocks throughout the fishery, was recently supported by the Abalone Resource Planning Committee.

Ongoing development of the Structured Fishing Program and technical procedures to handle, audit and analyses the data are the focus of the current very limited resources, supplemented by support from the FRDC TRF. Improvements to logbook catch reporting (e.g. time of bin full, sub-zone) could improve the ability for IINSW to audit the GPS logger data held by Industry, through checks of

consistency between the independent databases prior to combination, and the cost-efficiency of the hand-paper based system. Individual divers will also be able to retain copies of their own data to facilitate independent audit with IINSW records. Once developed and established, with IINSW, processes for data handling and analysis will be easily audited. Development and establishment of a more informative design for structured fishing in Region 1 and 2, building on the information collected to date and its extension throughout the fishery should be a high priority to ensure a catch is allocated for the area.

A vision is building within the Industry for a fishery managed at a finer scale than state-wide, with extensive fine scale assessment information being used in a bottom-up approach to TAC setting. Once established, technical database procedures should be able to quickly transfer recent GPS logger outputs into spatial maps of catch information (e.g. catch, effort, catch rate, mean size, under-size) that can be combined with other available data to provide the input to Industry workshops to provide stock and TAC advice for management. To achieve this there must be adequate resources and support from IINSW and Shareholders, to continue to develop the geographical information system for the GPS logger data, and particularly to automate analysis and auditing options.

a)



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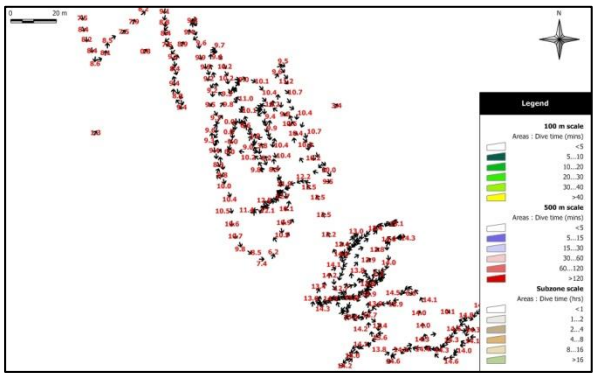

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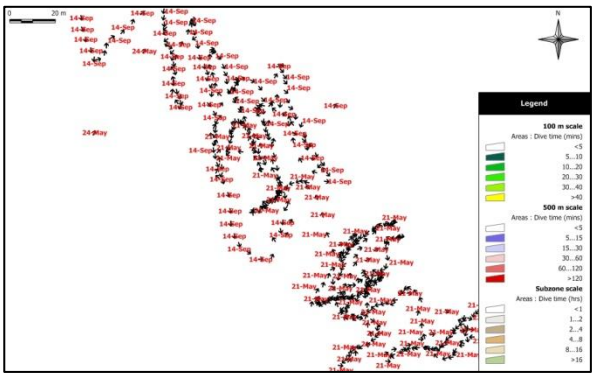

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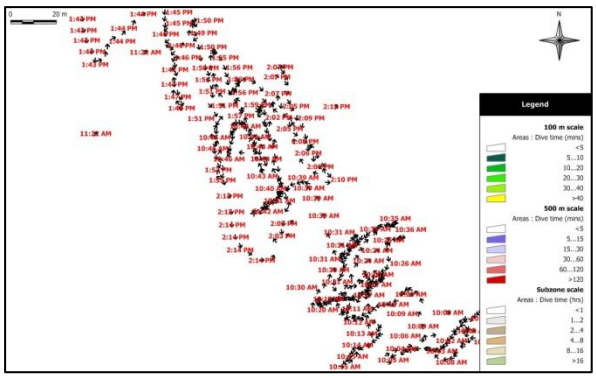

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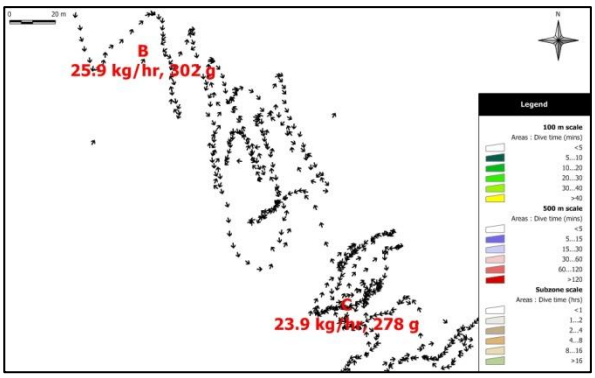
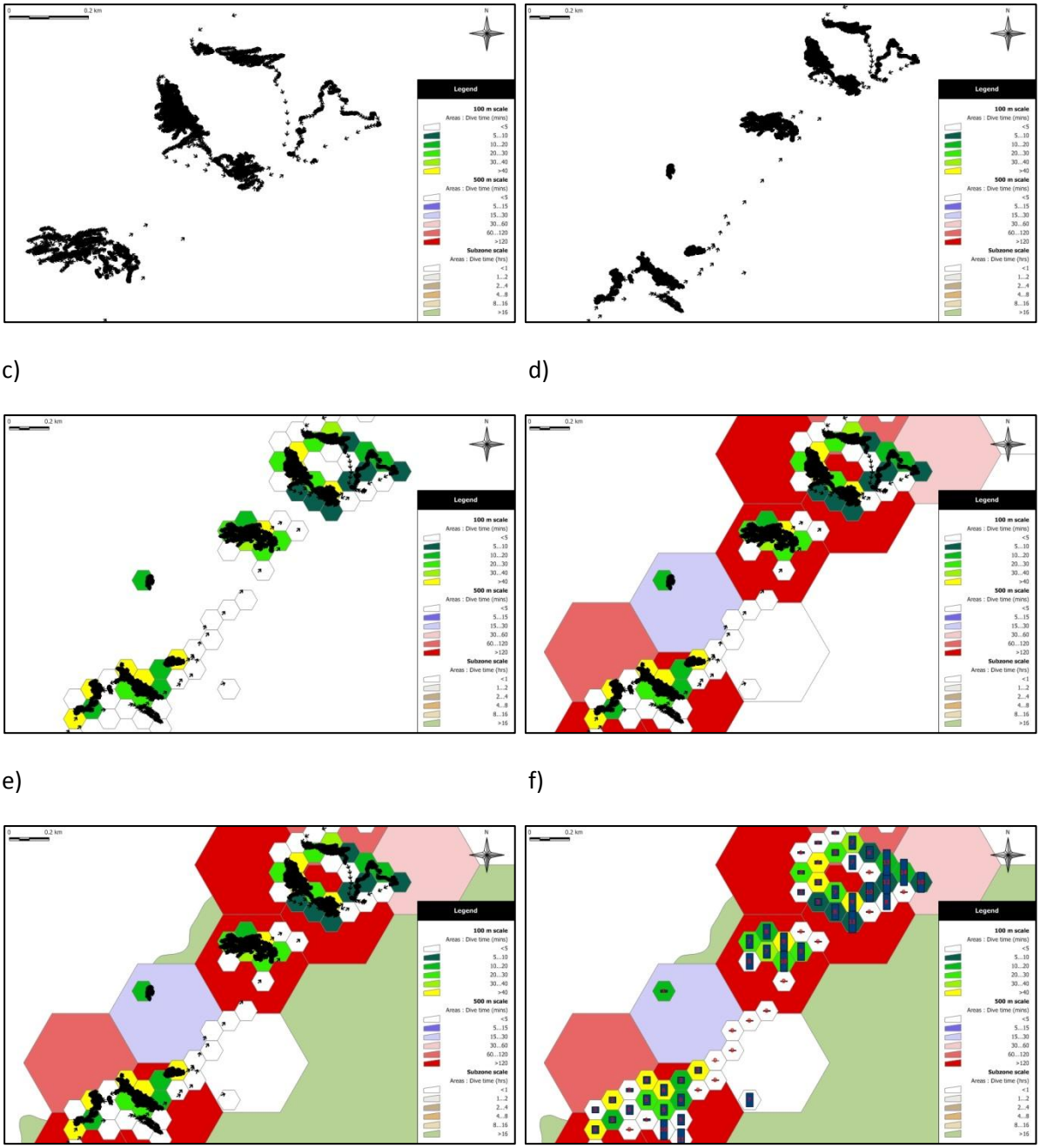


Figure 1. Spatial distribution of effort shown as simple GPS records with direction indicated by the arrow, where no coastline is shown to retain privacy and a) red letters indicate bins of abalone being filled, b) the depth of the diver at each GPS record, c) the date of fishing d) the time of fishing, and e) the catch rate and mean size of abalone in each bin. This figure shows about 500 GPS records with some of the associated data, or less than 0.1% or 1/1000 of the total records currently held in the database.

a)

b)



c)

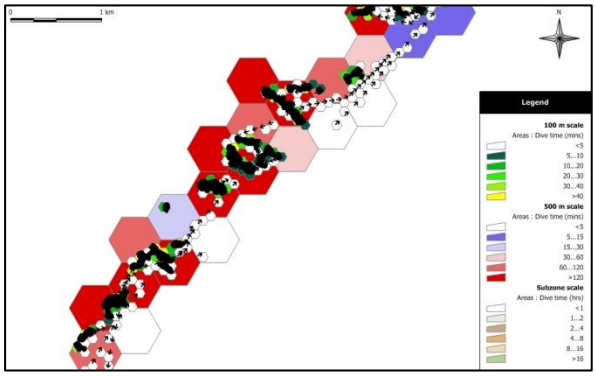
d)

e)

f)

Figure 2. Spatial distribution of effort shown as simple GPS records with direction indicated by the arrow, where no coastline is shown to retain privacy and a) a larger scale than Figure 1, b) and a larger scale than a), c) with 100 m hexagons and colour indicating total effort, d) with 500 hexagons, e) with subzone, and f) showing the ability to summarise data within the hexagons, here showing average depth of the effort as a histogram within each hexagon and depth in m.

a)



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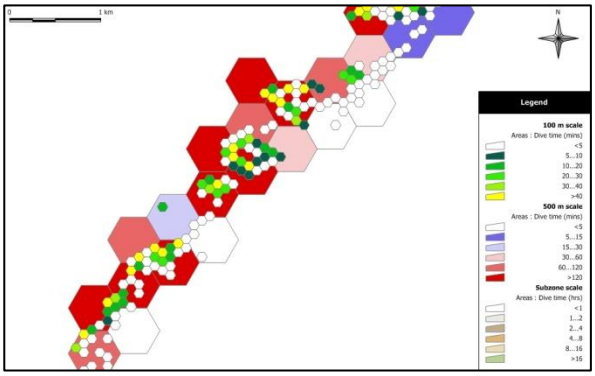

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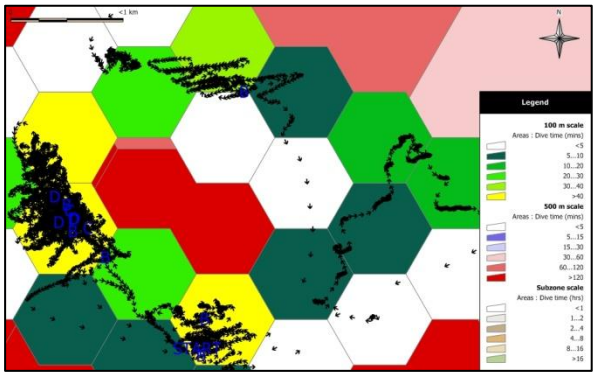

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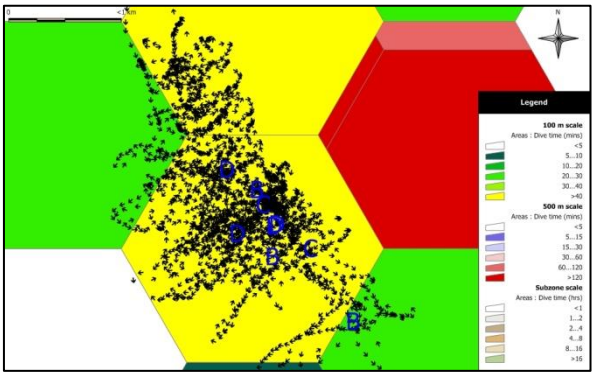


e)

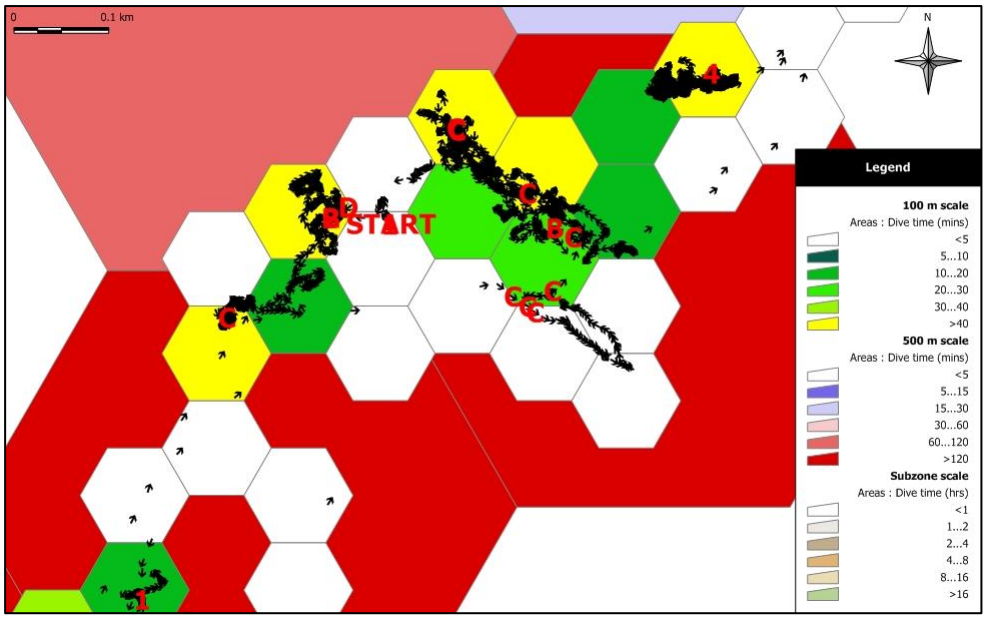
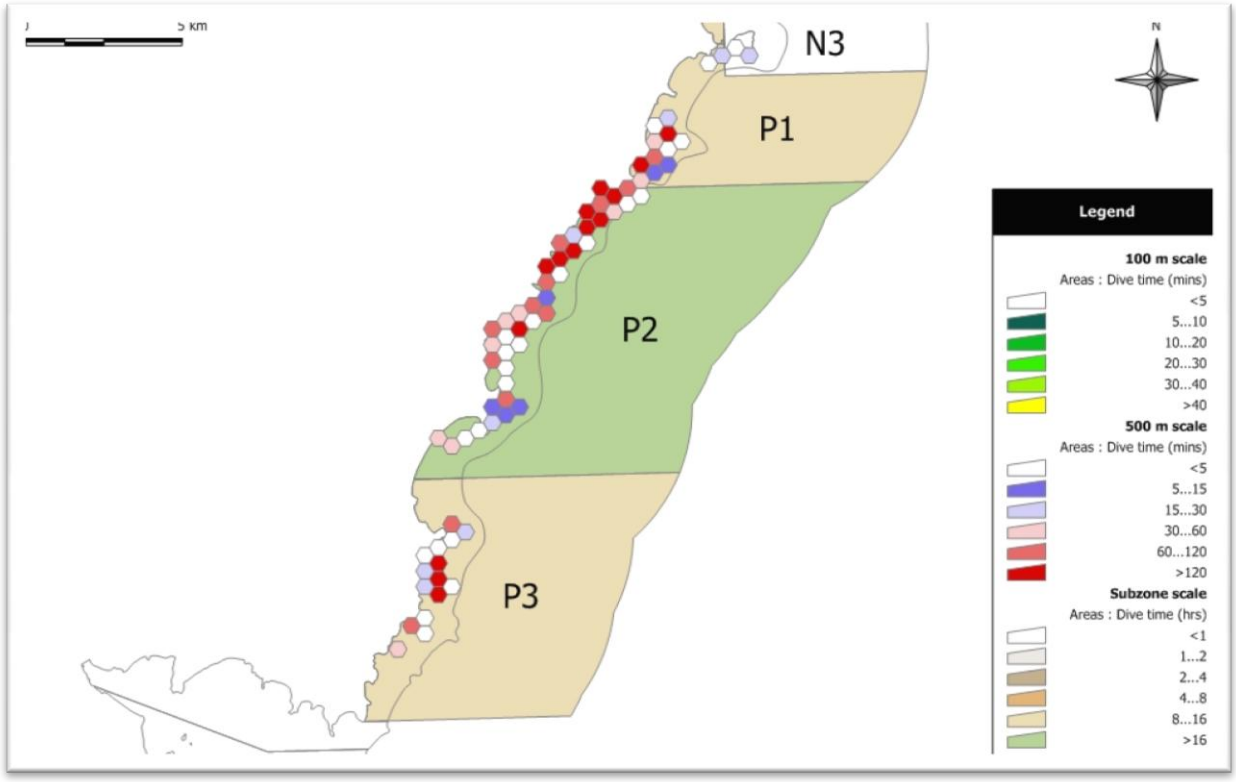


Figure 3. Spatial distribution of effort shown as simple GPS records with direction indicated by the arrow, where no coastline is shown to retain privacy and a) a larger scale than Figure 2, b) with GPS records removed, c) an area with bin full records aggregated in 1-2 areas, d) a smaller scale than c) for 1 of the areas, and e) an example of estimates of the abundance of undersize abalone of 1/5 in the bottom left hexagon and 4/5 in the top right hexagon separated by about 500 m.

Figure 4. Spatial distribution of all effort recorded on GPS loggers at a 500 m scale in subzones D1 to L4 in Region 1 and subzone M1 to R1 in Region 2. (Note, only an example for N3-P3 is shown in the report for public release).



Note Marine Park closures in these areas.

Appendix 1. Correspondence to Industry from IINSW in May 2008.

Proposed Structured Fishing Program for fishing in Region 1 and 2 of the Abalone Fishery.

In April 2008, the Minster approved the introduction of a structured fishing program in Regions 1 and 2 for the commercial harvest of abalone. Fishing under a structured fishing program may allow the Department to monitor and regulate commercial fishing at a finer scale. The commercial catch information derived from the program provides the ability to assess and manage the stocks at a more local scale.

Fishing under the structured fishing program will be authorised through a research permit issued under section 37 of the *Fisheries Management Act 1994* (the Act). Adherence to the permit conditions is mandatory.

The specifications of the structured fishing program have been developed in consultation with Industry. Certain elements will be voluntary (although adherence is strongly recommended), whilst other requirements will be mandatory conditions in the permit.

It should be noted that it is likely that elements of the Structured Fishing program will be amended based on analysis of initial results. Participants will be notified of any changes to the program.

The agreed specifications for the structured fishing program are (in no particular order):

1. Reporting fishing activity at a finer scale
GPS data loggers are strongly encouraged. Position and depth loggers should be used to record where catch is taken under this structured fishing program. If fishers are not utilising data loggers information, on the location of drops (ie, latitude and longitude) fished will be required to be attached to their log sheet.

2. Trip limit of 200kg per day.
A voluntary 200kg trip limit per day will apply. Industry noted this should benefit local fishers and was defensible on that basis. A trip limit may also promote better distribution of catch throughout fishable areas.

3. Catches from each drop to be separated.
Fishers will keep catches from different drops in separate bins and record information for each bin separately. This links information on statutory paperwork such as bin-by-bin abalone quantities and dive times to fishing events at individual drops. Commercial catch per unit effort can be checked against data logger records of fishing if available. This information will also provide higher resolution information on the average size of abalone (through bin weights).

Divers or deckhands will need to do the following:

1. arrange the bins in the order they were fished, and
2. note next to the bin details (on the logsheet) for the first bin from each drop, what time that drop was fished.

Bins need to be kept separate in order to associate the average weight of abalone in each bin to the location where the fishing took place.

In order to assess in more detail, how sensitive bin weights are to changes in average length, length measurements will be taken at processors in a way that will demonstrate the relationship between variations in mean abalone weight and changes in mean length. Bin weight classes will be determined for the range of likely bin weights and a target number of bins from each weight class will have measurements of abalone taken. This work will be done with both DPI staff (to set up the program) and using in-kind or paid staff in processors.

4. Recommended maximum catches at the subzone level in R1(S) and R2
Regional catch caps of 5,000kg for Region 1 (N), 4,500kg for Region 1 (S) and 6,000kg for Region 2 will apply.

The table below sets out the distribution of these commercial catch recommendations for specific areas. Participants of this program will be advised electronically (if email is available) on a regular basis of total catches are in relation to these limits. Adherence to the 3 regional caps is required.

Catch limits are based on the annual fishing period. They should be used for distributing fishing effort during fishing in the 2007/08 quota year. There may be some areas that are seen as very attractive by several divers and industry needs this advice to ensure fishing is coordinated even in the remaining time of the present quota year.

Zone/Subzone/Area	Catch Caps (kg)
Region 1 North	
A to E	5000
Total R (N)	**5,000**
Region 1 South	
F1	200
F2	350
F3	200
F4	150
G1	300
G2	200
G3	100
G4	100
H	250
J	900
K	1250
L	500
Total R1(s)	**4,500**
Region 2	
M1	300
M2	300
N1	950
N2	200
N3	0
P1	600
P2	1500
P3	600
P4	250
Q1	450
Q2	50
Q3	50
Q4	50
Q5	100
R1	550
R2	50
Total R2	**6,000**

Limits have been provided at several spatial scales in this program, as these estimates have been derived differently for Region 1 (North), Region 1 (South) and Region 2. Region 2 regional limits have been distributed to subzone using historical catch levels (allowing for new Marine Park closures).

Limits for Region 1(S) are based on Region 1(S) survey (size of abalone, catch rates and post-harvest interviews with divers). A catch target for Region 1 (N) is set for the whole area due to unpredictability of fishing in that area.

5. Prior reporting of all fishing in Regions 1 and 2 to local fisheries office

The participants must report ramp/access point and indicative subzones for fishing to the nearest fisheries office (see attached fishery office contact) prior to the commencement of the fishing operation (i.e before the boat has been launched).

6. Perkinsus protocol

For all fishing in Region 1 (S), participants will be required to adhere to the following protocols to minimise the risk of spreading *Perkinsus*:

1. Abalone must only be disposed of to processors with isolated seawater systems (also known as recirculation aquaculture systems).

2. Any hanging of abalone must be between the area where the abalone were taken and the boat ramp where the boat was launched. It is preferable that abalone are hung at the drop where they were caught.

It is also strongly recommended that abalone divers fishing in Region 1 (S) adhere to the hygiene protocols identified in the 'Standard Operating Procedures: decontamination for commercial abalone divers' (SOP) document. These standard operating procedures have been designed to minimise the disease translocation risk posed by abalone fishing. A copy of this SOP is available upon request from the DPI.

7. Size limit

Adherence to a 117 mm minimum size limit will be condition of the permit under this program. It is strongly recommended however that fishing occurs under a minimum size limit of 120mm. If voluntarily fishing to this size limit, fishers should specify this on their log sheets.

8. Notification from DPI to MAC and processors (routine, regular)

DPI will report electronically to the program participants (if available) and interested stakeholders with a regular update of catches in the two regions. All permit holders will have to waive privacy provisions so DPI can report to stakeholders where catches are relative to targets. Similarly, if industry and not DPI is collecting logger data, data owners will have to agree to share all data with DPI.

Note.

For all references to Region 1 (S) in this document, Region 1 (S) is the area between Port Stephens south to the Region 1/Region 2 border.

This structured fishing program is a working document and is subject to change.

For any questions relating to administration of this structured fishing program, please contact Nathan McNamara, Fisheries Manager on (02) 9527 8588. For enquires of a scientific nature, please contact Dr Doug Ferrell, Senior Scientific Officer on (02) 9527 8514.

Appendix 1. Correspondence to Industry from IINSW in October 2008.

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Ref: OUT08/10995

<Abalone Endorsement>>
<Address 1>
<SUBURB> <NSW> <POSTCODE>

Abalone Harvest in Regions 1 and 2

Region 1 south (the waters between Port Stephens and the middle of Wreck Bay, Jervis Bay) has been completely closed to the harvest of abalone since November 2002 to help the recovery of abalone stocks.

On 3 August 2007, all of Region 1 (the waters between Wreck Bay and the QLD border) and Region 2 (waters between Tuross Lake and Wreck Bay) was closed to commercial fishing in response to recommendations for a zero commercial harvest contained in the 2007/08 TAC Committee's determination.

In its 2008/09 report, the TAC Committee indicated that up to 5 tonne of abalone may be taken from each of Region 1 (North), Region 1 (South) and Region 2 under a structured commercial fishing or research program designed to gain better information on abalone stocks in those areas. In making an allowance for structured commercial fishing in Regions 1 and 2, the TAC Committee recommended a number of objectives and project specifications that should be addressed in any such structured fishing program.

The intent of structured commercial fishing is to provide information about changes in abalone stocks and to spread the commercial catch appropriately. AbMAC Industry representatives have requested the opportunity to complete the structured commercial fishing program in Regions 1 and 2 under voluntary arrangements, and to extend the implementation of structured fishing to the whole fishery.

NSW DPI has removed the previous closure applicable to Region 2 and has issued permits authorising access into Region 1, allowing structured fishing in both areas. The permits issued for fishing in Region 1 have several conditions, in particular they require adherence to the best practice biosecurity protocols (Standard Operating Procedures: Decontamination for commercial abalone divers), which aims to minimise the risk of translocating *Perkinsus*, an active parasite in this area.

In summary, it is intended that NSW DPI will continue to regulate the commercial catch within Regions 1 and 2 using broad scale management arrangements, such as regional catch caps, whilst Industry will manage abalone harvest at a finer scale utilising a voluntary catch plan and collect greater information about abalone stocks and fishing. The data collected will provide information on the stocks in this area to be used in management of the fishery.

Industry will be responsible for the collection, management and delivery of structured fishing information. NSW DPI will facilitate operation of the program and take an audit role with the data produced to ensure appropriate delivery of the program.

Fisheries Operations
Fisheries, Compliance and Regional Relations Division
202 Nicholson Parade CRONULLA NSW 2230
PO Box 21, CRONULLA NSW 2230

ABN 51 734 124 190
www.dpi.nsw.gov.au
Tel: 02 9527 8411
Fax: 02 9527 8576

Role of NSW DPI in relation to the structured fishing program:

1. The *Fisheries Management Act 1994* (the Act), and associated regulations are administered by NSW DPI. The Act authorises the commercial harvest of abalone in NSW, consistent with its objectives which ensure conservation, sustainable development and sharing of the abalone resource for the benefit of the present and future generations.
2. NSW DPI monitors the performance of the commercial abalone fishery against the identified objectives, performance indicators and triggers points listed under the Abalone Share Management Plan.

NSW DPI will:

(a) Request authorisation from commercial divers to release catch and effort information to allow monitoring of the structured fishing program.
(b) Close regions once the reported commercial catch has reached the recommended 5 tonne limit for 2008/09.
(c) Facilitate reviews of the distribution of catch as area/subzone catch targets (**Attachment A**) are reached, with the potential to close areas, if needed.
(d) Work with Industry to develop and implement data collection methods, analysis and reports describing the results of the structured fishing program.
(e) Maintain an audit role for data collection and storage to ensure consistency.
(f) Purchase a limited number of GPS and depth loggers for use in the structured fishing program.

Responsibilities of industry stakeholders in relation to the structured fishing program:

Industry will:

(a) Implement the agreed structured fishing program, including ongoing review and adjustments to ensure appropriate delivery against objectives of the structured fishing program.
(b) Provide information derived from the dataloggers, when agreed and requested by NSW DPI.
(c) Provide the facility for an agreed audit of the processes for collection, storage and analysis of information collected from the dataloggers, when requested by NSW DPI.
(d) Facilitate communication to all Industry stakeholders about the intent of the structured fishing program, including monitoring of catch against the catch plan.
(e) Facilitate collection of agreed abalone size structure information.

Divers will:

(a) Distribute catch and effort in a manner consistent with the Catch Plan described in Attachment A, including fishing in some pre-specified areas, when agreed and requested.
(b) Carry and use GPS and depth dataloggers as required by the structured fishing program, and throughout the fishery when available.
(c) Authorise the release of catch and effort information (form enclosed)
(d) Provide information derived from the dataloggers, when agreed and requested.
(e) Operate in a manner consistent with bio-security standard operating procedures.

Industry stakeholders who intend to participate in the voluntary structured commercial fishing program within Regions 1 and 2 or its extension throughout the Abalone Fishery are encouraged to indicate their acceptance of the above responsibilities, by signing the attached declaration.

If you have any questions regarding these arrangements please contact Nathan McNamara on 02 9527 8598.

Peter Turnell
Director Fisheries Operations
Date: 10 October 2008

Fisheries Operations
Fisheries, Compliance and Regional Relations Division
202 Nicholson Parade CRONULLA NSW 2230
PO Box 21, CRONULLA NSW 2230

ABN 51 734 124 190
www.dpi.nsw.gov.au
Tel: 02 9527 8411
Fax: 02 9527 85764

Appendix 3. Summary of TAC Committee recommendations about Region 1 and 2 from their 2009-10 determination report.

Specifically, the Committee **recommends** the new information and analyses needed are:

Region 1 North

- Analyse the existing structured fishing data from 2008/9 to assess the status of the stocks, the areas and size of commercial stocks, the relative abundance of sub-legal abalone, and the appropriate size limit for commercial fishing.
- Identify the information required and the design of future surveys or structured fishing to provide ongoing information to support management of the fishery. This should include data access and sharing between the industry and department. The limitations identified in the preliminary analysis of structured fishing data from 2007/08, and any limitations that emerge from analysis of the 2008/09 data, should be addressed.

Region 1 South

- Complete the preliminary analysis of the 2007/08 structured fishing and survey data and analyse the 2008/09 structured fishing data. This should address the extent of stock depletion (including prior to the *Perkinsus* infection), the relative abundance of sub-legal abalone, and calibration between any new monitoring method and the Fishery Independent Surveys.

Region 2

- Analyse the 2008/09 structured fishing data. This should address the extent of stock depletion, the relative abundance of sub-legal abalone, and calibration between any new monitoring method, the Fishery Independent Surveys and historical commercial CPUE.