FINAL WAMSI PROJECT REPORT

Project Details

Project Number and Title:	4.4 Captured Species Assessments
Node Leader:	Dr Rick Fletcher
Project Leader:	Dr Brett Molony
Project Team:	Dr Brett Molony, Dr Richard Evans, Dr Gary Jackson, Dr David Fairclough, Dr Rod Lenanton, Dr Phillip England, Dr Oliver Berry, Dr Jenny Chaplin, Ms Michelle Gardner, Dr Daniel Gaughan, Dr Rich Little, Dr Brent Wise
Project Start Date:	1/1/2008
Project End Date:	31/12/2011
Due Date for Final Report:	31/12/2011
Project Team:	Dr Brett Molony, Dr Richard Evans, Dr Gary Jackson, Dr David Fairclough, Dr Rod Lenanton, Dr Phillip England, Dr Oliver Berry, Dr Jenny Chaplin, Ms Michelle Gardner, Dr Daniel Gaughan, Dr Rich Little, Dr Brent Wise
Project Funding:	

1. Project Objectives and Achievement Criteria

Confirmation of the project objectives and the delivery of milestones against the Key Performance Indicators:		
4.4.1 Assessment and Monitoring of Bycatch	**Status**	**Notes**
Project and recruitment and selection of staff commences.	√	1
Development of bioregional databases of cumulative bycatch.	√	
Assessment of impact of interactions of fishing with protected and threatened species.	√	
Development of long term monitoring of bycatch scheme.	√	2
4.4.2-1 Stock Structure (DoF)		
Collection and sample preparation.	√	
Completion of IRMS and IC-LAPMS.	√	
Analysis and results in final report. Completion of inshore dispersal study.	√ √	3
4.4.2-2a Stock Structure (CSIRO)		
Dhufish microsatellites identified.	√	
Microsatellite genotyping protocol developed.	√	

Complete genotyping of sampled dhufish populations.	√	
Hydrodynamic dispersal modelling, spatial analyses and manuscript preparation.	√	4
4.4.2-2b Stock Structure (MU)		
Marker development (list of all potential microsatellite loci and associated primers for both species – snapper and baldchin groper).	√	
Preliminary data (information about target loci and preliminary data about patterns of variation within and between populations at these loci for both species). Completion of first twelve months of PhD top-up.	√	
Raw data (raw data tables provided). Completion of first twenty four of PhD top-up.	√	
Completion of final report.		5
Completion of PhD top-up.		5
4.4.2-3 Stock Structure (CSIRO)		
Spatially explicit assessment models will be trialled for the West Coast demersal scalefish fishery.	√	6
4.4.3 Assessment and Monitoring of the Non-commercial sector		
Project commences and design for phone diary survey begins.	√	
Priority outputs and sources of data for IFM determined. Synthesis of available data from all recreational survey methods completed.	√	
Comparison of recreational volunteer methods completed. (Note – full assessment of cost benefits for volunteer methods will occur once the integrated survey methods component has been completed).	√	
Department of Fisheries to convene national workshop on integrated State-wide boat-based survey design.	√	
Complete draft report on integrated State-wide boat-based survey design. (This will incorporate the original milestone i.e. Comparison of recreational survey methods completed).	√	
Development of appropriate ongoing recreational collection methods completed. Complete cost benefit analysis of recreational survey methods. Integrated State-wide boat-based survey implemented.	√	
Final report completed.	√	7

Notes.

1. Two Principal Investigators resigned during the course of the WAMSI project. This resulted in the Project Leader taking over the finalisation of this sub-project.
2. This component resulted in a trial of new technology (cameras) as to test the efficacy of remote technology for recording bycatch interactions with fisheries. (See *Pilot evaluation of the efficacy of electronic monitoring on a demersal gillnet vessel as an alternative to human observers*).
3. Analysis and publishing of final results are currently being finalised. The delay was due to errors in coding of the dispersal model that has now been rectified. (See, *Problems encountered* for sub-project 4.4.2-2a).
4. Analysis and publishing of final results are currently being finalised. The delay was due to errors in coding of the dispersal model that has now been rectified. (See, *Problems encountered* for sub-project 4.4.2-2a).
5. The PhD is scheduled to be completed in June 2012.
6. This subproject is currently being completed and will be finalised by 31 December 2011 as per milestone renegotiation.
7. The completed draft report on integrated State-wide boat-based survey from the workshop is currently being finalised. This is in addition to the final FRDC report for FRDC project 2005/034.

2. Overview

To meet the objectives of the Project, the following Sub Projects were undertaken. Full accounts of these can be found in the Attachments.

4.4.1: Assessment and monitoring methods for bycatch species composition and abundance (Short title: Assessment and Monitoring of Bycatch)

Management Question being addressed:

Do temperate State fisheries impose a high risk to sustainability of TEPS and other bycatch species?

Projects undertaken:

i. Ranked risk assessment for bycatch in multiple fisheries: a bioregional risk assessment method. Richard D. Evans and Brett W. Molony

ii. Pilot evaluation of the efficacy of electronic monitoring on a demersal gillnet vessel as an alternative to human observers. Richard D. Evans and Brett W. Molony

4.4.2 Implications of mobility and stock structure of species for management approaches (Short title: Stock Structure)

Management Question being addressed: What is the stock structure and connectedness of populations of indicator species (Western Australian Dhufish, Pink Snapper, Baldchin groper) of the West Coast Demersal Scalefish Fishery?

Projects undertaken:

4.4.2-1 Stock structure:

i. Rapid and cost-effective assessment of connectivity among assemblages of *Choerodon rubescens* (Labridae), using laser ablation ICP-MS of sagittal otoliths. David V. Fairclough*, John S. Edmonds, Rod C.J. Lenanton, Gary Jackson, Ian S. Keay, Brett M. Crisafulli and Stephen J. Newman

ii. Comparison of the stock structures of two exploited demersal teleosts *Glaucosoma hebraicum* (Glaucosomatidae) and *Pagrus auratus* (Sparidae), employing complementary methods of otolith chemistry. Fairclough, D. V., Edmonds, J. S., Jackson, G., Lenanton, R. C. J., Kemp, J., Molony, B. W., Keay, I. S. and Crisafulli, B. M.

iii. Drifter trajectories along the Western Australian continental shelf: November 2008 to November 2009. Alan Pearce, Ming Feng, Steve Guy, Jeff Norriss, Dirk Slawinski, Carli Telfer, Michael Tuffin and Dan Gaughan.

4.4.2-2a Stock structure:

Multidisciplinary assessment of marine fish dispersal: using microsatellites and hydrodynamic modelling to reveal the extent of larval transport and gene flow between management zones in an exploited marine fish. Oliver Berry, Phillip England, David Fairclough, Gary Jackson.

4.4.2-2b Stock Structure:

Genetic determination of the stock structures of Pink snapper (*Pagrus auratus*) and Baldchin groper (*Choerodon rubescens*) in Western Australian waters. PhD thesis, Murdoch University. Michelle J. Gardner. (Commencement date 19th January 2009. Expected completion date July 2012).

4.4.2-3 Stock Structure:

A management simulation model for dhufish in the West Coast Demersal Scalefish Fishery. L. Richard Little, Oliver Berry and Brett Molony.

4.4.3: Development of cost-effective methods for monitoring the catch of the non-commercial sector (Short title: Assessment and Monitoring of the non-commercial sector)

Management Question being addressed: How can cost-effective estimates of catch and effort by non-commercial sectors (recreational) be generated to allow robust monitoring of the non-commercial sector?

Projects undertaken:

i. Determination of cost effective techniques to monitor recreational catch and effort in Western Australian demersal finfish fisheries. Brent Wise, Ken Pollock, Norm Hall.

ii. Design and implementation of survey techniques for estimating harvest, effort and catches by recreational boat-based fishers throughout Western Australia. Brent Wise, Ken Pollock, Norm Hall.

3. Summary

Half page to full page Executive Summary of results from each Sub Project. Must link directly to Objectives of Project.

4.4.1 Assessment and Monitoring of Bycatch

i. Ranked risk assessment for bycatch in multiple fisheries: a bioregional risk assessment method. Richard D. Evans and Brett W. Molony

This report demonstrates a method to rapidly assess the cumulative risk to sustainability of bycatch species of multiple fisheries. The method draws on other techniques already published in scientific literature and adds a new cumulative ranked estimate of total catch across multiple fisheries. The Ranked Risk Assessment of Multiple Fisheries (RRAMF) allows one to rank bycatch species data within each fishery and cumulate the ranks across multiple fisheries incorporating the relative impact of each fishery. Another feature of this study is that it does not present a single risk result for each species, rather it shows a range of scores based on a variety of combinations of double-weighted parameters used in the risk assessment. The RRAMF method was tested on the West Coast and Gascoyne Coast Bioregions of Western Australia using fishery independent data for general teleost and elasmobranch bycatch; and fishery dependent data for threatened, endangered and protected species (TEPS) (which also included the South Coast Bioregion). Bycatch in this study is defined as any discards from fishing events, and does not include by-product or target species unless the individuals are under/over size or above statutory catch limits. It is important to note that no score was above 48% of the maximum possible score. All bycatch species received low to moderate risk scores using this method for the fisheries in this location. Those species that were most vulnerable to the cumulative impacts of fishing in these Bioregions were those species with sensitive biological life histories such as elasmobranchs were ranked predominantly in the high end of the low-moderate risk category and into the moderate risk category. The RRAMF for the TEPS showed that while most species have high biological risk, the low interaction rates reported by fisheries maintained low to moderate risk categories for most species groups. Turtles and pinnipeds featured highly in the low-moderate to moderate risk categories, and Australian Sea Lions (*Neophoca cinera*) were the most vulnerable with a risk category ranging from moderate to moderate-high. This method uses transparent and repeatable methods that provide information for Ecosystem Based Fisheries Management (EBFM) at a Bioregional level. The method is limited by the availability of relevant and contemporary bycatch data and consequently the results generated require cautious interpretation.

ii. Pilot evaluation of the efficacy of electronic monitoring on a demersal gillnet vessel as an alternative to human observers. Richard D. Evans and Brett W. Molony

A large number of documents exist in peer reviewed and 'grey' scientific literature that describe 'how to' establish a generic observer program for bycatch. Rather than repeat the many reviews of establishing observer programs, this component of WAMSI project 4.4.1 undertook a pilot trial to test the efficacy of using Electronic Monitoring (EM) in place of on-board human observers to record and identify the catch composition of a commercial demersal gillnet vessel. Approximately 80% of all catch (including target, by-product and bycatch species), including interactions with threatened, endangered and protected species (TEPS) could be identified to the same taxon as reported by commercial fishers in logsheets. With additional tuning and regular maintenance of the EM equipment (particularly the camera), it is likely that the identification of all catch to the appropriate taxonomic level could approach 100%. The outcomes of the initial small-scale pilot trial of EM provide a basis for future evaluation of EM systems in Western Australian fisheries.

4.4.2-1 Stock Structure

i. Rapid and cost-effective assessment of connectivity among assemblages of *Choerodon rubescens* (Labridae), using laser ablation ICP-MS of sagittal otoliths. David V. Fairclough*, John S. Edmonds, Rod C.J. Lenanton, Gary Jackson, Ian S. Keay, Brett M. Crisafulli and Stephen J. Newman

A rapid and cost-effective assessment was required to provide advice to management on the connectivity between juvenile and adult life-cycle stages of Baldchin Groper *Choerodon rubescens*, a labrid endemic to the west coast of Australia, that has high social value, but relatively low commercial fishery importance. To minimise costs we used laser ablation ICP-MS to analyse levels of a small suite of elements (Ca, Mg, Mn, Cu, Zn, Sr, Rb, Ba and Pb) at the margin (adult phase) and core (juvenile phase) of the same otoliths of adult *C. rubescens*, collected at ten locations in five management zones. The elemental composition of both otolith margins and cores differed significantly among management zones and in some cases

among locations within zones. Similarity of the pattern of among-zone elemental composition in otolith margins and cores indicated that, when cores are laid down, individuals have already recruited to the zones they will occupy as adults and there is no evidence of discrete juvenile nurseries. Thus, movement of juvenile or adult *C. rubescens* is likely to occur at relatively small spatial scales. Monitoring and management of adult stocks at the management zone level may be appropriate to sustain stocks broadly, but may not detect more localised, within zone, depletion. Methods of elemental analyses are discussed and costs and benefits of this study *vs* an equivalent tagging study are compared.

ii. Comparison of the stock structures of two exploited demersal teleosts *Glaucosoma hebraicum* (Glaucosomatidae) and *Pagrus auratus* (Sparidae), employing complementary methods of otolith chemistry. Fairclough, D. V., Edmonds, J. S., Jackson, G., Lenanton, R. C. J., Kemp, J., Molony, B. W., Keay, I. S. and Crisafulli, B. M.
Complementary methods of otolith chemistry, i.e. IRMS of stable isotopes and laser ablation ICP-MS of trace elements, were employed to elucidate the stock structures of two exploited demersal teleosts, the endemic West Australian Dhufish *Glaucosoma hebraicum* and the southern Australasian Snapper *Pagrus auratus*, in Western Australia. The extent of residency of adults of both species during recent life history and the determination of whether important nursery locations exist for each were examined, employing the elemental composition of otolith margins and cores, respectively. These data were used to infer whether existing spatial management boundaries are appropriate for the management of their stocks.

Stable isotopes of oxygen (^{18}O) in both otolith margins and cores of *G. hebraicum* otoliths reflected the different latitudes and thus water temperatures of the nine locations within four management areas of the West Coast Bioregion (WCB) at which they were collected. Statistical tests and classification analyses demonstrated that the among-area pattern of the composition of $\delta^{18}O$ and $\delta^{13}C$ in otolith margins and cores broadly paralleled that of the trace elements Mg, Sr and Ba. Together, these data indicated that, not only are adult *G. hebraicum* resident within each management area, but that by the early juvenile stage, fish have recruited to the area within which they will develop into adults and there are no major spatially distinct nursery locations in the WCB from which adults are derived.

Stable isotope and, to a lesser extent, trace element signatures, in the margins of otoliths of adult *P. auratus* indicated that adults were resident within each of the large Gascoyne (GCB), West and South Coast (SCB) bioregions, but also within the four smaller management areas of the WCB. However, although $\delta^{18}O$ levels in otolith cores did not reflect water temperatures of the locations at which fish were caught, multivariate stable isotope and trace element data sets indicated a proportion of self-recruitment to the WCB and SCB and also to two of the four management areas within the WCB, but that stocks at the southern extent of the GCB may be partially reliant on immigration.

Elemental signatures in otoliths of *G. hebraicum* and *P. auratus* demonstrated that adults in each management area of the WCB could be treated as separate stocks. Recruitment of juvenile *G. hebraicum* to adult stocks would occur primarily from multiple locations within management areas. Adult *P. auratus* within a bioregion or area are derived from a range of nurseries, including from across management boundaries.

iii. Drifter trajectories along the Western Australian continental shelf: November 2008 to November 2009. Alan Pearce, Ming Feng, Steve Guy, Jeff Norriss, Dirk Slawinski, Carli Telfer, Michael Tuffin and Dan Gaughan.

The trajectories of 6 free-drifting GPS-tracked buoys between November 2008 and November 2009 have both confirmed previous knowledge of the broad-scale /seasonal surface currents off south-western Australia and materially added to our understanding of the oceanic processes affecting potential drift patterns of fish eggs and larvae. While a reasonably steady northward Capes Current is driven by the persistent southerly wind-forcing along the continental shelf during the summer months, there can be periods when the current reverses to south-flowing for a few days, thus tending tor retain larvae within a limited latitudinal range of the spawning area. Two of the 6 drifters released along the inner shelf initially moved northwards, but then diverged from the coast and rapidly moved into and/or beyond the Leeuwin Current. One of them in fact drifted northwards offshore of the Leeuwin Current, including an 8-month recirculation in a complex eddy system offshore at a latitude between Exmouth and Shark Bay. Technical problems have temporarily delayed the continuation of the drifter program, but further buoy releases are scheduled for summer 2010 in the dhufish spawning area.

4.4.2-2a Stock structure

Multidisciplinary assessment of marine fish dispersal: using microsatellites and hydrodynamic modelling to reveal the extent of larval transport and gene flow between management zones in an exploited marine fish.

i. Tri- and tetranucleotide microsatellites in dhufish *Glaucosoma hebraicum* (Perciformes). Burridge, C.P. and England, P.R. (2009). *Molecular Ecology Resources,* 9, 948-951.

Thirteen polymorphic tri- and tetranucleotide microsatellite markers are reported for the exploited marine dhufish (*Glaucosoma hebracium*) from southwestern Australia. Variation was assessed among 48 individuals collected from a single locality. Most loci had 2–5 alleles, although one had more than 20 alleles, with corresponding observed heterozygosities of 0.02–0.81. These loci were also polymorphic in congeneric species.

ii. Microsatellites and hydrodynamic modelling reveal the extent of larval transport and gene flow between management zones in an exploited marine fish (*Glaucosoma hebraicum*). *Fisheries Oceanography.* Oliver Berry, Phillip England, David Fairclough, Gary Jackson (in press)

Determining the extent of dispersal in exploited marine fishes is essential for understanding their population dynamics and optimising management. The West Australian dhufish, *Glaucosoma hebraicum*, is a sought-after, large and long-lived reef-dwelling species, endemic to south-western Australia. Stock assessments indicate that this indicator species is overexploited. The fishery is managed using a zone-based system, which implicitly assumes a high degree of demographic independence among zones. While tagging studies indicate limited movement of adult *G. hebraicum*, there is no understanding of the spatial scale of dispersal of its larvae and thus the true extent of interdependence of management zones. We analysed 13 microsatellite loci to characterise the extent of gene flow, and conducted particle tracking simulations to model larval transport in this species. Genetic data demonstrated that some local recruitment was likely, but that on a broad scale gene flow between the management zones was extensive, and the entire fishery represents a single genetic stock. In contrast, hydrodynamic modelling predicted that the majority of dhufish larvae recruit from within the management zone where they are spawned, and that inter-annual variation in current velocities has little effect on the extent of larval transport. The existing management zones are likely to be largely independent in terms of both larval and adult recruitment.

4.4.2-2b Stock Structure

The objective of this research was to use microsatellite markers to elucidate the stock structures of the Baldchin groper, *Choerodon rubescens,* and the Pink snapper, *Pagrus auratus,* in Western Australian waters, focussing on the West Coast Bioregion (WCB). The microsatellite data, when viewed in combination with the results of other projects within WAMSI 4.4.2, suggest that the Baldchin groper consists of a series of overlapping stocks connected mainly by larval movements within the WCB and probably over its entire range. The microsatellite results suggest that the Pink snapper consists of a semi-continuous stock in Western Australian waters, where connectivity declines 'smoothly' with geographic separation and geographic distance is the main factor limiting gene flow/dispersal, *i.e.,* discrete stock boundaries do not exist and connectivity is highest between neighbouring groups. Genetic homogeneity in the Pink snapper appears to occur over distances in the order of hundreds of kilometres, including within the WCB, but the spatial scale at which population dynamics in this species is determined will be much smaller than this. It should be possible to establish whether connectivity in the Pink snapper is mediated via the movements of adults and/or larvae when the genetic results are combined with the results of other projects in WAMSI 4.4.2. Despite exploitation, the effective population sizes of the Pink snapper and the Baldchin groper have been sufficient for these species to retain high levels of genetic diversity.

4.4.2-3 Stock Structure (CSIRO – Rich Little/Oliver Berry)

A management simulation model for dhufish in the West Coast Demersal Scalefish Fishery. L. Richard Little, Oliver Berry and Brett Molony.

The project explored the effects of managing dhufish (*Glaucosoma hebraicum*) in the West Coast Demersal Scalefish Fishery (WCSF). A simulation framework was used to show the potential effect of management scenarios with different levels of effort, across the four inshore demersal management zones of the fishery and under different larval migration or mixing hypotheses. The simulation model used was a spatial meta-population model with 20 local sub-populations, spread across the four management

zones, and linked through larval migration that was determined through hydrodynamic modelling in WAMSI project 4.4.2-2a.

The simulation model that was used is known as ELFSim, a decision support software designed to evaluate options for conservation and harvest management. It includes a number of key components: a population dynamics model of target species that captures the full life history (including larval dispersal, reproduction, development, and habits), a model of fishing dynamics.

Management scenarios examined in ELFSim include the effort levels currently operating in the fishery in the commercial, charter and recreational fleets. These levels were based on effort levels estimated to meet a 50% reduction in commercial catches relative to 2005/6 catch levels, an outcome of management changes to ensure sustainability of the fishery. Other management scenarios included the possibility of a further reduction in effort to 50% those effort levels again, as well as an increase of 50% and 100% of the current effort levels. We also included a scenario of the current effort levels but where the recreational fleet increased its effort by 2% per year throughout the simulation period.

Combined with the management scenarios were hypotheses about larval migration within the fishery. These hypotheses included situations where no migration actually occurred among zones in the fishery, where larvae could go to any other location equally, and two situations developed from hydrodynamic models when the Capes Current was strong, and where it was relatively weak.

Results show that the larval migration model influences the spawning biomass in all zones across the fishery. In general, Dongara (in the Mid West Zone) tended to have the least fishing depletion and was closest to its pre-exploitation levels after the simulation period, except under a weak Capes Current migration scenario. The effect of the different management scenarios indicated that when current effort is reduced by 0.5, all regions result in increasing spawning biomass through the simulation period. When effort increases however, some regions are affected more than others. Notably, when effort doubles the increased recreational effort that is allowed in the Metropolitan Zone, decreases the spawning biomass in that Zone relative to current levels (i.e. status quo conditions).

Future potential management monitoring, assessment and decision procedures can be tested using this simulation platform. The sensitivity of the results to the hydrodynamic modelling data offers new insight into fisheries management. Future hydrodynamic modelling should be considered to be incorporated into management of the fishery, especially under climate change scenarios.

The simulation modelling used can capture a large degree of management actions applied to this fishery. This can help determine the efficacy of fisheries management procedures, and offers a powerful tool to test management practices in a computer setting before testing them in reality.

4.4.3 Assessment and Monitoring of the non-commercial sector

A comparison of recreational volunteer methods was undertaken as part of a FRDC funded project (FRDC # 2005/034) with the final report due in 2011. Given the need for broader survey methods to be considered in the design of a 2011 state-wide boat-based recreational survey a workshop bringing together professional experts from Australian and New Zealand was conducted. The workshop was held between 22-26 February 2010 to design integrated surveys for the estimation of total recreational fishing harvest, catch and effort. The workshop brought together professional experts from Australian and New Zealand involved in recreational fisheries, survey design, fisheries research and management. Emphasis was placed on the design of a telephone diary survey employing the sampling frame from the recently implemented Western Australian fishing from boat licence, which will be undertaken in parallel with a variety of complementary on-site survey methods. The completed draft report on integrated State-wide boat-based survey from the workshop is currently being finalised.

The report identifies an integrated State-wide boat-based survey involving:

1. A 12 month phone logbook survey of licence holders stratified around WA to estimate regional effort and catch by numbers of key recreational species
2. A boat ramp survey to provide on-site biological information and validation of information collected in the phone logbook surveys, a targeted boat ramp based survey will be undertaken at specific boat ramps and times to carry out on-site face to face interview with fishers.
3. A remote video survey mounted at key boat ramps to monitor launches and retrievals. This will assist the validation of effort levels over 24-hour periods.
4. Fisheries Marine Officer patrols to provide data on licence coverage and levels of non-

compliance.

One of the most comprehensive State-wide boat-based surveys in WA and possibly elsewhere commenced on the 1 January 2011. The survey involves:

1. A 12 month phone logbook survey of 3000 participants stratified around WA to estimate regional effort and catch by numbers of key recreational species
2. A biological survey at key boat-ramps around WA to collect length, weight and other biological information for the conversion of catch estimates by numbers in weight.
3. A validation survey at the 6 key boat-ramps in the Perth metropolitan area to investigate any significant differences between onsite and offsite catch information
4. A remote camera survey of 6 regional ramps around WA and the 6 key boat-ramps in the Perth metropolitan area to provide 24/7 coverage and allow comparison of activity around the State and potential utilised to improve effort estimate precision.
5. A non-compliance survey at key ramps in the Perth metropolitan area.

The survey finishes in December 2011 and will be analysed in 2012. This will be ongoing with the second biennial survey scheduled to commence in January 2013.

4. Discussion

Implications for Management and/or Advancement of the Field – Describe the key findings as they relate to the objectives and the management questions discussed at the outset of the project.

4.4.1 Assessment and Monitoring of Bycatch

Do temperate State fisheries impose a high risk to sustainability of TEPS and other bycatch species?

Outcomes and outputs of relevance to management

- Risk assessment framework for assessing bycatch across fisheries
- Risk level by species
- Identified gaps in information
- Allowed the re-evaluation of risk assessments
- Informed risk assessments of all bycatch species in three Bioregions
- Direct input to management of ecosystems and fisheries in the Department's Ecosystem Based Fisheries Management process that will support the risk-based approach to determining management priorities.
- Trial of new monitoring technology to potentially fill data gaps

Based on current available data most species are low to moderate risk.

However TEPS interactions will always be socially 'high risk'

4.4.2 Stock Structure

What is the stock structure and connectedness of populations of indicator species (Western Australian Dhufish, Pink Snapper, Baldchin groper) of the West Coast Demersal Scalefish Fishery?

4.4.2-1 Stock Structure

Outcomes and outputs of relevance to management

- Indicator species (Western Australian Dhufish, Pink Snapper, Baldchin groper) of the West Coast Demersal Scalefish Fishery in management zones of the West Coast Bioregion do not consist of separate genetic stocks but do have a high degree of localised recruitment.
- Therefore management boundaries are not reflective of genetic stock boundaries.
- However, zonation allows the management of fishing effort to limit the risks of localised depletion of demersal fish stocks..
- Current monitoring (indicator species by management zone) is appropriate and this broad scale monitoring should continue especially as fishing effort varies among zones.

This is a national and world first applying these complimentary techniques – otolith microchemistry, otolith stable isotope analyses and genetic techniques - on the same individual fishes to determine natal origins, interconnectedness, and sources and sinks of demersal scalefishes.

New management question identified from this work: How to manage stocks of the same species that

cross bioregional boundaries? For example, Pink snapper in the Gascoyne Coast Bioregion are likely to supply recruits to the Kalbarri zone of the West Coast Bioregion but fisheries in both Bioregions are managed separately. There is a similar situation for pink snapper and dhufish between the south-west zone of the West Coast Bioregion and the South Coast Bioregion.

This information will directly input to the Department's Ecosystem Based Fisheries Management process that will support the risk-based approach to determining management priorities.

4.4.2-2b Stock Structure

Management Implications.

For the Baldchin groper, this species should be managed holistically rather than on a management jurisdiction basis in view of the fact that it likely consists of a series of overlapping stocks over its entire range. Larval movements are likely to be critical in maintaining connections among stocks and hence connectivity in the Baldchin groper could be highly variable in space and time, *e.g.* as oceanographic conditions vary. The presence of connections among the assemblages in different locations will reduce the risk of extirpation (localised extinction) in this species. However, the resilience of this species to the effects of local fishing pressure may be limited, even if there is a large influx of larvae into an area, because removed adults will typically be replaced by settling larvae.

For the Pink snapper, this species should be managed holistically rather than on a management jurisdiction basis in view of the semi-continuous nature of the stock of this species. The Pink snapper should be afforded some resilience to the effects of local fishing pressure by the presence of genetic connections over relatively large distances, although the degree of resilience will depend on the temporal scale and strength of the connections and whether the connections are mediated via larvae and/or adult dispersal. Although the Pink snapper is genetically homogeneous within West Coast Bioregion, complete mixing of individuals of this species within this region is unlikely.

Advancement of Field

The genetic results, when combined with the otolith microchemistry and particle modelling data, highlight the value of a multi-disciplinary approach to stock discrimination.

When the results of the genetic, otolith microchemistry and particle modelling projects are considered for both the Baldchin groper and Pink snapper, they raise the possibility that larval dispersal may particularly important in maintaining connectivity among spatially isolated assemblages of demersal fish species in Western Australian waters.

4.4.2-2a and 4.4.2-3 Stock Structure

The key management question as outlined at the outset was "*determining how the stock structure of the key indicator species in each bioregion interacts with the existing and potential spatial management arrangements". In view of this, the following outcomes have been achieved:*

- Gene flow between the WCDSF management zones is extensive, and the entire fishery represents a single genetic stock.
- The majority of dhufish larvae are likely to recruit from within the management zone where they are spawned, and inter-annual variation in current velocities is likely to have little effect on the extent of larval transport.
- The existing management zones are likely to be largely independent in terms of larval recruitment.
- Gene flow between sites along the west coast (i.e. within the WCDSF) is more extensive than it is between the west and south coast dhufish populations.

Advancement of the Field

- Species-specific molecular markers have been developed for the dhufish. These provide opportunities for future research on reproductive behaviour, larval swimming behaviour (cohesion as pelagic larvae, mechanisms of transport), and non-invasive genetic mark and recapture estimates of abundance and mortality (gene-tagging).
- This project produced the first characterisation of the extent of gene flow in the dhufish.
- This project produced the first comprehensive models of larval transport in the dhufish.

4.4.3 Assessment and Monitoring of the non-commercial sector

Outcomes and outputs of relevance to management:

Development and implementation of one of the most comprehensive surveys of boat-based recreational fishing in Australia and possible worldwide. The survey will deliver;

- Robust estimates of recreational catch and effort for the boat-based sector across the State
- Support biological collection (species identification, lengths and weight data, otolith collections and collections of gonads and gut samples) that is critical to other monitoring, assessment and research projects managed by the Department of fisheries.
- Supports a framework for voluntary data collection

The survey commenced on the 1 January 2011 and involves;

- A 12 month phone logbook survey of 3000 participants stratified around WA to estimate regional effort and catch by numbers of key recreational species
- A biological survey at key boat-ramps around WA to collect length, weight and other biological information for the conversion of catch estimates by numbers in weight.
- A validation survey at the 6 key boat-ramps in the Perth metropolitan area to investigate any significant differences between onsite and offsite catch information
- A remote camera survey of 6 regional ramps around WA and the 6 key boat-ramps in the Perth metropolitan area to provide 24/7 coverage and allow comparison of activity around the State and potential utilised to improve effort estimate precision.
- A non-compliance survey at key ramps in the Perth metropolitan area.

The survey finishes in December 2011 and will be analysed in 2012. This will be ongoing with the second biennial survey scheduled to commence in January 2013.

The survey will provide the first state-wide estimates of recreational catch and effort and will be a major input to the management processes for the Department of Fisheries for both sustainability assessments and sectoral allocation decisions.

This information will directly input to the Department's Ecosystem Based Fisheries Management process that will support the risk-based approach to determining management priorities.

Problems encountered (if any) – Describe any major problems/issues encountered during the study and how they were addressed.

Delays were experienced in most subprojects for various reasons but these were typically overcome. The issue of additional workload created by in-kind contributions of staff requires careful management so that the benefits of additional funding outweigh the inherent costs.

New Research Directions (if any) – Identify new research directions pursued during the course of the project and reasons for modifying original research plans. Describe how the changed research agenda improved the project.

4.4.1 Assessment and Monitoring of Bycatch

- Compared several methods of risk assessment to ensure robust assessments of risk.
- Developed new risk assessment approach to deal with bycatch reported in a range of units (e.g. numbers, weights)
- Trialled new technology in WA fisheries (cameras) to potentially use in place of observers.

4.4.3 Assessment and Monitoring of the non-commercial sector

- Delivery of the most robust approach to estimating catch and effort of the recreational boat sector in Australia and beyond.
- Already implemented

5. Overall Project Accomplishments

Students supported – Record the name of each student involved with the project. Indicate whether PhD or other (give details) and briefly describe their role.

Michelle Jenifer Gardner – PhD candidate. The microsatellite-based analyses of the stock structures of the Baldchin groper and Pink snapper form the basis of Michelle's PhD research. Michelle leads the genetic work on Baldchin groper and Pink snapper.

PhD theses, Dissertations and Student Placement – Please give complete citation for theses and

dissertations (student's name, month and year completed or expected, level of degree, institution). Please provide a copy of the abstract of the thesis or dissertation when complete.

Gardner MJ (In preparation) Genetic determination of the stock structures of Pink snapper (*Pagrus auratus*) and Baldchin groper (*Choerodon rubescens*) in Western Australian waters. PhD thesis, Murdoch University. Commencement date 19th January 2009. Expected completion date July 2012.

Publications - List in standard academic format the citations of literature produced during the reporting period. Include journal articles, book chapters, reports, etc. submitted, in press and printed. Please provide a paper and electronic version copy of each publication resulting from the project. If there is a link to the journal electronically, please also include this.

4.4.1 Assessment and Monitoring of Bycatch

Evans, R. and Molony, B. W. 2010. Ranked Risk Assessment for Bycatch in Multiple Fisheries: a Bioregional Risk Assessment Method. Fisheries Research Report No. 212. Department of Fisheries, Western Australia. 88 pp.

Evans, R. and Molony, B. W. 2011. Pilot evaluation of the efficacy of electronic monitoring on a demersal gillnet vessel as an alternative to human observers. Fisheries Research Report No. 221. Department of Fisheries, Western Australia. 16 pp.

4.4.2-1 Stock Structure

Fairclough, D. V., Lenanton, R. C. J and Jackson, G. 2011. Rapid and cost-effective assessment of connectivity among assemblages of baldchin groper *Choerodon rubescens* (Labridae), using laser ablation ICP-MS analysis of sagittal otoliths. *Journal of Experimental Marine Biology and Ecology*. **403:** 46–53.

Fairclough, D. V., Edmonds, J. S., Jackson, G., Lenanton, R. C. J., Kemp, J., Molony, B. W., Keay, I. S. and Crisafulli, B. M. (in prep.). Comparison of the stock structures of two exploited demersal teleosts *Glaucosoma hebraicum* (Glaucosomatidae) and *Pagrus auratus* (Sparidae), employing complementary methods of otolith chemistry.

4.4.2-2a Stock structure

Burridge, C.P. and England, P.R. (2009) Tri- and tetranucleotide microsatellites in dhufish *Glaucosoma hebraicum* (Perciformes). *Molecular Ecology Resources,* **9,** 948-951. http://onlinelibrary.wiley.com/doi/10.1111/j.1755-0998.2008.02508.x/abstract.

Berry, O. England, P. Fairclough, D. And Jackson, G. Microsatellites and hydrodynamic modelling reveal the extent of larval transport and gene flow between management zones in an exploited marine fish (*Glaucosoma hebraicum*). Fisheries Oceanography, minor revisions.

4.4.2-2b Stock Structure

Gardner MJ, Chaplin JA, Shaw KM (2011) Development and characterisation of novel microsatellite loci for the baldchin groper (*Choerodon rubescens*) and cross-amplification in seven other labrid species. *Conservation Genetics Resources*, **3(3)**, 461– 466. http://www.springerlink.com/content/n4t1n55163332712/ DOI: 10.1007/s12686-010-9379-y

4.4.2-3 Stock Structure

L. Richard Little, Oliver Berry and Brett Molony. In prep. A management simulation model for dhufish in the West Coast Demersal Scalefish Fishery.

4.4.3 Assessment and Monitoring of the non-commercial sector

Wise, B. et al. (in review) Determination of cost effective techniques to monitor recreational catch and effort in Western Australian demersal finfish fisheries. Final report to the Fisheries Research and Development Corporation for Project - 2005/034. *Fisheries Research Report*.

Presentations - Cite any presentations resulting from the project, including conferences, symposiums, etc.

Presentations and reviews by Project Leader (Brett Molony)

- Node 4 review, February 2010
- Node 1 and 4 Synthesis , May 2010
- WAMSI Kimberley symposium, May 2011

Presentations from sub-project leaders for all WAMSI sub-projects

- WAMSI Node 4 Public Presentations. Department of Fisheries WA, 26 November 2008
- WAMSI Node 1, 2nd Symposium, CSIRO Floreat, Thursday 30 July 2009 (dhufish work presented alongside work from node 1).
- Annual WAMSI Node 4 Symposium, Department of Fisheries WA, November 2, 2009.
- Dhufish mini-workshop, Dept. Department of Fisheries WA, 2nd December 2009.
- WAMSI-AMSA *WA Marine science in Western Australia*: *Show and Tell* symposium, WA Maritime Museum, 9th February 2010.
- WAMSI Node 4 Synthesis and Integration Day, Department of Fisheries WA, 17th June 2010.
- WAMSI Node 4 Peer Review and Synthesis Day, Department of Fisheries WA, 6th Dec 2010

Additional presentations based on WASMI supported projects

- Gardner MJ, Chaplin JA, Fairclough D, Jackson G, Berrry O (2011) A multi-disciplinary approach to investigating stock delineation in Baldchin groper, a labrid endemic to the west coast of Australia. Annual International Conference Fisheries Society of the British Isles, Bournemouth, UK.

Other Communications Achievements - Interviews, press releases, etc.

- Interview of Brett Molony as WAMSI Project Leader, October 2010. (Arranged by Steve Blake).
- Pearce, A. and Fairclough, D. 2010. Where are they now? Article in the magazine, *Western Fisheries*, July 2010, pp 48 – 49.

6. Overall Project Benefits Please note: Benefits go beyond Results and Accomplishments to provide information on direct physical, environmental, economic or social gains realised as a result of a research project or outreach activity.

Discovery and Application of New Products and Processes (if applicable) - Describe any actual or anticipated products or processes discovered or developed in the project.

4.4.1 Assessment and Monitoring of Bycatch

- Compiling and centralising all bycatch data in the Department for the West Coast Bioregion.
- Involvement and liaison with commercial fisher to allow fitting of camera gear on commercial vessel to support the project.

4.4.2-1 Stock Structure

- Multidisciplinary information about the stock structures of West Australian dhufish, Baldchin groper and Pink snapper in Western Australian waters and influences of hydrodynamics on gene flow and connectivity in these species and how these relate to current spatial management arrangements.
- PhD student training in the field of fish population genetics.
- The findings of this work have been prepared for publication with fisheries biologists Gary Jackson and David Fairclough. In combination with information on stock structure from other sources such as otolith microchemistry, it provides a strong basis for understanding the spatial ecology of the dhufish and evaluating how it is likely to interact with existing spatial management. Upon completion of the project and peer review it will be appropriate for discussions to be held with managers of the West Coast Demersal Scalefish fishery.
- Species-specific molecular markers have been developed for the dhufish, baldchin groper and pink snapper. These provide opportunities for future research on reproductive behaviour, larval swimming behaviour (cohesion as planktonic larvae, mechanisms of transport), and non-invasive genetic marks and recapture based estimates of abundance and mortality (gene-tagging).
- This project produced the first characterisation of the extent of gene flow in the dhufish.
- This project produced the first comprehensive models of larval transport in the dhufish. There are opportunities to integrate this information into ecosystem models that incorporate biological processes and rates of exploitation.

4.4.3 Assessment and Monitoring of the non-commercial sector

- The first state-wide integrated survey of the recreational boat fishing sector is underway, based on WAMSI-supported research. The first estimates of recreational boat-based harvest, effort and catch levels will be provided to managers in 2012.

Tools, Technologies and Information for Improved Ecosystem Management - Describe how project results are being (or will be) translated into sustainable use and management of coastal and ocean ecosystems. Tools might include benthic habitat maps or environmental sensitivity indicators. Technologies might include remote and bio-sensing, genetic markers, and culture systems. Information might include technical assistance, training and educational materials.

4.4.1 Assessment and Monitoring of Bycatch

- This information will directly input to the Department's Ecosystem Based Fisheries Management process that will support the risk-based approach to determining management priorities.
- Informed risk assessments of all bycatch species in three Bioregions
- Allowed the re-evaluation of risk assessments
- Identified only moderate risks
- Identified knowledge gaps
- Trialled new technology to potentially fill data gaps

4.4.2 Stock Structure

- Stock structure determined from all methods is already being considered by fishery managers.
- This information will directly input to the Department's Ecosystem Based Fisheries Management process that will support the risk-based approach to determining management priorities.
- The particle tracking simulations generated in this project have provided the first models of larval dispersal in the dhufish, which is a targeted species within the WCDSF. These simulation results are being explicitly incorporated into the ELFSim ecosystem model for the dhufish (see 4.4.2-3).
- Microsatellite markers for genetic studies of the Baldchin groper and Pink snapper and related species. Three of the microsatellite markers developed for the Pink snapper have already been used as part of an analysis of the genetic implications of the restocking of black bream *Acanthopagrus butcheri* in Western Australian waters. (Gardner MJ, Cottingham A, Hesp S, Chaplin JA, Jenkins GI, Potter IC (In review) Comparisons of the biological and genetic characteristics of restocked and wild individuals of a sparid (*Acanthopagrus butcheri*) in an estuary. Fisheries Reviews.)

4.4.3 Assessment and Monitoring of the non-commercial sector

- The new integrated survey currently underway will deliver spatial estimates of recreational harvest for direct consideration by mangers for sustainable management of the resources and assessment of the effect of recreational harvest on the ecosystem.
- This information will directly input to the Department's Ecosystem Based Fisheries Management process that will support the risk-based approach to determining management priorities.

Forecasting for Natural Resource Management Decisions - Describe how results already are being used - or are expected to be used after project completion - by natural resource management to make decisions based on project forecasts. Forecasts may be due to field and laboratory studies and models. Examples include hypoxia forecast models, algal bloom alerts, forecasts of fishery harvest, and prediction of impacts from ecosystem stressors such as pollutants or invasive species.

4.4.2 Stock Structure

- The results of stock structure analysis along with particle tracking simulations and other sources of information (otolith microchemistry) will be used to evaluate the appropriateness of the existing scales of management as defined by the West Coast Demersal Scalefish Fishery management zones.
- The results will also inform fishery managers on the connectivity of pink snapper and dhufish in the Gascoyne and South Coast Bioregions

4.4.3 Assessment and Monitoring of the non-commercial sector

- Estimates of recreational effort and catch will be used to assess the potential risk of population changes in various parts of the state
- Estimates will also allow better forecasting of the impacts on spatial closures (e.g. via marine planning or coastal developments that may restrict recreational fishing access).

Impacts - Impacts are higher order, usually long-term results of a project's activities that have significant scientific, economic or social benefits. Impacts may involve behavioural, policy or economic changes. Describe impacts (anticipated or realized. These impacts may involve behavioural, policy or economic changes. Seminal contributions to science are considered impacts especially if the research findings lead to major progress in a particular field, implementation of new technologies or have a substantive bearing on an economic or societal issue.

4.4.1 Assessment and Monitoring of Bycatch

- Highlighted that the sustainability risks to bycatch are low-moderate, breaking broadly held public perceptions

4.4.2 Stock Structure

- Found that the stock structure of some of the indicator species – West Australian Dhufish and Pink Snapper – are extensive, extending beyond the bioregional boundaries. This needs to be considered in the sustainable management of these resources.
- Identified that there are few nursery areas of pink snapper and thus management of Cockburn Sound needs consider non-fishery threats to the sustainability of this species.
- Currents are more complex than broadly considered and have implications on the dispersal and recruitment of many species. This means that recruitment pulses are likely to be unpredictable and that sustainability of fishery resources needs ongoing management of the extractive component; it can't rely on good recruitment.
- The combined results of the genetic, microchemistry and particle modelling analyses will be used to assess whether current spatial management measures for the Baldchin groper and Pink snapper are appropriate/optimal.
- This project, in combination with 4.4.2-1 has provided a uniquely multi-disciplined approach to defining stock structure in a marine fish. In doing so it has generated a more comprehensive understanding of the spatial ecology of the dhufish than would have been possible if using each analysis method in isolation. Recent reviews in the international fisheries biology literature emphasise the value of multi-disciplinary stock structure analysis (Selkoe, et al. (2008). *Fish and Fisheries,* **9,** 363-377), and we are hopeful that it will lead to similar initiatives in the future.

4.4.3 Assessment and Monitoring of the non-commercial sector

- The current integrated survey will allow better evaluation of the value and extent of recreational fishing throughout Western Australia. This will better allow managers to account for the social and secondary economic impacts and benefits of recreational fishing in WA.

7. Project Metadata and Data Generated

These must be available at an open access repository/data centre/iVEC.

- All metadata is already available and lodged with iVEC.
- All data will be made available upon the completion of the project.

8. Linkages to Associated Projects – can be WAMSI and non-WAMSI

Project 4.4 links directly with the Department of Fisheries Ecosystem Based Fisheries Management (EBFM) process and directly with the Department of Fisheries project on management of the West Coast Demersal Scalefish resource.

Specifically, the three major sub-projects also have links with the following projects;

4.4.1 Assessment and Monitoring of Bycatch

- FRDC 2007/059
- FRDC 2010/001
- WAMSI Node 4 – other projects and sub-projects

- Links with WAMSI Node 1

4.4.2 Stock Structure

- Results have led to the development of a new FRDC project that will commence in the upcoming financial year (FRDC 2011/016, led by CSIRO)
- Additional investment in the drifter component of this project has resulted in additional investment and release of drifters to collect further information on West Coast on-shelf currents to better define spatial models
- Links with WAMSI Node 1 and 6
- The results will support the upcoming (2012) reassessment of the status of the West Coast Demersal scalefish by the Department of Fisheries
- It has also supported a review of indicator species by suite and Bioregion for monitoring and assessment purposes by the Department of Fisheries.
- The outcomes have also resulted in new finding applications to the FRDC and WANRM to support similar work in other the South Coast Bioregion and nearshore scalefish suite, leveraging form the investment and skills developed by the WAMSI process.

4.4.2-2a Stock structure

- Results have led to the development of a new FRDC project that will commence in the upcoming financial year (FRDC 2011/016, led by CSIRO)
- Links with WAMSI Node 1 and 6

4.4.2-2b Stock Structure

- Michelle Gardner will continue to investigate aspects of the stock structure of the Pink snapper in Western Australian waters as she continues her PhD research into 2012. Among other things, the additional research will attempt to disentangle the basis for conflicting reports about the relationships among the assemblages of Pink snapper inside and outside of Shark Bay.

4.4.2-3 Stock Structure

- Particle tracking simulations developed in this project to quantify the levels of dhufish larval transport between regions of the WCDSF have been integrated into project 4.4.2.3.
- Links with WAMSI Node 1 and 6

4.4.3 Assessment and Monitoring of the non-commercial sector

- FRDC 2005/034
- Has led to the development and investment in the Department of Fisheries' iSurvey, currently implemented and underway.

9. Other Comments and General Discussion

All information from this project (4.4) will directly input to the Department's Ecosystem Based Fisheries Management process that will support the risk-based approach to determining management priorities.

4.4.1 Assessment and Monitoring of Bycatch

This WAMSI sub-project was the first to estimate the levels of bycatch across fisheries and bioregions. This cumulative risk assessed showed that although data gaps exists, sustainability risks to bycatch are low or low-moderate, breaking broadly held public perceptions. Nonetheless, fishery interactions with TEPS (Threatened, Endangered and Protected Species) will remain a social risk, regardless that interactions with fisheries are rare events. The new information provided by this project is already informing risk assessments with the Department of Fisheries.

4.4.2 Stock Structure

The multi-disciplinary nature of the assessment of stock structure and discrimination for the three indicator species (genetics, hydrodynamics, otolith microchemistry, otolith stable isotope analyses) was a powerful approach to the address the management issue, and delivered comprehensive spatial information for the three indicator species.

The involvement of fisheries geneticists and fisheries biologists in this project was invaluable as it focused the genetic analysis on the specific biological problems relevant to the management of the dhufish. The

fisheries biologists also provided a link to management practices for the fishery.

The overall management outcome is that the indicator species in the management zones of West Coast Bioregion do not have separate genetic stocks; they are part of broader stocks that cross management zones, and in the case of pink snapper and dhufish, cross Bioregional boundaries. This is critical information for fishery managers. Nonetheless, the current fishery management zones in the West Coast Bioregion are critical for limiting fishing effort within a zone, thereby reducing the risks of localised depletions. This is required because the adults of each species are somewhat limited in their movements so individuals typically reside within the one management region.

The project also highlighted the value of multi-species studies, such that general trends may start to emerge, (*e.g.* that larval movements may be particularly important in broad-scale connectivity in demersal fish species). Thus hydrodynamic information is an important consideration in understanding the dynamics of recruitment and sustainability of fish stocks.

Information generated in this project will support the 2012 assessment of the status and risks to sustainability of West Coast Demersal Scalefish resource and fisheries.

The investment in hardware (Micromiller machine) and staff in the project has produced an approach that can be applied to other management questions in extractive fisheries. Since the initial WAMSI investment, other projects using similar approaches have commenced (e.g. West Coast nearshore finfish sustainability and connectivity) and other projects have been submitted for consideration to other funding bodies (e.g. South Coast finish sustainability and connectivity). These two later projects have also involved WAMSI collaborators.

4.4.3 Assessment and Monitoring of the non-commercial sector

This WAMSI investment has already led to the development and implementation of the Department of Fisheries' first state-wide survey of boat-based recreational catch and effort. The estimates and information generated from iSurvey are critical to sustainable management of fisheries throughout the state and will also be used as inputs for allocation considerations by fishery managers. The results of the first iSurvey will be available during 2012. Future iSurveys are planned to occur biennially.

10. Annexures

- Sub-project reports presented
- Additional attachments

4.4.1 Assessment and Monitoring of Bycatch

1. Evans, R. and Molony, B. W. 2010. Ranked Risk Assessment for Bycatch in Multiple Fisheries: a Bioregional Risk Assessment Method. Fisheries Research Report No. 212. Department of Fisheries, Western Australia. 88 pp.

2. Evans, R. and Molony, B. W. 2011. Pilot evaluation of the efficacy of electronic monitoring on a demersal gillnet vessel as an alternative to human observers. Fisheries Research Report No. 221. Department of Fisheries, Western Australia. 16 pp.

4.4.2-1 Stock Structure

3. Fairclough, D. V., Lenanton, R. C. J and Jackson, G. 2011. Rapid and cost-effective assessment of connectivity among assemblages of baldchin groper *Choerodon rubescens* (Labridae), using laser ablation ICP-MS analysis of sagittal otoliths. *Journal of Experimental Marine Biology and Ecology*. **403:** 46–53.

4. Fairclough, D. V., Edmonds, J. S., Jackson, G., Lenanton, R. C. J., Kemp, J., Molony, B. W., Keay, I. S. and Crisafulli, B. M. (in prep.). Comparison of the stock structures of two exploited demersal teleosts *Glaucosoma hebraicum* (Glaucosomatidae) and *Pagrus auratus* (Sparidae), employing complementary methods of otolith chemistry.

4.4.2-2a Stock structure

5. Burridge, C.P. and England, P.R. (2009) Tri- and tetranucleotide microsatellites in dhufish *Glaucosoma hebraicum* (Perciformes). *Molecular Ecology Resources,* **9,** 948-951.

6. Berry, O. England, P. Fairclough, D. And Jackson, G. Microsatellites and hydrodynamic modelling reveal the extent of larval transport and gene flow between management zones in an exploited marine fish (*Glaucosoma hebraicum*). Fisheries Oceanography. Reviewed - minor revisions required, to be resubmitted by 9th September 2011. Abstract and title only attached.

4.4.2-2b Stock Structure

7. Gardner MJ, Chaplin JA, Shaw KM (2011) Development and characterisation of novel microsatellite loci for the baldchin groper (*Choerodon rubescens*) and cross-amplification in seven other labrid species. *Conservation Genetics Resources*, **3(3)**, 461– 466.
http://www.springerlink.com/content/n4t1n55163332712/ DOI: 10.1007/s12686-010-9379-y

8. Gardner, M.J., Chaplin, J.A., Fairclough, D., Jackson, G., Berry, O. 2011. A multidisciplinary approach to investigating stock delineation in Baldchin groper, a labrid endemic to the west coast of Australia. Poster presented at the Annual International Conference Fisheries Society of the British Isles, Bournemouth, UK.

9. Gardner MJ (in prep) Genetic determination of the stock structures of Pink snapper (*Pagrus auratus*) and Baldchin groper (*Choerodon rubescens*) in Western Australian waters. PhD thesis, Murdoch University. Commencement date 19th January 2009. Expected completion date July 2012.

10. Gardner, M.J., Chaplin, J.A. and Phillips, N.M. (in prep) Isolation, characterisation and cross amplification of novel microsatellite markers for use in population structure analysis of Pink Snapper, *Pagrus auratus*.

11. Gardner, M.J. and Chaplin, J.A. (in prep) Population genetic structure of the Baldchin groper, *Choerodon rubescens*: genetic evidence of widespread gene flow mediated via larval dispersal.

12. Gardner, M.J. and Chaplin, J.A. (in prep) Microsatellite and mitochondrial DNA assessment of population structure and gene flow in Pink snapper, *Pagrus auratus*, in Western Australian waters

4.4.2-3 Stock Structure

13. L. Richard Little, Oliver Berry and Brett Molony. (in prep). A management simulation model for dhufish in the West Coast Demersal Scalefish Fishery.

4.4.3 Assessment and Monitoring of the non-commercial sector

14. Wise, B. et al. (in review) Determination of cost effective techniques to monitor recreational catch and effort in Western Australian demersal finfish fisheries. Final report to the Fisheries Research and Development Corporation for Project - 2005/034. *Fisheries Research Report*.