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Scientific review of the West Coast Demersal Scalefish Fishery, Western Australia

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Government of **Western Australia**
Department of **Fisheries**

Western Australian Fisheries
and Marine Research Laboratories

Fish for the future

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1 Summary and background

In December 2008 the Hon Norman Moore MLC, Minister for Fisheries Western Australia appointed two independent experts to assess separately 1) the validity of scientific advice to management and 2) options to manage recreational fishing of west coast demersal scalefish. The following review (1) assesses the validity of research outlining the status of baldchin groper (*Choerodon rubescens*), West Australian dhufish (*Glaucosoma hebraicum*) and snapper (*Pagrus auratus*) as described in the terms of reference. In addition to the terms of reference, an opinion was requested regarding the current appropriateness of the research advice (Wise et al 2007) and the resulting management goal to reduce the catches of each of the WCDS species by at least 50% from 2005/06 levels across all sectors. This review covers existing assessment reports, new data and analyses produced by the Department of Fisheries, Western Australia. It also comments on the peer review outcomes from Dr Malcolm Haddon and assesses the degree to which any scientific recommendations have been implemented. The department's previous scientific review by Dr Haddon provides extensive well-written commentary clearly describing the theoretical processes, data, results and their interpretation. This review will not duplicate this, but rather focus on the important components critical for providing scientific advice to management. This review also provides suggestions on future opportunities to improve assessments and reduce uncertainty in classifying the status of baldchin groper, dhufish and snapper, there by improving the quality of the scientific advice to managers.

Since the previous assessments on 2005/06 data, Western Australian scientists have done considerable work collecting and maintaining the annual time-series of frequencies of fish-at-age and utilised this to estimate fishing mortality. The most recent assessments on 2007/08 age structured data for baldchin groper, dhufish and snapper indicates high fishing mortalities. Specifically research indicates that both dhufish and pink snapper are being overfished throughout their geographic range on the west coast and that baldchin gropers are being overfished at the Abrolhos Islands (Fairclough, 2009, Draft only; Fisheries, 2009; Wise et al., 2007).

The previous and new assessments have produced valid scientific advice and were sustained on solid collection of age and length data and analyses. The assessments were as thorough as possible, given their available resources and quality constraints on fishery catch and effort data. Clearly described risk tables were presented which clarified the current knowledge and uncertainties for management and stakeholders to consider (Wise et al., 2007). It should be noted that innovative spawning egg and recruitment surveys are currently being carried out to develop fishery independent abundance indices for snapper; these will provide future clarity on the status of the snapper stock. Overall, the assessments of baldchin groper, dhufish and snapper supply quality information, which provides constructive opportunities for management and stakeholders to improve the status of the stocks, commercial profitability and recreational angling quality.

From the available data, updated estimates of fishing mortality (Fairclough, 2009, Draft only), following the triggers of reference points ($F_{current} > F_{limit}$) and decision rules, it is not possible to recommend a more accurate reduction in fishing effort than the 50%-100% range. With the available information, the current management goal to reduce fishing effort by 50% with a view to reviewing this as necessary when scientific evidence allows is appropriate.

In 2007 a scientific review was undertaken by Dr Malcolm Haddon (Haddon, 2007; Wise et al., 2007) on data up to 2005/6. The review supported research findings that effective effort (fishing power) had been increasing and stock indicators declining for dhufish, snapper and baldchin groper. Five important scientific recommendations were made by Dr Haddon, of which all are in the process or have been addressed: 1) standardisation of commercial catch rates, 2) daily commercial catch reporting, 3) recreational catch surveys scheduled once every two or three years, 4) additional focus on quantifying recreational catches from Cockburn Sound, and 5) clearly defined fishing mortality reference points.

As for any review of fishery assessments, there are suggestions for improvement. Some suggestions promote further investment in and use of fishery independent monitoring data. If done this will reduce uncertainty in classifying the status of the three fish stocks and improve the precision of scientific advice to management. Other suggestions outline data requirements to enable more detailed quantitative stock assessment. The suggestions do not change the current assessment conclusions or triggers of reference points. The following is a list of the main suggestions made in this review document:

- Further develop annual times series of fishery independent abundance indices for baldchin groper, dhufish and snapper. It would be most beneficial if the indices covered both recruitment and the adult populations.
- Complete at least biennial estimates of recreational total catch and effort. Ideally levels of fishing effort, harvested and released fish would be quantified by two depth strata split at 30 metres to factor in discard mortality estimates. For abundance indices, maintain annual records of recreational fish catch rates.
- Develop formal quantitative management evaluation models to investigate expected effects of current and future management changes, reference points and decision rules. Fishery managers and stakeholders should take the leading role in defining the frequency of management reviews and assessments, and setting target/operational objectives. Narrower decision-rule-responses, than the broadly prescribed 10-50% or 50-100%, could then be tailored to match the management framework and schedule.
- Develop age structured population models to explore stock status scenarios and degrees of overfishing.
- Explore the use of longitudinal (cohort) methods to estimate improved measures of fishing mortality.
- Verify the appropriate shape of fishing selectivity schedules and allow for modification due to any changes in fish size limits.
- Develop the potential for commercial and recreational catch rates to be used as indices of abundance. This involves further statistical analyses to standardise catch rates, ensuring appropriate effort variables are recorded in daily logbooks and catch interviews, and historically cataloguing fishing gears and technologies.

- Maintain the annual time-series of frequencies of fish-at-age and utilise this to estimate fishing mortality.

2 Stock assessment

In general the documents provided to the review were all technically sound. Together they covered the data requirements for stock assessment (Figure 1), with all data and analyses transparent. The authors did not apply formal mathematical stock assessment models because of the lack of complete time series. This was appropriate as assessments based on few years of data can give misleading results on stock status. However, further estimates on stock status can be achieved through modelling scenarios of longer annual time series of harvest through stock reduction analyses (Walters et al., 2006) and management strategy evaluations (MSE). Developing a MSE tool should be considered as one of the next steps of research (outlined in next section). For dhufish and snapper, sufficient data has been collected on fish total catches, catch rates, fishery independent abundance indices, age structure and biology to conduct more complex analyses. The lack of long-time-series should not limit the exploration of different stock assessment methodologies.

Due to the lack of time series of assessment data (outlined above), the WCDSF fishery can be viewed as relatively data poor. In these data situations simple analyses are commonly used to describe the status of a fishery. This is the current approach taken by assessment scientists, where fishing mortalities were estimated directly from observed declines in the frequencies of fish with age for each year. Despite the limitations on data, the fishery is being successfully managed using simple analyses based directly on fish age frequencies, simple reference points and clearly defined management responses. The harvest strategy framework with time and increased data will allow more precise analyses leading to more accurate scientific advice to management.

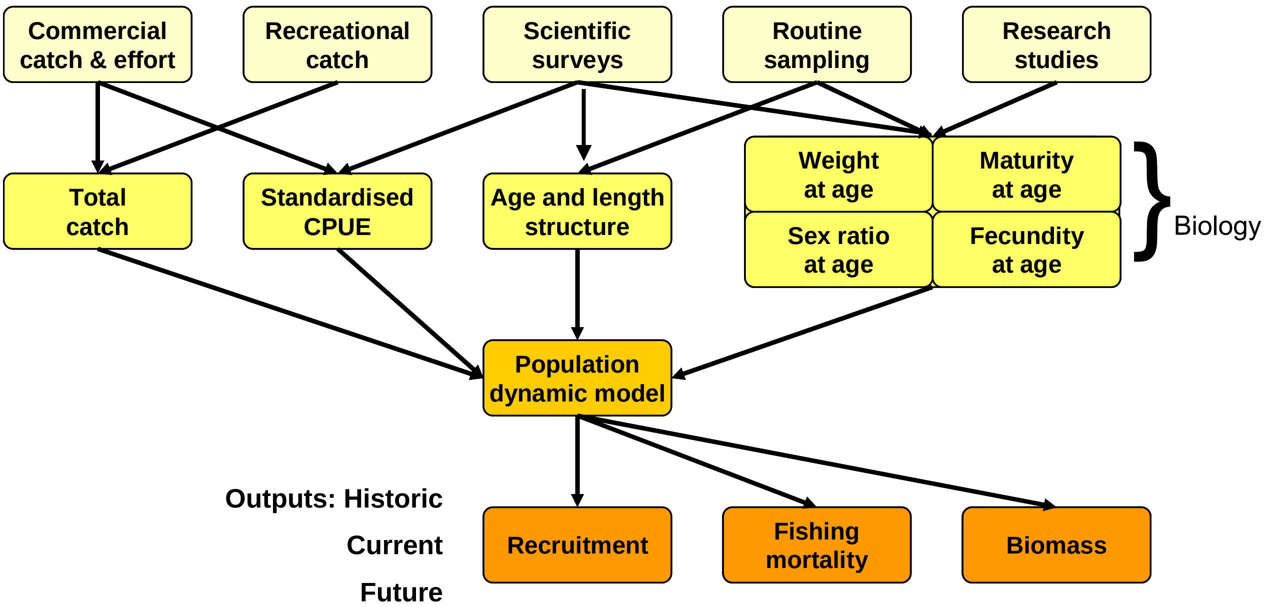
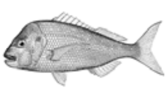


Figure 1 Stock assessment findings come from an integration of data and analyses. The 2nd row of flow chart (yellow cells) illustrates the typical data required for assessment.



2.1 Sampling and aging fish

Appropriate numbers of fish were aged between 2003 and 2008 to provide sufficient information to calculate fishing mortalities (Lenanton et al., 2009a). The majority of fish (≥ 85%) were sampled across the north, metropolitan and south zones from the commercial and recreational sectors. Adding a summary of the number of catches sampled from each sector into the 2007/08 assessment report would further demonstrate the fishery coverage of sampling. The data were structured according to a random-stratified sampling strategy (zone * fishing sector). The sampling unit for collecting age and length frequencies is the "catch". It is important to demonstrate that the samples of fish were from many catches rather than sampling large numbers of fish from only a few catches or fishers. Dr Haddon stated that age samples of at least 300 fish are required to characterise the age structures (Haddon, 2007); this is in line with the general principles for sampling and aging many other species of fish (Sumpton and O'Neill, 2004).

Fish aging protocols were sound, included methods for multiple otolith readings and statistics to quantify reading bias and precision (Lenanton et al., 2009a). Age verification analyses were completed for baldchin groper, dhufish and snapper (Fairclough, 2005; Hesp and Potter, 2000; Hesp et al., 2002; Lenanton et al., 2009a; Nardi et al., 2006). If aging protocols continue to include multiple reading of all otoliths (i.e. following a balanced experimental design), then including all readings to construct age frequency distributions (proportions) will avoid the need to possibly reject otoliths or take mean ring counts and the age distributions will include reading uncertainty; when aging large numbers of fish, random reading errors should average out with zero mean effect. Summary statistics are required to report on numbers and lengths of fish/otoliths not used to calculate age frequencies and fishing mortalities. Rejecting too many otoliths due to inconsistent reading can potentially bias age frequencies down if discarded otoliths are mostly older/larger fish. The number of otoliths removed from analyses was probably low; this needs to be documented. For fishing mortality analyses age data need to ensure all fish are of the same cohort. This was done in the 2007/08 assessment report (Fairclough, 2009, Draft only).

2.2 Fishing mortality

For the three key indicator species, estimates of 2007/08 fishing mortalities (F) were, in most cases, greater than the threshold (M) or limit (1.5M) trigger points (Fairclough, 2009, Draft only). A range of methods were applied to examine the significance of age frequency truncation and show the uncertainty around F. The annual fishing mortalities for snapper following method 1 were re-examined, noting the data provided were not adjusted to ensure all fish were of the same cohort. The effect of truncating the regressions between different ages (5 and 15) was tested, confirming the levels of F estimated in 2007/08 and that F has been consistently high since 2004 (section 8, Appendix 1). Baldchin groper or dhufish were not reanalysed, but the data decisions and methods applied to estimate F for these species in 2007/08 were appropriate. In Wise et al (2007), they combined data over years (2003-2006) and cohort groupings (adjustments) were not specified as done; the cohort groupings were done in 2007/08 assessment. In general grouping age data across years artificially smooths the age distributions, removes contrast to identify strong or weak age classes and removes variability. Given the high levels of F estimated by Wise et al (2007), it is unlikely that making the cohort adjustments and analysing each year separately would change the inferences or triggers of reference points.

The background description on age compositions and their interpretation was clearly and accurately described. The significance of age frequency truncation (i.e. total mortalities) was assessed appropriately using three different methods, with the improved method 3 using all age data by incorporating fishing vulnerability. Given a reasonable time series of age frequencies has now been built (2003 to 2008; 6 years), the use of the data could be maximised by calculating fishing mortalities for fish cohorts using method 1, method 3, and age structured stock analyses:

- Longitudinal catch curves should be constructed by taking proportion data for single cohorts. This will eliminate the constant recruitment assumption (Hilborn and Walters, 1992). For example, to build a catch curve for the cohort that was recruited in 2003, one would take the proportion of one ring-olds observed in 2003, the proportion of 2 ring-olds in 2004, and so on. However, care is needed when comparing the proportion of observations in different years of sampling. Simple proportions taken each year cannot capture changes in abundance from year to year. Thus all proportions should be multiplied by an index of abundance (e.g. standardised catch rate) in longitudinal catch curves. Note that this is not currently a problem in the cross-sectional case (currently used) because each curve is built from data sampled in a single year. All data should be analysed through a single GLM such as: $\log(\eta_{i,y}) = \alpha_i + yZ_i$, where η = normalised proportion (*p*) of fish-at-age in each year *y* for cohort *i* $\eta_{i,y} = p_{y,i}cpue_y \Big/ \sum_y p_{y,i}cpue_y$, α_i = model intercepts for each cohort *i*, *y* = year and Z_i = estimated total mortalities for each cohort. The application of this approach is dependent on an available index of abundance.
- Method 3 can also be applied to the same age data by comparing outputs considering selectivity estimated/derived inside and outside of the model (such as exploring simple equilibrium VPA derivatives or tagging data; Allen et al., 2006; Myers and Hoenig, 1997).
- For a more quantitative technique apply the age data through age-structured stock models (see comments under future assessment).

Other considerations:

- Selectivity schedules with age or length should be examined closely. Many long-lived fish species show evidence of dome-shaped relationships between selectivity and age or size (Assessment review by Dr Carl Walters; Allen et al., 2006). This is the case for snapper on the east coast Australia, and may also be plausible in Western Australia for dhufish, snapper and baldchin groper. If true, current mortality values will be overestimates. However, this effect may not change many of the decision rule inferences. Obtaining an understanding of how selectivity changes with age or length is important and difficult. Historical changes in size limits also changes selectivity through time, and can confound abundance changes.

- Present standard errors on F estimates. Use these to calculate probabilities of exceeding threshold and limit reference points. This will add to the already well presented and thorough risk tables (Wise et al., 2007).
- Where applicable, outline more clearly the age ranges used to estimate F.

What do the estimates of fishing mortality mean? Wise et al (2007) correctly states that high estimates of fishing mortality do not necessarily imply critical damage to the stock. However, fishing mortality estimates have in general been greater than thresholds for snapper and dhufish since 2002. If high fishing mortalities continued for a number of years, an overfished stock (exploitable biomass less than B_{MSY}) will eventually result. The weight of evidence approach presented in the report suggests this may be the case and that the states of the baldchin groper, dhufish and snapper are most probably at undesirable levels. How undesirable? This cannot be quantified without extensive modelling. However, possibilities can be generated from simulation analyses. For example, a population simulation including harvest data, biological data, statistical and biological process errors, and a monitoring model for collating fish catch-at-age data (including observation errors) will clarify the performance of simple measures of total mortality (Z=F+M; method 1 or 3) against levels of exploitable biomass or spawning biomass ratios for a fully developed fishery. Appropriate levels of stock-recruitment steepness (or Rmax, Myers et al., 1999) and biological uncertainties will have to be assumed.

2.3 Reference points

The use of F in decision rules was clearly set out in Wise et al (2007). Given the number of triggers for F > F_{LIMIT}, scientists have followed the decision rules and reported the corresponding management action listed for a reduction in WCDSF effort of between 50%-100% (pers. comm. Dr Molony). Management have selected 50%, under the harvest strategy framework (pers. comm. Dr Molony). The current decision rules for the F triggers do not allow for smaller percentage reductions than this. If Government considers percentages less than a 50% reduction in effort, then substantial ongoing fishery independent survey work and fishery data collection will be required to trade more knowledge on the stocks for lower reductions in effort. Management strategy evaluations will then be required to re-define the decision rule percentages. Also an adaptive management approach can be used to determine if the desired reduction in effort leads to a reduction in the level of fishing mortality (Wise et al., 2007). However, it may take some time for the measures of F to reduce. It should be noted that the harvest strategy rules (triggers and percentages) should evolve further over time and should be considered to mange effort adaptively.

From the available data, updated estimates of fishing mortality (Fairclough, 2009, Draft only), following the triggers of reference points ($F_{current}$ > F_{limit}) and decision rules, it is not possible to recommend a more accurate reduction in fishing effort than the 50%-100% range. With the available information, the current management goal to reduce fishing effort by 50% with a view to reviewing this as necessary when scientific evidence allows is appropriate. Note that the previous statement emphasised reducing fishing effort, not catch. Initially a management response to reduce total fishing effort (E_T) by x% would expect to reduce total catch (C_T) by the same x%; assuming constant catch rate (c_r), where $C_T = c_r E_T$. However, it should be recognised that the relationship between fish population sizes, total catches and total efforts through time are dynamic and nonlinear. Of particular note is the situation where the proportional reduction in catch is less than the reduction in effort; this can occur if fishers respond to the curtailed effort limits by fishing more intently or efficiently. Managing recreational catches via limiting total harvests would be a difficult task compared to effective (in terms of sustainability and costs) effort controls (Cox, 2000; Post et al., 2002; Walters and Cox, 1999).

The current decision rules, when fishing mortalities are triggered high, recommend fishing effort reductions of either 10-50% or 50-100%. The decision rules for low fishing mortalities do not prescribe an amount for increasing fishing effort. The decision rule responses are currently quite broad and should be narrowed when research allows.

2.4 Catch rates

Fishery catch rates are used as a basis for assessing stocks in many fisheries. If fishery catch rates are proportional to fish abundance, then trends over time can inform stock models directly on stock status, fishing mortality and recruitment variation. Unfortunately the proportionality between fishery data and abundance is not often true. Spatial and temporal patterns of clustered fishing, lack of reporting appropriate effort variables, increases in fishing efficiency, and the nature of schooling fish produce hyperstable data. Therefore statistical analyses are required to adjust time series of catch rates so that they more closely relate to abundance.

The issue of hyperstability was well documented in the report and authors have correctly carried out necessary adjustments to nominal (unstandardised) effort and catch rates (section 5 Wise et al., 2007). The adjustments made significant changes indicating 40%-60% declines in catch rates between 1970's and 2000's (Fig. 69, Fig. 70 and Fig. 71; compared to lesser or no declines in unstandardised catch rates shown in Fig. 44, Fig. 50 and Fig. 56). The declines in standardised catch rates are consistent with the levels of fishing mortality implied by age structures, lending strong weight towards overfishing. More work is needed to confirm the current time series of adjusted catch rates:

1. Produce summary statistics for each region demonstrating the selection of fishers surveyed on fishing technologies was representative of the fishery. This is minor, but important to show as the sample estimate of efficency_increase is applied across all fishing effort. Haddon (2007) noted that the sample of fishers was low, however I could not source documentation on the sample fraction of total licensed fishers in each region. Wise et al (2007) reports that 11 of 34 fishers could not provide efficiency data, limiting the accuracy of estimates. More surveys on fishing efficiency may be required.
2. Re-estimate all three schedules of adoption using logistic regression models. The adoption data for colour sounders, GPS and hydraulic reels should consider each fisher's effort in each year (days fished). Confirm adoption values calculated from hydraulic reel equation (Table 6, Wise et al., 2007).
3. For each fish species, verify efficiency increases through generalised liner models (GLM) by comparing monthly catches taken with and without the presence of colour sounder, GPS and hydraulic reels (analyses on subsets of data maybe required). For the GLM modelling using log data or log link functions would ensure multiplicative errors. Compare trends in predicted standardised catch rates from GLM using model estimated coefficients and offset schedules to explore possible abundance/fishing power

confounding (Bishop et al., 2008; O'Neill et al., 2003; O'Neill and Leigh, 2007). The efficiency estimates were derived from fishers' observations and experience using the technologies across all species. These are important priors for the efficiency coefficients, especially if a Bayesian procedure is used for the GLM modelling. However independent analyses are needed to verify efficiency increases and declines in standardised catch rates by fish species.

Following the additive methods of Wise et al (2007), where nominal effort increases by $\prod_{i=1}^{3} 1 + p_{adopted,i}(y) \times efficiency\_increase(\beta_i)$, the strong influence of the assumed coefficient for GPS has been illustrated (Figure 2). Large standard errors were reported compared against median efficiency increases. Changing this GPS coefficient can result in a large difference in effective effort and standardised catch rates depended on the reference years.

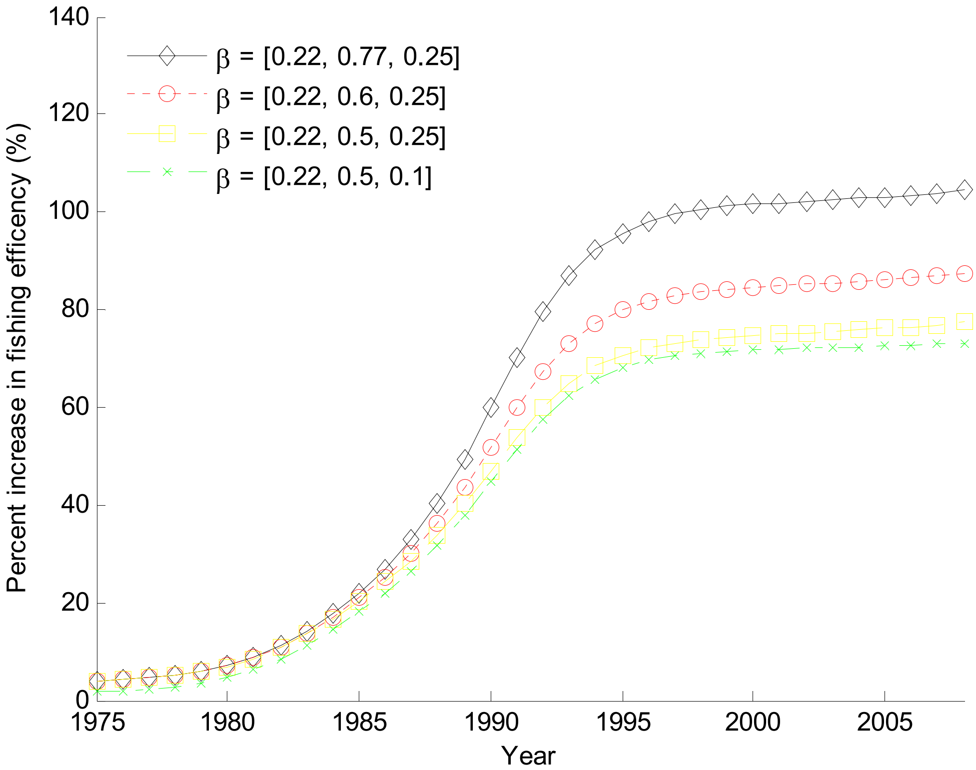


Figure 2 Comparison of fishing power schedules derived using 1) current median efficency_increase for fishing with colour sounder, GPS and hydraulic reels (Table 7; Wise et al., 2007), 2) reducing the GPS coefficient to 0.6, 3) reducing the GPS coefficient to 0.5, and 4) reducing the GPS coefficient to 0.5 and hydraulic reel coefficient to 0.1.

2.5 Future assessment

Stock reduction analyses (or other age-structure stock models) should be considered to explore current stock status (biomass ratio) scenarios and degrees of overfishing (Walters et al., 2006). The models should be run on the longest possible time-series of annual total harvest (Allen et al., 2006). Ideally the analysis and harvest time series should start close to unfished levels (e.g. post WWII). If possible, recreational and commercial harvests should be reconstructed using all sources of information such as historical fish board records, departmental records of commercial licences, charter and recreational vessel registrations, catch rates etc. Note that outputs from reconstructed catch histories provide informative trends in stock status (e.g. biomass ratios B_t/B_{MSY}). However, outputs on biomass or sustainable tonnages will be influenced by uncertainties in harvest. If a long history of harvest cannot be calculated, then modelling from 1975 (when commercial catch reporting started) may still be informative assuming starting biomass ratios (e.g. $B_{1975}/B_0 = 0.7\ldots0.9$) or calculating starting biomass based on an assumed average pre-1975 fishing mortality. A MCMC algorithm will be required for tuning log-likelihood functions (to standardised catch rates and age structures) and to allow recruitment variation. The analysis should also include discard mortality. For example fish numbers could be calculated as:

$$N_{t,a,g} = N_{t-1,a-1,g}\, e^{-M_g} \left(1 - S_{1,a-1,g} U_{t-1}\right)\left(1 - S_{2,a-1,g} U_{t-1} D\right), \qquad (1)$$

where

- N is the number of fish at time *t*, aged *a* and gender *g*,
- *M* is instantaneous natural mortality,
- S_1 is the selectivity for fishing legal sized fish (kept fish),
- S_2 is the selectivity for discard mortality (released fish),
- *U* is the exploitation rate, and
- *D* is the mortality rate of discards.

In the short term management strategy evaluations (MSE) can be used to investigate the expect effects of management changes. The MSE will simulate dhufish, snapper and baldchin groper populations into virtual futures that are subject to defined harvest strategies, observation and process errors. The results will assess the consequences of a range of management strategies and be presented in a way which lays bare the trade-offs in performance across a range of management objectives (Smith, 1994). The approach does not define a final fishing strategy or decision, but rather provides information on which to base management choices, given a set of management objectives. The conceptual framework for a multispecies spatial MSE was described by Dr Norm Hall (Lenanton et al., 2009a). The operating models and their driving data still require further detail to ensure the biological processes will be captured accurately, such as:

- Weekly or monthly spatial dynamics. Important characteristics to consider are spatial recruitment patterns, the paired spawning strategy by dhufish and the predictable spawning patterns of snapper. Depending of the management questions, spatial areas could be represented by the west coast zones split by depth at 30 metres (a depth threshold between low and high discard mortality -

barotrauma) or 30x30 degree square grids (small scale). Catchability coefficients for different species need to be inflated/adjusted for different area sizes. For more ideas on spatial population models read Walters and Martell (2004).

- Movement transition matrix to swim fish between spatial areas. Were possible, these should be constructed based on tag-recapture data quantifying seasonal directions and rates of movement (more so for snapper than dhufish).
- Cohort specific transition matrices to grow fish from length *l'* to length *l* each week or month.
- Fishing model for describing seasonal and spatial patterns of effort. Some time should be invested in developing this component. Walters and Martell (2004) outline different approaches for programming spatial fishing patterns and decision making. They cover ideas from simple gravity models to complex statistical decision making; see also ELFSIM ITQ project, R. Little CSIRO. If decisions on commercial fishing effort in the WCDSF are influenced by catches and profits from outside fisheries, then this should be considered.
- Well defined target goals (from management and scientific committees) to optimise fishing mortality and harvest to recover fish stocks to reference points such as $1.2B_{MSY}$ by the end of a ‘rebuild period’ (e.g. five or ten years).

2.6 Future monitoring

In the ideal world stock assessment would utilise annual time-series of fish data from a range of sources: 1) total harvest across all fishing sectors, 2) fishery independent relative abundance indices proportional to the stock, 3) fishery independent length and age structures of the population, 4) tag-recapture estimates of fishing mortality, 5) survey biomass estimates, etc. However, this is unachievable without extensive resources. With real world resource limitations, scientists must be smart about selecting sampling strategies and tools for the future.

Mackie et al (2009) has completed a modernistic study examining fishery-independent approaches to monitoring fish spawning aggregations. This very practical and technically sound report examined the use of single and multi-beam sonar’s, and under water video for monitoring fish. The sonar techniques produced quite visually exciting data for identifying fish aggregations. The data are dependent on precise sonar strength models to identify different fish species and this requires continual/extensive truthing via underwater video. Of other appeal for developing a times series of relative fish abundance was the use of baited remote underwater videos (BRUVS).

For dhufish, BRUVS were reported as a useful and reliable data on fish abundance, sex ratio, size, habitat and behaviour (Mackie et al., 2009). This is possibly also the case for snapper and baldchin groper in certain habitats. However use is restricted from strong currents and shallow turbid waters. The success of using BRUVS for monitoring fish abundance is dependent on utilising modern video technologies (e.g. multiple high definition cameras with wide viewing angles etc), together with computer software to quickly and easily quantify images. The potential for BRUVS will only be realised when research can prove their reliability to count fish and cost effectiveness to meet survey requirements (i.e. high numbers of survey sites). To calculate an abundance index from BRUVS, co-variates such as date, time of day, tide, weather, reef site, GPS way points, depth, bottom type, bait type, time recorded, cumulative count of each fish species and time as they appear on video are required. Abundance indices can be estimated for presence/absence and numbers of fish using two-component generalised linear models (Mayer et al., 2005; O'Neill and Faddy, 2003).

For snapper, the daily egg production method (DEPM) for surveying spawning biomass in Cockburn sound has proved viable (Mackie et al., 2009). This survey should continue, assuming survey CV’s and the statistical power are sound. It would also be of value to add more fishery independent sampling of juvenile snapper (as done in Cockburn Sound, Wakefield, 2009, Draft manuscript). Together the spawner and recruitment indices would provide indices of relative abundance that will aid future assessments.

In addition to survey tools above, it is critical for sampling designs to have monitoring units randomly allocated with spatial and temporal replication. If too few years of data are collected it can be difficult to separate population trends from confounding sources such as irregular environmental perturbations, autocorrelation due to population processes and stochasticity associated with sampling. The objectives for monitoring are to estimate the change in population means, so it is best to use the same sites for each survey (Skalski, 1990). However, exploring a serially alternating rotating panel design with augmentation would provide a mix of fixed and random sites (Brown, 2001; Skalski, 1990). Over time more sites would be monitored ensuring good geographical and temporal coverage.

One of the key requirements for future stock assessment and management is the frequent and accurate monitoring of recreational catches. A time series of standardised recreational catch rates of dhufish, snapper and baldchin should be maintained as another index of abundance. Zero inflated modelling techniques are recommended to estimated the presence/absence and numbers of fish caught (Mayer et al., 2005; O'Neill and Faddy, 2003). As with fishery dependent data, it is important to record all the appropriate effort variates (travel time, search time, fishing time, gear, location, depth strata, on-board technologies). In addition, annual or biennial estimates of recreational catch and effort will enable formal stock assessments. Ideally estimates of total fishing effort, harvested fish and released fish would be quantified by two depth strata split at 30 metres in order to factor in discard mortality rates.

Finally of course, scientists should maintain collecting the annual time-series of frequencies of fish-at-age and utilised this to estimate fishing mortalities.

2.7 *Haddon review*

In 2007 a scientific review was undertaken by Dr Malcolm Haddon (Wise et al., 2007) on catch rate and aging data up to 2005/6. The review by Dr Haddon provided extensive commentary clearly describing the theoretical processes, data, results and their interpretation. The review supported research findings that effective effort (fishing power) had been increasing and stock indicators declining for dhufish, snapper and baldchin groper. Five important scientific recommendations were made by Dr Haddon (Table 1). For recommendation 1, a manuscript has been drafted with some analyses still required to complete the full draft for journal submission. All other recommendations have been implemented. The daily commercial fish catch logbook has been active for two years. Recreational catch surveys for 2008 in the west coast region, including Cockburn sound, have just been completed. The harvest strategy framework has been implemented, with the decision rules recommending 50%-100% reduction in WCDSF fishing effort. In addition, all the research work completed since the Dr Haddon Review, including the stock structure, and snapper egg and recruitment surveys in Cockburn Sound should be recognised.

Table 1 Scientific recommendations summarised from Dr Haddon review (Haddon, 2007); management recommendations assessed separately by Dr Neville review.

Recommendation	Implemented?
1. Commercial catch rates by vessel and month could be further explored to determine whether they provide more informative trends than the presently used catch rates.	Yes, but more analyses required to complete journal manuscript.
2. The commercial catch and effort logbooks are to be moved to daily recording.	Yes
3. Conduct recreational surveys and collect samples of dhufish catches, at least once every two or three years.	Yes
4. Further surveys of recreational snapper catches should be made in Cockburn Sound.	Yes
5. The representation of the limit, threshold, and target reference points should be refined.	Yes

3 Review meetings and diary

Table 2 Summary of review activities.

Date, February 2008	Purpose	Attendees (+ reviewer)
Monday 23rd, AM	Introduction and meet WA Fisheries staff at Hillarys research laboratory; Discussion of review roles, past and current research and assessment.	Ian Keay, Dan Gaughan, Rod Lenanton, Dave Fairclough, Ross Marriott, Brent Wise, Brett Molony, Peter Stephenson, Rick Fletcher
Monday 23rd, PM	Meeting to discuss commercial catch rate standardisation.	Brent Wise and Ross Molony
	Meeting to discuss fish age data and estimation of fishing mortalities.	Brent Wise, Ian Keay and Dave Fairclough
Tuesday 24th, AM	Two one hour meetings with stakeholders to discuss and document their scientific concerns with WCDSF assessments.	Meeting 1: Frank Prokop (Recfish West), Andrew Rolland (Recreational fishing), Karenina Mansell, Kevin Donaghue, Mark Pagano.
		Meeting 2: Ian Stagles (Recreational fishing), Jeff Ellis (Recreational fishing), Hale Harvey (tackle industry), Doug Bathgate (Recreational fishing advisory committee), Felicity Horn (WAFIC; commercial fishing), Karenina Mansell, Kevin Donaghue, Mark Pagano.
	Meeting with Minister Moore.	Minister, Stuart Smith, Rick Fletcher, Brett Molony, Kevin Donaghue, Mark Pagano
Wednesday 25th, AM	Update of review progress and discussion of important outcomes from Tuesday's meetings.	Brent Wise, Rod Lenanton, Dave Fairclough, Brett Molony, Rick Fletcher, Ross Marriott.
Thursday 26th, AM	Discuss Dr Haddon review and his scientific recommendations.	Brett Molony and Rod Lenanton.
Friday 27th, AM	Wrap up and brief outline of conclusions.	Dan Gaughan, Rod Lenanton, Dave Fairclough, Brett Molony, Rick Fletcher, Gary Jackson.
Thursday 5th March, AM	Provide scientific advice to the management review.	Peter Neville, Brisbane.

4 Scientific issues raised by stakeholders

On Tuesday 24th two stakeholder meetings were held in Perth city (Department of Fisheries, Western Australia). The meetings were organised by the fishery managers, for the purpose of stakeholders to raise their concerns relating to the science used in the fishery assessments to determine the status of baldchin groper, dhufish and snapper in the west coast region.

The meetings were both very positive. All stakeholders provided extra background about the fishery, and expressed their strong passion for the fishery and support for scientific research. Meeting participants were in general agreement that dhufish were overfished, with some mixed opinions about the level of over fishing on snapper. No comments were provided on Baldchin groper. In should be noted that the term 'overfished' and 'overfishing' implied here to summarise stakeholders comments refers only indicating a possible problem with the dhufish and snapper stocks and that their exploitable abundances are perceived to be below desired levels. They do not imply a collapse in the populations.

Most stakeholders meeting time centred on the validity, inferences and inconsistent reporting of recreational fish catch and effort estimates. These comments and concerns do not relate or impact on the fish aging or fishing mortality methods currently used to indicate the status of baldchin groper, dhufish and snapper. However, they are relevant for any future population age-structured assessment conditioned on catch or fishing effort. Review of the recreational fishing surveys was not a part of the terms of reference (section 7) and will be assessed separately through another independent scientific review (pers. comm. Brett Molony). Appendix 2 (section 9) lists the issues raised throughout the stakeholder meetings.

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7 Terms of reference

To provide advice as to the soundness of the previous and current assessments of the status of west coast demersal finfish stocks by the Department of Fisheries Research Division by:

- further reviewing the data underlying relevant Fisheries reports and providing comment on the peer review outcomes of Dr Malcolm Haddon and assess the degree to which any recommendations outlined in the Haddon review have been implemented;
- reviewing all additional research generated by the Department of Fisheries, and commenting as to the affect these may have on any stock status advice, in particular:
    i. a recent study on the biology and ecology of dhufish and pink snapper funded by to the Fisheries Research and Development Corporation;
    ii. new age-frequency information for dhufish, pink snapper and baldchin groper from samples collected in 2007/08; and
    iii. a new estimate of fishing mortality for dhufish and pink snapper based on 2007/08 age data; and
- To provide any additional scientific advice that may be useful to the person undertaking the management review.

8 Appendix 1: Snapper catch curve estimates of total mortality (Z)

82 TABULATE [PRINT=totals; CLASSIFICATION=fiscal_year,zone,sector; MARGINS=no] n

Total number of fish analysed between age classes 5 and 15; Important to note sample sizes for interpreting Z estimates below.

	sector	Commercial	Recreational
fiscal_year	zone		
2007/08 = 2008	Kalbarri	160.0	118.0
	Metro	71.0	84.0
	Mid	184.0	219.0
	South	21.0	51.0

Regression analysis

Response variate: logp
Fitted terms: fiscal_year.zone.sector + age.fiscal_year.zone.sector

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	15	73.98	4.9322	16.28	<.001
Residual	46	13.94	0.3030		
Total	61	87.92	1.4413		
Change	-8	-64.66	8.0819	26.67	<.001

Percentage variance accounted for 79.0
Percentage sum of squares accounted for 84.1
Adjusted r-squared statistic 0.790
R-squared statistic 0.841
Standard error of observations is estimated to be 0.550.
Dispersion parameter is estimated to be 0.303.
Akaike information criterion is estimated to be 195.
Schwarz information criterion is estimated to be 229.

Estimates of parameters

Parameter	estimate	s.e.	t(46)	t pr.
Regression intercepts:				
fiscal_year 2008 .zone Kalbarri .sector Commercial	0.981	0.665	1.47	0.147
fiscal_year 2008 .zone Kalbarri .sector Recreational	0.836	0.612	1.36	0.179
fiscal_year 2008 .zone Metro .sector Commercial	-0.122	0.700	-0.17	0.863
fiscal_year 2008 .zone Metro .sector Recreational	0.726	0.858	0.85	0.402
fiscal_year 2008 .zone Mid .sector Commercial	3.638	0.858	4.24	<.001
fiscal_year 2008 .zone Mid .sector Recreational	0.921	0.632	1.46	0.152
fiscal_year 2008 .zone South .sector Commercial	-1.414	0.756	-1.87	0.068
fiscal_year 2008 .zone South .sector Recreational	-0.758	0.787	-0.96	0.341
Regression estimates of Z:				
age.fiscal_year 2008 .zone Kalbarri .sector Commercial	-0.4425	0.0711	-6.23	<.001
age.fiscal_year 2008 .zone Kalbarri .sector Recreational	-0.4050	0.0636	-6.37	<.001

age.fiscal_year 2008 .zone Metro .sector Commercial	-0.2770	0.0779	-3.55	<.001
age.fiscal_year 2008 .zone Metro .sector Recreational	-0.375	0.104	-3.61	<.001
age.fiscal_year 2008 .zone Mid .sector Commercial	-0.841	0.104	-8.09	<.001
age.fiscal_year 2008 .zone Mid .sector Recreational	-0.4162	0.0663	-6.28	<.001
age.fiscal_year 2008 .zone South .sector Commercial	-0.0783	0.0877	-0.89	0.376
age.fiscal_year 2008 .zone South .sector Recreational	-0.1578	0.0932	-1.69	0.097

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
- Constant	-1	-424.0094	424.0094	1399.35	<.001
+ fiscal_year.zone.sector	8	433.3369	54.1671	178.77	<.001
+ age.fiscal_year.zone.sector	8	64.6552	8.0819	26.67	<.001
Residual	46	13.9382	0.3030		
Total	61	87.9209	1.4413		

81 RWALD

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
fiscal_year.zone.sector	29.33	8	3.67	0.002

Residual d.f. 46

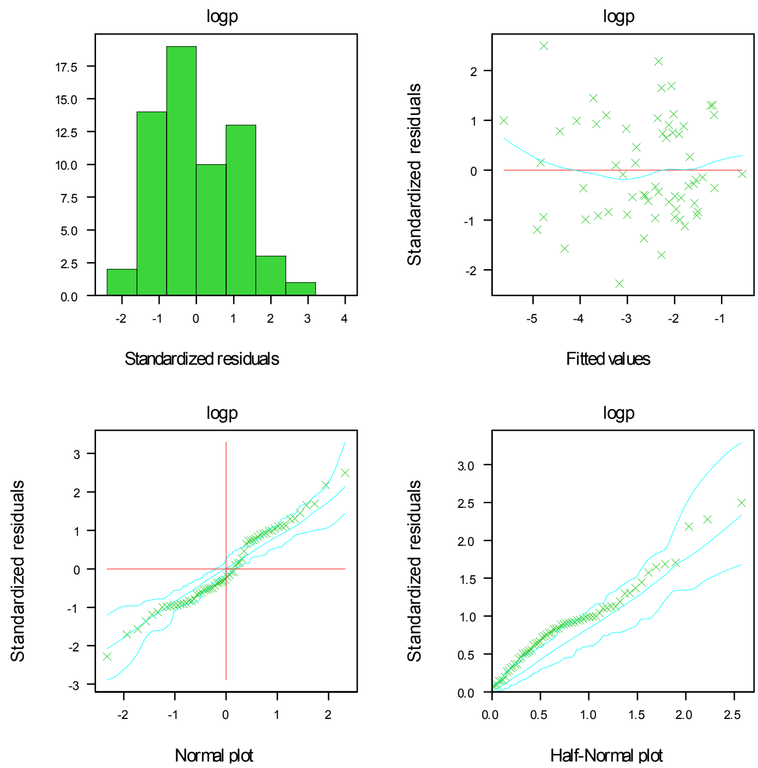

Figure 3 Residuals plots

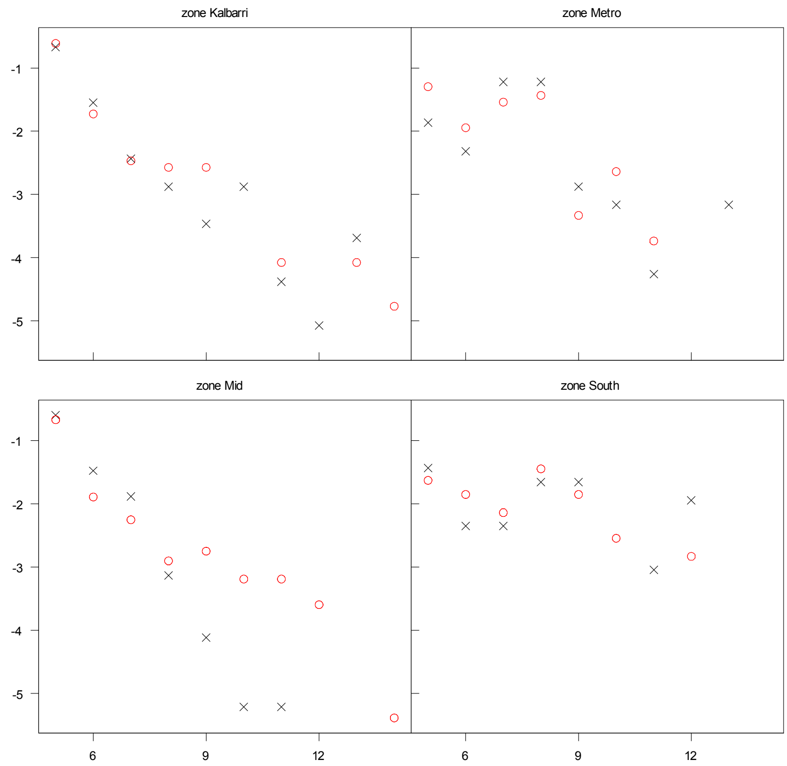

Figure 4 Plot of age vs log(proportions); circles=commercial, crosses=recreational.

9 Appendix 2: Notes from stakeholder meetings

The following table lists of the main issues raised at stakeholder meetings (recorded by reviewer). The points are general and separated under science and management related headings:

Research

Cage experiments biased discard mortality estimates upwards.
Commercial fishers have accepted the science and the 50% reduction in their effort; 10 years too late.
Communicate more information on the recreational survey data and how it is analysed.
Concern with the lack of transparency of recreational survey data.
Concerned with the appropriateness of the creel survey methodology.
Concerned with the appropriateness of the creel survey methodology: how it is done, quality of data and inferences, where and when data are collected, lack of geographic coverage.
Confused by inconsistent results produced by different methods. Which are correct?
Consideration for changing environment and catchability in recreational catch estimates
Creel survey data are not appropriate to expand across the entire west coast management region.
Declines in dhufish populations, not snapper.
Discard mortality estimates by depth need to be weighted by recreational fishing effort; Significant amount of fishing effort is believed to in water depths less than 45m. Re: Figure 13, FMP 225. and (Lenanton et al., 2009b)
Fish stocks are in no state of collapse.
Generally agree of the status of dhufish and snapper stocks
Have not noticed a large decline in fish stocks.
Highlighted the unreported harvest taken by commercial lobster fishers.
It takes too long to provide research results to stakeholders.
More and better communication is required on appropriate catch and release techniques.
Recreational fishers only target dhufish about twice a year; therefore over estimating recreational fishing effort.
Poor dissemination of research results to recreational stakeholders.
Poor engagement with recreational sector.
Potential for re-stocking snapper.
Praised the Mackie et al (2009) report as well written and good example of collaborative research with recreatiopnal stakeholders.
Recreational catch and effort are over estimated.
Recreational catch and effort estimates don't align with the number of vessels targeting WCDSF.
Recreational fisher registration / licence system with logbooks are required to accurately quantify catch and effort.
Recreational fishing sector wants to be partners in research and engage more in the science.
Recreational licence + logbook system will impact on tackle businesses.
Some growth overfishing of west coast demersal fish, not recruitment overfished.
Strong concerns about the creel survey design and data. Specifically: treatment of bad weather days, use of daily and seasonal trends in effort.
The amount of research on recruitment dynamics is poor.
Want to ensure sustainable fish stocks.
What are the effects of recruitment spikes on recreational catch estimates?

Management

The proposed management options to reduce recreational fishing effort by 50% will result in an actual 90% reduction - ; due to overestimates of recreational catch and effort statistics used by management.
Commercial sector concerned with the delay in management.
Don't use Commonwealth survey estimates of recreational catch in management decisions.
Equity: need to consider previous recreational management changes.
No consistency between figure 17 FMP No 225 and figure 5 FMP No 228.
Proposed management changes are not inline with fishers expectation.
Recreational sector do not agree on the harvest strategy decision rules (50% reduction).
Recreational sector sceptical on the appropriateness of seasonal spawning closures; do they work? Are fish aggregations more susceptible to fishing?
Unreported commercial catch