FORMAL REPORT: BENEFIT / NRF STOCK ASSESSMENT WORKSHOP 2004
(12 – 17 January 2004, University of Cape Town)

1. OPENING

1.1 Welcome

Doug Butterworth welcomed all attendees on behalf of the sponsors of the workshop: BENEFIT, the Benguela Current Large Marine Ecosystem (BCLME) Programme, and the South African National Research Foundation. He thanked the Namibian Hake Association and the SA Deep Sea Trawling Association for agreeing to sponsor two social functions for participants. He explained that the workshop had been organized by a Steering Committee consisting of himself, Rob Leslie, Ian Hampton, Di Loureiro and Carola Kirchner, and those persons would be responsible for organizational matters relating to the workshop during the week.

1.2 Introduction of Chair and Participants

Dr Tony Smith opened the meeting. The participants and the observers introduced themselves. A full list of attendees is given as Appendix 1.

1.3 Terms of Reference

The terms of reference for the workshop, in respect of the two resources to be considered in detail (South African and Namibian hake), were:

i) to critically review past assessments and management procedure evaluations;
ii) to consider possibilities for including multi-species effects in assessments, particularly hake cannibalism and inter-species predation; and
iii) to make recommendations for future research.

The workshop was also to review progress in regard to the assessment and OMP evaluations for the Nambian fur seals based on the recommendations made during the BENEFIT 2002 workshop.

1.4 Daily time schedule, meal and other arrangements

The agenda is listed as Appendix 2. Doug Butterworth outlined the technical arrangements for the workshop, including the daily "question and clarification" sessions run by the invited scientists to assist attendees less advanced in the stock assessment field.

1.5 Rapporteurs

Anabela Brandão, Doug Butterworth, Carryn Cunningham, Jim Ianelli, Susan Johnston, Carola Kirchner, Éva Plagányi, John Pope, André Punt and Rebecca Rademeyer acted as rapporteurs with assistance from the Chair.

1.6 Computing arrangements

The Chair informed the attendees that there was the opportunity for limited additional computations during the workshop.

1.7 Report adoption procedures

Doug Butterworth explained that the report would be adopted by the full-time participants on the final day of the workshop. He further explained that the full-time participants comprised the scientists so appointed by South Africa and Namibia, the scientific representatives of industry, and the extra-Africa invited scientists.

2. REVIEW OF DOCUMENTS

The documents available to the workshop were divided into four series and are listed in Appendix 3.

3. SOUTH AFRICAN HAKE

3.1 Background and basic data

BEN/JAN04/SAH/1a summarized the available data for hake off South Africa.

3.1.1 Catches

Customary local usage of the word “catches” refers only to the quantity landed, and does not include estimates of discards. The workshop noted that there was little basis for disaggregation of the catches for the early years of the fishery in terms of their distribution by species and area. There is anecdotal information is available on this issue. The workshop **recommended** (B.9) that industry be consulted to develop alternative hypotheses regarding the levels and spatial distribution of the historical catches.

The workshop noted that little information is available for the handline fleet. It **recommended** (B.1) that the catch by this sector, the species- and sex-structure of the catch, and its size-structure should be monitored.

3.1.2 Ageing information

The workshop noted the critical importance of having reliable ageing information when conducting assessments of hake. This information is used, *inter alia*, to determine growth curves and to construct catch-at-age data. The workshop noted the general lack of strong cohorts in the catch-at-age matrices for hake off South Africa and Namibia and hence that the assessments implied that recruitment variability (particularly off South Africa) is less than would be expected from the results of assessments for other biologically similar species. The lack of large fish in the catches and during surveys implies either high natural mortality, declining selectivity with age (and hence that a large proportion of the older fish are unavailable to the fishery), or errors with the ageing.

The workshop highlighted the importance of having reliable and routine information on the age-structure of the commercial and survey catches. It **agreed** (#6) that, even though stock assessment methods can be modified to account for missing catch-at-age data, this was a “patch” and that every effort should be made to obtain annual catch-at-age information. The workshop noted that a lack of capacity in recent years has led to an inability to develop age-length keys for hake. In relation to ageing, the workshop also **recommended** (A.1, A.2) that:

a) consideration be given to applying methods (such as biochemistry, radiocarbon) that should be used to validate the ageing procedure.
b) a workshop be conducted on ageing techniques for hake. This workshop should consider both the objectives of the ageing program (e.g. estimating growth curves *versus* developing age-length keys) and the sampling scheme used to collect data for ageing purposes.

The workshop **strongly supports** (#1) the planned BENEFIT project to exchange samples and methodologies between Namibian and South African age-determination scientists. A technical sub-group was convened to discuss issues related to ageing and their findings are summarized in Appendix 4.

The workshop noted that the current assessments are based on the assumptions that maturity is age rather length-specific, maturity is knifed-edged at age 4, weight is an effective proxy for egg production, and spawning success is not related to age or size. The information available on batch fecundity against ovary-free fish mass (Osborne *et al*., 1999) suggests a non-linear relationship between these quantities. However, in the absence of information about batch spawning, it is not possible to draw definitive conclusions. The workshop **recommended** (A.15) that the existing data be examined to evaluate these assumptions. The workshop also **recommended** (B.10) that research should be conducted to determine the spatial and temporal dynamics of hake spawning and early life history using surveys.

3.1.3 Stock structure and movement

The workshop noted that previous assessments of South African hake have been based on the assumption of separate west and south coast populations. Appendix 5 summarizes information on the distribution of *M. capensis* based on surveys. The workshop **agreed** (#7) that the assumption of a single *M. capensis* stock off South Africa was more plausible than separate west and south coast stocks based on this information. The workshop noted that this conclusion was based on indirect evidence for movement because there is virtually no information on longshore movement of hake. Indirect support onshore/offshore movement of hake arises from the seasonality of the catches by handline fleet. The workshop **recommended** (A.16) that research (e.g. through longline-based tagging) be conducted to address this issue. The workshop also **agreed** (#8) that the assumption of a single stock of *M. paradoxus* was more plausible than separate south and west coast stocks. There is some uncertainty about whether *M. paradoxus* caught off Namibia also form part of this stock (see Section 4.1).

3.2 Data refinements

Commercial hake catches are not recorded by species. However species-specific information is required in order to generate CPUE series and for use in the stock assessments for *M. capensis* and *M. paradoxus*. This problem has been addressed in the past by applying an algorithm developed by Geromont *et al.* (1995), which uses depth to predict the proportion of *M. capensis* in the trawl catch.

BEN/JAN04/SAH/2b revises the algorithm for splitting annual hake catches into *M. capensis* and *M. paradoxus* first developed by Geromont *et al*. (1995) by applying a different functional form (a variant of the logistic) for proportion-by-depth and making use of the further survey data which have become available since that time. The proportion-by-depth is assumed to be binomially distributed about its expected value. A separate proportion-by-depth relationship is estimated for the south and west coasts. This analysis provides considerably improved fits to the updated data than the previous function and suggests that the present species splitting procedure for commercial trawl catches likely underestimates the *M. capensis* and overestimates the *M. paradoxus* proportions on the west coast, with the south coast situation not being as clear. In the addendum to BEN/JAN04/SAH/2b, the method is extended to include the possible effects of season, as well as year. Only the year effect on the west coast is found to be significant.

BEN/JAN04/SAH/2c presents an alternative algorithm to determine the proportion of *M. capensis* in the trawl catch off the South African south coast based on trawl survey data up to 2002. It also investigates the importance of other factors in the relationship. The key findings of BEN/JAN04/SAH/2c are: (a) substantially different proportion-depth relationships exist for different size-classes of fish; (b) variances are such that the model is inadequate without consideration of size; (c) the longshore location of the catch adds some precision to the proportion estimates; and (d) there is no significant year, season or time of day effect on the proportions.

Further information on the geographic distribution of the two hake species off the South African west coast are shown in Appendix 6.

The workshop noted that the use of methods such as those outlined in BEN/JAN04/SAH/2b and BEN/JAN04/SAH/2c depended on the extent to which the survey data were representative of the commercial fishery. The workshop also noted that the importance of the choice of the algorithm used to disaggregate the historical trawl catches by species depended on whether the results of assessments and OMP evaluations were sensitive to different choices for this algorithm. Appendix 7 contrasts the species-specific catches off the south coast based on the Geromont *et al*. (1995) approach and selected algorithms from those in BEN/JAN04/SAH/2b and BEN/JAN04/SAH/2c. The results in Appendix 7 suggest that there are appreciable differences in estimates of catch by species depending on the algorithm used. The workshop **recommended** (B.2) that the observer data should be used to test the validity of the algorithms for splitting the past commercial trawl catches among species and over time.

The workshop **recommended** (B.3) that the algorithm used to split the historical catches to species should take fish size as well as depth of capture into account. The workshop noted that this will require some further analysis because the use of an algorithm which utilizes the commercially-reported size-categories of small, medium and large presents some problems due to differences in the definitions of these categories among fishing companies and over time.

The workshop **recommended** (B.7) that the catch and effort data for the longline fishery should be analyzed to determine trends over time and space. The algorithms in BEN/JAN04/SAH/2b and BEN/JAN04/SAH/2c are not appropriate to disaggregate the longline catches by species.

BEN/JAN04/HB/1d summarized the attempts to quantify the individual sources of error in Namibian and South African hake surveys at the BENEFIT Survey Errors Workshop in December 2000, and the results of Monte Carlo simulations of the overall effect of the errors on the trawl survey estimates. The simulations suggested a positive bias of the order of 10% (q about 1.1) in both the Namibian and the South African surveys. The uncertainty in the bias factor was greatest for the surveys on the South African south coast, largely because of the uncertainty associated with the large proportion of untrawlable ground there. The results should be treated with caution as input to management because of the large CVs on the bias factors, the somewhat arbitrary nature of some of the inputs to the simulation, and the omission of certain potentially large sources of error such as fish being off the bottom for protracted periods in response to environmental conditions.

The workshop considered the factors that would determine the size of the bias factors for the hake surveys off Namibia and South Africa. The workshop **recommended** (A.3) that attempts to develop informative prior distributions for the catchability coefficient, *q*, should be pursued and **expressed support** (#9) for research into environmental and behavioural effects that could have a significant effect on *q*. If priors can be agreed, they should be evaluated for use in stock assessments (either as penalty functions or by fixing catchability to some appropriate summary statistic of the distribution, such as its mode).

BEN/JAN04/SAH/2a details how GLMs are applied to obtain species-disaggregated standardized CPUE series, and presents the results of these methods.

The workshop identified a number of potential ways in which the analyses in BEN/JAN04/SAH/2a could be extended and **recommended** (A.11) that they be explored:

- The log-normal bias-correction factor is not applied when computing the year-effects. While generally small, this factor may be important in this case given the unbalanced nature of the data.
- Regressions are conducted separately for *M. capensis* and *M. paradoxus*. The possibility of assuming that the values of the vessel factors are the same for the two species should be explored. Also, the residuals from the regressions should be examined for negative correlation.
- There is a need to routinely examine standard diagnostics when conducting catch-effort standardizations. Examples of such diagnostics are: (a) the fraction of the variation explained by the year-factor (e.g. through the Type III sum-of-squares) - if this is small, the reliability of the standardized index as an index of abundance may be questionable, (b) the number of data points in each (for example) depth*year stratum should be tabulated, and (c) plots of catch-rate against possible covariates should be examined to visually identify potentially important covariates.
- Consideration should be given to including environmental variables when standardizing the catch and effort data. The survey data should be examined to determine plausible environmental variables to consider.
- Vessel * year interactions should be considered when standardizing the data.
- Bycatch should be standardized by vessel when included as covariates in GLM analyses.

The workshop **recommended** (A.4) that the spatial distribution of the catch-rate information should be included in papers that standardize catch and effort information.

The workshop noted that data are missing for some of the strata (e.g. combinations of year and latitude) that define interactions. An interpolation algorithm is used to specify the interaction terms that cannot be estimated using the GLM. The workshop highlighted that even if catch and effort data are standardized, this does not automatically guarantee that the resultant index is proportional to abundance. The workshop **recommended** (A.12) that the sensitivity to ignoring this index and to considering alternative relationships between standardized catch-rate and exploitable (essentially fishable) biomass be considered when evaluating OMPs.

3.3 Assessments and their key uncertainties

BEN/JAN04/SAH/3a presents updated ASPM assessments of the *M. capensis* and *M. paradoxus* resources off South Africa and compares these to previous assessments. The two species are assessed independently. The *M. capensis* resource is assessed separately for the south coast and the west coast. The assessment of the *M. paradoxus* resource is for the south and west coasts combined. The large multiplicative bias for the survey of the south coast *M capensis* resource, which is estimated to be about 2.7, calls the reliability of this assessment into question. The assessment of the west coast *M. capensis* resource is not satisfactory, especially given its low estimate for the steepness parameter. The results of the assessment for *M. paradoxus*, for both coasts combined, seem satisfactory.

BEN/JAN04/SAH/3b points out that species-disaggregated assessments of the South African hake resource have had to make broad assumptions with little foundation about the disaggregation of the commercial catch and CPUE. The paper investigates an alternative approach to these assessments, in which both the *M. capensis* and *M. paradoxus* populations (treated as single populations on the south and west coasts) are assessed jointly under the assumptions that their relative selectivity by the offshore trawlers changes in a steady manner over time. In contrast to the standard assessments, the annual catch by species is not taken to be fixed but is estimated, via the fishing proportions, in the model fitting procedure. This approach reveals some promising aspects, but some shortcomings remain, such as the fact that only data readily analyzed on a both-coasts-combined basis can be fitted straightforwardly, and the assumption that a CPUE series based upon species-aggregated catches is proportional to the sum of the exploitable biomass components of the two species irrespective of changes in the distribution pattern of fishing over time. It is suggested that many of the problems of this approach could be resolved by moving to a spatially disaggregated model formulation.

The workshop considered that the values of *M* obtained in the assessment appear unrealistically high. It was noted that forcing *M* to be lower by making selectivity-at-age domed-shaped leads to deterioration in the fits to the historical CPUE data (discussed further below).

3.4 Future assessments and resolution of key uncertainties

The workshop identified an approach for the future assessment of hake off South Africa and Namibia based on the following features, and **recommended** (A.5) that it form the basis for future assessments:

- age-length keys for one year should not be applied to the length-frequency data for another year – rather, if length-frequency data are available for a year for which an age-length key is not available, the model should be fitted to the length-frequency data for that year (cf. BEN/JAN04/NS/3b).
- a model which considers both species simultaneously should be developed and its results aggregated to fit to data that cannot be disaggregated between species (e.g. the ICSEAF CPUE series);

- the initial spatial structure of the model should involve four components (west coast inshore, west coast offshore, south coast inshore, south coast offshore) – the definition of inshore and offshore should be based on biological considerations and data availability;
- the initial version of the model should estimate component- and species-specific “selectivity” (which includes both gear selectivity and availability) patterns;
- the values for the parameter that determines the split among species of the exploitation rate on fully-selected animals should be calculated to mimic the catches by species each year, with a prior placed on the extent to which it may vary over time;
- future assessments should be sex-structured with selectivity defined in terms of length (rather than age) because hake are sexually dimorphic – this will require the collection and use of sex-structure data;
- the longline catches should be split to species, e.g. using observer data to develop a suitable algorithm; and
- allowance should be made for age-determination error when fitting the catch-at-age information.

The workshop further **recommended** (B.4) that the lower bound imposed on the residual standard deviation for the CPUE data should be increased appreciably because, at present, the model overemphasizes the need to fit (for example) the GLM CPUE data at the expense of other indices of abundance (such as the results from fishery-independent surveys).

The above approach should form the initial focus for future assessments. Other approaches should be examined to consider the robustness of the assessment. For example:

- apply a delay-difference model which models the average length of the population, the square of the average length, etc. (Pope, 2003);
- apply a fully length-structured method of stock assessment;
- rather than assuming a single homogenous stock as is implied by the above specifications, model movement of animals among spatial strata explicitly;
- examine sensitivity to the choice of the method for standardizing the catch and effort data and to different forms for the stock-recruitment relationship; and
- fit the models to the length-frequency data and the age-length keys separately.

It was noted that improved performance of the estimator may result from estimating age-specific selectivity rather than assuming selectivity to be governed by (say) a logistic curve, as has been the case in certain situations. The development of an assessment that involves fitting to length-frequency data for some years will involve some decisions: (a) the choice of plus and minus groups when fitting the length-frequency data, and (b) how to estimate the growth curve, the variability about this curve, and how/whether it changes over time,

The current assessment assumes that the same stock-recruitment relationship applies throughout the entire (80+ year) period of the assessment. This relationship and the need to fit the historical (ICSEAF) catch-rate series constrains the assessment substantially. The workshop was concerned that this constraint could: (a) lead to an inability to fit recent catch-at-age and catch-rate data, and (b) lead to unrealistically high values for natural mortality M. To address the second issue, the workshop **recommended** (A.6) that a series of scenarios be constructed that lead to a range of values for M for example by: (a) allowing for changes over time in carrying capacity, and (b) adjusting the historical catch-rate data.

The workshop also **recommended** (A.13) that the assessment model should be applied with a more recent start year to assess whether the use of the early data, the assumption of that the stock-recruitment relationship has not changed over time, and the assumption that the population was at pre-exploitation equilibrium at the start of exploitation, may be constraining the fit to the recent catch-at-age and catch-rate data.

The workshop **recommended** (A.7) basing the value assumed for the extent of variation in recruitment on the results of the analyses of the seal scat samples or directly from surveys. It also **recommended** (A.17) that the value of using the variances estimated from the application of GLMM models to the catch and effort data to weight the catch-rate indices should be investigated. The workshop **recommended** (A.18) that an analysis (such as Principal Components Analysis, PCA) should be applied to examine the correlation structure of the model parameters.

It was noted that discarding of small hake has occurred in the past (and may have been particularly substantial off Namibia in the late 1980s). Although sensitivity has been examined to increasing the historical catches to account for discarding, additional sensitivity tests should examine alternative assumptions about the size-structure of the discards. One way to model discarding of non-marketable fish is to parameterize a "retention curve" (by length) based on actual gear selectivity relative to what was marketed.

3.5 Including multi-species effects in assessments, particularly hake cannibalism and inter-species predation

BEN/JAN04/HB/5b presented a summary of potential approaches to model both intra- and inter-species interactions between the two hake species as well as extending this to consider interactions with other components of the ecosystem, most notably Cape fur seals. Some of the research topics identified as being particularly important in this regard include: a) analyzing hake stomach content data available since the earlier analyses, and b) giving consideration as to what are the appropriate functional response formulations to be considered in models of hake-hake and hake-seal interactions. The paper stressed the need to consider the relative merits and costs of the various approaches carefully. Moreover, some problems are identified with the operational definition as given in the "ecosystem relations" criterion for continued certification as provided by the Marine Stewardship Council (MSC) in their review of the South African hake trawl fishery.

3.5.1 Purpose of multispecies modelling

The meeting **agreed** (#10) that multispecies/ecosystem studies and the choice of multispecies models need to be linked to scientific goals and / or management objectives. The workshop **agreed** (#2) that before initiating sampling programs aimed at improving understanding of multispecies interactions, this needs to be balanced with data collection and analysis needs related to the single-species assessment process.

A number of possible goals for multispecies modelling / ecosystem studies were noted. Broadly these could be consolidated into three major goals:

1. to address the Marine Stewardship Council's (MSC) condition that gaps in the understanding of ecosystem relationships be addressed by appropriate research;
2. to provide ballpark figures for the implications of the "hake-hake-seal" subset of interactions and more generally to provide a better basis for the evaluation of future OMP's; and
3. to move towards an Ecosystem Approach to Fisheries (EAF). This broad goal might include several sub-aims: a) describing and, if possible, explaining any regime shifts/major switching events, b) estimating how many fish there were in the sea (cf. Census of Marine Life), c) achieving a better understanding of by-catch and damage to non-target species, and d) other issues such as closed areas.

The first goal might be best seen as a need to develop a research plan and review process that would address at least some of the items listed under the third goal. It was also noted that existing research programmes already partly address this issue.

Goal 2 is the most well-specified. If this goal is to be addressed, the workshop **recommended** (A.19) that, in the first instance, existing models should be adapted to provide estimates of the predation mortality on hake that is generated by the two hake species. These models could then perhaps be extended to include seal predation on the hake species. If it were appropriate, predation by other fish on hake or the effect on hake mortality of including other hake prey could then be added. Such studies would be essentially hake-centric and aim to provide a better basis to evaluate hake OMPs.

Goal 3 has a much wider scope. Some sub-aims (e.g. achieving a better understanding of regime shifts) might help to resolve problems with current assessments. However, the broad aim would be to obtain an overview of the status of the Benguela marine ecosystem. Goal 3 might also encompass predicting the likely effects of proposed management measures. The North Sea Quality Status Report and subsequent work by ICES/OSPAR provides an example of ongoing research along these lines.

3.5.2 Appropriate modelling approaches.

Goal 2 will clearly require the use or development of suitable multispecies models. However, the research needed to satisfy goal 3 may initially be descriptive in nature, though ultimately better framed as an ecosystem model.

The development of a simple "Fishing Fleet" type model might be a good starting point to address goal 2. This could be based upon current single-species models (possibly length-based). There may be a need for length-structured models because most feeding interactions are strongly sized-based and therefore using a size-based model eases both coding and attendant data requirements. Such models could initially concentrate on the dynamics of the two hake species and could be extended as required to achieve greater realism. Alternatively, they could be contracted to focus on essential interactions which are likely to be related to predation-mediated changes in hake recruitment. The aims of these models would be a clearer understanding of the population dynamics of the two hake species and as a basis for the operating models used to test OMPs.

Modeling requirements for goal 3 might include the following:

- developing/refining a description of the broad estimates of biomass through time of the known, important, components of the ecosystem (e.g. hake, seals, pelagics etc.) would be helpful;
- identification of the major environmental drivers and any changes in their intensity (in the Barents Sea, PCAs of the environmental time-series (Ottersen and Loeng 2000) were rather instructive); and
- providing simple descriptors of aspects of ecosystem structure (e.g. size spectrum or K-dominance curves) - where possible, these should be shown together with equivalent descriptions of exploitation in a similar format (e.g. catch size spectra).

The workshop **agreed** (#11) that Ecopath / Ecosim models could be used to address objectives related to broad-scale questions regarding the structure of the ecosystem; other models may be more appropriate for more specific questions.

3.5.3 Data requirements

Multispecies models require inputs (preferably data) on size and species food preferences of predators and ration sizes. Ideally, sampling would span all regions and seasons (c.f. the ICES “years of the stomach” in the North Sea). However, this is very expensive and labour-intensive and hence is seldom practical. In the case of the Benguela region, stomach sampling is a routine practice on annual research surveys. This sampling may be difficult to achieve at other times of year using observers on commercial vessels. Despite these drawbacks, biased (e.g. seasonal) or haphazard collection of stomachs can be mined to give less precise, though still useful, indications of the size and species preferences of predators. Size of prey as well as size of predator is an essential item of data to record. The workshop **recommended** (A.20) that novel, cost-effective ways of estimating suitability (prey preferences) should be explored. A possible (though untried) route is to compare the size and species preferences of predators that are caught at the same place and time. It was noted that the assumption of an Ursin (log-normal distribution) size preference function (Rice *et al.*, 1991) is a useful simplification in such studies. It was also noted (BEN/JAN04/NH/3c) that scat samples seem to give a rather coherent picture of seal predation on *M. capensis* in Namibia, and this approach could be extended to South Africa.

3.5.4 Using Ecosystem models to improve biomass and production estimates

BEN/JAN04/SAH/5b noted that trophic models of the southern Benguela ecosystem have been developed using the Ecopath with Ecosim (EwE) approach. Model results relating to South African hakes are summarised with respect to hakes as predators, hakes as prey, simulations of altered fishing on hakes (also in relation to cannibalism), and model fitting to time series (the latter is necessary if EwE models are to be used in policy analysis). Data requirements are listed to facilitate further progress in using EwE to assess South African hake in an ecosystem context, and thereby to contribute to an ecosystem approach to fisheries (EAF).

The workshop had a wide-ranging discussion on the advantages and disadvantages of the EwE approach. The advantages of the approach include the ability to comment on whole-ecosystem dynamics, something that is not possible in other approaches such as minimal realistic models. Although the form of the EwE predation term is flexible in some respects, results using this model are sensitive to the vulnerability parameters, and uncritical use of default settings can be a problem.

BEN/JAN04/SAH/5a investigated the potential for the constraints associated with ECOPATH to improve estimates of biomass and productivity in the Southern Benguela region. The ECOPATH-mass-balanced equation (Christensen and Pauly, 1992) provides a mathematical basis for specifying the predator-prey-association constraints on all the species in an ecosystem. Ecotrophic efficiency was treated as unknown in this equation and all other quantities as given. Markov Chain Monte Carlo (MCMC) was used to estimate biomass and the production-to-biomass ratio for each species. Bounds were placed on both the biomass and the production-to-biomass ratio for each species; these were ± 20 for the reference case and ± 10, ± 40 and ± 60 for the sensitivity cases. These bounds were implemented as uniform distribution priors. Chains of 2.5 million runs were carried out saving every thousandth. The marginal posterior distributions showed that there are only small improvements for the reference case, typically less than 10% for most species. There also seemed to be a slightly smaller improvements when the there was uncertainty in the diet in addition to the biomass and the production-to-biomass ratio. Improvement seemed to be largest (typically 60%) when the original uncertainty is large.

BEN/JAN04/HB/5a used the same methods as BEN/JAN04/SAH/5a, but the data utilized were for the northern Benguela for the 1980s. Results obtained are preliminary because they were conducted only for a single uncertainty range (uniform ±20%) and no uncertainties in diet compositions were included. The results suggest that the overall relative changes between the prior and posteriors for biomass and the production-to-biomass ratio are less than 10%, indicating that only a small amount of updating occurred. Hake is one of the species that showed one of the largest extents of updating.

It was noted that it might be possible to use biomass estimates that are relatively precisely determined to improve the precision of the estimates of biomass for less well researched species. The size of this effect can be evaluated using the simulation frameworks outlined in BEN/JAN04/SAH/5a and BEN/JAN04/HB/5b. In a similar way, the predation mortality estimated to be generated by a predator of known biomass on a prey of known biomass might be extrapolated to quantify biomass of poorly-studied prey species from the results of stomach contents.

BEN/JAN04/HB/5a provided a summary of the Punt-Butterworth "minimal realistic model" of the hake-seal system that focused on the biological interaction among Cape fur seals *Arctocephalus pusillus pusillus* and the Cape hakes *Merluccius capensis* and *M. paradoxus* to examine the effects of possible culls of seals on catches and catch rates of the bottom-trawl fishery for the Cape hakes off the South African west coast. Suggestions are made for updating this work to account for *inter alia* changes in and extensions to the data used as inputs as well as an improved understanding of the distribution and dynamics of the species involved.

The workshop **agreed** (#12) that disagreements between the predictions of single- and multi-species models can be informative and lead to the generation of hypotheses for system behaviour.

The workshop **agreed** (#3) that, while clearly some advances have been made in this field, understanding of multi-species and ecosystem interactions is still at a relatively early stage, and that a range of modelling approaches should be considered when addressing these issues. Caution should be exercised in making use of the predictions of such models unless there was substantial agreement between these across different approaches.

3.6 Management procedures, past and future

BEN/JAN04/SAH/6a summarized the basis for the most recent TAC recommendation for the South African hake resource. Previously OMPs had been used for the south coast *M. capensis* and for both species combined on the west coast, with an adjustment based upon differences in estimated replacement yield used to motivate an allowance added for the component of the *M. paradoxus* resource which occurs on the south coast. For the recommendations for 2004, the OMP for the west coast had not been used because updated assessments suggested a recent abundance trend below the confidence intervals for the assessment at the time (1997) that OMP had been developed and tested. Recent assessments suggested a replacement yield for the whole hake resource of some 184,000 tons, compared to the 2003 TAC of 164,000 tons. Projections based upon these assessments were used to motivate that a continuation of the 3,000 tons per year TAC phase-down first implemented for 2003 would not lead to undue resource reduction, contingent upon relatively larger reductions being made to the *M. capensis* component of the anticipated 2003 catch.

BEN/JAN04/SAH/6b summarized previous comparisons of the hake-specific biological merits of trawling and longlining. Although earlier evaluations had suggested longlining to be preferred, subsequent perceptions that natural mortality *M* was higher than previously assumed had led to a revised view that there was no clearcut preference between the two.

The possible need to revisit the consequences of the sex imbalance in longline catches in some regions was noted. The workshop **recommended** (B.8) that the comparison of the hake-specific biological impacts of trawling and longlining needs to be updated in the light of further information now available.

The workshop agreed that the baseline assumption for stock structure for a new OMP for the South African hake resource should be one coastwide *M. capensis* and one coastwide *M. paradoxus* stock. In due course consideration might need to be given to the incorporation of spatial- and sex-disaggregation. Models used would need to account for the different fleets (sectors) in the industry. The workshop **recommended** (B.5) that this new OMP for South African hake should be developed through tests based on a joint model for the two hake species. Given the time needed to conduct the associated evaluations, this OMP could not be ready for implementation before late in 2005**,** though this would dovetail conveniently with a 10-year rights allocation process scheduled for implementation at the start of 2006. It is essential for such an approach that information on the commercial catch composition by species be available. To this end the workshop **stressed** (B.6) that the observer programme for South Africa needs to provide regular and reliable information on the species-split of the hake catch. It also **stressed** (#13) that while this new OMP for the South African hake populations should output *TAC*s disaggregated by species (and perhaps by area), it is not proposed that allocations comprise species-specific quotas to a rights holder. Management options that might best achieve the desired species split of the overall catch still need to be proposed and evaluated. A suggested approach along these lines as set out in Appendix 8 was noted.

While initial OMP evaluations would likely be restricted to TAC-related issues, the workshop **emphasized** (#4) that evaluation of management controls need not be restricted to *TAC*s, but might also include input controls and time/area closures, though perhaps only for the longer term. The issue of Marine Protected Areas (MPAs) was also raised. The general objectives for MPAs placed these outside the workshop's ToR, and it was **agreed** (#14) that assessment of the implications of MPAs for biodiversity conservation needs a dedicated workshop and will need to consider the implications of bycatch. Ideally, management of coastwide stocks requires coastwide abundance surveys. Accordingly the workshop **agreed** (#15) that changes in survey strategy towards coastwide surveys should be considered but existing surveys should not be modified unless analyses indicate that this will improve their utility in the short- to medium-term.

Given that implementation of a new OMP would not occur before 2005, and so provide TAC recommendations only in time for the 2006 season, an interim basis would be required to provide such recommendations for the 2005 season. Note was taken of the projection results for *M. paradoxus* in BEN/JAN04/SAH/6a. Furthermore, BEN/JAN04/SAH/6c considered the implications of different phase down options for the South African hake TAC over the next few years that are reported in BEN/JAN04/SAH/6a. That paper had considered variations in the future catch of *M. paradoxus* only, with a fixed reduction of the overall *M. capensis* catch from 39,000 to 26,000 tons assumed for all the options considered. BEN/JAN04/SAH/6c briefly considers the implications of this and other catch reduction programmes for the south coast *M. capensis* resource, under the associated assumption that the catch from the smaller west coast *M. capensis* population is reduced from the current 6,000 to 2,000 tons. Keeping the current catch unchanged would not result in an unsustainable situation, but CPUE would remain near its current low level. By reducing the catch, the CPUE should improve towards the average level over the 1980s and 1990s, as had been the objective for the OMP for this resource to maintain the economic viability of the associated industries.

The workshop **agreed** (#16) that the existing phased decline could serve as a default basis to determine a 2005 TAC recommendation for South African hake, unless strong contrary evidence was put forward.

The workshop **agreed** (#5) that given the possibility of a shared *M. paradoxus* stock between South Africa and Namibia, thought needs to be given to how TAC sharing arrangements might best be developed should such an eventuality arise, noting that there are certain prerequisites for this such as some form of common resource assessment agreed between the two countries and adequate monitoring of catch- and abundance-by-species. It was noted that the SADC regional Protocol on Fisheries provides a possible framework for, *inter alia*, research and management of shared resources, and that SADC is developing guidelines (e.g. Penney *et al*., 2003) for management of stocks shared among SADC countries.

A number of examples of sharing arrangements between other countries were discussed. BEN/JAN04/HB/7b describes how the TACs for trans-boundary stocks of cod, haddock and yellowtail flounder on Georges Bank will be allocated between the

USA and Canada. The agreed share is based on both the historic share of the catch by the two countries and the geographical distribution of the fish between the two countries. Initially these factors will be weighted 40/60 when computing the shares but over time will move towards a share based upon a 10/90 weighting, i.e. towards a weighting which heavily emphasises the geographical distribution of fish. The geographical distribution is to be measured by annually updating smoothed estimates of distribution based on the time-series of surveys conducted by both countries. The agreed protocol was the end result of a process of negotiation. Hence, while the Georges Bank protocol gives guidance as to how such agreements might be reached, it does not provide a precise template. An important lesson to learn from this example is that the protocol has to be precisely defined both legally and scientifically. Agreement between the two countries was assisted by several factors. It was aided by the broadly similar fisheries management objectives of the two countries involved. It was also aided by the extensive time-series and seasonal spread of groundfish surveys made by both countries over much of the range of the three fish stocks. An ongoing problem is that while Canada sets annual *TAC*s the USA manages these fisheries using fishing effort controls and technical measures (such as extensive closed areas). This means that the annual fish take of the two countries may not match the agreed share precisely.

The workshop **emphasized** (A.21) that the OMP evaluation process should be used to evaluate the potential benefits of additional data collection (e.g. of genetics data) to better specify stock structure.

3.7 Priorities for further research

Appendix 9 lists the prioritized research recommendations. BEN/JAN04/HB/7a provided a list of potential research topics. It included research areas considered important by the workshop but which it did not have time to discuss, e.g. economic factors, and the reasons for some of the “anomalies” in the assessments (such as the very low value for steepness and hence productivity for Namibian hake).

4. NAMIBIAN HAKE

4.1 Background and basic data

Carola Kirchner overviewed the biology of and fishery for hake off Namibia along with current management and assessment methods. The Namibian fishery catches mostly *M. paradoxus*. The catch rates of both hake species have been declining recently. *M. capensis* off Namibia are considered a separate stock from *M. capensis* off South Africa.

BEN/JAN04/NH/1c argued the case that there is only one stock of *M. paradoxus* in the Benguela region. Previous studies of feeding, parasites and genetics provided no evidence for separate stocks; furthermore a high level of spawning had been observed only on the Agulhas Bank, and only slight differences in morphology were evident between fish off South Africa and off Namibia. The paper showed that small *M. paradoxus* were found only south of 23^0S off Namibia, and that survey estimates of density reflected continuity across the South Africa / Namibia border. Initial estimates of otolith microstructure also did not reveal regional differences. The management implications of a single shared stock, in contrast to the conventional assumption of two separate stocks (separated by the Orange River) of *M. paradoxus*, were discussed.

The workshop noted that the power of many of the tests in BEN/JAN04/NH/1c was likely to be low, implying that even if there were separate stocks of *M. paradoxus* off Namibia and South Africa, the data would be unlikely to detect this. In the context of genetic approaches to stock-structure, the workshop noted that Dr Paulette Bloomer (Dept. Genetics, Univ. of Pretoria, 0002 Pretoria, pbloomer@postreo.up.ac.za) has received funding from BCLME to examine hake stock structure issues using genetic methods. The workshop **recommended** (A.8) that hake scientists should be encouraged to collaborate with population geneticists to address stock structure issues, especially those related to trans-boundary questions. Possible methods for analyzing the genetics data to address these issues include "Boundary Rank" (Martien and Taylor, 2001) and tests for isolation by distance.

Although the conclusions of BEN/JAN04/NH/1c are stated more strongly than might be suggested by the available data, the paucity of juveniles and the lack of evidence of spawning in Namibia is certainly suggestive of the lack of separate stocks of *M. paradoxus* in the north and south of the Bengulea system.

BEN/JAN04/NH/3b summarized the methods and results of the hake ageing programme in Namibia. Age-length keys (ALKs) are available for 1993, 1999 and 2000. Catch-at-age matrices for these years were created based on: 1) the 1993 ALK only, 2) the 1999 ALK only, 3) the 2000 ALK only, and 4) a combination of the three. When one ALK was applied to all years, it changed the catch-at-age matrix quite substantially. For example, when the 1999 ALK was applied to the 1993, 1999 and 2000 survey length-frequencies, it showed a modal peak at age-group 3, whereas when the 1993 and 2000 ALKs were applied to these length-frequencies, they showed a modal peak at age-group 2. Growth parameters and weight-at-age were calculated for 1993, 1999 and 2000, and maturity ogives were calculated for 1999 and 2000.

BEN/JAN04/NH/3c examined possible reasons why the catch-at-age matrices calculated from ALKs based on otoliths collected during the 1999 and 2000 surveys were substantially different. The otoliths collected in 1999 and 2000 were read by the same two age-readers. These readers each read 1,434 (1999 survey) and 871 (2000 survey) otoliths twice. There is no valid reason for discarding the 1999 ALK even though between-reader average percent agreement did increase over the period of data collection. The time of sampling, mean lengths-at-age and growth rates did not differ significantly between 1999 and 2000. The differences between the two ALKs stems rather from adding different proportions of age-at-length, so seems to be a result of differences in cohort strength between the two years.

The workshop noted the lack of data from the longline catches off Namibia and **recommended** (C.3) that species- and sex-composition, length frequency (and otoliths, if possible) be collected from these catches.

4.2 Data refinements

BEN/JAN04/NH/2a described various General Linear Model (GLM) analyses that have been applied to the commercial catch per unit effort (CPUE) data for Namibian hake. The principle objective of these GLM analyses has been to obtain a model that incorporates factors that explain a significant fraction of the variation in the hake CPUE data and to obtain a standardized CPUE series that indexes abundance. A summary of other GLM analyses performed aimed at investigating some aspects arising from the survey analyses, namely to shed light on the likely annual variability in survey biomass estimates of Namibian hake and to provide a means to account for diurnal variability in catchability in the estimation of abundance indices from surveys is also given.

The workshop noted its earlier comments on catch-effort standardization (see Section 3.2). It was noted that bycatch CPUE were not considered as a covariate in BEN/JAN04/NH/2a. The workshop **recommended** (C.5) that bycatch species be considered as a covariate in future analyses along these lines.

The workshop **recommended** (C.1 and C.6) that an attempt be made to obtain the raw tow-by-tow data for the Spanish surveys (which will allow estimation of the length- and age-composition of the survey catches to be calculated) and to correct the Spanish survey indices for errors.

4.3 Assessments and their key uncertainties

BEN/JAN04/NH/3a presents results from a routine update of the (species-aggregated) assessment of Namibian hake. Steepness is not well estimated and the Reference Case assessment therefore fixes this parameter to 0.3 similar to earlier estimates. Values of steepness much above 0.5 result in systematic trends in the residuals to the fits to the ICSEAF CPUE data. Some sensitivity tests are conducted. The addendum to this paper considers the sensitivity of the updated assessment results to alternative data sets for post-independence catch-at-age proportions and for weights-at-age. Using the different catch-at-age sets has substantial effects on the results; all of these leading to more pessimistic results than the routine update described in the original paper. The use of the alternative weight-at-age vectors leads to more optimistic appraisals of resource productivity and current status, but the differences are relatively small.

BEN/JAN04/NH/3b presents a first attempt at assessing the Namibian hake resource based on catch-at-length information rather than catch-at-age. The reason for attempting to use the length data directly is that ageing of the hake otoliths has only occurred somewhat fitfully over recent years so that these ageing data are available for only very few years. This analysis was not presented as definitive, but only as an illustration of the application of the method.

BEN/JAN04/NH3c overviewed the implications of data from seal scats. Analyses of seal scats from Namibian seal colonies have shown that fur seals in the northern Benguela preyed on at least 36 species of teleost fish in the past decade. Juvenile horse mackerel was the most important prey (in biomass) in the northern half of Namibia while juvenile *M. capensis* (mostly between 7 and 21 cm TL) dominated in the south. Hardly any *M. paradoxus* was consumed. Fur seals feed on only one cohort at a time, so that growth parameters of 1-group fish can be calculated from otolith measurements. Growth is virtually linear with a slope of 11.8 cm / year in good years. However, environmental anomalies (anoxia and Benguela Nino events) can impact on the growth rate (and most probably also survival rates) drastically as shown during January-June 1994 (anoxic event) or January-March 1995 (Benguela Nino Event). The abundance of juvenile hake in the diet was found to be tightly linked to the cohort strength of the fish spawned the year before. This permits estimation of cohort strength from the seal diet up to one year prior to the time those pre-recruits can be assessed by surveys and therefore provides an early warning of recruitment failures or exceptionally strong cohorts.

The workshop believed that the relationship identified in BEN/JAN04/NH/3c had considerable potential for use as index of recruitment. It was noted that one reason for the high correlation between the seal scat index and the survey data might be availability common to both data types. Furthermore, the seal scat-based index will be less useful as an index of recruitment if prey switching (by seals) occurs. Nevertheless, the workshop **recommended** (C.2) that the utility of this index be examined further, and that it be included in tests of assessment sensitivity. Given the results of further analyses, consideration should be given to including this index in the reference case assessment.

Noting the potential value of an index of hake recruitment based on seal scats, the workshop **recommended** (A.22) that alternative indices of hake recruitment (e.g. along the lines of the Namibian seal scat-based index of hake recruitment) should be developed. Specifically the workshop **recommended** (B.11) that consideration be given to the development of a similar index for South African hake. The workshop also **recommended** (C.4) that the possibility of identifying the younger cohorts in the survey length-frequencies using modal analysis should be examined. It was noted that information from seal scats could also be used to assist with age-validation,

4.4 Future assessments and resolution of key uncertainties

The workshop agreed that the approach to stock assessment outlined in Section 3.4 be adopted for Namibian as well as South African hake.

4.5 Including multi-species effects in assessments, particularly hake cannibalism and inter-species predation

See Section 3.5

4.6 Management procedures, past and future

BEN/JAN04/NH/6a reported that the management advice provided for the 2002 and 2003 TAC for the Namibian hake resource had been based on an OMP developed in 2001. Although the results of a routine updated assessment had proved to be on the verge of falling outside the 90% CI’s of the original assessment, the Namibian Hake Working Group had decided that this did not (quite) provide sufficiently strong evidence to override the OMP TAC recommendation. Application of the OMP formulae had resulted in a recommended TAC reduction from 196,000 to 176,000 tons (the maximum 10% reduction allowed in terms of the OMP’s formulae).

Considerable discussion took place concerning the OMP approach as a basis for TAC recommendation. Strong concerns were expressed that managers and industry lacked adequate understanding of the approach, and reservations were expressed regarding lack of clarity as to the circumstances under which TAC recommendations forthcoming from an OMP might be overridden at the scientific level given additional scientific data. Points made in support of the approach and its accompanying development process were its evaluation of long term consequences and risks in line with the Precautionary Approach, and the opportunity the framework provided to involve stakeholders in consideration of alternative management options. In line with an Ecosystem Approach to Fishing (EAF), the workshop **recommended** (A.14) that the OMP development process should include tests that reflect possible trophic interaction effects.

In response to the concerns raised, the workshop **agreed** (A.9. A.10) that a high priority be given to explaining the development and implementation of OMPs to managers and industry in plain language, and to evaluating the cost-benefit of the OMP approach relative to other approaches.

The general recommendations made in Section 3.6 for South African hake management apply also to Namibian hake. The proposal for a species-disaggregated model basis for OMP evaluation requires the capability to split commercial catches in this manner. It was noted that data collected on observer programmes rendered this possible for Namibian hake. It was further suggested that additional mechanisms be incorporated in any new OMP for Namibian hake to achieve a speedier reaction to spawning stock declines.

4.7 Priorities for further research

Appendix 9 lists the prioritized research recommendations.

5. FUR SEALS

5.1 Progress on December 2002 Workshop recommendations for Namibian seals

Appendix 10 (modified from BEN/JAN04/NS/1) summarizes the recommendations arising from the December 2002 BENEFIT workshop regarding the Namibian fur seal resource, and overviews progress against each recommendation. The workshop discussed progress relative to the recommendations from that workshop along with issues that arose during 2003.

The workshop reiterated its recommendation from last year that a forum at which biologists and modelers could discuss data (and modeling) issues should be established. It **recommended** (D.1) that the changes to the seal pup census database be documented and finalized. Some pupping occurred in South Africa in 2001 at newly developed colonies which may not be currently included in the pup census. The seal pup census database should be extended to include pup counts from these new colonies. MCM confirmed that it is the intension to continue the three-yearly pup censuses. MFMR indicated that the annual pup survival rates will also continue to be calculated from monitoring at a study site.

It was noted that there may be little value in applying a GLM to the pup census data because of differences in trends in pup numbers among colonies.

MFMR indicated that the management plan that is to be developed by the Namibian authorities will deal more with technical issues (quota regulations, introducing eco-tourism), and does not imply a change from the use of an OMP for Namibian fur seals.

Availability of bulls (e.g. between age-classes) varies with the time of year and there is evidence that the selectivity of the harvest might vary as well (with time of year and quota level – e.g. more quota resulting in more young bulls taken). Data on the bull harvest are important because they provide information on how the bull selectivity pattern changes from year to year. The workshop reiterated its recommendation from 2002 regarding the importance of the collection of these data. The workshop further **recommended** (D.3) that the sensitivity of the OMP results to variation in the bull selectivity pattern be examined because the OMP may prove robust to this source of uncertainty.

The workshop **recommended** (D.4) that the data on pup harvest selectivity be analyzed to evaluate the hypothesis that in good years all pups are equally likely to be harvested whereas, in bad years, when the pup mass is lower than average, industry tends to select the larger pups. The results of this examination could be used to develop a relationship between mass and selectivity. Data on pup mass should continue to be collected. The timing of pupping changes from year to year even within the same colony. This may affect pup survival rates. The workshop therefore **agreed** (#17) that information continue to be collected on the timing of pupping.

The workshop **agreed** (#18) that the future assessments and OMP development work take account of spatial structure because of the apparent different trends in different areas and the movement of animals among colonies. It was noted that a colony-specific model may, however, be infeasible given the available data and a compromise between spatial resolution and data availability would need to be determined when moving to a model that considers the spatial distribution and movement of the Cape fur seals.

BEN/JAN04/NS/2 presented the updated Namibian fur seal population assessment model and provided some projections. This paper concluded that the low December 2001 pup census result was most likely a result of lower than normal pregnancy rate (rather than an increase in adult female mortality). Annual catches up to a maximum of 60,000 pups and 5,000 bulls appear to be sustainable in the short-term for the seal population, although the longer-term implications of this level of bull harvest may need to be considered further in due course, particularly given the increasing ratio of 4+ females to 12+ males.

It was suggested that bias in the (early) pup count data could be driving estimates of female survivorship to be higher than is biologically realistic (0.98). The workshop **recommended** (D.2) that the sensitivity of the results of the assessment to the selection of which pup counts to include in the assessment (and how to adjust them to correct for possible bias) should be re-examined.

The workshop noted that one consequence of estimating annual pregnancy rates and additional adult mortalities in 1989, 1994 and 2001 is that it is no longer possible to estimate carrying capacity reliably. The workshop **agreed** (#19) that the current assessment cannot be used to estimate quantities related to carrying capacity such as Maximum Sustainable Yield, *MSY*, and the population size associated with *MSY*. The workshop noted, however, that loose bounds could be placed on carrying capacity based on ecosystem and spatial constraints but that calculations for doing this had not been presented and hence reviewed.

Anecdotal information suggests that bulls younger than 12+ have recently been holding territories. It was suggested that monitoring trends in harem bulls was possible through, for example, photogrammetry. Natural mortality increases for harem bulls and it is hypothesized that a reduction in the number of 12+ bulls leads to an increase in the natural mortality of younger males. The workshop therefore **recommended** (D.5) that the model be amended to examine this hypothesis.

BEN/JAN04/NS/3 provided some updates to work presented in BEN/JAN04/NS/2. This work includes estimation of adult female natural survivorship, initial OMP development, and an MCMC-based Bayesian assessment.

With respect to OMP development, the workshop **recommended** (D.6) that future projections should include robustness tests in which an event similar to the 1994 anomaly occurred on an infrequent basis rather than frequent less extreme events.

The workshop noted that the MCMC algorithm had failed to converge and suggested that the likelihood value be included in the set of quantities routinely assessed for convergence. It also suggested that the parameter estimates may be highly correlated and that this should be examined in future work.

5.2 Modelling seal-hake interactions

The discussion of this item is recorded under Section 3.5.

5.3 Priorities for future research

Appendix 9 lists the prioritized research recommendations.

6. ADOPTION OF REPORT

The workshop participants (see Appendix 1) adopted the report of the meeting as reflected above.

7. COMMENTS BY THE INTERNATIONAL PANEL

The international panel noted the importance of the hake resources to both Namibia and South Africa. While considerable effort is clearly expended in both countries in monitoring and assessing these resources, the panel expressed particular concern about the availability and quality of recent data on age of hake. The panel also stressed the need to monitor all sectors of the fishery, and to ensure that any changes to surveys are accompanied by suitable inter-calibration research and do not compromise long-term data series. The panel noted with approval the move to species disaggregated assessments, but also noted that this, along with poor age data, had resulted in interim problems in developing consistent assessments. Given that all the assessments are "in transition", it was difficult for the panel to develop a clear view of the status and recent trends in the hake resources in the region. For South Africa, the deep-water hake stock appears to have increased since the late 1970s, but has declined since 2000. The results for the shallow-water hake are less certain, in particular because past assessments have been conducted for the west and south coasts separately, while recent studies suggest that the fish from the two coasts most likely are part of the same stock. After a period of stability for shallow-water hake over the 1980s and 1990s, there are some indications of a decline, though this is of a lesser extent than that of the deep-water hake. No species disaggregated assessment was presented for Namibian hake resource, but there are concerns about continuing downward trends in catch rates and fishable biomass from surveys, and anecdotal evidence suggests that this is particularly a problem for the shallow-water species. The very low estimates for productivity parameters for Namibian hake are also of concern. It remains to be seen whether this is resolved by refinements of the analysis, such as moving to a species disaggregated assessment.

Notwithstanding the clear potential benefits of the OMP approach used in both countries to provide scientific recommendations for the management of the hake resources, the panel was concerned at evidence of lack of acceptance and/or understanding of the approach by some key managers, industry representatives and scientists, particularly in Namibia. This issue should be addressed as a matter of urgency. Both the general approach, and its application to managing hake resources, need to be explained in plain language so that all participants in the process have a clear understanding of what they are agreeing. It may also be helpful to develop a simple spreadsheet model that illustrates the approach and its application.

8. CLOSURE

Thanks were recorded to the sponsors of workshop and of the associated functions, the Chair, the rapporteurs and participants (particularly the review panel) and the steering committee. Di Loureiro and Nobukhosi Dlamini were thanked for providing administrative support.

9. REFERENCES

Christensen, V. and D. Pauly. 1992. ECOPATH II – A software for balancing steady-state models and calculating network characteristics. *Ecol. Modelling* 61: 169-185.

Geromont, H.F, Leslie, R.W. and D.S. Butterworth. 1995. Estimation of *Meluccius capensis* and *paradoxus* proportions in Cape hake catches. Unpublished Sea Fisheries Demersal Working Group Document, WG/03/95 D:H:2.

Martien, K.K. and B.L. Taylor. 2001. A new method of generating hypothesized population structures for continuously distributed species using genetic data. Paper SC/53/SD7 presented to the IWC Scientific Committee, July 2001 (unpublished) 16pp;

Osborne, R.F., Melo, Y., Hofmeyer, M. and D. Japp. 1999. Serial spawning and batch fecundity of *Merluccius capensis* and *M. paradoxus*. *S. Afr. J. Mar. Sci.* 21: 211-216.

Ottersen, G. and H. Loeng. 2000. Covariability in early growth and year-class strength of Barents Sea cod, haddock, and herring: The environmental link. *ICES J. mar. Sci.* 57: 339–348.

Penney, A.J., Hampton, I., van der Elst, R.P., Wood, A.D., Boyer, H.J., Fennessy, S. and T.G. Andrew. 2003. Requirements for development of effective cooperative arrangements for the management of shared fish stocks in the SADC region. Report to the SADC Regional Fisheries Information System Project, Windhoek, Namibia (Envirofish Africa (Pty) Ltd).

Pope, J. 2003. Golden ages or magic moments. *Natural Resource Modeling*. 16: 439-464.

Rice, J.C., Daan, N., Pope, J.G. and H. Gislason. 1991. The stability of estimates of suitabilities in MSVPA over four years of data from predator stomachs. *ICES Marine Sciences Symposia* 193: 34-45.

Appendix 1 : Workshop attendees

Participants

Australia
Smith, Tony (CSIRO)*

Norway
Stroemme, Tore (IMR)*

Namibia
Iilende, Titus (NatMIRC)
Kirchner, Carola (NatMIRC)
Maurihungirire, Moses (MFMR)
Moroff, Nadine (NatMIRC)
Mukapuli, Ndako (NatMIRC)
Nichols, Paul (MFMR)
Roux, Jean-Paul (NatMIRC)
Wilhelm, Margit (NatMIRC)

South Africa
Akkers, Theressa (MCM)
Augustyn, Johann (MCM)
Bergh, Mike (OLRAC)
Butterworth, Doug (UCT)
Glazer, Jean (MCM)
Holloway, Susan (UCT)
Hutchings, Larry (MCM)
Leslie, Rob (MCM)
Matshili, Justice (MCM)
Osborne, Renee (MCM)
Plagányi, Éva (UCT)
Rademeyer, Rebecca (UCT)
Sims, Peter (MCM)

United Kingdom
Cook, Robin (FRS)*
Pope, John (NRC)*

USA
Ianelli, Jim (AFSC)*
Powers, Joseph (SEFSC)*
Punt, André (UW)*

*** Members of the International Review Panel**

Observers (Full- and Part-time)

South Africa
Antony, Luyanda (MCM)
Attwood, Claire (BCLME)
Bacon, Peter (Viking Fish.)
Ball, Richard (Pioneer Fish.)
Badenhorst, Awie (SA Pelagic)
Bailey, Daniel (Bato Star Fish.)
Booi, Kwanele (MCM)
Brandão, Anabela (UCT)
Bross, Roy (DSTI)
Buthelezi, Pakamani (MCM)
Cunningham, Carryn (UCT)
de Bruyn, Paul (ORI)
Durholtz, Dean (MCM)
Elwen, Simon (MRI)
Fairweather, Tracey (Rhodes)
Gaylard, James (OLRAC)
Govender, Anesh (UCT)
Hall, Candice (Capricorn)
Hampton, Ian (BENEFIT)
Isaacs, Moenieba (UWC)
Jacobs, Albie (OLRAC)
Japp, David (Capricorn)
Kirkman, Steve (UCT)
Kleinschmidt, Horst (MCM)
Le Clus, Frances (MCM)
Lipinski, Marek (MCM)
Mori, Mitsuyo (UCT)
Mqoqi, Mandisile (MCM)
Oosthuizen, Herman (MCM)
Penney, Andrew (PISCES)
Popose, Gcobani (Sea Harvest)
Pope, John (Marpro)
Reddell, Tim (Quayside)
Rose, Barrie (I&J)
Share, Andre (MCM)
Shannon, Lynne (MCM)
Somhlaba, Sobahle (UCT)
Versfeld, Antionette (DA)

Namibia
Hamukuaya, Hashali (BCLME)
Iiyambo, David (BENEFIT)
O'Toole, Mick (BCLME)
Sweijd, Neville (BENEFIT)

Chile
Paya, Ignacio (IFOP)

Appendix 2 : Agenda

1. OPENING
    - 1.1 Welcome
    - 1.2 Introduction of Chair and Participants
    - 1.3 Terms of Reference
    - 1.4 Daily time schedule, meal and other arrangements
    - 1.5 Rapporteurs
    - 1.6 Computing arrangements
    - 1.7 Report adoption procedure

2. REVIEW OF DOCUMENTS

3. SOUTH AFRICAN HAKE
    - 3.1 Background and basic data
    - 3.2 Data refinements
    - 3.3 Assessments and their key uncertainties
    - 3.4 Future assessments and resolution of key uncertainties
    - 3.5 Including multi-species effects in assessments, particularly hake cannibalism and inter-species predation
    - 3.6 Management procedures, past and future
    - 3.7 Priorities for further research
    - 3.8 Comments by the review panel

4. NAMIBIAN HAKE
    - 4.1 Background and basic data
    - 4.2 Data refinements
    - 4.3 Assessments and their key uncertainties
    - 4.4 Future assessments and resolution of key uncertainties
    - 4.5 Including multi-species effects in assessments, particularly hake cannibalism and inter-species predation
    - 4.6 Management procedures, past and future
    - 4.7 Priorities for further research
    - 4.8 Comments by the review panel

5. FUR SEALS
    - 5.1 Progress on December 2002 Workshop recommendations for Namibian seals
    - 5.2 Modelling seal-hake interactions
    - 5.3 Priorities for future research
    - 5.4 Comments by the review panel

6. ADOPTION OF REPORT

7. COMMENTS BY INTERNATIONAL PANEL

8. CLOSURE

9. REFERENCES

Appendix 3 : List of documents

General

BEN/JAN04/GEN/1: Workshop Announcement
BEN/JAN04/GEN/2: Agenda and Programme
BEN/JAN04/GEN/3: List of Documents

Hake: Both countries

BEN/JAN04/HB/1a: Assessment of and Management Procedures for the hake stocks off southern Africa (Rademeyer)

BEN/JAN04/HB/1b: Sustainable management initiatives for the southern African hake fisheries over recent years (Butterworth and Rademeyer)

BEN/JAN04/HB/1c: Is there one stock of *Merluccius paradoxus* Da Franca in the Benguela region? (Burmeister)

BEN/JAN04/HB/1d: Errors in Namibian and South African hake surveys, as assessed at BENEFIT Survey Errors Workshop in December 2000 (Hampton)

BEN/JAN04/HB/5a: Summary of Punt and Butterworth Minimal Realistic Model approach to model the biological interactions among the Cape fur seal and the two Cape hake populations on the South African west coast (Plagányi)

BEN/JAN04/HB/5b: Summary of potential approaches to model biological interactions, particularly among the two cape hake populations on the South African west coast (Plagányi)

BEN/JAN04/HB/5c: The effects of future consumption by the cape fur seal on catches and catch rates of the Cape hakes. 1.Feeding and diet of the Cape hakes *Merluccius capensis* and *M. paradoxus* (Punt and Leslie)

BEN/JAN04/HB/7a: Potential topics for future data collection, analysis and research for the southern African hake resources (Butterworth and Rademeyer)

BEN/JAN04/HB/7b: The role and determination of residence proportions for fisheries resources across political boundaries: the Georges Bank example (Gavaris and Murawski*)*

South African hake

BEN/JAN04/SAH/1a: Summary of data available for SA hake stock assessment (Leslie)

BEN/JAN04/SAH/2a: The General Linear Models applied to standardize the catch per unit effort data of the Cape Hake stocks, *Merluccius capensis* and *M. paradoxus*, caught offshore off the coast of South Africa (Glazer and Butterworth)

BEN/JAN04/SAH/2b: Update on the estimation of *Merluccius capensis* and *M. paradoxus* proportions at depth from survey data (Butterworth and Rademeyer) (with Addendum)

BEN/JAN04/SAH/2c: An investigation into the procedure used to split commercial catches of hake on the South African south coast into *Merluccius paradoxus* and *Merluccius capensis* (Gaylard and Bergh)

BEN/JAN04/SAH/3a: Species disaggregated assessments of the South African hake resource (Butterworth and Rademeyer)

BEN/JAN04/SAH/3b: Simultaneous assessment of the *M. capensis* and *M. paradoxus* resources, for the south and west coasts combined (Butterworth and Rademeyer)

BEN/JAN04/SAH/5a: What is the potential for the constraints associated with ECOPATH to improve estimates of biomass and productivity in the southern Benguela region? (Sobahle, Plagányi, Butterworth, Rademeyer)

BEN/JAN04/SAH/5b: Summary of trophic model results pertinent to the South African hake resource (Shannon)

BEN/JAN04/SAH/6a: Current South African hake management recommendations (Butterworth and Rademeyer)

BEN/JAN04/SAH/6b: Past biological comparisons of trawling vs. longlining of South African hake (Butterworth)

BEN/JAN04/SAH/6c: Implications of different future catch levels for *M. capensis* on the south coast (Rademeyer and Butterworth)

Namibian hake

BEN/JAN04/NH/1a: A decade of exploitation and management of the Namibian hake stocks (Van der Westhuizen)

BEN/JAN04/NH/1b: Age and growth parameters of the Namibian hake *Merluccius capensis* and *M . paradoxus* (Wilhelm, Dealie and Voges)

BEN/JAN04/NH/1c: Possible reasons for the differences between 1999 and 2000 age-length keys (ALK) of the Namibian hake *M . capensis* and *M. paradoxus* (Wilhelm)

BEN/JAN04/NH/2a: A summary of General Linear Model analyses applied to the commercial and survey CPUE data for Namibian hake (Brandao and Butterworth)

BEN/JAN04/NH/3a: Routine updated assessment for the Namibian hake resource (Rademeyer and Butterworth)

BEN/JAN04/NH/3b: First attempt at a length-based assessment for the Namibian hake resource (Rademeyer and Butterworth)

BEN/JAN04/NH/3c: Cape hake (*Merluccius capensis*) as prey of Cape fur seals in Namibia: prey size, juvenile hake growth rates and hake cohort strength estimations from scats analysis (1994-2003) (Roux)

BEN/JAN04/NH/5a: Do the constraints provided by the ECOPATH mass-balance equation improve existing estimates of resource abundance and productivity for the northern Benguela (Iyambo, Plagányi, Rademeyer)

BEN/JAN04/NH/6a: An update on OMP-based management advice provided for the TAC for the Namibian hake resource (Butterworth and Rademeyer)

Namibian seals

BEN/JAN04/NS1: BENEFIT 2002 recommendations on Namibian seals, with comments on progress made (Johnston, Butterworth and Mukapuli)

BEN/JAN04/NS2: Namibian seal population assessments and projections (Johnston and Butterworth)

BEN/JAN04/NS3: Further Namibian seal assessments and projections under a simple OMP (Johnston and Butterworth)

Appendix 4 : Report of the Age-determination Group

Akkers, Durholtz, Ianelli, Kirchner, Leslie, Lipinski, and Wilhelm

The group discussed the importance of comparing age-determination methods both among countries and, where possible, with older collections (as aged by different scientists using different methods). Use of other data (e.g., scat-analysis as presented in BEN/JAN04/NH/3c) for validation purposes (e.g., initial otolith increment deposition) was encouraged.

The issue of rejecting difficult-to-age specimens was reviewed along with some general properties of aging error. The group noted that close collaboration with assessment scientists was required to avoid the problem of under-sampling older specimens since they are most difficult to age and often fail the testing procedures used in some laboratories. For example, the estimation of aging error based on percent agreement can and should be used appropriately in assessment models. Figure 1 illustrates a typical estimate of ageing precision for another species of gadid. The group reviewed the fact that size selection can affect estimates of size-at-age and noted that strata weighting should reflect biomass estimates (from surveys) and catch (from fisheries) appropriately. Also, the importance of evaluating data for outliers was emphasized.

Finally, it was clear that the ability to staff scientists to conduct the age-determinations is one of the major limitations to providing useful age data required for assessments. Problems with establishing age-determination laboratories that regularly produce reliable age-determinations may be remedied by a proposed international laboratory. The small group was supportive of such a laboratory and recommended that it be given high priority for funding. However, it was reported that a clear set of priorities for research and analyses would be required for the age-determination laboratory to fulfill its intended functions.

Recommendations from the small group

- BENEFIT should convene a workshop for exchange of samples for testing (this has been planned and is likely to occur in June or July 2004).
- Re-evaluate the sampling protocol (ensure that growth curve estimation methods are appropriate for sampling method).
- The proposed ageing laboratory should be funded with close coordination from national laboratories.
- Age-length keys should be applied only to length frequency data for the year of sampling.
- Data should be carefully screened (close examination of outliers).
- Where possible, comparisons with past age structures should be evaluated relative to current methods.
- A study to evaluate surface age-reading vs methods where the otoliths are sectioned should be conducted. This will provide a means to inter-calibrate between datasets where the ageing methods differ.
- Assessment models should account for errors in age-determinations (and carefully evaluate sample size issues).
- Agencies should try to minimize the current turnover of professional staff trained in age-determination methods. Also, agencies should assign priority to

employ staff scientists assigned to age-determination issues needed for stock assessments.

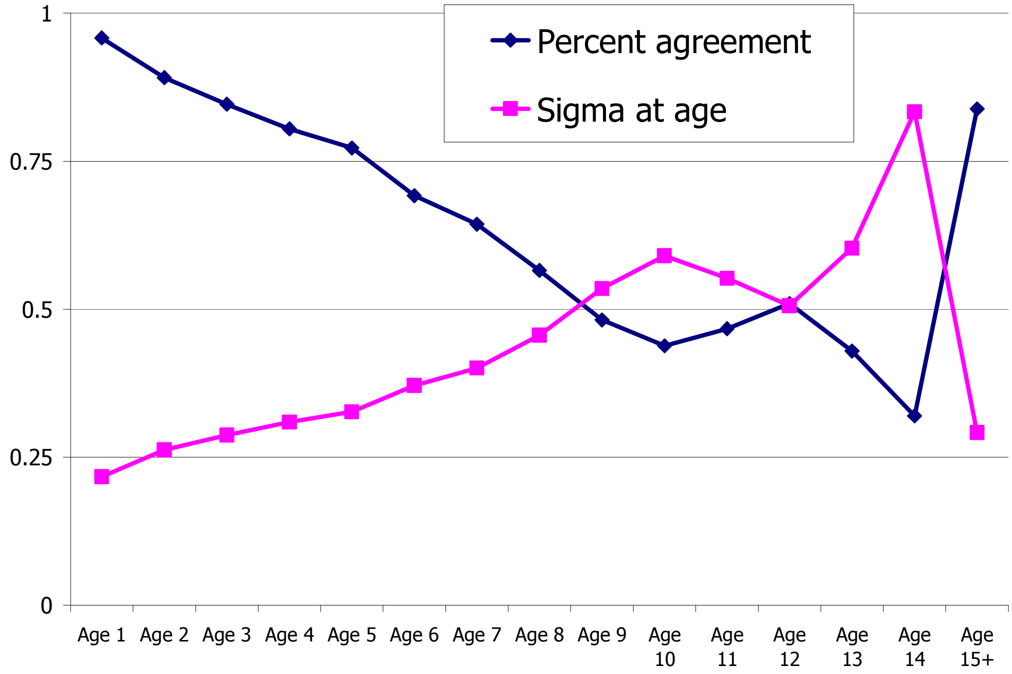


Figure 1. An example (based on Bering Sea pollock) of average between-reader agreement and estimated standard deviations (sigma at age) used to construct the ageing-error matrix. The “Age 15+” values represent the between-reader agreement for pollock specimens aged 15 or older (and hence have a higher agreement rate than say for age 10).

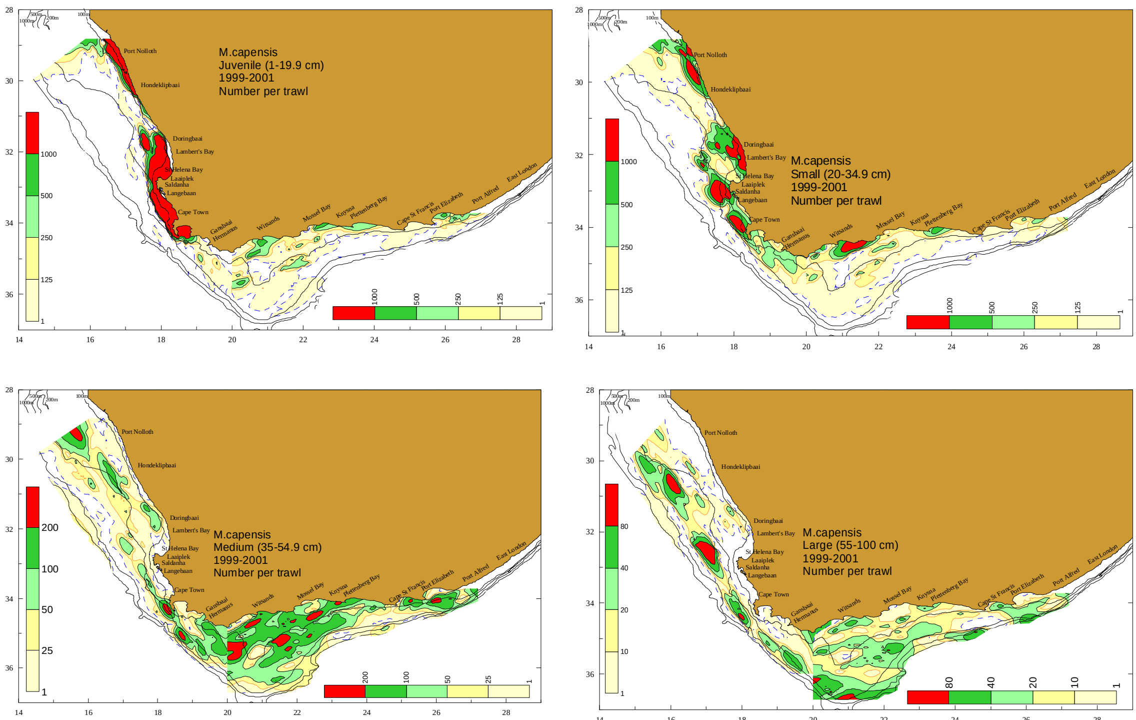
Appendix 5 : Spatial Patterns in Size-dependent Abundance Distribution of Shallow-water Hake: 1999-2001

Frances le Clus, MCM

The abundance distribution (number per standardized trawl) of four size-classes of shallow-water hake was determined from research surveys. The surveys were conducted to 500m depth, in January/February 1999-2001 on the West Coast and April 1999, April 2000 and September 2001 on the South Coast. Kriging was used to plot contour maps to visualise spatial trends. Spatial trends of Cape hakes are compromised because of hazardous grounds, especially at the shelf-edge on the South Coast. Furthermore, juvenile numbers may be underestimated, as young hake less than about 7 cm may remain near the surface in extensive schools.

The spatial trends in distribution of the four size-classes are shown in Figs1a-d. High densities of juvenile and small shallow-water hake were found inshore at depths less than 200 m on the West Coast north of Cape Point, whereas on the Agulhas Bank densities were lower and present mainly at depths less than 100 m (Figs 1a&b). In contrast, there were higher concentrations of medium-sized (35-54.9 cm) shallow-water hake on the Agulhas Bank (from south of Cape Town) than on the West Coast north of Cape Town (Fig. 1c). Large shallow-water hake (> 55 cm) were widely distributed on the Central Agulhas Bank, but were found at higher densities towards the shelf-edge on the West Coast (Fig. 1d). Similar trends were also found on surveys conducted during surveys in the period 1990-1997.

Fig.1: Spatial trends in abundance distribution of four size-classes of shallow-water hake, from research surveys in summer on the West Coast and in autumn or spring on the South Coast, in the period, 1999-2001: (a) juveniles (1-19.9 cm), (b) small (20-35 cm), (c) medium (35-54.9 cm) and (d) large (55-100 cm).



Appendix 6 : Species Split for West Coast Hake

T.P. Fairweather
Department of Ichthyology and Fisheries Science, Rhodes University
PO Box 94, Grahamstown 6140, SOUTH AFRICA

INTRODUCTION

This working document focuses on using spatial tools to propose a resolution to the species disaggregation issue for hake on the West Coast of South Africa.

MATERIALS AND METHODS

General

The West Coast extends 1478km; three fishing zones were defined by lines of latitude and, for simplicity, named sequentially after the largest ports found on the West Coast. These were from north to south - Port Nolloth (28.5°S – 32°S), Saldanha Bay (32°S – 34.5°S) and Cape Town (34.5°S – 37°S).

West Coast catch and effort data from commercial trawl vessels was obtained from Marine and Coastal Management (M&CM) with the permission of the South African Deep-Sea Trawling Association. All catch records reported to M&CM are referenced to a commercial grid system that is composed of 20'×20' blocks extending to the boundary of the EEZ.

Biomass survey trawl data collected by the *FRS Africana* along the West Coast between 1986 and 1999 was used in the analysis. The data consisted of summer (January/February) and winter (July/August) surveys until 1989 and only summer surveys for the remaining years.

Species Split

Although MCM have constructed a species disaggregated operating model, further methods were investigated for comparison. A Syrjala (1996) test was used to assess whether the distributions of each hake species were random. This test is non-parametric and compares normalised densities of two populations at geographical locations. The significance of the results was determined using a randomisation test that compares *n* random pair-wise comparisons of the data against that which has been observed. A randomisation test was necessary because of the sample size (n>100 for each year), 20 data points would require 20^{20} = 1 048 579 permutations. If 10% of the randomised test statistics were greater than the point statistic, then the hypothesis that the two populations are random can only be rejected 90% of the time, i.e. equivalent to a p-value of 0.1.

Research survey catch data was used to map the distribution of *M. capensis* and *M. paradoxus* for each year investigated (1986 to 1999). Catch was mapped as point pie charts depicting the ratio of each hake species present at each sampling point (Figure 1). The percentage of *M. capensis* at a particular survey catch point was calculated as the proportion of both hake species present. This value was only calculated for catch points where at least one of the species was sampled.

A logistic model relating the percentage of *M. capensis* to depth was constructed, similar to the method employed by MCM (Geromont *et al* 1999). To account for latitudinal differences in hake abundance found by Millar (2000), a two-parameter linear model was constructed that relates the percentage of *M. capensis* (PC) to depth and latitude for the entire West Coast and within each fishing zone. The modified logistic model was of the form:

$$PC = 100 - \frac{100}{1 + e^{\left[-(d - d_{50})/\delta\right]}},$$

where d_{50} is depth at 50% abundance and δ is the steepness of the ogive. Whereas the linear model was of the form:

$$PC = \beta_1 * depth + \beta_2 * latitude + \beta_0,$$

where *PC* is the percentage *M. capensis* and β the vector of regression coefficients. The proportion of *M. capensis* caught during the study period was calculated using the estimated regressions where the latitude co-ordinate was at the centre point of the commercial grid block in which fishing occurred. The catch data used in this study does not include catches that were not spatially referenced, and outliers were removed using criteria developed by MCM before the *M. capensis* total catch for that year was calculated (Table 1). The coefficient of determination was calculated as:

$$r^2 = 1 - \frac{residual \quad SS}{total \quad SS}.$$

RESULTS

General

Length frequency data collected on research surveys indicate that the average size of *M. capensis* found between 201 and 300m is 40cm, increasing to 51cm between 301 and 400m. Similar results are observed in Figure 1. Unfortunately, research trawls have not extended much beyond 500m (Table 2), in the last 14 years almost 90% of the trawls have been in water shallower than 401m.

Species Split

The depth-dependent distribution of hake is clearly evident in Figure 1, with *M. capensis* and *M. paradoxus* non-randomly distributed across the West Coast (Table 3).

Commercial catches are reported by statistical 20’x20’ grid blocks. For the analysis, the latitudinal co-ordinate corresponding to the mid-point of the grid block was applied to all catches from that block. Although this is not entirely accurate, the estimation faces a maximum error of only 10’ for each trawl completed in the grid where the gear was shot.

The logistic model relating the percentage of *M. capensis* to depth provided a superior fit (Table 4) when compared to the linear model, which incorporated both depth and latitude (Table 5). However, the specific models for each of the fishing zones provided a better fit then the models for the West Coast (Table 4 and 5). Catches predicted in this study were considerably higher than those calculated by MCM. This is attributed, in part, to the assumption MCM make regarding the absence of *M. capensis* deeper than 289m, in contradiction to observer data collected on commercial trawl vessels (Table 6). The logistic models predict a minimum of 4% *M. capensis* at 289m (Table 4).

Table 1 Total annual hake (both species) landings (Geromont 1999) and *Merluccius capensis* catch and CPUE estimations (Glazer 1999). All catches and landings are reported in tons.

Year	*Merluccius sp.*	*M. capensis*		*M. capensis*			
		Catch	CPUE (kg.min^{-1})	WC logistic[1]	Zone logistic[2]	Zone linear[3]	WC linear[4]
1978	101 140	6 068	1.83				
1979	92 704	8 343	2.00				
1980	101 538	8 123	1.92				
1981	100 678	9 061	2.19				
1982	85 970	7 737	2.08				
1983	73 677	4 407	2.31				
1984	88 410	7 044	2.32				
1985	99 590	4 921	3.05				
1986	109 091	4 309	2.81				
1987	104 010	4 018	1.65				
1988	90 131	3 398	1.31				
1989	84 896	3 384	1.47				
1990	78 918	2 356	1.84				
1991	85 521	855	2.54				
1992	86 280	1 726	2.98				
1993	98 110	981	1.99				
1994	102 770	911	1.51	7 040	4 956	13 237	14 879
1995	94 716	844	1.04	6 943	4 136	15 309	15 371
1996	91 364	889	1.10	9 854	3 771	16 926	14 785
1997	92 328	808	1.43	6 032	3 763	14 341	13 714
1998	107 248			7 053	4 764	14 411	14 708
1999	100 000			5 592	3 655	12 725	12 107

Table 2 *Merluccius capensis* length frequencies measured during nine research surveys conducted over six years (1986, 1988, 1990, 1992, 1994 and 1999). No fish were measured at depths greater than 500m although trawls were completed.

Length	**100m**	**200m**	**300m**	**400m**	**500m**	**600m**	**700m**	**800m**	**900m**	**999m**
10cm	43 430	634	10	0	0					
20cm	64 726	70 775	796	0	0					
30cm	136 547	118 597	7 380	1	0					
40cm	3 631	29 929	11 239	119	0					
50cm	121	5 361	8 741	869	0					
60cm	28	1 554	5 100	1 568	20					
70cm	7	476	2 256	932	24					
80cm	2	156	670	147	18					
90cm	2	24	138	48	5					
100cm	0	5	20	6	0					
110cm	0	0	2	1	0					
Trawls	153	760	571	231	179	4	0	12	7	6
100%	(8%)	(39.5%)	(29.7%)	(12%)	(9.3%)	(0.2%)	(0%)	(0.6%)	(0.4%)	(0.3%)

Footnotes for Table 1

[1] Catch calculated using logistic depth model for the entire West Coast.
[2] Catch calculated using logistic depth model for each fishing zone.
[3] Catch calculated using linear depth and latitude model for each fishing zone.
[4] Catch calculated using linear depth and latitude model for the entire West Coast.

Table 3 Results of the Syrjala (1996) test for *Merluccius capensis* and *M. paradoxus* research CPUE (3000 random pair-wise permutations). Minimum possible p-value was 0.0003.

Year	*M. capensis*		*M. paradoxus*	
	Xi	p-value	Xi	p-value
1986	1.792	0.0003	2.842	0.0003
1987	1.609	0.0003	2.603	0.0003
1988	1.289	0.0017	1.809	0.0023
1989	0.990	0.0067	4.982	0.0003
1990	1.618	0.0550	4.445	0.0003
1991	1.504	0.0003	1.879	0.0010
1992	0.849	0.0040	0.726	0.1127
1993	0.363	0.1380	0.767	0.0693
1994	0.457	0.0030	0.833	0.0440
1995	0.811	0.0137	2.438	0.0003
1996	0.628	0.0003	2.947	0.0003
1997	1.465	0.0027	1.791	0.0007
1998	0.779	0.0003	1.256	0.0067

Table 4 Results of the logistic regression model relating the percentage of *Merluccius capensis* to depth and latitude within each fishing zone and for the entire West Coast.

Coefficients	Cape Town	Saldanha Bay	Port Nolloth	West Coast
R^2	0.780	0.600	0.505	0.534
D_{50}	220.008	201.115	192.121	209.331
δ	21.116	49.208	59.579	55.807
PC at 289m	3.7%	14.4%	16.4%	20.0%

Table 5 Results of the linear regression model relating the percentage of *Merluccius capensis* to depth and latitude within each fishing zone and for the entire West Coast.

Coefficients	Cape Town	Saldanha Bay	Port Nolloth	West Coast
R^2	0.492	0.436	0.449	0.434
β_0	5.678	117.495	70.725	80.445
β_1	-0.196	-0.205	-0.236	-0.215
β_2	3.019	-0.852	0.964	0.577
ANOVA				
Pr (depth)	0.000	0.000	0.000	0.000
Pr (latitude)	0.468	0.607	0.401	0.064
N	278	552	886	1919

Table 6 *Merluccius capensis* data collected on trawler vessels by MCM staff from 1994 to 1999, number of fish measured and the depths at which catches were recorded.

Year	n	Depth (m)
1994	0	310, 340, 346, 415, 410, 330, 380, 353
1995	774	350, 345, 349, 417, 302, 420, 320, 370, 370, 240
1996	1 714	300, 310, 320
1997	962	130, 420, 440, 250, 265, 270, 370, 280, 350
1998	328	391, 300, 310, 350, 360, 400, 270, 420, 275, 380, 370, 430, 475
1999	728	330, 340, 355, 320, 342, 315, 266, 350, 264, 220, 400, 360, 345, 380

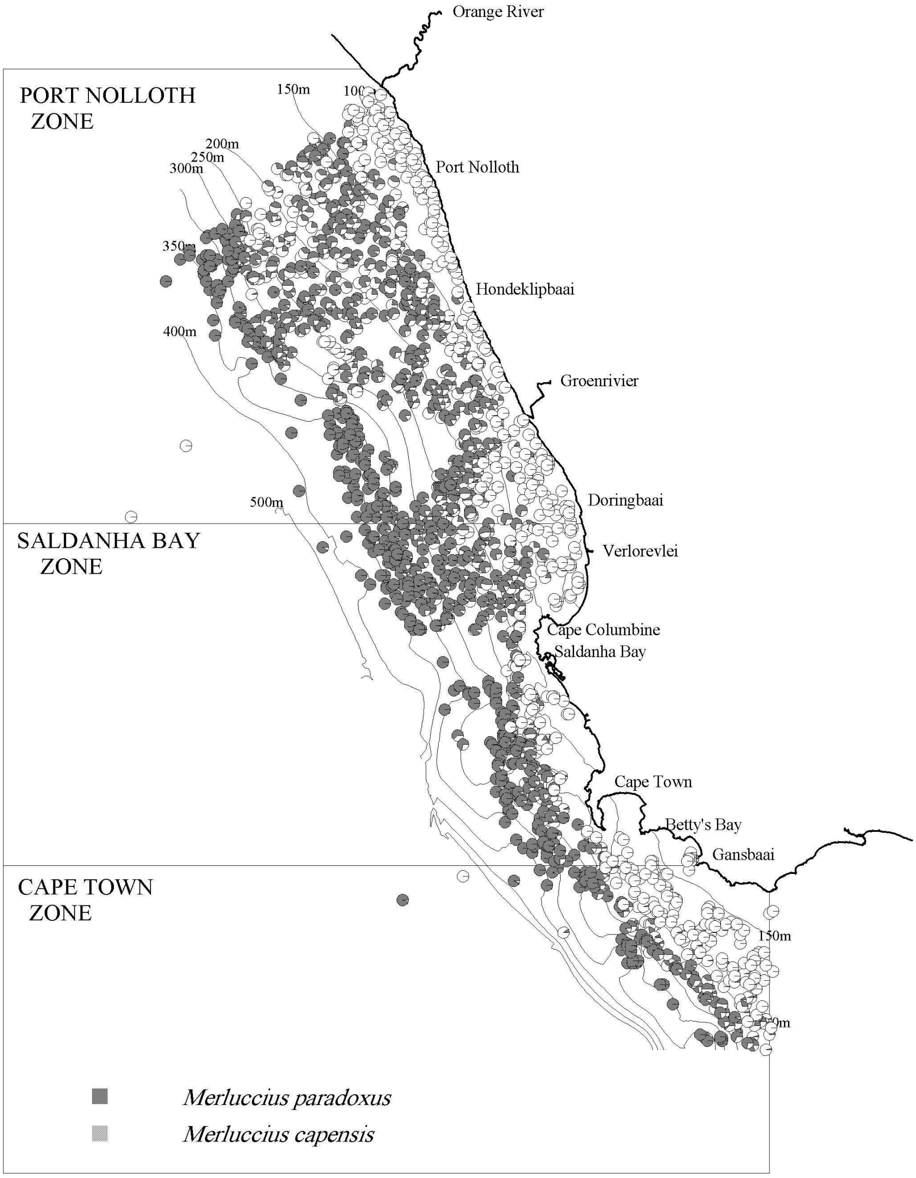


Figure 1 Relative proportion of *Merluccius capensis* and *M. paradoxus* caught in research surveys from 1986 to 1999.

DISCUSSION

While recognizing the limitations of the data collected during the annual West Coast Demersal Survey (in terms of seasonality, trawl duration, gear type and vastly different fishing techniques), basic application of the data has raised several issues.

Although the final results of fishing zone specific calculations were not vastly different to those for the entire West Coast, they provide a superior fit to the data. The large discrepancy between the results of the logistic model and the linear warrants investigation. Differential latitudinal abundance of hake along the West Coast has been documented (Millar 2000), which suggests that *M. capensis* catch in previous years is likely to be different to that indicated by models based exclusively on depth. Regression estimates conducted at a finer spatial scale than three fishing zones may provide a better fit than the current depth logistic employed, however the increase in precision must be balanced by an awareness of the potential increase in bias.

The annual catch figures calculated by MCM for *M. capensis* were significantly different to those calculated in this study. The large difference can be attributed to two factors: the minimal depth range at which MCM consider *M. capensis* to be found i.e. no deeper that 289m (Glazer 1999), and the assumption that *M. capensis* is uniformly distributed.

It is necessary to incorporate finer spatial detail in the collation of catch data and collection of sampling data. The calculation of an accurate *M. capensis* CPUE time series is crucial. Research surveys should perhaps extend trawls beyond the 500m depth range and include collection of length frequency data.

There is a need to incorporate spatial analysis into stock assessment procedures. Models including spatio-temporal variation would be highly complex and, as such, error prone. Model predictions can be compared to a spatial visualisation of what actually occurred e.g. parental stock (i.e. large fish) distribution and the distribution and associated effort shift of each vessel. This would facilitate model refinement and verification on an annual basis.

REFERENCES

GEROMONT, H.F. 1999 - Recommendation for the West Coast component of the hake TAC for 2000 in terms of the revised management procedure. *Marine and Coastal Management: Demersal Working Group Document WG/05/99/D:H:10*; 4 pp.

GEROMONT, H.F., DE OLIVEIRA, J.A.A., JOHNSTON, S.J. and CUNNINGHAM, C.L. 1999 - Development and application and management procedures for fisheries in southern Africa. *ICES Journal of Marine Science*; 56: 952-966.

GLAZER, J. 1999 - Standardising the West Coast and South Coast *Merluccius capensis* and *M. paradoxus* CPUE data. *Marine and Coastal Management: Demersal Working Group Document WG/05/99/D:H:02*; 16 pp.

MILLAR, D.L. 2000 - Distribution and abundance of Cape hakes (*Merluccius capensis* and *Merluccius paradoxus*) in relation to environmental variation in the Southern Benguela. MSc Thesis, University of Cape Town, South Africa; 126pp.

SYRJALA, S.E. 1996 - A statistical test for a difference between the spatial distributions of two populations. *Ecology*; 77 (1): 75-80.

Appendix 7 : Results from applying revised species split algorithms to the hake catches

Jean Glazer

The algorithms to separate the commercial hake catches into species (*Merluccius capensis* and *M. paradoxus*) as derived by Geromont *et al* (1995), Butterworth and Rademeyer (2004) and Gaylard and Bergh (2004) have been applied to the offshore South Coast hake catches (east of 20oE) for comparative purposes. Similarly, the West Coast species splits using the Geromont et al (1995) and Butterworth and Rademeyer (2004) algorithms are compared. The results are presented in the figures below.

Note that Gaylard and Bergh (2004) considered a number of models, some of which are size-disaggregated. In the comparisons below only the size-aggregated models are considered, namely Models 1.2, 1.3, 2.1 and 2.2.

References

Butterworth, D.S and R.A. Rademeyer. 2004. Update on the Estimation of Merluccius capensis and M. paradoxus Proportions at Depth from Survey data. Unpublished Benefit Document, BEN/JAN04/SAH2b

Gaylard, J.D. and M.O. Bergh. 2004. An investigation into the procedure used to split commercial catches of hake on the South African South Coast into Merluccius paradoxus and Merluccius capensis. Unpublished Benefit Document, BEN/JAN04/SAH2c

Geromont, H.F., Leslie, R.W. and D.S. Butterworth. 1995. Estimation of *Merluccius capensis* and *paradoxus* proportions in Cape hake catches. Unpublished Sea Fisheries Demersal Working Group Document, WG/03/95 D:H:2.

Figure 1: South Coast *M. capensis* catches east of 20ºE

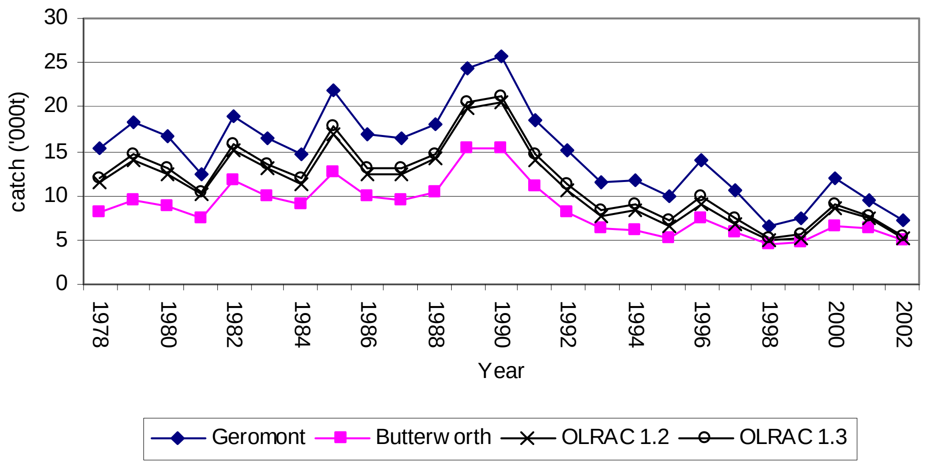


Figure 2: South Coast *M. capensis* catches east of 20ºE

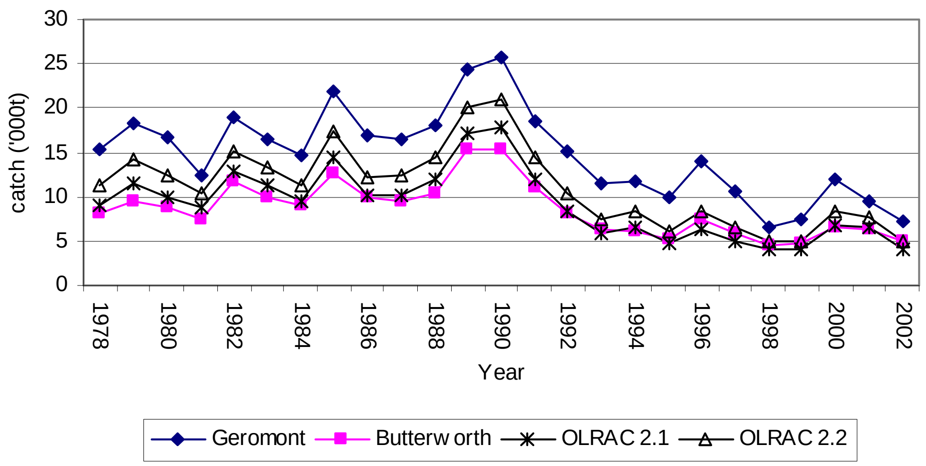


Figure 3: South Coast *M. paradoxus* catches east of 20ºE

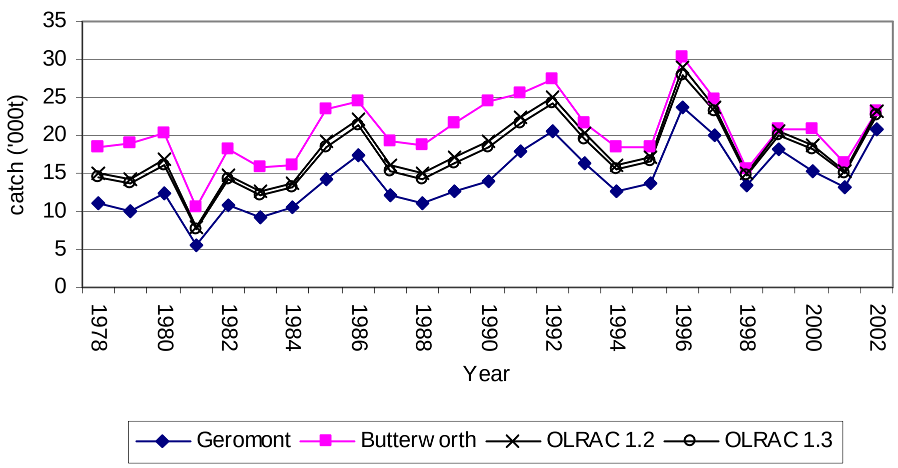


Figure 4: South Coast *M. paradoxus* catches east of 20ºE

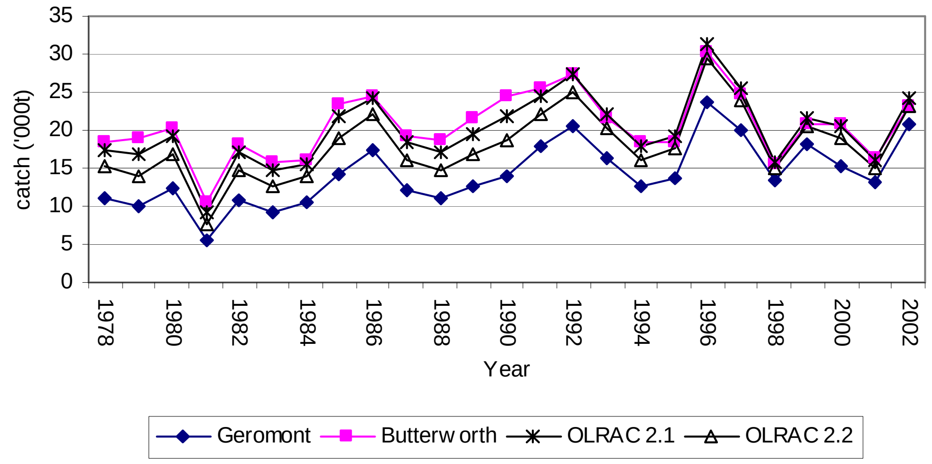


Figure 5: West Coast *M. capensis* catches

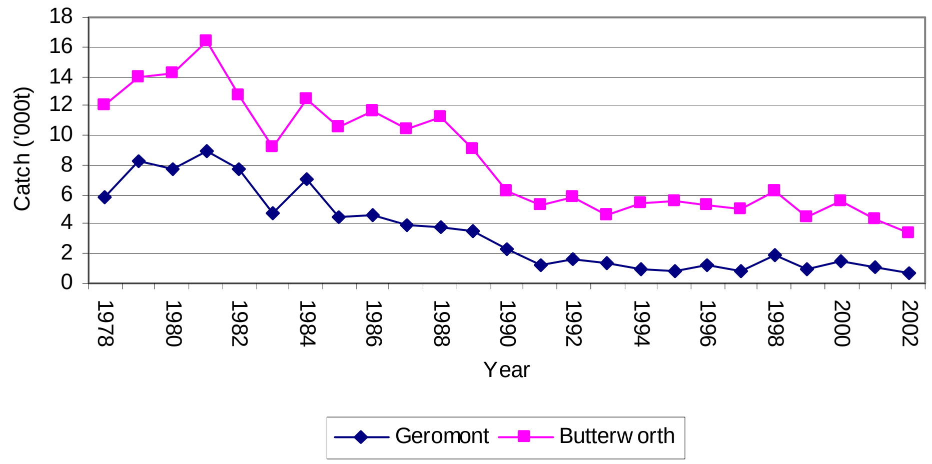
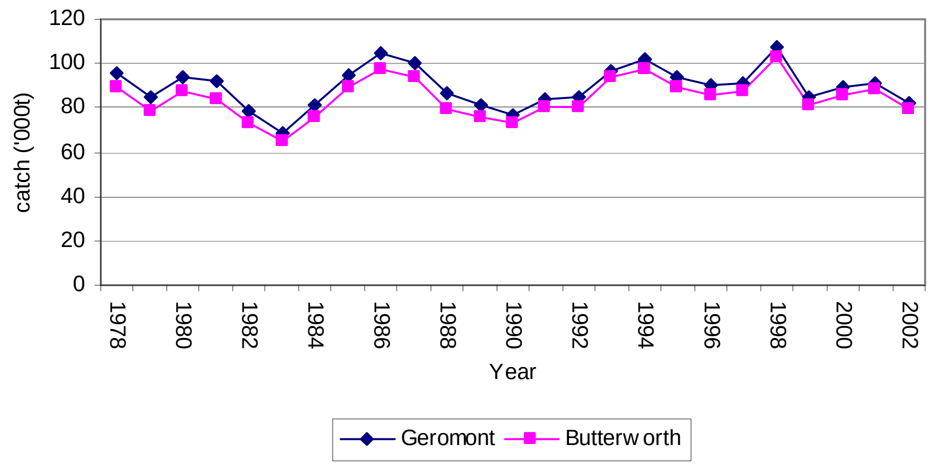


Figure 6: West Coast *M. paradoxus* catches



Appendix 8 : Matching Sectorial Allocations to the Productivity of Each Component of the Hake Resource

R.W. Leslie

A principle that the Demersal Working Group strongly supports is the apportionment of the global ***TAC*** on a proportional, rather than on a quantum basis, especially when rights are allocated for more than one year.

However, it must be remembered that the hake resource is comprised of two species, and that the different sub-sectors of the hake sector target different components of the resource. For example, the Handline and Inshore Trawl sub-sectors are based on the South Coast, where they target only *Merluccius capensis*. Thus setting the allocation for these sub-sectors to a proportion of the global ***TAC*** could lead to over- or under-exploitation of the *M. capensis* resource on the South Coast if the proportional contribution of this component to the global ***TAC*** changes over time. It is therefore recommended that the allocation per sub-sector be determined as a fixed percentage of each component of the global hake ***TAC*** that that sub-sector exploits.

A procedure to link sub-sector allocations to separate components of the global ***TAC*** is suggested, and illustrated using the allocations granted for 2001. The components of the global $\boldsymbol{TAC_{2001}}$, and the quanta allocated to each sub-sector for 2001 are presented in Tables 1 and 2 respectively. Table 3 presents the proportion of each component of the global $\boldsymbol{TAC_{2001}}$ that was allocated to each fishery sub-sector for 2001.

Table 1: The contribution of the components of the hake resource to the global hake $\boldsymbol{TAC_{2001}}$

Component of the hake resource	Contribution to the global $\boldsymbol{TAC_{2001}}$
Merluccius capensis east of 20°E	25 000 t
West Coast *M. capensis* and *M. paradoxus* combined	107 000 t
ad hoc adjustment to account for *M. paradoxus* on the South Coast[1]	34 000 t
Global *TAC*	166 000 t

[1] The *M. paradoxus* resource is not regarded as coast-specific, and this species is exploited primarily by the West Coast-based offshore fishery, therefore the *ad hoc* adjustment for *M. paradoxus* on the South Coast can be regarded as part of a "West Coast component” for the purposes of allocation among fishery sectors.

Table 2: Quanta allocated to each sub-sector for 2001 and the component of the resource targeted by the sub-sector

Fishery	Quantum allocated in 2001*	Component targeted by the fishery
Handline	5 500	*M. capensis* on the South Coast only
Longline	10 840	Divided evenly between West and South coasts. South Coast operators target *M. capensis* only.
Inshore Trawl	10 165	*M. capensis* on the South Coast only
Offshore Trawl	138 495	Mostly *M. paradoxus* from both coasts

* Note that this does not total 166 000 t as there is a non-sector specific reserve of 1 000 t (Mozambique bi-lateral agreement)

Table 3: The proportion and quantum (in parenthesis) of each component of the global hake $\boldsymbol{TAC_{2001}}$ that was allocated to each sub-sector of the hake fishery for 2001

Component / Fishery	South Coast *M. capensis*	West Coast *Merluccius* sp plus South Coast *M. paradoxus*	Total
Handline	22.00% (5 500)	----	5 500
Longline	21.68% (5 420)	3.87% (5 420)	10 840
Inshore Trawl	40.66%(10 165)	----	10 165
Offshore Trawl	15.66% (3 915)	96.13% (134 580)	138 495
Total	100.00%(25 000)	100.00% (140 000)	165 000

It should be noted that:

- Amounts of hake held in sector-specific reserves should be taken from the allocation to that sector, and that amounts held in non-specific reserves should be subtracted from the global ***TAC*** prior to allocation to sectors.
- It is assumed that the *M. paradoxus* resource is a single stock, so it is not necessary for the "South Coast *M. paradoxus* component" to be taken on the South Coast. Further, this component is exploited only by the offshore trawl sector. Therefore, for the purposes of allocation among sectors, the *ad hoc* adjustment is treated here as part of a "West Coast" component.
- The take of *M. paradoxus* from the South Coast (east of 20°E) will be limited by the amount of *M. capensis* available to the offshore trawl fleet. Over the past 5 years, catches by the offshore trawl fleet taken on the South Coast have averaged 35% *M. capensis* and 65% *M. paradoxus*. If this species ratio is maintained, then the total hake catch (both species combined) taken on the South Coast by the offshore fleet should not exceed 2.85 times the *M. capensis* allocation to this fleet. Since the species ratio in the hake catches can be altered by changing the average

fishing depth, it should not be too difficult for the offshore fleet to maintain this target species split.

- The intention is to develop three species-specific OMPs for the hake resource, viz: a South Coast *M. capensis* OMP, a West Coast *M. capensis* OMP and a coast combined *M. paradoxus* OMP. Once developed, and accepted, the latter two OMPs will replace the current West Coast OMP and the *ad hoc* adjustment to account for *M. paradoxus* on the South Coast.
- The part of the allocation to the Longline sub-sector derived from the *M. capensis* component should be allocated to South Coast operators, and the remainder to West Coast operators.
- The annual quantum per sector is the determined by summing the annual quanta derived from the percentage of the two components of the ***TAC*** (viz: a *M. capensis* component and a "*M. paradoxus*" component) allocated to that fishery sector.

Appendix 9 : Recommendations and Agreements

The following represent the recommendations and agreements arising from the discussions held during the workshop. Each recommendation was ranked High, Medium or Low by the workshop participants based on the importance of the recommendation in terms of its likely impact on management decisions, and its feasibility. The workshop also divided the recommendations into those which pertain to administrators ("A"), scientists ("S") and both "(A/S").

The workshop did not rank research recommendations within the H, M and L categories. The workshop recognized that the time required to implement some of the recommendations would be substantial and that decisions regarding future OMPs may have to be made prior to even some of the high priority research topics being addressed. The numbers against each recommendation refer to the sections in the main text where the recommendation arose and where additional commentary may be found.

I. Agreed recommendations

A. Both hake species

A.1 (H, 3.1, A/S) Methods (such as biochemistry, radiocarbon) should be applied to validate the ageing of hake.

A.2 (H, 3.1, A). Given the clear hiatus in hake ageing in recent years, due to a dearth of ageing competency in both countries, the workshop on ageing techniques for hake referred to in Appendix 4 should be conducted.

A.3 (H, 3.2, S). Attempts to develop informative prior distributions for the catchability coefficient, *q*, should be pursued. If priors can be agreed, they should be evaluated for use in stock assessments (either as penalty functions or by fixing catchability to some appropriate summary statistic of the distribution, such as its mode).

A.4 (H, 3.2, S). The spatial distribution of the catch-rate information should be included in papers that standardize catch and effort information.

A.5 (H, 3.4, S). Stock assessments to form the basis for the evaluation of future OMPs should be based on the framework outlined in Section 3.4.

A.6 (H, 3.4, S). In view of the uncertainty regarding the value for natural mortality, when evaluating OMPs, a series of scenarios should be constructed that lead to a range of values for *M* for example by: (a) allowing for changes over time in carrying capacity, and (b) adjusting the historical catch-rate data.

A.7 (H, 3.4, S). The extent of variation in recruitment could be estimated from the results of the analyses of the seal scat samples or directly from surveys.

A.8 (H, 4.1, A/S). Hake scientists should be encouraged to collaborate with population geneticists to address stock structure issues, especially those related to trans-boundary questions.

A.9 (H, 4.6, A/S) Ways of explaining the development and implementation of OMPs to managers and industry in plain language must be developed.

A.10 (H, 4.6, A/S) The cost-benefit of the OMP approach relative to other approaches needs evaluation.

A.11 (M, 3.2, S). Given the importance of catch-effort data in the assessment, the issues related to catch-effort standardization identified in Section 3.2 should be explored.

A.12 (M, 3.2, S). The sensitivity to ignoring the recent catch-rate index and to considering alternative relationships between standardized catch-rate and exploitable (essentially the fishable) biomass should be considered when evaluating OMPs.

A.13 (M, 3.4, S). The assessment model should be applied with a more recent start year to assess whether the use of the early data, the assumption that the stock-recruitment relationship has not changed over time, and the assumption that the population was at pre-exploitation equilibrium at the start of exploitation, may be constraining the fit to the recent catch-at-age and catch-rate data.

A.14 (M, 4.6, S). The OMP development process should include tests that reflect possible trophic interaction effects.

A.15 (L, 3.1, S) Existing data should be examined to better characterize the relationship between length (and age) and maturity / effective spawning potential (fecundity).

A.16 (L, 3.1, A) Research (e.g. through longline-based tagging) should be conducted to provide more information on longshore movement.

A.17 (L, 3.4, S). The value of using the variances estimated from the application of GLMM models to the catch and effort data to weight the catch-rate indices should be investigated.

A.18 (L, 3.4, S). An analysis (such as Principal Components Analysis) should be applied to examine the correlation structure of the model parameters.

A.19 (L, 3.5, S). As a first attempt to address hake-multi-species interactions, existing models should be adapted to provide estimates of the predation mortality on hake that is generated by the two hake species.

A.20 (L, 3.5, S). Novel, cost-effective ways of estimating suitability (prey preferences) should be explored.

A.21 (L, 3.6, S). The OMP evaluation process should be used to evaluate the potential benefits of additional data collection, e.g. of genetics data.

A.22 (L, 4.3, A/S). Alternative indices of hake recruitment (e.g. along the lines of the Namibian seal scat-based index of hake recruitment) should be developed.

B. South African hake

B.1 (H, 3.1, A). The catch by the handline sector and its species-, sex- and size-structure should be monitored.

B.2. (H, 3.1, S). The observer data should be used to test the validity of the algorithms for splitting the past commercial trawl catches among species.

B.3 (H, 3.1, S). The algorithm used to split the historical trawl catches to species should take the fish size as well as depth of capture into account.

B.4 (H, 3.4, S). The lower bound imposed on the residual standard deviation for the CPUE data should be increased appreciably.

B.5 (H, 3.6, A/S). A new OMP for South African hake should be developed through tests based on a joint model for the two hake species. Given the time needed to conduct the associated evaluations, this OMP could not be ready for implementation before late in 2005.

B.6 (H, 3.6, A). The observer programme for South Africa needs to provide regular and reliable information on the species-split of the hake catch.

B.7 (M, 3.2, S). The spatial and temporal trends in the catch and effort data for the longline fishery should be analyzed.

B.8 (M, 3.6, S). Comparison of the hake-specific biological impacts of trawling and longlining needs to be updated in the light of further information now available.

B.9 (L, 3.1, S). Industry should be consulted to develop alternative hypotheses regarding the levels and spatial distribution of the historical catches.

B.10 (L, 3.1, S/A). Research should be conducted to determine the spatial and temporal dynamics of hake spawning and early life history using surveys.

B.11 (L, 4.3, S/A). A seal scat-based index of hake recruitment should be developed for South African hake.

C. Namibian hake

C.1 (H, 4.2, S). The Spanish survey indices should be corrected.

C.2 (H, 4.3, S). The utility of the seal scat-based index of hake recruitment should be examined further, and be included in tests of assessment sensitivity.

C.3 (M, 4.1, A). Species- and sex-composition, length-frequency (and otoliths, if possible) should be collected from the longline catches.

C.4 (M, 4.3, S). The possibility of identifying the younger cohorts in the survey length-frequencies using modal analysis should be examined.

C.5 (L, 4.2, S). The effects of catches of other species on the catch rates of Namibian hake should be investigated.

C.6 (L, 4.2, S). An attempt should be made to obtain the raw tow-by-tow data for the Spanish surveys.

D. Namibian fur seals

D.1 (H, 5.1). The changes to the seal pup census database should be documented and finalized.

D.2 (H, 5.1, S). The sensitivity of the results of the assessment to the selection of which pup counts to include in the assessment (and how to adjust them) should be re-examined.

D.3 (M, 5.1, S). The sensitivity of the OMP evaluation results to variations in the bull selectivity pattern should be examined.

D.4 (M, 5.1, S). The data on pup harvest selectivity should be analyzed to evaluate the hypothesis that in good years all pups are equally likely to be harvested whereas, in bad years, when the pup mass is lower than average, industry tends to select the larger pups.

D.5 (M, 5.1, S). The model should be amended to examine the hypothesis that a reduction in the number of 12+ bulls leads to an increase in the natural mortality of younger males.

D.6 (M, 5.1, S). Future projections should include robustness tests in which an event similar to the 1994 anomaly occurs on an infrequent basis rather than frequent less extreme events

II. Workshop agreements

A. Strategic issues

#1. There is strong support for the planned BENEFIT project to exchange samples and methodologies between Namibian and South African age-determination scientists.

#2. Before initiating sampling programs aimed at improving understanding of multispecies interactions, this needs to be balanced with data collection and analysis needs related to the single-species assessment process.

#3. While clearly some advances have been made in the multi-species/ecosystem modelling field, understanding of multi-species and ecosystem interactions is still at a relatively early stage, and a range of modelling approaches should be considered when addressing these issues. Caution should be exercised in making use of the predictions of such models unless there is substantial agreement between these across different approaches.

#4. Evaluation of management controls need not be restricted to *TAC*s, but might also include input controls and time/area closures, though perhaps only for the longer term.

#5. Given the possibility of a shared *M. paradoxus* stock between South Africa and Namibia, thought needs to be given to how TAC sharing arrangements might best be developed should such an eventuality arise, noting that there are certain prerequisites for this such as some form of common resource assessment agreed between the two countries.

B. Other issues

#6. Even though stock assessment methods can be modified to account for missing catch-at-age data, this is a "patch" and every effort should be made to obtain annual catch-at-age information.

#7. The assumption of a single stock of *M. capensis* off South Africa is more plausible than separate south and west coast stocks.

#8. The assumption of a single stock of *M. paradoxus* off South Africa is more plausible than separate south and west coast stocks.

#9. There is support for research into environmental and behavioural effects which could have a significant effect on q

#10. Multispecies/ecosystem studies and the choice of multispecies models need to be linked to scientific goals and / or management objectives.

#11. For objectives related to broad-scale questions regarding the structure of the ecosystem Ecopath / Ecosim models could be used; other models may be more appropriate for more specific questions.

#12. Disagreements between the predictions of single- and multi-species models can be informative and lead to the generation of hypotheses for system behaviour.

#13. While a revised OMP for the South African hake populations should output *TAC*s disaggregated by species (and perhaps by area), it is not proposed that allocations comprise species-specific quotas to a rights holder. Management options that might best achieve the desired species split of the overall catch still need to be proposed and evaluated.

#14. Assessment of the implications of MPAs for biodiversity conservation needs a dedicated workshop and will need to consider the implications of bycatch.

#15. Changes in survey strategy towards coastwide surveys should be considered but existing surveys should not be modified unless analyses indicate that this will improve their utility in the short- to medium-term.

#16. The existing phased decline could serve as a default basis to determine a 2005 TAC recommendation for South African hake, unless strong contrary evidence was put forward.

17. Information should continue to be collected on the timing of pupping.

#18. Future assessments and OMP development work should take account of different spatial scales (e.g. colony-specific and regional).

#19. The information content of available data is inadequate for the current assessment to be able to estimate quantities related to carrying capacity such as Maximum Sustainable Yield, *MSY*, and the population size associated with *MSY*.

Appendix 10 : BENEFIT 2002 Recommendations for Namibian Seals, with comments of Progress made

S.J. Johnston
MARAM, Department of Mathematics and Applied Mathematics
University of Cape Town,
Rondebosch, 7701

The following represent the agreed recommendations arising from the discussions held at the December 2002 BENEFIT Stock Assessment Workshop. Each recommendation was ranked High, Medium or Low by the Workshop participants based on the importance of the recommendation in terms of its likely impact on management decisions, and its feasibility. The Workshop recognised that the time required to implement some of the recommendations would be substantial and that decisions regarding future OMPs may have to be made prior to even some of the high priority research topics being addressed.

Namibian Seals

1 (H). A long period has elapsed since seal biologists of the region met to update data and debate interpretations thereof. There is a need to establish a forum at which seal biologists and modelers can regularly discuss issues related to the data inputs and assumptions for any modelling work.

A proposed BCLME research project envisages an appointee to initiate modelling work on trans-boundary exchange aspects of the South African and Namibian components of the seal population. Constitution of the forum would likely best wait until this appointee is in place.

2 (H). Models should be based on total counts of all births during a year but it is seldom that the entire population was censused simultaneously. An agreed pup count time-series (by colony and year) needs to be developed. One approach to developing such a time-series would be to apply a GLM to the raw count data for all years, taking account of their uncertainty.

Although an agreed pup count time-series exists, gaps in the data are currently filled using average values of prior and post counts. No further GLM analysis work has been carried out on the data base to date.

3 (H). The data used for assessment purposes should be stored in a database and maintained on an ongoing basis.

There is currently an agreed pup census database. This consists of the raw data and the “adjusted” database for which missing data are “filled in” using specified methods. Other data, e.g. catch data and pup survival (Ω values), are however reported in a variety of documents without to date being collated into a single database.

4 (H). Further data on bull harvests prior to 1970 were presented to the workshop. Future assessments should incorporate the revised time-series of bull harvests.

Assessments since the last BENEFIT 2002 Workshop, when these bull harvest data were provided, have incorporated them. These data were reported in an Appendix in the BENEFIT 2002 report.

5 (H). It appears that the information available is sufficient to determine the survival rate for 1+ females. This parameter should therefore be estimated along with the other parameters of the model, either by treating as a free parameter of the model, or by profiling across a range of plausible values.

BEN/JAN04/NS/3 reports model sensitivity to the female survival rate. Treating the female survivorship as a free parameter results in an unrealistically high estimate (0.98). The Reference Case model continues to fix female survivorship at 0.94 as values lower than this result in a substantial decline in the log-likelihood of the fit to the pup census data.

6 (H). In order to check the extent to which estimates of the survival rates from different data sets are compatible, the size of the likelihood components for the data from branded harem bulls and for the age data for animals collected at sea should be presented along with other population model outputs and diagnostic statistics.

This work is reported in BEN/JAN04/NS/3.

7 (H). Appendix 7 provides specifications developed during the workshop on how to model pup survival, pregnancy rates and carrying capacity. These specifications should form the basis for future assessments. The modelers and seal biologists need to work together to refine the hypotheses underlying these specifications in the event that some of the specifications in Appendix 7 prove unsatisfactory.

These specifications form the basis of the current assessment. For example, the current modeling framework takes into account time-dependent pregnancy rates (see BEN/JAN04/NS/2). The specifications provided all appear to have been satisfactory.

8 (H). There are a number of appreciably different interpretations of the recent seal pup census data. Future management of the Namibian fur seal should be based on a management procedure approach to ensure that management decisions are robust to this uncertainty.

An OMP approach is currently being developed and will test robustness to different uncertainties in assessments. These will include the uncertainty referenced, which relates to distinguishing whether a lower than expected pup count from an aerial census in a particular year reflects an unusually large adult female mortality rate, or a lower than usual proportion of adult females giving birth that year.

9 (H). The Namibian authorities need to provide the modelers with more explicit management objectives to constrain the number of situations requiring evaluation.

The Namibian MMS (Marine Mammal Section) is aiming at developing a proposal for a comprehensive management plan for the Namibian fur seal to submit to Namibian fisheries management authorities. This proposal will outline alternative management objectives and procedures to calculate quotas, and it will discuss the short and long term effects of these options in qualitative terms. The proposal will be submitted to the Namibian fisheries management to decide upon coherent objectives, population targets and reference values, and strategies for managing the seal population.

10 (H). The Namibian authorities need to specify the types of data on which an OMP could be based. This could form the basis for evaluating the cost-effectiveness of alternative data collection schemes.

Data on which an OMP could be based currently include aerial pup counts, catch data and Ω values (pup survival indices). Catch data will continue to be collected, and Namibian scientists intend to continue annual collection of data to determine Ω_y^1, Ω_y^2 and Ω_y^3 data. South African scientists have carried out the aerial censuses in the past and will continue to do so in the future. There will be a full survey of all colonies in December 2003, though future frequency has yet to be agreed. The OMP under development will contain meta-rules for situations in the future for which data are not collected.

11 (H). Previous OMP evaluations involved projections for only 15 years. The time horizon for the OMP projections should be long enough to capture the time-lags in the dynamics of the population.

Projections are now calculated to 2050 (see BEN/JAN04/NS/3).

12 (M). To assist in interpretation of the output of the population model, the number of pups prior to the harvest should be included in the model output in addition to the number of pups born and the number of pups when the pup counts are conducted.

This output is provided for the reference case in BEN/JAN04/NS/3).

13 (M). To assist in estimating the selectivity of the bull harvest through the model, the bull harvest should be sampled for length, and teeth should be collected for ageing.

The Namibian MMS is collecting the following data from the bull harvest: length, girth and teeth for age determination. This is a time series that is planned to continue. These data, once transformed to age-distributions, will provide a basis to estimate bull selectivity within the model. However, the extent of selection practised by the harvesters varies from year to year; furthermore the age-distribution of bulls present at colonies changes within a season, so that timing of the harvest can effect selectivity.

Thus some inter-annual variability about an overall selectivity function must be explored.

14 (M). In order to develop diagnostic statistics related to bulls, additional data need to be collected on their abundance.

Since the previous BENEFIT workshop, MCM (South Africa) have attempted to get a MSc student to compare Bull/Cow and Bull/Pup ratios from aerial photographs (time series from 1974 to the present are available). This would give an idea whether the bull numbers are declining. So far, no student has taken up this project, and hence these results are not yet available (Ooshuizen, pers. commn).

15 (M). The selectivity pattern for the pup harvest may change as a function of environmental conditions, with consequences for projections. Therefore, this pattern (by size and sex) should be re-evaluated using available data.

No further progress has been made on this issue. Oosthuizen reports that no environmental data are available. There are some *ad hoc* historical data on harvested pup weights and sex ratios in some field notes.

16 (M). Estimates of male/female survival rates have been obtained from the age data for animals collected at sea. In the past, these data have been considered to provide biased estimates of survival rate because of under-representation of older animals at the shallower depths at which samples have been collected. The data should be examined further to confirm this.

Herman Oosthuizen and Robin Thompson are currently reviewing the age data for animals collected at sea. Their intended analysis disaggregates these data into three depth strata, and attempts to use sighting survey estimates of seal density within each of these strata for weighting purposes, so as to ascertain whether or not the original aggregated analysis might be expected to produce biased results (and if so, the direction of this bias).

17 (M). Fur seals are known to move between South Africa and Namibia. Sensitivity tests to examine the implications of the movement need to be developed.

An assessment model which models the whole stock (Namibia plus South Africa) will be developed in the near future as part of a BCLME initiative.