FORMAL REPORT:
BENEFIT / NRF / BCLME STOCK ASSESSMENT WORKSHOP
(6 – 11 DECEMBER 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 Midwater Trawling Association for agreeing to sponsor two social functions for participants. He noted that this year's meeting included a separate formal training component on the afternoons of 8 and 9 December.

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, in respect of the horse mackerel fisheries to be considered in detail, were:

i) to critically review data available for, and past assessments of, the horse mackerel resources of the Benguela Current region;
ii) to further develop these assessments during the Workshop; and
iii) to make prioritised recommendations for future research, having special regard for the possible trans-boundary nature of these resources.

The workshop was also to review progress on the assessment and OMP evaluations for the hake resources off South Africa and Namibia based on the recommendations made during the January 2004 BENEFIT/NRF/BCLME 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

Graca D'Almeida, Anabela Brandão, Carryn Cunningham, Susan Johnston, Carola Kirchner, Rob Leslie, Éva Plagányi, André Punt, Rébecca Rademeyer, Paul Starr and Filomena Vaz-Velho acted as rapporteurs with assistance from the Chair.

1.6 Computing arrangements

The Chair informed the attendees that there was the opportunity for additional computations during the workshop and that two of the external invited scientists (André Punt and Paul Starr) had stock assessment packages which could be applied 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 Angola, Namibia and South Africa, the scientific representatives of industry, and the external invited scientists.

2. REVIEW OF DOCUMENTS

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

3. HORSE MACKEREL

3.1 Background, catch history and geographic distribution

BEN/DEC04/HM/ALL/1a provided a view of the sector of the Industry in South Africa and Namibia that operates large dedicated midwater trawl vessels. It stressed the importance for stock assessments and the resulting management considerations of understanding horse mackerel behaviour and seasonal and spawning migrations (particularly those which straddle the continental shelf break), as well as escapement behaviour during targeted trawls used in stock assessments.

The workshop **recommended** that efforts be made to understand the influence of oceanographic changes on the spatial distribution and biomass of horse mackerel, including inter-annual fluctuations in biomass and the spread of age-classes in the populations. Consideration needs to be given to biases in CPUE data (both commercial and survey) because of changes in fleet strategies, depth limitations on commercial fisheries, catchability of survey trawls and inter- annual variation in the spatial distribution of the populations.

3.1.1 South Africa

BEN/DEC04/HM/SA/1a provided a historical background to the South African horse mackerel fishery and its management. The commercial fishery, which consists of a demersal fishery (predominantly on the South Coast) and a pelagic fishery (on the West Coast), started in 1950. Management of this fishery has been based on a number of modelling approaches, including a surplus production model based on a Japanese CPUE series for the 1980s, a Beverton-Holt yield-per-recruit type modelling approach and, in more recent years, an age-structured production model. The workshop **recommended** that a midwater CPUE index series should be developed.

3.1.2 Namibia

There is a spatial structure to the horse mackerel resource off Namibia and the associated fishing fleets. Horse mackerel appear to spawn south of 20°S and the pelagic fleet tends to concentrate its effort in this area, seeking juveniles. The midwater fleet is concentrated north of 20°S, primarily by regulation (this fleet is excluded from waters shallower than 200m) and because it prefers to target horse mackerel larger than 20cm, which are more abundant further north. The largest horse mackerel are found on the bottom south of 23°S where presently there is not a large fishery. The workshop **recommended** that the catch and length frequency data should be plotted spatially to pursue this issue further.

The fishery for horse mackerel off Namibia appears to respond to the seasonal migrations of the target species, which may be partially environmentally driven. The workshop noted that catches (and length frequency data) may have to be stratified by season if there is a seasonal structure to the length frequency data. It was noted that the Namibian horse mackerel fishery is not particularly profitable, and that this leads to fishing strategies that tend to discourage much exploration for higher catch rates and to favour a return to known areas of good fishing. This type of strategy minimises costs without substantially sacrificing catch rates**.**

The workshop noted that the large pelagic catch in 1971 (140 000t) may include misreported sardine catches because the sardine fishery was restricted from 1970 which is likely to have led to a high level of species mis-reporting during 1971. The data for years prior to 1991 are reported by ICSEAF (International Commission for the Southeast Atlantic Fisheries) statistical area (Divisions 1.3, 1.4 and 1.5 - 5° blocks from 15° S to 30° S). ICSEAF Divisions 1.3 and 1.5 straddle the international boundaries between Angola and Namibia and between Namibia and South Africa respectively. The workshop examined the spatial distribution of the catches of horse mackerel off southern Namibia and **agreed** that the impact on assessment results of some of the catches from ICSEAF Division 1.5 coming from South African waters is likely to be negligible.

3.1.3 Angola

BEN/DEC04/HM/AN/1a overviewed the fishery for horse mackerel off Angola. Two species of horse mackerel occur off Angola. The Cunene horse mackerel (*Trachurus trecae*) occurs over most of the Angolan continental shelf, while the Cape horse mackerel (*T. capensis*) is associated with the cold waters of the Benguela current and therefore is caught mainly in the south of Angola.

Acoustic estimates of biomass are available for horse mackerel off Angola for the period 1985-2004. However, these estimates are subject to uncertainty because on the acoustic transects carried out during the night sardinella are also detected , while in addition to horse mackerel, a variety of demersal fish are detected on the daytime acoustic transects. Maturity and length frequency data and length-age relationships are available from all surveys on a split-species basis. Length-frequency data from commercial catches are available for the central region of Angola (Luanda – Benguela) only. The workshop noted that coefficients of variation are not available for the survey estimates of abundance for Angolan horse mackerel, and **recommended** that efforts be made to obtain such estimates. It was noted that standard methods for estimating coefficients of variation cannot be applied in this instance given the design used for these surveys, and that a geostatistical approach may be worth pursuing.

The workshop noted that the catch data available at present are likely to be unreliable because of under-reporting. Furthermore, estimates of catches of horse mackerel for the years before 1984 include catches taken off the Democratic Republic of the Congo and Namibia.

3.2 Stock structure

BEN/DEC04/HM/ALL/2a summarised available information on genetic evidence for stock structure, and contained some references to other biological information. For South Africa, there is some slight evidence (different growth rates, minor morphological differences) in support of different West and South Coast stocks. However, the spatial distribution of fish of different sizes and molecular genetic information suggest a single South African stock. With regard to the relationship between Namibian and South African horse mackerel, molecular data suggest that *T. capensis* is a single genetic stock and that there may be more mixing between *T. capensis* and *T. trecae* than previously thought, but the sample size is very small.

The workshop **agreed** that the available data for *T. capensis* are consistent with the current working hypothesis that the horse mackerel off Namibia and South Africa are independent stocks, and can be assessed and managed as such. There is limited sharing of a *T. capensis* stock between Namibia and Angola.

In relation to South Africa, the most plausible hypothesis is that horse mackerel off the West and South Coasts constitute a single biological stock. Evidence for this is primarily biological, including that only one major spawning area has been identified. The workshop noted that horse mackerel most likely act like other pelagic species off South Africa, with the adults spawning on the Agulhas bank, larvae moving north in the Benguela current followed by juveniles returning southward along the West Coast, and then adults moving back on to the South Coast. There is no evidence to suggest that horse mackerel do not exhibit this pattern. Some older fish may move back to the West Coast. There may be value in conducting an assessment for the South Coast component of the population only, as the bulk of recent catches have been taken from this area, but it is not clear whether it is meaningful to conduct an assessment of the West Coast component of the population on its own.

BEN/DEC04/HM/ALL/2b examined whether there are one or two genetic stocks of the southern African population of *T. capensis*. mtDNA markers were examined for 37 horse mackerel collected along the southern African coastline (29 from South Africa and 8 from Namibia). The sample size was small and only two haplotypes were identified: a northern and a southern haplotype. However, the genetic differences between the haplotypes were at a species level rather than at the population level. Therefore BEN/DEC04/HM/ALL/2b assumed that the northern haplotype refers to *T. trecae* and the southern haplotype to *T. capensis*, and concluded that there was no evidence of genetic stock structure within *T. capensis*.

Although the authors hypothesised that the northern haplotype should refer to *T. trecae*, the workshop considered that there were alternative possible explanations for the differences in the samples in BEN/DEC04/HM/ALL/2b other than the possibility that *T. trecae* are found in substantial numbers off Namibia, including that the samples may have been contaminated or that there is a cryptic species of horse mackerel off Namibia.

Although BEN/DEC04/HM/ALL/2b did not find any evidence of geographic structure among the *T. capensis* samples, this does not contradict the working hypothesis of separate South African and Namibian stocks of *T. capensis* for assessment and management purposes. This is because the lack of genetic differences between samples is not sufficient to rule out the existence of multiple stocks. The existence of separate spawning areas in Namibia and South Africa suggests that there might be two stocks even though no genetic distinction has been identified.

The workshop noted that there is a proposal to BCLME to analyse additional genetics data for horse mackerel. The workshop **expressed support** for such a proposal and **recommended** that it should consider both mtDNA and microsatellite markers and be based on samples collected widely off South Africa, Namibia and Angola. The results of this project may shed light on the interpretation of the two mtDNA haplotypes identified from fish collected off Namibia, as reported in BEN/DEC04/NM/ALL/2a.

3.3 Further data for use in assessments

3.3.1 South Africa

BEN/DEC04/HM/SA/3a provided a summary of the biological information used in the assessment of South African horse mackerel, *viz.* the growth curve (length-at-age), length-weight relationship, weight-at-age, age-at-maturity and rate of natural mortality.

The basis for the values of the biological parameters listed in BEN/DEC04/HM/SA/3a is not adequately documented and appears inconsistent. Furthermore, the assumption of knife-edge maturity at age 3 differs substantially from the maturity-at-age vector estimated for Namibian horse mackerel (BEN/DEC04/HM/NA/3a). The workshop therefore **recommended** that a self-consistent database containing length, weight, age and maturity information should be established. The various biological functions and relationships could then be estimated in a self-consistent manner. The workshop noted however, that there is no ageing programme for the South African horse mackerel at present, although it is hoped that this will resume in 2005.

BEN/DEC04/HM/SA/1b described the data available for the South African horse mackerel resource. These data consist of catches, two series of abundance estimates based on demersal swept area surveys, and catch-at-age data for the period 1975-1988. The only reliable CPUE series is that from the Japanese demersal trawl fleet for the period 1976-87. This CPUE series ended when foreign vessels were excluded from South African waters. The workshop **recommended** that the length-frequency data from the South African midwater and demersal fleets and for the Japanese demersal fleet should be examined to determine whether it is necessary to model all three of these fleets separately.

The two abundance indices in BEN/DEC04/HM/SA/1b (“Survey 1” and “Survey 2”) are based on the same data to some extent so should not be included together in assessments. It was noted, however, that “Survey 2” did provide some way to place a lower bound on absolute biomass, although to do so it had needed to pool data for different areas and data collected at different times of the year. Section 3.4.1 discusses further how to treat the demersal trawl survey data in assessments. The workshop noted that the trawl gear on *F.R.S. Africana* was changed in June 2003 so that the swept area biomass estimates after June 2003 are not directly comparable to the earlier estimates.

BEN/DEC04/HM/SA/3b describes a study carried out in October 2004 during the South Coast demersal survey east of Mossel Bay in which renewed attempts were made to develop a combined acoustic/bottom trawl method of surveying horse mackerel on the South Coast. The main findings were that it is practical to survey the fish over the outer shelf acoustically at night, and that it may be possible to survey them acoustically on the inner shelf during the day as well, in between bottom trawls. An important observation was that the bottom trawl appears to be sampling horse mackerel off the bottom during retrieval of the net, which reduces the value of the bottom trawl estimates as absolute estimates of abundance. BEN/DEC04/HM/SA/3b also provides a proposal to develop a largely acoustic method for surveying horse mackerel on the South Coast.

BEN/DEC04/HM/SA/3c summarised attempts between 1991 and 1994 to assess horse mackerel abundance on the South Coast through a combination of bottom trawling and acoustic surveying, and the information on horse mackerel abundance on the West and South coasts that can be obtained from acoustic surveys in May and November. Recent acoustic work on horse mackerel from a commercial midwater trawler and from *F.R.S. Africana* during a South Coast demersal survey is discussed briefly, and information on size and position of catches in the midwater trawl fishery on the South-East Coast over the past two years is presented. BEN/DEC04/HM/SA/3c concluded that acoustic surveys, supported by acoustic and catch information from the commercial midwater trawlers operating there, offer the best and most cost-effective prospect for assessing horse mackerel abundance on the South Coast. The information on horse mackerel abundance from the pelagic surveys appears to be of little value, except possibly as an index of recruitment.

The workshop **recommended** that a study examining how horse mackerel react to trawl nets should be conducted to provide insight into what the demersal trawl surveys are actually surveying, - i.e. do these trawls catch horse mackerel primarily during hauling, for which there is recent evidence? If this is the case, it will lead to the estimates of absolute abundance derived from demersal trawl surveys being biased. The workshop **agreed** that although the trawl net used in the bottom trawl surveys may be catching horse mackerel off the bottom for much of the time, the catch rates could still provide a useful relative index of abundance.

The workshop **recommended** that work on developing combined acoustic and bottom trawl surveys for horse mackerel should continue. Specific issues that will require attention in this regard are: a) acoustic target identification methods; b) aggregating behaviour and vertical and horizontal migration patterns; c) trawl performance and the reaction of horse mackerel to the bottom trawl; and d) *in situ* estimation of horse mackerel target strength.

The workshop **agreed** that there were considerable benefits to collecting acoustic data from commercial midwater trawlers fishing for horse mackerel whose catches are sampled by onboard scientific observers. For example, these data could help to elucidate broad-scale migration patterns and provide information about aggregating and vertical migratory behaviour.

3.3.2 Namibia

BEN/DEC04/NM/NA/3b described the input data used for previous assessments of horse mackerel off Namibia. These data comprise commercial information from the midwater and pelagic/purse seine fleets and the results of acoustic surveys. Catch statistics from the period 1961–1990 for both commercial fleets were collected by ICSEAF, and may have been understated by the countries fishing during that period. All of the commercial data from 1991 onwards have been collected by the Ministry of Fisheries and Marine Resources (MFMR). The surveys used to estimate abundance between 1990 and 1998 were conducted mainly during the winter months with variable designs, coverages, vessels, gear, etc. The surveys from 1999 onwards were standardised and therefore only abundance estimates based on these surveys were used in the assessments reported in BEN/DEC04/HM/NA/4a.

The workshop noted that the conversion factor used to estimate nominal (green) weight from fish meal production in the pelagic fishery was changed from 5.556 to 4.25 in 1997 on the advice of industry. The workshop **recommended** that the conversion factor of 4.25 should be used from 1991 to the present for purposes of assessments. Although the basis for neither conversion factor was available to the workshop, the 4.25 value was favoured since it is more recent and is presumably based on better information.

Effort data are available from the recent (i.e. post-Independence) fishery. These data are available on a daily basis for the period 1991–96 and on a tow-by-tow basis from 1997 onwards. The workshop discussed whether the associated CPUE indices are a reliable measure of abundance, or whether they are rather measures of responses of the fleet to economic factors. For example, it may be the case that the fleet can maintain a high CPUE even as stock size declines because of the aggregating behaviour of horse mackerel. Alternatively, economic considerations, such as smaller bags and market demand for certain size ranges of product, may cause a reduction in CPUE even if abundance is unchanged.

The workshop **recommended** that a GLM approach should be used to calculate the CPUE indices for the recently-operating midwater fleet that are used in stock assessment models. The GLM should include an interaction between year and area. This interaction would be appropriate if fishing distribution has changed over time. The workshop noted that annual CPUE-based indices could be obtained from the GLM analysis by integrating across area, using the size of each area as the weight.

Several survey estimates of abundance are available for possible inclusion in assessments. The surveys from 1999 conducted from the research vessel *Welwitschia* are comparable. The survey estimates for the years before 1999 are problematic because there are differences over time in spatial coverage and in the time of the year that the surveys occurred. The workshop **recommended** that a summary should be made available for the surveys off Namibia of the areas and depths covered during each survey. The workshop **recommended** that GLM techniques should be used to provide estimates to "fill-in" area-depth strata for which data for some of the earlier surveys (particularly those conducted by the *R.V. Dr Fridtjof Nansen* since 1990) are missing, and hence construct a second index of abundance for use in assessments.

Length-frequency data for the surveys since 1994 and those for the midwater and pelagic fleets suggest that the existing surveys are indexing primarily fish aged 0 and 1 (Appendix 4), while the midwater fleet is catching much larger/older animals. This can be handled in a stock assessment model by:

a) assuming that the survey selectivity in the model is a dome-shaped function of length and age; or by
b) restricting the length-frequency data used in the assessment to lengths for fish aged 0 and 1 (i.e. making the survey into an index of newly recruited fish).

Possible reasons for the bias identified in Appendix 4 include the exclusion of the midwater fleet from waters inside 200 m and the possibility that the survey trawl gear may under-sample the larger horse mackerel (e.g. due to too-low a towing speed). The workshop **recommended** that further studies be conducted to examine how horse mackerel react to research trawl nets to establish the proportion-by-length of fish insonified in acoustic surveys which is captured in trawls made during these surveys.

BEN/DEC04/HM/NA/3a reported that the recent age data for Namibian horse mackerel were collected during two years (1996 and 2004). The 1996 data were generated during the 2003 BENEFIT otolith reading workshop (BENEFIT, 2003) using the "burn and slice" method. The 2004 data were generated from readings of unprepared otoliths. Von Bertalanffy growth functions were fitted to both years' data leading to estimates for $L_{\inf}$ and k of 44.4cm and 0.25yr^{-1} (1996) and 57.2cm and 0.11yr^{-1} (2004). A maturity ogive fitted to the 2004 age data showed an age-at-50% maturity of 1.6 yr. The 2004 length-at-age distributions (LAK) were used to estimate catch-at-age proportions for each year for which length frequency data were available for the midwater and pelagic fleets, as well as for the survey. Cohorts are clearly evident in the catch-at-age data based on the LAK method, unlike the case when the 1996 age-length key is applied to the length-frequency data for the period 1991-2004.

The surface reading method was used in 2004 because it is less expensive and the otolith readings are obtained much faster than from the "burn and slice" method. The workshop **recommended** that a comparison between these methods should be conducted. Such a workshop has already been held for South Africa and Angola (BENEFIT 2001).

BEN/DEC04/HM/NA/3a constructed age-compositions for the midwater and pelagic fisheries and for the surveys using two methods (by applying the 1996 age-length key and by using the LAK method of Clarke (1981). The workshop **agreed** that if age-composition data are required, it would be better to use the LAK method than to apply an age-length key for one year to the length-frequency data for several years (but see also Section 3.4.2). Nevertheless, the workshop noted that it remains preferable to fit population models to catch-at-length data for years for which ageing was not conducted.

The workshop compared growth curves based on length-age data collected during 1996 and those collected during 2004, and found that a single growth curve can be used to represent both data sets (Appendix 5). Data on length-at-age are also available for the period before Namibian Independence in 1990. The workshop **recommended** that an analysis similar to that in Appendix 5 should be conducted using length-age data from many years to evaluate further the extent to which growth rates vary over time, and hence the extent to which the assumption of time-invariant growth is likely to be violated.

It was noted that the length-at-maturity for Namibian horse mackerel had dropped from above 20cm to 16cm between 1996 and 2004. The workshop **recommended** that data on maturity-at-age and maturity-at-length should be examined quantitatively to determine whether there is evidence of changes in these quantities over time. If such changes are identified, it may be necessary to make maturity density-dependent in assessment models.

The workshop noted that estimates of the mass of fish taken by the pelagic fishery are available for the period 1971-2004. However, information on the length- (and age-) structure of these catches is available only from 1991. The workshop **recommended** that earlier ICSEAF data on the length structure of the pelagic catches should be obtained and incorporated in the assessment if available.

3.3.3 Angola

Data on historical catches and information on the split of the survey estimates of abundance among species are listed in Appendix 6. The workshop noted that the catches for the period 1973-1984 are for *T. trecae* and *T. capensis* combined. Catches by species, obtained by using the survey data to determine the proportion of the catch which is *T. trecae*, are available from 1985. The workshop **recommended** that information about the spatial distribution of the catch could be used to split the historical catch data to species (e.g. catches north of the Benguela-Cunene survey stratum are likely to have been *T. trecae* while catches within this stratum are likely to have consisted of both species). The catches from 1998 can be allocated to gear type. The workshop noted that there has been a large drop in effort since 1998 because of restrictions on the number of vessels that can operate in the fishery.

The workshop noted that the fishery for horse mackerel off Angola reflects a highly data-poor situation, and consequently **recommended** that continuing the survey programme be accorded the highest priority. Although it is a more difficult task, the workshop also **recommended** that every attempt should be made to obtain estimates of catch and samples of the length-frequency of the commercial landings. The workshop noted that some of the data required to improve assessments of horse mackerel off Angola could be collected by observers. The workshop **agreed** that the weakness of information on catches of horse mackerel off Angola compromises the reliability of assessment results, and that therefore improved data collection and further analyses are needed.

3.4 Review of existing assessments

3.4.1 South Africa

BEN/DEC04/HM/SA/4a summarised the assessment of the South African horse mackerel resource. This assessment is based on an age-structured production model which assumes that there is a single stock (West Coast plus South Coast) of horse mackerel off South Africa. It incorporates the historical catch data and fits to the two survey biomass series using a maximum likelihood approach. The model is deterministic, and estimates only one parameter (K^{sp} – the carrying capacity in terms of spawning biomass). Both h (the steepness of the stock-recruitment relationship) and q_2 (the catchability coefficient for Survey Series 2) are set externally. The implications of various combinations of h and q_2 are examined in BEN/DEC04/HM/SA/4a. The model was also used to project the resource ahead for the period 2002-2020 under several alternative scenarios regarding future demersal and pelagic catches. These projections suggested that sustainable catch levels were greater for a demersal fishery.

In discussion, it was noted that the selectivity pattern assumed for the years 1950-62 in BEN/DEC04/HM/SA/4a is inconsistent with the length-frequency and age-composition data in Geldenhuys (1973).

The workshop **recommended** that future assessments of the South African horse mackerel resource should be based on the following baseline assumptions/specifications (these assumptions may be modified once the results of initial analyses are available):

a) Include the following "fleets": the pelagic fishery prior to about 1969 when catches of large fish were recorded (the "early" pelagic fishery); the pelagic fishery after about 1969 when catches have consisted of small fish; the South

African demersal fishery off the West and South Coasts separately; the foreign fleet and the recent South African midwater fishery.

b) Fit to the bottom trawl survey indices of abundance for the West and South Coasts (treated as relative indices of abundance, possibly with a constraint on the two survey catchability coefficients so that they sum to less than one) and the Japanese CPUE series.
c) Fit to the length-frequency data for each of the fleets (to determine selectivity patterns and to estimate year-class strengths). Unlike in many other assessments based on the age-structured production model approach, it may be necessary to estimate the strengths of some of the year-classes spawned during the 1950s to be able to mimic the length-frequency data for the “early” pelagic fishery.
d) Estimate the selectivity ogives rather than pre-specifying them.
e) Set the rate of natural mortality equal to 0.4 yr^{-1} instead of 0.3 yr^{-1}.

The workshop identified the following sensitivity tests and **recommended** that they be conducted:

a) Set the rate of natural mortality equal to 0.5 yr^{-1}
b) Exclude the Japanese CPUE series.
c) Increase the rate of natural mortality for age 0 fish to 1.0 or 0.9 yr^{-1} (as considered appropriate for sardine and anchovy of this age). This sensitivity test is designed primarily to examine further the trade-off between catching horse mackerel using pelagic rather than midwater gear.
d) Replace the assumption of an age-at-maturity at age 3 by the maturity-at-age vector estimated for horse mackerel off Namibia.

3.4.2 Namibia

BEN/DEC04/HM/NA/4a assessed the horse mackerel stock off Namibia using a fleet-disaggregated age-structured production model. Trends in CPUE indices and in indices of biomass from acoustic surveys since 1989 as well as catch-at-age data were used to estimate current stock status. Results based on these data indicated that the stock is at a low level, below the Maximum Sustainable Yield Level (*MSYL*), and would not be able to support catches as high as the current level of some 350 000t until the stock is rebuilt to its *MSYL*.

BEN/DEC04/HM/NA/5a assessed the horse mackerel stock in ICSEAF Divisions 1.3, 1.4 and 1.5 using a fleet-disaggregated age-structured production model. CPUE and catch-at-age data for each fleet were used to estimate stock status in 1986. The results of this preliminary exercise were found to be clearly unrealistic.

The workshop specified additional assessment runs (see Appendices 7 and 8) based on the analyses presented in BEN/DEC04/HM/NA/4a and BEN/DEC04/HM/NA/5a for exploratory purposes. The baseline specifications for these assessment runs were:

a) Include all of the catch data from the period 1961-2004, split into six “fleets”: Namibia midwater, pelagic, Bulgaria, Poland, Romania, and USSR. There are some catches by fleets additional to these (e.g. South Africa). These catches are treated as having been caught using gear with a selectivity pattern the same as that of the Namibian fleet.

b) Set the catch by the pelagic fleet for 1971 to 14 000t.
c) Fit to the CPUE series for Namibia midwater, Bulgaria, Poland, Romania, and USSR as well as to the survey data for the period 1999-2004. Estimate the residual standard deviations for the CPUE series subject to the constraint that they are no larger than 0.2, and set the coefficients of variation for the survey indices equal to their sampling coefficients of variation.
d) Assume that M = 0.3 yr^{-1}, h = 0.6, and that the catchability coefficient for the survey data is 2 (purely for consistency with the baseline assumptions of BEN/DEC04/HM/NA/4a and BEN/DEC04/HM/NA/5a).
e) Set the extent of recruitment variability, σ_R, to 0.4.
f) Use the maturity-at-age data based on the samples collected during 2004.

Appendix 9 presents results for a variant of the assessments in Appendices 7 and 8 in which the model is fitted to the length-frequency data when length-frequency but not age-length keys are available. The results of the analyses in Appendix 9 are qualitatively quite similar to those in Appendices 7 and 8 (which are nearly identical), except in recent years. The workshop noted that the model in Appendix 9 at its present stage of development was unable to mimic the length-frequency data for the Namibian midwater fishery adequately. It was suggested that one way to resolve this problem might be to allow selectivity to depend on length rather than on age.

Following review of the results in Appendices 7 and 8 the workshop **recommended** that future assessments of horse mackerel in Namibia should be based on the approach in Appendix 9 (if it can be modified to resolve the problem associated with fitting to the length-frequency data for the Namibian midwater fishery) except that:

a) The revised growth curve in Appendix 10 should be used.
b) The pelagic catches for the period 1991-1996 should be replaced by values based on a conversion factor of 4.25.
c) The CPUE index for Poland should be ignored when fitting the model.
d) The CPUE series for the period 1973-1986 should be down-weighted relative to the Namibian midwater CPUE series and the survey index because these CPUE series overlap temporally (c.f. BEN/DEC04/HA/SA/4b).

The results in Appendix 8 remain preliminary, and considerable additional work may be required to obtain an assessment that is able to mimic all of the available information (e.g. the survey indices of abundance) satisfactorily. The workshop noted that the data available at present provide relatively little information about the value of the survey catchability coefficient. The workshop noted that the BENEFIT Survey Errors Workshop in 2001 (Anon, 2003) developed a prior for the survey catchability coefficient for acoustic surveys targeted at horse mackerel. The workshop **recommended** that such a prior should be included in the assessment of Namibian horse mackerel, noting that it will be necessary to account for the fact that the prior from the BENEFIT Workshop did not apply to survey catchability as it is defined in the assessments reported in Appendices 7 to 9.

The workshop **recommended** that the following sensitivity tests be conducted for the assessment of Namibian horse mackerel:

a) Ignore the recent CPUE series.
b) Ignore the historical CPUE series.
c) Include the survey estimates of abundance for the period 1994-1998, along with their length/age-composition information.
d) Vary the values assumed for M, h, σ_R and survey catchability.
e) Estimate the value for the survey catchability coefficient.

The workshop noted that further analysis may lead to some of the items currently listed as sensitivity tests becoming part of the "baseline" assessment specifications. It was also noted that choosing wider length bins when fitting the model would reduce the extent of auto-correlation in the residuals about the fit to the length-frequency data.

The workshop also **recommended** that the growth curve for Namibian horse mackerel should be revised by examining alternative parametric forms for the relationship between length and age, attempting to allow for ageing error, and by examining alternative relationships in the extent of variation in length-at-age with age.

The workshop discussed methods for determining appropriate sample sizes for, for example, age-length keys and length-frequencies. It **agreed** that the benefits of different sampling schemes (including different sample sizes and ranges of lengths when constructing age-length keys) could be evaluated by simulating the application of the assessment model to data sets constructed by randomly sampling data from the existing information. This approach has the advantage that the impact of other uncertainties (e.g. the precision of the survey indices of abundance) is taken into account when sampling schemes are evaluated.

3.4.3 Angola

Past assessments of horse mackerel off Angola have been conducted using the BioDyn package (Punt and Hilborn, 1996). The workshop developed a similar assessment based on the Schaefer observation-error production model. Results of this assessment are outlined in Appendix 11.

The results of the assessment in Appendix 11 are questionable primarily because the data do not contain enough information to estimate all of the parameters of the Schaefer model. In principle, this assessment could be improved by fixing the survey catchability (for example to 1) and the intrinsic rate of growth (for example, from values in FishBase), and by not interpolating species splits for years for which survey data are unavailable. However, given current uncertainty, the best way to provide management advice appears to be to estimate the current replacement yield. Appendix 12 provides an example of the calculation of current replacement yield and its associated uncertainty.

The workshop endorsed the approach in Appendix 12 and believed it to be a useful first step. The workshop **recommended** that this approach should be explored further as a possible basis for management advice. Possible areas of further investigation include examination of the sensitivity to the catch for 2001 and the period over which the model is applied, and of the implications for the estimation of replacement yield of the apparent decline in *T. trecae* over the period considered in Appendix 12.

3.6 Priorities for further research

BEN/DEC04/HM/SA/6b suggested two analysis initiatives related to the assessment and management of the South African horse mackerel resource. The first concerned the possibility of using indices of horse mackerel recruitment as a basis for varying the limit on catches of juvenile horse mackerel by the purse seine fleet. The second involved the use of an adaptive harvesting strategy as a basis for determining experimentally the extent to which the resource could support an increased midwater/demersal catch.

The workshop noted that a fisheries-independent method for determining whether incoming recruitment was good or not would be valuable when providing advice about the cap on the catch of juvenile horse mackerel by the pelagic fishery. Although the pelagic surveys have the potential to estimate year-class strength, such estimates would only become available in June, after most of the pelagic catch is already taken. A further requirement for using the results from the pelagic surveys as an index of recruitment is to check that the estimates of recruitment based on the pelagic surveys are consistent with the estimates of recruitment from the stock assessment. Unfortunately, the stock assessment appears to be unable to estimate recruitment reliably at present, precluding this type of comparison for the time being.

Horse mackerel may migrate in and out of areas in which the midwater trawlers are allowed to operate. It is important that CPUE indices of abundance are evaluated in a way that takes this into account (e.g. by appropriate spatial stratifications in GLM standardizations - see Section 3.3.2).

The workshop **agreed** that, given the relatively little information on horse mackerel off South Africa, the use of an adaptive harvest strategy is an appropriate way to substantially improve knowledge of the status and productivity of the resource in the short-to-medium term. This approach has been applied in Australia and New Zealand, although the changes in catch levels there, while small in an absolute sense, are large in percentage terms. The workshop **recommended** that Industry should be fully consulted if an adaptive harvest strategy is to be considered, particularly to determine desirable (and undesirable) levels of change in catch levels, given the expected benefits of “adaptive management”. The workshop noted that even though survey estimates are noisy, they probably provide the best basis for use in any adaptive harvest strategy.

Appendix 13 lists the prioritised research recommendations. In prioritising them, the workshop noted that several topics applied to horse mackerel in all three countries. These topics have been included in the “All” category.

4. HAKE

4.1 Progress on January 2004 Workshop recommendations

Appendix 14 (modified from BEN/DEC04/H/ALL/1a) summarises the recommendations arising from the January 2004 BENEFIT workshop regarding the South African and Namibian hake resources, and overviews progress against each recommendation.

The workshop noted that a workshop on hake ageing (BENEFIT, 2004) had been held since the January 2004 workshop, but that there had been little progress towards age validation for hake. The workshop stressed the importance of continuing to make progress on this issue. It noted that perceptions of stock status and productivity depend critically on the longevity of a species and that these would change substantially if the current approach to hake ageing is shown to be wrong. The workshop therefore **strongly recommended** that the issue of validating hake ageing be accorded a very high research priority.

4.2 Matters arising from presentation of progress report on BCLME project re socio-economic optimal harvesting strategies

Rashid Sumaila gave a presentation on the ongoing BCLME Hake Project: Socio-Economic Exploration of Harvesting Strategies, funded by the BCLME Programme. The main objective of the project is to "Explore the bio-socio-economics of hake trawl and longline fisheries in Namibia and South Africa, with the goal of assisting the resource managers in their attempts to achieve the best long-term ecological, economic and social outcomes for the fisheries". More specific questions include a) what are the current and potential contributions (in terms of income, added value, exports earnings, employment, etc.) of hake to the national and possibly regional economies of the two countries and b) what proportion of the above contributions come from trawled and longlined hake, respectively. With regards to the approaches to be applied, the project has three components, namely:

(i) database development: compiling an historic account of economic and social aspects of the hake trawl and longline fisheries;
(ii) socio-economic assessment: analyzing economic and social aspects of the hake trawl and longline fisheries using biological outputs from current models; and
(iii) bio-socio-economic modelling: developing analytical and computational bioeconomic models to study the hake fisheries.

These research components of the project are supported by workshops and a training session. The first workshop took place in Cape Town in May 2004. The second workshop and training session will take place in Swakopmund in early August 2005 (www.feru.org provides the latest information on this). The database and modelling frameworks are in an advanced stage of development, and considerable data have already been collected.

In discussion, the workshop highlighted the importance of considering uncertainty (in, for example, recruitment and the information available to fishers) associated with the conceptual model envisaged. It was pointed out that although a conceptual model that assumes perfect information and no recruitment variability is simpler for decision makers to use, results from such a model may be unrealistic.

4.3 Identified issues for further discussion re South African hake

4.3.1 Calibration of new trawl gear for surveys, and associated implications for OMP design

BEN/DEC04/H/SA/3a reported on the use of GLM methods to estimate calibration factors for the research vessel *F.R.S. Africana* with its new gear compared to the gear used previously. The calibration was effected through parallel trawls between *F.R.S. Africana* (with previously used gear) and *R.V. Dr Fridtjof Nansen,* and between *F.R.S. Africana* with new gear and *R.V. Dr Fridtjof Nansen*. The results suggest a calibration factor close to 1 for *Merluccius paradoxus*, but surprisingly of only some 0.6 for *M. capensis*. Attempts to better understand the reason underlying this last result by introducing depth, mean weight and depth-calibration factor interactions into the analysis failed to provide any obvious clarification

The results of BEN/DEC04/H/SA/3a suggest that *M. capensis* reacts very differently to the new net than *M. paradoxus*. The only clear differences between the two types of gear are the vertical opening of the net, which is approximately 2m higher for the new gear, and the type of foot rope. It is not clear how this could affect the catchability of *M. capensis* only. There is therefore no clear explanation as to why there should be a large difference in the efficiency of catching *M. capensis* between the two types of gear. The workshop **recommended** that until this issue is resolved, assessments of *M. capensis* should consider the ratio of catchability of the new to the previous *F.R.S. Africana* net to be below 1, but not as low as the ratio of 0.6 estimated from these calibration experiments.

4.3.2 Current assessment updates for each species

BEN/DEC04/H/SA/3b provided coast-wide updated assessments for each of the *M. capensis* and *M. paradoxus* resources, taking into account a number of the recommendations of the preceding January workshop. The assessments nevertheless remained separate for the two species, with a consequent inability to fit to some species-pooled data, and also with the species split of earlier catches effected external to the model and then used as inputs. From 1978, depth-based species-splitting algorithms based on information collected during research surveys could be used to make these splits (for CPUE as well as catch), since depth information was recorded from that time for commercial catches, but coarse assumptions had to be made for earlier periods. The results suggested a relatively stable *M. capensis* resource above its *MSYL*, but an *M. paradoxus* stock at a low level, and probably requiring catch reductions to ensure recovery towards *MSYL*.

The workshop considered whether the CPUE series are still being accorded too much weight compared to the survey series and **recommended** that sensitivity to increasing the lower bounds on the residual standard deviations for the CPUE series should be explored. The workshop also **recommended** that retrospective analyses should be included in future assessments.

The workshop discussed the fact that the estimated survey catchability coefficients for the South Coast are much larger than unity. It was suggested that this might be due to the fact that approximately 80% of the South Coast area is untrawlable (rocky grounds) compared to approximately 20% on the West Coast, and that hake may prefer trawlable areas even though it has been assumed, when estimating biomass from survey data, that the density on untrawlable grounds is the same as that on trawlable grounds. The workshop **recommended** that longline catch rates on rocky and smooth grounds should be compared to obtain some idea of the relative densities of hake on the two types of ground. It was noted that the apparently anomalous catchability coefficients for the South Coast trawl surveys might also be an artefact caused by errors in ageing (and hence in the estimate of natural mortality), or in the assumption that the historical CPUE series reflects the trend of both resources.

4.3.3 Planned methodology to refine assessments

BEN/DEC04/H/SA/3c detailed a framework for future assessments of the South African hake resource which fully incorporated the recommendations of the preceding January workshop. This involved a four spatial component model for each of the *Merluccius capensis* and *M. paradoxus* stocks, and a joint estimation procedure which provided a split of past catches by species, and allowed use of earlier species-aggregated data in the model fitting process. Incorporation of these features did however require an appreciable increase in model complexity. Specifications of the temporal and spatial details of the advocated structure had been based on consultations with biologists and industry.

The workshop endorsed the basic approach in BEN/DEC04/H/SA/3c, but noted that it is very complicated. The external scientists commented that similarly complicated models have been used as the basis for assessments elsewhere (e.g. school shark in Australia and hoki in New Zealand), but that it can take a substantial amount of time to fully develop and fit such models. They also noted that such models can potentially impose structural certainty on the assessment results and should be implemented with caution. The workshop noted that it was inappropriate to include complexity in analyses simply for the sake of increased “realism”, but that the level of complexity should be commensurate with the nature of the data available. It was noted that simplifications of the scheme outlined in BEN/DEC04/H/SA/3c may still lead to adequate fits to the data.

The workshop then discussed how to proceed given the need to provide management recommendations by mid-2005, including advice on the performance of OMPs. The workshop **agreed** that this deadline did not allow sufficient time to implement the approach of BEN/DEC04/H/SA/3c, although this approach should remain the long-term goal, in particular to address trans-boundary issues. Instead, variants of the approach of BEN/DEC04/H/SA/3b could be used provided a wide range of scenarios regarding the historical catches is tested; this approach might perhaps also be extended in the direction of the model of BEN/DEC04/H/SA/3c. This last (or similar) models could also be used to examine the question of the optimum choice of model complexity.

The workshop emphasised the need to move towards species-separate assessments because of the introduction of the longline fleet which differentially targets *M. capensis* compared to *M. paradoxus*. Although no species-specific OMPs have been developed to date, the workshop noted that in practice the only aspect of management advice which could be based on species-specific catch recommendations would be for the inshore trawl fleet on the South coast which targets *M. capensis* only. A sub-TAC for this fleet could increase or decrease depending on the recommended *M. capensis* catch. For the other fleets, a combined-species TAC would still have to be calculated.

4.4 Identified issues for further discussion re Namibian hake

See Section 4.1 and Appendix 14.

4.4.1 Comparison of CPUE and survey trends

BEN/DEC04/H/NA/4a conducted statistical tests for differences in slope between the hake survey total biomass time series and the standardised commercial CPUE indices over a range of post-Independence periods. The CPUE trend shows a lesser slope by an amount which stabilises at around some 10% p.a. as more years' data become available. This difference is statistically significant at the 1% level if the data are assumed to be uncorrelated. If serial correlation is taken into account, the difference is no longer statistically significant, but the distinctly higher correlation for the CPUE series would then suggest that this series should be down-weighted relative to the survey estimates in population model fits.

Appendix 15 reports additional results based on survey estimates of fishable biomass. The difference between the slopes for the CPUE indices and the survey data is no longer statistically significant at the 5% level (p = 0.07 when all the data are used).

An explanation for these differing results could be that the CPUE and survey data are indexing different components of the population. For example, the CPUE data represent density in waters deeper than 200 m, the fishable biomass includes fish (particularly *M. capensis*) in waters shallower than 200 m, while the total biomass includes the biomass of small fish in addition to the biomass of "fishable" animals.

BEN/DEC04/H/NA/4b reported updated assessments of the Namibian hake resource based on both catch-at-age and (for years for which no ageing was conducted) catch-at-length information, as recommended by the previous workshop. A notable feature of the results is the sensitivity of the results to the inclusion or otherwise of recent CPUE data. If such data are excluded, leaving surveys as the only index of recent abundance trends, the assessment suggests that the resource has been depleted to some 20% of its initial spawning biomass level, that it has been relatively stable over the past twenty years, and that the annual replacement yield is in the vicinity of 150 thousand tons. If the post-Independence CPUE data are included, this picture changes appreciably, indicating a steadily declining resource now at only 6% of its pristine spawning biomass level, with an annual replacement yield of as little as some 50 thousand tons. However, inclusion of a further time-series, based on some (as yet unchecked) industry information on the CPUE of seven vessels which fished both before and after Independence, indicates a resource well above its *MSY* level. A general feature of the results is an estimated natural mortality *M* above 0.6yr^{-1}, which seems unrealistically high, and also for all but the last of the cases mentioned, an unusually low estimate of steepness *h* (near 0.3).

The workshop considered the sensitivity of the assessment results to the inclusion of the seven-vessel CPUE series. It was noted that because this series was constructed from company data using daily production figures, these data may not be identical to those recorded in logbooks. The workshop **recommended** that, if possible, additional data for these seven vessels should be obtained and the series extended and compared formally with the GLM-standardised series. It also **recommended** that the logbook data for these vessels should be extracted and analysed to determine whether CPUEs, once standardised, are different from the GLM-standardised series. Finally, the workshop **recommended** that the logbook data should be examined for year/vessel interactions. The utility of CPUEs as an index of abundance will be diminished if year/vessel interactions are found to be statistically significant, or if the trend for the seven vessels since 1991 differs appreciably from that of the GLM-standardised series.

The workshop reiterated that the values estimated for some of the model parameters appear anomalous (e.g. natural mortality and the steepness of the stock-recruitment relationship). It was noted that assessments could be conducted fixing the values for some of these parameters using auxiliary information, and representing the results in the form of a decision table. However, it was noted that fixing some of the parameters could result in very poor fits to some of the data.

The workshop **recommended** that a sensitivity test based on starting the model in a more recent year (e.g. 1991) and applying it on a species-disaggregated basis should be used to examine the impact of assumptions related to the start of the fishery. The workshop noted that it is likely that the predominant species in the catch during the 1970s and early 1980s was *M. capensis*, while it is known that at present the predominant species is *M. paradoxus*. The current two-species model (BEN/DEC02/H/NA/4b) makes the implicit assumption that the ratio of the two species has not changed, but a long term shift in this proportion could lead to model misspecification problems and may be a source of some of the model-fitting problems described above.

4.4.2 Providing advice regarding the risks of alternative TAC decisions in circumstances of assessment uncertainty

The workshop did not have time to discuss this issue in detail, but noted that advice regarding alternative TAC levels could be provided by using decision tables as discussed during the Training Session.

4.4.3 Developing OMPs that allow for flexibility in management decisions

BEN/DEC04/H/NA/4c considered possible approaches for developing OMPs which output ranges rather than unique values for TACs. The core suggestion made was that flexibility in TAC decisions could be taken into account in simulation testing in a manner analogous to implementation error, which reflects that the catches that are eventually made may differ from the TACs set. A key requisite for this approach is reliable models of the manner in which TACs will vary from year to year about a "central level" output by the OMP. For example, a possible approach is a "block quota" system whereby, for example, a three year TAC is set, but with the proviso that in any one year the catch taken may not exceed, say, 40% of this TAC.

The workshop **agreed** that the approach outlined in BEN/DEC04/H/NA/4c provides a framework within which the issue of allowing for flexibility in management decisions within an OMP setting can be addressed. Decision makers need to be consulted to ensure that any simulations conducted adequately capture likely reality concerning the implementation of flexibility.**.**

4.4.4 The interpretation of *MSY* as a management objective

BEN/DEC04/H/NA/4d questioned the current appropriateness of *MSYL* as a target recovery level for the Namibian hake resource. Problems identified were: a) the sensitivity of estimates of the ratio of current biomass to *MSYL* to the inclusion or otherwise of various CPUE series in the assessment, b) the complexities that have had to be introduced into OMPs to attempt to refine estimates of an *MSYL*-related target as more data became available, and c) indications that the carrying capacity *K* for the resource might have decreased over recent decades. The suggestion was made that defining an increase of current abundance of, say, 20% as a surrogate *MSYL* for the time being might provide a pragmatic solution of these difficulties.

The workshop agreed that estimation of *MSYL* is problematic in many situations, particularly when the data are in conflict. It noted that many fisheries jurisdictions used *MSY* and *MSYL* when formulating management advice. However, it is not necessary to base advice related to the objectives of *MSY* and *MSYL* on the specific outputs from a stock assessment model. For example, it is clear for some resources that they are below *MSYL,* even though the extent to which they are below is not well quantified. In these circumstances, management measures that simply aim to increase abundance clearly still remain consistent with the objective of moving the resource towards the *MSYL*. It is also possible to adopt the biomass during a pre-specified period (e.g. when the fishery was stable and catches high) as a “proxy” for *MSYL*.

4.5 Priorities for further research

Appendix 13 lists the prioritised research recommendations for hake arising from the workshop.

5. OTHER

5.1 Weighting different data sets

The workshop noted that the weights assigned to the CPUE, survey and catch-at-age/ length data in the assessments conducted in southern Africa are generally determined by the fit of the model to the data set (i.e. data sets that are fitted best by the model are assigned the highest weight). Thus, data series (such as CPUE indices) which are smooth and are available for many years tend to get more weight than short and apparently noisy data series (such as survey estimates of abundance which should, if properly designed, provide unbiased estimates of trend and perhaps even absolute abundance).

In New Zealand and Australia it is common to pre-specify the relative weight assigned to the different data sources based on qualitative considerations of their relative reliability. The workshop highlighted the value of sensitivity tests which include only a subset of the data sources in the assessment to identify data sources that are in conflict (either providing results which are significantly different statistically, or which have appreciably different management implications). The workshop identified three distinct bases for weights:

a) Weights based on *a priori* considerations of the relative reliability of the different data sources. Such weights could be obtained by categorising each data set according to qualitative considerations (e.g. a well-designed survey should *a priori* be given greater weight than an unstandardised CPUE series) and choosing weights to conform with this categorisation. Down-weighting historical data is a means of forcing the model to better fit recent trends.
b) Weights based on diagnostics included in the model. For example, the weights assigned to each data series could be chosen so that the variance of the residuals is similar to that implied by the weights.
c) Weights based on “reality checks”. Reality checks could include checks on whether the estimates of the parameters of the model are realistic, and on whether the model is able to mimic recent trends adequately (which is likely to be important for making reliable predictions).

6. ADOPTION OF REPORT

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

7. COMMENTS BY INTERNATIONAL PANEL

Namibian hake

In addition to the comments and recommendations already contained in the report of the workshop, the external review panel also offered the following observations:The results on Namibian hake presented at the workshop, while based on a technically competent assessment, are of considerable concern. In particular, the conclusions about current levels of depletion, as well as sustainable yields, are extremely sensitive to the inclusion of two time series of commercial CPUE. It was also noted that some of the parameter estimates arising from these assessments are clearly unrealistic. This is not a satisfactory basis on which to provide management advice.

The panel recommends further stepwise exploration of the sensitivities of these assessments to all the data sets. In particular, an attempt should be made to identify model formulations that result in credible parameter values for steepness, natural mortality, and/or survey catchabilities. A major concern is that the ageing is incorrect. This could be explored by fitting to length data only, and estimating the growth parameters within the model. Another obvious concern is the potential bias arising from the use of species-aggregated data, particularly since there is some suggestion that the relative ratio of the two species has changed systematically over the period of assessment. A suggestion for interim progress is to undertake a species-disaggregated replacement yield (RY) analysis based on survey data. In the longer term, it is clear that a species-disaggregated approach is highly desirable. The possibility of a temporal change in productivity and/or carrying capacity was also raised in discussion. While this is worth exploring, it could be that this effect (if apparently real) is a consequence of the changing ratio of these two species over the assessment period.

Ageing hake

Given the importance of hake to the economies of the region, and particularly to Namibia, it cannot be stressed too strongly how important it is to validate the present ageing methodology for these species.

Progress in modelling in Namibia

The panel was pleased to note the considerable progress made by Namibian scientists in undertaking quantitative assessments for horse mackerel. It is important that Namibia continues to develop domestic capabilities in this area, which can be facilitated by continuing cooperation in the regional context. However, the panel stressed that the development of independent assessment capacity needs to occur in conjunction with a system of peer review at international standards.

Focus on training in these workshops

The panel noted with interest the discussion, following the Training Session of this workshop, on the strong training requirements needed in the region and the need for alternative approaches to training. It is clear that improved training, both in quantitative methods such as stock assessment, and in the ability to interpret and make use of such information, should be an on-going priority in the region. The experience gained from the December 2004 workshop suggests that it is possible to simultaneously achieve the objectives of critical technical review of research and modelling, while also helping to improve understanding at a more general level. In future, this might include an opening half day session that explains some of the basic concepts that will be covered during the technical review process, together with another half-day “hands on” session mid-way through the workshop along the lines of that conducted in this meeting.

8. CLOSURE

Thanks were recorded to the sponsors of the 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.

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Appendix 1 : Workshop attendees

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Reddell, Tim (Quayfish)
Somhlaba, Sobahle (UCT)

Appendix 2 : Agenda

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   - 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

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     - 3.1.1 South Africa
     - 3.1.2 Namibia
     - 3.1.3 Angola
   - 3.2 Stock structure
   - 3.3 Further data for use in assessments
     - 3.3.1 South Africa
     - 3.3.2 Namibia
     - 3.3.3 Angola
   - 3.4 Review of existing assessments
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4. HAKE
   - 4.1 Progress on January 2004 Workshop recommendations
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     - 4.3.1 Calibration of new trawl gear for surveys, and associated implications for OMP design
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     - 4.4.4 The interpretation of *MSY* as a management objective
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6. ADOPTION OF REPORT

7. COMMENTS BY INTERNATIONAL PANEL

8. CLOSURE

9. REFERENCES

Appendix 3 : List of documents

General

BEN/DEC04/GEN/1: Workshop Announcement
BEN/DEC04/GEN/2: Agenda and Programme
BEN/DEC04/GEN/3: List of Documents

Horse mackerel: General

BEN/DEC04/HM/ALL/1a: Midwater Trawl Industry contribution for tabling at the 2nd BENEFIT Horse Mackerel stock assessment workshop to be held 5th – 11th December 2004, UCT. (Midwater Trawl Industry).

BEN/DEC04/HM/ALL/2a: Summary of information on stock structure of the Cape horse mackerel. (Leslie).

BEN/DEC04/HM/ALL/2b: Lack of mitochondrial variability in southern African populations of the Cape horse mackerel, *Trachurus capensis* (L.). (Naish, Harley and Grant).

Horse mackerel: South African

BEN/DEC04/HM/SA/1a: Historical background to the South African horse mackerel fishery and its management. (Johnston, Butterworth and Leslie).

BEN/DEC04/HM/SA/1b: Current data available for the South African horse mackerel resource. (Johnston, Butterworth and Leslie).

BEN/DEC04/HM/SA/3a: Summary of biological information used in assessment of the South African horse mackerel. (Johnston and Butterworth).

BEN/DEC04/HM/SA/3b: Acoustic study of horse mackerel on Cape South Coast, October 2004. (Hampton).

BEN/DEC04/HM/SA/3c: Survey and commercial midwater trawl data of potential value in the assessment of horse mackerel biomass in South African waters. (Hampton, Coetzee and Japp).

BEN/DEC04/HM/SA/4a: The South African horse mackerel assessment using an age-structured production model, with future biomass projections. (Johnston and Butterworth).

BEN/DEC04/HM/SA/6a: A list of data which could be made available for future South African horse mackerel assessments. (Johnston and Butterworth).

BEN/DEC04/HM/SA/6b: Proposed assessment/management related analysis initiatives for the South African horse mackerel. (Butterworth).

Horse mackerel: Namibian

BEN/DEC04/HM/NA/3a: Age and growth data of the Namibian Horse Mackerel *Trachurus trachurus capensis*. (Wilhelm and Brinkman).

BEN/DEC04/HM/NA/3b: Horse mackerel commercial and survey data for stock assessment. (Kanandjembo).

BEN/DEC04/HM/NA/4a: A stock assessment of the Namibian horse mackerel (*Trachurus trachurus capensis*) based on an age-structured production model. (Kirchner, Kanandjembo, Namwandi, Wilhelm and D’Almeida).

BEN/DEC04/HM/NA/4b: Butterworth, D.S., G. Hughes and F. Strumpfer. 1990. VPA with *Ad Hoc* tuning: Implementation for disaggregated fleet data, variance estimation, and application to the Namibian stock of Cape horse mackerel *Trachurus trachurus capensis*. *S. Afr. J. mar. Sci*. 9: 327-357.

BEN/DEC04/HM/NA/5a: A stock assessment of horse mackerel (*Trachurus trachurus capensis*) for 1986 using an age-structured production model. (Kirchner).

Horse mackerel: Angolan

BEN/DEC04/HM/AN/1a: Summary of Cunene horse mackerel information from Angola. (Vaz-Velho, Luyeye and Barros).

Hake: General

BEN/DEC04/H/ALL/1a: BENEFIT/NRF/BCLME January 2004 Recommendations for Hake, with Comments and Progress made. (Butterworth, Rademeyer, Leslie and Kirchner).

Hake: South African

BEN/DEC04/H/SA/3a: Obtaining a multiplicative bias calibration factor between the *African*a with the old and the new trawl gear. (Brandao, Rademeyer and Butterworth).

BEN/DEC04/H/SA/3b: Revised assessments of the *Merluccius paradoxus* and *M. capensis* resources for the south and West Coasts combined. (Rademeyer and Butterworth).

BEN/DEC04/H/SA/3c: Update of the proposed model framework to form the basis for immediate future assessments of the South African hake resource. (Rademeyer and Butterworth).

Hake: Namibian

BEN/DEC04/H/NA/4a: Comparison of trend slopes for Namibian hake survey biomass and standardised commercial CPUE indices. (Brandao and Butterworth).

BEN/DEC04/H/NA/4b: Further updates of an assessment of the Namibian hake resource, including both catch-at-age and catch-at-length information. (Rademeyer and Butterworth).

BEN/DEC04/H/NA/4c: Possible approaches for developing OMPs which output ranges rather than unique values for TACs. (Butterworth).

BEN/DEC04/H/NA/4d: Is *MSYL* currently an appropriate target level for the Namibian hake resource? (Butterworth and Rademeyer).

Appendix 4 : Length-frequency Distributions for Namibian Horse Mackerel (1994-2004)

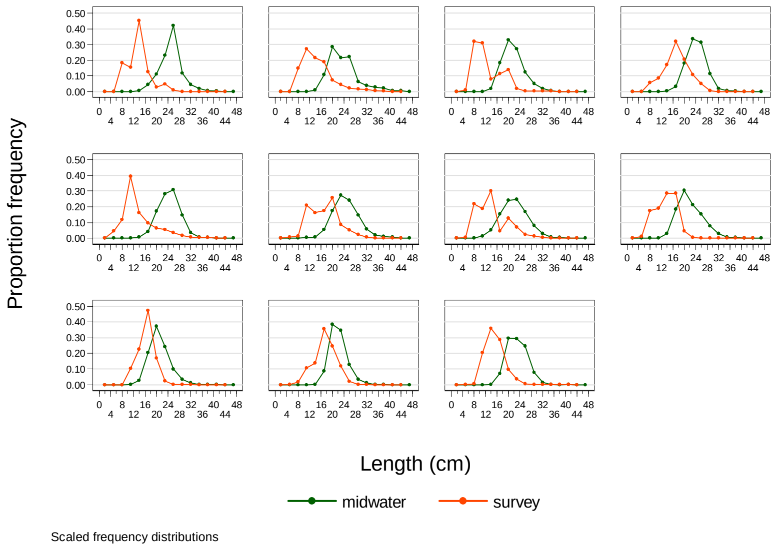


Figure 1. LF distributions for the midwater trawl and survey data from 1994 to 2004. One box per year (upper left is 1994).

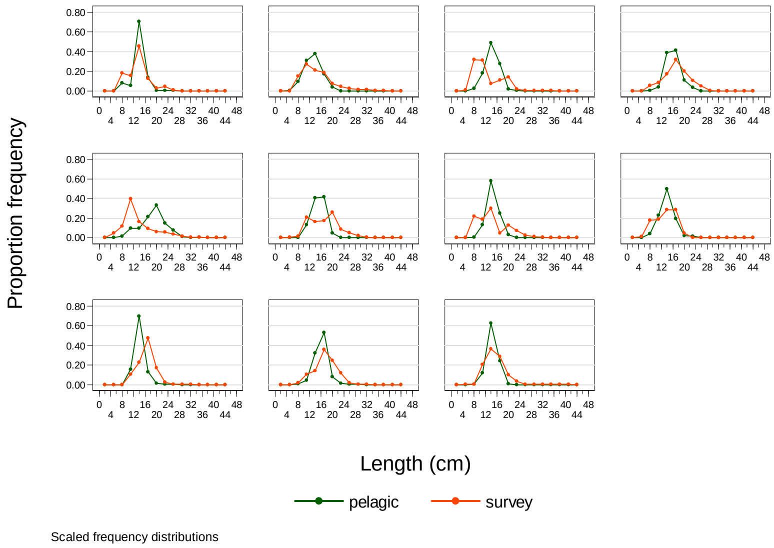


Figure 2. LF distributions for the pelagic and survey data from 1994 to 2004. One box per year (upper left is 1994).

Appendix 5 : Comparison of growth curves

Anabela Brandão

Model fitted:

$$length_a^{set} = a^{set} + b^{set}\left(\frac{age}{3}\right)^{c^{set}}$$

Hypothesis tested:

H_0: $a^{set} = a$; $b^{set} = b$; $c^{set} = c$
H1: $a^{set} = a$; $b^{set} = b$; c^{set},

where set = 1 is the Namibian growth data for 1996 and set = 2 is the Namibian growth data for 2004.

Table 1. Parameter estimates of growth curves under the two hypothesis and testing of hypothesis that the growth curves for the four sets of growth data are equal.

Parameter estimates	**H_0**	**H_1**
a	10.651	10.635
b	13.747	13.853
c^1	0.956	0.883
c^2	0.956	0.973
σ	0.164	0.164
-Log-likelihood	-1290.50	-1291.99
Log-likelihood ratio test		2.98
p-value		0.395

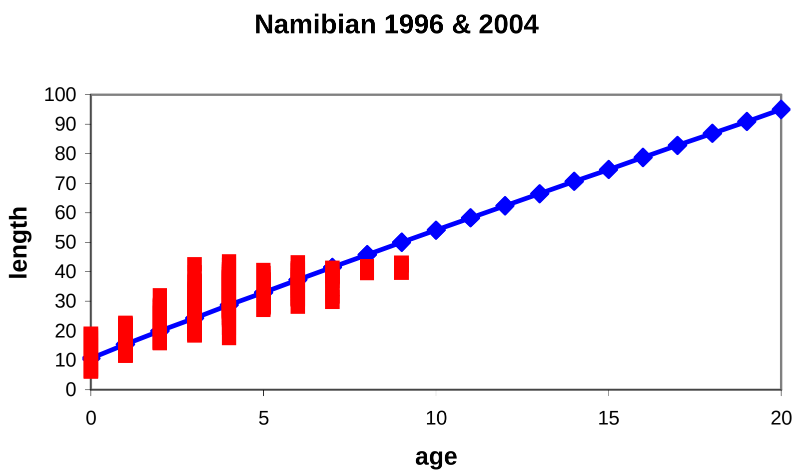
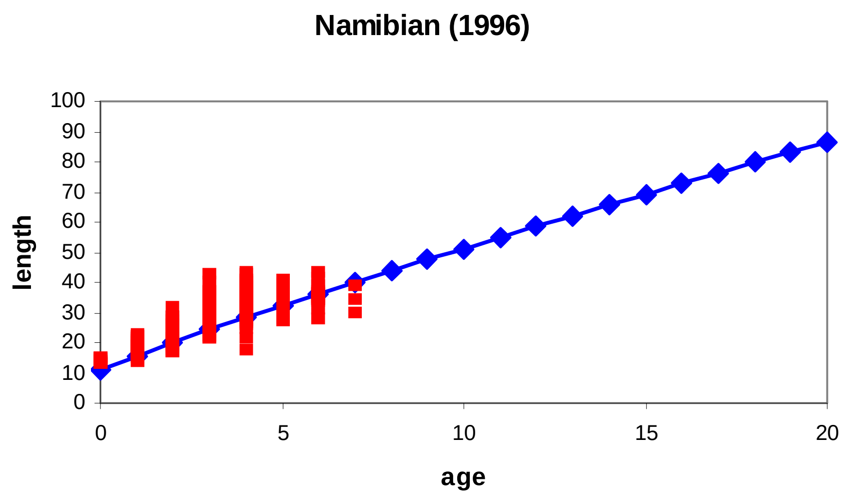


Figure 1. Growth curve fit under the hypothesis of equal growth curves for all sets of growth data.



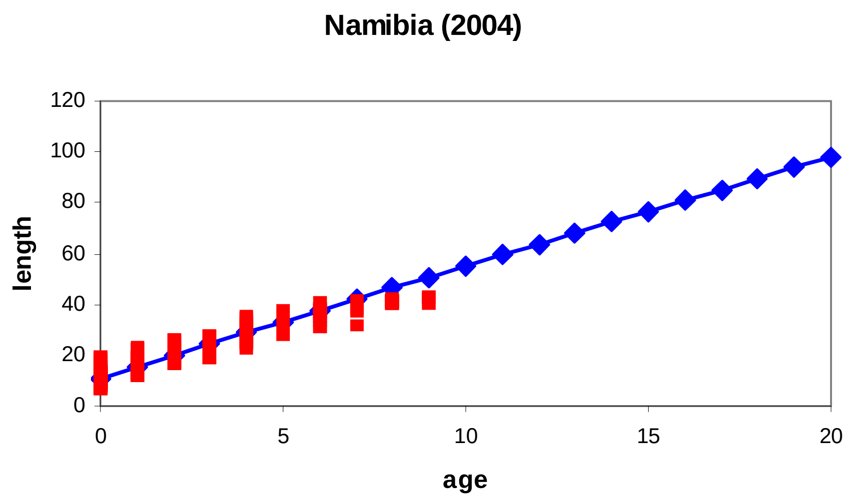


Figure 2. Growth curve fits under the hypothesis of different growth curves for the different sets of data.

Appendix 6 : Current data available for the Angolan horse mackerel resource

L. Henriette and G. Assunção

This document reports the data currently available for assessment purposes.

1. Catches

The FAO time series of the total catch comprising both the local and international fleet area available from 1973-1994. Although the catch provided by FAO are referred to as *T. trecae* comparison with local catch for 1993 and 1994 indicated that most likely correspond to carapau (i.e. both species combined). Therefore from 1984 the proportion of *T. capensis* in the area estimated by the surveys in the corresponding years (Table 5) was subtracted from the total catch provided by FAO to obtain the *T. trecae* catch. Purse-seine, mid-water and demersal catches were specified on a monthly basis from 1995 to 2004.

2. Length composition of the catches

Length frequency data are available from 1982 to 1997. The sample are taken per month and consisted of *T. trecae* (Table 2). The sample corresponds only to the central area (Luanda – Benguela).There is not full coverage of all months and the sample size seems too small, particularly in early years. Information on gear or position corresponding to the catch from which sample were taken is not available.

3. Surveys

Table 5 shows the surveys carried out for horse mackerel in Angola. There is a high variation in survey effort in terms of the day at sea, distance steamed and number of trawl stations. This is mainly due to the fact that the objectives varied between surveys and survey period.

Most of the pelagic surveys covered the shelf area from a depth of about 20 m along the shore out to the shelf edge at about 200m depth. Since 1996 the depth was expand to 500 m. From 1994 a distance from the coast of 20 nautical miles was kept in the northern region (between Cabinda and Ambriz) because of security reasons and important inshore areas could therefore not be surveyed. Furthermore, since 1995 the Cabinda has not been covered because of the extensive oil drilling activities in that region. Since 2000 the survey design was standardised to a systematic survey track with parallel longitudinal acoustic transect lines with 5 nm spacing between the lines were followed throughout the survey for the acoustic recording.

4. Length composition from the surveys

Length composition data are available for all surveys.

5. Maturity

Maturity data is collected in all the surveys following the Holden & Raitt (1974) reproductive scale. The length of maturity has been decrease from 21 cm in 1997 to 17 cm in the recent surveys.

Table 1: Landings of horse mackerel.

Year	Total catch	Purse-seine	Pelagic	Demersal
1973	191694			
1974	132994			
1975	128208			
1976	45723			
1977	252565			
1978	380150			
1979	297247			
1980	109665			
1981	142216			
1982	105072			
1983	109985			
1984	54923			
1985	29140			
1986	92453			
1987	77830			
1988	84854			
1989	84638			
1990	48710			
1991	33598			
1992	77212			
1993	63370			
1994	49944			
1995	52503			
1996	137766			
1997	154037			
1998	47761	5884	31315	10562
1999	38080	3072	27429	7579
2000	33511	7738	12832	12941
2001	120000	4456	105120	10424
2002	80358	6104	64843	9411
2003	60000	2267	52682	5050

Table 2. Length frequency information from commercial catches. The sample size refers to the number of fish measured in the year.

Year	Months	Sample size
1982	Jan-Jul	1135
1983	Jan,Apr,May,Jun,Jul, Oct	1875
1984	Jan, Apr,May,Jun, Oct, Dec	1682
1985	Jan,Mar,July, Sep	1822
1986	May	197
1987	Jan-Dec	6692
1988	Jan-Dec	3880
1989	Jan, feb,Sep, Oct, Dec	2227
1990	Feb-Dec	6745
1991	Jan,Feb, Sep,Oct,Dec	2477
1992	Jan, Apr,Jun,Aug, Dec	1840
1993	Mar, feb, Jun,Aug	3342
1994	Jan,Feb,Jun,Aug	2120
1995	Mar, Aug, Sep	805
1996	Jan,Aug,Sep	805
1997	Jan- Mar, May-Sep	3621

Table 4: Operational details of the Angolan surveys. Area 1: Benguela- Cunene; Area 2: Luanda- Benguela; Area 3: Cabinda – Luanda

Year	**Month**	**Type of survey**	**Area covered**
1-85	January-February	Acoustic/demersal	1-2-3
3-85	August-September	Acoustic/demerasl	1-2-3
3-86	March-April	Acoustic/demersal	1-2-3
1-89	February-March	Acoustic/demersal	1-2-3
2-89	April-May	Acoustic/demersal	1-2-3
1-91	May-June	Acoustic/demersal	1-2-3
2-95	August-September		1-2-3
1-96	February-April		1-2-3
1-97	March-April		
2-98	**August-September**		
2-99	**August-September**		
2-00	**August-September**		
2-01	**August-September**		
2-02	**July-August**		
2-03	**July-August**		
2-04	**July-August**		

Table 5: Survey estimation of the biomass for the two species of horse mackerel, corresponding to stratum Benguela- Cunene and total biomass of Cunene horse mackerel

Survey data	***T.capensis***	***T.trecae***	***Total trecae***	***ratio trecae/total***
l-85	170	30	435	0.61
3-85	220	50	400	0.45
4-85	270	70	515	0.48
1-86	40	130	285	0.86
1-89	125	35	255	0.51
2-89	135	25	380	0.64
4-89	240	170	440	0.45
1-91	310	100	510	0.39
3-95	63	68	403	0.84
1-96	0	286	506	1.00
3-96	42	98	360	0.88
1-97	23	210	427	0.95
2-98	129	141	254	0.49
2-99	128	124	321	0.60
2-00	242	92	333	0.27
2-01	187	64	89	
2-02	92	118	162	0.43
2-03	133	120	166	0.20
2-04	39	32	229	0.83

Appendix 7 : Revised Assessment of Horse mackerel off Namibia based on a Fleet-Disaggregated Age-Structured Production Model

Carola Kirchner and André E. Punt

1. Data used

Tables 1, 2 and 3 list respectively, the catch data (in mass), the CPUE and survey indices and the catch-at-age matrices. Note that in the absence of information about the age-structure of the catches by fleets other than Bulgaria, Poland, Romania, and the USSR and about the catches prior to 1973, the selectivity pattern for these catches has been assumed to be same as that for the recent midwater fishery in Namibia.

Table 4 lists the values assumed for weight-at-age (start and middle of the year) and for maturity-at-age.

2. Parameterisation and parameter estimation

Table 5 lists the parameters of the population dynamics model and the objective function and how each is treated in the analyses. Table 6 lists the plus- and minus-groups assumed when fitting to the catch-at-age data for the fishing fleets and the survey data.

3. Results

Figures 1 and 2 summarise the results of the assessment in terms of the estimated time-trajectories of spawner biomass (in absolute terms and relative to 1961), the recruitment residuals and the fit of the (assumed) stock-recruitment relationship to the data. The 95% confidence intervals shown in Figure 2 are based on an asymptotic approximation. Figure 3 shows the estimated selectivity patterns for the six fleets and for the survey indices.

Figures 4-6 summarise the ability of the model to mimic the survey indices and the CPUE series (Figure 3) and the catch-at-age data (Figures 5 and 6).

Table 7 and Figure 7 summarise the results of sensitivity tests in which the values for M, h and the catchability coefficient for the survey indices are modified from those in Table 5.

Table 1. The catch data (in ‘000 tons).

Year	Fleet					
	Namibia+ Other	Pelagic	Bulgaria	Poland	Romania	USSR
1961	47	0	0	0	0	0
1962	23	0	0	0	0	0
1963	21	0	0	0	0	0
1964	71	0	0	0	0	0
1965	126	0	0	0	0	0
1966	100	0	0	0	0	0
1967	72	0	0	0	0	0
1968	69	0	0	0	0	0
1969	47	0	0	0	0	0
1970	51	0	0	0	0	0
1971	77	14	0	0	0	0
1972	51	22	0	0	0	0
1973	43.6	12	0	8.5	0	197.9
1974	34.5	31	0	9.7	0	109.8
1975	49.2	14	0	27.4	0	178.4
1976	45.6	24	0	42.2	0	396.2
1977	63.6	82	0	42.1	0	175.3
1978	116.5	10	0	122.6	27.2	271.7
1979	88	33	0	82	67.3	150.7
1980	64.7	39	18.6	69.5	31.8	322.4
1981	27.3	4	37.3	118.8	40.2	362.4
1982	44.6	68	48.4	94.7	74.7	329.6
1983	100.1	107	51.2	108.3	116.2	117.2
1984	91.1	88	50.5	76.1	107.8	193.5
1985	73.1	22	42.8	36.1	69.4	216.6
1986	86	84	48.5	14.5	97.6	169.4
1987	514	34	0	0	0	0
1988	393	17	0	0	0	0
1989	381	32	0	0	0	0
1990	342	85	0	0	0	0
1991	351	83	0	0	0	0
1992	310	116	0	0	0	0
1993	401	74	0	0	0	0
1994	331	33	0	0	0	0
1995	259	51	0	0	0	0
1996	229	91	0	0	0	0
1997	212	88	0	0	0	0
1998	286	25	0	0	0	0
1999	294	27	0	0	0	0
2000	336	21	0	0	0	0
2001	301	23	0	0	0	0
2002	299	61	0	0	0	0
2003	317	52	0	0	0	0
2004	320	41	0	0	0	0

Table 2. The CPUE series and the survey indices of abundance (with CV in parenthesis).

Year	CPUEs					Survey
	Namibia	Bulgaria	Poland	Romania	USSR	Indices
1973	0	0	1.574	0	40.396	0
1974	0	0	1.448	0	80.854	0
1975	0	0	3.806	0	33.111	0
1976	0	0	3.103	0	35.71	0
1977	0	0	3.479	0	36.04	0
1978	0	0	8.884	1.863	38.165	0
1979	0	0	8.039	5.752	35.459	0
1980	0	1.755	5.43	2.052	24.343	0
1981	0	4.388	9.354	2.173	25.66	0
1982	0	5.042	6.764	5.116	25.817	0
1983	0	3.657	7.963	8.42	17.836	0
1984	0	4.106	5.397	5.765	15.289	0
1985	0	5.487	2.888	3.792	19.826	0
1986	0	4.949	1.007	7.284	45.089	0
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0
1989	0	0	0	0	0	0
1990	4.07	0	0	0	0	0
1991	7.75	0	0	0	0	0
1992	8.24	0	0	0	0	0
1993	8.24	0	0	0	0	0
1994	7.16	0	0	0	0	0
1995	5.65	0	0	0	0	0
1996	5.3	0	0	0	0	0
1997	5.43	0	0	0	0	0
1998	5.86	0	0	0	0	0
1999	5.83	0	0	0	0	1808 (0.24)
2000	5.08	0	0	0	0	1473 (0.3)
2001	4.83	0	0	0	0	861 (0.21)
2002	5.02	0	0	0	0	803 (0.35)
2003	5.65	0	0	0	0	1059 (0.18)
2004	4.92	0	0	0	0	1375 (0.14)

Table 3. The catch-at-age data (proportion-at-age for each year).

Year	Age							
	0	1	2	3	4	5	6	7+
Namibia								
1991	0.000	0.000	0.040	0.800	0.140	0.020	0.000	0.000
1992	0.000	0.020	0.010	0.120	0.750	0.090	0.000	0.000
1993	0.000	0.000	0.010	0.190	0.770	0.030	0.000	0.000
1994	0.000	0.040	0.040	0.300	0.580	0.040	0.000	0.000
1995	0.000	0.020	0.340	0.290	0.290	0.050	0.000	0.000
1996	0.000	0.060	0.400	0.400	0.120	0.020	0.000	0.000
1997	0.000	0.020	0.010	0.560	0.400	0.010	0.000	0.000
1998	0.000	0.040	0.070	0.440	0.450	0.010	0.000	0.000
1999	0.000	0.050	0.090	0.420	0.360	0.080	0.000	0.000
2000	0.000	0.140	0.270	0.350	0.220	0.020	0.000	0.000
2001	0.000	0.090	0.420	0.260	0.200	0.030	0.000	0.000
2002	0.000	0.080	0.490	0.340	0.070	0.020	0.000	0.000
2003	0.000	0.010	0.310	0.600	0.060	0.020	0.000	0.000
2004	0.000	0.050	0.370	0.380	0.120	0.080	0.000	0.000
Pelagic								
1991	0.010	0.386	0.601	0.003	0.000	0.000	0.000	0.000
1992	0.030	0.412	0.149	0.409	0.000	0.000	0.000	0.000
1993	0.392	0.458	0.090	0.060	0.000	0.000	0.000	0.000
1994	0.008	0.992	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.331	0.657	0.013	0.000	0.000	0.000	0.000	0.000
1996	0.069	0.921	0.000	0.009	0.000	0.000	0.000	0.000
1997	0.010	0.736	0.224	0.030	0.000	0.000	0.000	0.000
1998	0.077	0.196	0.470	0.258	0.000	0.000	0.000	0.000
1999	0.050	0.865	0.085	0.000	0.000	0.000	0.000	0.000
2000	0.050	0.880	0.070	0.000	0.000	0.000	0.000	0.000
2001	0.126	0.873	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.000	0.729	0.270	0.000	0.000	0.000	0.000	0.000
2004	0.111	0.792	0.094	0.003	0.000	0.000	0.000	0.000
Bulgaria								
1980	0.000	0.227	0.663	0.073	0.020	0.005	0.005	0.006
1981	0.003	0.003	0.458	0.473	0.052	0.007	0.001	0.001
1982	0.000	0.079	0.797	0.102	0.016	0.005	0.000	0.000
1983	0.000	0.077	0.522	0.290	0.092	0.014	0.003	0.001
1984	0.000	0.073	0.571	0.229	0.082	0.034	0.009	0.002
1985	0.000	0.293	0.554	0.128	0.022	0.002	0.001	0.000
1986	0.000	0.085	0.502	0.343	0.055	0.013	0.001	0.000

(Table 3 Continued)

Year	Age							
	0	1	2	3	4	5	6	7+
Poland								
1973	0.000	0.026	0.434	0.159	0.138	0.144	0.066	0.033
1974	0.000	0.006	0.039	0.033	0.055	0.188	0.177	0.503
1975	0.000	0.027	0.128	0.375	0.290	0.136	0.027	0.018
1976	0.000	0.046	0.090	0.322	0.265	0.184	0.065	0.027
1977	0.000	0.029	0.262	0.139	0.248	0.125	0.106	0.092
1978	0.000	0.005	0.084	0.123	0.261	0.140	0.197	0.189
1979	0.001	0.277	0.274	0.393	0.042	0.005	0.002	0.007
1980	0.000	0.000	0.066	0.199	0.249	0.256	0.170	0.060
1981	0.000	0.001	0.073	0.355	0.484	0.082	0.004	0.000
1982	0.000	0.000	0.063	0.484	0.366	0.080	0.006	0.000
1983	0.000	0.004	0.236	0.393	0.290	0.070	0.005	0.001
1984	0.001	0.037	0.117	0.320	0.394	0.127	0.004	0.000
1985	0.000	0.132	0.330	0.226	0.157	0.105	0.043	0.006
1986	0.001	0.079	0.492	0.317	0.079	0.024	0.004	0.004
Romania								
1978	0.000	0.128	0.246	0.437	0.150	0.029	0.009	0.001
1979	0.004	0.288	0.427	0.244	0.032	0.004	0.001	0.001
1980	0.001	0.194	0.423	0.246	0.099	0.026	0.008	0.003
1981	0.013	0.139	0.468	0.239	0.105	0.029	0.005	0.002
1982	0.007	0.094	0.458	0.295	0.123	0.018	0.004	0.003
1983	0.008	0.106	0.365	0.294	0.151	0.063	0.010	0.004
1984	0.003	0.070	0.276	0.242	0.207	0.122	0.058	0.022
1985	0.004	0.292	0.452	0.169	0.054	0.019	0.008	0.001
1986	0.003	0.085	0.581	0.242	0.058	0.024	0.004	0.003
USSR								
1973	0.000	0.010	0.092	0.312	0.250	0.182	0.051	0.103
1974	0.000	0.066	0.059	0.441	0.237	0.069	0.042	0.085
1975	0.000	0.011	0.050	0.428	0.340	0.091	0.025	0.055
1976	0.000	0.035	0.010	0.218	0.472	0.165	0.040	0.060
1977	0.002	0.066	0.205	0.306	0.276	0.125	0.005	0.016
1978	0.000	0.121	0.170	0.278	0.228	0.115	0.051	0.038
1979	0.003	0.135	0.233	0.224	0.199	0.104	0.047	0.056
1980	0.001	0.078	0.172	0.303	0.249	0.111	0.049	0.036
1981	0.000	0.012	0.174	0.424	0.280	0.065	0.014	0.032
1982	0.000	0.005	0.093	0.493	0.292	0.064	0.031	0.022
1983	0.000	0.016	0.105	0.423	0.314	0.119	0.016	0.008
1984	0.004	0.041	0.135	0.327	0.332	0.099	0.021	0.041
1985	0.000	0.095	0.396	0.209	0.197	0.069	0.019	0.014
1986	0.000	0.005	0.160	0.477	0.258	0.069	0.023	0.008
1999	0.197	0.305	0.364	0.135	0.000	0.000	0.000	0.000
2000	0.371	0.376	0.045	0.208	0.000	0.000	0.000	0.000
2001	0.335	0.529	0.136	0.000	0.000	0.000	0.000	0.000
2002	0.000	0.602	0.398	0.000	0.000	0.000	0.000	0.000
2003	0.030	0.398	0.474	0.097	0.000	0.000	0.000	0.000
2004	0.086	0.747	0.135	0.032	0.000	0.000	0.000	0.000

Table 4. Maturity-at-age proportion and weight-at-age (gm)

	Age (yr)							
	0	1	2	3	4	5	6	7+
Maturity	0	0.196	0.733	0.969	0.997	1.000	1.000	1.000
W-start	7	34	57	151	136	313	218	473
W-mid	15	53	114	189	271	355	435	510

Table 5. The parameters of the population dynamics model (λ is selectivity slope).

Parameter	**Value**
Population dynamics model	
Virgin Biomass	Estimated
Natural mortality	$0.3 yr^{-1}$
Steepness	0.6
Selectivity parameters	
$S_1, S_2, S_3, S_4, S_{5+}$ (Namibia, Bulgaria, Poland, Romania, USSR)[1]	Estimated
$S_{0,} S_1, S_2, \lambda$ (Pelagic)	Estimated
Recruitment residuals (1969-2004)	Estimated
Objective function	
Extent of recruitment variation, σ_R	0.4
Catchability coefficients (CPUE indices)	Estimated
Catchability coefficient (survey indices)	2
Residual variation (CPUE indices)	Estimated (lower bound 0.2)
$S_{0,} S_1, S_2, \lambda$ (Survey indices)	Estimated

[1] S_0=0 for these fleets.

Table 6. Specifications for the plus and minus groups when fitting the catch-at-age data.

Fleet	Minus-group	Plus-group
CPUE indices		
Namibia	1	5
Pelagic	0	3
Bulgaria	1	5
Poland	1	5
Romania	1	5
USSR	1	5
Survey indices	0	3

Table 7. Stock assessment results using various combinations of the parameters *M*, *h* and *q*-survey. Maximum sustainable yield (*MSY*) for the midwater fleet, current depletion, current biomass in thousand tons and the negative log-likelihood are tabulated.

q=2 M=0.4	*MSY*	$B^{sp}_{2005}/B^{sp}_{1961}$	B_{2005}	-lnL
h=0.4	484	0.23	1425	-54.75
h=0.6	541	0.28	1386	-56.33
h=0.8	627	0.34	1497	-56.67
q=2 M=0.3				
h=0.4	439	0.25	2056	-55.46
h=0.6	504	0.3	1901	-57
h=0.8	572	0.35	2006	-57.6
q=2 M=0.5				
h=0.4	579	0.22	1176	-52.77
h=0.6	594	0.28	1202	-54.02
h=0.8	690	0.34	1318	-53.96
q=1.5 M=0.4				
h=0.4	497	0.29	1881	-56.07
h=0.6	583	0.37	1887	-57.65
h=0.8	693	0.42	2001	-58.34
q=1.5 M=0.3				
h=0.4	450	0.32	2821	-56
h=0.6	535	0.39	2722	-57.47
h=0.8	627	0.44	2772	-58.27
q=1.5 M=0.5				
h=0.4	534	0.27	1490	-55.16
h=0.6	632	0.39	1738	-57.15
h=0.8	748	0.45	1848	-57.72
q=1 M=0.4				
h=0.4	541	0.4	2912	-56.64
h=0.6	682	0.49	2900	-58.33
h=0.8	831	0.54	2902	-59.25
q=1 M=0.3				
h=0.4	489	0.45	4568	-55.92
h=0.6	615	0.53	4373	-57.33
h=0.8	744	0.56	4248	-58.14
q=1 M=0.5				
h=0.4	585	0.4	2355	-56.9
h=0.6	742	0.5	2455	-58.64
h=0.8	900	0.55	2515	-59.52
additional runs				
h=0.75, M=0.3				
q=2	552	0.34	1977	-57.47
h=0.6, M=0.4				
q=2	541	0.28	1387	-56.33
h=0.6, M=0.3				
q estimated	742	0.44	3168	-57.51

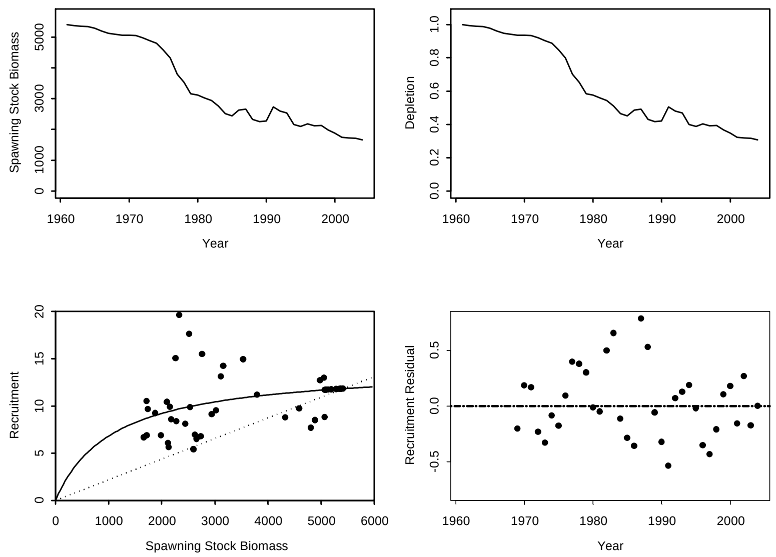


Figure 1. Time-trajectories of spawner biomass (in absolute terms and relative to that in 1961), the fit of the stock-recruitment relationship, and the time-series of recruitment residuals.

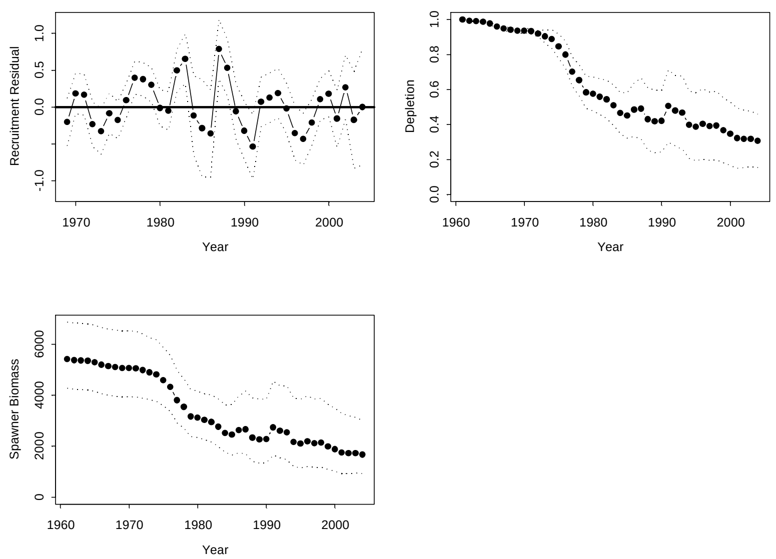


Figure 2. Time-trajectories (with asymptotic 95% confidence intervals) for the recruitment residuals, spawner biomass relative to that in 1961, and spawner biomass in absolute terms.

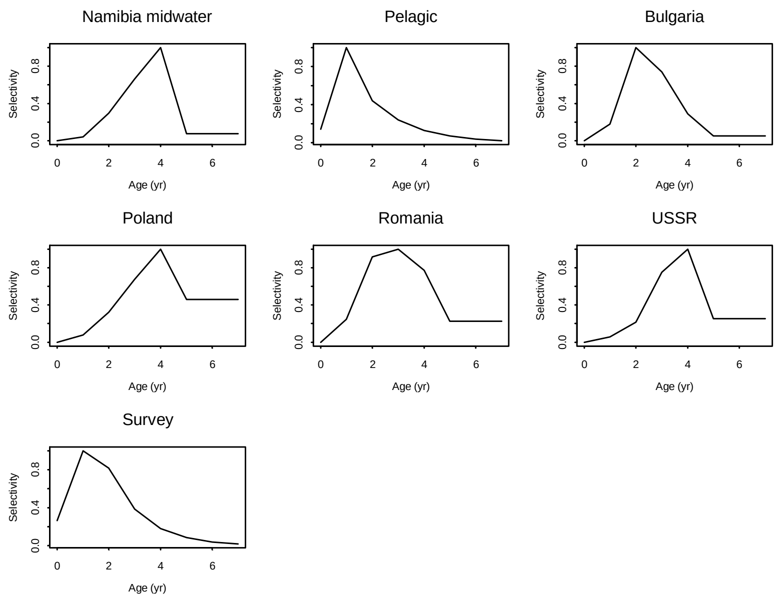


Figure 3. Selectivity as a function of age for the six fleets and for the survey indices.

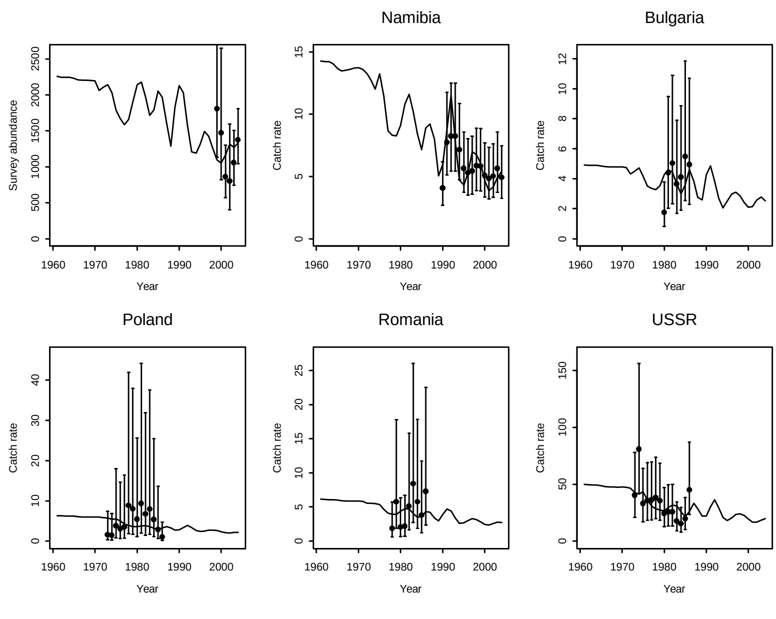


Figure 4. Fits to the survey data and the CPUE series for five of the six fleets. The vertical bars for the CPUE series denote 95% confidence intervals for the data based on the estimated residual standard deviations.

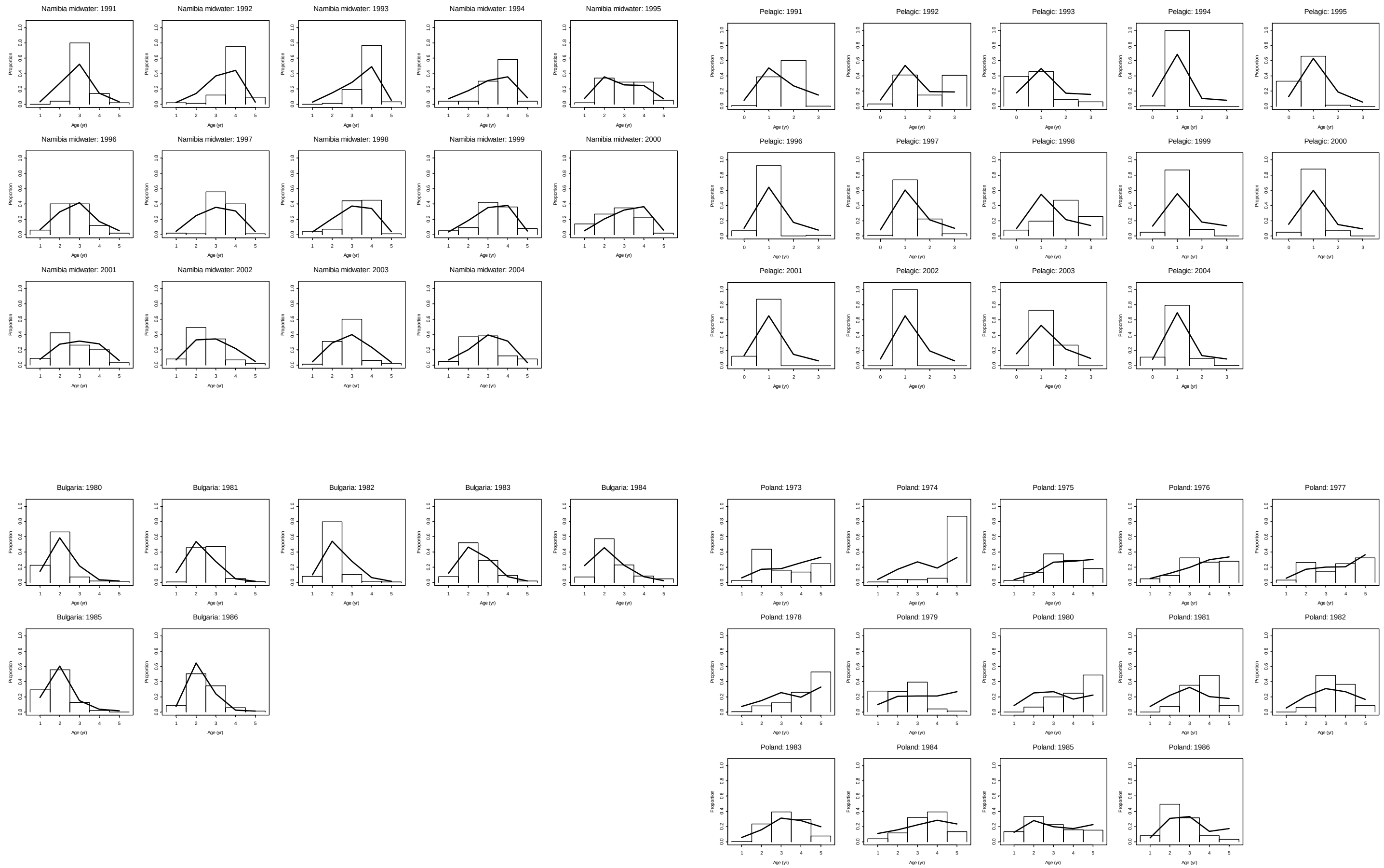
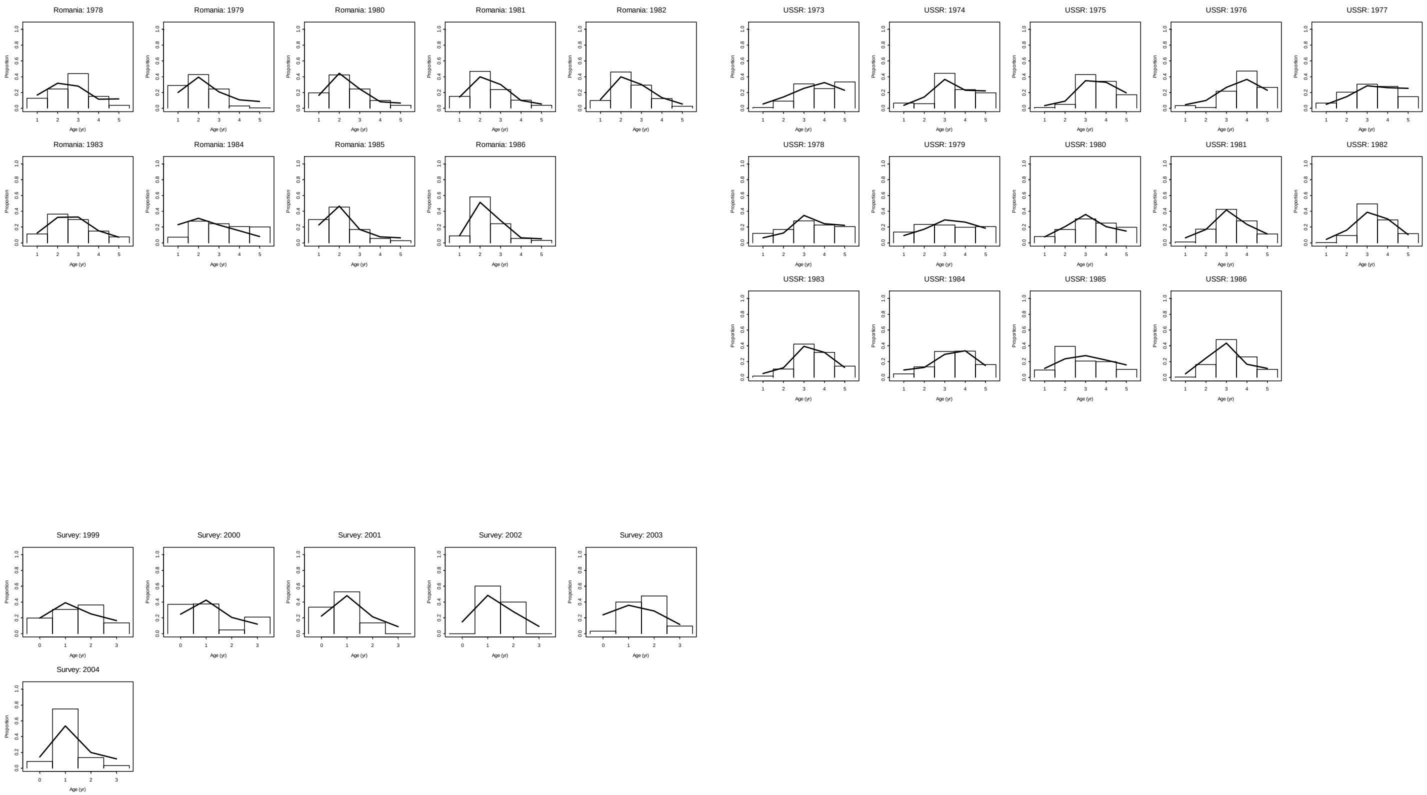


Figure 5. Fits to the catch-at-age data for the six fleets and to those for the survey indices.

(Figure 5 Continued)



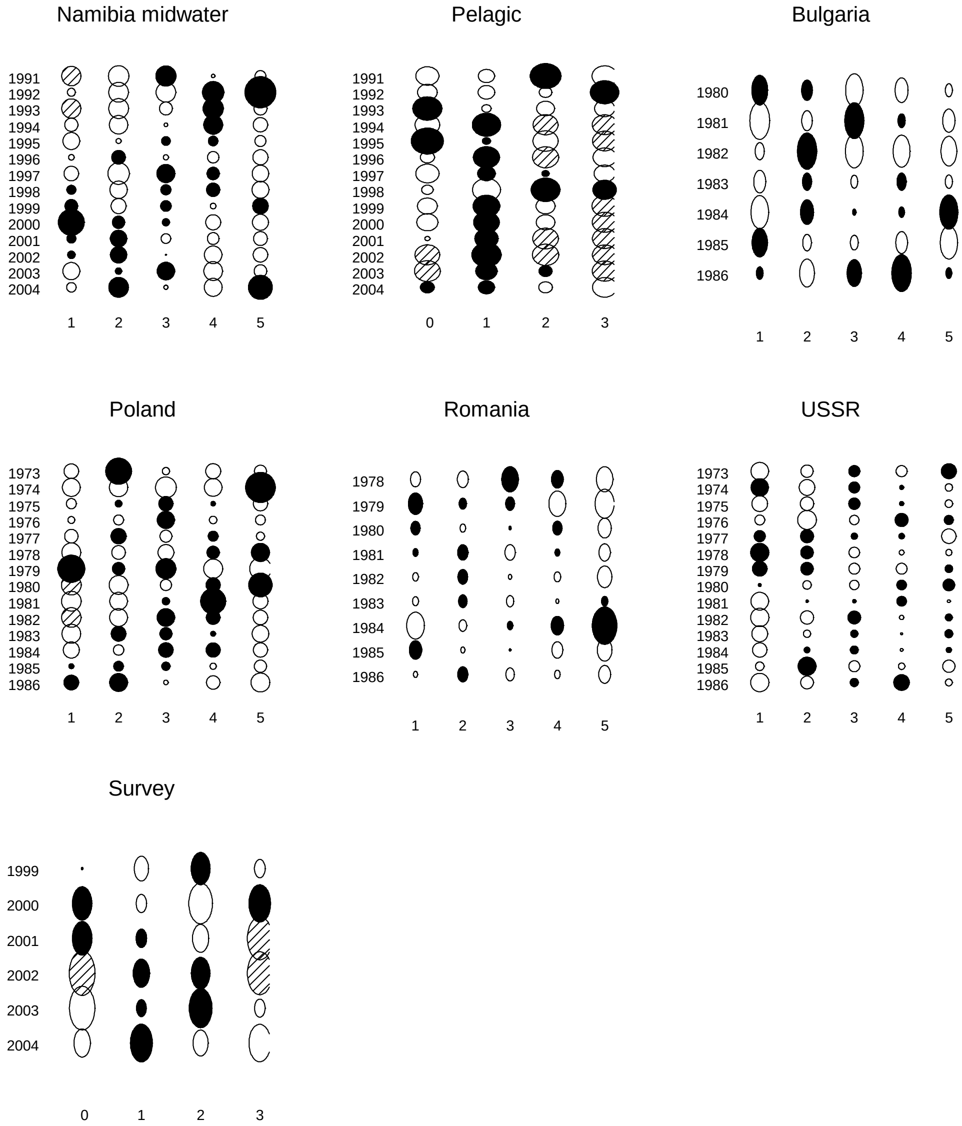


Figure 6. Bubble plots summarising the fits to the catch-at-age data for the six fleets and those to the catch-at-age data for survey indices.

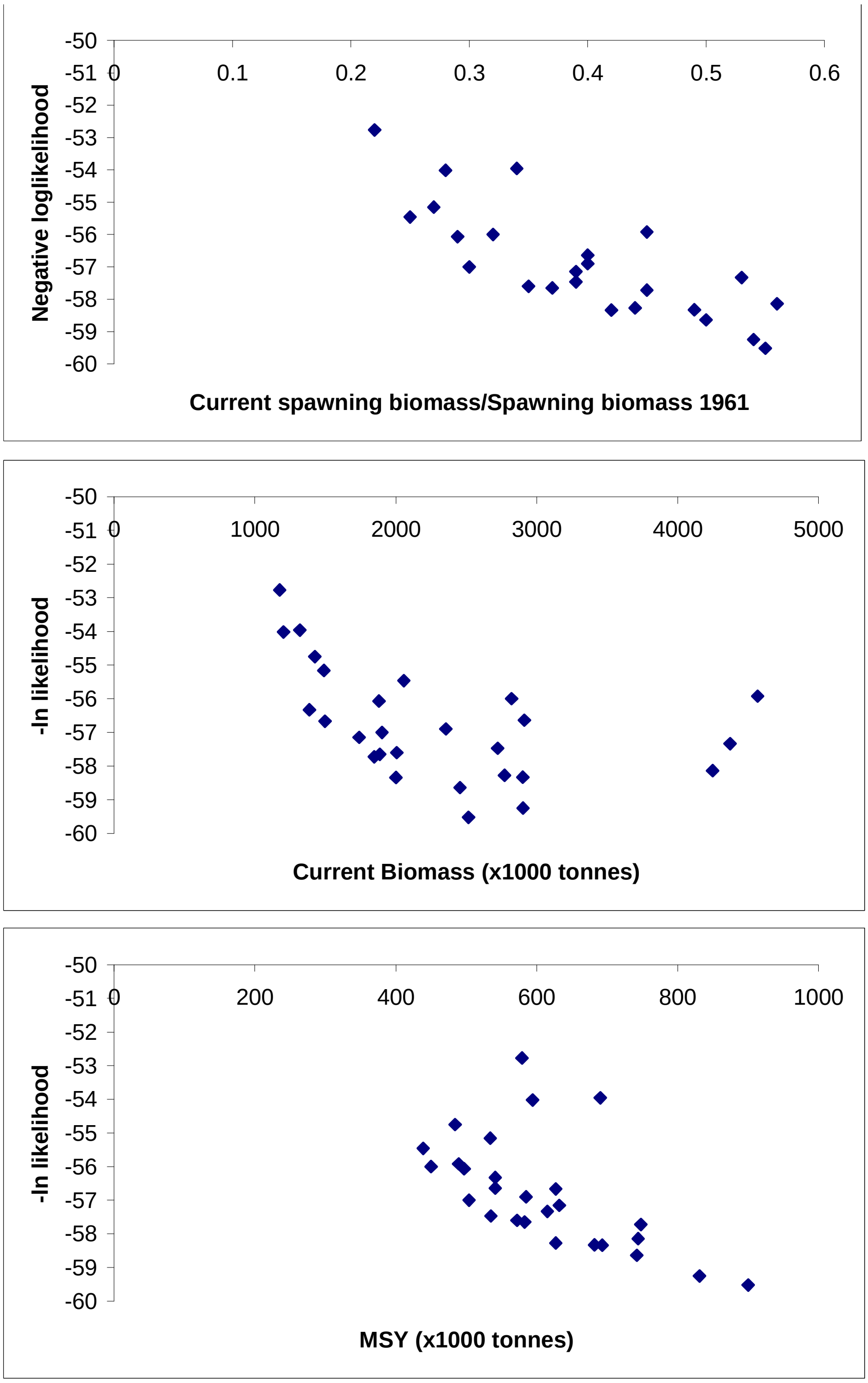


Figure 7. Depletion (2005), current biomass and *MSY* levels are plotted against log-likelihood values.

Appendix 8 : Sensitivities on the Assessment of the Namibian Horse Mackerel Resource

RA Rademeyer and DS Butterworth

The assessment of the Namibian horse mackerel resource presented in a working paper (with catch-at-age but catch-at-length information) is updated with a CV on the recruitment residuals (σ_R) of 0.4 instead of 0.25 (Reference Case). Three sensitivities on this assessment are also presented: i) with the survey bias correction factor q estimated rather than fixed to 2, ii) omitting the GLM-standardised CPUE series for the midwater trawl fishery and iii) with M=0.4 and h=0.75.

20-year projections have been carried out assuming a constant catch of 320 and 41 thousand tons for the midwater and pelagic fleets respectively (i.e. as in 2004).

Table 1: Estimates of management quantities for a) the Reference Case assessment of the Namibian horse mackerel resource and b)-d) three sensitivities on this assessment. Values fixed on input are shown in bold.

	a) Reference Case (σ_R=0.4)			b) q survey estimated			c) excl. midwater GLM CPUE series			d) with h=0.75 and M=0.4		
'-lnL:overall	-19.2			-19.6			-8.0			-7.1		
'-lnL:CPUE	-23.8			-24.9			-8.2			-8.2		
'-lnL:Survey	-3.2			-3.1			-3.7			-3.7		
'-lnL:CAA	-6.5			-6.1			-14.9			-13.9		
'-lnL:CAAsurv	1.7			1.7			1.3			1.5		
'-lnL:LAA	-			-			-			0.0		
'-lnL:LAAsurv	-			-			-			0.0		
Recruitment_Pen	12.6			12.8			17.5			17.3		
		Midwater	Pelagic		Midwater	Pelagic		Midwater	Pelagic		Midwater	Pelagic
K^{sp}	5036			5554			5339			3786		
K^{ex}	2050	1902	1776	2230	2066	1739	2005	1866	1437	1737	1622	1581
B^{sp}_{2004}	1347			2020			1455			1331		
B^{ex}_{2004}	753	685	760	1086	990	965	751	678	693	770	695	924
h	**0.600**			**0.600**			**0.600**			**0.750**		
M	**0.300**			**0.300**			**0.300**			**0.400**		
$MSYL^{sp}$	1608	1583	1726	1767	1739	1888	1682	1655	1794	1002	982	1051
$MSYL^{ex}$	812	743	754	895	818	747	817	751	625	565	498	624
MSY	369	392	247	399	426	260	378	404	236	491	523	320
B^{sp}_{2004}/K^{sp}	0.268			0.364			0.273			0.352		
B^{ex}_{2004}/K^{ex}	0.367	0.360	0.428	0.487	0.479	0.555	0.375	0.364	0.482	0.443	0.429	0.585
$B^{sp}_{2004}/MSYL^{sp}$	0.838	0.851	0.781	1.144	1.162	1.070	0.865	0.879	0.811	1.329	1.356	1.267
$B^{ex}_{2004}/MSYL^{ex}$	0.927	0.922	1.009	1.213	1.210	1.292	0.920	0.903	1.109	1.363	1.397	1.482
$MSYL^{sp}/K^{sp}$	0.319	0.314	0.343	0.318	0.313	0.340	0.315	0.310	0.336	0.265	0.259	0.278
$MSYL^{ex}/K^{ex}$	0.396	0.391	0.424	0.401	0.396	0.429	0.407	0.402	0.435	0.325	0.307	0.395
Age	Survey1	Midwater	Pelagic	Survey1	Midwater	Pelagic	Survey1	Midwater	Pelagic	Survey1	Midwater	Pelagic
S(0)	0.31	0.00	0.14	0.31	0.00	0.14	0.30	0.00	0.14	0.26	0.00	0.12
S(1)	1.00	0.04	1.00	1.00	0.04	1.00	1.00	0.04	1.00	0.95	0.03	1.00
S(2)	0.93	0.28	0.43	0.93	0.30	0.42	0.96	0.30	0.41	1.00	0.25	0.45
S(3)	0.43	0.63	0.35	0.41	0.67	0.32	0.43	0.69	0.29	0.49	0.63	0.35
S(4)	0.20	1.00	0.29	0.18	1.00	0.25	0.20	1.00	0.21	0.24	1.00	0.28
S(5)	0.09	0.14	0.23	0.08	0.12	0.19	0.09	0.08	0.15	0.12	0.13	0.22
S(6)	0.04	0.14	0.19	0.04	0.12	0.15	0.04	0.08	0.10	0.06	0.13	0.17
S(7)	0.02	0.14	0.16	0.02	0.12	0.12	0.02	0.08	0.07	0.03	0.13	0.13
	Midwater	Bulgaria	Poland	Midwater	Bulgaria	Poland	Midwater	Bulgaria	Poland	Midwater	Bulgaria	Poland
Commercial_q's	0.008	0.003	0.002	0.006	0.003	0.002	0.007	0.003	0.002	0.007	0.003	0.002
Commercial_sigma's	0.202	0.423	0.795	0.200	0.405	0.793	0.600	0.394	0.791	0.600	0.396	0.809
Survey_q's	**2.000**			1.399			**2.000**			**2.000**		

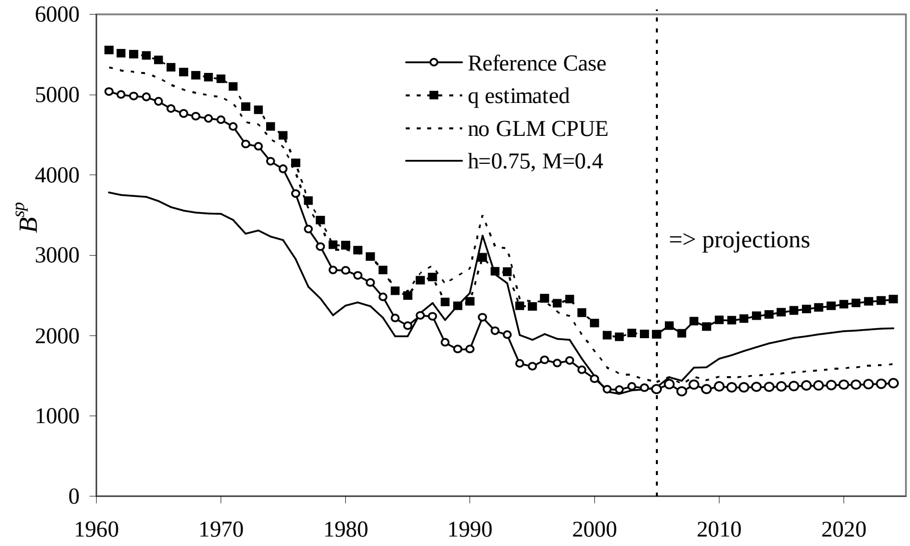


Fig. 1a: Time-series of estimated spawning biomass for the Reference Case and three sensitivities for the Namibian horse mackerel resource. Projected spawning biomass under a constant catch strategy is also shown.

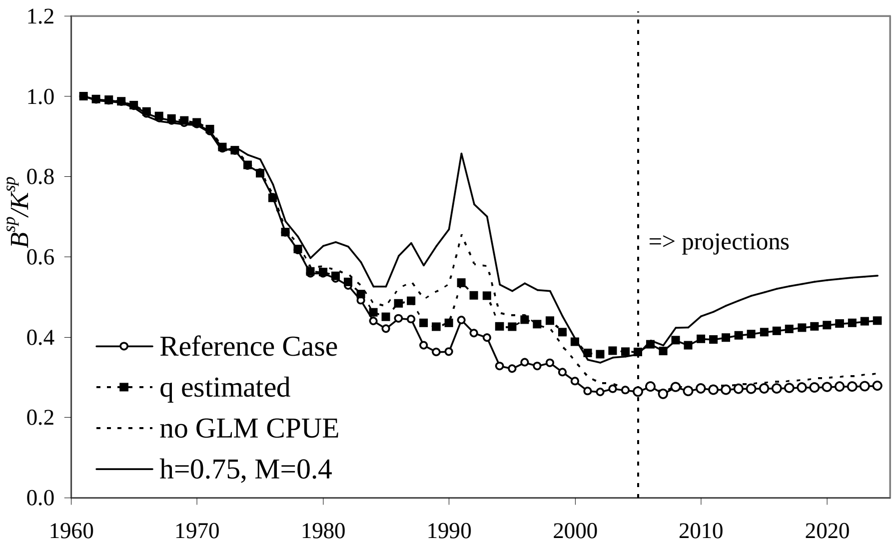


Fig. 1b: Time-series of estimated depletion for the Reference Case and three sensitivities for the Namibian horse mackerel resource. Projected spawning biomass under a constant catch strategy is also shown.

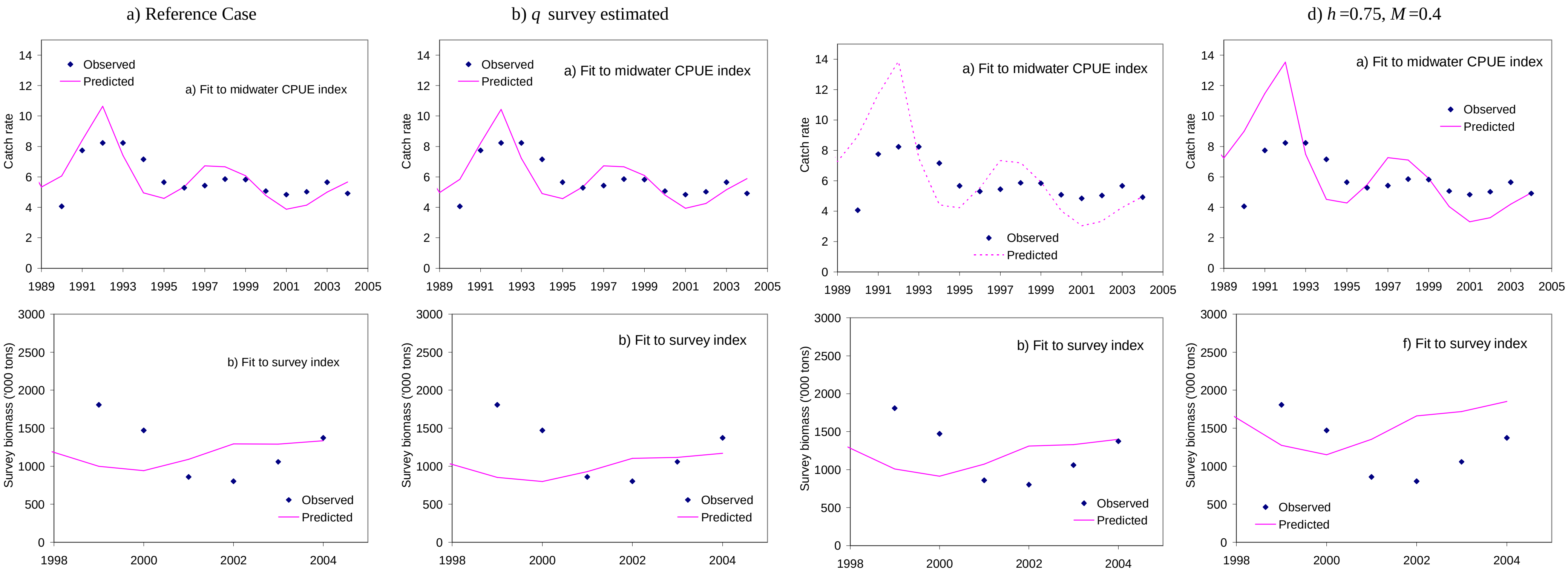


Fig. 2: Model fits of the Reference Case and three sensitivities to the midwater GLM CPUE and survey abundance indices for the Namibian horse mackerel resource.

Appendix 9 : Assessment of the Namibian Horse Mackerel Resource, Including Both Catch-at-Age and Catch-at-Length Information

RA Rademeyer and DS Butterworth

The data, parameterisation and parameter estimation used in this assessment are as described in Kirchner and Punt (Appendix 7). Age-length keys for the Namibian horse mackerel are available for 1996 and 2004 and for those years, the catch-at-age data are used as input (data as in Appendix 7). For the years where no age-length keys are available, catch-at-length data have been used to fit the model (data derived as in Appendix 10). The length-at-age is estimated by the Von Bertalanffy growth equation, with the following Von Bertalanffy parameter values: L_∞=57.19cm, K=0.11 and t_0=-1.65.

20-year projections have been carried out assuming a constant catch of 320 and 41 thousand tons for the midwater and pelagic fleets respectively.

Table 1: Estimates of management quantities for the assessment of the horse mackerel resource.

'-lnL:overall	-43.7						
'-lnL:CPUE	-25.8						
'-lnL:Survey	-1.2						
'-lnL:CAA	-68.1						
'-lnL:CAAsurv	1.5						
'-lnL:LAA	27.3						
'-lnL:LAAsurv	4.8						
Recruitment_Pen	17.8						
		Midwater	Pelagic	Bulgaria	Poland	Romania	USSR
K^{sp}	5077						
K^{ex}	2871	2753	701	1678	3810	3119	2746
B^{sp}_{2004}	923						
B^{ex}_{2004}	666	607	260	447	630	678	518
h	**0.600**						
M	**0.300**						
$MSYL^{sp}$	1655	1638	1603	1602	1702	1663	1651
$MSYL^{ex}$	1171	1098	318	720	1280	1242	987
MSY	334	365	180	305	431	352	418
B^{sp}_{2004}/K^{sp}	0.182						
B^{ex}_{2004}/K^{ex}	0.232	0.221	0.372	0.266	0.165	0.217	0.189
$B^{sp}_{2004}/MSYL^{sp}$	0.558	0.563	0.576	0.576	0.542	0.555	0.559
$B^{ex}_{2004}/MSYL^{ex}$	0.569	0.553	0.819	0.620	0.492	0.546	0.524
$MSYL^{sp}/K^{sp}$	0.326	0.323	0.316	0.315	0.335	0.328	0.325
$MSYL^{ex}/K^{ex}$	0.408	0.399	0.453	0.429	0.336	0.398	0.360
Age	Survey1	Midwater	Pelagic	Bulgaria	Poland	Romania	USSR
S(0)	0.25	0.00	0.07	0.00	0.00	0.00	0.00
S(1)	0.85	0.05	1.00	0.18	0.08	0.25	0.06
S(2)	1.00	0.84	0.25	1.00	0.32	0.91	0.22
S(3)	0.35	1.00	0.12	0.73	0.68	1.00	0.75
S(4)	0.12	0.76	0.05	0.28	1.00	0.75	1.00
S(5)	0.04	0.25	0.03	0.07	0.62	0.31	0.34
S(6)	0.01	0.25	0.01	0.07	0.62	0.31	0.34
S(7)	0.01	0.25	0.01	0.07	0.62	0.31	0.34
	Midwater	Bulgaria	Poland	Romania	USSR		
Commercial_q's	0.007	0.004	0.002	0.002	0.020		
Commercial_sigma's	0.200	0.451	0.796	0.626	0.336		
Survey_q's	**2.000**						

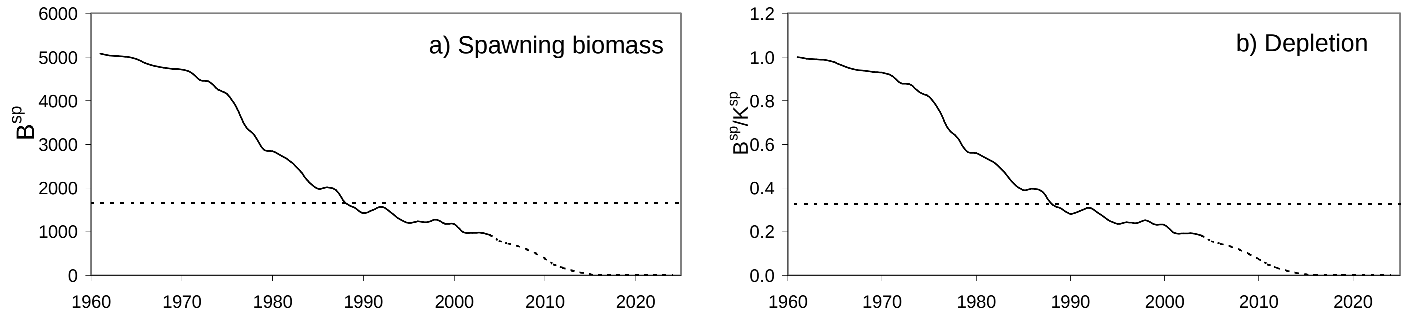


Fig. 1: Time-series of estimated spawning biomass for the Namibian horse mackerel resource. Projected spawning biomass under a constant catch strategy is also shown (dashed lined).

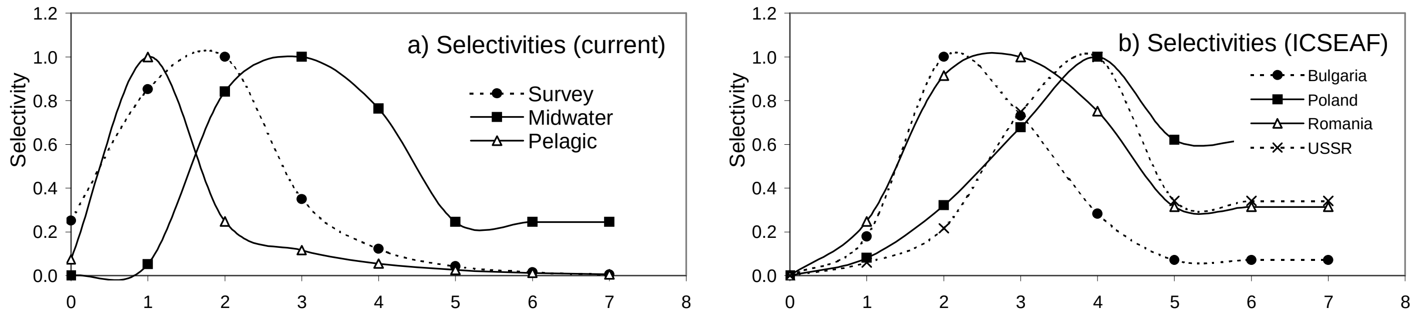


Fig. 2: Commercial and survey fishing selectivities estimated.

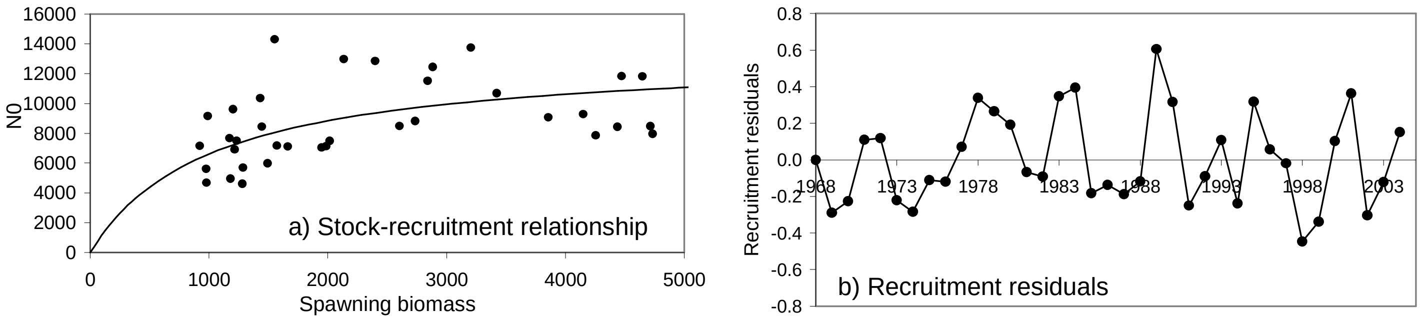


Fig. 3: a) Estimated stock-recruitment relationship and b) time-series of model estimated recruitment residuals.

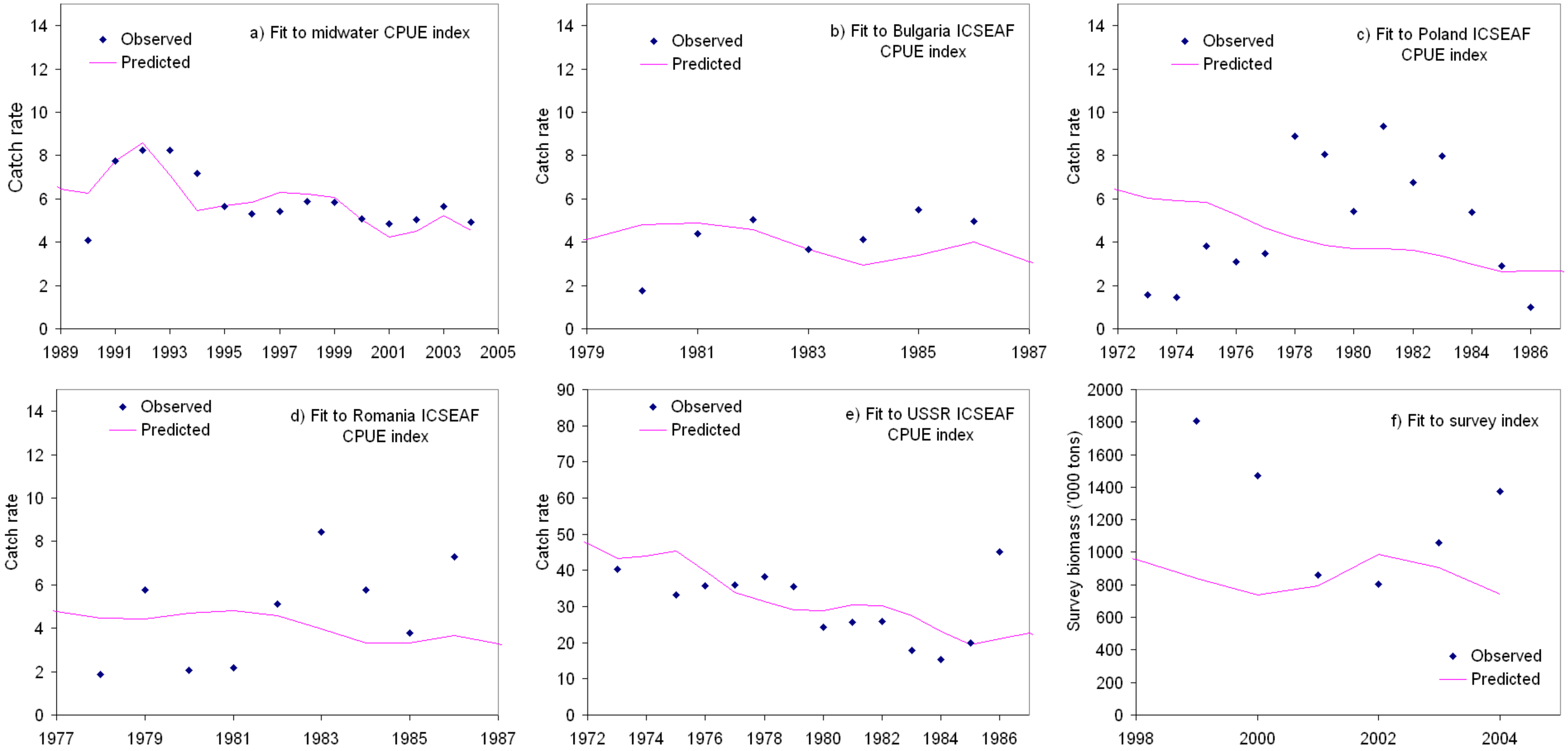
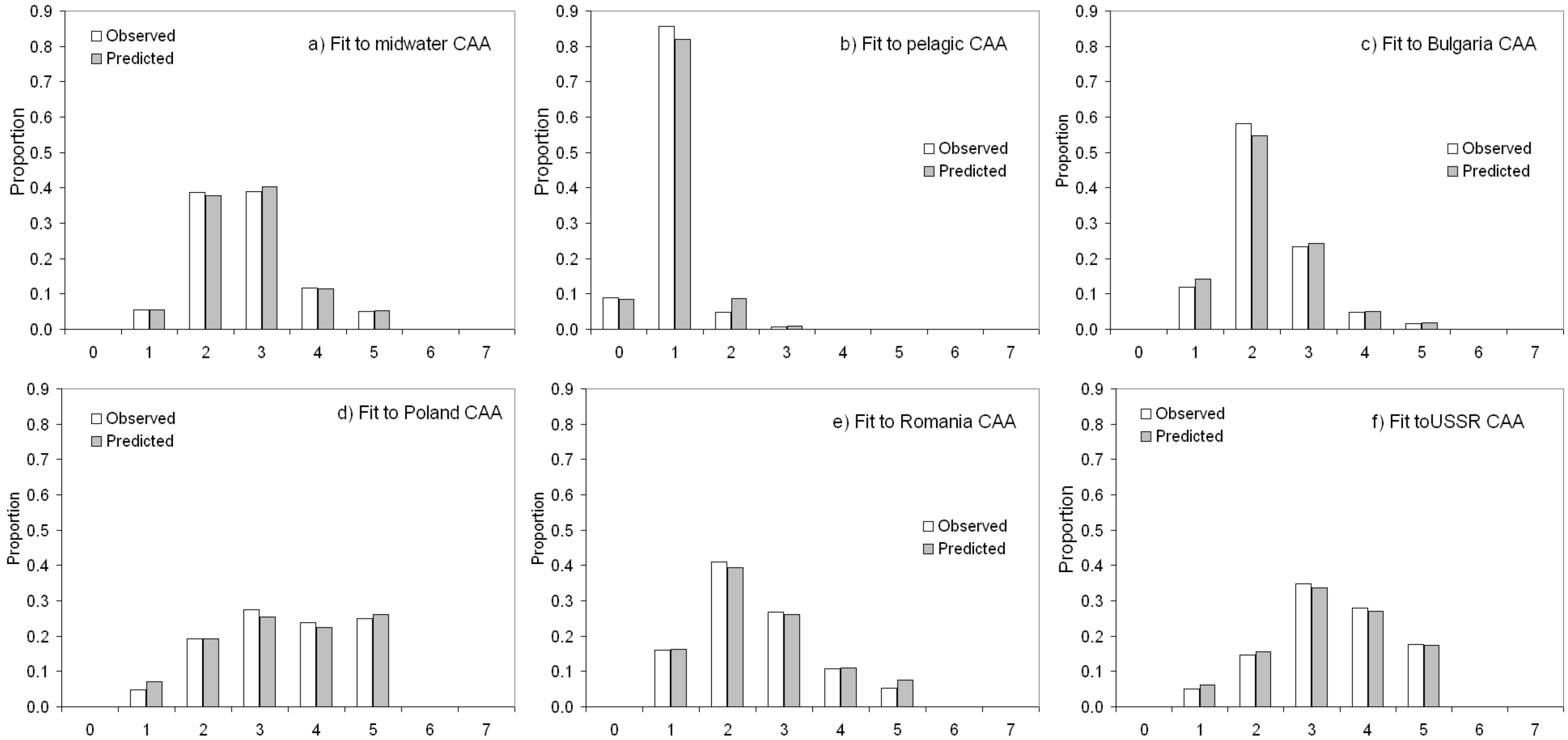


Fig. 4: Model fits to the CPUE and survey abundance indices for the Namibian horse mackerel resource.



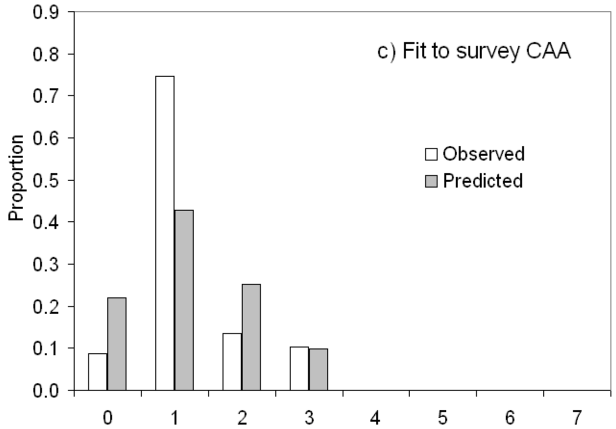
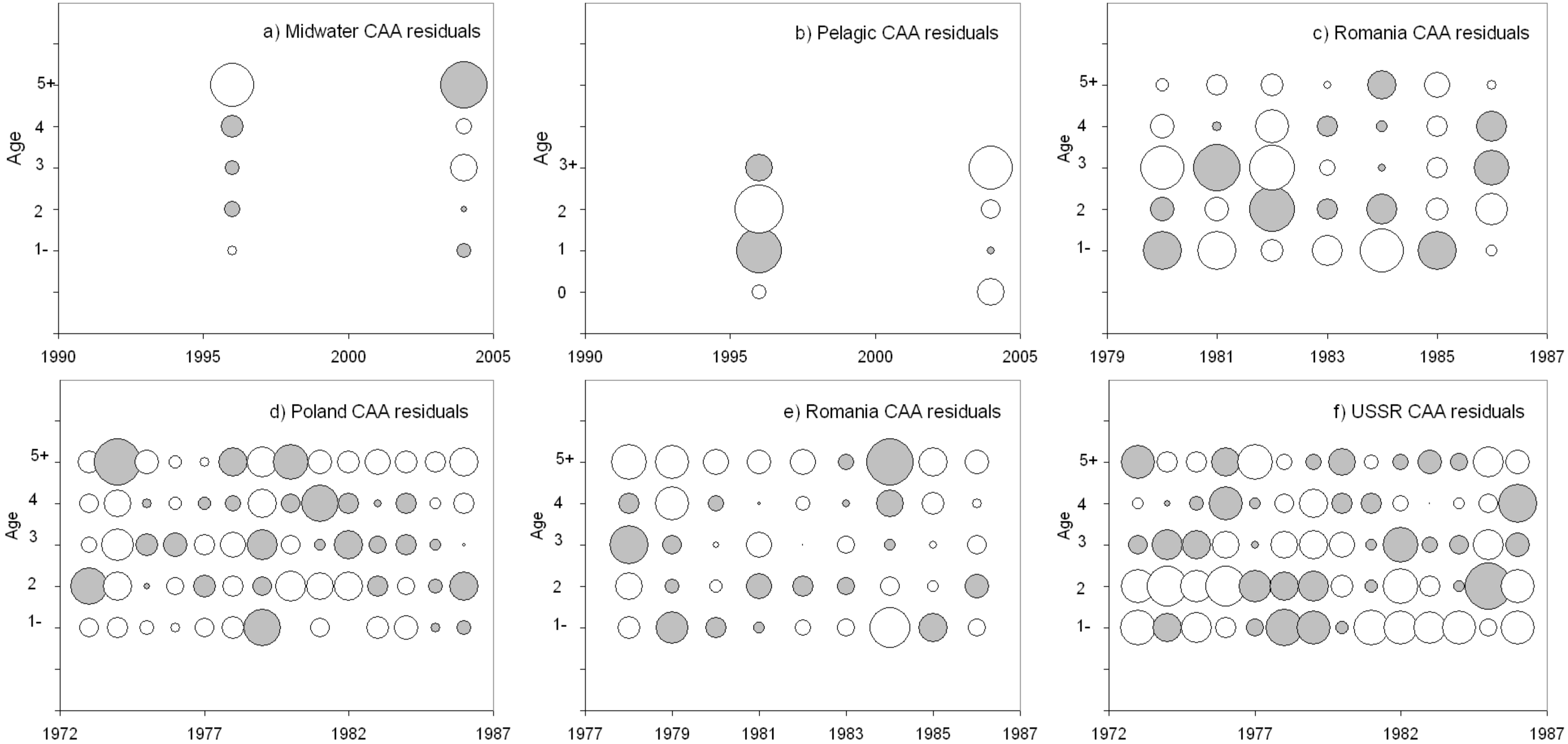


Fig. 5: Model fits to the catch-at-age proportion data, as averaged over all the years with data.



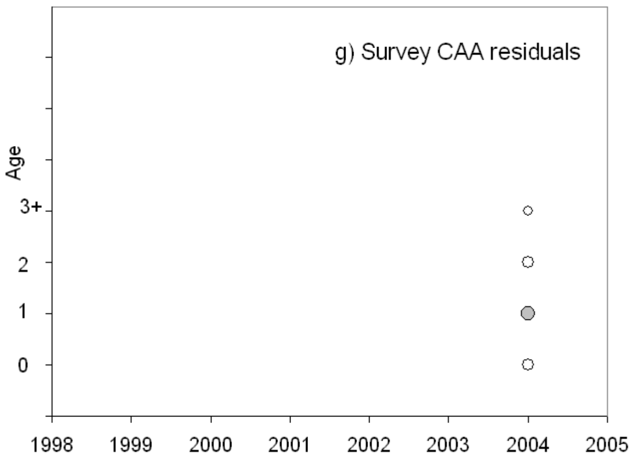


Fig. 6: “Bubble plots” of the catch-at-age residuals for the Namibian horse mackerel assessment. The size (area) of the bubble is proportional to the corresponding standardised residual. For positive residuals, the bubbles are grey and for negative residuals, the bubbles are white.

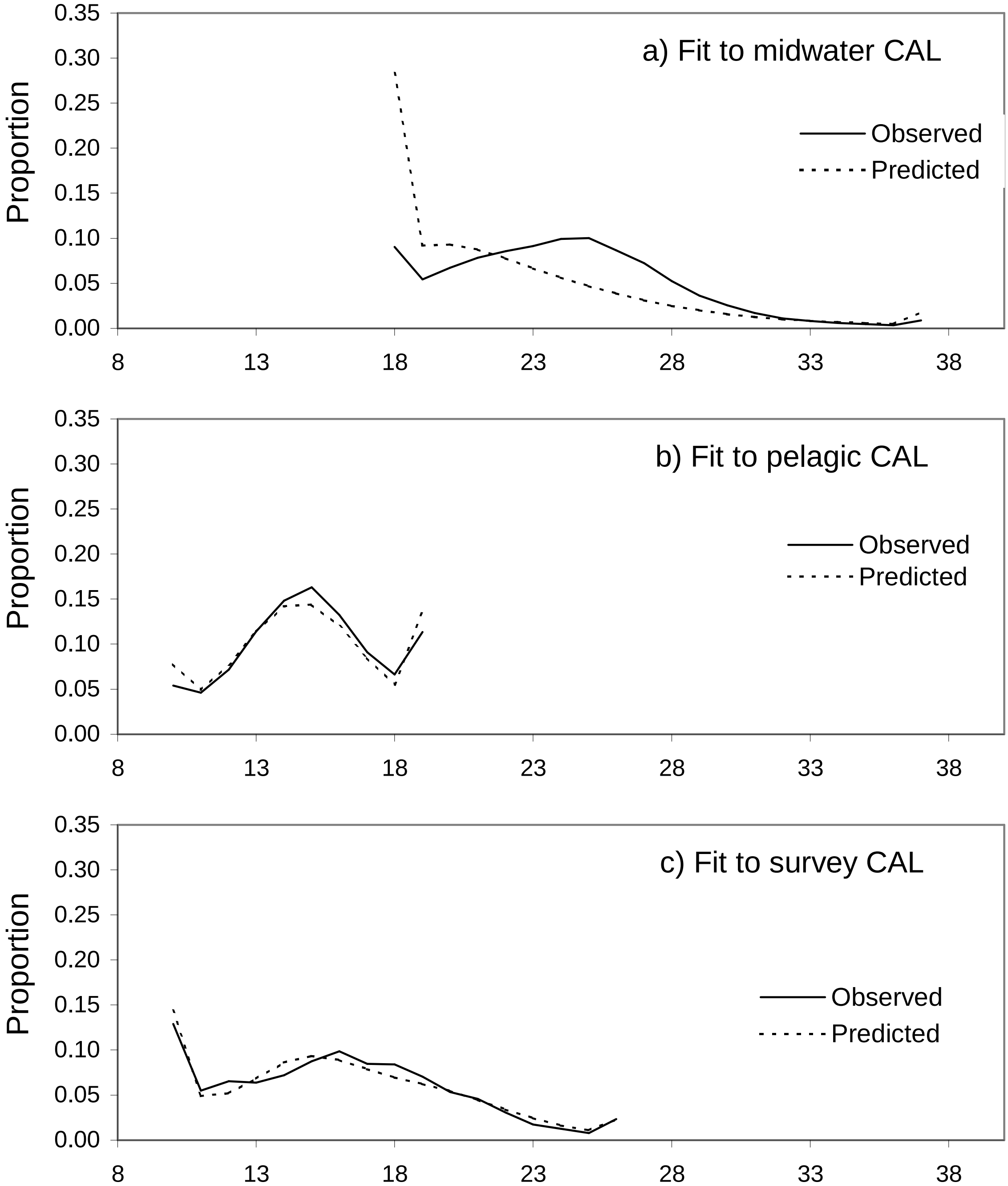


Fig. 7: Model fits to catch-at-length proportion data, as averaged over all the years with data . The "spikes" at the two ends of the plots reflect minus- and plus-groups.

Appendix 10 : Fitting a von Bertalanffy model to age-length data from the 1996 and 2004 *Welwitschia* acoustic surveys

Paul J. Starr

Data sources

Two sets of age-length data from the 1996 and 2004 *Welwitschia* acoustic surveys are available (Table 1~~Table 1Table 1~~).

Table 1. Number of length and age observations in each data set.

Survey	Number length observations	Number age observations
1996 acoustic	220	220
2004 acoustic	1411	768

Methods

A three parameter von-Bertalanffy model was fitted to each of the data sets described in Table 1~~Table 1Table 1~~.

$$\hat{l}_i = L_\infty\left(1 - e^{-k(a_i - t_0)}\right) \tag{1}$$

where a_i is the age and $\hat{l}_i$ is the predicted length (cm) of the i'th fish. Parameters are estimated as indicated in Table 2~~Table 3Table 2~~. Parameters were estimated by minimising (using the EXCEL solver) the negative log-likelihood in Eq. 2 over n observations in each of the two data sets and the combined data set (Table 1~~Table 1Table 1~~):

$$-\ell nL = \sum_{i=1}^{n} \ell n(\sqrt{2\pi\sigma^2}) + \tfrac{1}{2\sigma^2}\left(\ell n l_i - \ell n \hat{l}_i\right)^2 \tag{2}$$

Analysis by Brandao (Appendix 5) indicates that there is no statistical difference between the 1996 and 2004 data sets so it is justified to combine these sets.

Table 2~~32~~. Parameters estimated for the von Bertalanffy model.

Parameter	
L_∞	Estimated
k	Estimated
t_0	Estimated
σ	Estimated

Results

The parameter estimates tended to imply a relatively straight line through the 2004 data set and the combined data set (Table 3~~Table 5Table 3~~; Figure 3~~Figure 3Figure 3~~). The fitting procedure showed that a wide range of values for the model parameters fit the model with little change in the negative log-likelihood, so it may be useful to fit a different and more appropriate model these data.

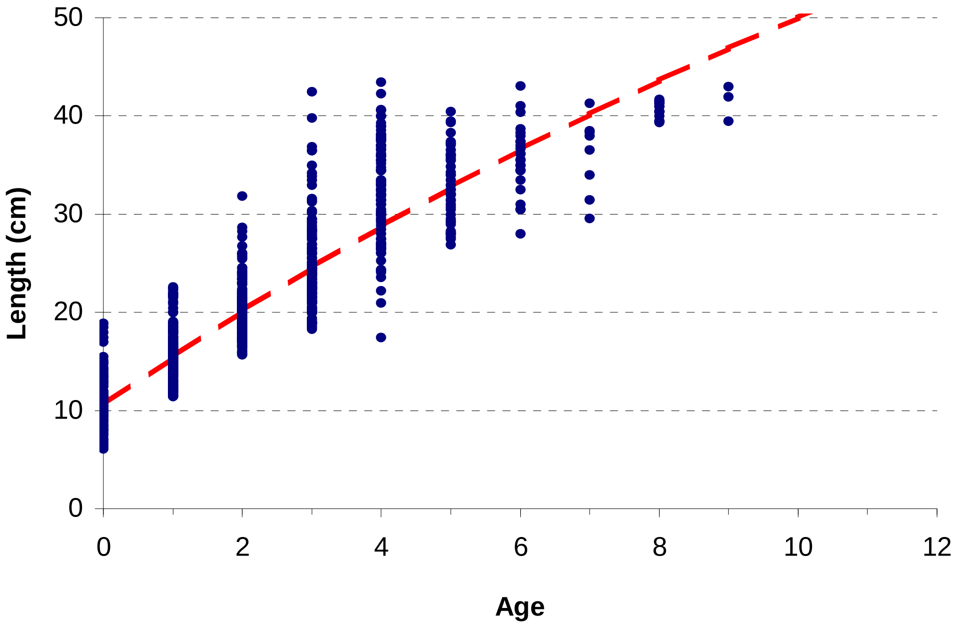


Figure 3. von-Bertalanffy model fitted to age-length data collected during the 1996 and 2004 *Welwitschia* acoustic surveys.

Table 35~~3~~. Parameter estimates and the negative log-likelihood for the two Namibian data sets and the combined data set.

	Estimate		
Parameter	**1996 data only**	**2004 data only**	**Combined data**
L_∞ (cm)	56.895	99.031	109.619
k (yr^{-1})	0.141	0.052	0.051
t_0 (yr)	-1.834	-2.136	-2.000
σ	0.159	0.143	0.164
$-\ell nL$	-91.825	-403.846	-387.037

Appendix 11 : Further Angolan horse mackerel assessments

S.J. Johnston

This document reports preliminary results of fitting a Schaefer surplus production model to three sets of 1985+ survey biomass estimates from the Angolan horse mackerel fishery. These biomass estimates are for:

i) *T. trecae* only
ii) *T. capensis* only
iii) *T. trecae* plus *T capensis*

For each of these biomass series, a corresponding catch series from 1985 has been defined. Table 1 reports the survey biomass series, and Table 2 reports the catch series. As the "raw" catch data for Angolan horse mackerel from 1985 is for *T. trecae* only, an assumed catch series for *T. capensis* was calculated using the observed ratios of *T. trecae* and *T. capensis* from the survey biomass estimates. It was thus assumed that the proportion of *T. capensis* and *T. trecae* are the same in both the catch and survey biomass series. The biomass estimates are treated as relative indices in the model fit, with an estimable multiplicative bias factor q in relation to absolute abundance.

Catch data (for both species combined) is also available for 1973-1984. A fourth assessment is thus reported, which uses this catch series in conjunction with the *T. capensis* plus *T. trecae* survey biomass series (for 1985+). For this assessment, it is assumes that $B_{1973} = K$ (i.e. the α value, where $\alpha = B_{start\ year} / K$, is fixed at 1.0).

Results

The model output is presented in Table 3. A minimum constraint of 0.10 on the r parameter is imposed. This was necessary as in some cases, the model would fit an impossible low r value. Convergence was not achieved for any of the fits (ADMB was used). The model appeared in general to have difficulty in fitting to the data.

Table 1: Biomass survey estimates (‘000 t) used for the assessments reported here, as well as the relative ratios between the two species. Note that for some years more than one survey was conducted and the average for that year is used. Linear interpolation has also been used to estimate biomass in years for which no surveys were conducted.

	Ratio *trecae*	**Ratio *capensis***	**Biomass *trecae***	**Biomass *capensis***	**Total Biomass *capensis + trecae***
1985	0.67	0.33	450	220	670
1986	0.88	0.12	130	40	170
1987	0.82	0.18	193	70	263
1988	0.75	0.25	255	100	355
1989	0.69	0.31	318	130	448
1990	0.66	0.34	209	220	429
1991	0.62	0.38	100	310	410
1992	0.68	0.32	92	248	340
1993	0.74	0.26	84	187	271
1994	0.80	0.20	76	125	201
1995	0.86	0.14	68	63	131
1996	0.95	0.05	433	21	454
1997	0.95	0.05	210	23	233
1998	0.66	0.34	141	129	270
1999	0.71	0.29	124	128	252
2000	0.58	0.42	92	242	334
2001	0.32	0.68	64	187	251
2002	0.64	0.36	118	92	210
2003	0.56	0.44	120	133	253
2004	0.85	0.15	32	39	71

Table 2: Catch (t) series used for the various assessments.

	Total	*T. trecae*	*T. capensis*
1973	191694		
1974	132994		
1975	128208		
1976	45723		
1977	252565		
1978	380150		
1979	297247		
1980	109665		
1981	142216		
1982	105072		
1983	109985		
1984	54923		
1985	43493	29140	14353
1986	105060	92453	12607
1987	95302	77830	17472
1988	100683	75848	24835
1989	122664	84638	38026
1990	74366	48710	20947
1991	54190	33598	13728
1992	113547	77212	25548
1993	85635	63370	16842
1994	62430	49944	10509
1995	61050	52503	8547
1996	145017	137766	7251
1997	162144	154037	8107
1998	72365	47761	24604
1999	53634	38080	15554
2000	57778	33511	24267
2001	375000	120000	255000
2002	125560	80358	45202
2003	107143	60000	47143

Table 3: Model output statistics. [Note: r is constrained to be ≥ 0.1.]

	***T. trecae* 1985+**	***T. capensis* 1985+**	**Both species 1985+**	**Both species 1973+**
K	1274	1123	2998	942
r	0.1	0.1	0.1	0.91
α	1.0	0.94	0.4	1.0 fixed
q	0.18	0.11	0.29	0.34
MSY	32	28	75	214
$RY(2005)$	26	27	37	155
B_{2004}/K	0.35	0.64	0.19	0.59

Figure 1a: Catch series (t) for the Angolan horse mackerel fishery..

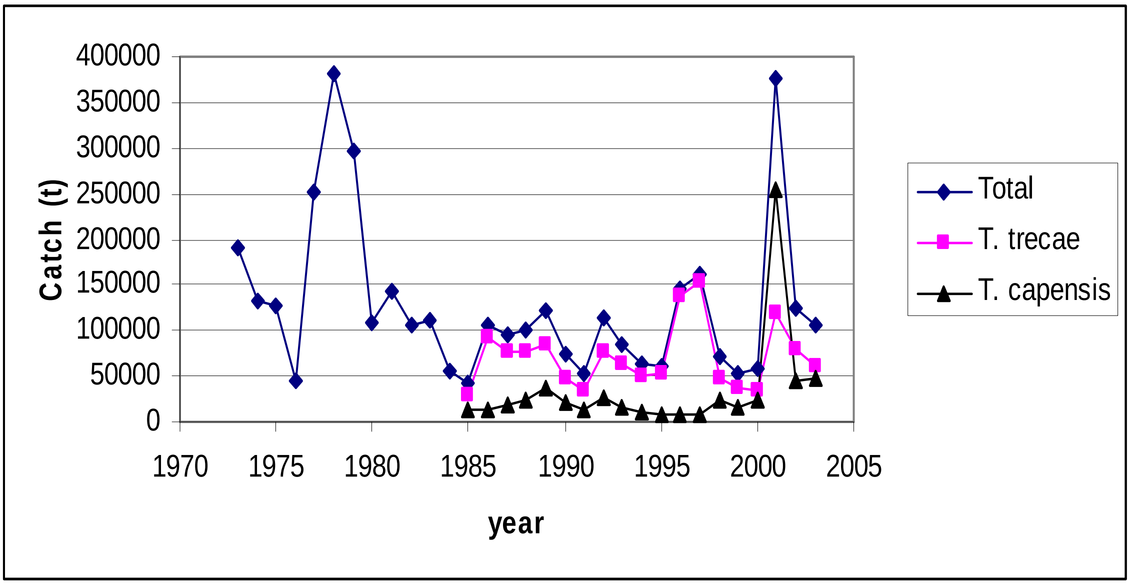


Figure 1b: Survey biomass estimates for the Angolan horse mackerel fishery.

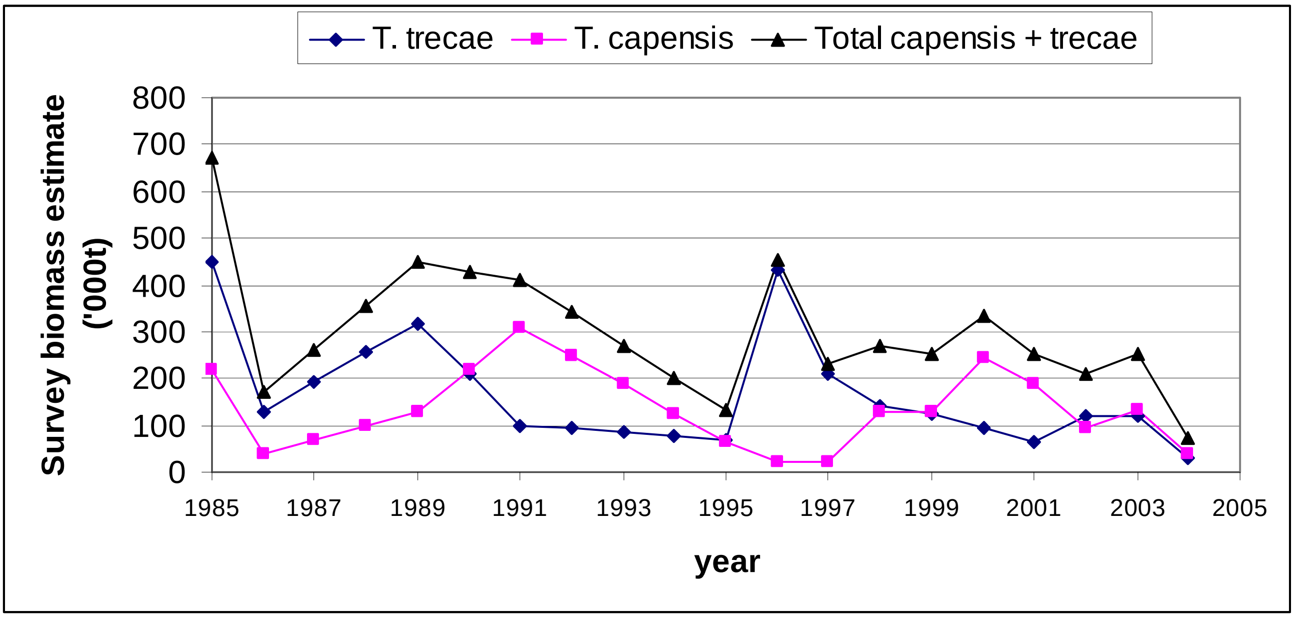


Figure 2a: Model fit to *T. trecae* (1985+) survey biomass estimates.

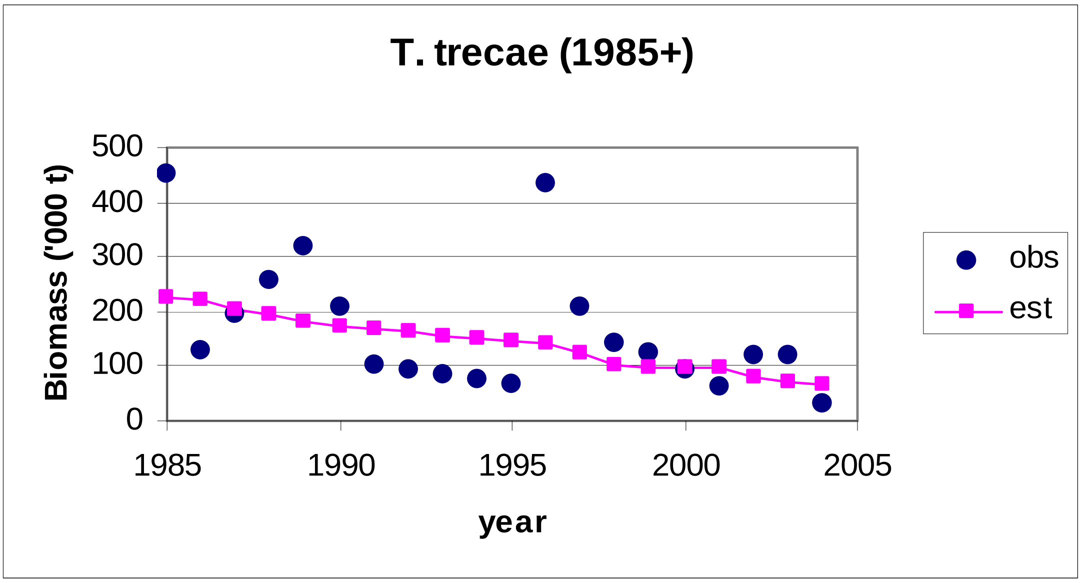


Figure 2b: Model fit to *T. capensis* (1985+) survey biomass estimates.

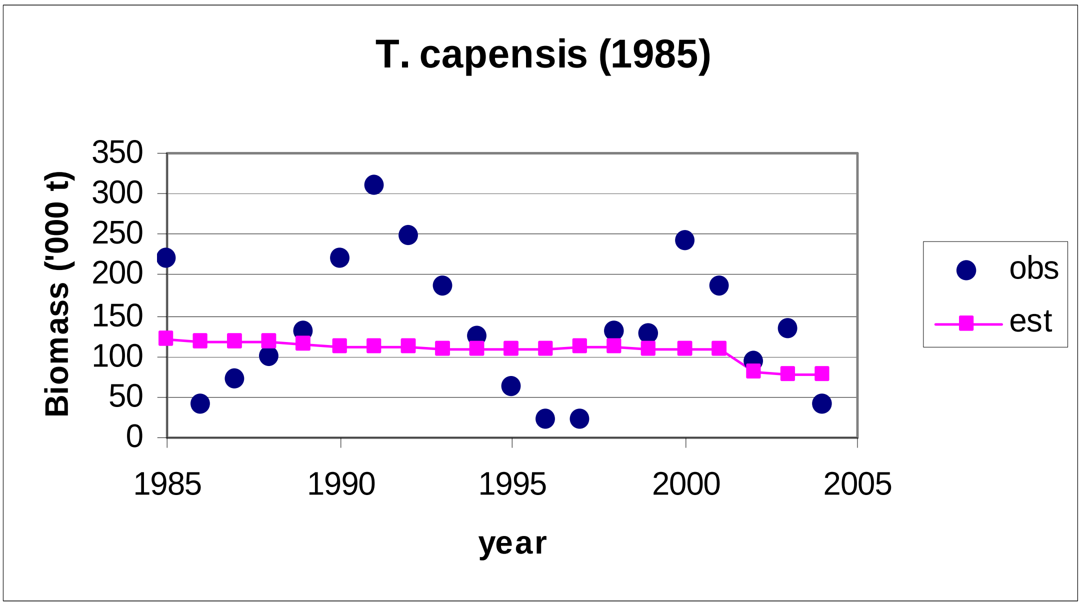


Figure 2c: Model fit to *T. trecae* + *T. capensis* (1985+) survey biomass estimates.

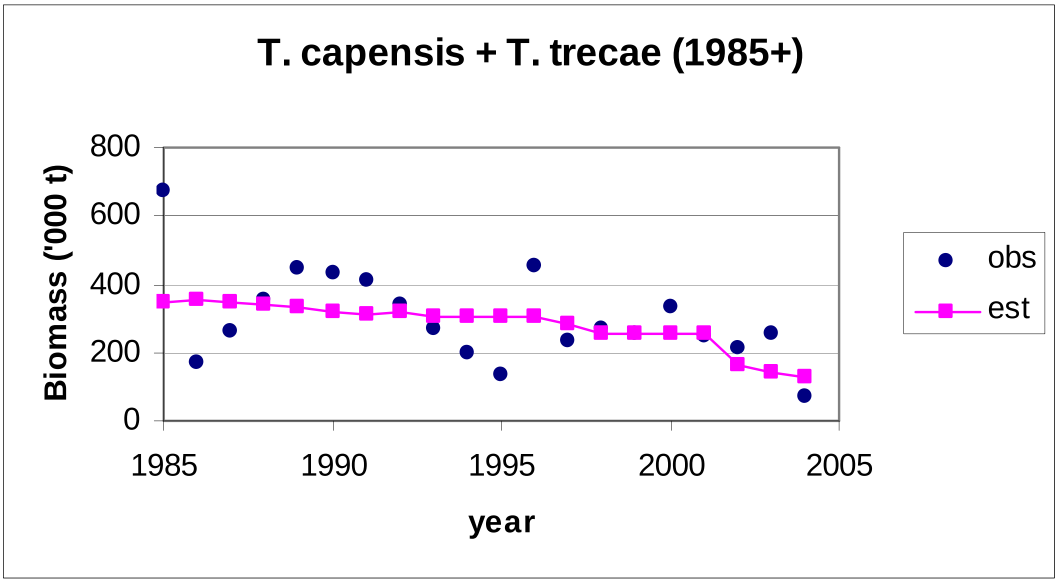
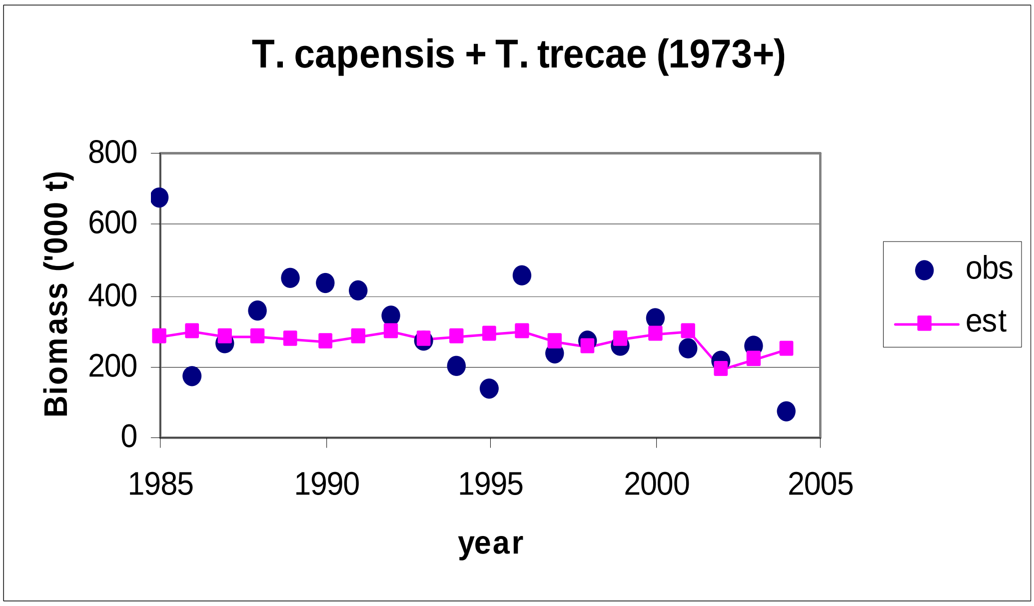


Figure 2d: Model fit to *T. trecae* + *T. capensis* (1985+) survey biomass estimates – model starts in 1973.



Appendix 12 : Replacement Yield Model fits to Angolan horse mackerel data.

S.J. Johnston

A replacement yield model has been fitted to the Angolan horse mackerel survey biomass data and catch data for the period 1985-2004.

Three series of data are available: *T. trecae* only, *T. capensis* only, and *T. trecae* and *T. capensis* combined.

The replacement yield model fitted to the data is simply:

$B_{t+1} = B_t + RY - C_t$ and
$S_t = qB_t e^{\varepsilon}$,
where RY = replacement yield, and S_t is the survey biomass estimate.

We assume $q = 1$, i.e. that the survey biomass estimates are absolute biomass estimates. The estimable parameters are thus B_{1985} (the first year biomass), and RY.

The data are reported in Table 1. Model results are reported in Table 2. Standard errors (Hessian-based) are reported in parenthesis. Figure 1 provides the model fits to the survey data as well as plots of biomass and catch.

[The *T. capensis* catch value for 2001 of 255000 t seems somewhat unrealistic. The *T. capensis* catch values are calculated by using the relative ratio of *trecae:capensis* in the survey biomass, and the *trecae* catch series. In 2001, it was reported from the survey that the *capensis* biomass was more than twice the size of that of *trecae*, and this results in the *capensis* catch being so large for that year.]

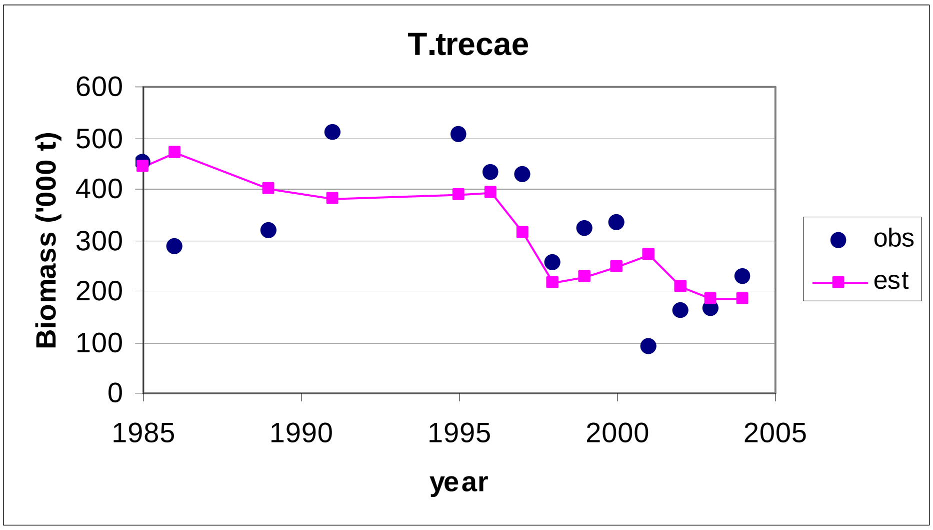
Table 1: Catch (in t) and survey biomass (in '000 t) for Angolan horse mackerel.

	Catch ***T. trecae***	**Catch** ***T. capensis***	**Catch** ***T. capensis + T. trecae***	**Biomass** ***T. trecae***	**Biomass** ***T. capensis***	**Biomass** ***T. capensis + T. trecae***
1985	29140	14353	43493	450	220	670
1986	92453	12607	105060	285	40	325
1987	77830	17472	95302			
1988	75848	24835	100683			
1989	84638	38026	122664	318	130	448
1990	48710	20947	74366			
1991	33598	13728	54190	510	310	820
1992	77212	25548	113547			
1993	63370	16842	85635			
1994	49944	10509	62430			
1995	52503	8547	61050	506	63	569
1996	137766	7251	145017	433	21	454
1997	154037	8107	162144	427	23	450
1998	47761	24604	72365	254	129	383
1999	38080	15554	53634	321	128	449
2000	33511	24267	57778	333	242	575
2001	120000	255000	375000	89	187	276
2002	80358	45202	125560	162	92	254
2003	60000	47143	107143	166	133	299
2004				229	39	268

Table 2: Model output statistics. [Value in parenthesis is one standard error]. Biomass units are in '000 t.

	Both species 1985+	***T. trecae*** **1985+**	***T. capensis*** **1985+**
B_{1985}	464 (80)	443 (89)	72 (48)
RY	94 (5.2)	58 (6.0)	31 (3.1)
B_{2004}	272 (40)	208 (40)	68 (29)
B_{2004}/B_{1985}	0.59 (0.13)	0.47 (0.15)	0.95 (0.57)

Figure 1a: Model fits to survey biomass (top figure) and plots of biomass and catch (bottom figure) for *T. trecae*.



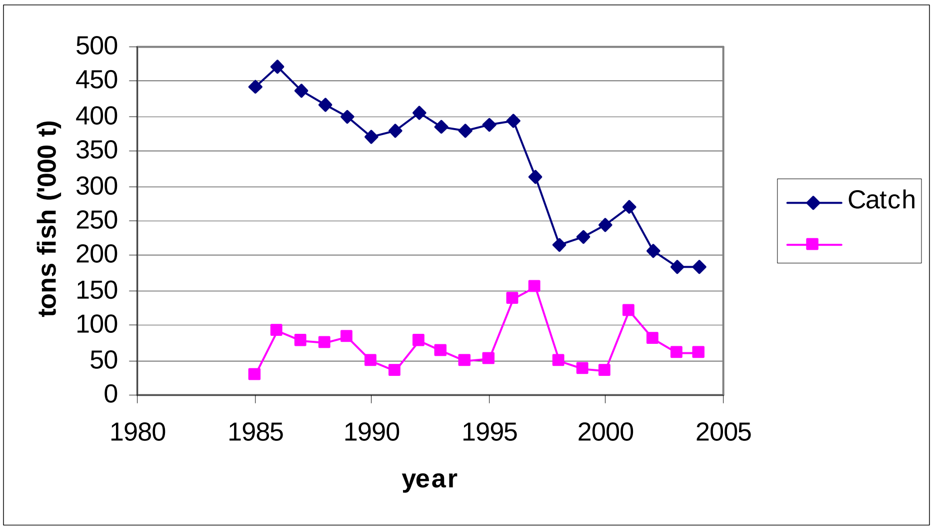
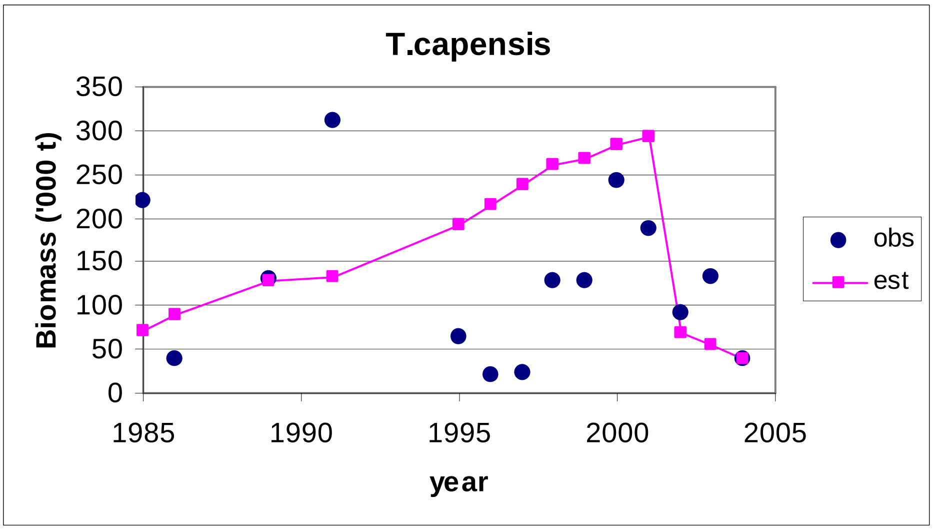


Figure 1b: Model fits to survey biomass (top figure) and plots of biomass and catch (bottom figure) for *T. capensis*.



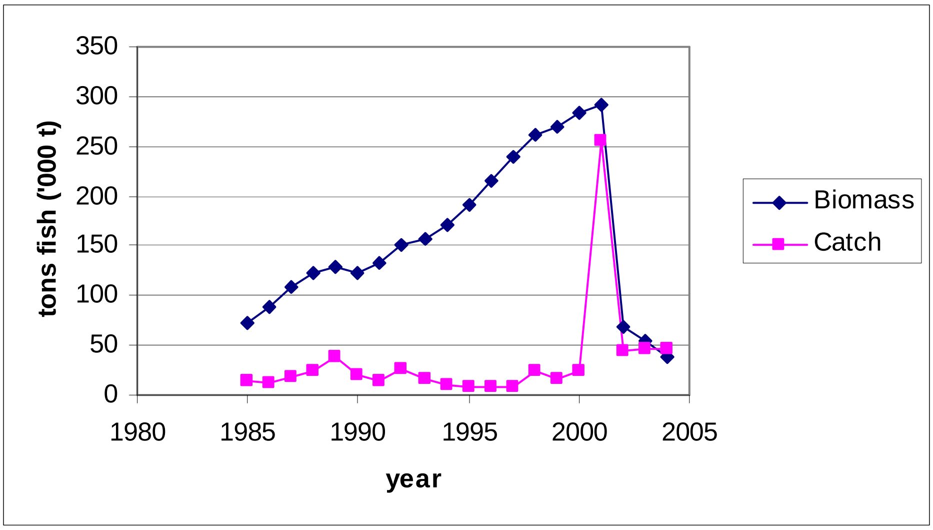
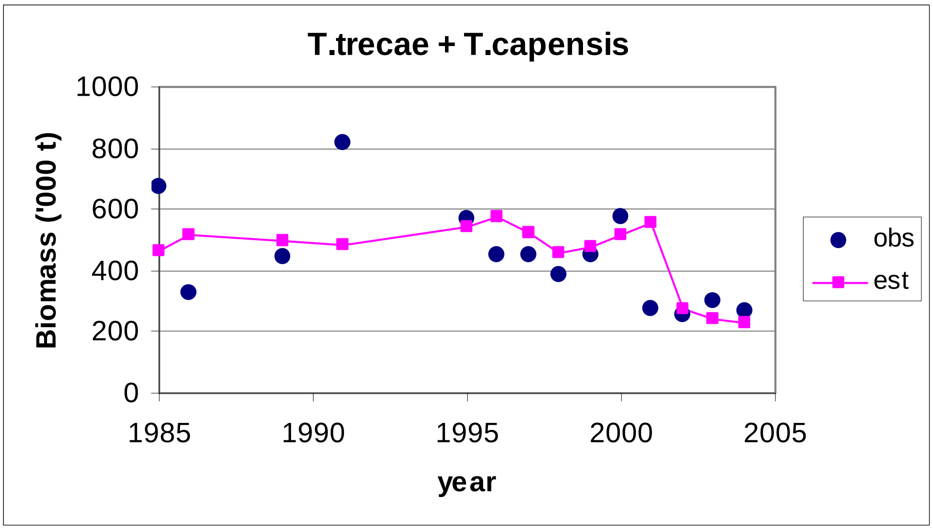
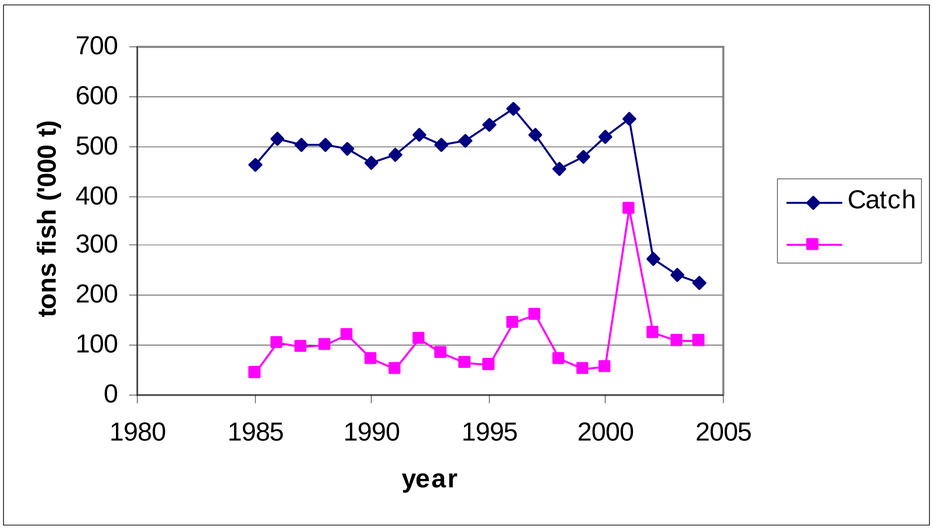


Figure 1c: Model fits to survey biomass (top figure) and plots of biomass and catch (bottom figure) for both *T. trecae*. and *T. capensis*.





Appendix 13 : Recommendations and Agreements

The following are 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 ranked research recommendations in H, M and L categories, but did not rank them within these categories. The workshop recognised that the time required to implement some of the recommendations would be substantial, and that management advice may have to be provided 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. Recommendations

A. Horse mackerel – general

A.1 (H, 3.2) The BCLME proposal to analyse additional genetics data for horse mackerel should be conducted, should consider both mtDNA and microsatellite markers and be based on samples collected widely off South Africa, Namibia and Angola.

A.2 (M, 3.1) Efforts should be made to understand the influence of oceanographic changes on fish distribution and aggregation.

B. Horse mackerel – South Africa

B.1 (H, 3.3.1) A study examining how horse mackerel react to trawl nets should be conducted to provide insight as to what the demersal trawl surveys are actually surveying, and thereby insight concerning the proportion of the catch that is taken in the water column rather than off the bottom.

B.2 (H, 3.3.1) Work on developing combined acoustic and bottom trawl surveys for horse mackerel should continue.

B.3 (H, 3.4.1) Future assessments of the South African horse mackerel resource should be based on the specifications and sensitivity tests listed in Section 3.4.1.

B.4 (H, 3.6) Industry should be fully consulted if an adaptive harvest strategy is considered for South African horse mackerel (see II.B.3.), particularly to determine desirable (and undesirable) levels of change in catch levels given the expected benefits of "adaptive management".

B.5 (M, 3.3.1) A self-consistent database containing length, weight, age and maturity information should be established and the various biological functions and relationships estimated therefrom.

B.6 (M, 3.3.1) The length-frequency data from the South African midwater and demersal fleets and the Japanese demersal fleet should be examined to determine whether it is necessary to model all three of these fleets separately.

B.7 (M, 3.1.1) A CPUE index series should be developed for the midwater trawl fishery.

C. Horse mackerel – Namibia

C.1 (H, 3.3.2) A GLM approach should be used to calculate the CPUE indices for the recently-operating midwater fleet that are used in stock assessment models.
C.2 (H, 3.3.2) GLM techniques should be used to provide estimates to "fill-in" area/depth strata for which data for some of the earlier surveys are missing, and hence construct a second index of abundance for use in assessments.
C.3 (H, 3.4.2) Future assessments of horse mackerel in Namibia should be based on the approach outlined in Section 3.4.2.
C.4 (H, 3.4.2) A prior for the survey catchability coefficient for acoustic surveys targeted at horse mackerel along the lines of that developed by the BENEFIT Survey Errors Workshop in 2001 should be included in the assessment.
C.5 (H, 3.3.2) The "burn and slice" and surface ageing methodologies should be compared.
C.6 (H, 3.3.2) For assessment purposes, the factor of 4.25 should be used to estimate the nominal (green weight) catch by the pelagic fishery between 1991 and the present from fishmeal production.
C.7 (M, 3.3.2) A summary should be made available for the surveys off Namibia of the areas and depths covered during each survey.
C.8 (M, 3.3.2) Further studies examining how horse mackerel react to research trawl nets should be conducted to establish the proportion-by-length of fish insonified in acoustic surveys which is captured in trawls made during these surveys.
C.9 (M, 3.3.2) An analysis similar to that in Appendix 5 should be conducted using length-age data from many years to evaluate further the extent to which growth rates vary over time, and hence the extent to which the assumption of time-invariant growth is likely to be violated.
C.10 (M, 3.3.2) Data on maturity-at-age and maturity-at-length should be examined quantitatively to determine whether there is evidence of changes in these quantities over time.
C.11 (L, 3.1.2) The catch and length frequency data should be plotted spatially.
C.12 (L, 3.3.2) ICSEAF data on the length-structure of the pelagic catches should be obtained and incorporated in the assessment if available.
C.13 (L, 3.4.2) The growth curve for Namibian horse mackerel should be revised by examining alternative parametric forms for the relationship between length and age, attempting to allow for ageing error, and by examining alternative relationships in the extent of variation in length-at-age with age.

D. Horse mackerel – Angola

D.1 (H, 3.1.3) Coefficients of variation should be obtained for the survey estimates of abundance.
D.2 (H, 3.3.3) Estimates of catch, and samples of the length-frequency of the commercial landings should be obtained.
D.3 (H, 3.3.3) Information about the spatial distribution of the catch could be used to split the historical catch data to species.
D.4 (H, 3.4.3) The approach in Appendix 12 should be explored further as a possible basis for management advice.
D.5 (H, 3.2.3) The survey programme should be continued.

E. Hake – South Africa and Namibia

E.1 (H, 4.1) Age validation for hake should be accorded a very high research priority.
E.2 (M, 4.3.2) Retrospective analyses should be included in future assessments.

F. Hake – South Africa

F.1 (H, 4.3.1) The extent to which catch efficiency for *M. capensis* is estimated to have decreased for the new research survey trawl net should be reduced in assessments until a plausible explanation for this might be found. Assessments of *M. capensis* should take the ratio of the catchability of the new to the previous *F.R.S. Africana* net to be below 1, but not as low as the ratio of 0.6 estimated from the calibration experiments.
F.2 (H, 4.3.2) Longline catch rates on rocky and smooth grounds should be compared to obtain some idea of the relative densities of hake on the two types of ground.
F.3 (H, 4.3.2) Sensitivity to increasing the lower bounds on the residual standard deviations for the CPUE series should be explored.

G. Hake – Namibia

G.1 (H, 4.4.1) Additional data for the "seven vessel" CPUE series should be obtained and the series extended and compared formally with the GLM-standardised series.
G.2 (H, 4.4.1) The logbook data for the seven vessels should be extracted and analysed to determine whether CPUEs, once standardised, are different from the GLM-standardised series.
G.3 (H, 4.4.1) The logbook data should be examined for year/vessel interactions.
G.4 (H, 4.4.1) A sensitivity test based on starting the model in a more recent year (e.g. 1991) and applying it on a species-disaggregated basis should be conducted.

II. Agreements

A. Horse mackerel – general

A.1 (3.2) The available data for *T. capensis* are consistent with the current working hypothesis that the horse mackerel off Namibia and South Africa are independent stocks and can be assessed and managed as such. There is limited sharing of a *T. capensis* stock between Namibia and Angola.
A.2 (3.3.2) If age-composition data are required, it would be better to use the LAK method of Clarke (1981**)** than to apply an age-length key for one year to the length-frequency data for several years (but see also Section 3.4.2). Nevertheless, it remains preferable to fit population models to catch-at-length data for years for which ageing was not conducted.

B. Horse mackerel – South Africa

B.1 (3.3.1) Although the trawl net used in the bottom trawl surveys may be catching horse mackerel off the bottom for much of the time, the catch rates could still provide a useful relative index of abundance.

B.2 (3.3.1) There are considerable benefits to collecting acoustic data from commercial midwater trawlers fishing for horse mackerel whose catches are sampled by onboard scientific observers.

B.3 (3.6) Given the relatively little information on horse mackerel off South Africa, the use of an adaptive harvest strategy is an appropriate way to substantially improve knowledge of the status and productivity of the resource in the short-to-medium term.

C. Horse mackerel – Namibia

C.1 (3.1.2) The impact on assessment results of some of the catches from ICSEAF Division 1.5 coming from South African waters is likely to be negligible.

C.2 (3.4.2) The benefits of different sampling schemes (including different sample sizes and ranges of lengths when constructing age-length keys) could be evaluated by simulating the application of the assessment model to data sets constructed by randomly sampling data from the existing information.

D. Horse mackerel – Angola

D.1 (3.3.3) The weakness of information on catches of horse mackerel off Angola compromises the reliability of assessment results, and therefore improved data collection and further analyses are needed.

E. Hake

E.1 (4.3.3) There is a need to provide management recommendations for South African hake by mid-2005, including advice on the performance of OMPs. This deadline does not allow sufficient time to implement the approach of BEN/DEC04/H/SA/3c, although this approach should remain the long-term goal, in particular to address trans-boundary issues. Instead, variants of the approach of BEN/DEC04/H/SA/3b could be used provided a wide range of scenarios regarding the historical catches is tested; this approach might perhaps also be extended in the direction of the model of BEN/DEC04/H/SA/3c.

E.2 (4.4.3) The approach outlined in BEN/DEC04/H/NA/4c provides a framework within which the issue of allowing for flexibility in management decisions within an OMP setting can be addressed. Decision makers need to be consulted to ensure that any calculations conducted adequately capture likely reality concerning the implementation of flexibility.

Appendix 14 : BENEFIT/NRF/BCLME January 2004 Recommendations for Hake, with Comments and Progress made

DS Butterworth[1], RA Rademeyer[1], RW Leslie[2] and C Kirchner[3]
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A. Both hake species

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

No progress as yet; new staff expert in ageing have been appointed recently.

2) (H) 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 workshop on hake aeging has been conducted this year. Results were not encouraging. Difference between readings by the same reader and between readers were very large (up to 10 years) for sliced otoliths as compared to 2-3 years for whole otoliths. The decision was made to continue using whole otoliths; however methods to validate ageing must be applied.

3) (H) 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).

Further discussions have yet to be held.

4) (H) The spatial distribution of the CPUE information should be included in papers that standardize catch and effort information.

Brandão and Butterworth (2004) considered the information available for Namibian hake in some detail, finding evidence of an expansion to deeper water over the last four years in particular, and also a notable concentration of fishing effort close to Walvis Bay in 1993.

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

Work is in progress for the South African hake resource: see BEN/DEC04/H/SA/3b and 3c.

6) (H) 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 CPUE data.

This will be done during next round of OMP testing.

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

This has yet to be attempted; the seal scat data have been requested but as yet not made available.

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

The BCLME is discussing the possibility of funding further hake genetics work under Dr. Paulette Bloomer.

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

A document providing a simple explanation was written, and two power-point talks given to industry and to senior management (including the Minister) in Namibia.

10) (H) The cost-benefit of the OMP approach relative to other approaches needs evaluation.

A discussion of qualitative pros and cons was included in the items listed under 9).

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

The GLM update for this year was not modified in the interests of comparability with the previous year's analyses when inputting to assessment updates. However, some of the factors listed will soon be explored, though it should be noted that earlier analyses have indicated that the log-normal bias correction factor has minimal impact, and further that all co-variates for which data are readily available are already taken into account in the existing GLM standardization.

12) (M) The sensitivity to ignoring the recent CPUE index and to considering alternative relationships between standardised CPUE and exploitable (essentially the fishable) biomass should be considered when evaluating OMPs.

This will be done during next round of OMP testing.

13) (M) 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 CPUE data.

Not attempted as yet.

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

This will be done during next round of OMP testing.

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

No progress as yet.

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

No progress as yet.

17) (L) The value of using the variances estimated from the application of GLMM models to the catch and effort data to weight the CPUE indices should be investigated.

Not attempted as yet.

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

Not attempted as yet.

19) (L) 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.

Scheduled for consideration in the next stage of development of the SA hake assessment models.

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

No progress as yet.

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

No progress as yet.

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

No progress as yet.

B. South African hake

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

This work has commenced and some initial estimates have been made.

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

There are some doubts concerning the reliability of the species-split information from the observer program, especially during the early years. The concern is based on questions of species identification, but mainly on the experience of the observer with respect to collecting a valid random sample. The usefulness of the observer data will be greatly enhanced by grading the collected data by the experience/ability of the observer.

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

An extensive analysis by Gaylard and Bergh (2004) has been completed and is already in use to split catches by species.

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

This recommendation has been implemented in recent assessments.

5) (H) 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.

The construction of this joint model is imminent.

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

Plans to obtain these data from the observer programme have been implemented. Reliability of the species-split information is dependent on the experience of the observer.

7) (M) The spatial and temporal trends in the catch and effort data for the longline fishery should be analysed.

Initial discussions have been held and analyses are planned, though comparability over time in immediate past years is questionable.

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

Discussions have taken place on this matter, which will also be addressed in a BCLME project headed by Sumaila.

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

Discussions have taken place. See paper BEN/DEC04/H/SA/3c.

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

Cruises are being organised under the BENEFIT programme.

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

This first awaits demonstration of progress using the Namibian seal scat data.

C. Namibian hake

1) (H) The Spanish survey indices should be corrected.

This has been done.

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

This has yet to be attempted; the seal scat data have been requested but as yet not made available.

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

This has not yet been attempted, but will start in the near future (2005)

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

This has yet to be attempted.

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

This is planned for consideration in the next round of GLM standardisation of this CPUE.

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

This has yet to be attempted.

References

Brandão, A. and D.S. Butterworth. 2004. Further investigations of the Namibian hake CPUE data. Unpublished report, NatMIRC Nov 2004 meeting, Doc. 3 (16pp).

Gaylard JD and Bergh MO. 2004. A species splitting mechanism for application to the commercial hake catch data 1978 to 2003. Unpublished report, MCM, South Africa. WG/09/04/D:H:21.

Appendix 15 : Additional Calculations Related to Changes in Survey and CPUE Indices for Namibian Hake

Anabela Brandão

The log-linear regression analyses described in BEN/DEC04/H/NA/4a are repeated here for the fishable component of the survey biomass indices of abundance. The regressions are fitted to all the data as well as to only “comparable” years. (note that the fishable component values used here have not been corrected for certain errors, which were corrected for the data used in BEN/DEC04/H/NA/4a, but the consequent differences are believed to be small.)

Table 1. Parameter estimates and their associated standard error of trend for the fishable survey biomass and the commercial standardised CPUE indices of abundance. The estimates (and standard error) of the difference of the slopes and the test of the hypothesis of equal slopes is shown.

All data		
	Final year	**2004**
Survey	**slope estimate**	-0.0323
	std error	0.0309
	Degrees of freedom	13
CPUE	**slope estimate**	-0.1006
	std error	0.0184
	Degrees of freedom	10
Difference of slopes	**slope estimate**	0.0683
	std error	0.0360
	Degrees of freedom	23
	95% CI	-0.0061
		0.1427
	t statistic	1.8992
	p-value	0.0702
Comparable years		
	Final year	**2004**
Survey	**difference estimate**	-0.0898
	std error	0.0271
	Degrees of freedom	11
CPUE	**difference estimate**	-0.1006
	std error	0.0184
	Degrees of freedom	10
Difference of slopes	**difference estimate**	0.0108
	std error	0.0328
	Degrees of freedom	21
	95% CI	-0.0573
		0.0789
	t statistic	0.3297
	p-value	0.7449