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**DEVELOPMENT OF ECOLOGICAL SUSTAINABLE FISHERIES PRACTICES IN THE**

**BENGUELA CURRENT LARGE MARINE ECOSYSTEM (ECOFISH)**

**SYNTHESIS WORKSHOP, 29.-31. May 2017, DAFF, Cape Town**

# Report

**Monday 29th of May 201**

**Opening of the workshop** by Hashali Hamukuaya

Hashali Hamukuaya reported on recent developments in BCC and emphasized the relevance of progress in Ecofish towards a sustainable management of shared resources within the remits of BCC. Thus, expectations in the project and the Synthesis workshop are high. For agenda of the workshop, see appendix 1.

**Introduction to the workshop and state of the play in Ecofish** by Fritz Köster (session 0, ppt no. 1)

The objectives of the workshop are:

1. Review of results, deliverables and status of activities to date. This will also serve as input to an update of the Narrative report 2016.
2. Identify gaps to be filled and actions to be conducted to fulfil the work programme and deliverables. This will also serve as input to a budget check on allocation of remaining resources.
3. Preparation of presenting results at the ASF in October 2017. Other dissemination should be considered – EU would like increased visibility.
4. Help reporting results and defining the legacy of EcoFish for the final report, to be submitted in January 2018. What is needed to achieve further progress and who provides input to the report?

Focus is mainly on WP1, task 1.2, 1.4-1.7 and WP2, task 2.1-2.3 targeting hake and how the biological tasks feed into the modelling WP, and what is needed to progress towards transboundary assessments. Other WP's and tasks as well as small pelagics are covered, but in a more overarching fashion.

Ecofish has delivered many new results, and has also implemented new methodology, but we underestimated challenges with respect to biological processes, specifically stock structure and distribution, as well as ageing and growth. This had negative consequences on model design and implementation, i.e. a tendency to guide model development by existing information and data, ignoring lack of biological knowledge, and without adequate effort to improve knowledge in parallel.

Consequently, WP2 had to be strengthened during the course of the project and a 10 month prolongation was granted by the EU Commission, with the implementation period now ending on 31 October 2017 with a following 3 months reporting period.

Due to these difficulties, the linkage of WP1-2 to WP3 has suffered as well, both with respect to integrating stakeholder information and implementing the Ecosystem approach. In addition the increasing focus of funding organisations on dissemination is not well reflected in the Ecofish Work Programme. While it is scientifically still well up to date, the lack of focus on information about the project and results, apart from communication with the scientific community and with stakeholders, is typical for a project designed in 2009/2010. During the Consultative meeting held 28-29 November 2016 the EU made clear that they expect more dissemination activity.

In the discussion, it was emphasized that stakeholder involvement was also considered important at the on-set of Ecofish, but dissemination requests have broadened also to the public. For these reasons a review on WP3 for Namibian hake is included under Session 5. Deon Durholtz suggested to engage with the SA National Committee for Oceanographic Research (SANCOR) to facilitate dissemination to the SA and Namibian marine science community.

With respect to EAF related developments since writing the work programme, it is evident that presently focus is on rather concrete aspects such as fisheries impacts on ecosystems, e.g. by-catch including sea birds. This development should be taken into consideration when reporting. Doug Butterworth and Deon Durholtz have ideas for a paragraph of the final report to frame this.

EAF-related activities/research: In early 2015, the DAFF Demersal Scientific Working Group (DSWG), adopted an approach that prioritized ecosystem-related issues of relevance, subsequently identifying a number of projects that could be realistically addressed within a reasonable time frame. Four projects were considered high priority:

- Management of by-catch in the inshore trawl fishery
- Appropriate stock assessments of key by-catch species in the hake trawl fisheries
- Evaluation and management of by-catch of species of conservation concern by the midwater trawl fishery
- Evaluation of the impacts of the hake trawl fisheries on benthic habitats and biota

It was felt that this “targeted” approach would be the most useful in achieving progress in in those areas of EAF implementation that fall within the ambit of the DSWG. The results of the 2011 hake Ecological Risk Assessment (ERA) review (facilitated by WWF South Africa) were considered during the process, and specifically those areas highlighted as gaps in the research and management regimes at that time.

On the importance of ageing problems, opinions differed depending on whether one consider the impact on perceived stock development, stock assessment or management procedures. The last two are more robust than the first in respect of this impact. The possible impacts of age determination errors was evaluated by Rademeyer and Butterworth (2010) using robustness tests during the development of the 2010 South African hake Operational Management Procedure (OMP-2010). Two robustness tests were applied to both hake species, the first assuming that the age estimates were in error by one year less, while the second test assumed that the true ages were half those estimated from otolith analyses. Results of OMP projections based on these alternatives showed minor impacts on projected *M.*

*paradoxus* female spawning biomass (relative to other sources of uncertainty), but somewhat larger impacts on projected *M. capensis* (particularly in the case of the second test), although not to the extent that future *M. capensis* female spawning biomass declined to below the Maximum Sustainable Yield level.

Reference: Rademeyer, R.A. and D.S. Butterworth (2010): Conditioning of the full set of robustness tests for the South African hake resource to be used in OMP-2010 testing and constant catch projections. Unpublished scientific working group document MCM/2010/JUNE/SWG-DEM/31.

**Work Package 1: Development of Regional Stock Assessment Methods (Session 1)**

1. SCAA by Doug Butterworth (Task 1.2) (session 1, ppt 1)

Doug Butterworth described the model set-up and input data of the SCAA for hake with two species, treated as separate populations, but assessed within the same framework to take account of commercial size data that cannot be disaggregated by species. Sexes are disaggregated, growth curves are estimated internally, fitting to age-length information under the assumption of time-invariant length-at-age distributions. Different selectivities are estimated for the West and South coast to reflect different age/ length structures present in those locations. Secondly he described the next steps planned which include i) to refine assessment to provide Operating Models for 2018 as a basis for the SA OMP revision process, ii) use of an M(year, age) matrix from the hake predation model.

Discussions circled around i) the dome-shaped selectivity including modelling selectivity as a random walk process to mimic model selectivity in SAM and ii) the effect of predation and especially the latter is important to estimate the current levels of these two stocks relative to their levels yielding MSY.

The task will continue in 2017 to determine results for modelling key aspects of hake dynamics and management related quantities. The work on management procedures for hake links with similar work in ICCAT and CCSBT on MPs for bluefin tuna, and also contributed to an invited world overview on MPs which was presented to the World Fisheries Congress held in Korea in 2016.

2. Spatial-box modelling of South African hake (Task 1.2 and 1.4) (session 1, ppt 2)

Doug Butterworth described the developed Spatial Box Model for SA Hake with explicit movement, which includes representation of movement matrices estimated on basis of a gravity model to reduce the number of movement parameters needing to be estimated so as to improve estimability. The model was updated, after review by the International Stock Assessment Review Workshop (IWS) in December 2016, with input data to 2016. Alternative runs were conducted including results from GeoPop with and without down-weighting the input surveys' spatial information and keeping only the time trend information. The differences between in- and excluding GeoPop data were limited, showing some impact on SSB in the most recent years and changed movements of age 1 hake of both species in west SA. Nevertheless there are concerns about attempts to estimate movement parameters, with the model experiencing convergence difficulties. A key problem is that there are no data which measure movement explicitly (typically tag-recapture data play an important role in assisting reliable estimation from such models; see also task 2.3). Doug concluded that quantifying the extent of any trans-boundary movement is of importance in terms of the interpretation of the results from any joint SA-Namibian

assessment, but questioned whether attempts to estimate movement parameters in the manner attempted here is the best way to go? Results will be reviewed again by the IWS in December 2017.

3. Cannibalism and inter-species predation (Task 1.5) (session 1, ppt 3)

Doug Butterworth described the major outcomes of Andrea Ross-Gillespie's PhD finalised in 2016 as well as planned work steps in 2017. A key result from this work was the indication that there was some predation release of *M. paradoxus* as a result of the reduction of large *M. capensis* predators as the historical fishery developed (concentrating first on the shallow water species). Results indicated that the *M. paradoxus* population was somewhat (though not substantially) less depleted below its pristine level than has been suggested by models without explicit modelling of predation effects. An immediate and important spin-off from this work was the explicit provision of an indication of appropriate values to choose for hake mortality-at-age vectors. Choices for these vectors constitute a major uncertainty in the current (non-predation) assessments of the hake resources in South Africa, and the predation results will provide a more justifiable basis for specifying these vectors. An update incorporating further data from 2016 is in progress.

The work was reviewed by IWS in December 2016 and the panel made several suggestions for improvement, which are being pursued to be reviewed by the IWS in 2017. An alternative multispecies model by OLRAC shows different results, especially for the pristine stock; a careful comparison exercise for the two analyses is underway, though with a completion date which is uncertain.

The discussion addressed i) differences of derived natural mortality rates from those in the standard SCAA (higher for young and lower for old fish), ii) differences in daily rations of both hake species and possibilities for verification such as use of bio-energetics modelling (which requires, however, reliable growth rates) and iii) the impact of population level differences estimated by the present and the OLRAC model for management.

4. Age- and web-based SAM and Namibian hake model (Task 1.1 and 1.6) (session 1, ppt 4-5)

John Kathena presented i) a general introduction to SAM, methodological achievements within the Ecofish period and the availability as a web based model as well as ii) results from species specific SAM model runs for Namibian hake, contrasting two independent single-species assessments, one for each species, and one combined assessment treating the two species as a single stock. Catch-at-age information from commercial fishery and annual swept-area biomass survey estimates from 1998–2012 were used. The results of the species specific SAM demonstrate that the estimated spawning stock biomass of *M. capensis* has been increasing in recent years, while estimated fishing mortalities are higher on *M. paradoxus*. These observations are not visible in the species-combined assessment. However, the species-combined estimates of fishing mortality and biomass have less uncertainty than the sum of the single-species estimates. Hence, the choice between species-combined and species-specific assessment is a trade-off between bias and variance: Combining data and treating the two species as one decreases the variance by enlarging the database, but introduces a bias originating from difference in population dynamics rates between the two species, when their relative abundances change in time.

Future work was discussed, incl. the extension into ICSEAF period from (1964)-1976 onwards (presently the model runs from 1998 onwards), which may be of limited value when the earlier reported regime

shift in late 1980's was real. The necessities for having a historical stock reference level for a potential MSC certification were discussed. Another part of the discussion focused on results from a GAM analysis of species specific commercial hake catch rates, which confirmed the spatial density patterns resolved by GeoPop, supporting the appropriateness of the algorithm used in splitting the species in commercial recordings.

6. Length-based SAM trials (Task 1.6) (session 1, ppt 6)

Jan Beyer gave an overview on attempts to develop a length based SAM. Despite progress made both to enhance the modelling platform and the model itself, it is not realistic to assume to implement a length based SAM model for hake within Ecofish. Main reasons are: i) lack of clear recurring peaks in the length distributions, ii) increase in dimensionality compared to age-based modelling and iii) growth, mortality, recruitment, and selectivity are confounded. Much work is needed before such a model could be used for joint hake assessment. Future work steps:

- Logistic-normal likelihood option
- Further refinement of recruitment process equation
- Include maturities (S-R relationship)
- Option to estimate trend in growth parameters
- Option to include age-length samples to inform growth parameters
- Time-varying growth parameters
- Estimation of natural mortality when growth is known with good precision (assumed or from age-length samples)
- How to best estimate a standardized length based survey index?

**Work Package 1: towards Work Package 2 (Session 2)**

1. Geostatistical population modelling (Task 1.7) (session 2, ppt 1 was delayed to Tuesday 30th)

Jan Beyer presented results from extensive GeoPop analyses for *M. capensis* and *M. paradoxus*, being already published and in the process of being published, respectively. Results enabled to follow temporal and spatial changes in the distribution and infer movements from the recruitment/nursery areas, through the juvenile phase and the adults' migration to the spawning areas outside/upstream of the nursery areas. The results for *M. paradoxus* indicated one primary recruitment/nursery area on the west coast of South Africa and a secondary less productive recruitment/nursery area on the South African South Coast. Juveniles initially migrate away from the main recruitment area, followed by natal homing by larger individuals. This perception of a, primarily, panmictic population that performs transboundary ontogenetic migrations between Namibia and South Africa corresponds to the results obtained in WP2 task 2.1. The analysis allowed further to estimate average growth and mortality rates. Results were used in modelling tests of task 1.2 and 1.4.

Results for *M. capensis* identified different stocks in Namibia and SA. GeoPop indicates two juvenile areas and two spawning stocks in Namibian waters (Walvis and Lüderitz-Orange) as hypothesized by Wilhelm et al. (2015) – in contrast to genetic analysis from WP2 task 2.1. This result was extensively discussed and reviewing available evidence did not confirm any further evidence for the two stocks in Namibian waters; neither in an analysis of gonadosomatic indices (Jansen et al. 2015), nor in an analysis

of commercial catch rates (Kathena et al 2017). A careful review of the GeoPop results will be conducted and new genetic sampling covering different seasons is underway, but will not be available within the life time of Ecofish. Conclusion: so far one stock of M. capensis in SA and one in Namibian waters with the borderline as mixing area seems to be the most likely case.

Commercial catch rates (Kathena et al. 2017) show *M. capensis* concentrations on border to Angola, surveys show this even for *M. paradoxus* (Jansen et al. 2017), indicating migration to Angolan waters, but no spawning.

Estimated average growth rates (not age resolved), confirm high growth rates described for Namibian shallow water hake by Wilhelm et al. (2015 and 2017), as well as *M. paradoxus* confirming the SA age determination rather than the Namibian (see further WP2 task 2.3).

2. Gear intercalibration (Task 1.7 and 2.2) (Session 2, ppt 2)

Gear-effects are in the present GeoPop analysis hardcoded, based on conducted intercalibration analysis of survey trawl-gears using paired hauls.

The intercalibration analysis is based on a novel method which addresses explicitly small-scale size-structured clustering. This is the nugget effect which in GeoPop was removed to estimate the large scale spatio-temporal variability of the underlying population assuming known relative selectivity effects. Here the task is the opposite one i.e. to estimate relative selectivity. The idea is to avoid the effect of large scale variabilities by interpreting the differences in the two estimated size-spectra of the underlying population at each station as entirely due to relative selectivity effects once the nugget effect has been removed. Thus in this application the observation of the relative selectivity at one station is considered stochastically independent of the observation of the relative selectivity at any other station. The results demonstrate that it is feasible to estimate the relative selectivity in each size class, and to test statistically the hypothesis that the selectivity is independent of time.

Jan Beyer gave a short presentation on the conducted analysis and results, which are close to submission (Thygesen et al. 2017). Results initiated a discussion on why the differences between gears are quite different for the two hake species.

**Work Package 2: Input to Stock Assessment Models (Session 3)**

1. Stock structure of hake (task 2.1) (session 2, ppt 1)

Romina Henriques gave on overview of the results from the genetic analyses conducted. A total of 2100 fishes were analysed for mitochondrial DNA (representing longer-term developments) and nuclear microsatellite loci (short-term development) to investigate genetic diversity levels, and the possibility of population sub-structuring in *M. capensis* and *M. paradoxus*. Despite large estimated population sizes, both species exhibited low levels of contemporary genetic diversity, and observed findings suggest that fishing has had a significant impact on their genetic composition and evolutionary trajectories. Further, for *M. paradoxus*, significant temporal, but not spatial, divergence points to the presence of genetic chaotic patchiness. In contrast, *M. capensis* exhibited a clear latitudinal cline in genetic differentiation between Namibia and South Africa, with low estimates of contemporary gene flow, clearly separating these as different stocks. Seascape analyses reveal an association with bathymetry and upwelling

events, suggesting that adaptation to local environmental conditions may drive genetic differentiation in *M. capensis*. There is no indication of hybridisation between both species, but of convergent evolution in the genetic markers previously used to detect hybridization.

The discussion focussed on:

i) Reasons for the appearance of "Namibian" *M. capensis* in SA waters appear to be linked to hydrographic conditions, specific algal bloom events.

ii) The absence of any signal for a 2nd stock of *M. capensis* in Namibian waters cannot be explained by lack of sampling between Lüderitz and the Orange River or shallow water sampling, as the signal should have been picked up by other samples, given the spatial/temporal life cycle hypothesized by Wilhelm et al. (2015) and indicated by the GeoPop analysis in Jansen et al. (2016). Similarly, lack of winter sampling for genetic analysis, may have an impact on the interpretation where the stock is spawning, but very likely not on the apparent stock structure. Winter samples (pooled samples) have been collected now from four different areas: SA south coast, SA west coats, Southern Namibia and Northern Namibia. However, funding for Namibia sample analysis is needed.

iii) Spawning migrations are in agreement with GeoPop results by Jansen et al. (2016) interpreted as natal homing. *M. capensis* spawns most intensive in austral winter (Jansen et al. 2015), and these ontogenetic spawning migrations are visible in commercial catch rates (Kathena et al. 2017), confirming conceptual life cycle model by Wilhem et al. (2015 Fish Oc.).

iv) Nuclear DNA microsatellite analyses suggest separation of the SA and the Namibian stock of *M. capensis* long before fisheries developed in mid-last century.

v) The low effective population size and the low genetic diversity both for nuclear DNA microsatellite loci and mtDNA of *M. paradoxus*, indicates that some process has reduced the stock size in historical times, which could be predation by *M. capensis*, with this predation pressure released first after the development of the fishery in mid of last century.

vi) Return of *M. paradoxus* from Namibia to spawn in SA waters is perceived as ontogenetic migration. Natal homing is also suggested by GeoPop (Jansen et al. 2017), confirmed by and large by an analysis of gonadosomatic indices (Jansen et al. 2015), commercial catch rates (Kathena et al. 2017) and survey catch rates (Strømme et al. 2016). Spawning takes place around year with increased intensity in March and August to October.

Future research: otolith microchemistry is an option for future migration studies, but expensive and addressing ageing in parallel not easy. Tagging is as well difficult, as hake are staying deep and are relatively fragile. Molecular tagging is possibly a viable option in future studies. Migration is becoming a key issue and Deon will summarise past experience on tagging hake for the final report and conclude on the most promising avenues as well as feasibility studies required.

**Tuesday 30th of May 2017**

The day started with a presentation by Jan Beyer on geostatistical population modelling (Task 1.7) (session 2, ppt 1), which is reported above, followed by:

2. Variability in hake catchability (task 2.2) (session 3, ppt 2)

Paulus Kainge gave an overview of results to date. Results with respect to the South African West Coast survey are : i) time of day effect not relevant (survey robust), ii) wind effect in a part of the area important (stations excluded), iii) high portion of *M. paradoxus* at depths larger than covered by surveys 2002 – 2010 depend on bottom temperature, method for 'adding' biomass established and time series corrected. Data from survey in 2014 and 2015 have been compiled and analyzed for a potential effect of 'Green water' on the catch rates in hake surveys. Results will be reported at the ASF 2017 in October 2017. There was, however, a time of day effect on survey catch rates in the Namibian waters, mostly for *M. capensis* where lower catch rates were observed during night in shallower waters.

The modelling work on 'Environmental effects on survey catch rates of *M. capensis* and *M. paradoxus* in Namibian waters' using updated survey data from 2002 to 2015 was completed, and accepted for publication in a peer-reviewed journal.

The Ecofish instrument package has been transferred to Namibia where it has been used during the demersal biomass survey in January/February 2016. The data from this survey has been used for the annual NatMIRC standard report on environmental conditions off Namibia, and a data set for studying fine-scale effects on hake catch rates is currently prepared. The instrument package has been damaged and needs repair and subsequently calibration. The most practical way forward to accomplish this incl. the ownership was discussed. At present DTU is still the official owner, but a transfer to NatMIRC or BCC should be unproblematic.

Discussions on future research needs included:

i) the use of information on bottom type, perhaps even topographic maps or hydroacoustic derived bottom structure, considering e.g. refuge effects,
ii) diel feeding studies in the region, e.g. through the EAF Nansen Programme.

Recommendations:

i) developed instrument package should be used on all trawl stations in future surveys (if time does not allow recording of ordinary CTD profiles on each station); this was accomplished on the SA (west coast) survey,
ii) further improvements of survey design in Namibia,
iii) harmonize surveys on regional level, which will be a step wise procedure not to destroy existing time series,
iv) initiate a regular joint data collection program with the industry.

3. Current practice of analyzing ageing data and fitting growth curves (task 2.3) (session 3, ppt 3)

Dawit Yemane Ghebrehiwet reported from a training workshop hold in April in Swakopmund focusing on analyzing ageing data, e.g. computing and visualizing of ageing bias and precision, computation of ALKs and using ALK to get numbers at age, fitting growth curves (mainly the typical parametrization of VBGF) and comparing growth curves, and finally modelling maturity. An emphasis of the workshop was to get participants to do all analyses in R, see further under session 6 reporting on Training and Capacity Building.

4. Ageing and growth rate of hake, horse mackerel and sardinella (task 2.3) (session 3, ppt 4)

Margit Wilhelm summarized results on different studies of age validation and age determination, covering *M. capensis* fish length analyses from fur seal scat samples 1996–2007 showing substantially faster growth rates for *M. capensis* in age groups 0-2 (Wilhelm et al. 2013) than previously assumed. The formation of winter and summer translucent zones for young fish were studied by Wilhelm et al. (2015b) indicating that in minimum two translucent zones were formed in the otoliths per year, explaining the previous over-estimation of ages. These high growth rates were confirmed for adults using annual survey- and monthly commercial length-frequency distributions (Wilhelm et al. 2017). The marginal increment analysis conducted with otoliths from Namibian monthly port samples revealed summer (January, April) and winter (August) zonation being indirectly associated with spawning and fish condition (publication under review). Conversion factors from old (slow growth) to new (fast growth) age structure are under preparation. Preliminary analyses for *M. paradoxus* suggest the same tendency with faster growth rates than previously assumed, but slower than for *M. capensis*; however analyses are not as advanced.

Horse mackerel (*Trachurus capensis*) lack sufficient samples for age validation (geographical and seasonal – monthly, though partly rectified now). For *Trachurus tracae* two age-length keys were produced. For Sardinella there is no adequate data available, which needs to be addressed by the BCC Small Pelagic WG.

The discussion centered around:

i) Implications of these faster growth rates of hake in terms of size-at-age, maturity ogives and hake trawl selectivity; the effect of alternative ALKs has been explored for SA *M. capensis*, but mainly with focus on the operational management procedure.
ii) GeoPop analysis confirms fast growth rates for *M. capensis*; as well as results for *M. paradoxus*; for the latter the derived growth rates fit reasonably well to the SA age determination, but not with the Namibian, which show considerably slower growth.
iii) Two steps modal progression analyses applied in Wilhelm et al. (2017) should be checked, suggestion Deon and Doug to help.

Future research

i) Daily ring analysis is an alternative, but likely only functional for young fish.
ii) Monthly otolith sampling in any case a good idea.
iii) Radiocarbon could be an alternative (but works only for fish >10 years).
iv) Growth experiments are difficult to perform.

**Integration of WP2 results into WP1 (Session 4)**

Jan Beyer opened the session with a Food for Thought presentation (session 4 ppt 1) emphasizing the overall challenge for performing integration of process knowledge into stock assessment. The DTU-front page with its many formulas logo indicate that it is important to develop robust theory, but solid data is equally important, which is why the multitude formula part is covered with a fishing boat. It is a slow process requiring time, as illustrated by the remaining equation presenting the core in the Andersen and Ursin Multispecies model, developed almost 50 years ago. This equation links all exploited stocks according to how predation and food consumption takes place. Still today, it is basically the traditional Beverton and Holt single species model, which is used worldwide. History shows the need for

cooperative teams, but also that our ultimate common goal of implementing spatial explicit multispecies assessment models will require at least 10 years more. What we need to focus on at this workshop is the first steps we have and can realistically achieve in Ecofish in 2017.

Coupling various points in the agenda the discussion centered around the need to transboundary assessments. A number of quotes on this central issue are given below:

Doug Butterworth/MARAM: Whether there is a need, depends! Commonly assumed that a transboundary approach is required, but we first need to quantify the extent of stock overlap between the countries. We need data on the table and both parts can be using available stock assessment models taking movements into account in standard fleets-as-areas approaches.

Deon Durholtz/DAFF: At one point we do accept the need for a transboundary assessment, but hake resources have been managed separately in the two countries for 30 years. So what can joint assessment really give us?

Hashali Hamukuaya/BCC: Very soon we will have to begin preparing and consider the feasibility of transboundary assessment. The development of a framework is required from policy level and must result in a plan by 2018, implementation can take very well 10 years or more. This is an important project which fits into the structure of BCC, and I'm delighted to hear which recommendations the Ecofish project will lead to. Not only confined to transboundary assessment, but every aspect of the project such as the future of ageing, further investment in genetics etc.

Paulus Kainge/NatMIRC: Implementation and development needs to be driven by the BCC Demersal and Small Pelagic Working Groups.

Fritz Köster/DTU Aqua: Agreed that it is important to make BCC's WGs operationally, which requires resources.

Jan Beyer/DTU Aqua: It is important to distinguish between stock assessment and giving advice on management of stocks.

Fritz Köster/DTU Aqua: History in Europe confirms that. ICES stock assessment has been established before the EU Common Fisheries Policy. When implemented, the management chose an arbitrary year as starting point, fixing the relative share of quotas for member states. This relative stability has functioned until ca. 5 years ago, when climate change impact got more and more obvious for pelagic fish stocks, starting to invalidate the concept. Implement something which is scientifically acceptable and better abstain from giving advice when the rest of the world does not want it, but at a certain point policy will demand advice on management of shared stocks and then the basis should be in order.

Doug Butterworth/MARAM: Science comes first, and even if not used directly in management advice, it is required for MSC certification, e.g. interactions of stocks with Namibia need to be clarified even when certifying nationally in SA and this needs information and data being available.

Paulus Kainge/NatMIRC: It needs as well model development and availability.

Beau Tjizoo/NatMIRC: …including the codes.

Dawit Yemane Ghebrehiwet/DAFF: It needs a suite of models.

Doug Butterworth/MARAM: … incl. model evaluations. The organization responsible for conducting assessments has to have the code, members representing member countries can use and modify, but should not distribute.

Deon Durholtz/DAFF: We should not forget that we need to deliver to the Operational Management Procedure nationally in parallel.

Kai Wieland/DTU Aqua: Ecofish has at least two positive examples: GeoPop and Genetics, and for stock assessment split of hake data into species is now available for Namibian waters, thanks to progress made by Ecofish.

Subsequently, Jan Beyer/DTU presented an approach to determine movement of cod in a SAM assessment of Kattegat cod including natal homing migration of the North Sea component (session 4, ppt 2).

Margit Wilhelm/UNAM: Process knowledge is important to inform these type of model implementations.

In an attempt to conclude on necessary and realistic steps forward, an agreement was reached on the following: ***The present model implementation appears to be sufficient for M. capensis, with clearly separated stocks in South African and Namibian waters. However, available models and results suggest only one M. paradoxus stock in the region, requiring a transboundary assessment. It is envisaged, that the BCC Demersal WG forms the platform for such combined stock assessment, taking over responsibility for collation of data and handling of models, with clear agreements on access to data and model codes and code of conducts for nationally nominated experts.***

The need for obtaining separate and independent data on fish movements was discussed and it is often thought that tagging is an option but it is not that easy for cape hake.

Successfully tagging and releasing tagged hake is complicated by the depths at which the animals live (barotrauma-induced mortality when fish are brought to the surface to be tagged).

A trial study was conducted on the SA South Coast in 2010. *M. capensis* were caught using handlines in shallow water. Unsuccessful – barotrauma and seal predation on caught fish yielded very few survivors (only 2 fish successfully tagged and released out of more than 200 caught).

The approach of de Pontual et al 2003 (catching hake in very shallow water using a demersal trawl with a sealed cod-end) may be useful for *M. capensis* tagging, but unlikely for *M. paradoxus.* Requires extended ship time and expertise in handling the fish during tagging (and particularly in puncturing the swim bladder to minimize barotrauma-related mortality).

The possibility of tagging fish at depth using a demersal longline with detachable hooks (which then act as tags) was considered in the early stages of ECOFISH, but the hooks apparently fall out after 1 year, which may limit the usefulness of the approach.

<u>Future research</u>:

The potential offered by analyses of otolith microchemistry for future migration studies, should be explored. In view of the expense of such analyses, a feasibility study should be the first step, beginning with a desktop study of international experience in the field, sampling and analytical requirements, and associated likely costs.

Molecular tagging may be a viable option in future studies.

Alternative options for tagging fish at depth should be explored (e.g. the Icelandic apparatus that is incorporated into the cod-end of a demersal trawl, with remotely controlled tagging equipment). The cost of this equipment is currently prohibitive.

**Wednesday 31st of May 2017**

**Work Package 3: Incorporation of Stakeholders' Knowledge in Data Collection and Analysis (Session 5)**

1. Introduction to WP3 and the case of Namibian hake by Hashali Hamukuaya, on behalf of Barbara Patterson (session 5, ppt 1)

The objectives of the study under WP 3 were specifically to develop social and economic indicators; to develop an expert system based on objectives hierarchies and to develop a methodology to integrate stakeholder knowledge into fisheries management. It was further elaborated that the decision support system that was employed under WP3 follows the approach suggested for sustainable fisheries in Australia that was adopted by FAO. It illustrates the EAFs in terms of three separate dimensions: ecological wellbeing, human wellbeing and the ability to achieve. The workshop recognized that this model was essential and underpins most of the EAF work that is currently ongoing in the region (but see note in Session 0 on recent EAF debate turning EAF into situations of fishery topics in South Africa, including inshore by-catch and impact of mining, which are outside the scope of Ecofish).

In the context of the ecological wellbeing of the hake fishery, the focus is on the interaction between the harvesting sector and the ecosystem. A healthy harvesting sector relies on adequate TACs, which in turn require both a healthy target stock and a healthy wider ecosystem. Other high-level objectives are fleet efficiency, compliance with regulation. Human wellbeing in the context of the hake fishery points towards the processing sector, notably secure employment, the health of the employees and with that the health of the households as well as sufficient raw material. The ability to achieve includes objectives such as fair and appropriate resource access; control and protection of the resource and the workforce alike. It is such general qualitative statements that are difficult to link to quantitative stock assessment in WP1 reflecting that EAF today is not considered well-defined.

The results from WP3 shows that the Namibian trawler fleet operates more widely and at depths of 200-1000m with the bulk of the effort (70%) concentrating in 200-400m depths. Between 2003 and 2005, 44% of all trawl sets were made in the central area, more than half of these in the area between Henties Bay and Walvis Bay. These data suggest a disproportionate amount of fishing effort in the central area, which has also been identified as a major spawning area for *M. capensis*. Management measures aimed at protecting spawners and young fish are in place, including the closed area shallower than 200m depth and the annual closed season during October. However, the concentration of fishing effort in the area between 200-400m depths highlights the possibility of fish being intercepted during the spawning migration. Both trawl and longline skippers confirmed this concern during the interviews that *M. capensis* move inshore to spawn; that aggregations of large size fish move fast and that spawning fish don't mix with non-spawning fish. Skippers also reported that in the Luderitz fishing grounds, *M. capensis* seems to behave differently from fish along the northern part of the coast. The workshop

noted that indeed, fishers knowledge is consistent with the research findings under WP1 task 1.7 and WP2 task 2.1 and the two can complement each other. In fact a research project involving both fishers and fisheries scientists may be able to take advantage of the skippers' high-resolution information on hake distribution to learn more about migration and aggregation behavior of hakes.

WP3 revealed that the trawl skippers have abundant knowledge about the migration of *M. paradoxus* between South Africa and Namibia, which is currently disregarded in the assessments in both countries. Thus in the future, a jointly developed research with fishers should make it possible to collaboratively test assumptions regarding migration and range contraction in a way that is acceptable to both fishers and scientists, as has been done in some Canadian fisheries.

From WP 2 work, it is known that hake lifts off the seabed during the day, which affects their catchability by bottom trawl gear. This, in turn, introduces a variable bias into the results of bottom trawl surveys because a proportion of the fish is excluded from the biomass estimates. To complicate matters logbook analysis has suggested that this phenomenon is different for *M. capensis* and *M. paradoxus*. During interviews under WP3, it got obvious, that observations by and knowledge of the industry about catchability and behaviour are consistent with the results of WP2, Task 2.2. Fishers report that they make constant improvements in their fishing gear.

Trawl effort is measured as a number of hours trawled, standardized according to vessel size, and does not take into account net size and engine power. In addition, improved fish finding equipment, knowledge of fish movements, aggregation and shifting across stocks are likely to increase fishing efficiency relative to abundance, offsetting the effects of resource decline. In the stock assessment efficiency is treated as constant, which is clearly inaccurate. The workshop echoed that a closer investigation and quantification of this trend is an opportunity to involve fishers in the assessment process and has the potential to improve the accuracy of the assessment.

Longline skippers describe several types of *M. capensis,* which they refer to as 'white' or 'silver', 'brown' and 'black hake' that are caught in different places: white and brown *M. capensis* are caught on the slope to the south of Luderitz while white *M. capensis* on the shallow parts. The fact that fishers report catching two types of *M. capensis* in different areas at different depths, might point to different habitat conditions and diet, might also point to the possibility of multiple sub-stocks.

Fishing gear in the longline fishery has also changed over time. In the past fishers used to tie hooks directly to the fishing lines, but today a swivel is placed between the hook and the line, which permits the hook to turn independently. Fishers report that the introduction of swivels has increased their catch rates by 20%. The number of hooks set per year has decreased since 2005 while the catch per hook has increased, suggesting an increase in efficiency.

Lack of understanding of hake behavior and the social and ecological factors affecting fishing behavior may lead to inaccuracies in the current assessment of resource abundance. Logbook data are only one source of fishers' knowledge and, ideally, need to be interpreted using substantial knowledge of fishery dynamics – information that is often only available from fishermen. Moreover, disregarding efficiency increase and fishing strategy leads to inflated indices of abundance based on CPUE data. Collecting fishers' information systematically is therefore important. When fishers' information matches scientific information, uncertainty in the assessment is reduced and fishers' confidence in the assessment is strengthened. The workshop concluded that when the information diverges, further investigation of

both types of information (research and fishers) is required, which will ultimately strengthen the knowledge base. Observers are needed for standardization of effort, and the direct contact with the fishers is most important. For example a change in efficiency is often occurring because when fish abundance is going down only the very good fishers remain so efficiency goes up.

Based on the results of the WP3, the Synthesis Workshop concluded that it is essential for fishermen's input into stock assessment and that mechanisms should be developed to ensuring that BCC captures fishermen's knowledge to inform stock assessment in particular and management in general.

2. The case of Angolan fisheries for sardinella and horsemackerel by Kumbi Kilongo

Kumbi Kilongo opened the discussion informing the audience that the consultancy contract on "Evidence based management recommendations for the Angolan horse mackerel and sardinella fishery with special emphasis on use value and employment" was undertaken by Holísticos – Serviços, Estudos & Consultoria, Lda., based in Luanda, Angola. The final report of the study was delivered to the BCC Secretariat in June 2016.

He informed that the activities were mainly concentrated on i) the evolution of the Angolan fishery for sardinella and horse mackerel, ii) institutional dimensions of the Angolan fisheries, iii) fisheries data in Benguela, Namibe and Luanda Provinces and iv) the constraints in the evolution of small pelagic fisheries.

Concerning the evolution of the Angolan fishery for both sardinella and horse mackerel, Kumbi focused on the trends of the biomass and the TAC attributed to these resources according to the registered fluctuation along the years. He informed the audience that due to the very low biomass registered from 2007 to 2009, the fishery for horse mackerel was closed in 2010.

About the institutional dimensions of the Angolan fisheries for sardinella and horse Mackerel, Kumbi informed the following:

a. The fishing rights can be assigned to all citizens, individual or collective, national or foreign, but only the nation citizens have the right for the artisanal fishery.
b. Concerning the participation of fishers, fish workers and community level institutions, he emphasized that from the total catch of Angola, about 35 – 40% results from the artisanal fishing subsector and includes more than 5,000 fishing boats and 50,000 direct jobs. It is estimated that the sector employs more than 85,000 people (direct and indirect jobs). The number of women involved in these fisheries at different level is very low.
c. According to the interactions between different policies, the National Development Plan's (NDP) policy in support of the sector puts emphasis on increased competitiveness and development of industrial and artisanal sub-sectors on a sustainable basis. Different support centers structure for Artisanal Fisheries were developed.

Kumbi also presented the trends of the total catches (Kg) of sardinella and horse mackerel of Luanda, Benguela and Namibe provinces in different years, emphasizing that they have fluctuated along the years according to the fluctuations of the biomass. The caches are supposed to be underestimated due to lack of reporting and excessive landing sites.

The constraints presented for good development of both sardinella and horse mackerel fisheries are: i) difficulty to access credit under the socio-economic category, ii) less fish available under the ecological category and iii) lack of support from government under the management/governance category.

After the presentation, the discussion mainly concentrated on the quality/consistency of the registered catch data.

**Work Package 4: Training and Capacity Building (Session 6)**

The list of conducted courses in Ecofish was presented (last slide in session 7, ppt 1), with specific focus on recent 2017 courses:

- WP1 Stock assessments interpretation course, 18-21. April 2017, Cape Town
- WP2 Age training workshop, 24-28. April 2017, Swakopmund (see Session 3, ppt 3)

The assessment interpretation course was attended by c. 20 senior scientists and managers from INIP/Angola, NatMIRC/Namibia and DAFF/South Africa. In addition c 20 managers, scientists and students from a variety of South African's affiliations also participated. The final report will describe the course in details.

This is the first course of its kind we have had in Ecofish and it appears innovative in advanced stock assessment circles worldwide. Usually focus is automatically placed on technical aspects of conducting stock assessments, which of course is also important, although today not so easy to implement with high variability in stock assessment experience and in mathematical/statistical training among countries and within single fisheries institutes (see below).

The purpose of this course was to assist scientists, when presented with a stock assessment analysis, in interpreting the results, and in particular in understanding what aspects they should be looking for and what questions they should be asking. The course focused on concepts and explanation of terminology with limited mathematical, statistical or coding detail (see course outline in Appendix B).

The Synthesis workshop concluded that Doug Butterworth's assessment interpretations course fulfilled even the highest expectations. Consequently, another course like the one Doug presented would be most useful. Doug spent a great deal of time on data inputs (and their limitations) and the various types of models, implying limited time available for evaluation of the case studies. Senior scientists were in particular happy with the use of these case studies to illustrate/clarify various concepts, as well as an exercise in "guided" critical evaluation of the various assessments. The workshop believes that the rest of the participants would support this view and therefore recommends precisely such a "guided" evaluation from someone like Doug as the most useful approach to getting senior scientists and managers up-dated on interpreting stock assessments, and even providing useful input on their development by properly qualified analysts.

The Synthesis workshop also concluded that training in technical aspects of assessment implementation i.e. proper understanding of the underlying mathematics and then translating this into a model through the coding is not something that can be done during a 1 or 2 week workshop. This rather requires an extended period (months, if not years) of partnerships with properly qualified assessment scientists.

However, recruitment is a problem in all three countries. It is a very limited number of mathematicians and statisticians coming through at post-graduate level who appear to be interested in pursuing fish stock assessment as a career. The workshop proposes a strategy, which will promote the integration of students at an early stage. Students need to be motivated already at undergraduate level, and this must be followed-up with participations on e.g. research cruises and other activities to make sure they understand how the results are used etc.

UNAM similarly pointed out the need for students and asked if the right basis in statistics and mathematics is offered. Moreover there is a need for teaching the teachers. Teachers may not have the capacity to develop models and although most modelling doesn't have to be developed from scratch, lack of access to an assessment expert is a problem. It was suggested to start with data analyses to understand better how data and biological knowledge impact stock assessment. The workshop confirmed that it becomes interesting to understand how stock assessment is linked to ecology. We have seen how important linking growth, ageing and mortalities is becoming. The world is more dynamic than what stock assessment scientists usually believe or want to believe!

The present situation is also characterized by a complete lack of success at employing a properly qualified and experienced senior level stock assessment scientist to lead this work within DAFF. At NatMIRC only one person is presently being recruited as a PhD in applying up-to-date stock assessment methods. The situation is even worse at INIP. INIP, NatMIRC and DAFF were offered by BCC at an early stage of Ecofish to recruit PhD students for stock assessment training at DTU Aqua as this appeared the best option for securing sustainable capacity building. There is, however, also a need to consider the risk that promising scientists move into manager positions.

The workshop expressed that the fact that two NatMIRC scientists, enrolled at DTU Aqua, are expected to finish their PhD studies in 2017, is a success story, which will be of importance for capacity building at NatMIRC. One PhD on environmental impact on survey results as corrected input for stock assessment and another PhD on applying highly advanced stock assessment methods. The latter is able to run and understand age based stock assessment such as SAM and two of the most innovative data-limited methods. As a first consequence, Namibian monkfish stock assessment will now be implemented by Namibians using SAM.

**Summary (Session 7)**

Fritz Köster went through an updated version of the PSC summary presentation on WP1, 2 and 4 (session 7, ppt 1) reporting status in tasks against deliverables, reflected in this synthesis report.

Activities still to be conducted within the remaining time of the project were discussed and a time plan set-up:

- September/October 2017: Meetings of the BCC Demersal (if feasible) and Small Pelagic Working Groups
- 24. October 2017: Final PSC meeting
- 25-27. October 2017: session at the ASF in Windhoek
- 31. October 2017: End of the implementation phase of the project, i.e. only reporting/result evaluation, but costs cannot be acclaimed anymore (information from EU 16. June 2017)
- 27. November-1. December 2017: review of results under task 1.2 and 1.4 by IWS

- 31. January 2018: Final report to be delivered (Narrative report 2017 is not necessary). Information on the structure of the Final report will be distributed.

Tentative list of talks for the ASF

1. Hashali: Ecofish idea and perspectives (could include key EAF aspects)
2. John: Hake species specific assessment in the northern Benguela
3. Romina: What do we learn about stock structures of hake from genetics
4. Teunis Jansen and Jan E. Beyer: Stock structure of hake inferred from geostatistical modelling
5. Margit: Ageing and growth of hake (and horse mackerel?)
6. Paul: Variability in Cape hakes survey catchability in the Northern Benguela
7. Kai: The interpretation of trawl surveys and commercial CPUEs of Cape hakes
8. Casper W. Berg and Jan E. Beyer: Length based stock assessment of hake: can it be done?
9. BCC: Importance of stakeholder knowledge, collaboration, and capacity building (WP 3 & WP 4)
10. Fritz W. Köster: Ecofish achievements 2011-2017 and beyond

The importance of dissemination was highlighted and every participant was asked to conduct a list of dissemination activities conducted within the life time of the project, covering;

- scientific literatures (peer reviewed and none peer reviewed)
- scientific reports
- national and international conference contributions (please give details on which conference, when and where and what the title of your presentation was)
- international working group participation (please give details)
- briefs to managers
- implementation of advice based on activities in Ecofish
- web articles
- articles or interviews to the public
- etc.

Also dissemination in submission, review or press should be listed.

Finally, the workshop was closed by Hashali Hamukuaya, who characterized it as constructive and major step forward and thanked all participants and especially DAFF for their hospitality.

## Appendix A

**DEVELOPMENT OF ECOLOGICAL SUSTAINABLE FISHERIES PRACTICES IN THE**

**BENGUELA CURRENT LARGE MARINE ECOSYSTEM (ECOFISH)**

**SYNTHESIS WORKSHOP**

**Agenda**

**Venue: DAFF, Cape Town, South Africa**

**Monday 29th of May 2017 - Day 1**

| **Time** | **Agenda items** |
|---|---|
| 09:00 | Registration and coffee/tea |
| 09:30 | Opening remarks and general introduction by Hashali Hamukuaya and Fritz Köster |
| **10:00** | **Session 1 on Work Package 1: Development of Regional Stock Assessment Methods, chair: Hashali Hamukuaya**<br>1. SCAA by Doug Butterworth (Task 1.2)<br>2. Spatial-box modelling of South African hake by Doug Butterworth (Task 1.2 & 1.4)<br>3. Cannibalism and inter-species predation by Doug Butterworth (Task 1.5)<br>4. SAM by John Kathena (Task 1.1 & 1.6)<br>5. Age-based and web-based SAM of Namibian hake by John Kathena (Task 1.1 & 1.6)<br>6. Length-based SAM trials by Jan Beyer (Task 1.6) |
| 13:00 | Lunch |
| **13:30** | **Session 2 on WP1 towards WP2, chair: Hashali Hamukuaya**<br>1. GeoPop by Jan Beyer (Task 1.7)<br>2. Gear intercalibration by Jan Beyer (Task 1.7 and 2.2) |
| **14:00** | **Session 3 on Work Package 2: Input to Stock Assessment Models, chair: Deon Durholtz**<br>1. Stock structure of hake by Romina Henriques (Task 2.1) |
| 15:00 | Coffee break |
| 15:15 | Stock structure of hake continued |
| 16:00 | Closure |

**Tuesday 30th of May 2017 - Day 2**

| Time | Agenda items |
|---|---|
| **09:30** | **Session 3 on Work Package 2 continued, chair: Deon Durholtz** |
| | 2. Variability in hake catchability by Paulus Kainge (Task 2.2)<br>3. Current practice of analyzing ageing data and fitting growth curves by Dawit Yemane Ghebrehiwet<br>4. Ageing and growth rate of hake, horse mackerel and sardinella by Margit Wilhelm (Task 2.3) |
| 11.00 | Coffee |
| **11:30** | **Session 4 on integration of WP 2 results into WP1, chair Jan Beyer** |
| | 1. Implications of hake stock structures?<br>2. Implications of M. paradoxus migration?<br>3. Implications of ageing and growth uncertainties?<br>4. Implications of variability in hake catchability? |
| 13.30 | Lunch |
| **14:00** | **Session 4 on integration of WP 2 results into WP1 continued, chair Jan Beyer** |
| | 1. Moving towards transboundary hake stock assessment: How can it be done?<br>2. Different viewpoints? |
| 15.00 | Coffee |
| | 3. Extending GeoPop to take commercial catches into account?<br>4. Is an alternative simple starting point feasible? |
| **17:30** | Closure |

**Wednesday 31th of May 2017 - Day 3**

| Time | Agenda items |
|---|---|
| 09:30 | Other issues we need to take into consideration for producing the final report of WP2- to-WP1 integration? |
| 11:00 | Coffee break |
| **11:30** | **Session 5 on Work Package 3: Incorporation of Stakeholders' Knowledge in Data Collection and Analysis, chair Johannes Iitembu** |
| | 1. Namibian hake fisheries by Hashali Hamukuaya<br>2. Angolan small pelagic fisheries by Kumbi Kilongo |
| 13.00 | Lunch |
| **13:30** | **Session 6 on Work Package 4: Training and Capacity Building, chair Kumbi Kilongo** |
| | **1.** What have we learned from stock assessment training?<br>2. What have we learned from stock assessment Ecofish meetings? |
| 15:00 | Coffee/tea break |
| **15.30** | **Session 7 Summary, chair: Fritz Köster** |
| | 1. Activities still to be implemented before ASF?<br>2. What are the most important findings of Ecofish?<br>3. Dissemination (ASF programme? Other activities? Reporting/final report) |
| 17:30 | Closure |

# Appendix B

## ECOFISH - STOCK ASSESSMENT INTERPRETATION COURSE

18 – 21 April 2017, Cape Town, South Africa

**COURSE PURPOSE AND STRUCTURE**

- Although stock assessments provide the primary basis for scientific advice on measures to regulate the extent of fishing, most fisheries scientists will never themselves carry out detailed stock assessments, but do need to be able to contribute to these exercises, particularly in discussions of their development and their results.
- The purpose of the course was to assist such scientists, when presented with a stock assessment analysis, in interpreting the results, and in particular in understanding for what aspects they should be looking and what questions they should be asking.
- The course focused on concepts and explanation of terminology, with limited mathematical, statistical or coding detail (this was NOT a course on technical aspects of conducting stock assessments).
- Stock assessments for South African and other resources were used as examples to facilitate the explanation of concepts and interpretation

**COURSE OVERVIEW**

1. Objectives of stock assessment
2. Data available
3. Models – types, projections, fit diagnostics
4. Management procedures
5. Further aspects – stock structure, movement, multi-species, data limited

**1. OBJECTIVES OF STOCK ASSESSMENT**

- Quantitative prediction
- Does the model fit the data?
- Estimation of parameters
- Estimation of precision

**2. DATA AVAILABLE**

- Catch (and errors)
- Effort
- Abundance indices
  - Absolute vs relative
  - Surveys [types (trawls, acoustic, egg); design based/stratification; model based; swept area; bias and variance
  - CPUE [bias and standardisation methods; variance]
- Tag-recapture
  - Types (conventional, genetics)

    - Adequate mixing
    - Tag loss and reporting rate
- Catch-at-length/Catch-at-age
    - Sampling of catches (groupings)
    - Extrapolation to population
    - Ageing and reading error
- Demographics
    - Weight at age
    - M
    - Maturity at length/age
- Genetics
    - Classical
    - Close-kin

**3. MODELS**

- **Types**
    - Basic types *[Types; determining which to use]*
    - Aggregated density independent *[Replacement Yield example]*
    - Aggregated with density dependence *[Schaefer model and variants]*
    - Inclusion of age structure
        - Stock-recruitment relationships (and residual statistical properties)
        - Selectivity
        - M and its dependencies
        - Fit criteria
        - Estimation approaches *[MLE; Bayesian; Intermediate (e.g. SAM); Variance estimation]*
        - Model variants *[ASPM; SCAA; SCAL; directly fitting ALKs]*
        - Outputs *[Abundance measures; fishing mortality measures (relation to fishing effort); reference points and their proxies; tabular presentations (including diagnostics); graphical presentations (trajectories and diagnostics)]*
- **Projections**
    - Assumptions
        - Future recruitments *[Deterministic options; stochastic aspects]*
        - Future selectivities *[Surveys; catches]*
        - Future exploitation *[Constant catch; constant fishing mortality (effort)]*
    - Outputs
        - Trajectories
        - Probability envelopes and worm plots
- **Diagnostics**
    - Residual plots and distributions
    - Estimates close to bounds
    - Retrospectives

- Weighting of different data inputs + Data conflicts
- Interpretation of q estimates
- Acceptability of selectivity doming
- Fit convergence (MLE and MCMC)

- **Examples to illustrate concepts and interpretation**
  - SA hake – M, selectivity, S/R relation, two species, multiple fisheries
  - US witch flounder – retrospectives, doming, absolute estimates, data weighting
  - US GoM cod – M vs selectivity vs reference points
  - SA kingklip – RY
  - SA toothfish – data conflict, use of tagging data
  - SA abalone – estimating extent of illegal catch
  - SA anchovy and sardine – S/R relation, stock structure
  - SA WCRL – pre-exploitation level estimation
  - Western NA Bluefin – S/R relation

**4. MANAGEMENT PROCEDURES**

- Why MPs (MSE)
- Objectives
- Alternative scenarios
  - Which to consider
  - Plausibility weighting
- Performance statistics
  - Which to choose
  - How to present/plot
  - How to interpret

**5. FURTHER ASPECTS**

- Stock structure
  - Genetics
    - Conventional
    - Close kin
- Movement
- Multi-species models
  - Whole ecosystem *[EwE, OSMOSE, ATLANTIS]*
  - Minimum realistic/MICE
  - Estimation problems

Data limited approaches