Questions to IWS 2019 Panel with respect to hake, together with brief summaries of the documents provided

Q1) In 2014, the Panel considered a single paradoxus stock in SA and Namibia the most plausible stock structure hypothesis for paradoxus (see MARAM/IWS/2019/Hake/P1). Does more recently available information indicate a need for a change in that view, and if so to what?

Q2) The MSC ask that metapopulations be categorised in terms of Table G2 in the excerpt below from their Standard; which option does the Panel consider provides the most appropriate categorisation of the SA-Namibian hake complex?

Q3) What are the priorities for future genetics data collection and analysis (including analysis of existing samples)?

Q4) How should the various SA-Namibian hake stock structure alternatives shown schematically in Hake/P4 be amended, given more recent information, for initiating further assessment analyses?

Q5) MARAM/IWS/2019/Hake/P4 proposed, and the 2014 Panel concurred [MARAM/IWS/2019/Hake/P1] , that the first (base case) joint assessment attempt be based on a fleets-as-areas approach, which implicitly assumes complete "re-mixing" of stocks each year so as to distribute themselves in an unchanged way from year to year. Should this remain the first step. And if not, what else?

Q6) The base case multiple stock model would assume no permanent interchange between any two stocks of the same species, and furthermore that the spatial distribution (in relative terms) of any one stock at the start of each year was time invariant (as is implicit in the fleets-as-areas approach).

a) Is there a need to consider the possibility of permanent interchange between different hake stocks of the same species; if so, how might the rate of that interchange be best estimated from (e.g.) genetic data (or alternatively specified in some way)?
b) If there is a need to assume some "inertia" in a stock's recovery of its original spatial distribution following spatially different fishing mortality levels exerted the previous year, how best would this be modelled, and how might one estimate how quickly the distribution would be expected to revert to its original pattern?

Table G2. Level of assessment expected and considerations when scoring the stock outcome and harvest strategy components of a unit stock for different forms of metapopulations.

Stock Structure	Description (degree of connectivity and self-recruitment)	Implications for management of the Stock (assessment of Outcome and Harvest Strategy)
A. Single population	Completely isolated. Self-contained with no emigration or immigration of individuals from or to the stock. Occupies a well-defined spatial range and is independent of other stocks of the same species.	Whole population. Fishing on the population has no effect on the dynamics of neighbouring populations. Normal expectations may apply for reference points. The fishery must manage the stock above the point of recruitment impairment (PRI) to ensure recruitment is sustained.
B. Local population with partial isolation	Partially isolated and minimal connectivity. Self-sustaining. The degree of connectivity with other LPs in the metapopulation is so weak that, for management purposes, it can be considered a self-sustaining population. This may be true even if occasional larval exchanges between LPs are enough to maintain a certain degree of genetic flow and homogeneity.	Local population. Fishing on the local population appears to have no effect on the dynamics of neighbouring populations. Normal expectations may apply for reference points. The fishery must manage its own local unit stock above a point of recruitment impairment (PRI) to ensure recruitment is sustained. Requires information on the biology of the species, larval dispersal, source-sink dynamics, and oceanographic conditions supporting management at a local level. Information and uncertainties related to stock structure need to be scored in PIs 1.2.2, 1.2.3 and 1.2.4
C. Local population (s) with moderate connectivity within the metapopulation	Moderate connectivity. The degree of connectivity between LPs is enough to maintain genetic flow and some degree of homogeneity. Source-sink dynamics with variable degree of self-recruitment. Sources of recruits act as core areas in the species range where the species occurs in all years and where the typical age composition exhibits regular recruitment patterns with multiple age classes present. There may be sinks where occasional individuals or low densities usually occur and where populations typically consist of only one or a few age groups, often of old individuals.	Local populations(s). Fishing on local populations affects the dynamics of neighbouring populations. Fishing and the management decision affecting upstream populations will have impacts on the components downstream. Local populations are not entirely in control of their productivity. The fishery must manage its own local unit stock above a PRI to ensure recruitment is sustained, but reference points also need to take into account connections with and dependences on neighbouring local populations. Per recruit reference points (e.g., percentage spawners per recruit) may confirm the good management of the fishery to contribute to the wider surrounding populations. Separate monitoring of absolute reference points (either of incoming recruitment or of local population levels) may also be needed to confirm that the inputs of external recruitment are being sustained. Requires information on the biology of the species, larval dispersal, source-sink dynamics, and oceanographic conditions supporting management at local level. Information and uncertainties related to stock structure need to be scored in PIs 1.2.2, 1.2.3 and 1.2.4.

D Local populations with maximum connectivity within the metapopulation	Maximum connectivity. Metapopulation is panmictic (mating is random within the entire metapopulation). Subpopulations are arbitrary. Well-mixed larval pool	Whole metapopulation. Fishing on local populations affects the dynamics of neighbouring populations. The fishery must manage the whole metapopulation (unit stock) above a PRI to ensure that recruitment is sustained. Special attention may be needed in setting reference points to ensure that the LP structure is not impacted by fishing. Scored against the whole metapopulation. Information and uncertainties related to stock structure need to be scored in PIs 1.2.2, 1.2.3 and 1.2.4.

A brief description of each document is provided in red italics, with the particular aim of linking the documents to the key questions to the Panel. The number in [] refers to the relevant question.

<u>Primary Documents</u>

MARAM/IWS/2019/Hake/P1. Dunn, A., Link, J. S., Punt, A. E., Stefansson, G. and Waples, R. S. 2014. Excerpts from the 2014 International Review Panel Report for the 2014 International Stock Assessment Workshop.

This document summarises the views of the IWS Panel in 2014, which was the last occasion on which the IWS discussed SA-Namibian hake stock structure, particularly in the light of the genetic evidence available at the time, and further the Panel commented on initial approaches to assess the hake stocks in the whole region given their possible transboundary nature. [Q1, Q2, Q3, Q4, Q5]

MARAM/IWS/2019/Hake/P2. Henriques, R., von der Heyden, S., Lipinski, M., du Toit, N., Kainge, P., Bloomers, P., and Matthee, C. 2016. Spatio-temporal genetic structure and the effects of longterm fishing in two partially sympatric offshore demersal fishes. 19pp.

This document provides the most recent detailed published analysis of genetic information for the hake stocks off Namibia and South Africa. [Q1, Q2, Q3, Q4]

MARAM/IWS/2019/Hake/P3. Henriques, R., Kaleinasho, V., Schultze, M., Ndaula, H., von der Heyden, S. and Matthee, C. 2019. Supporting the Blue Economy: Using Genomic Tools for Assessing Population Connectivity and Evolutionary History in the Cape Hakes. Fisheries document FISHERIES/2019/OCT/SWG-DEM/23. 19pp.

An initial analysis, using SNPs genetic data for the first time, which has only very recently become available to inform on the stock structure of the Namibian and South African hake resource. [Q1, Q2, Q3, Q4]

MARAM/IWS/2019/Hake/P4. Butterworth, D.S. and Rademeyer, R. A. 2014. First cut at broad model specifications for the development of transboundary hake stock assessments. International Stock Assessment Workshop document MARAM/IWS/DEC14/Hake/P10. 4pp.

This was the document that provided the basis from which the 2014 IWS Panel developed their comments on hake stock structure hypotheses and approaches to trans-boundary assessments. [Q4, Q5, Q6]

MARAM/IWS/2019/Hake/P5. Questions to IWS 2019 Panel with respect to hake, together with brief summaries of the documents provided

MARAM/IWS/2019/Hake/P6. Japp, D., Durholtz, D. and Fairweather, T.P. 2019. Spatial aspects of spawning of hakes (*Merluccius capensis* and *M. paradoxus*) in the BCLME – a review of available information.

A summary of available hake spatial structure information relating to spatio-temporal spawning patterns. [Q1, Q2, Q4, Q5, Q6]

MARAM/IWS/2019/Hake/P7. 2019. Bergh, M. Use of a no-adult migration model with one-way egg and larval migration in MSE's.

Alternative models for M. paradoxus in the Benguela system with different patterns of fish and larval migration [Q4, Q5, Q6]

Background Documents

MARAM/IWS/2019/Hake/BG1. Ross-Gillespie, A. and Butterworth, D.S. 2019. Response to the review panel report for the 2018 International Stock Assessment Workshop: Hake.

*Note that the 2018 Panel's comments followed from consideration of assessment analyses for the hake resource off South Africa **only**. [Q5, Q6]*

MARAM/IWS/2019/Hake/BG2. Durholtz, M.D. 2018. An overview of the SA hake fishery. 8pp.

General background for and history of the SA hake resource and fishery. [Q4]

MARAM/IWS/2019/Hake/BG3. Waples, R. S. 1998. Separating the Wheat from the Chaff: Patterns of Genetic Differentiation in High Gene Flow Species. 13pp.

Background commentary related to how genetics information can be used to inform on marine species stock structure and management. [Q1, Q2, Q3, Q4]

MARAM/IWS/2019/Hake/BG4. Waples, R.S., Punt, A. and Cope, J. 2008. Integrating genetic data into management of marine resources: how can we do it better? *Fish and Fisheries,* 2008, 9, 423-449. 27pp.

Background commentary related to how genetics information can be used to inform on marine species stock structure and management. [Q1, Q2, Q3, Q4]

MARAM/IWS/2019/Hake/BG5. Waples, R. 2015. Testing for Hardy-Weinberg Proportions: Have We Lost the Plot? *Journal of Heredity*, 2015:106(1):1-19. 19pp.

Background commentary related to how genetics information can be used to inform on marine species stock structure and management. [Q1, Q2, Q3, Q4]

MARAM/IWS/2019/Hake/BG6. Waples, R., Hoelzel, A., Gaggiotti, O., Tiedemann, R., Palsboll, P. J., Cipriano, F., Jackson, J., Bickham, J. and Lang, A. 2018. Guidelines for genetic data analysis. *J. Cetacean Res. Manage.* 18: 33-80, 2018. 48pp.

Background commentary related to how genetics information can be used to inform on marine species stock structure and management. [Q1, Q2, Q3, Q4]

MARAM/IWS/2019/Hake/BG7. Butterworth, D. S. 2019. Some inferences from an overview of genetic and other information regarding some key aspects of *M. paradoxus* stock structure off South Africa and Namibia. Fisheries document FISHERIES/2019/AUG/SWG-DEM/11. 7pp.

A short summary of the more important information on deepwater hake stock structure that became available after the 2014 IWS Panel meeting. [Q1, Q2, Q3, Q4, Q5]

MARAM/IWS/2019/Hake/BG8. Jansen, T., Kainge, P., Singh, L., Wilhelm, M., Durholtz, D., Stromme, T., Kethena, J, and Erasmus, V. 2015. Spawning patterns of shallow-water hake (*Merluccius capensis*) and deep-water hake (*M. paradoxus*) in the Benguela Current Large Marine Ecosystem inferred from gonadosomatic indices. *Fisheries Research* 172 (2015) 168-180. 13pp.

Background information on hake spawning patterns which is summarised in MARAM/IWS/2019/Hake/P6. [Q1, Q2, Q4, Q5, Q6]

MARAM/IWS/2019/Hake/BG9. Kainge, P., Kjesbu, O. S., Thorsen, A. and Salvanes, A. G. 2007. *Merluccius capensis* spawn in Namibian waters, but do *M. paradoxus*? African Journal of Marine Science 2007, 29(3): 379-392.

Background information on hake spawning patterns which is summarised in MARAM/IWS/2019/Hake/P6. [Q1, Q2, Q4, Q5, Q6]

MARAM/IWS/2019/Hake/BG10. Ross-Gillespie, A. and Butterworth, D.S. 2019. Updated specifications, conditioning results and projections for the Hake OMP2018 Reference Set models. Fisheries document FISHERIES/2019/MAR/SWG-DEM/03.

Detailed results for the current Reference Set assessment models used for the SA hake resource, following adjustments made to the models to address comments made by the Panel for the 2018 International Stock Assessment workshop. [Q4, Q5, Q6]

MARAM/IWS/2019/Hake/BG11. Ross-Gillespie, A. and Butterworth, D.S. 2019. Update to the hake Reference Case model incorporating the 2018 commercial and 2019 survey data. Fisheries document FISHERIES/2019/OCT/SWG-DEM/22rev.

An update to the Reference Case operating model presented in MARAM/IWS/2019/Hake/BG10 to take the latest survey and commercial data into account. [Q4, Q5, Q6]

MARAM/IWS/2019/Hake/BG12. Kirchner, C., Kaigne, P. and Johannes, K. 2012. Evaluation of the Status of the Namibian Hake Resource (*Merluccius* spp.) using Statistical Catch-at Age Analysis. *Environment for Development Discussion Paper Series,* October 2012.

An example of the species-aggregated assessment approach currently used to inform the management of the Namibian hake resource. [Q4, Q5, Q6]

MARAM/IWS/2019/Hake/BG13. Kathena, J. N., Nielsen, A., Thygesen, U. H. and Berg, C. W. 2016. Hake species (*Merluccius capensis* and *M. paradoxus*) assessment in the Benguela Current Large Marine Ecosystem. *Environmental Development* 17 (2016) 193-201.

A relatively recent species-disaggregated assessment of the Namibian hake resource. [Q4, Q5, Q6]

MARAM/IWS/2019/Hake/BG14. Jansen, T., Kristensen, K., Kainge, P., Durholtz, D., Stromme, T., Thygesen, U. H., Wilhelm, M., Kathena, J., Fairweather, T., Paulus, S., Degel, H., Lipinski, M. and Beyer, J. 2016. Migration, distribution and population (stock) structure of shallow-water hake (*Merluccius capensis*) in the Benguela Current Large Marine Ecosystem inferred using a geostatistical population model. *Fisheries Research*, 179 (2016) 156-167.

Application of a geostatistical approach to inform on spatial patterning and movement of the ***shallow-water*** *hake species off South Africa and Namibia. [Q4, Q5, Q6]*

MARAM/IWS/2019/Hake/BG15. Jansen, T., Kristensen, K., Fairweather, T. P., Kainge, P., Kathena, J. N., Durholtz, M. D., Beyer, J. E. and Thygesen, U. H. 2017. Geostatistical modelling of the spatial life history of post-larval deepwater hake *Merluccius paradoxus* in the Benguela Current Large Marine Ecosystem. *African Journal of Marine Science,* 39:3, 349-361. 14pp.

Application of a geostatistical approach to inform on spatial patterning and movement of the ***deepwater*** *hake species off South Africa and Namibia. [Q4, Q5, Q6]*