

List of the key focus question(s) for the panel regarding sardine, together with brief summaries of the documents provided

Following primarily the work by Teske *et al.* (2021) (MARAM/IWS/2023/Sardine/BG2), the stock structure of South African sardine as modelled previously requires modification. A conceptual framework for a revised stock structure hypothesis was developed by de Moor *et al.* (2022) (MARAM/IWS/2023/Sardine/BG3) and some associated initial results presented to the International Stock Assessment Review Panel in December 2022. Feedback from the panel included (MARAM/IWS/2022/General/6):

However, the Panel found that the conceptual model still contains assumptions that appear inconsistent with the conceptual understanding (e.g. that warm temperate sardine (WTS) and cool temperate sardine (CTS) spawn at the same time on the west coast but remain genetically distinguishable). Under the new hypothesis, there appears to be an inconsistency between the data of parasite prevalence and intensity on WTS, which imply that a large fraction of WTS must stay for a reasonably long period on the West coast, and the maintenance of genetic separation between CTS and WTS. Moreover, the preliminary modelling led to results that were inconsistent with the conceptual model, which required adding constraints [to] the model fitting process by introducing penalties (e.g. by fixing the R parameter in MARAM/IWS/2022/Sardine/P4) when restructuring of the model might be more appropriate. The Panel concludes that further domestic discussion is needed to describe the stock hypothesis conceptually (e.g. where are stocks spatially during each month by life stage and to how the available data relate to model components) before models (simple or otherwise) are implemented.

This year, the International Stock Assessment Review Panel is being requested to focus on the additional work undertaken to describe the sardine stock hypothesis conceptually, together with the implications of initial results from the revised model. This revised model has been developed to reflect the sardine as consisting either of two components distributed between two areas, or of three components (distinguishing between WTS originating from spawning off the south and the southwest coasts) distributed between three areas.

The documents provided are listed below. *A brief description of each document is provided in red italics.*

Primary papers

MARAM/IWS/2023/Sardine/P1: List of key focus questions for the panel regarding sardine, together with brief summaries of the documents provided.

MARAM/IWS/2023/Sardine/P2: van der Lingen CD, de Moor CL and Coetzee JC. 2023. Available data for determining the occurrence and distribution of Cool Temperate and Warm Temperate Sardine components by life history stage.

This document was developed in direct response to the 2022 International Stock Assessment Review Panel's recommendation above and compiles observed data on sardine from fisheries-dependent and fisheries-independent sources that may be useful in determining where the stocks are spatially during each month and by life stage, and for comparison with the behaviour of these components in the new Operating Model. Life stages / events considered are (i) eggs and larvae / spawning; (ii) pre-recruits; (iii) recruits and (iv) adults. Each stage is described separately.

MARAM/IWS/2023/Sardine/P3: de Moor CL, van der Lingen CD and Teske PR. 2023. A revised hypothesis for South African sardine stock structure.

The revised sardine stock structure hypothesis is conceptualised given newly available genomic and transcriptomic research. This is an update of MARAM/IWS/2022/Sardine/P3 to take account of new information resulting from MARAM/IWS/2023/Sardine/P2. The hypothesis consists of two primary components: (i) some fish of Atlantic Ocean origin (CTS) actively move eastward to take part in the Sardine Run on the East Coast; and (ii) some spawning products of Indian Ocean origin (WTS) are passively transported to the West Coast for a period of time before returning to the South Coast as adults. Those WTS which remain on the (South) West Coast as adults for a period of time before returning to the South Coast, are assumed to spawn there. A notable update

from MARAM/IWS/2022/Sardine/P3 is the assumption that spawning of CTS and WTS on the West Coast is not random and that the components do not mix during spawning. This document provides some necessary background to MARAM/IWS/2023/Sardine/P4.

MARAM/IWS/2023/Sardine/P4: de Moor CL. 2022. Proposed equations for the model of the revised South African sardine stock structure hypothesis.

A brief model description (model equations provided in the appendix) of the model designed to fit the revised stock structure hypothesis to available data. The model is designed to reflect either two components in two areas or three 'components' in three areas, with the latter distinguishing between WTS originating from spawning off the south and southwest coasts.

MARAM/IWS/2023/Sardine/P5: de Moor CL. 2022. Initial results from the revised population dynamics model of the South African sardine resource modelling two components in two areas.

Initial results corresponding to MARAM/IWS/2023/Sardine/P4, modelling two components in two areas.

MARAM/IWS/2023/Sardine/P6: de Moor CL. 2022. Initial results from the revised population dynamics model of the South African sardine resource modelling three components in three areas.

Initial results corresponding to MARAM/IWS/2023/Sardine/P4, modelling three 'components' in three areas.

Background documents

MARAM/IWS/2023/Sardine/BG1: Coetzee JC, de Moor CL, van der Lingen CD and Butterworth DS. 2022. A summary of the sardine (and anchovy) fishery.

This was presented as MARAM/IWS/2022/Sardine/BG1, and is considered sufficiently up-to-date for the purposes of this workshop. It is a summary document providing an overview of the sardine resource and fishery, and a brief description of the data available, together with past assessments and management of the fishery.

MARAM/IWS/2023/Sardine/BG2: Teske PR, Emami-Khoyi A, Golla TR, Sandoval-Castillo J, Lamont T, Chiazzari B, McQuaid CD, Beheregaray LB, van der Lingen CD. 2021. The sardine run in southeastern Africa is a mass migration into an ecological trap.

This was presented as MARAM/IWS/2022/Sardine/P2. Genomic and transcriptomic data are used to identify two 'stocks': cool temperate (Atlantic Ocean) and warm temperate (Indian Ocean) sardine, with sardine participating in the Sardine Run off the east coast comprising primarily cool temperate sardine. This document provided the primary foundation for the difference in stock structure described in MARAM/IWS/2023/Sardine/BG3 and now MARAM/IWS/2023/Sardine/P3 from the previously assumed stock structure. Note, in particular, Figure 3 with the majority of sardine found off the South coast having exclusively "warm temperate" ancestry, and very few individuals having some "hybrid" ancestry (a mixture of cool and warm temperate ancestry). Given the high frequency of hybrid sardine not only on the (south) west coast, but also in the Sardine Run (in which individuals from the "warm temperate" type that dominate the South coast do not participate), hybrid sardine have been proposed by the SWG-PEL to behave as cool temperate sardine for modelling purposes – the preference being to model two population components rather than three.

MARAM/IWS/2023/Sardine/BG3: de Moor CL, van der Lingen CD and Teske PR. 2022. A new hypothesis for South African sardine stock structure.

This was presented as MARAM/IWS/2022/Sardine/P3, and is included here for reference purposes. It details the conceptual framework for the revised sardine stock structure hypothesis put together during 2022. The hypothesis consists of two primary components: (i) some fish of Atlantic Ocean origin (cool temperate sardine) actively move eastward to take part in the Sardine Run on the East Coast; and (ii) some spawning products of Indian Ocean origin (warm temperate sardine) are passively transported to the West Coast for a period of time before returning to the South Coast as adults.