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Hake species (*Merluccius capensis* and *M. paradoxus*) assessment in the Benguela Current Large Marine Ecosystem

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ABSTRACT

An important resource of the Benguela Current Large Marine Ecosystem (BCLME) is the hake fisheries, and accurate assessments of hake stocks are essential. Traditionally, the two species *M. capensis* and *M. paradoxus* have been assessed combined as a single stock, since commercial catch data does not distinguish the two species, but differences in biology and ecology suggest that this could lead to a biased assessment. Here, we apply three state space models to assess BCLME hake stocks off Namibia: Two independent single-species assessments, one for each species, and one combined assessment which treats the two species as a single stock. Catch-at-age information from commercial fishery and annual swept-area biomass survey estimates conducted during 1998–2012 were used, together with information on maturity at age, stock mean weight-at-age and natural mortality. The results 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 an example of a generic trade-off between bias and variance in assessments of structured stocks: Combining data and treating the two species as one decreases the variance by enlarging the data base but introduces a bias originating from difference in rates between the two species, when their relative abundances change in time.

1. Introduction

The Benguela Current Large Marine Ecosystem (BCLME) is endowed with abundance of biodiversity including commercially important fish stocks (BCC, 2012). The ecosystem is shared by Angola, Namibia and South Africa, a situation that underscores the need for collaboration at the ecosystem level, in ensuring sustainable utilisation of transboundary fish stocks. This Ecosystem is home to a well-developed commercial trawl fishery, exploiting two species of Cape hake (shallow water *Merluccius capensis* and deep water *M. paradoxus*) that extend from southern Angola southwards through Namibia and into South African waters (Fig. 1). The total stocks between Namibia and South Africa represent over one-third of the world hake biomass (Sylvia, 1995).

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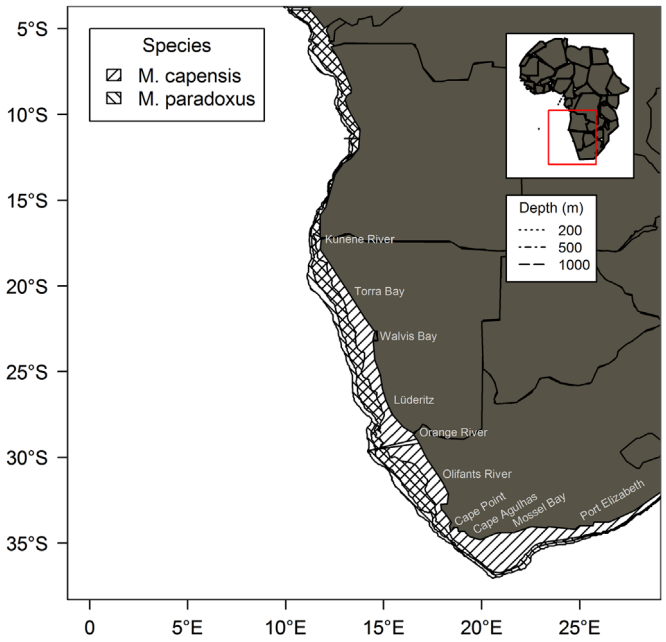

Fig. 1. Distribution of the BCLME shallow-water hake (*Merluccius capensis*) and deep-water hake (*M. paradoxus*) and place names referred in the text.

Given the importance of hake stocks for the Namibian and South African fisheries, and their transboundary nature-BCLME was established to monitor the major transboundary fish resources in the region (Strømme et al., 2015). The BCLME programme has therefore supported appropriate research that contributed to conservation and management of these transboundary fish resources for many years (Strømme et al., 2015). Surprisingly transboundary stock assessment of these fish resources has not yet been carried out in the region and currently there is an ongoing international project Ecofish supporting effort to move towards split-species assessment, transboundary stock assessment and spatial explicitly assessment.

This work presents a stock assessment of two stocks *Merluccius capensis* and *M. paradoxus* off Namibia that have historically been assessed as a single stock (Butterworth and Geromont, 2001; Butterworth and Rademeyer, 2005; Kirchner et al., 2012) since commercial catch data does not distinguish between the two species and due to lack of a developed algorithm for separation of this data. The two hake species are morphologically very similar in appearance e.g. shape, structure and colour (Gordoa and Duarte, 1991; Lloris et al., 2005) but differing in numbers of vertebrae (von der Heyden et al., 2007) pigmentation of the gill rakers and colour of the anal fin (Gordoa et al., 1995) and the shape of otoliths and pectoral fin (Inada, 1981). The morphological similarity and overlapping distributions have made it difficult to register the two species separately in the commercial catches. This has prevented biologically plausible single-species stock assessments from being carried out. The species separating method in the commercial catches has since been developed (Johnsen and Kathena, 2012) and a single species assessment is now possible.

The purpose of this study is to illustrate the difference between combined and single species assessment and the implications thereof. The focus is on estimating species specific management quantities and assesses how that affects the current perceptions of the hake stock. A state-space model (Nielsen and Berg, 2014) is used to compare the join species assessment using combined data with two independent single species assessments using data that has been separated into species. A key feature of the state-space assessment is time varying selectivity. Contrasting with the combined species assessment approach, a single species approach provides species specific estimates of spawning stock biomass and fishing mortality which are useful management quantities that can be used in management recommendation and ease the process of setting the total allowable catches (TAC).

The two stocks are characterized by marked differences in depth preference with *M. capensis* occupying 50–400 m bottom depth, while *M. paradoxus* inhabit deeper water 250–800 m (Gordoa and Duarte, 1991; Burmeister 2001). *M. paradoxus* overlaps with *M. capensis* between 250–400 m bottom depths (Botha, 1985, Boyer and Hampton 2001; Burmeister, 2001). Geographically *M. capensis* occupies shallower water and more northerly area than *M. paradoxus* (Burmeister, 2001), although, *M. paradoxus* is also observed in shallow water but only south of Luderitz (Johnsen and Kathena, 2012). The survey data suggest that catches deeper than 600 m bottom depth are solely *M. paradoxus* (Johnsen and Kathena, 2012). Diel variation in bottom trawl catch rates of the two stock revealed that average catch rates were about 3.6 times higher around noon that during the night, but areas dominated by *M. capensis* recorded a higher diel variation (Johnsen and Iilende, 2007), indicating differences between the two species in vertical behaviour and catchabilities. Trophic analysis using stable isotopes has also suggested that *M. paradoxus* feed at higher trophic level than *M. capensis* (Iitembu et al., 2012).

Spawning patterns of the two hake species differ in area, depth and timing (Jansen et al., 2015). *M. paradoxus* spawn offshore 200–650 (Jansen et al., 2015), whereas M. capensis spawners were found in shallower water (Kainge et al., 2007). *M.*