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Original Research

Distribution patterns of spawning stock of hake maturity stages in the Benguela ecosystem of Namibia

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ABSTRACT:

Distribution of maturity stages within populations of *M. capensis* and *M. paradoxus* were investigated along the Namibian coast between 17 – 28°S latitudes and within 100 m to 600 m water depths. Sampling was conducted in summer, during the period of January-February 2012 with a bottom trawl on board the MFV Blue Sea research vessel. A total of 217 stations along the coast were sampled targeting the two species of hake. Results indicated significant differences in the distribution of active stage of *M. capensis* and in the ripe and running, ripe and inactive stages for *M. paradoxus* with regard to latitude. Whilst for depths significant differences were only observed in ripe, ripe and running maturity stages for *M. capensis* and the inactive stage for *M. paradoxus*. Maturity stages distribution between the two species differs significantly in inactive stage with regard to latitude and in the active and inactive stages with regard to depth. There exists fluctuation in maturity stages of the two hake species and this can be due to feeding behavior, spatial distribution and differences in spawning locations.

Keywords:
Benguela ecosystem, maturity distribution, hake species, maturity stages.

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INTRODUCTION

Namibia's commercially exploited marine resources are dominated by hake species of *Merluccius capensis* and *Merluccius paradoxus* (Franca, 1960) which are the most economically important species (Van der Westhuizen, 2001; NatMIRC, 2007). These species amongst others are managed based on stock biomass estimation. Moreover, gonadal maturity of species can also be considered in the management of the stock. This is mainly because gonadal maturation estimation could also be linked to age and size at which 50% of individuals mature (Jorgensen, 1990; Heino *et al.,* 2002).

The Namibian marine environment is a part of the Benguela Current Upwelling system which stretches from Cape Agulhas (35°S) to Angola (15°S) (Sakko, 1998). The temporal and spatial variability of the Benguela ecosystem are inherent characteristics of the system and results in a diversity of marine habitats, characterized by dynamic processes which can cause remarkable changes in distribution of fish species (Nashima, 2012). In the Benguela ecosystem along the Namibian coast, studies of maturity behavior of hake species are well documented (Gordoa *et al.,* 1995). However, maturity stages of hake stocks in terms of spatial distribution are poorly represented. Understanding the dynamics of distribution of maturity life stages of the species is crucial as it can help complement and improve on the existing management regulations such as area restriction to protect and safeguard the critical spawning stage of the stock. Therefore, this study examined the distribution of spawning stages of hake stock in the Benguela ecosystem for probable distributional patterns.

MATERIALS AND METHODS

Study area

The study area falls within the 200 nautical miles (NM) Exclusive Economic Zone (EEZ) of Namibia and was confined between Kunene river in the north bordering with Angola and Orange river in the south which border with South Africa – at latitude 17°S; 12°E and 28°S; 15°E, respectively. The area lies at depths of 100 m to 600 m.

Study design

The survey design used for data collection was based on transects, where stations are semi-randomly distributed along transects that run perpendicular to the coast, approximately 20 – 25 Nm apart and cover distances between 20-80 Nm. Stations within transects were selected in such a way that each 100 m bottom depth had at least one station.

Sampling procedures

Maturity data of hake (*M. capensis* and *M. paradoxus*) in the Benguela ecosystem of Namibia were collected during the period of January – February 2012 on the MFMR Blue Sea research vessel. Maturity data were sampled at 2[illegible] stopover stations within the study area using a [illegible] m trawl net with inner mesh size of 10[illegible] mm. At each station, hake species sampled were sorted by species and counted. In addition, they were sexed visually through gonad observation and assigned to one of five maturity stages (i.e. inactive, active, ripe, ripe and running, spent) by looking at the gonad development.

Data analysis

The abundance of the various maturity stages of both hake species was calculated for 100 m, 200 m, 300 m, 400 m, 500 m and 600 m seafloor depths along latitudinal transect lines (i.e. 17°S - 28°S). A One-way Analysis of Variance (ANOVA) was used to test for significant differences in abundance of fish maturity stages at different water depths and also along different latitudinal lines. A Paired sample t-test was used to test for significant differences in maturity stage distribution of the two hake species with regard to changes in depths and latitudes. Furthermore, a *Dunnett's post-hoc* test was used to determine means which are significantly different from each other.

RESULTS

Maturity stage classification of hake species

Table 1: Maturity stage classification in males and females for both *M. capensis* and *M. paradoxus* (Shikongo, 2010).

Stage	Females	Males
1	Inactive: Gonads small, slender, transparent, and no visible signs of the eggs.	*Inactive*: Gonads very small, slender, transparent, ribbon like and unlobed
2	*Active*: Gonads large and filled with small, pink-orange, opaque and visible eggs	*Active*: Gonads large and distended, white opaque, typically lobed
3	*Ripe*: Gonads very large in relation to fish size, distended and filled with clearly visible opaque eggs-some eggs already translucent; colour of ovaries bright orange to deep pink	*Ripe*: Gonads very large in relation to fish size, white opaque, distended with sperm, with pronounced lobes
4	*Ripe and running*: Translucent eggs can be extruded through the cloaca with slight abdominal pressure	*Ripe and running*: Gonads very large and distended, with sperm flowing spontaneously
5	*Spent*: Gonads visually completely empty, but large, flabby, prominently veined and often bloodshot	*Spent*: Gonads very small, lobed, flabby but not distended

Source: Shikongo, 2010

Assessment of the distribution of various maturity stages along latitudinal gradients

Maturity stages distribution of hake species fluctuated along the latitudinal gradients and no clear trend was observed (Fig. 1). The maturity stages of the two hake species indicated higher abundance of active and ripe stages compared to the other stages. Total abundance in maturity distribution of spent and inactive stages of both hake species was very minimal (<100 individuals) along the latitudinal gradient.

The analysis of results revealed a significant difference in the abundance of *M. capensis* in the active stage (F= 3.75, df = 12, p=0.000) at some of the sampled sites along the latitudinal gradient. The *Dunnett's post hoc* test further indicated significant differences among the following latitudes: (a) 22°S and 29°S (b) 25°S and 29°S (c) 28°S and 29°S (p<0.05). As for *M. paradoxus,* a significant differences in abundance of maturity stages of ripe and running (F=2.77, df=11, p=0.004), ripe (F=2.162, df=11, p=0.026), and inactive

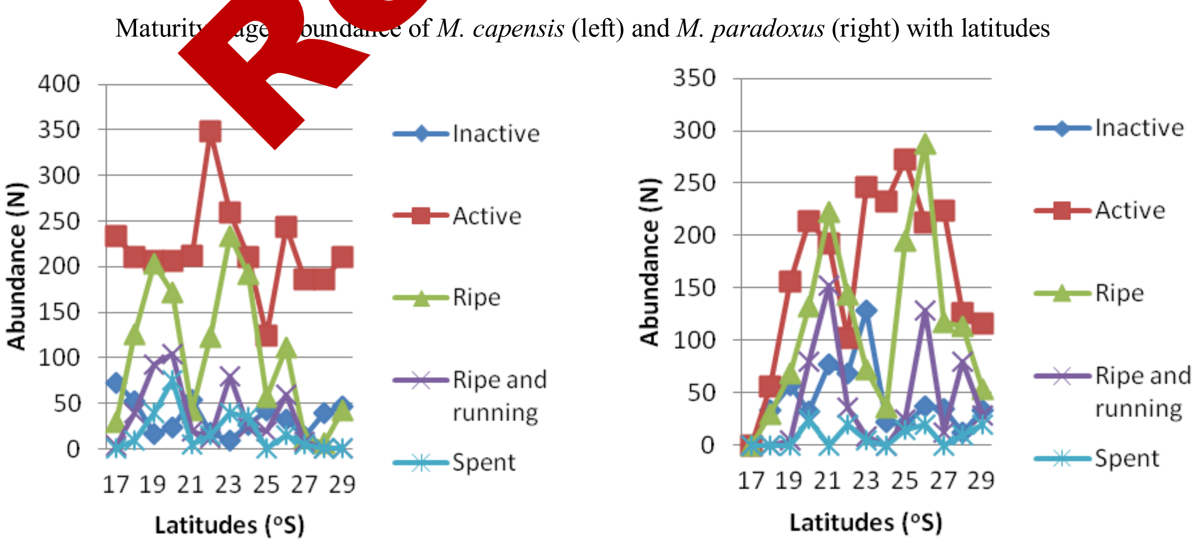

Figure 1: Abundance of *M. capensis* and *M. paradoxus* within the various maturity stages along the latitudinal gradients (°S).

stage (F=2.49, df=11, p=0.010) was observed. Further analysis with the *Dunnett's post-hoc* test indicated significant differences among the following latitudes: ripe and running at latitude 21°S and 29°S (p=0.047), ripe at latitude 26°S and 29°S (p=0.001), and for inactive stage at latitude 23°S and 29°S (p=0.006).

The distribution pattern of the maturity stages of the two species of hake indicate significant differences in the abundance of fish in the active stage (t = 1.74, df =12, p=0.25). The abundance of *M. paradoxus* in the active stage was significantly different from *M. capensis* at 17°S, 18°S, 22°S, 25°S and 29°S. The active maturity stage of *M. capensis* was highest at 22°S latitude (lowest for *M. paradoxus*) while for *M. paradoxus* it was highest at 25°S (lowest for *M. capensis*) (Fig. 2).

Assessment of the distribution of various maturity stages with depth

The mean abundance of the various maturity stages of *M. capensis* and *M. paradoxus* was highest for the active stage within the 100 - 400 m depth, followed by the ripe, ripe and running, inactive and finally the spent stages (Fig. 3). The highest abundance of all maturity stages for *M. capensis* was found between 200 m and 300 m water depths, while for *M. paradoxus* the highest abundances was observed at 300 m – 500 m water depth (Fig. 3).

Significant differences in abundance of *M. capensis* with depth were found between the ripe (F=2.82, df=3, p=0.044) and the ripe and running (F=3.90, df=3, p=0.012) maturity stages. The *Dunnett's post-hoc* test indicated that significant differences in the ripe stage was observed between 100 m and 300 m depths (p=0.049), while for ripe and running stage differences were observed between 300 m and 400 m depths (p=0.048). For *M. paradoxus* the ANOVA indicated significant differences in the inactive (F=2.58, df=5, p=0.032) and spent (F=4.71, df=5, p=0.001) maturity stages. The *Dunnett's post-hoc* test indicated that at 600 m depths the differences in abundance of *M. paradoxus* in the inactive stage was significantly higher than at [illegible] m depths (p=0.05), while for spent stage the differences in abundance was significantly high at [illegible] than at 600 m (p=0.016), and at (b) 300 m than [illegible] m (p=0.021).

There was a significant difference in the abundance of fish in the active maturity stage between the two species at all depths, except at 300 and 600 m water depths (t =-2.14, df =5, p=0.031). There was also a significant difference in the abundance of fish in the

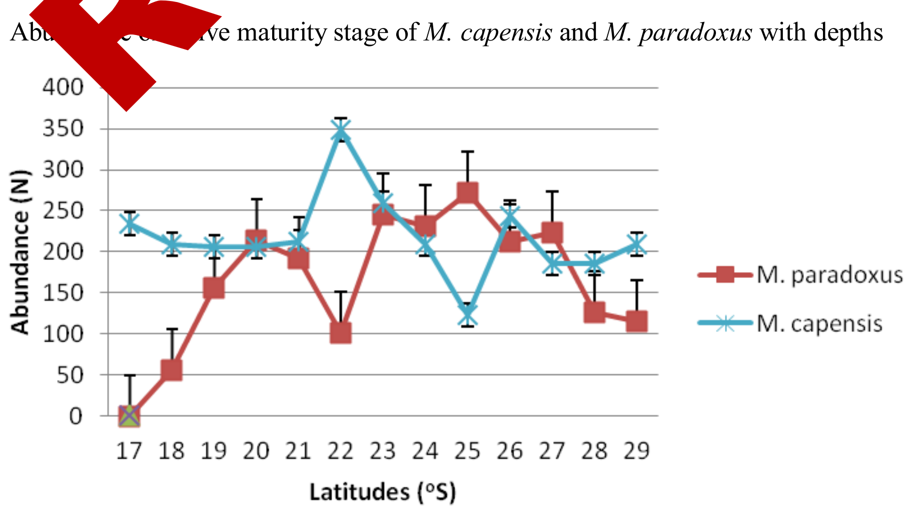

Figure 2: **Abundance of *M. capensis* and *M. paradoxus* of active maturity stage along the latitudinal gradients or bars indicate 95% confidence interval of the mean.**

Maturity stages abundance of *M. capensis* (left) and *M. paradoxus* (right) with depths

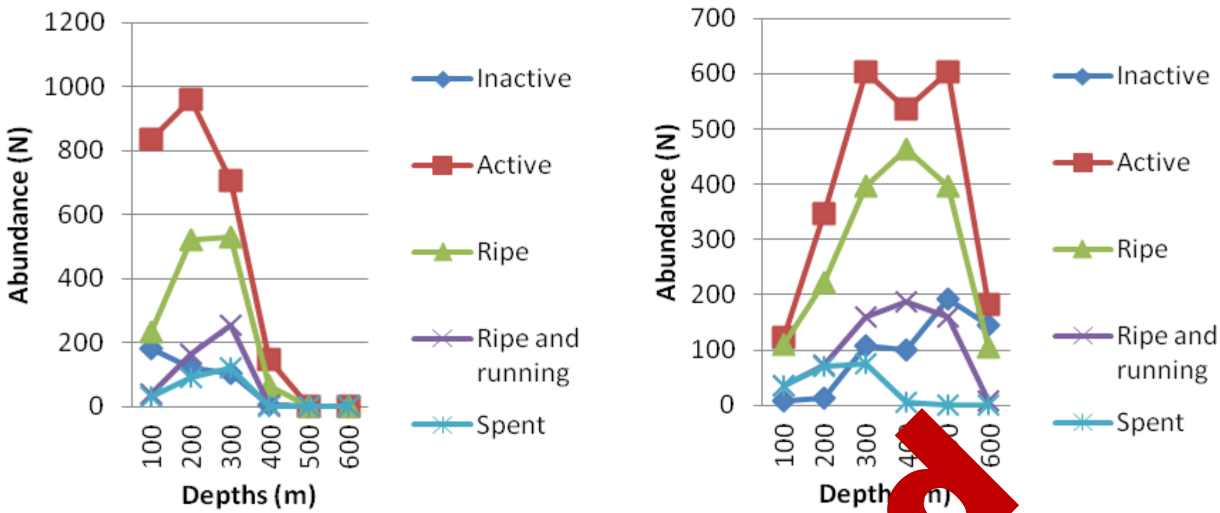

Figure 3: Abundance of the various maturity stages of *M. capensis* and *M. paradoxus* at different water depths (m).

Maturity stages abundance of *M. capensis* and *M. paradoxus* in active and inactive stages

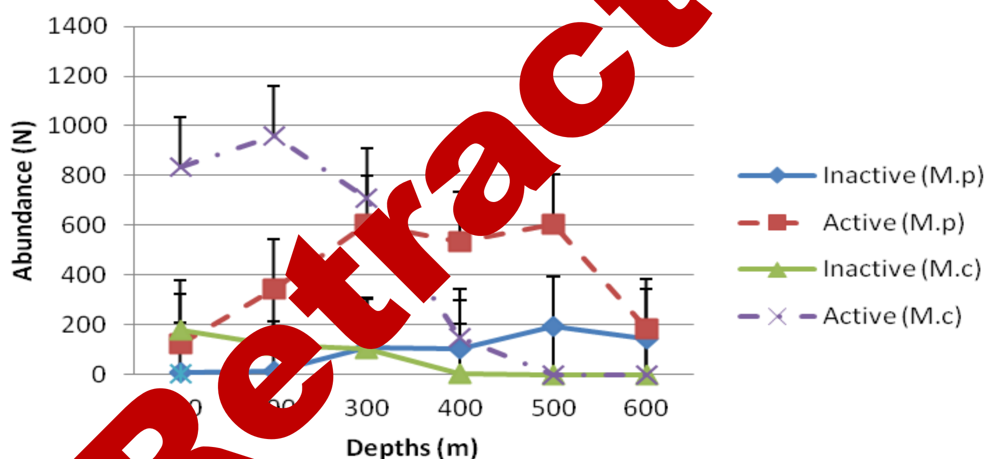

Figure 4: Abundance of *M. capensis (M. c)* and *M. paradoxus (M. p)* in active and inactive maturity stages at different water depths. Error bars indicate 95% confidence interval of the mean.

inactive maturity stage between the two species at all depths, except at 300 m water depth (t=2.13, df = 5, p= 0.53) (Fig 4). The comparison in abundance and distribution of other maturity stages for the two species of hake were non-significant.

DISCUSSION

This study investigates spatial patterns of distribution in abundance of different maturity stages of hake species in the Benguela ecosystem of Namibia during summer. Maturity stage distribution of the two hake species fluctuates along the Namibian coast with highest abundance observed of active and ripe stages located mainly at 22°S - 23°S for *M. capensis* and 23°S - 25°S for *M. paradoxus*. This area is a well-known nursery ground for most pelagic species including hake (Hutchings *et al.,* 2002), hence the high abundance of active and ripe stages of hake observed in this area. This distribution pattern can be linked to gonad maturity requirements. Carpentieri *et al.,* (2005) documented that energy demand is a critical for gonad development and that it require increased feeding intensity. Thus, the high occurrence of hake species of active and ripe stage can indicate that such stages demand that feeding can be increased for energy boost to support gonadal development. This explanation is in agreement with results obtained from a similar kind of study conducted by Khan *et al.,* (1988) on catfish (*Mystus nemurus).* They found that feeding intensity tend to change as fish approaches the first stage of maturity (active stage).

In this area (nursery ground) noteworthy observation in the low abundance of spent and inactive stages are seen. Trent and Hassler (1966) conducted a study on feeding behavior of adult striped Bass (*Roccus saxatilis*) in relation to stages of sexual maturity and they conclude that fasting occurs for only a brief period just before and during the act of spawning. This behavioral pattern if exists in hake species can explain low occurrences of spent and inactive stages in the vicinity of nursery ground. Although, *M. capensis* is believed to spawn throughout the year (Kainge *et al.,* 2007), a low abundance of ripe and running maturity stage individuals indicates that summer is not the peak season for hake spawning.

Though the peaks in spawning seasons of the two species coincide, the location differs for the two species. *M. capensis* is known to spawn on the Namibian coast where spawning of *M. paradoxus* is not likely in the same manner (Kainge *et al.,* 2007). This phenomenon might be dictated by environmental conditions. *M. paradoxus* is known to spawn on the western Agulhas Bank of the coast of South Africa during the late austral winter to spring in the months of September and October, when offshore currents are relatively weak (Grote *et al.,* 2012). Stronger currents of the Namibian coast (Hutchings *et al.,* 2002) might explain the absence of spawning of *M. paradoxus* in the Namibian coast.

The comparison in maturity stages of the two species along the latitudinal lines indicated significant differences in the abundance of individuals in the active stage. This might be due to differences in spawning time flame with *M. capensis* spawning throughout the year with the active stage nearly evenly distributed along the entire Namibian coast. The active stage of *M. paradoxus* was less pronounced in the far northern part of the country at 17-19°S. This can be related to the overall restricted geographic distribution of the species in the far north of Namibia (Grant *et al.,* 1987).

The abundance of the various maturity stages of *M. capensis* was high at 100 m – 300 m while for *M. paradoxus* it was high at 300 m and 500 m (Fig. 4). However, significant differences were only observed in the active and inactive stages of the two species at 100 m and 300 m depths as well as 300 m and 400 m for ripe and running stages. Although spatial separation in maturity abundance was observed, there are overlaps in their distribution with regard to depths. This overlap relates to feeding behavior as both are known as opportunistic predators of small fishes (Roel and Macpherson, 1988) while they can also be cannibalistic (Punt *et al.,* 1992).

CONCLUSIONS

This study highlighted several trends in spatial distribution of maturity stages of *M. capensis* and *M. paradoxus* in the Namibian waters. Significant differences in maturity stages distribution was observed within and between the two species at various depths and latitudes. Comparison in maturity stages distribution between the two species differs significantly in the active stage with regard to latitude and in the active and inactive stages with regard to depth distribution. The observed pattern of spatial distribution in maturity stages of the two hake species might be due to their feeding behavior and differences in spawning grounds. The current results are only based on summer months and therefore do not take season into account. Thus, further research needs to be taken to establish distribution pattern throughout the year.

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