Black hake (*Merluccius polli* and *M. senegalensis*) off Mauritania: spatio-temporal distribution of two sympatric species. 2. Population structure

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INTRODUCTION

The population structure of fishery resources is a very important information for stock assessment (REF). Data on size frequency distributions of catches of exploited species and their temporal evolution allow for a more accurate assessment of the exploited populations in a given area (Cadyma, 2002). Size also provides some information on the age structure of the population, since age and size are correlated. Catch-at-size data can therefore be converted into catch-at-age to obtain the age composition of the catch, or (García, 1986) to estimate growth rates (Bhattacharya, 1967; Sparre, 1987; Sparre and Venema, 1996).

All over the globe, hake stocks usually show an overlap of at least two species in their intermediate area of distribution. This is a quite difficult issue to address with, since the exploitation of hakes in their overlapping zones produces size distributions of landings corresponding to a mixture of *Merluccius* spp. specimens. In certain areas, the ignoring of this fact leads to entirely attribute hake landings to the dominant species (Roldán and Pla, 2001; Ressler *et al.*, 2004; Machado-Schiaffino *et al.*, 2008; García- Vázquez *et al.*, 2009).

Two black hake species, Senegalese hake (*M. senegalensis*) and Benguela hake (*M. polli*), are fished in Mauritanian waters and, despite their spatial and temporal segregation in the area but due to their resemblance and overlapping at certain depths, they are mixed in catches and are commonly marketed as *Merluccius* spp. Thus, black hake landings only provide data on the retained catch of the mixed species (*Merluccius* spp.), since the large landed volumes by fishing trip is extraordinarily hindering the sorting into species, especially when *M. senegalensis* is fished in low proportions (Fernández- Peralta *et al.*, 2013, in this WG). Unable to accurately separate the two species in the landings, these northwestern African black hake species have been evaluated as a single-species *Merluccius* spp. stock, historically assessed by production models (FAO, 1986; Ramos and Fernandez, 1995; FAO, 2011). The same problem occurs in other hake fisheries: the two Cape hake species, *M. paradoxus* and *M. capensis* (Payne and Punt, 1995); the two Argentinean hakes *M. hubbsi* and *M. australis* (Bezzi *et al.*, 1995; Tingley *et al.*, 1995), or the two hakes fished in Chilean waters *M. gayi* and *M. australis* (Aguayo-Hernández, 1995). In all these examples, the overlapping pattern of a shallower water species (in Mauritanian waters *M. senegalensis*) with a deeper species (*M. polli*) is verified (Lloris *et al.*, 2003; Fernández-Peralta *et al.*, 2006; 2008; 2011).

This study analyzes data on size frequency distributions collected both from commercial vessels and resource assessment surveys to describe the spatio-temporal evolution of the population structures of both species in Mauritanian waters. Improving our knowledge of the population structure of the Mauritanian black hake species will certainly help for a better management of mixed-species fisheries.

MATERIAL AND METHODS

We used data from two sources: a series of data from commercial vessels operating in the Mauritanian EEZ and a series of data collected from the oceanographic surveys in waters off Mauritania.

The Instituto Español de Oceanografía (IEO) placed scientific observers onboard commercial Spanish trawlers fishing for black hakes to sample 24 trips throughout years 2007, 2009 and 2011. They sampled a total of 843 hauls carried out between 33 and 1098 m depth. In 403 of these hauls, the observers sorted hakes into species and recorded their corresponding total lengths (TL, at the nearest cm). A total of 72800 specimens were measured for *M. polli* and 4595 for *M. senegalensis*. The average sampled weights per haul were 9% and 15%, respectively.

We also analyzed data collected during 4 demersal assessment surveys jointly carried out by Institut Mauritanien de Recherches Océanographiques et des Pêches (IMROP) and IEO onboard the Spanish R/V *Vizconde de Eza*, from 2007 to 2010 in mid-November to mid-December of each year. The methodology used in these campaigns is widely described in Ramos *et al.*, 2010 and Hernández-González *et al.*, 2011. The average depth range explored in these campaigns was from 79 to 1867 m, although this study analyzed a total of 189 hauls performed at depths up to 1100 m, the maximum bathymetric occurrence of Benguela hake, *M. polli*. Onboard and for each sampled haul, black hake species were sorted in the catches, and their size (TL, to the nearest cm) measured to record the length frequency distributions for both species.

To obtain a more robust information, we grouped all data from the same source (commercial fishing or surveys) and we did not take into account their inter-annual variation.

For each hake species, we have analyzed the length frequency distributions by bathymetric stratum, using both data from commercial catches and surveys. Also, we have analyzed the length frequency distributions by degree of latitude north and their variation in an annual cycle, using only data from the catches of commercial vessels. We are not considering *M. senegalensis* data from January (41 hauls sampled), March (only 6) and September (26), because they were made at deeper bottoms than those where this species is normally distributed. For both species, we have also analyzed the length frequency distribution data corresponding to the spawning period (grouping monthly data between October and March) compared to that of the resting period (monthly data from April to September), from the commercial catches.

Using data from commercial sampled trips, we have also estimated the length frequency distributions in the discarded fraction of the catch by depth, as well as the mean length. We have also compared the mean lengths of total catches by depth from surveys with those obtained from commercial data.

In 1998, Mauritanian authorities established a minimum landing size (MLS) for *Merluccius spp*. set in 30 cm (Ramos *et al.*, 1998). In Mauritanian waters, fishermen might discard hakes for two reasons: undersized individuals (below MLS) or damaged specimens of whatever size. However, we have observed that the discards are mainly composed of black hakes of less than 35 cm, by internal rule in the vessels to ensure compliance to the extent, and not of damaged specimens, marketed under a commercial category named “Rota”. Thus, most of the discarded black hake specimens are smaller than 35 cm.

RESULTS

Sizes by depth range

Figure 1 shows the length frequency distributions obtained for each species by depth stratum, both in scientific surveys and in commercial fishing trips.

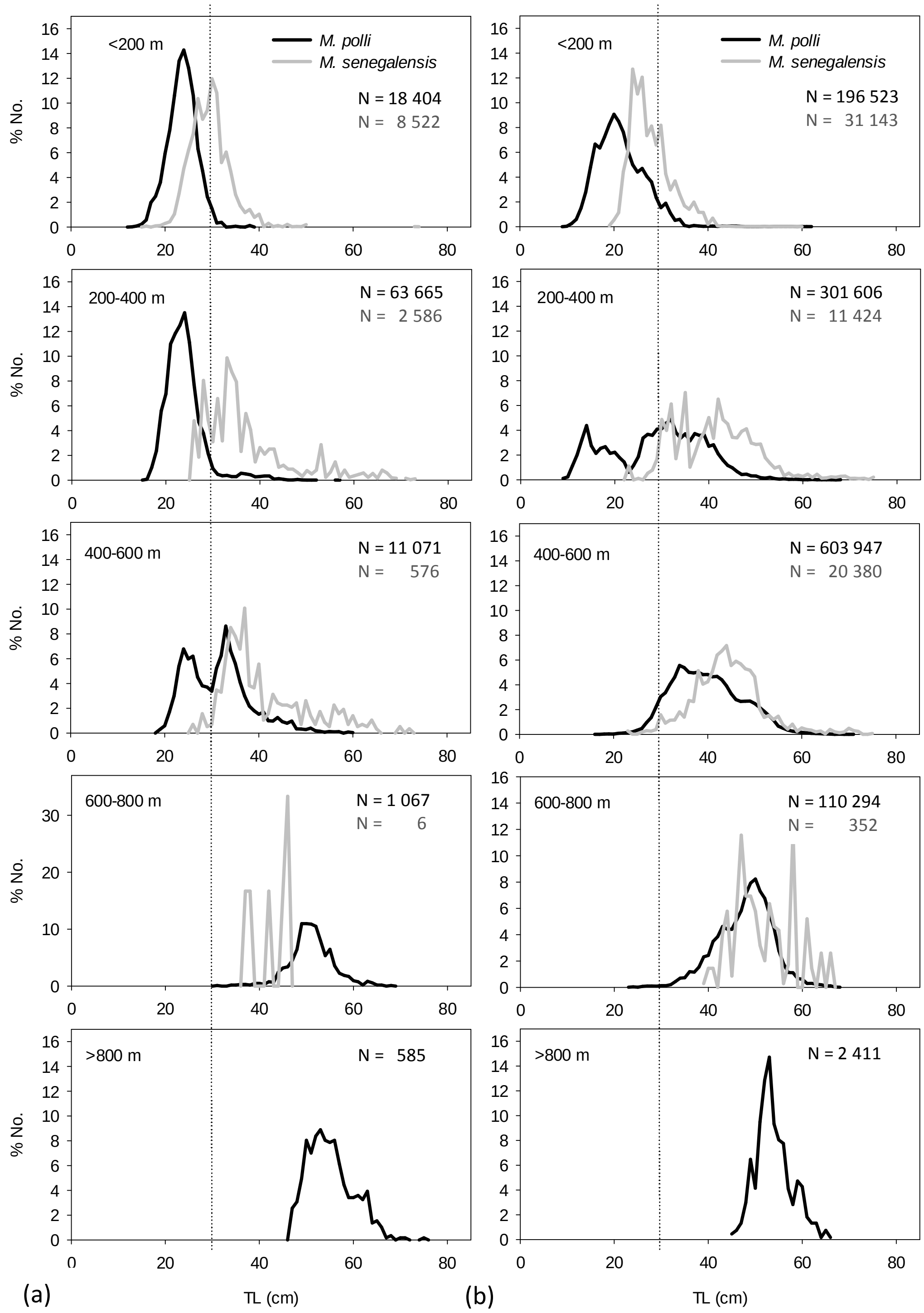

Figure 1. Length frequency distributions by depth range of *Merluccius polli* and *M. senegalensis* in scientific surveys (a) and in commercial fishing trips (b). Dashed line defines the population at 30 cm. N= number of specimens in the catches.

For each bathymetric stratum, size ranges of *M. senegalensis* were always more displaced to the right (higher sizes) than those of *M. polli.* It not considers the 600-800 m stratum from surveys since only six specimens of *M. senegalensis* were captured. This species becomes more rare below 400 m depth, and below 800 m we only found large specimens of *M. polli*. In size, *M. polli* specimens ranged between 12 and 75 cm in surveys and 7 and 71 cm in commercial trips, whereas *M. senegalensis* ranged between 16 and 82 cm and 19 and 85 cm, respectively.

Mean sizes by depth range

Figure 2 shows the mean lengths obtained for each species by depth stratum, both in scientific surveys and in commercial fishing trips. In both cases we observed that the mean lengths of *M. senegalensis* were bigger in all sampled strata, except in stratum 600 - 700 m in surveys where the *M. polli* captured specimens had a mean size of 49 cm, whereas *M. senegalensis* reached only 42 cm, but only six individuals were caught. In this same stratum, *M. senegalensis* averaged 45 cm in commercial fishing trips. The total mean size was higher for *M. senegalensis* in commercial trips that in surveys, unlike for *M. polli*.

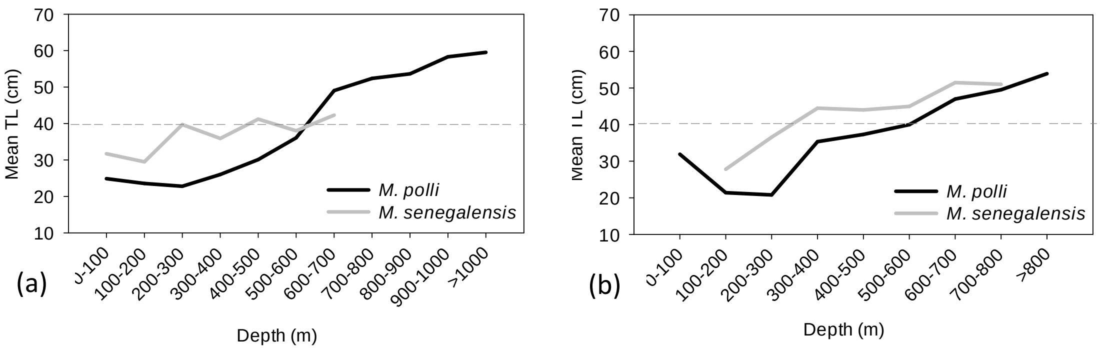

Figure 2. Mean lengths by depth range of *M. polli* and *M. senegalensis* in scientific surveys (a) and in commercial fishing trips (b).

Latitudinal distribution of sizes

Figure 3 shows length frequency distributions obtained for each species by degree of latitude, in commercial fishing trips.

Length data from commercial trips showed that *M. polli* had structured populations in the whole area, bimodal in some latitudes, and with wide size ranges southward. Also, we observed that small specimens of both hakes were discarded in the whole area, but their lower abundances were in 19° N. Again, this figure shows the few specimens of *M. senegalensis*.

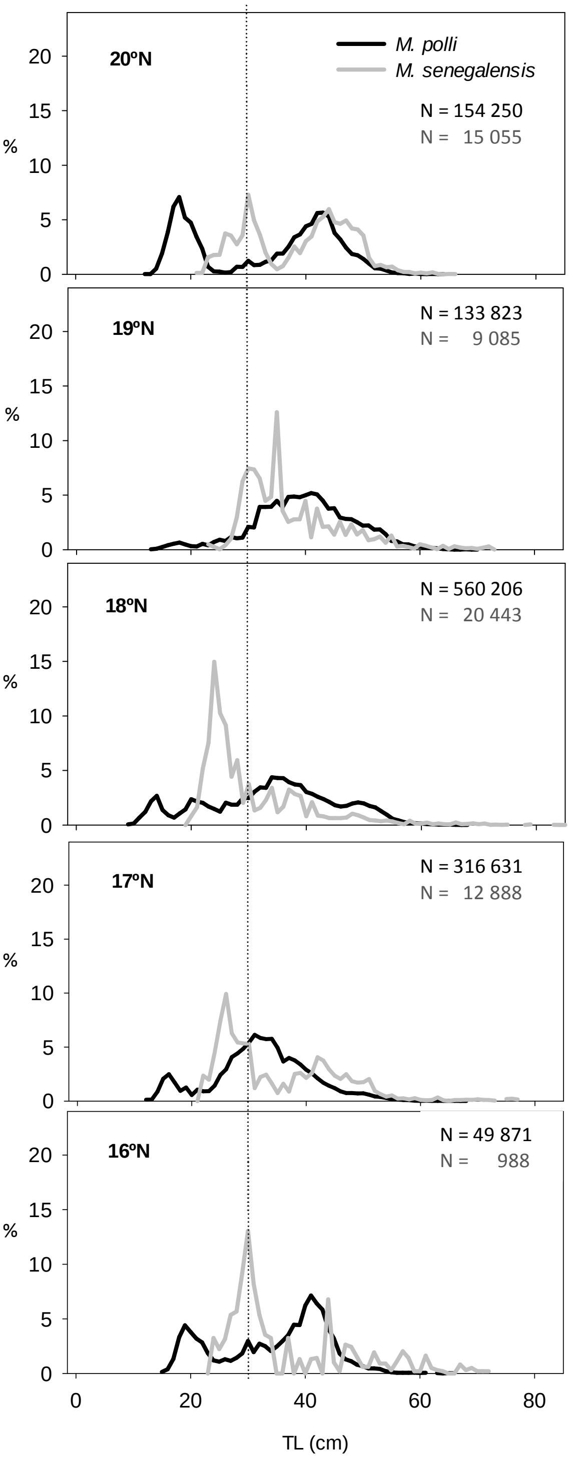

Figure 3. Length frequency distributions by degree of latitude of *Merluccius polli* and *M. senegalensis* in commercial fishing trips. Dashed line defines the population at 30 cm. N= number of specimens in the catches.

Monthly evolution of sizes

Figure 4 shows the length frequency distributions of *M. polli* and *M. senegalensis*, over an annual cycle grouping all data from commercial fishing trips.

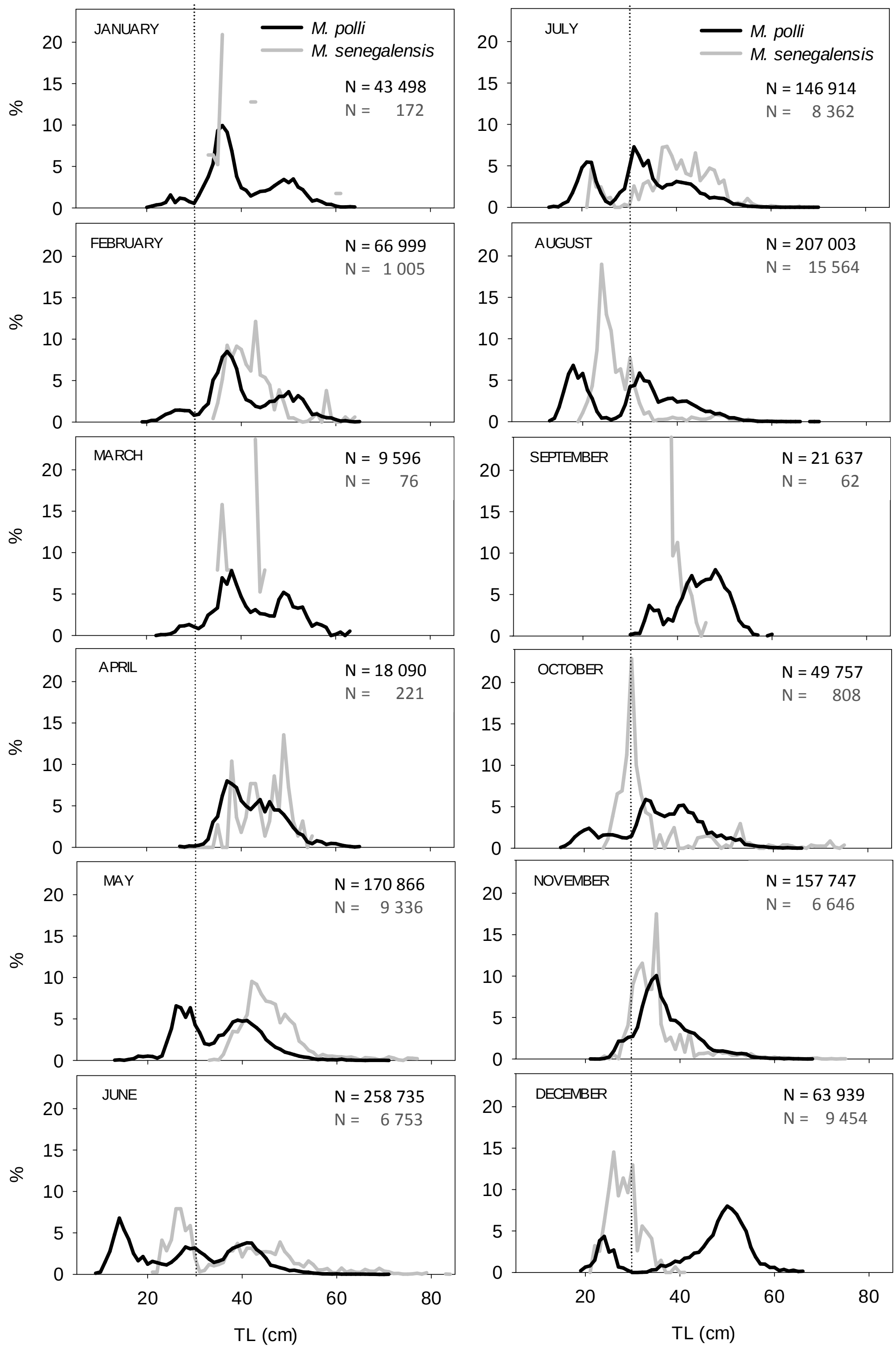

Figure 4. Length frequency distributions of *M. senegalensis* and *M. polli* on an annual cycle in the sampled commercial fishing trips. Dashed line defines the population at 30 cm. N= number of specimens in the catches.

M. polli shows bi- or tri-modal compositions and a better sampled population due to its greater abundance in catches. Strong recruitments and discards appeared between May and October (in September the sampling was too deep) and were weaker during the rest of the year. *M. senegalensis* showed again incomplete compositions due to its low abundance, specially in January, March and September that cannot be considered significant for this species (see Material and Methods), but we also observed recruitments and discarded specimens mainly between June and October. In December we recorded an increase in the recruitments for both species.

Figure 5 shows the grouped length frequency distributions of both species corresponding to the months of the spawning period (from October to March) and of the resting period (from April to September).

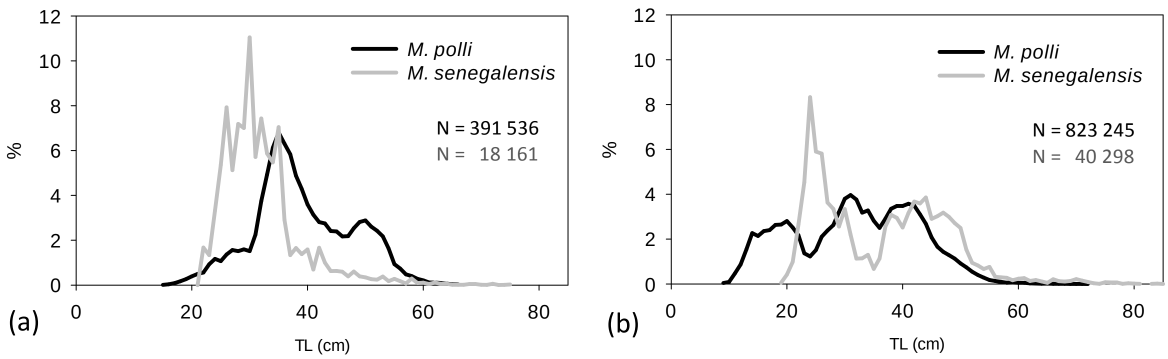

Figure 5. Length frequency distributions of *M. senegalensis* and *M. polli* caught in commercial sampled trips from two different semi-annual periods: spawning, from October to March (a) and resting, from April to September (b). N= number of specimens in the catches.

Figure 5a highlights the scarceness of adults *M. senegalensis* adult specimens in the spawning period. The Senegalese hake population had a mean size of 32 cm, and was composed of 79% of potentially discarded individuals (less than 30 cm) in the fishery. *M. polli* showed a more balanced population, with a significant proportion of adults but a 34% of specimens under 30 cm, which given its abundance is a great amount of discards. Figure 5b shows a tri-modal structure for resting *M. polli*. The recruits of this species increased up to 60%, while adults were less present than during the spawning season. On the contrary, very large specimens of *M. senegalensis* (reaching sizes between 75 and 85 cm) were observed during the resting period, with 50% of the fish measuring more than 35 cm TL and the same percentage of potentially discardable specimens.

Size distributions of the discards by depth range

Figure 6 shows the length frequency distributions of the discarded fraction of catches for both species and by depth, calculated from the sampled commercial fishing trips.

Above 400 m depth, *M. senegalensis* discarded specimens had largest sizes compared with *M. polli*, but between 400 and 600 m the differences in size were less evident. In waters below

600 m were discarded only *M. polli* specimens between 23 and 46 cm, and more than 50% of those discarded specimens were under 35 cm.

Globally, 90% of the discarded specimens were under 35 cm TL in *M. polli* and 92% in *M. senegalensis*.

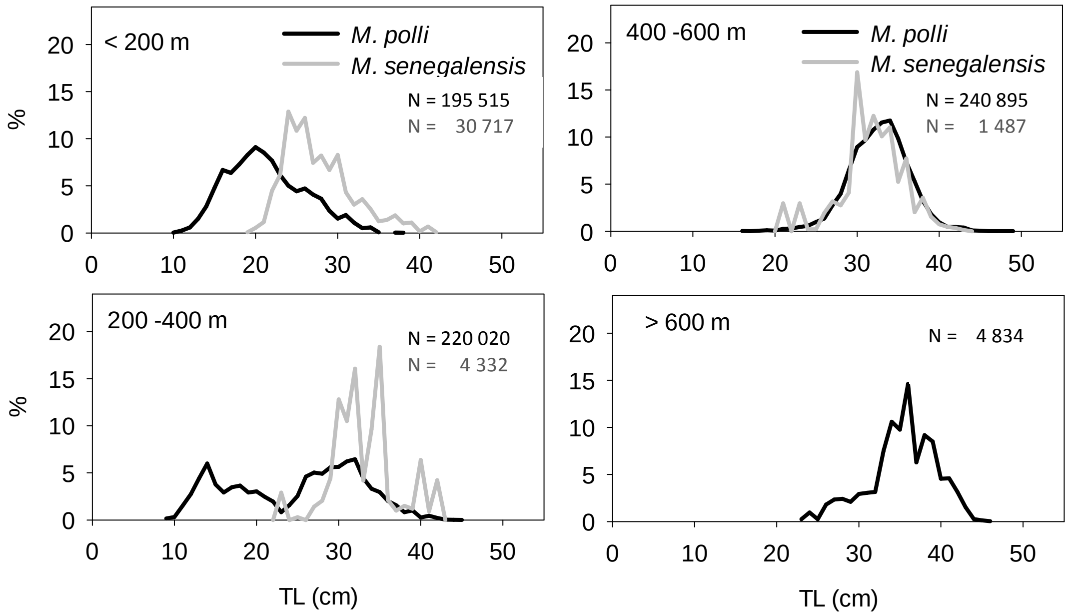

Figure 6. Length frequency distribution of the discarded fraction of catches of *M. senegalensis* and *M. polli* , calculated from the sampled commercial fishing trips per bathymetric stratum. N= number of specimens in the catches.

Figure 7 represents, for each black hake species, the mean lengths of the discarded specimens by depth strata. *M. senegalensis* discarded specimens were bigger in size than those of *M. polli*, except in the 400-600 m stratum, where its average size was slightly lower (32 cm) than that of *M. polli* (33 cm). The mean sizes of the discarded specimens within the bathymetric range of appearance varied between 28 and 33 cm for the coastal species, *M. senegalensis*, and between 21 and 35 cm for the deepest one, *M. polli*.

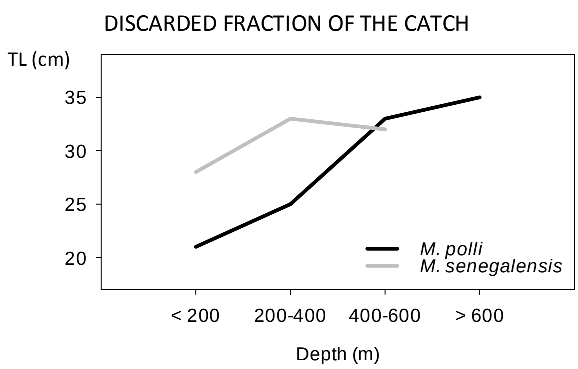

Figure 7. Mean lengths of the discarded *M. polli* and *M. senegalensis* individuals by depth range, calculated from data of commercial fishing trips.

DISCUSSION

The distribution area of both species has been extensively sampled (in latitude and depth), providing robustness to data collected from both sources.

For both hakes, the observed differences between the length frequency distributions obtained from surveys and commercial fishing trips are due to the different sampled periods: while surveys only recorded data from mid-November to mid-December, the commercial fishing trips were more representative of the population structure throughout an annual cycle.

However, the size ranges were similar for both datasets. The maximum size (85 cm TL) recorded for the Senegalese hake in commercial catches was higher than the to date reported as maximum TL for this species (81 cm, Lloris *et al.*, 2003) despite *M. senegalensis* being the most studied and referenced species (Boukatine, 1986; Bourdine, 1986; Cervantes and Goñi, 1986; Sobrino *et al.*, 1990; Lopez-Abellan and Ariz-Tellería, 1993; Lloris et al, 2003).

To date, there are very few studies comparing the spatio-temporal population structures of these two black hake species and covering a wide bathymetric range (Doutre, 1960; Boukatine, 1986; Caverivière, 1986, Lopez-Abellan and Ariz-Tellería, 1993; Wysonkinski, 1986). All over the globe, hake stocks usually show an overlap of at least two species in their intermediate area of distribution, but this overlapping remains a poorly investigated issue. There are some studies addressing this issue on Cape hake species (*M. capensis* and *M. paradoxus*), (Botha, 1985; Payne, 1989; Gordoa *et al.*, 2000; 2006; Burmeister, 2001), two African hakes with a strong resemblance regarding to the dynamics of their populations and from a phylogenetic point of view (Ho, 1990; Roldán and Pla, 2001; Grant and Leslie, 2001) with the two African black hakes studied here.

Again, the length frequency distributions clearly evidence the scarcity of *M. senegalensis*, especially beyond 200 m depth. Data on yields show that *M. senegalensis* is 7 times less abundant than that of *M. polli,* disappearing below approximately 700 m (Fernández-Peralta *et al.*, 2013 in this WG).

Our results also show a strong bathymetric segregation of both species by size: at every depth stratum, *M. senegalensis* specimens had larger sizes than *M. polli*. This size segregation was also confirmed by the analysis of mean lengths by depth. The GAM modeling yields obtained for both species by Quintanilla *et al.* (2013 a) also show significant differences in their inverse bathymetric distributions. *Merluccius* species usually form similar size schools, particularly at high population densities, forming independent groups on the fishing grounds (Gordoa and Duarte, 1991; Macpherson and Duarte, 1991) to avoid potential inter-specific competition for food resources and genetic flow (Arkhipkin *et al.*, 2003). Eventually, the mixing of sizes and species will take place inside the trawl gear during fishing operations.

Although for both species Individuals larger than 35 cm TL could be mostly considered as spawners (Fernández-Peralta *et al.*, 2011) the analysis of the commercial yields temporal evolution shows that they behave in a different way (Fernández-Peralta *et al.*, 2013). *M. senegalensis* mean sizes observed during the spawning season sampled during the research surveys (late autumn), were lower than those observed throughout the whole year in commercial catches. Although the number of *M. senegalensis* individuals in the surveys was negligible, mean sizes were much lower than those of *M. polli*, even at 600 - 700 m depth. In *M. polli*, as opposed to *M. senegalensis,* spawners were captured all year round in the area, with higher presence during the spawning season (autumn-winter) and larger sizes from research surveys than from the commercial fishery. Fernández-Peralta *et al.* (2013) discuss the scarcity of *M. senegalensis* large individuals during the spawning season as well as their lowest overall occurrence in the study area..

The discarding of the greatest sizes (< 30 cm TL) occurs during the resting period (post-spawning) in the cold-to-warm transition and warm hydrological seasons (May to August) and when spawning begins in autumn (October to December)(Fernández-Peralta *et al.*, 2013). These results are concordant with those obtained by Quintanilla *et al.* (2013 b). Both species are quite discarded in most of the study area (20° N - 17° N), except in 19° N, where discards were minimum. Assuming the fast growth model proposed for a close species of the same genus, *M. merluccius* (Meiners, 2007; Piñeiro *et al.*, 2008), the discarded individuals (< 30 cm) probably correspond to the specimens born during the previous year spawning period. Discarded *M. senegalensis* specimens were larger than *M. polli* ones around 400 m, but the discarded sizes were similar for both species between 400 and 600 m, although the population density of *M. polli* is much higher.

It is remarkable that juveniles and adults of both species cohabit at the same depths, as shown by the small sized discarded specimens at great depths, although juveniles are here present in low proportions. In deep waters, the most abundant recruits and juveniles are *M. polli* specimens, who cohabit with *M. senegalensis* spawners preying on them (Fernández-Peralta, pers. comm.).

Due to the heterogeneous fleet effort deployed by depth (only 9% of the hauls are performed between 100 and 300 m, Fernández-Peralta *et al.*, 2013) and due to the length frequency distributions obtained, we know that black hake species mortality is not uniform for all size classes: fishing mortality is lower on younger *M. senegalensis* and stronger on larger *M. senegalensis* specimens as well as on *M.polli* of any size, though weakly affects smaller sizes at 15 cm. Senegalese hake has certainly endured an unknown fishing mortality for decades by fleets targeting this juvenile stock fraction in shallow waters (above 100 m depth) and as a by-catch of pelagic and cephalopod trawlers' fleets (FAO, 2011). Other species of the genus, with a more coastal distribution also exhibit high concentrations above 100 m depth, such as *M. capensis* (Gordoa *et al.*, 2006) or *M. gayi* (San Martín *et al.*, 2011). We therefore conclude that the impact of the trawl hake fishery on the juvenile fraction is unimportant, since discard mean sizes are large (between 21 and 35 cm) for these species, that are among the smallest in the *Merluccius* genus (Lloris *et al.*, 2003).

For stock assessment purposes, it may be desirable for the two species to be analyzed separately. Our results provide an estimate of the hake species size composition from commercial catches, establishing a basis to separately assess the impact of commercial fishing on the two species. Relative abundance indices and size frequency distributions from commercial catches are essential data to estimate the catch percentage of each species by depth. Nevertheless, we think it is not possible to extrapolate our results to make such estimations based on the historical catch series, because over the past decade there has been a significant change in the fishing exploitation pattern of black hake species in Mauritanian waters.

The imposition of a minimum landing size (MLS) of 30 cm TL in the late 90s provoked a fleet displacement to deeper grounds (80% of the hauls are now performed between 400 and 800 m) to reduce discards and to catch larger and more valuable individuals. As a result, the catch is mostly composed of *M. polli* large individuals, fished at great depths, comprised between 600 and 1100 m), where *M. senegalensis* is absent.

In addition, the entire fleet was renewed in year 2000 so the new vessels could gradually shorten their trips to improve the quality of the landings, thus reducing their presence in the southernmost latitudes of Mauritanian waters (16° N). In fact, it seems that there has been a reverse in the proportion of both species in the catch, at least over the last decade (Fernández-Peralta *et al.*, 2013), even though this question needs further studies.

Further studies should be aimed at producing a reliable extrapolation procedure enabling a separation of the catches historically recorded as corresponding to a single species but in fact mixing *M. senegalensis* and *M. polli*. This will make possible to carry on separate assessments for each species and would certainly improve these stocks' management.

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