FINAL REPORT

ASSESSMENT OF STOCK STATUS AND INTENSITY OF EXPLOITATION FOR GROUPA, SARGO, AND MORAY EELS: DEMERSAL FISHERY RESOURCES IN THE WATERS SURROUNDING THE SANTO ANTAO-SAO VINCENTE-SAO NICOLAU INSULAR SHELF OF CAPE VERDE

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EXECUTIVE SUMMARY

Groupa

Landings of groupa for the Santo Antao-Sao Vicente-Sao Nicolua insular shelf in the last two decades have ranged from a maximum of 120 mt in 2002 to a low of about 45 mt in the late 1980s and 2005 (after the peak landings in 2002). In the period 2006-2012 landings cycled between 30 and 60 mt, averaging 50 mt. It is interesting and puzzling to note that during the period from 1998 to 2002 the CPUE index of effective catch per fishermen per hour, showed no significant trend, indicating no change in relative abundance of the species, and yet this occurred in a period when landings increased about 50%. A basic premise of surplus production theory is that as catch increases, the stock biomass and CPUE must be changing also, either positively or negatively.

A previous assessment of stock status of groupa in Cape Verdean waters stated that this species was fully exploited, and estimated that the sustainable level of catch was about 75 mt (Tariche-pastor, 2002). Landings of groupa for the Santo Antao-Sao Vicente-Sao Nicolua insular shelf well exceeded 75 mt for the period 1997-2003, and then reduced to an average of about 65 mt through 2012, suggesting the effects of overfishing during the previous period. Groupa is a slow growing, long lived species, that matures at more about one half its maximum length. These life history characteristics make the species very susceptible to overfishing (Tariche-Pastor, 2002).

Based on the length frequency distributions of the sampled catch in the period 2004 to 2012, it appears that groupa recruit to the fishery at a length of 20 cm, long before they fully mature, and are fully recruited to the fishery at about 30 cm, corresponding to the length of full maturity. The results of this study indicate that the mean and model lengths of the groupa landed during the period have significantly not changed significantly during period 2004 to 2012. The Length Based Catch Curve Analysis (LCCA) results in an estimated fishing mortality rate ($F_{current}$) in 2012 of 0.547, while the results of the YPR and SSBPR analyses indicate growth and recruitment overfishing mortality reference points (F_{max} and $F_{20\%}$) of 0.31 and 0.44. Therefore it is concluded that groupa is experiencing both growth and recruitment overfishing.

The management advice resulting from this study for groupa is as follows:

- There should be the establishment of a minimum size for groupa that are landed, and that this size should approach 30 cm so as to allow every fish to spawn at least once before being landed. This will contribute to an increase in the yield by reducing growth overfishing, and increase the spawning stock, allowing stock rebuilding.
- Fishing mortality on groupa must be reduced overall to allow the stock to rebuild, and to increase overall yield. This is best achieved by limiting effort and /or by establishing closed seasons.

Stripped sea bream

Landings of striped sea bream averaged about 20 mt in the late 1980s and early to mid- 1990s, but steadily decreased from 1997 to 2012. From 2007-2012, landings of striped sea bream averaged about 5 mt. Analysis of the means and modes of striped sea bream sampled from the landings indicate a significant increase in the size of the fish landed from 2005 through 2012. However, it appears that much of the increase is due to the reduction in the catch of very small striped sea bream (less than 20 cm) that occurred in 2005 and 2006. Without those data, there would be no significant trend in the mean or modal size of the fish landed.

The results of LCCA indicate a fishing mortality rate ($F_{current}$) for sargo in 2012 of -0.12 (an impossible situation indicating a problem with either the data, or the assumptions in the analysis). The results of the YPR and SSBPR analyses indicate growth and recruitment overfishing mortality reference points ($F_{0.1}$ and $F_{20\%}$) of 0.34 and 0.35, based on a length of entry into the fishery of 20 cm, and the results of the analysis indicate that sargo was experiencing overfishing in 2008.

The management advice resulting from this study for sargo is as follows:

- There should be the establishment of a minimum size for sargo that are landed, and that this size should approach 30 cm so as to allow every fish to spawn at least once before being landed. This will contribute to an increase in the yield by reducing growth overfishing, and increase the spawning stock, allowing stock rebuilding.
- Fishing mortality on sargo must be reduced overall to allow the stock to rebuild, and to increase overall yield. This is best achieved by limiting effort and /or by establishing closed seasons.

Moray eels

Landings of moray eels steadily increased from about 30 mt in the late 1980s to 65 mt in 2002, but decreased to an average of about 40 mt in the period 2007-2011. In 2012 landings were decreased further to 15 mt. However during the period from 2002-2012 the length frequency distribution of the catch remained unchanged, suggesting no negative effects of overfishing. Without reliable effort data, or information on markets, it is impossible to determine if the 2012 decrease in landings is due to changes in population abundance or fish availability to the gear, or due to a lack of market availability for the species.

The management advice resulting from this study for this species is that more data is needed on the life history characteristics of the species, and on the fishery including market demand.

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INTRODUCTION

This report is the second in a series of reports on the stock status and intensity of fishing on the fishery resources of Cape Verde. This report addresses demersal fishery resources; the first report addresses the small pelagic resources; and another report addresses the pink lobster fishery resource. A preliminary draft of this report was submitted in September of 2012. This final report includes analyses of data available through 2012.

The Instituto Nacional de Desenvolvimento das Pescas (INDP) is the government agency responsible for the collection of landings and effort data on the fisheries of Cape Verde, and there exist comprehensive summaries (Statistical Bulletins) of catch statistics dating to 1988 for most of the Cape Verdean fisheries. The most recent landings data available is through 2012. The biological sampling of the catch is through 2012 for some species, so the analyses are limited to those dates. There is no Catch per Unit Effort (CPUE) data available for the demersal handline fishery, so there are no analyses of stock status. The preliminary draft of this report considered the landings of and biological sampling data from Sao Vincente and Sao Nicolua only, whereas this report addresses the landings of Santo Antao, Sao Vincente and Sao Nicolua. This has required a complete re-analysis of all the data, and therefore has resulted in revised conclusions and recommendations. This report provides a more comprehensive analysis of the demersals handline fishery and resources of the insular shelf of the northeastern islands of Cape Verde.

In 2011 Dr. Joseph DeAlteris was contracted by West Africa Regional Fisheries Project-Cape Verde (WARFP-CV) to assist INDP with the development of stock assessments and management advice based on current data for the key fishery resources of Cape Verde. The scope of the contract includes small pelagic, demersal, and lobster fishery resources.

The demersal fishery resources in the waters surrounding the Santo-Antao-Sao Vincinte- Sao Nicolau insular shelf of the Cape Verde islands (Figure 1) consist primarily of three species groups: the groupa or African hind (*Cephalopholis taeniops*), sargo or stiped sea bream (*Lithognathus mormyrus*), and the moray eels: brown moray (*Gymnothorax unicolor*) and the purple mouth moray (*Gymnothorax vicinus*) (Figures 2 and 3). These demersal species are caught primarily by artisanal fishermen using handlines.

The purpose of this assessment and report is to review the fishery landings of groupa, striped sea bream and the moray eels, and to estimate the level of fishing exploitation for the period from the late 1980s through 2012 based on the data available. The report also provides advice on the management of these fishery resources for sustainability into the future.

Figure 1. Bathymatric map of the Cape Verde Islands and the surrounding waters. Note that the demersal fishery landings data and analyses are limited to the insular shelf of Santo Antao-Soa Vincente and Sao Nicolau.

a. 

b. 

Figure 2. Pictures of the Cape Verdean demersal species: a. groupa or African hind (*Cephalopholis taeniops*), and b. the sargo or striped sea bream (*Lithognathus mormyrus*).

a. 

b. 

Figure 3. Pictures of the Cape Verdean demersal species, the moray eels: a. brown moray (*Gymnothorax unicolor*) and b. the purple mouth moray (*Gymnothorax vicinus*)

DESCRIPTIONS OF THE FISHERIES AND THEIR LANDINGS

Fisheries

The artisanal fishermen in Cape Verde use seines, gillnets and handlines in their vessels, and capture a range of species including large pelagics, small pelagics and demersals. Cape Verde artisanal fisheries are all open access fisheries, that is, anyone can fish and fishing effort is not limited. The demersal handline fishery harvests a wide variety of species, but three principal fish species are: groupa, striped sea bream, and the brown and purple mouth moray eels. Artisanal handline fishermen fish for either or both pelagic and demersals species depending on availability, so effort data available for handline fishermen that is reported by trip is not useful for understanding catch per unit effort or relative abundance for the demersals fishery.

Landings

Landings by species for the handline sector of the artisanal fisheries of Cape Verde (groupa, striped sea bream, and moray eels) for the Santo Antao-Soa Vicente-Soa Nicolau insular shelf during the period 1989 to 2012 are summarized in Table 1 and plotted as time series in Figure 4. The terms landings and catch are used interchangeably in this report as all catch is landed. Landings of groupa increased from 1989 to 2002 peaking at almost 120 mt in 2002, then subsequently steadily decreased to a relative low of about 48 mt on 2005. Landings of groupa in the 2006-2012 period cycled between about 50 and 85 mt and averaged about 60 mt. Landings of sargo (striped sea bream) averaged about 20 mt in the late 1980s and early to mid- 1990s, but steadily decreased from 1997 to 2009. From 2007-2012, landings of striped sea bream averaged about 3 mt. Landings of moray eels steadily increased from the late 1980s at about 30 mt to 2002 at 60 mt, but decreased to an average of about 40 mt in the period 2007-2011. In 2012, landings of moray eels dramatically decreased to 15 mt.

Fishing effort for the handline fishery is reported in the INDP Statistical Bulletins in trips by small outboard boats for the artisanal fleet. Each trip on an artisanal vessel is most often a single day at sea of fishing. Unfortunately, this effort data is aggregated for all handline fisheries including tuna, small pelagics and demersals, and attempts to partition the data as the demersal catch represent about 40% of all handline catches provided uncertain results.

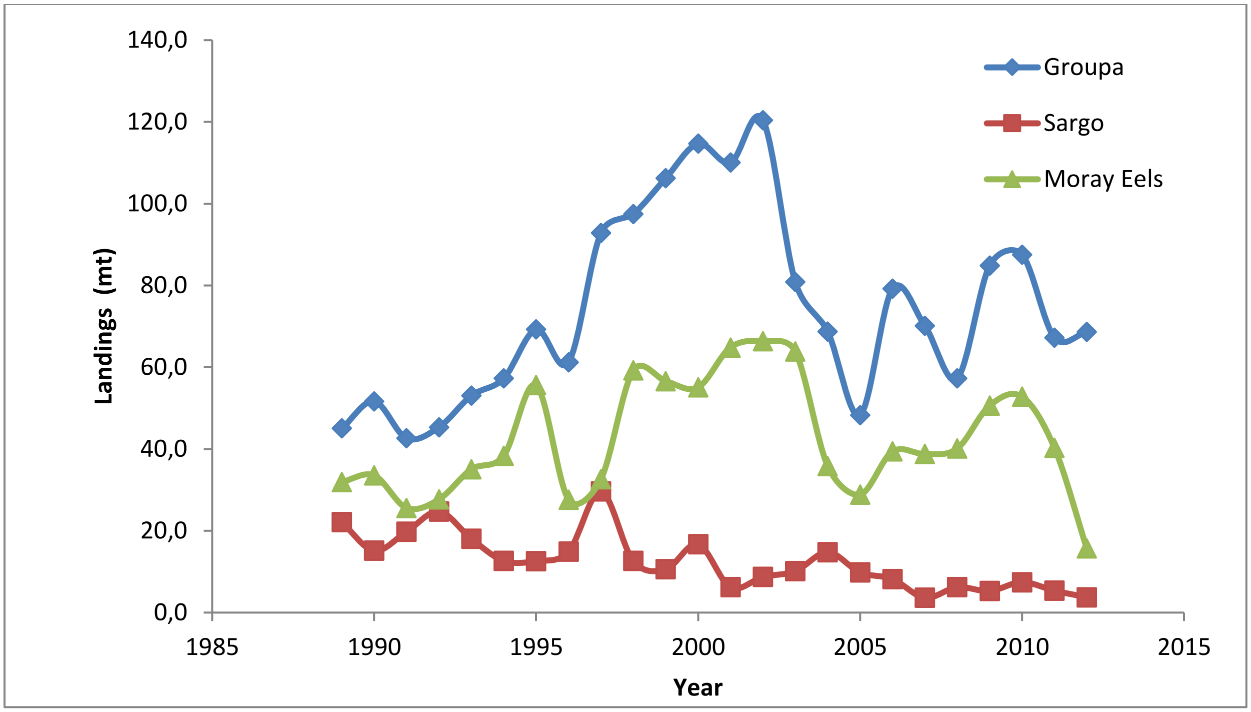

Figure 3. Artisanal handline landings (mt) of the groupa or African hid (*Cephalopholis taeniops*), sargo or striped sea bream (*Lithognathus mormyrus*), and the moray eels, brown moray (*Gymnothorax unicolor*) and the purple mouth moray (*Gymnothorax vicinus*) from the insular shelf of Santo Antao-Sao Vincente-Sao Nicolau of Cape Verde from 1989 to 2012.

Table 1. Landings (mt) of the groupa or African hind (*Cephalopholis taeniops*), sargo or stiped sea bream (*Lithognathus mormyrus*), and the moray eels, brown moray (*Gymnothorax unicolor*) and the purple mouth moray (*Gymnothorax vicinus*) for the insular shelf of Santo-Antao-Sao vincente-Sao Nicolua of Cape Verde in artisanal handline fisheries, as provided by INDP.

Year	Grouper	Sargo	Moray eels
1989	45.0	22.1	31.9
1990	51.7	15.1	33.5
1991	42.6	19.8	25.6
1992	45.3	24.7	27.7
1993	53.0	18.1	35.1
1994	57.3	12.6	38.4
1995	69.2	12.6	55.6
1996	61.2	14.9	27.6
1997	92.8	29.6	32.6
1998	97.5	12.6	59.2
1999	106.2	10.6	56.6
2000	114.7	16.7	55.1
2001	110.0	6.2	64.8
2002	120.4	8.7	66.4
2003	80.9	10.1	63.9
2004	68.8	14.8	35.8
2005	48.3	9.8	28.8
2006	79.2	8.2	39.4
2007	70.2	3.6	38.8
2008	57.3	6.2	40.1
2009	84.9	5.3	50.6
2010	87.6	7.4	52.8
2011	67.3	5.4	40.3
2012	68.6	3.7	15.7

PREVIOUS SCIENTIFIC WORK

Groupa

A comprehensive analysis of the life history and stock assessment of the groupa was conducted by Oksana Tariche-Pastor in 2002, and was updated by Tariche and Martins in 2007 and 2011. The results of the 2002 study predicted a sustainable yield from the resource of about 75 mt, noting that landings had risen from about 25 mt in the late 1980s to about 90 mt in 2000. In 2003 (published in 2005) and 2007 (published in 2011) the estimated fishing mortality rates based on a VPA analysis were 0.33 and 0.38. The estimated life history characteristics of the groupa included the parameters for Von Bertalanffy growth model (L_∞= 62.9 cm, K=0.12), the length-weight model (a=0.0067, b=3.2), the logistic maturity model (L_{50}=26.5-27.0 cm), longevity at 24.7 years and natural mortality (M=0.35). Tariche (2002) notes that a natural mortality of 0.35 is not consistent with the estimated longevity, therefore she uses a natural mortality of 0.25 in her analyses. In the 2002 report, Tariche also notes the existence of a limited time series of effective catch per fishermen per hour for the period 1998 to 2001.

Striped sea bream

There have been two investigations of striped sea bream biology or fishery stocks in Cape Verdean waters, Tariche and Martins (2007 and 2011). They estimated the parameters of the von Bertalanffy growth model at L_∞= 40.5 cm, K=0.1, the parameters of the Length-Weight relationship to be a=0.0020 and b=3.0, the $L_{50\%}$ for maturity to be 27.0 cm, and the instantaneous natural mortality coefficient M=0.3 . In 2003 (published in 2005) and 2007 (published in 2011) the estimated fishing mortality rates for Cape Verdean sea bream were 0.53 and 0.55 based on a VPA analysis. The life history characteristics of striped sea bream have also been investigated in Canary Islands, south Portugal and in the Adriatic Sea. Lorenzo, et al. (2002) studied striped sea bream in the Canary Islands. They estimated the parameters of the von Bertalanffy growth model at L_∞= 42.7 cm, K=0.19, the parameters of the Length-Weight relationship to be a=0.00003 and b=2.9, the $L_{50\%}$ for maturity to be 24.5 cm, and the instantaneous natural mortality coefficient M=0.4 . Pajuelo et al (2002) studied the age and growth of striped sea bream in the Canary Islands and estimated the parameters of the von Bertalanffy growth model at L_∞= 42.7 cm, K=0.19. Abecasis et al (2008) studied the age and growth of a variety of sea bream off the coast of south Portugal, and estimated the parameters of the von Bertalanffy growth model for striped sea bream at L_∞= 43.7 cm, K=0.21. And finally, Kraljevic at al. (1996) estimated the parameters of the von Bertalanffy growth model for striped sea bream in the Adriatic Sea at L_∞= 40.5 cm, K=0.20. They also note that striped sea bream are protandrous hermaphrodites, with sexual inversion from male to female occurring between 24 and 35 cm. They estimated the parameters of the Length-

Weight relationship at a= 0.0094 and b=3.063. Finally, they estimate the instantaneous natural mortality rate to be 0.42.

<u>Moray eels</u>

There have been no specific investigations of moray eels biology or fishery stocks in Cape Verdean waters, and in fact there is little known about the life history of moray eels in general, other than it is believed that they are relatively long lived and experience slow growth.

<u>Summary</u>

The three species of demersal fish analyzed in this investigation have similar life history strategies. All are relatively long lived, grow slowly, and mature at a relatively older age and larger size. These characteristics make these species susceptible to overfishing.

METHODS FOR THE ASSESSMENT OF STOCK STATUS AND INTENSITY OF EXPLOITATION

Index assessments

Index models are simple and require minimal data, but also provide minimal understanding of fish stock structure and dynamics, and little ability to forecast future trends in catch or abundance. Despite their apparent simplicity, index models are subject to uncertainty due to errors in landings or fishery effort data, and changes in survey data collection protocol.

Catch per unit effort (CPUE) or landings per unit effort (LPUE) are generally considered to be proxy for the abundance of a species. As long as the unit of effort is properly specified and the efficiency of that unit of effort remains constant over the times series of data, then CPUE is considered to be a reliable estimator of the abundance of a stock. Catch includes landings and discards, and in the Cape Verdean demersal handline fisheries, discards of small, undersize demersals is assumed to be negligible. Therefore, as noted previously, CPUE is considered to be the same as LPUE. A relative index of abundance can be used as a reference point for management purposes, commonly set as the lowest level of relative stock abundance or some level greater than that, from which the stock has demonstrated recovery. Of course, for a fish stock that has experienced a steady decline in the relative index of abundance, this reference point cannot be determined because recovery from the current level of stock abundance has not been demonstrated. It is impossible to develop CPUE indices for the demersal fishery resources of Cape Verde at this time due to the unavailability of effort data for the demersal handline fishery.

Analysis of the mode of the length-frequency distribution of the landings

As noted in a previous section of this report, length-frequency data from fisheries landings or from fishery independent surveys can be used to investigate the growth, natural mortality, and fishing intensity with various assumptions (Rosenberg and Beddington, 1988). However, at the most fundamental level, comparison of annual length-frequency distribution from the catch can be used to describe the size distribution of the fish landed, and most importantly to identify trends in the mode or mean of the fish landed over time. A reduction in the mean size of the fish landed, or mode of the length-frequency distribution of the fish landed in a developing fishery is perhaps one of the most obvious effects of fishing. A dramatic and continuing reduction in size of the fish landed is an indication of high exploitation (fishing mortality) and possibly overfishing (Beverton and Holt, 1957). In this study the means and the modes of the length-frequency distributions were evaluated as a function of time to investigate possible indications of overfishing. The slope of a regression line of the mean length of the sampled catch versus year was estimated and evaluated for being statistically different from 0. A significant negative trend in the mean size of the fish landed in a mature fishery is an indication of overfishing.

Catch Curve Analysis

In the early 1900s when catches of North Sea Plaice were grouped into size-classes of equal breadth, the plot of the logarithms of the numbers of fish in each class versus the mean age of fish in those size classes had a steeply ascending limb, a dome shaped upper portion, and a long descending right limb, which was nearly straight through its entire length. This was soon recognized as a convenient method of representing catches graphically. Catch Curve Analysis (CCA) is simply a graphical representation of the numbers of survivors in the stock for all ages following fully recruitment to the fishery (the long descending rigth limb) plotted against age.

Recall the exponential decay function or the survival equation is $N_t=N_0e^{-Zt}$, when this function is linearized, the slope of the linear function is the total mortality Z. In CCA, a linear regression of catch (*Ct*) as a function of age (*t*) is fit using the function

$$ln(Ct) = Zt + b$$

where *t* is age in years.

The absolute value of the slope, *a*, is equal to the total mortality *Z*. The variable *b* is the y-intercept. It is important that CCA be performed only on the portion of the stock that is fully recruited to the fishing gear. Also, the plus group is often not considered in catch curve analyses. CCA is most appropriate for data from a single year class collected over time. If CCA is used for a single year's catch, it should only be done when there is no interannual trend in recruitment.

Catch curves are very simple to calculate, but they hide numerous assumptions that one has to consider when interpretting the results. The survival rate must be uniform with age, over the range of age-groups in question. Since the survival rate is the complement of total mortality rate, and total mortality is composed of fishing and natural mortality, this will usually mean that each of these, individually, is uniform. There must be no change in mortality rate with time. The sample must be taken randomly from the age-groups involved. The age-groups in question were equal in numbers at the time each was being recruited to the fishery (constant recruitment).

If these conditions are satisfied, the right limb is a curve of survivorship which is both age-specific and time-specific. Two principal exceptions should always be kept in mind: 1) the decrease in vulnerability to fishing with age, and 2) the consequent tendency toward an increase in survival rate will not be reflected in the catch curve and, in some instances, will introduce a bias in the estimates. The most common application of the catch curve is estimating mortality on a cohort from research survey data, however fishery catch data can also be used. A critical part of the analysis is the conversion of the observed lengths to estimated ages using a re-arranged von Bertalanffy growth function. Therefore, L_∞ and K must be known or assumed, and natural mortality, M, must be assumed to separate fishing mortality, (F) from total mortality (Z).

<u>Yield per recruit and spawning stock biomass per recruit models</u>

A discrete time model (DeAlteris and Riedel, 1996) was developed to investigate the effect of minimum landing size regulations on the yield and potential spawning stock per recruit from a single cohort. The time step is set at 0.01 years, over the range of 0 to 20 years, so as to be able to evaluate knife edge selection at specific fish lengths in whole centimeter units.

The length of the fish (*L*) at age (*t*) is calculated using a simplified ($t_0 = 0$) von Bertalanffy growth equation:

$$L_t = L_\infty\left(1 - e^{(-Kt)}\right)$$

where L_∞ is the maximum length, and
K is the instantaneous growth rate.

The weight of the fish (*W*) at age *t* is determined using a length-weight relationship:

$$W_t = a\left(L_t\right)^b$$

where *a* is the *L-W* conversion factor, and
b is the *L-W* growth factor

The percent maturity (P_t) of individuals in the cohort at age is expressed using a LCDF:

$$P_t = \left(1 + e^{(-\alpha 1 * (t - \beta 1))}\right)^{-1}$$

where $\alpha 1$ is the steepness of the curve, and
$\beta 1$ is the length at 50% maturity.

Based on specification on knife edge selection as a function of fish length, the probability (PL_t) of individual fish of length (L_L) recruiting to the fishery was specified as either 0 or 1:

$$PL_L = 0\, for L_L < L_{\min} and = 1\, for L_L > L_{\min}$$

where L_{min} is the minimum fish size allowed to be landed.

Applying length-specific susceptibility to fishing (PL_L) at a specified level of fishing mortality (*F*) and including natural mortality (*M*), the number of individuals remaining in the fished cohort (NF_t) at each time step (*t*) was calculated as:

$$NF_t = NF_{(t-1)} e^{\left\{-[((PL_L)(F)) + M] * t * 0.01\right\}}$$

Thus, the yield of the fished cohort (Y_t) from each time-step is:

$$Y_t = \left[{}^{(PL_L * F)}\!\big/_{(PL_L * F + M)}\right] * \left(NF_{(t-1)} - NF_{(t)}\right) * \left(W_{(t)}\right)$$

and the spawning stock biomass of the fished cohort (SSB_t) at each time step is simply:

$$SSB_t = (NF_t)*(W_t)*(P_t)$$

Given these equations and specific values of L_∞, K, a, b, $\alpha 1$, $\beta 1$, and M, and with the specification of fishing conditions (F, L_{min}), the total yield and spawning stock biomass of the fished cohort are determined. By evaluating a wide range of L_{min} and F values, the resulting matrix of data, expressed as the yield per recruit (*YPR*) and % virgin spawning stock biomass per recruit (*%VSSPR*) for various values of L_{min} and F.

Yield per recruit (YPR) models provide evaluations of yield as a function of fishing mortality and age or size of entry into the fishery, incorporating information on biological parameters (growth, weight at age, and natural mortality rates). The YPR models provide two important reference points, and a growth overfishing definition. Y_{MAX} is the maximum yield that can be removed from a cohort, given a specific age or size of entry into the fishery and the biological parameters of the fish stock. F_{MAX} is the fishing mortality rate that provides Y_{MAX}, and is now considered a threshold or limit reference point. $F_{0.1}$ is a fishing mortality rate on the YPR curve at which the slope of the curve is 10% (0.1) of the slope of the curve at the origin. The $F_{0.1}$ measure, although arbitrary, is a target reference point, and also represents a bioeconomic reference point, in that additional increases in F only marginally contribute to yield.

Growth overfishing occurs at fishing mortality rates greater than F_{MAX} because overall yield is reduced, despite increased effort. The fishery is removing too many fish before the population reaches the maximum growth potential, thus reducing yield. Growth overfishing, although not usually biologically problematic on its own, is economically harmful to the fishing industry.

Spawning stock biomass (SSBPR or SPR) and egg (EPR) per recruit models are the complement to YPR models. The calculations are analogous to YPR models with the addition of maturation and fecundity data. These models provide evaluations of spawning stock biomass or egg production as a function of fishing mortality. Both SPR and EPR models generally express the dependent variable as a percentage of the spawning stock biomass or egg production in the absence of fishing (F = 0.0). The SPR and EPR models provide both target and threshold limit reference points, and a recruitment overfishing definition .

The selection of a particular percentage value is related to the steepness of the stock-recruitment relationship near the origin (low stock sizes), and the biological characteristics of the stock. The percentage chosen should allow sufficient recruitment to ensure sustainability of the stock. Long-lived, slow growing species can accommodate lower levels of percent spawning stock remaining ($F_{10\text{-}20\%}$), compared to short-lived, fast growing species that require higher levels of spawning stock remaining ($F_{20\text{-}40\%}$). Generally the target reference point is 5-10% higher than threshold or limit reference points.

The $F_{x\%}$ reference points are related to recruitment overfishing. Exceeding a particular $F_{x\%}$ of 10, 20, or 30 indicates that there will not be sufficient spawning biomass available for future reproduction, leading to recruitment failure.

RESULTS

The results of the analyses include a description of the trend in a groupa CPUE for a very limited period, the results of the length frequency mean and mode analysis, the results of the LCCA, and the results of the YPR and SSBPR analyses, if there was life history data for the species available. An Appendix to this report includes the EXCEL spreadsheets for all data and calculations, is available and has been provided to INDP.

Groupa

As noted previously, there is no effort data available for the demersal handline fisheries with the exception of limited time series of effective groupa catch per unit effort for the period 1998 to 2002 (Figure 4). The results of the regression analysis of this short time series indicate that while the trend is slightly negative, it is not significantly different from 0. Thus, based on these data it appears that the stock was neither increasing nor declining in abundance during the period.

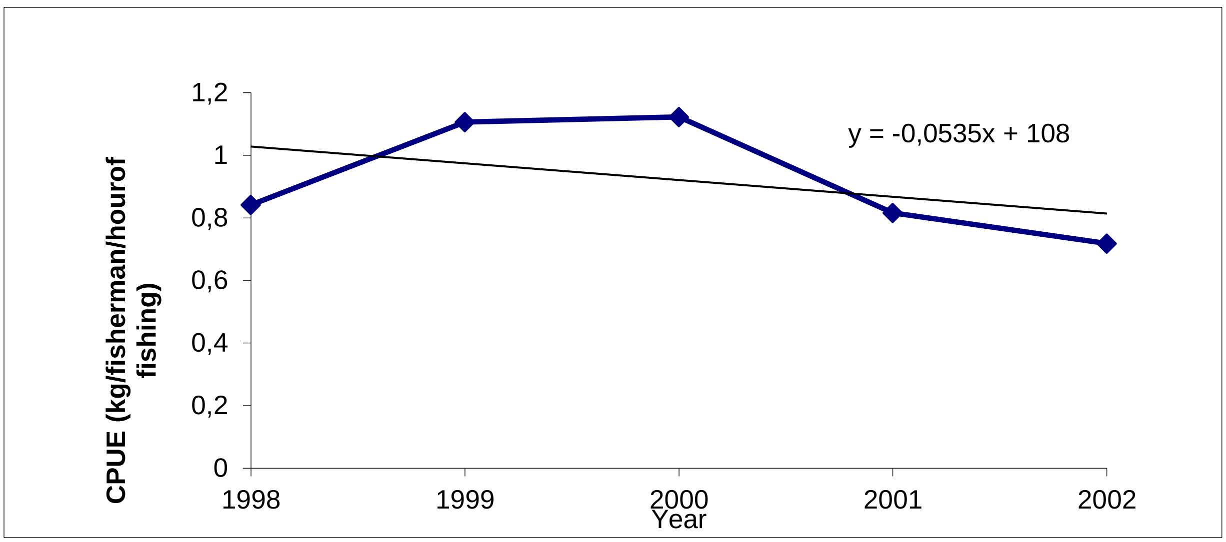

Figure 4. CPUE as effective catch (kg) per fishermen per hour of fishing for groupa for the period 1998 to 2002. Note that there is a slight trend, but that the slope is not significantly different from zero.

The results of the sampling of the lengths of the groupa catch for the period 2000 to 2011 are summarized in a series of length-frequency distributions for the period (Figure 5). From these data it is clear that the fish begin to recruit to the fishery at lengths of 20 cm, but are not fully recruited until lengths of about 30 cm. When the mean and mode of each annual length frequency distributions are plotted versus time, it is clear that there has been a small but steady increase in the mean length of the fish landed, and in fact it is a significant positive increase (Figure 6).

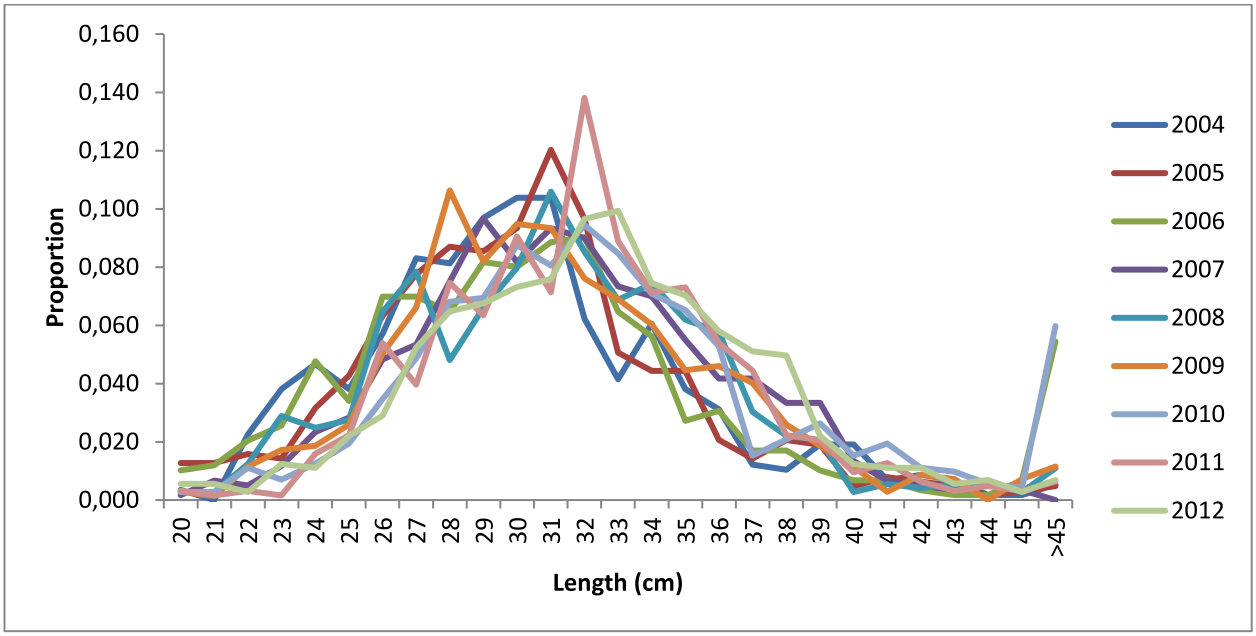

Figure 5. Length frequency distributions of groupa sampled from the handline catch for the period 2004 to 2012.

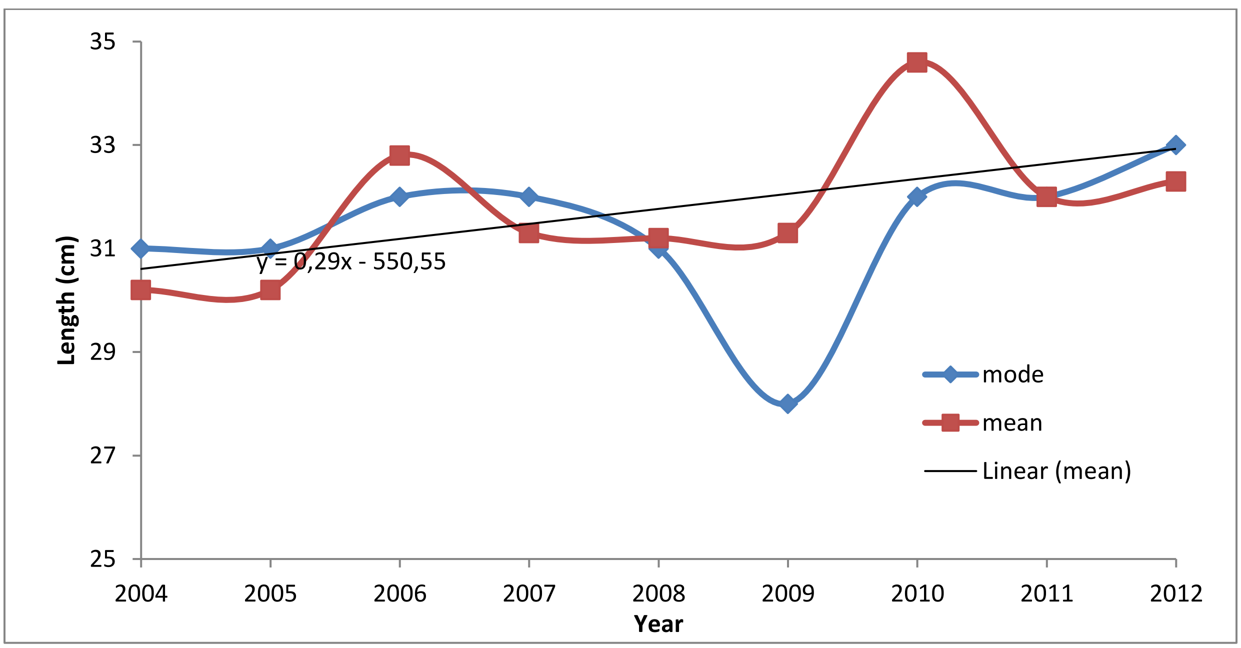

Figure 6. Mean and mode of the length-frequency distribution for the sampled landings of groupa during the period 2004 to 2012. Note that the slope of the mean trend line is positive, but is not significantly different from 0.

The results of the transformation of the length frequency distribution to an age-frequency distribution are shown in Figure 7 for three years during the study period, 2004, 2009, and 2012. It appears that groupa are fully recruited to the fishery at about age 6.

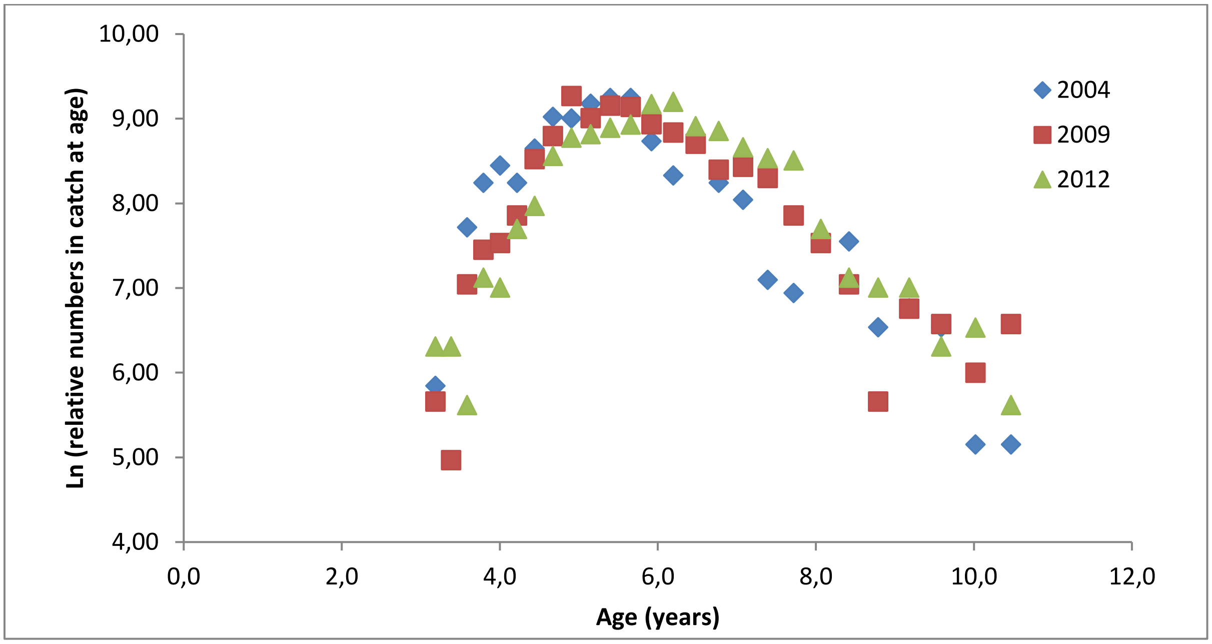

Figure 7. Natural log (ln) of relative numbers in catch at age versus age in years for groupa for the years 2004, 2009 and 2012.

When the slopes of the regression lines for the fully recruited relative numbers in the catch versus age are estimated, the total mortalities for years 2004, 2009, and 2012 are 0.745, 0.692 and 0.797, respectively. Given the best estimate of natural mortality (M) at 0.25, the estimated fishing mortality (F) for 2004, 2009, and 2012 are 0.492, 0.442, and 0.547, respectively (Figure 8). The natural mortality estimate used in these analyses differs from the value used by Tariche and Martins (2005 and 2011), but better accounts for the estimated longevity of groupa estimated to be 20+ years. The difference between the F values estimated in this analysis and those of Tariche and Martins (2005 and 2011) are primarily due to differences in the assumed natural mortality.

The results of the YPR and SSBPR analyses for groupa using the same values of the input parameters used in the LCCA analysis are shown in Figure 9. The values of the growth overfishing reference points, $F_{0.1}$ and F_{max} are 0.18 and 0.31, and the recruitment overfishing reference point $F_{20\%}$ is 0.44. Comparing the estimated fishing mortality level in 2012 of 0.547 to the overfishing reference points, it is clear that the groupa stock in 2012 is experiencing both growth and recruitment overfishing, and in fact has experienced both growth and recruitment overfishing for the entire study period. The potential benefits of increasing the minimum size of the groupa landed were evaluated in increments of 2 cm from 20 to 30 cm using the YPR and SSBPR analyses (Figure 11). Overall, if the minimum size were slowly increased and fishing mortality was managed at Fmax levels, yield could be increased 20+%, and stock rebuilding would occur at the reduced levels if fishing. Note that as the minimum size is increased, the level of maximum sustainable fishing (Fmax) increases.

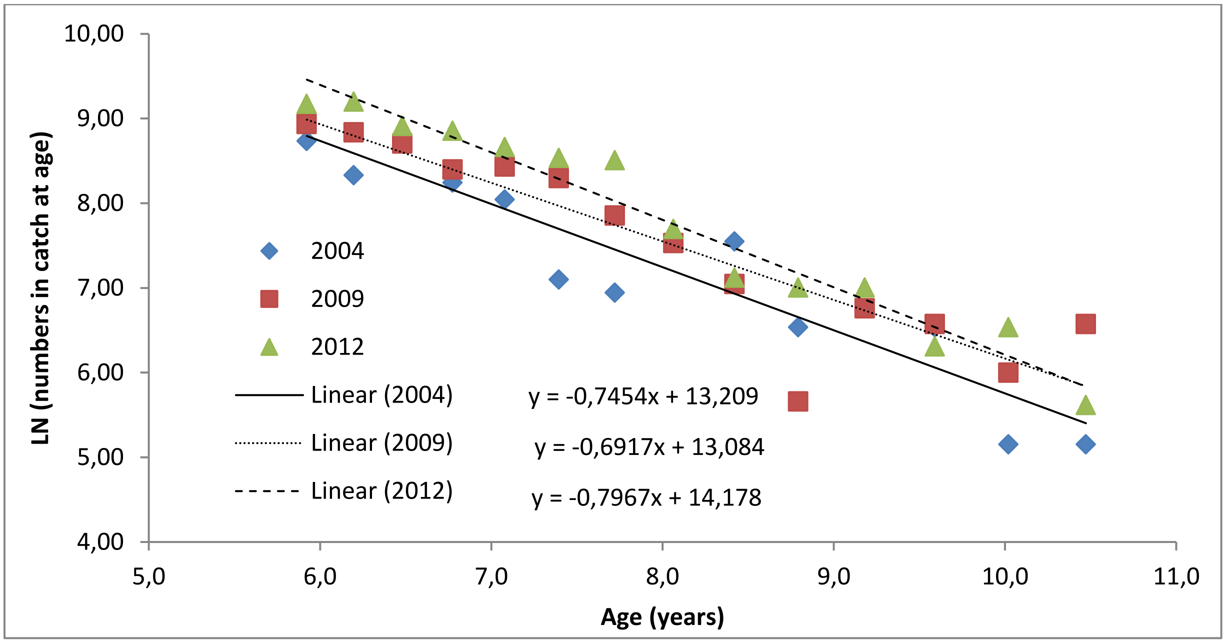

Figure 8. Results of length based catch curve analysis for groupa for fully recruited fish. Note that the slope of the regression line is the estimated total mortality (Z) and is 0.745, 0.692 and 0.797 for 2004, 2009, and 2012, respectively.

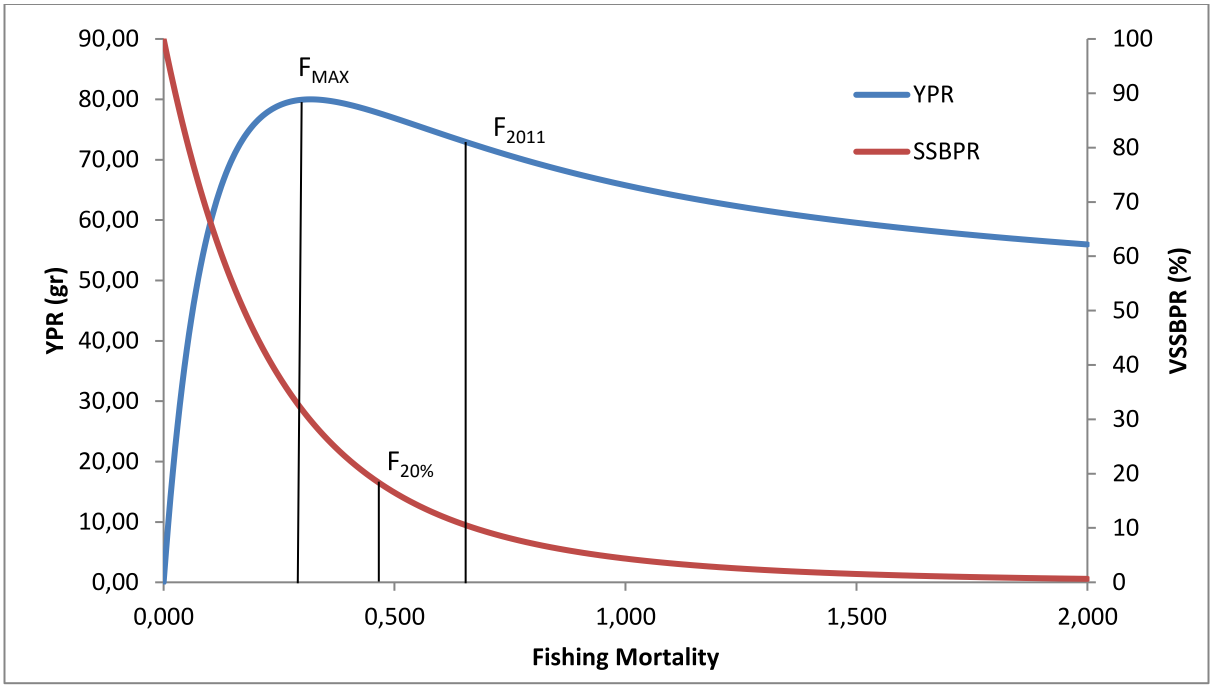

Figure 9. Results of YPR and SSBPR analysis for groupa assuming a length of entry into the fishery of 20 cm.

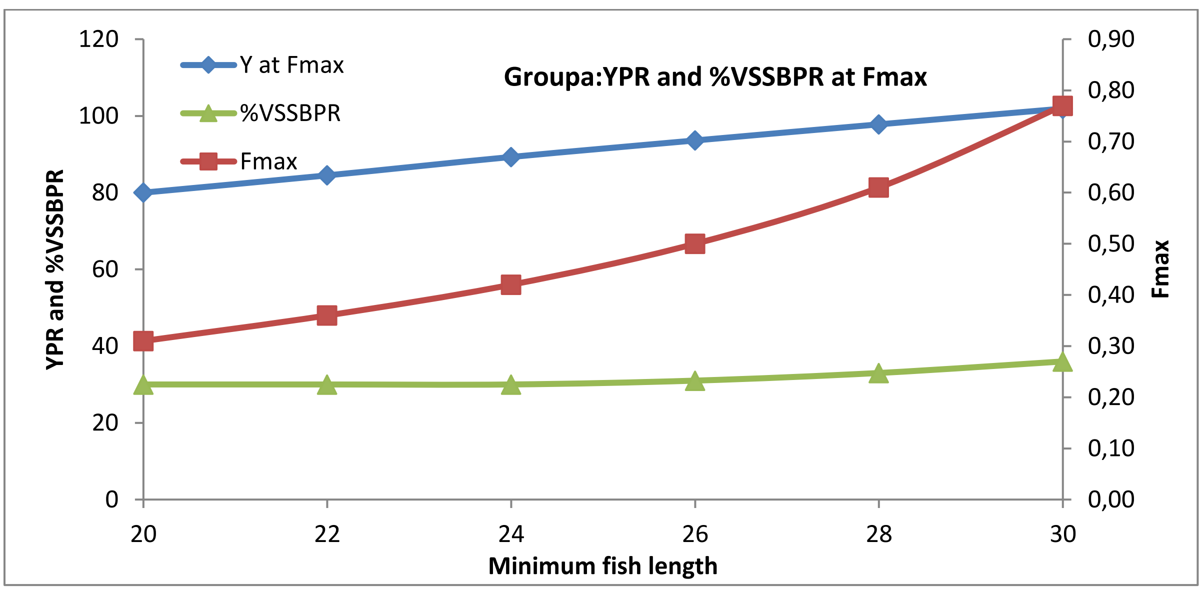

Figure 10. Results of the YPR and SSBPR analysis for groupa evaluating alternative lengths of entry into the fishery from 20-30 cm, assuming that the fishery is managed at Fmax.

Sargo or striped sea bream

As noted previously, there is no effort data available for the demersal handline fisheries, so there are no indices of relative abundance for sargo.

The results of the sampling of the lengths of the sargo or striped sea bream catch for the period 2005 to 2012 are summarized in a series of length-frequency distributions for the period (Figure 11). From these data it is clear that the fishery has changed or evolved over the 8 year period that data is available for. In the period 2005 to 2006, fish began recruiting to the fishery at very small lengths (less than 20 cm). Fortunately, from 2007 on, fish recruited to the fishery at lengths of 20 cm, but were not fully recruited until lengths of about 30 cm. When the mean and mode of each annual length frequency distributions are plotted versus time, it is clear that there has been a steady increase in the mean length of the fish landed, and in fact it is a significant positive slope (Figure 12).

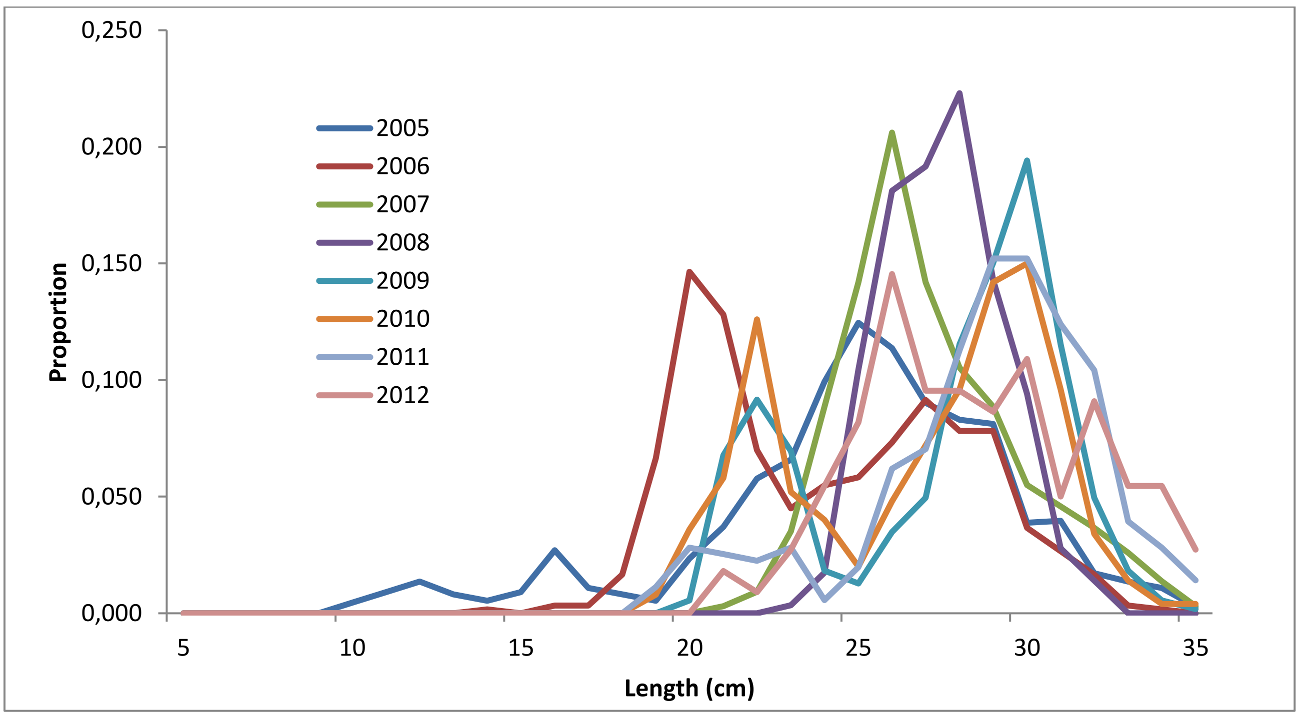

Figure 11. Length frequency distributions of sargo sampled from the handline catch for the period 2005 to 2012.

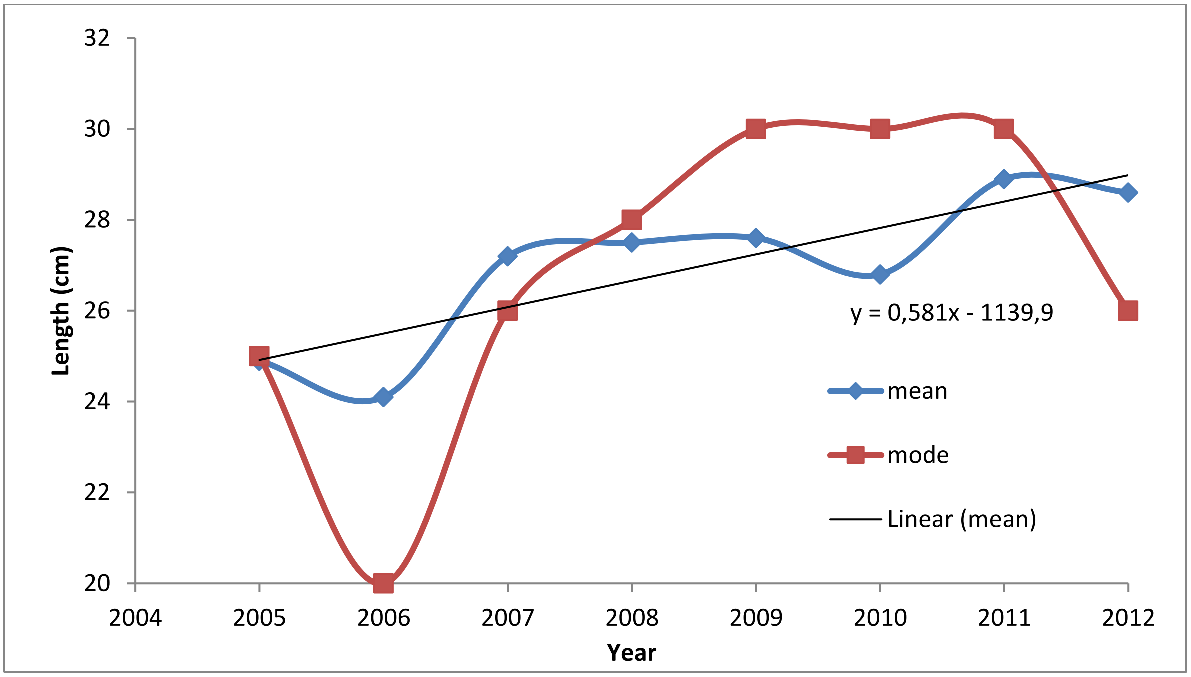

Figure 12. Mean and mode of the length-frequency distribution for the sampled landings of sargo during the period 2005 to 2012. Note that the slope of the trend line is positive and is significantly different from 0.

The results of the transformation of the length frequency distribution to an age-frequency distribution are shown in Figure 13 for three years during the study period, 2007, 2009, and 2010. It appears that sargo fully recruit to the fishery between ages of 6 and 7 depending on the year. When the slopes of the regression lines for the fully recruited relative numbers in the catch versus age are estimated, the total mortalities for years 2005, 2008, and 2012 are 0.56, 0.87 and 0.23, respectively. Given the best estimate of natural mortality (M) at 0.35, the estimated fishing mortality for 2005, 2008, and 2012 are 0.21, 52, and -0.12, respectively. The estimate of a negative fishing mortality for 2012 clearly indicates a problem with either the assumption of M=0.35, the growth rate (K) used to estimate the age of the fish from the length, or finally the representativeness of the length-frequency data used in the analysis.

The results of the YPR and SSBPR analyses for sargo or sea bream using the same values of the input parameters used in the LCCA analysis are shown in Figure 14. Assuming a minimum length of entry into the fishery of 20 cm, the values of the growth overfishing reference points, $F_{0.1}$ is 0.34, and the recruitment overfishing reference point $F_{20\%}$ is 0.35. Note F_{max} is not defined, as the YPR curve does not peak. Comparing the estimated fishing mortality level in 2008 to the overfishing reference points based on a length of entry into the fishery of 20 cm, it is clear that the sargo stock in 2008 was experiencing both growth and recruitment overfishing.

However, in 2012 the results of the analysis, suggest that neither growth nor recruitment overfishing in occurring.

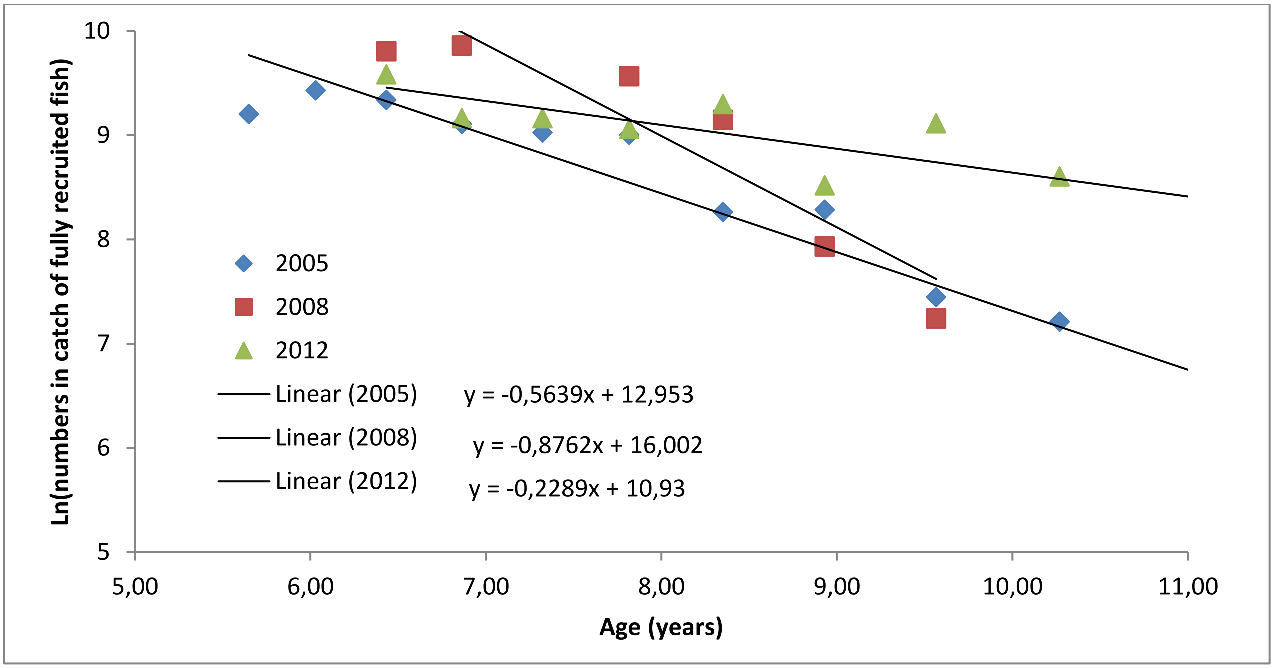

Figure 13. Results of length based catch curve analysis for sargo for fully recruited fish. Note that the slope of the regression line is total mortality (Z) and is 0.56, 0.87 and 0.23 for 2005, 2008, and 2012, respectively.

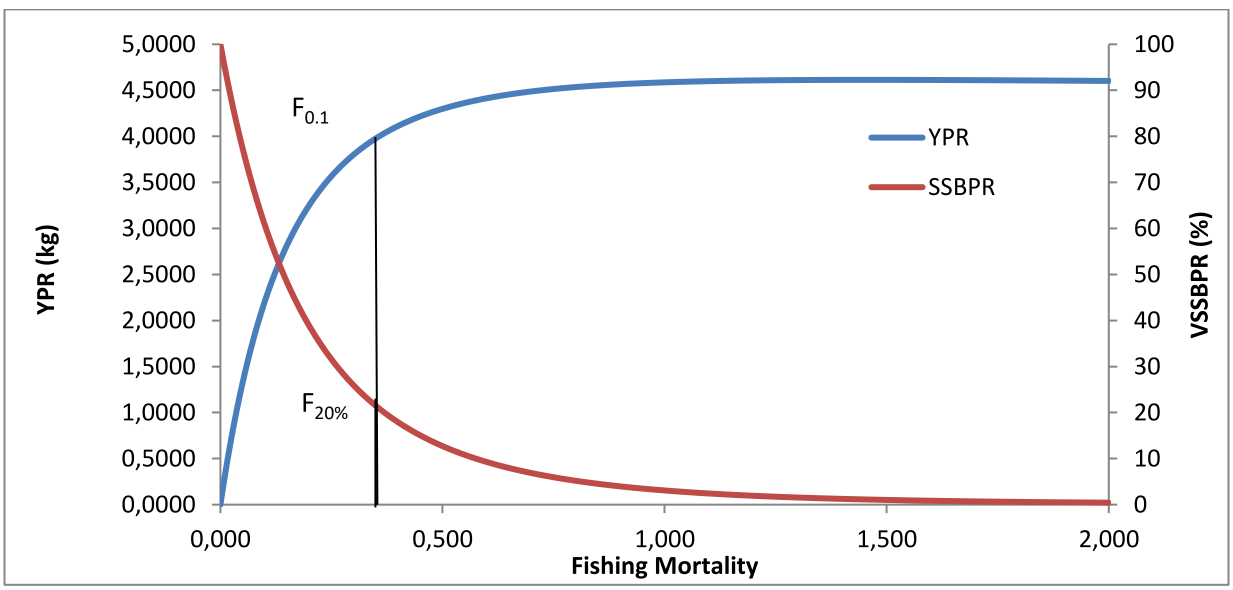

Figure 14. Results of YPR and SSBPR analysis for sargo assuming a length of entry into the fishery of 20 cm.

Moray eels

As noted previously, there is no effort data available for the demersal handline fisheries, so there are no relative indices of abundance for brown and purple mouth moray eels.

The results of the sampling of the lengths of the moray eel catch for the period 2002 to 2012 are summarized in a series of length-frequency distributions for the period (Figure 15). From these data it is clear that the length frequency distribution of the fish taken in the handline fishery has not changed over the period. The vast majority of the catch is primarily between 60 and 100 cm. When the mean and mode of each annual length frequency distributions are plotted versus time, the mean size of the eels landed has remained remarkably stable at 82 cm (Figure 16).

Given the lack of life history information, it is impossible to conduct a LCCA and similarly a YPR and SSBPR analysis. Therefore it is impossible to determine the level of exploitation of the moray eel resource.

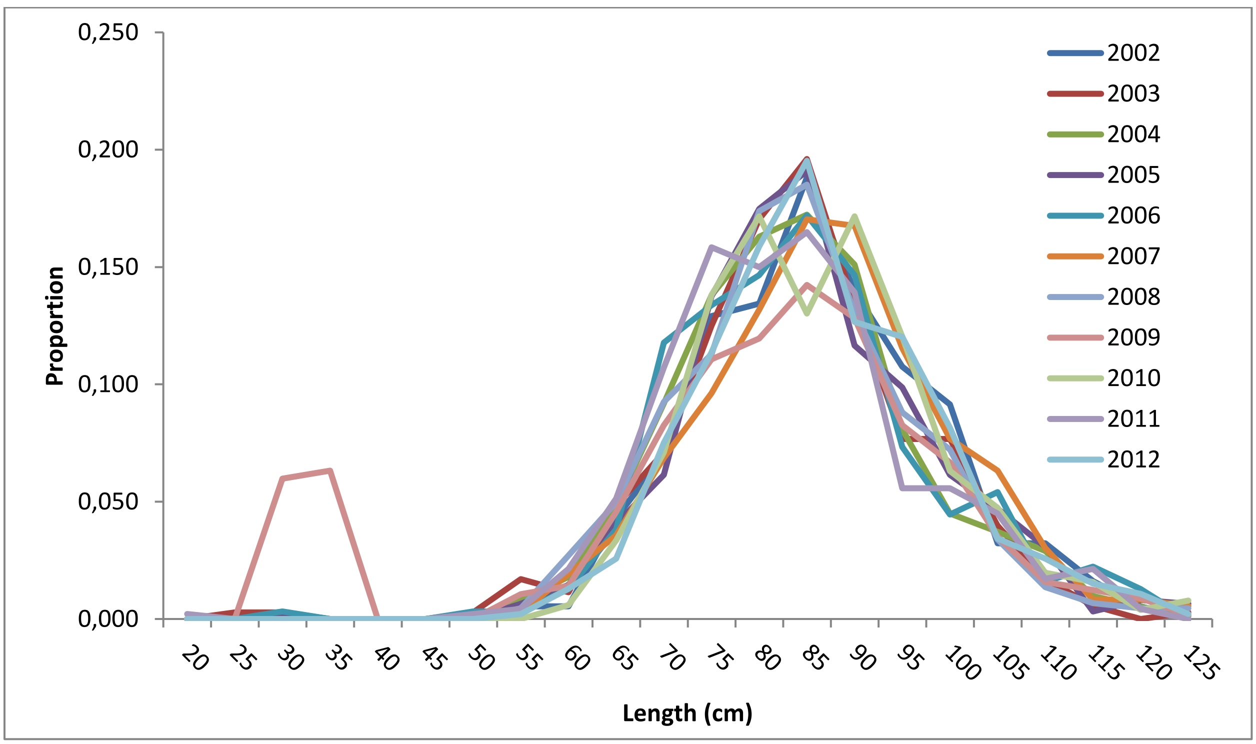

Figure 15. Length frequency distributions of moray eels sampled from the handline catch for the period 2002 to 2012.

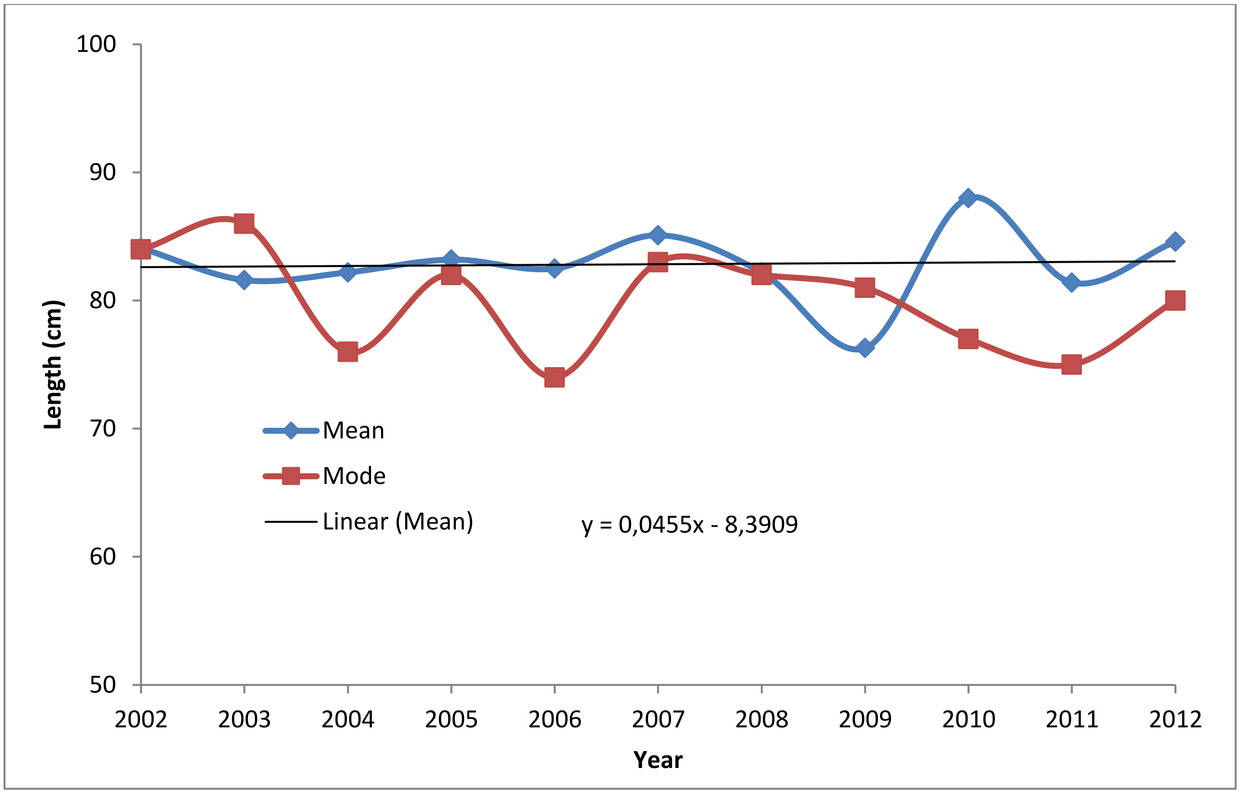

Figure 16. Mean and mode of the length-frequency distribution for the sampled landings of moray eel during the period 2002 to 2012.

DISCUSSION AND MANAGEMENT ADVICE

Groupa

Landings of groupa in the last two decades have ranged from a maximum of 120 mt in 2002 to a low of about 45 mt in the late 1980s and 2005 (after the peak landings in 2002). In the period 2006-2012 landings cycled between 45 and 85 mt, averaging 50 mt. It is interesting and puzzling to note that during the period from 1998 to 2002 the CPUE index of effective catch per fishermen per hour, showed no significant trend, indicating no change in relative abundance of the species, and yet this occurred in a period when landings increased about 50%. A basic premise of surplus production theory is that as catch increases, the stock biomass and CPUE must be changing also, either positively or negatively.

A previous assessment of stock status of groupa in all Cape Verdean waters stated that this species was fully exploited, and estimated that the sustainable level of catch was about 75 mt (Tariche-pastor, 2002). Note that the landings for just the north islands well exceeded 75 mt for the period 1997-2003, and then reduced to an average of 65 mt through 2012, suggesting the effects of overfishing during the previous period. Groupa is a slow growing, long lived species, that matures at more about one half its maximum length. These life history characteristics make the species very susceptible to overfishing (Tariche-Pastor, 2002).

Based on the length frequency distributions of the sampled catch in the period 2004 to 2012, it appears that groupa begin to recruit to the fishery at a length of 20 cm, long before they fully mature, and are fully recruited to the fishery at about 30 cm, corresponding to the length of full maturity. The results of this study indicate that the mean and model lengths of the groupa landed during the period have increased significantly during period 2004 to 2012. The results of LCCA indicate a fishing mortality rate ($F_{current}$) in 2012 of 0.547, while the results of the YPR and SSBPR analyses indicate growth and recruitment overfishing mortality reference points (F_{max} and $F_{20\%}$) of 0.31 and 0.44. Therefore it is concluded that groupa is experiencing both growth and recruitment overfishing. While the results of the LCCA indicate an overfishing situation, the increase in the mean size of the fish landed indicate that either the size frequency distribution of the population is increasing or that fishermen are discarding more of the smaller groupa that are captured.

The management advice resulting from this study for groupa is as follows:

- There should be the establishment of a minimum size for groupa that are landed, and that this size should approach 30 cm so as to allow every fish to spawn at least once before being landed. This will contribute to an increase in the yield by reducing growth overfishing, and increase the spawning stock, allowing stock rebuilding.
- Fishing mortality on groupa must be reduced overall to allow the stock to rebuild, and to increase overall yield. This is best achieved by limiting effort and /or by establishing closed seasons.

Stripped sea bream

Landings of striped sea bream averaged about 20 mt in the late 1980s and early to mid- 1990s, but steadily decreased from 1997 to 2012. From 2007-2012, landings of striped sea bream averaged about 5 mt. Analysis of the means and modes of striped sea bream sampled from the landings indicate a significant increase in the size of the fish landed from 2005 through 2012. However, it appears that much of the increase is due to the reduction in the catch of very small striped sea bream (less than 20 cm) that occurred in 2005 and 2005. Without those data, there would be no significant trend in the mean or modal size of the fish landed. Clearly the mode of the L-F distribution of the fish landed in 2012 decreased substantially.

The results of LCCA indicate a fishing mortality rate ($F_{current}$) for sargo in 2012 of -0.12 (an impossible situation), while the results of the YPR and SSBPR analyses indicate growth and recruitment overfishing mortality reference points ($F_{0.1}$ and $F_{20\%}$) of 0.34 and 0.35, based on a length of entry into the fishery of 20 cm. Therefore it is concluded that sargo is also experiencing recruitment overfishing.

The management advice resulting from this study for sargo is as follows:

- There should be the establishment of a minimum size for sargo that are landed, and that this size should approach 30 cm so as to allow every fish to spawn at least once before being landed. This will contribute to an increase in the yield by reducing growth overfishing, and increase the spawning stock, allowing stock rebuilding.
- Fishing mortality on sargo must be reduced overall to allow the stock to rebuild, and to increase overall yield. This is best achieved by limiting effort and /or by establishing closed seasons.

Moray eels

Landings of moray eels steadily increased from about 30 mt in the late 1980s to 65 mt in 2002, but decreased to an average of about 40 mt in the period 2007-2011. In 2012 landings were decreased further to 15 mt. However during the period from 2002-2012 the length frequency distribution of the catch remained unchanged, suggesting no negative effects of overfishing. Without reliable effort data, or information on markets, it is impossible to determine if the 2012 decrease in landings is due to changes in population abundance or fish availability to the gear, or due to a lack of market availability for the species.

The management advice resulting from this study for this species is that more data is needed on the life history characteristics of the species, and on the fishery including market demand.

RECOMMENDATIONS FOR FUTURE WORK

The analyses reported on herein have been severely limited by the availability adequate data on fishing effort in the demersals handline fishery, and further by the fact that the most recent landings data available for the fishery in 2014 is only 2012. While INDP is to be commended for summarizing the available landings and effort information annually in the annual Statistical Bulletins, there is no real database available to access the data in any form other than that provided in the annual Statistical Bulletins. More comprehensive data on landings and effort by species and fishery sector, that does not rely on the scaling up of limited observations, would be ideal.

The analysis reported on herein have also been limited to global models vice age or length structured models due to the lack of information on the length at age of the three species investigated. Analysis of biological samples in particular aging of fish, so as to be able to do age or length structured models is very important for future stock assessments of the demersal species.

Finally, there should be minimum landed fish length regulations for the various species landed in the demersal handline fishery. Minimum fish lengths that correspond to the length at 50% maturity at a minimum, and ideally correspond to a length of 75% maturity would avoid recruitment overfishing problems. Survival of discard undersize fish captured in the handline fishery should be evaluated to ensure that this is a sound management strategy.

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