# LINEFISH RESOURCES:
# ANNUAL REPORT FOR THE YEAR 2000
# PART 2: SPECIES PROFILE

*Chrysoblephus puniceus (marreco)*

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Polysteganus coeruleopunctatus (cachucho)

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*Cheimeirus nufar (robalo)*

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INDEX Page

## Abstract

This work refers to same biological aspects of *Chrysoblephus puniceus* (marreco), *Polysteganus coeruleopunctatus* (cachucho), and *Cheimeirus nufar* (robalo). This report shows the progress in the biological study of the three species but there are discrepancies that need to be resolved.

In 2000 the mean fork length of males and females of *C. puniceus* was established at 357 mm and 280 mm respectively. The length distribution of marreco confirms the different size structures of male and females in the catch as a result of sex change, with males predominating in the larger size. In the same year the overall sex ratio was determined to be m: f =1:7. The yield per recruit model for marreco revealed that the fishing effort directed to marreco is sustainable at he present levels.

The dominance of males in the larger size and the occurrence of two bisexual gonads provide reasonable evidence for sequential protogynous hermaphroditism in cachucho. The mean size of the cachucho trapped over the past four year has decreased. The current predicted SBPR level of 35 % for cachucho is slightly below the threshold level of 40% used for other linefish species. Fishing mortality and hence fishing effort, for this species should therefore not be allowed to increase.

The mean fork length of robalo caught by line increased from 1998 to 2000. The parameters used to assess robalo must be considered as preliminary and require substantial future verification. However, the level of F that would represent threshold (25%) and target (40%), lie between approximately F=0.185 and F=0.075, depending on the M value selected. These levels of F are very low, suggesting that threshold levels of spawner biomass can be attained at low fishing pressure.



## Resumo

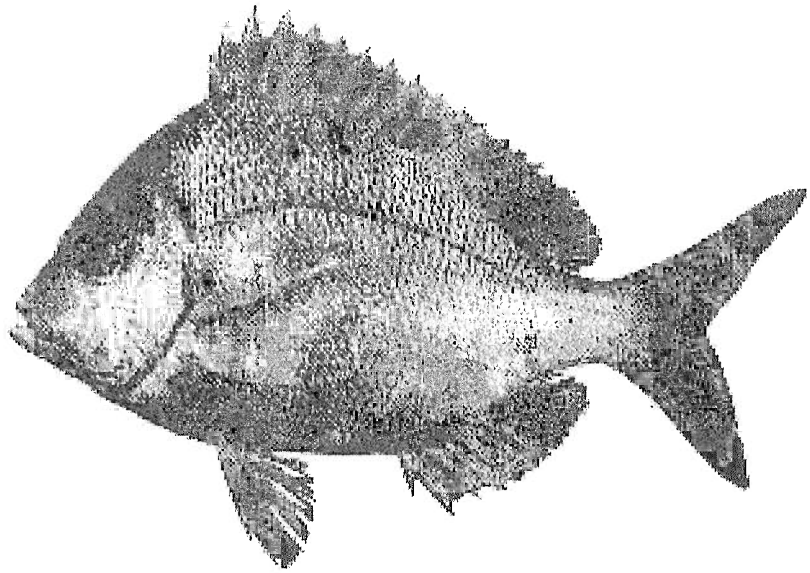
Este trabalho refere-se a alguns aspectos biológicos de *Chrysoblephus puniceus* (marreco), *Polysteganus coeruleopunctatus* (cachucho) e *Cheimeirus nufar* (robalo). O mesmo trabalho ilustra a progessão dos estudos da biologia das três espécies porém, mais estudos terão que ser realizados para esclarecer algumas discrepâncias encontradas em alguns resultados.

Em 2000, o comprimento médio à fúrcula de machos e fêmeas de marreco foi de 357 mm e 280 mm, respectivamente. A distribuição das frequências de comprimento de marreco confirma a diferença de tamanhos de machos e fêmeas na captura como resultado da mudança de sexo, onde os machos predominam nas classes de comprimento maiores. No mesmo ano a proporção de sexos foi de 1:7 (m: f). O modelo de produção de recruta revela que o esforço de pesca direccionado ao marreco é sustentável no presente nivel de mortalidade por pesca (F= 0,25 year$^{-1}$).

A predominância de machos nas classes maiores de comprimento à fúrcula e a ocorrência de duas gónadas hermafroditas indicam que o cachucho muda de sexo num determinado estágio da sua vida. O tamanho médio à fúrcula de cachucho capturado com covos tem vindo a decrescer nos últimos quatro anos. Avaliação preliminar sobre o estado de exploração do cachucho indica que a biomassa desovante por recruta é de 35 % da biomassa virgem no nível actual de mortalidade por pesca (F= 0,377 ano $^{-1}$). Esta percentagem está muito próxima de 40% que é o limite definido como aceitável nos recursos explorados pela pesca à linha. Sendo assim, não é recomendável o aumento do esforço de pesca.

O tamanho minimo à fúrcula de robalo capturado à linha sofreu um ligeiro aumento de 1998 a 2000. Os parâmetros usados na avaliação do robalo são preliminares e requerem uma verificação. Porém, o valor da mortalidade por pesca (F) atingido a 25 % e 40 %, intervalo de percentagem da biomassa virgem aceitável, indicam para F= 0,185 e F= 0,075, dependendo do valor da mortalidade escolhida. Estes valores de F são baixos, sugerindo que o valor máximo aceitável do sotck da biomssa virgem pode ser obtido a niveis baixos de esforço de pesca.

# 1. MARRECO OR SLINGER - *Chrysoblephus puniceus*



***Chrysoblephus puniceus***

This species is a protogynous hermaphrodite of the family Sparidae and is endemic to the region, from southern KwaZulu-Natal, South Africa to mid Mozambique. The marreco is traditionally the mainstay of the linefishery, both in Mozambique and in KwaZulu-Natal. Because of its value, prominence in catches and preferred target for much of the linefish sector, the status of the marreco is an important indicator of the linefishery as a whole. While considerable research has already been directed at this species, its life history remains difficult to interpret. In particular its age and growth rates are complex and at this stage defy complete understanding. A specific MSc study, undertaken by an IIP staff member, will throw more light on this species in the months ahead.

## 1.1. Assessment Strategy

The assessment of marreco revolves around a number of different data sets, including CPUE, length distribution, mortality rates, sex ratios, yield per recruit (modified for sex change) and spawning biomass per recruit. The latter two models are applied using biological reference points that have been developed over the past few years. Some uncertainty remains over these parameters, especially concerning the growth rate, which depends on the interpretation of the rings counted in the sectioned otoliths. This has significant implications for assessment, and thus management, and must be resolved in the near future. At this stage, the information proposed by Garratt *et al* (1993) and Mann (2000), is used as the primary source of input parameters. These data indicate that a single band is deposited in the otolith each year. Studies currently underway at IIP suggest that there may be two bands per year. This would significantly alter the assessment. However, the single band scenario is in fact the more conservative option and will for the moment be used in the assessment.

The management target of this fishery can be variously defined. However, most relevant would be the use of spawning biomass levels, set at target and threshold levels. There is considerable debate about the correct levels to use. However, a target of 40% and a minimum threshold of 25%, of unfished levels, is considered acceptable. Previously 35% was used as a minimum level in Mozambique assessments (van der Elst *et al* 1995) but additional studies suggest that 25% can be acceptable (see Mace and Sissenwine 1993; Mann 2000 and Fennessy 2001). Obviously, the 25% level must then be regarded as the absolute minimum. Levels lower than this would infer a serious stock collapse.

Note that all length measurements relate to fork length unless otherwise specified.
The parameters used in the 2000 assessment are as thus as follows-

Table1. Parameters of *C.puniceus* used in the 2000 per recruit stock assessment

| Parameter | Value | Source |
|---|---|---|
| $L_{inf}$ | 434.8 mm FL | Garratt *et al* 1993 |
| K | 0.201 | Garratt *et al* 1993 |
| $t_o$ | -1.279 yrs | Garratt *et al* 1993 |
| M | 0.3 | Punt *et al* 1993 |
| $t_c$ | 4 yrs | This study |
| Max age | 20 yrs | Assumed |
| A | $4.83 \times 10^{-5}$ | This study |
| B | 2.89 | This study |
| $t_m$ | 2 yrs | Punt *et al* 1993 |

(Note that these are not the same parameters used in Lichucha *et al* 2000)

## 1.3. Size Composition

A total of 4268 marreco were measured during 2000, all selected randomly from discharged landings in the port of Maputo. This frequency distribution is presented together with similar distributions recorded in previous years. (Figure 1) These graphs reveal a "gentle" right hand slope indicating that a wide range of size classes are present in most years. This in turn suggests a relatively healthy population size distribution.

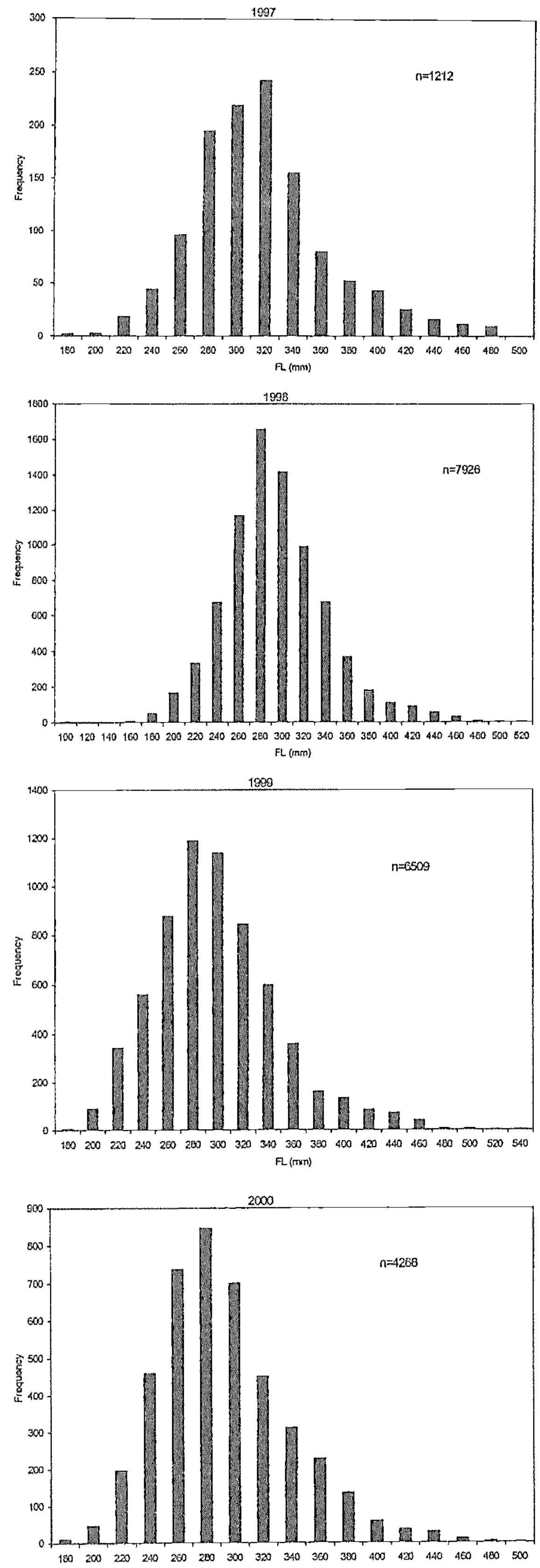



Figure 1. Length frequency distribution for *C. puniceus* recorded during the years 1997 to 2000.

In the 1980s, Piotrovsky (1990) collected considerable length frequency data from marreco, thus providing important insight into what was close to a virgin fishery situation. After his analysis in those early years no length data were recorded, until 1995, when it was recommended that such data be actively collected. Some of the key results from these length distributions in mm are summarised below:

Table 2. Length distribution of *C.puniceus* during the years 1988-2000

| | Sample (n) | Min (mm) | Mean (mm) | Mode (mm) | Max (mm) | Source |
|---|---|---|---|---|---|---|
| 1988 | 1480 | 220 | 407 | | 640 | (Piotovsky,1990) |
| 1990 | Small | 260 | 436 | | 560 | |
| 1994 | ? | | | | | |
| 1995 | ? | | | | | |
| 1996 | ? | 180 | 311 | 320-339 | | This study |
| 1997 | 1212 | 180 | 311 | 280-359 | 590 | This study |
| 1998 | 7926 | 119 | 299 | 260-319 | 525 | This study |
| 1999 | 6509 | 170 | 304 | 260-339 | 550 | This study |
| 2000 | 4268 | 180 | 295 | 260-319 | 500 | This study |

The above data indicate a modest reduction in mean, maximum and modal size over the past number of years. This is to be expected in a developing fishery, at least until such time that a level of sustainable stability has been reached.

A sub-sample of the total 2000 sample was used to establish length distribution by sex, which is reflected in Figure 2. This clearly confirms the different size structures of males and females in the catch as a result of sex change, with males predominating in the larger size classes. Males are seen to range mostly from 300mm to 500 mm, while females predominate in the 200mm to 380mm length range. The mean for males and females was established at 357mm and 280 mm respectively.

Comparing these mean lengths of each sex to past the past years suggests that there has been some change, although this may have been induced by a sampling bias in 1999.

Table 3. Mean length of *C. puniceus* sampled during 1999 and 2000

| | 1999 | 2000 |
|---|---|---|
| Males | 377 | 357 |
| Females | 311 | 280 |

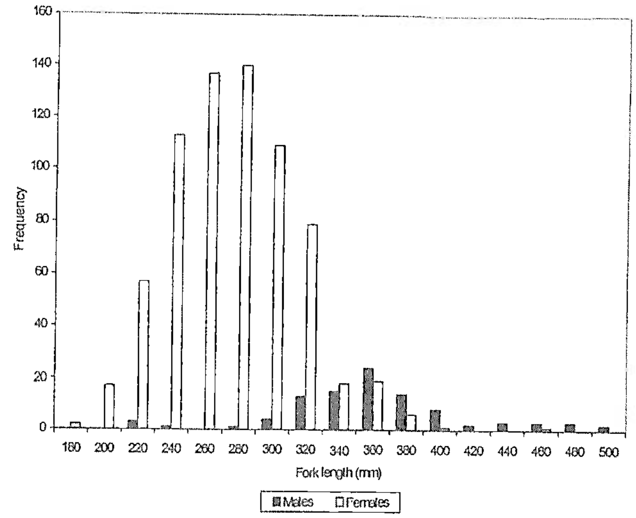



Figure 2. Length frequency distribution for male and female *C. puniceus* for the year 2000.

## 1.4. Sex Ratios

Determining the sex ratio in the catch is an important parameter that is proportional to the amount of fishing effort exerted on the stock (Garratt 1985; van der Elst *et al*, 1995.) The reason for these lies in the fact that removing the larger fish (ie males) from the stock alters the sex ratio in favour of females. Based on the relationship developed earlier (van der Elst *et al*, 1995), it is possible to estimate the fishing mortality rate F.

The overall sex ratio for 2000 was determined to be m:f = 1:7. Values for 1999 and 1998 were 1:3 and 1:6 respectively. Converting these ratios to F values gives the following results-

Table 4. Sex ratio and F values for *C. puniceus* during the years 1996 to 2000

| Year | Ratio:m/f | est. F |
|---|---|---|
| 1996 | 0.18 | 0.22 |
| 1997 | 0.10 | 0.32 |
| 1998 | 0.17 | 0.23 |
| 1999 | 0.33 | 0.15 |
| 2000 | 0.14 | 0.28 |

These indicate moderate levels of fishing mortality. The value for 1999 is surprising. However, on closer examination it appears that the samples obtained during that year were selected by the fishers themselves before giving access to IIP staff, so clearly these samples were biased. This is also apparent from the size distribution and especially the catch curves discussed later. The 1999, samples were selected to contain more of the larger fish so that would include more males and hence an artificially lower sex ratio and reduced F.

## 1.5. Mortality estimates

The estimation of mortality provides a good indicator of the state of the stock. If levels of F exceed the estimated levels of M, then, as a rule of thumb, the stock may not be able to sustain that level of pressure (Butterworth *et al* 1989). Comparing levels of mortality, such as total mortality Z, from year to year provides insight into the overall trend in pressure being exerted on the stock and may also indicate the efficacy of management measures.

Values of Z were calculated from the catch curves derived from the total sample measured. The growth parameters given above were used to convert the data into an age distribution. This means that the $L_\infty$ is taken as 435 mm (14 years) and the age at first capture = 4 years. Two analysis strategies were used, one calculating Z from ages 4 to 14 years and the other from ages 4 to 9. The reason for this latter approach was to remove the many older age classes that contained only small samples.

Table 5. Total mortality (Z) values of *C. puniceus* during the years 1997-2000

| Year | Z (4-14 years) | Z (4-9 years) |
|---|---|---|
| 1997 | 0.50 | 0.60 |
| 1998 | 0.57 | 0.55 |
| 1999 | 0.54 | 0.5 |
| 2000 | 0.53 | 0.58 |
| Average Z | 0.53 | 0.56 |
| Average F | 0.23 | 0.26 |

These values are surprisingly consistent between years, with the addition of 5 years (Z 4-14) not changing the results substantially. Considering that M was estimated to be 0.3, this means that the average value of F over the past four years was around 0.25, i.e. less than the value of M.

The above estimates are based on the number of fish caught in age-classes of the same year. However, it is also possible, and more realistic, to follow the abundance of a single age class (cohort) over a number of years if such annual data is available. Each cohort is expressed as a percentage of the total and then the abundance of a cohort in one year is compared to the same cohort in the following year. (Gulland, 1985). The following table provides the percentage abundance of various cohorts, followed by a table of instantaneous mortality values.

Table 6. Percentage abundance of various cohorts of *C. puniceus* followed by instantaneous mortality values.

| Percentage composition | | | | | | | |
|---|---|---|---|---|---|---|---|
| | age 4 | age 5 | age 6 | age 7 | age 8 | age 9 | |
| 1997 | 26.49 | 26.82 | 12.79 | 6.6 | 2.72 | 1.57 | |
| 1998 | 29.01 | 23.38 | 10.81 | 6.59 | 2.14 | 1.45 | |
| 1999 | 15.15 | 17.42 | 15.15 | 12.12 | 5.3 | 1.85 | |
| 2000 | 28.91 | 21.44 | 8.88 | 6.49 | 2.44 | 1.85 | |
| **Instantaneous total mortality Z** | | | | | | | |
| | 4>5 | 5>6 | 6>7 | 7>8 | 8>9 | | Average |
| 97>98 | 0.11 | 0.45 | 0.38 | 0.49 | 0.37 | | 0.36 |
| 98>99 | 0.33 | 0.30 | -0.13 | 0.18 | 0.13 | | 0.26 |
| 99>00 | -0.51 | 0.39 | 0.44 | 0.55 | 0.48 | | 0.21 |

All fish older than nine years and younger than four were excluded from this analysis. Their proportion of the catch is reflected below.

Table 7. Proportion of the catch from fish older than nine years and younger than four years of *C.puniceus*

| | % under 4 | %over 9 |
|---|---|---|
| 1997 | 14.4 | 2.1 |
| 1998 | 22 | 1.3 |
| 1999 | 17.4 | 2 |
| 2000 | 25 | 1.1 |

The results are interesting, indicating mostly a very low level of Z. This information suggests a relatively constant proportion of older fish but fewer young fish in 1997 and 1999. The cohort mortality data shows that in some cases the Z is negative. This is clearly impossible, and represents a poor sampling situation. Especially in 1999, it was known that the samples were probably biased through fisher pre-selection. For example, the 4-year old cohort in 1999 increased from 15.15% to 21.44 % in the following year. This reflects one of two situations:

a) the sample was poorly selected and not representative of the catch or
b) the fish landed were derived from new, unexploited fishing grounds and comprised a sudden increase in the abundance of older cohorts.

Notwithstanding the possible sampling bias, these values suggest that F is indeed low, if consideration is given to the entire stock of marreco. Unfortunately, it was not possible to separate the catches of this species between different localities so that local stock assessment of this species is masked and thus potentially compromised.

## 1.6. Yield and Spawning Biomass Per Recruit

The Yield per Recruit model for marreco has already been developed (Garratt *et al*, 1993; Lichucha *et al*, 1998), ready for application in any one year. This is plotted below (Figure 3), with an indication of the threshold and target levels of spawner biomass per recruit.

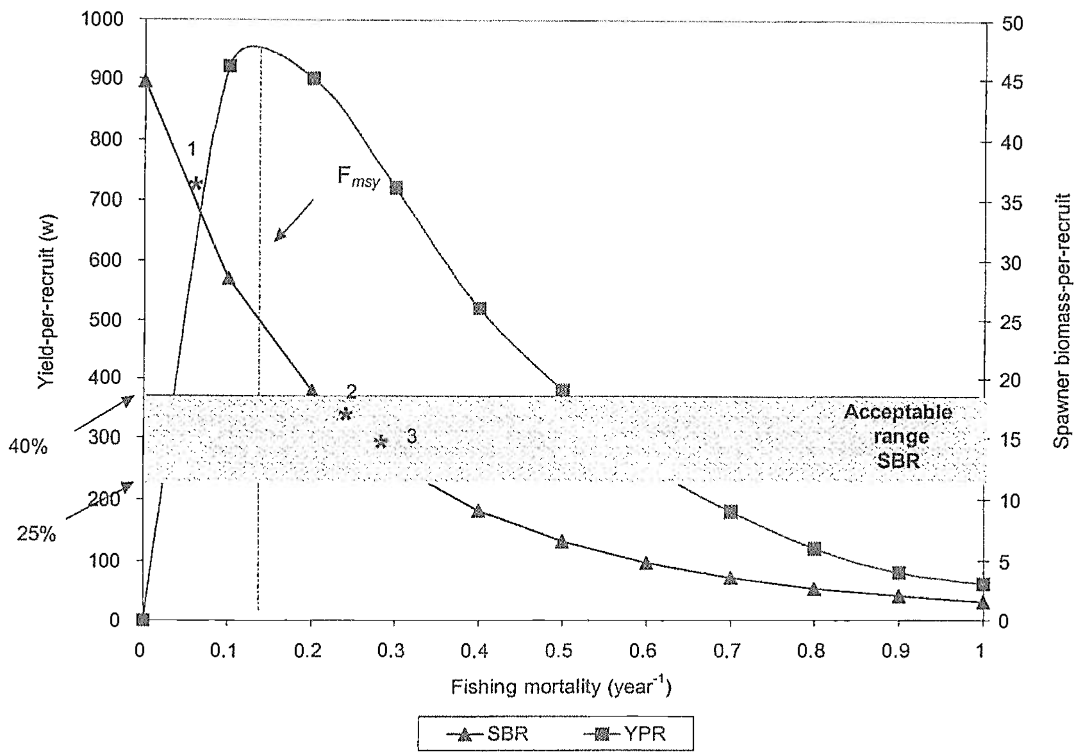



Figure 3. YPR and SBR curves, with threshold and target levels for ***C. puniceus.***

Thus, for the year 2000, the different values calculated for F need to be inserted in order to determine potential yield per recruit and especially the levels of spawning biomass. Noting that the threshold level is 25% SBR it is evident that none of the values of F (0.32; 0,23; 0.26; 0,06) produce SBR levels below the threshold level. The very low F=0.06 suggests that the resource would be under-utilised at this level, although this is not considered a reliable estimate.

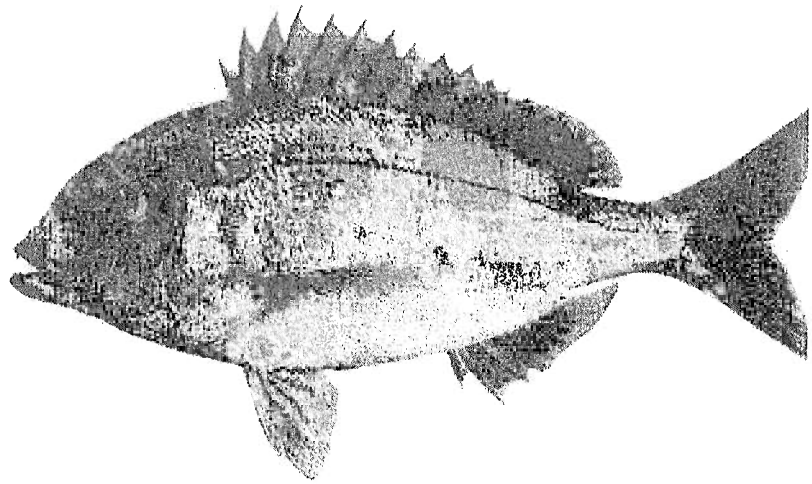
The maximum yield, according to the model, is achieved at F=0.15. Clearly, most of the F levels determined here suggest that yield is not maximised, although this would still be close to maximal levels possible.

## 1.7. Conclusion

There is compelling evidence to suggest that fishing effort directed at marreco is sustainable at the present levels. This is concluded because the different values of F calculated do not result in a drop below threshold levels of spawner biomass per recruit. However, there is a need for caution. It has been clearly shown, and confirmed by fishers, that fishing effort is progressively shifting away from Maputo perhaps by more than 60%. This is not because the markets have changed, but rather because local stocks have dwindled. The result is that vessels are now travelling much further to operate near Inhambane and beyond in zone 3. These operators are accessing new, sometimes near-virgin, fishing grounds, thus mixing their fish with those caught in the Maputo (zone 4) region. The result is that larger fish suddenly appear, causing a lower slope to the catch curve and thus lower perceived F values. This situation potentially holds very serious implications. Once the "new" fishing grounds have also been depleted, it can be expected that there will be a sudden collapse in marreco stocks. Clearly, it is imperative to monitor catches by zone so as to avoid this possibility, perhaps by managing access to this resource on a zone by zone basis.

It is also important to note that the reference points selected for marreco are not yet reliable. The confusion surrounding the age model, and thus K and M values, is serious. While a more conservative approach was adopted here, there is an urgent need to resolve this matter-preferably with a short-term intense sampling project, jointly in Mozambique and South Africa.

## 2. CACHUCHO, BLUESKIN OR TRAWL SOLDIER – *Polysteganus coeruleopunctatus*



*Polysteganus coeruleopunctatus*

### 2.1. Introduction

*Polysteganus coeruleopunctatus*, cachucho, blueskin or trawl soldier, belongs to family Sparidae and occurs from Red Sea to Natal South coast, where it frequents reefs, especially during winter, down to 100 metres (Smith and Heemstra, 1986). The fairly large liquid eye, the red to pink body and blue spot are characteristic of the live fish (Smith and Heemstra, 1986). This species could attain 60 cm and its carnivorous (Fisher *at al*, 1990).

In Mozambique cachucho is caught by traps, line and deep trawler fishery. Most attention is given to cachucho since the introduction of the trap fishery because cachucho before by-catch becomes target species.

Very few studies have been done about blueskin and this study will contribute for the increase of the knowledge about this fish. This study refers to aspects of age, growth and reproduction, included histological examination of gonad development. All these aspects above mentioned will be very useful to develop a management strategy for this species.

## 2.2. Materials and Methods

### 2.2.1. Collection of Specimens

From May 1999 to April 2000, a sub-sample of 30 cachucho per month was selected on board and kept on ice for up to ten days until the vessels returned to port, where gonads and otoliths were collected. Gonads were stored in 10% formal-saline until processed, and otoliths were stored dry in envelopes. Total length, fork length, whole fish weight and gonad weight were collected for each of these fish, and sex and maturity stage were also noted using macroscopic methods. (Table 8). Lengths were also collected from a random sub-sample of catches from both the trap fishery and the line fishery (both onboard and in Maputo harbour). A length-weight relationship (Weight (g) = a x FL (mm)$^b$) was calculated, and differences in mean lengths of males and females were assessed using a t test.

Table 8. Description of macroscopic gonad stages of *Polysteganus coeruleopunctatus*

| Stage | Description |
|---|---|
| Inactive/immature | Gonads small. Ovaries are round in cross-section and transluscent yellow. Testes are thin and off-white in colour. |
| Active | Ovaries are swollen and yellow-orange in colour, with eggs just visible. Testes are white and small amounts of sperm are visible if the gonad is cut and squeezed. |
| Ripe | Ovaries are yellow-orange, swollen and extend most of the body cavity. Eggs are clearly visible and hydrated eggs may occur in very ripe ovaries. Ovarian blood vessels may be numerous. Testes are white, large and sperm is easily extruded from the sperm duct. |
| Spent | It is uncertain whether gonads of this stage occurred in cachucho, as this species potentially spawns throughout the year (see results). |

### 2.2.2. Reproductive Biology

Cross-sections from the mid-region of preserved gonads were processed at INIVE (Instituto Nacional de Investigação Veterenária) according to standard histological techniques, sectioned at 5 µm, stained with haemotoxylin and eosin and mounted on slides (Garratt 1986). On examination at the IIP laboratory using a Nikon profile projector V-12 B, gonads were assigned to maturity stages based on the criteria described in the results. The classifications obtained were compared with the classifications obtained using macroscopic methods.

### Spawning Season

This was investigated using a monthly gonad index calculation of the form:

GSI = (Gonad weight ÷ fish weight) * 100

as well as by examining the relative proportions of maturity stages per month.

### Size/age at maturity

This was determined by examining the relative monthly proportions of mature (active and ripe) fish and immature fish, and fitting a logistic curve of the form:

$Y = 1/1(1\ n + \exp(-(x_{mid} - x_{0.5}))/\delta)$ (Butterworth *et al.* 1989)

Where Y is the proportion of mature fish in length class X, $X_{mid}$ is the midpoint of the class interval, $X_{0.5}$ is the length at 50% maturity and $\delta$ is the length of the maturity ogive. Normally, this is calculated only for fish that have been sampled during the spawning season, but in this analysis, all specimens were used because it appeared that spawning in cachucho occurs throughout the year (see Results). The size at maturity was converted to an age at maturity using the growth curve.

## 2.2.3. Age and Growth

The otoliths of cachucho are thick and opaque, so they were embedded in clear resin, sectioned at 0.4 mm using a mono-bladed diamond saw at the Oceanographic Research Institute in Durban, and mounted on slides. Examination of otoliths using transmitted light was initially done at the University of Eduardo Mondlane (n = 160) and thereafter at IIP using a Nikon profile projector (n = 167). Otoliths were read three times by one reader and once by another reader, and opaque rings were counted. If two or more counts coincided, that value was accepted as the best estimate of age, otherwise the otolith was rejected. Differences between male and female lengths at age were assessed using t tests.

The reproducibility of the age estimates was assessed using the average percentage error method of Beamish and Fournier (1981). Validation of periodicity of ring deposition was undertaken using marginal zone analysis, and the relative monthly proportion of opaque and hyaline rings was calculated. A von Bertalanffy growth model was fitted to the observed age at length data using an Xcel spreadsheet model which minimised the sum of squared residual differences between observed and predicted lengths.

### 2.2.4. Mortality and Stock Assessment

An age-length key was constructed using the age data and all lengths measured in 2000. Total mortality (Z) was estimated from the descending limb of the age-converted catch curve. Natural mortality (M) was estimated from the Pauly (1980) equation using a sea temperature of 20°C. Note that selection of this temperature was based on the fact that this species occurs primarily at depths greater than 100 m, where 20°C prevails in Mozambique (Gammelsrod and Hoguane 1995). Fishing mortality (F) was derived from the difference between Z and M. The mortality and growth parameters were used in per recruit analyses using a spreadsheet model to provide a preliminary report on stock status of cachucho.

## 2.3. Results

### 2.3.1. Reproductive Biology

The histological material was carefully studied, both by the IIP staff and by the consultants. As a result, a suite of histological descriptions of the gonad stages of cachucho were developed which are described below and photographically documented in Appendix I.

**Males**

*Inactive*

No testes of this stage were found. These gonads are normally small and consist mostly of spermatogonia and a few seminiferous tubules showing early stages of spermatogenesis i.e. primary and secondary spermatocytes.

*Active (n =100)*

These testes consisted mainly of primary and secondary spermatocytes arranged in cysts within tubules. Each cyst consisted of spermatocytes at the same developmental stage. Some tubules, particularly those closest to the sperm duct, contained spermatids in the centre of the tubule. The tubules that contained spermatids were larger and more elongate than the less well-developed tubules. The main sperm duct of many of these gonads contained small amounts of spermatozoa (sperm). Testes of this stage were found in all months that were sampled. Several testes contained one or two brown-bodies, the function of which is uncertain.

*Ripe (n = 32)*

These testes contained many tubules that were filled with spermatids, and the main sperm duct also contained sperm in varying amounts. There were also tubules, particularly on the periphery of the gonad, that were not as advanced in development and which still contained primary and secondary spermatocytes. Included in this stage were testes that appeared to be partly-spawned i.e. which contained several tubules which were empty or which only contained remnants of spermatids.

*Spent* (n =2)

These testes had a disrupted appearance and a relatively greater amount of connective tissue. Some tubules, particularly on the periphery of the gonad, still contained primary and secondary spermatocytes and spermatids, while the central tubules were mainly empty.

**Females**

*Inactive (n =56)*

There were three types of inactive ovaries. Inactive/immature ovaries were small, compact and consisted of closely-packed, irregularly shaped previtellogenic oocytes (PVOs) with a large nucleus. Many of these nuclei contained peripheral nucleoli. Inactive/mature ovaries were much larger in size, with the PVOs arranged in lamellae around a lumen. The tissue had a disrupted appearance, with numerous gaps, indicating previous spawning. Some ovaries from larger fish did not exhibit obvious signs of previous spawning, and these were designated as inactive ovaries. There were also three large (FL 400, 330 and 285), presumably mature fish with gonads undergoing massive atresia - PVOs were all atretic, and there was a large amount of cell debris in the gonad. Although no obvious signs of male tissue were observed in these gonads, these fish were designated as potentially changing sex.

*Active (n = 73)*

The ovaries contained PVOs as well as numerous primary and secondary yolk vesicle oocytes, characterised by their enlarged size and appearance of zona radiata and lipid droplets.

*Ripe (n =32)*

The ovary consisted of many large, tertiary yolk vesicle oocytes as well as primary and secondary oocytes and PVOs. Towards the end of this stage, hydrated oocytes (eggs) occurred. The occurrence of several stages of oocyte development in a single gonad indicates that spawning of eggs probably occurs in batches.

*Spent*

No ovaries of this stage were observed. Normally, these gonads have a disrupted appearance and consist of large numbers of atretic, vitellogenic oocytes.

*Bisexuals (n = 2)*

Only two gonads were classified as bisexual. These gonads were largely male in appearance, with several stages of spermatogenesis (primary and secondary spermatocytes and spermatids). Separated from the male region by a band of connective tissue was a region of female tissue consisting of numerous PVOs that appeared to be atretic. Two other gonads that were classified as male also contained a few very small, atretic PVOs. It was anticipated that at least some female gonads would have a region of inactive male tissue (observed in sparids that are protogynous hermaphrodites - e.g. Buxton 1986), but no obvious indications of this were observed.

## 2.3.2. Comparison Of Macroscopic And Histological Staging

Comparing the results based on macroscopic staging with that of histological staging revealed that while macroscopic staging produced reasonable results for determination of sex, the determination of reproductive stage was often inaccurate (Table 9). This may have partly been caused by difficulties in establishing macroscopic stages of gonads from fish that were not fresh (i.e. had been kept on ice for some time), and/or uncertainty in recognising macroscopic stages. Macroscopic staging also does not readily allow distinction between inactive/immature and inactive/mature gonads. Consequently, all the analyses below were based on categorisation of sex or maturity using histological definitions.

Table 9. Comparison of macroscopic and histological staging of 327 gonads of cachucho collected from May 1999 to April 2000.

| | No. (%) |
|---|---|
| Macroscopic stage male, histological stage female | 7 |
| Macroscopic stage female, histological stage male | 13 |
| Macroscopic stage male, histological stage bisexual | 2 |
| % incorrect (macroscopic vs. histological) | (7%) |
| Males - macroscopic staging incorrect | 88 (66%) |
| Females - macroscopic staging incorrect | 78 (45%) |

## 2.3.4. Population Structure

Length frequency distributions and sex ratios revealed that the sampled population is significantly female biased, particularly in the smaller size classes (Table 10, Figure 4), while males predominated in the larger classes. Females ranged in length from 120 mm to 440 mm FL, and males ranged in length from 220 mm to 460 mm FL. The two bisexual individuals occurred in the intermediate size classes.

Table 10. The average size, minimum, maximum, t-test and sex ratio of female and male of cachucho trapped during 1997-2000

| | Females | | | | Males | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | n | Min (mm) | Max (mm) | Avg (mm) | n | Min (mm) | Max (mm) | Avg (mm) | t-test | Sex ratio |
| 1997 | 267 | 170 | 420 | 277.8 | 73 | 250 | 540 | 327.7 | 9.83* | 1:3.65 |
| 1998 | 1546 | 140 | 470 | 314.6 | 744 | 170 | 470 | 307.5 | 3.31* | 1:2.07 |
| 1999 | 1527 | 200 | 460 | 280.4 | 610 | 200 | 490 | 338.3 | 26.39* | 1:2.05 |
| 2000 | 1373 | 200 | 470 | 295.2 | 563 | 210 | 480 | 353.01 | 25.44* | 1:2.43 |
| **Overall** | 4713 | 140 | 470 | 295.8 | 1990 | 170 | 540 | 330.6 | 26.51* | 1:2.36 |

* indicates $P<0.001$

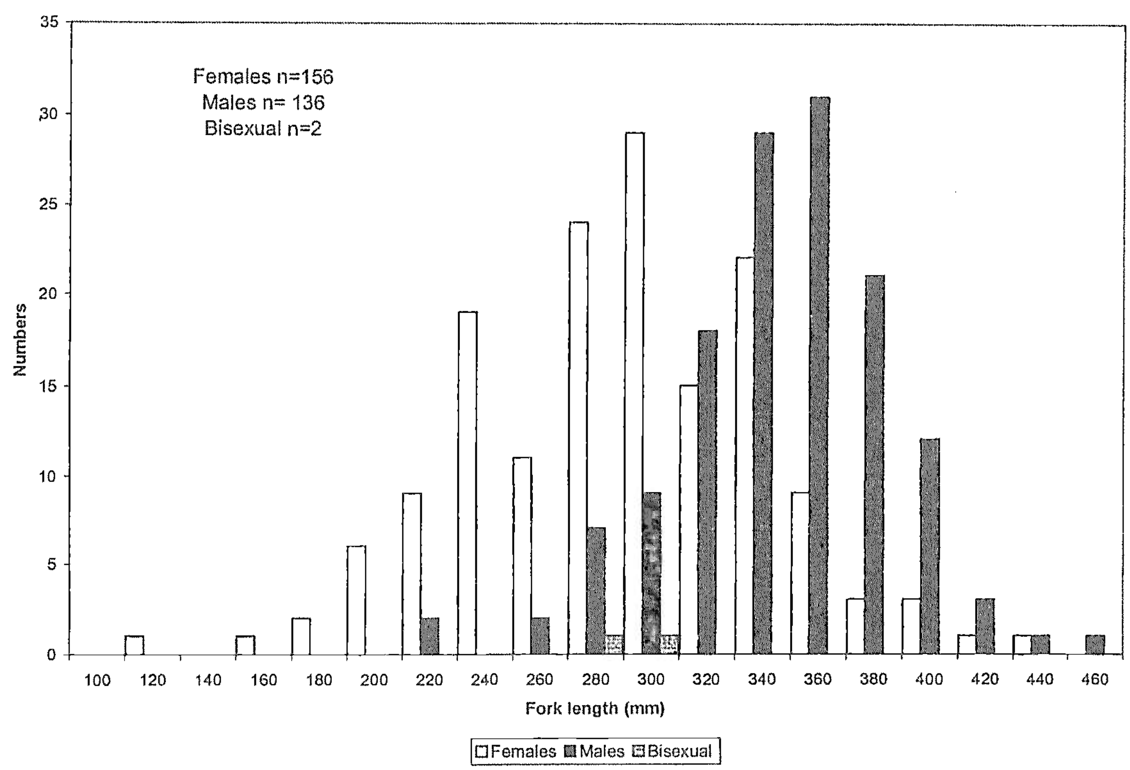



Figure 5. Frequency distribution of *P. coeruleopunctatus*

## 2.3.5. Reproductive Seasonality

Examination of the plots of the gonadosomatic index for males and females revealed that reproductive activity appeared to increase from June to November/December (Figure 6a+ b). The plot of the relative monthly occurrence of reproductive stages in females also suggests that most spawning occurred during these months, although reproductively active (ripe) fish were recorded almost throughout the year (Figure 7a + b). Of relevance is that ovaries with hydrated eggs were recorded in January, February, July, September and October, and that no spent ovaries were observed. This suggests that spawning may occur over most, if not all, of the year. The plot of relative monthly occurrence of reproductive stages in males also suggests that there is spawning activity throughout the year, with spent individuals occurring in March and October. Also, sperm was found in sperm ducts in all months of the year for which samples were collected. It is important to note, though, that numbers of monthly samples are generally small, which may confound interpretation of the plots.

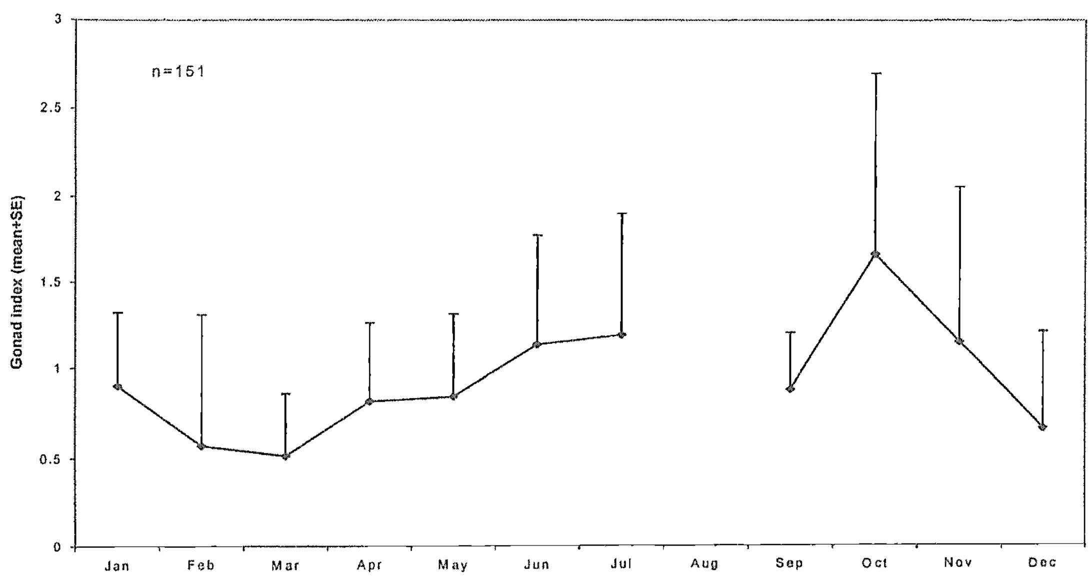



Figure 6a. Monthly gonad somatic index for females of *P. coeruleopunctatus*

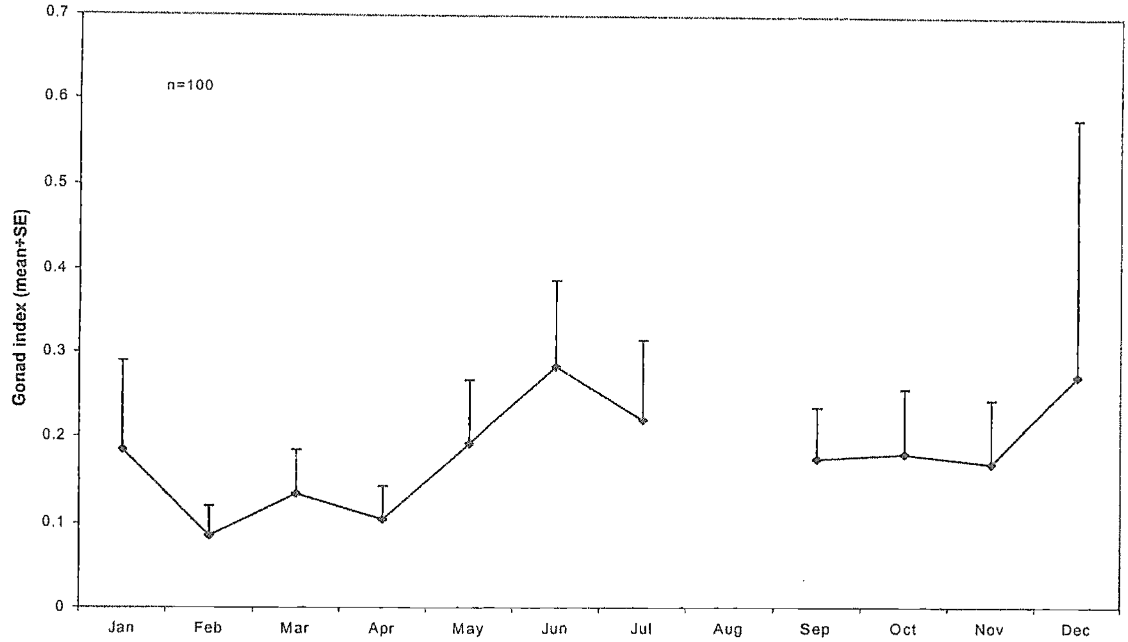



Figure 6b. Monthly gonad somatic index for males of *P. coeruleopunctatus*

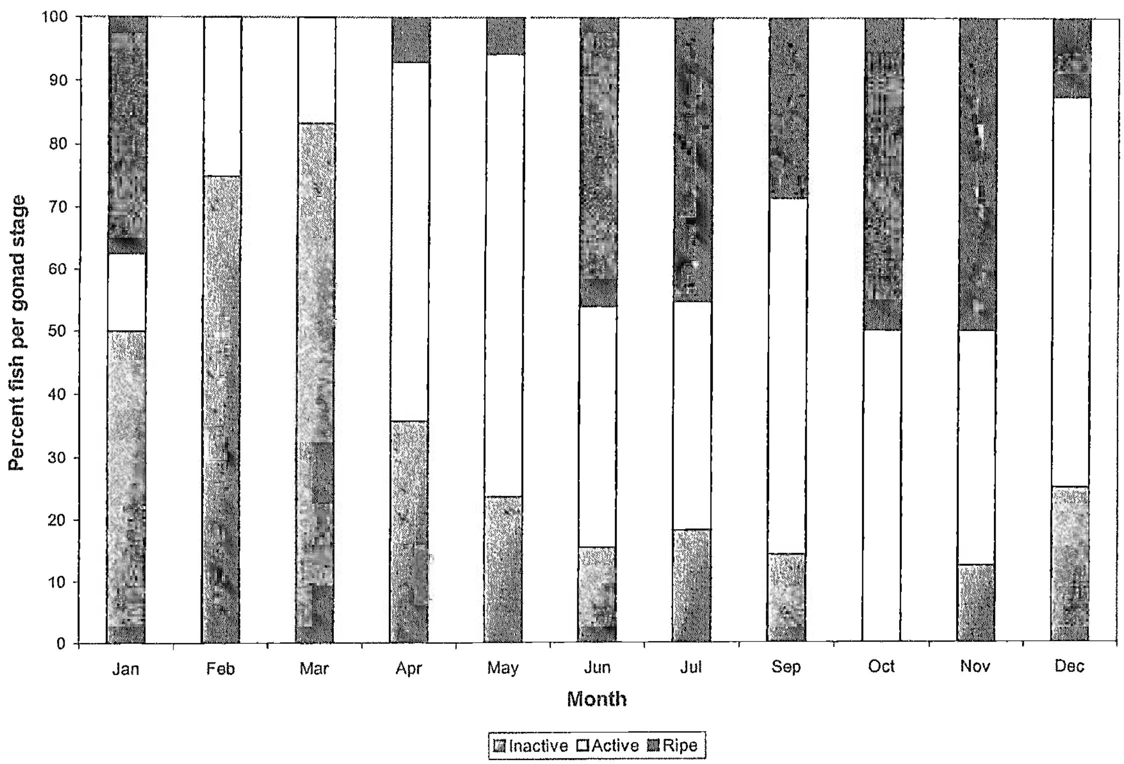



Figure 7a. Monhtly occurence of reproductive stage of female of *P. coeruleopunctatus*

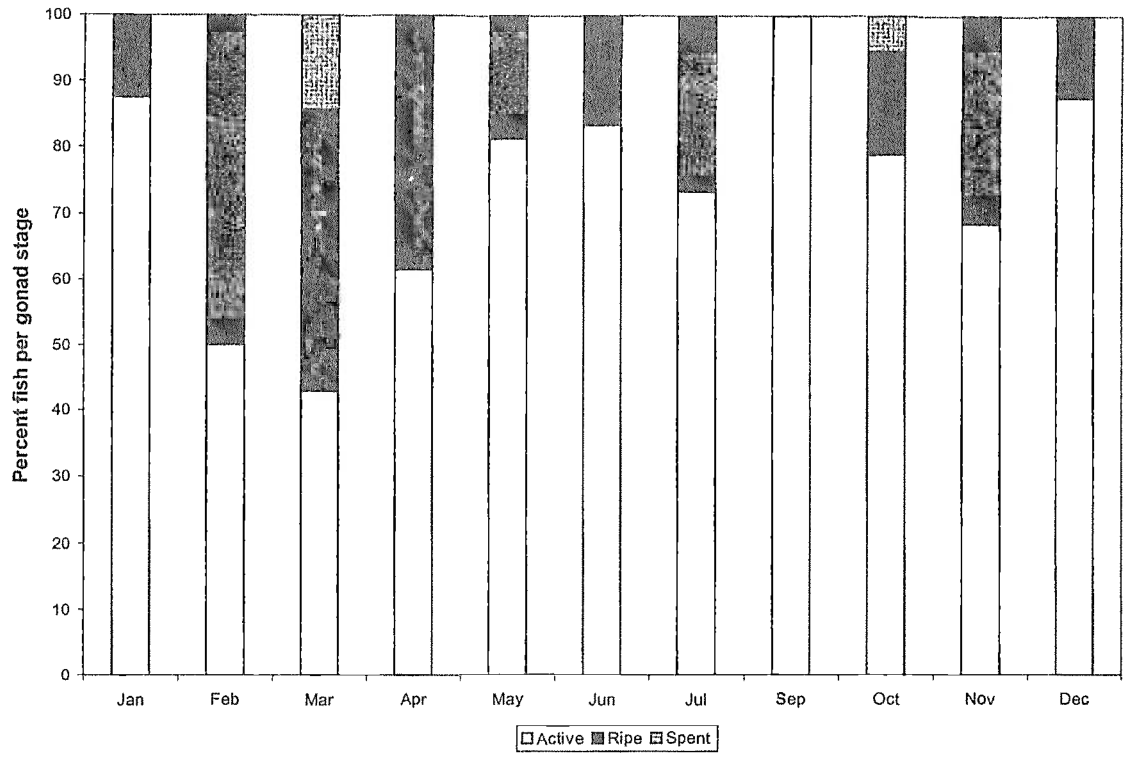



Figure 7b. Monhtly occurence of reproductive stage of male of *P. coeruleopunctatus*

## 2.3.6. Size/Age at Maturity

Size at maturity could not be calculated for males, as no immature males were observed. The smallest mature male was 210 mm FL and the smallest mature female was 190 mm FL. Female size at 50% maturity was estimated at 227 mm FL (Figure 8), and all females larger than 300 mm FL were assumed to be mature. This was necessary because some large females showed no signs of reproductive activity although probably mature. These were classified as inactive females, and their inclusion with the immature females would have artificially increased the estimated size at 50% maturity. Age at maturity, using the growth curve, was estimated as 2.7 years.

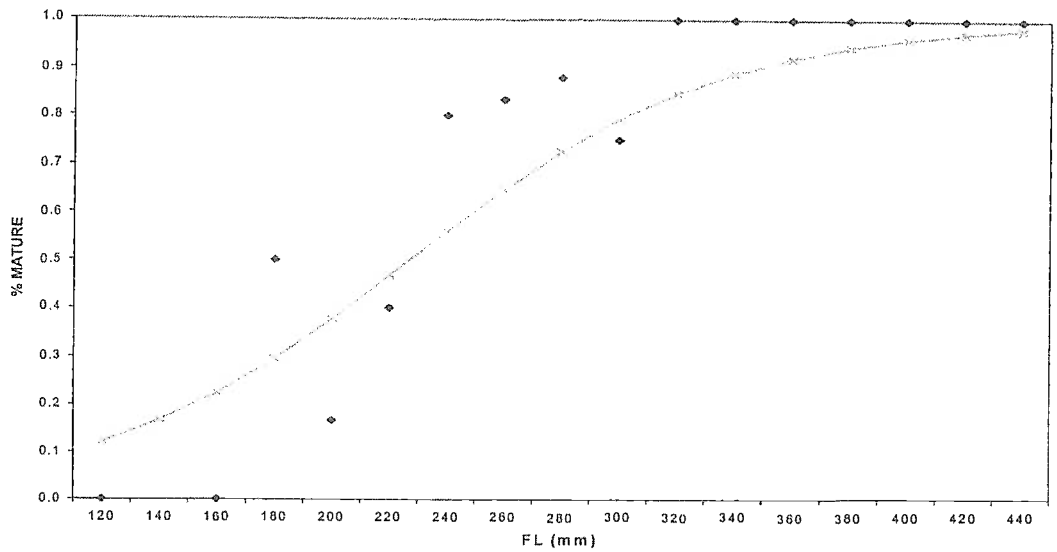



Figure 8. Length at 50% maturity (females data only) of *P. coeruleopunctatus*

### 2.3.7. Age and Growth

Although alternating opaque and hyaline rings were observed in all sectioned otoliths, they proved difficult to read, particularly those from larger fish. Of the 327 otoliths sectioned, a proportion (n = 25.7%) were rejected because of discrepancies in age estimates. Consequently, the Average percentage error (APE) estimate was high at 23.1%. Analysis of the otolith margins was inconclusive and did not provide evidence for the deposition of a single annual ring (Figure 9). The analysis was done for all otoliths as well as for a sub-sample of fish with less than nine rings, but the possibility that more than one ring is laid down per year could not be excluded using this method. However, there is no precedent for biannual deposition of rings in the Sparidae. Also, an assumption of two rings per year would mean a maximum age of about 8 years for this species, which is unrealistic when compared to other similar species in this family. For the purpose of growth and stock assessment, therefore, deposition of rings was assumed to be annual i.e. one hyaline and one opaque ring were together assumed to represent one years growth. This is also a conservative approach to growth determination, because if ring deposition is assumed to be biannual, growth rate would be twice as fast. For example, if a fish of 100 mm FL has an otolith with two opaque rings, and rings are assumed to be annual, this means it takes two years to attain 100 mm in length; if rings are biannual, it would take one year to attain the same length. Females ranged in age from 1 to 17 years, males from 4 to 16 years, and the two bisexual fish were 5 and 6 years old.

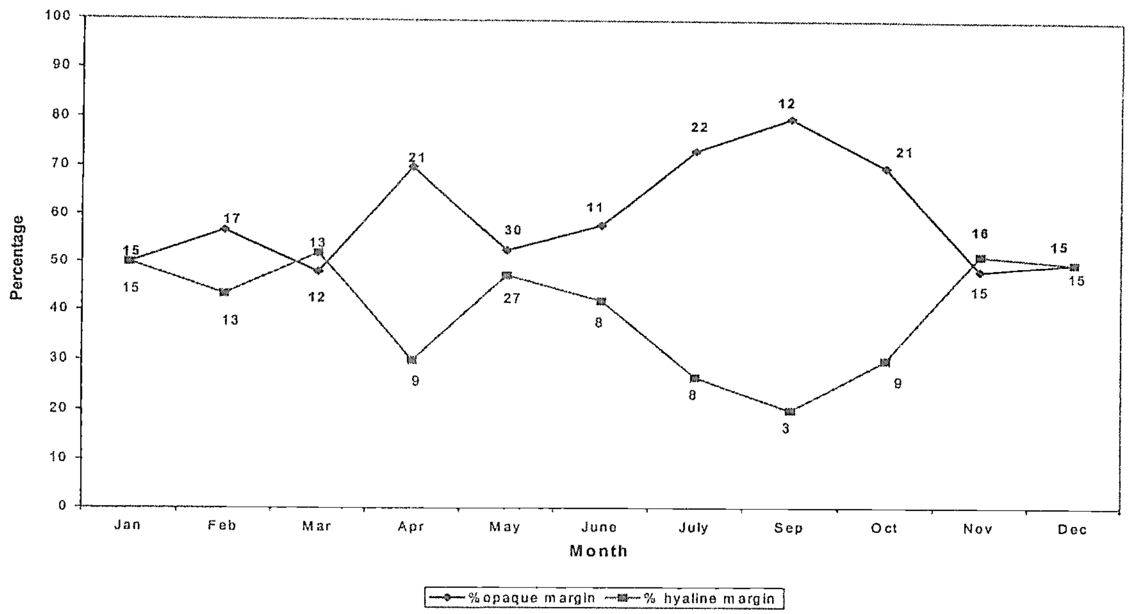



Figure 9. The percentage of otoliths with opaque and hyaline margins in *P. coeruleopunctatus*. Numbers (in bold for opaque margin) indicate sample size of otoliths in each month.

There were significant differences in mean lengths at age for males and females (Table 10), suggesting that males grow faster than females, or that faster-growing fish change into males. The von Bertalanffy parameters are presented in Table 11, and the combined growth curve used in subsequent analyses is shown in Figure 10.

Table 10. Comparative mean lengths at age for cachucho collected from the trap fishery during 2000.

| | Females | Number of Samples | Males | Number of samples | t-stat | |
|---|---|---|---|---|---|---|
| Age | | | | | | |
| 4 | 247.3 | 13 | 330.0 | 3 | 3.863 | * |
| 5 | 266.4 | 7 | 347.5 | 2 | 1.850 | ns |
| 6 | 247.8 | 9 | 287.7 | 13 | 2.997 | ** |
| 7 | 285.8 | 13 | 341.8 | 14 | 4.016 | ** |
| 8 | 276.1 | 18 | 328.5 | 34 | 5.734 | ** |
| 9 | 310.0 | 12 | 350.8 | 20 | 3.447 | ** |
| 10 | 287.7 | 13 | 367.7 | 11 | 7.654 | ** |
| 11 | 288.1 | 8 | 367.7 | 15 | 6.571 | ** |
| 12 | 319.2 | 6 | 365.8 | 6 | 1.238 | ns |
| 13 | 298.3 | 6 | 358.0 | 5 | 2.692 | * |

* P<0.05 ** P<0.001 ns Nsignificant

Table 11. Estimated von Bertalanffy growth parameters for cachucho collected from the trap fishery during 2000.

| | Males | Females | Combined |
|---|---|---|---|
| $L_{infinity}$ (mm FL) | 398.4 | 327.9 | 357.9 |
| *k* yr | 0.189 | 0.153 | 0.202 |
| $T_0$ yrs | -1.73 | -5.12 | -2.24 |

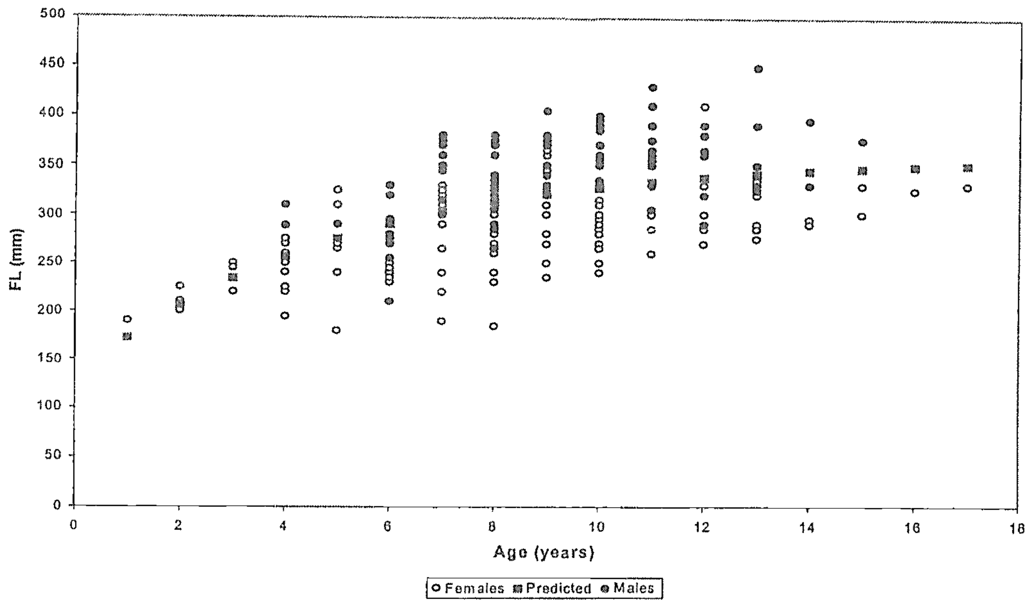



Figure 10. Von Bertalanffy growth curve fitted to observed length at age data for cachucho.

## 2.3.8. Mortality and stock assessment

The catch curve used to estimate total mortality (Z) is presented in Figure 11. A catch curve based on a scenario whereby two rings are deposited in the otoliths each year was also produced, which resulted in a Z estimate of 0.38 $yr^{-1}$. However, the natural mortality (M) rate which was calculated based on this set of age-length data (i.e. assuming two rings per year) was 0.42 $yr^{-1}$ i.e. larger than Z, which is not possible. This provides further support for the assumption that one ring is deposited per year.

Estimated parameters used in the stock assessment procedure are presented in Table 12. Age at first capture ($t_c$) is traditionally estimated from the top of the catch curve (Butterworth 1989), but in this case, the estimate was assessed as being too high (8 years). This was probably as a result of the difficulty experienced in aging these fish, with up to 12 ages occurring in a single size class of 275 mm. Consequently, the midpoint of the modal size class (260 - 280 mm) of the length frequency histogram for 2000 was used, and converted to an age using the growth model. This produced an estimated $t_c$ of about 2.4 yrs.

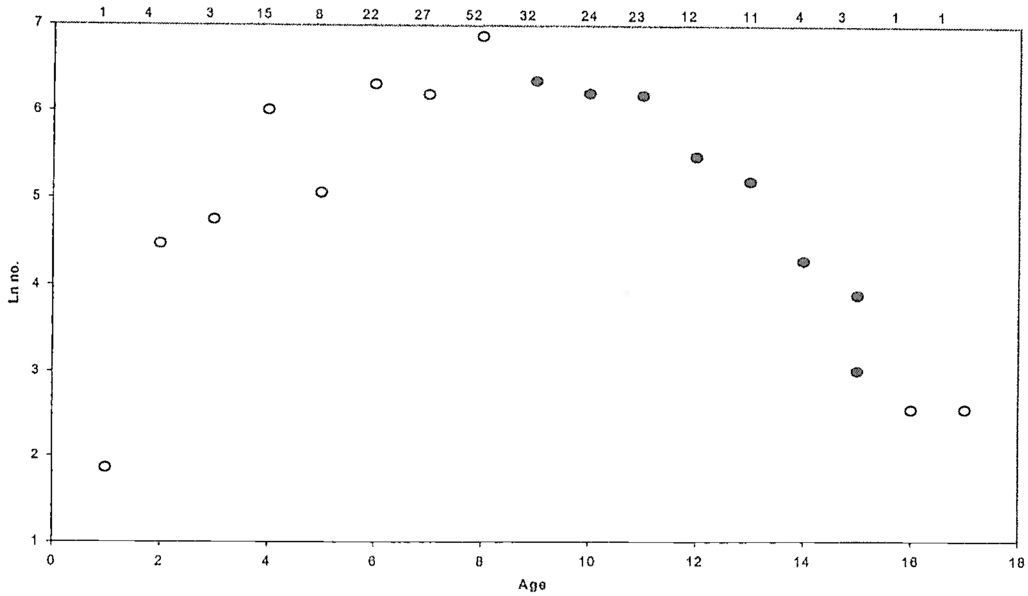



Figure 11. Catch curve of *P. coeruleopunctatus* caugth in Southern Mozambique

Table 12. Parameters used in the per-recruit stock assessment for cachucho.

| Parameter | | Source |
|---|---|---|
| Z | 0.645 $yr^{-1}$ | Catch curve - this study |
| M | 0.268 $yr^{-1}$ | Pauly (1980) |
| F | 0.377 $yr^{-1}$ | Z - M |
| *A* | 0.000303 | This study |
| *B* | 2.568 | This study |
| $L_{infinity}$ | 357.9 mm FL | This study |
| *K* | 0.202 $yr^{-1}$ | This study |
| $t_0$ | -2.24 yrs | This study |
| $t_c$ | 2.4 yrs (270 mm FL) | This study |
| $t_m$ | 2.7 yrs (227 mm FL) | This study |

Based on these parameters, current spawning biomass per recruit (SBPR) is about 35 % of the virgin (unexploited) level (Figure 12). This result is fairly sensitive to the value of M: if M is increased or reduced by 50%, SBPR is 45 - 23% respectively. Plots using alternative values of $t_c$ are included for comparison (Figure 12).

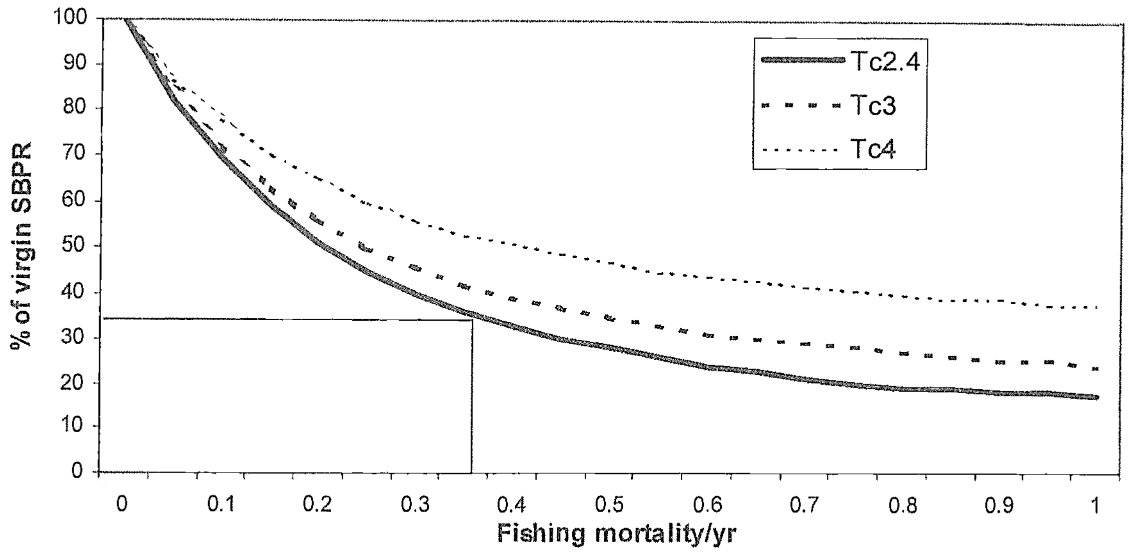



Figure 12. Plot of spawning biomass per recruit against fishing mortality for cachucho. Current fishing mortality rate is indicated with a solid line, and three alternative scenarios of age at first capture ($t_c$) are shown.

## 2.3.9. Discussion

The female-biased sex ratio, the dominance of males in the larger size class and the occurrence of two bisexual gonads with mainly testicular tissue and remnant ovarian tissue provide reasonable evidence for sequential protogynous hermaphroditism in cachucho. Definitive evidence for female to male sex change is the observation of a gonad which has functioned as a female (for example, with atretic vitellogenic oocytes) and which has proliferating testicular tissue (Sadovy and Shapiro 1987). However, such gonads may be difficult to observe, particularly if the period of sexual transition is rapid, or if numbers of samples are low. The age data also support a diagnosis of female to male sex change, as the youngest male was aged four years (older than the female age at maturity), suggesting that males can only be derived from mature females. Not all fish change sex, as the oldest fish recorded was a female of 17 years.

Considerable difficulties were experienced in aging cachucho, probably because of the thick, opaque nature of the otoliths. This is reflected in the large range in ages for a given size class, and the high rejection rate of otoliths. Similar difficulties were experienced in ageing other samples of cachucho from Mozambique (W. Mastenbroek, pers. comm. c/o Oceanographic Research Institute, PO Box 10712 Marine Parade 4056, South Africa). There is also uncertainty in the seasonality of ring deposition, which could further have confounded age determination and hence the analyses based thereon.

Nevertheless, the preliminary stock assessment presented here is thought to be reasonably representative of the current status of cachucho in Mozambique. In support of this, the size of the fish caught in the trap fishery has decreased over the past four years (mean length from 323 (SD 44) mm FL to 304 (SD 52) mm FL; modal length from 330 to 280 mm FL), signifying that the resource is under pressure. Catch rates per set show no consistent trend, although the time series is short, but catch per day has increased sharply, which is cause for concern (see section of the report dealing with the trap fishery). Also of concern is that the proportion of cachucho caught by the linefishery is increasing, as the line vessels move into deeper water in search of alternative resources (see section in the report dealing with the line fishery). The current predicted SBPR level of 35% for cachucho is slightly below the threshold level of 40% used for other linefish species (Mann, 2000). Fishing mortality, and hence fishing effort, for this species should therefore not be allowed to increase.

## 2.4. Recommendations

The differences between gonad stages as defined by macroscopic and histological methods suggest that there should be caution in the use of existing macroscopic staging data for the determination of spawning season and size at maturity - at least for this species. There needs to be more accuracy developed for macroscopic staging - this could be achieved by making detailed descriptions of the gonad stages, followed by histological examination of the same gonads, in order to clarify the macroscopic features used in staging. This procedure would be of value for other species too.

Greater numbers of gonads in the size range 120 to 220 mm FL (a total of 10 fish per 20 mm size class) are required to more precisely determine size at maturity - at least for females. For conformity with the analyses used in this report, these gonads should be examined histologically. The size at maturity parameter could be used in future if changes in trap mesh size need to be introduced.

Increased sampling of mature-sized females (> 300 mm FL) in August, September, October and November (at least 10 more fish per month) are needed to establish the duration of spawning season. Again, these fish will need to be examined histologically to establish gonad stage.

More otoliths from smaller and larger fish need to be collected, to improve the estimation of growth parameters. Ideally, there should be about 20 fish per 20 mm size class for the construction of a growth curve. This means that for the size classes 100 to 220 mm and > 400 mm, more otoliths are needed. Note that for the calculation of a catch curve, the numbers of otoliths per size class should be proportional to the histogram based on random lengths. This did happen for the current otolith collection, but must be continued if more otoliths are collected.

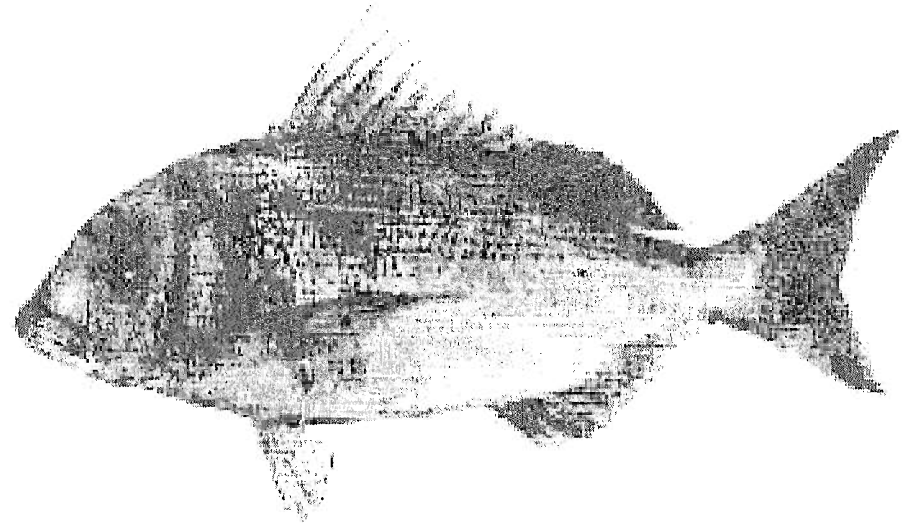
Age determination needs to be re-done. It would be best to read each otolith twice (using one or two readers) on the same microscope, then reading a third time if the readings do not agree. If two of the three readings agree (e.g. 1,2,1), that reading is accepted (1); if the smallest and largest readings differ by two rings (e.g. 1,2,3), take the middle reading (2); if the smallest and largest readings differ by > two rings (e.g. 1,2,4), reject the otolith.

The seasonality of ring deposition needs to be resolved. This may be resolved by re-doing the age determination, particularly with the inclusion of smaller otoliths. The age range over which the opaque/hyaline analysis is done should be restricted to the younger ages (e.g. < 8 rings). It is unlikely that validation by means of tetracycline will be possible in the short term.

## 2.5. Conclusions

The biological and length data collected on cachucho have allowed a preliminary description of the biology of this species to be prepared. Almost nothing is known about the biology of this species, which occurs along most of the east African coast. This information is therefore valuable both for the Mozambican trap fishery and for other fisheries both locally and elsewhere. However, some additional information is required to complete the understanding, and recommendations to collect this have been described above. The stock assessment shows that spawning biomass levels are rapidly reduced, even at low levels of fishing mortality, which is typical of slow-growing species. Fishing effort for this species should therefore not be allowed to increase.

# 3. ROBALO, SOLDIER- *Cheimeirus nufar*



*Cheimeirus nufar*

This species belongs to the family Sparidae, but has a less restricted geographic range, occurring in many parts of the West Indian Ocean as well as the Pacific. Local stocks are believed to range from Cape Agulhas to central Mozambique (Mann 2000). Robalo is an important linefish species that is often caught in association with marreco. A number of investigations, both in South Africa and in Mozambique, have generated information on this species. However, much uncertainty remains, for example whether this species undergoes sex change. This species has been recorded in this study as reaching 705 mm FL, equivalent to 796 mm TL. Timochin (1992), calculated L infinity as 700 mm TL (=619 mm FL), while Coetzee & Baird (1981) suggested it could reach 950 mm TL. Clearly there is variability in estimates of this parameter.

## 3.1. Assessment Strategy

The assessment of this species follows much the same approach as that for marreco. However, the level of detail and extent of data collected has been less intense. The biological parameters selected for modelling are those generated by studies of Coetzee and Baird (1981), Garratt (1984), Druzhin (1975) and Timochin, (1992). This information can be gleaned from Mann (2000). However, these biological parameters must be considered preliminary and require substantial future verification.

Similar to marreco, the threshold and target levels of the spawner biomass per recruit are set at 25% and 40% respectively. The following parameters are used in the 2000 assessment.

Table 13. Parameters used in the per recruit assessment for *C.nufar*

| Parameter | Value | Source |
|---|---|---|
| $L_{inf}$ | 619 mm FL | Coetzee & Baird (1981 |
| K | 0.17 | Timochin (1992) |
| $t_o$ | 0.22 (Pauly)0.3 Ralston | |
| Tc | 2 years | Coetzee & Baird (1981) |
| Max age | 10 years (for assessment only) | |
| A | $5 \times 10^{-5}$ | This study |
| B | 2.8 | This study |
| $t_m$ | 3 yrs | Coetzee & Baird (1981) |

Values derived from the preliminary YPR are as follows:

Table14. Values preliminary YPR of *C. nufar*

| Estimate | % Spawner biomass | |
|---|---|---|
| F | M= 0.22 | M= 0.3 |
| 0.075 | 40 | 47 |
| 0.1 | 34 | 41 |
| 0.15 | 25 | 30 |
| 0.185 | 20.5 | 25 |

This suggests that the levels of F that would represent threshold (25%) and target (40%) lie between approximately F=0.185 and F=0.075, depending on the M value selected. These levels of F are very low, suggesting that threshold levels of spawner biomass are attained at low fishing pressure.

Length data of robalo have been collected since 1996 and have been plotted as frequency distributions in Fig 13. These can be converted to age-based catch curves for each year, so that estimate of Z can be determined. It seems that these values are high. Even if the growth model is known to be a preliminary estimate, the steep right-hand slope of the distribution suggests that there is a rapid fall off in small fish. While the reason could certainly be heavy fishing pressure, it is also probable that linefishing only targets a limited size range of this species. As robalo can be found to 200 m, depths where little or no linefishing takes place, this may well be the depths, which the larger fish occur.

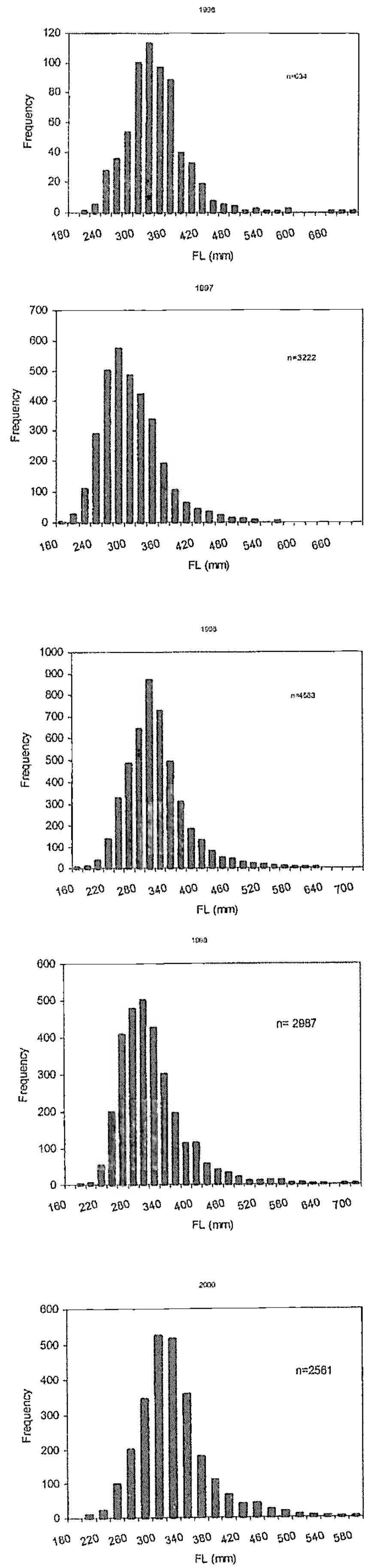



Figure 13. Length frequency distribution for *C. nufar* recorded during the years 1996 to 2000.

Subtracting values of M from these Z estimates, a preliminary assessment of F in the context of the target SBPR estimates can be made. Notwithstanding the preliminary nature of these results, it would appear that *C. nufar* is currently being exploited at levels well in excess of the threshold limit. However, urgent attention must be given to collecting improved data in order to derive more reliable model input parameters.

Table15. Length composition and F values of *C. nufar*

| Year | Min | Mean | Max | F(M=.3) | F(M=.22) |
|---|---|---|---|---|---|
| 1996 | | | | 0.63 | 0.71 |
| 1997 | | | | 0.69 | 0.77 |
| 1998 | 170 | 318 | 660 | 0.87 | 0.95 |
| 1999 | 180 | 321 | 705 | 1.03 | 1.03 |
| 2000 | 220 | 325 | 540 | 0.56 | 0.64 |

## 3.2. Conclusions and Recommendations

While there has been good progress in the biological study of the three species described above, there are clearly significant discrepancies that need to be resolved. These revolve primarily around age determination, which results in incorrect stock assessments. The preliminary data presented here indicate that all three species are inherently vulnerable at low levels of fishing pressure. Although none of the species are considered overexploited at this stage, this is in part due to the ever wider ranging fishing effort, which continues to capture species of unexploited stock. This effect can mask the real situation and a sudden decrease may occur once no new fishing grounds are detected.

# 4. ACKNOWLEDGEMENTS

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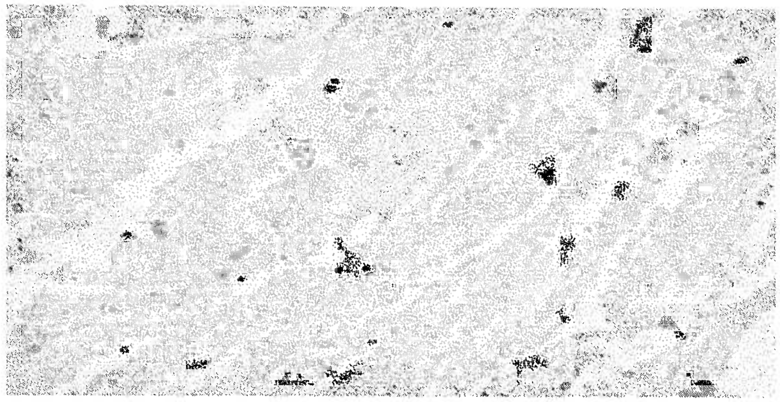
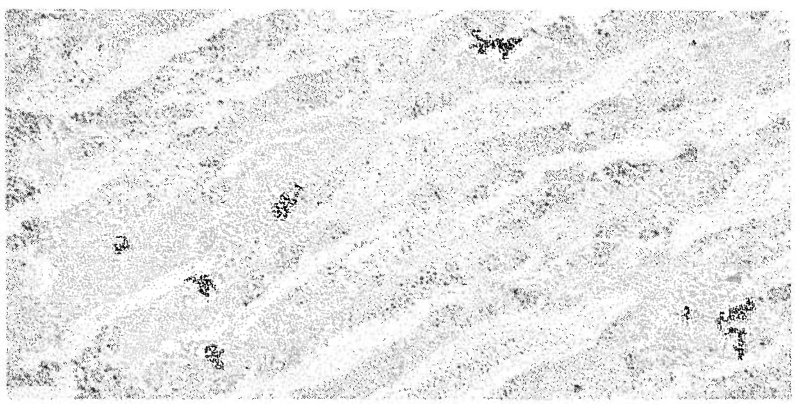
# 6. APPENDIX

**APPENDIX I**: Transverse sections through the gonads of *P. coeruleopunctatus* (cachucho) illustrating gonodal development. The histological descriptions of the gonad stages were developed in pages 15 and 16.

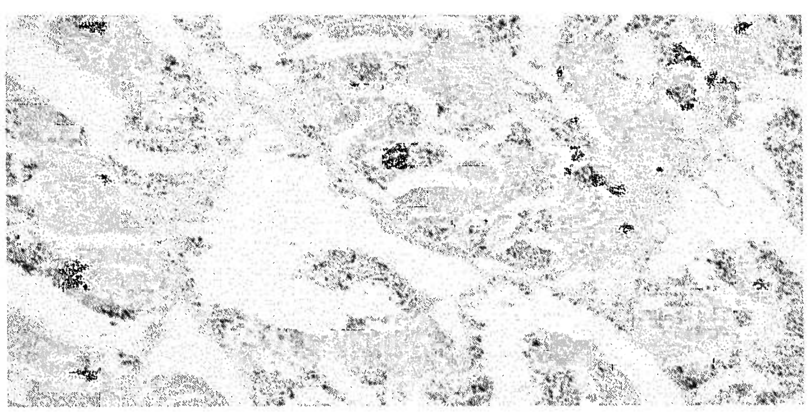
**Males- active**



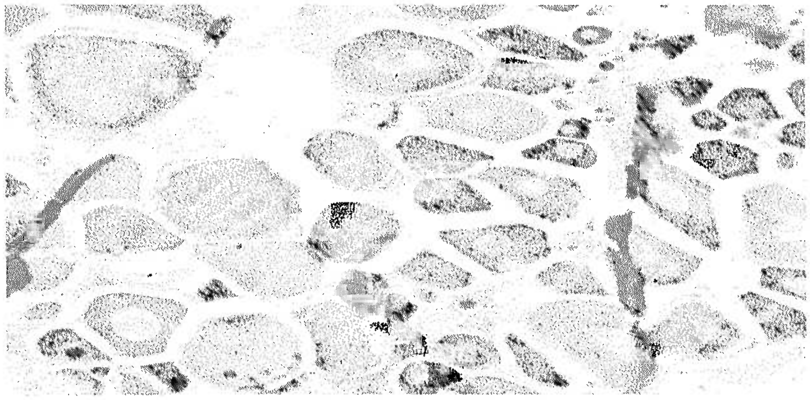
**Males- ripe**



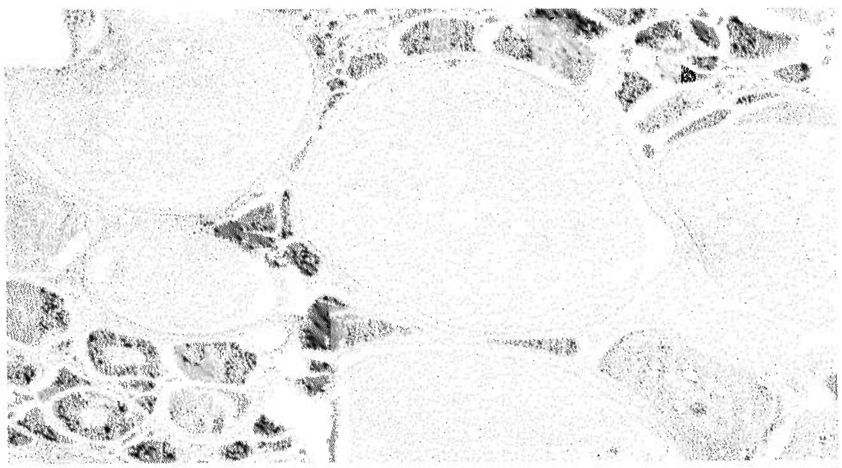
**Males- Spent**



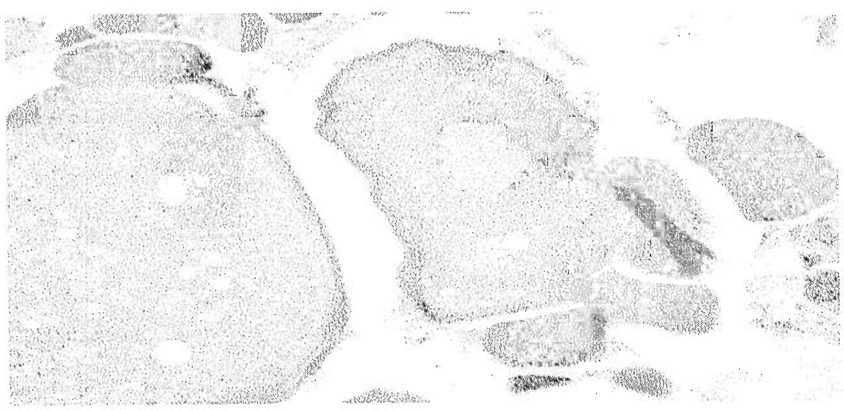
Females- Inactive



Females- Active



Females- Ripe



Bisexuals