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# ASSESSMENT OF THE ROUNDNOSE GRENADIER (*CORYPHAENOIDES RUPESTRIS*) STOCK IN THE ROCKALL TROUGH AND NEIGHBOURING AREAS (ICES SUB-AREAS V, VI AND VII).

By

**Pascal Lorance(*), Hervé Dupouy(**) and Valérie Allain(**)**

## ABSTRACT

The catch (landings and discards) at age of roundnose grenadier (*Coryphaenoides rupestris*) are used to assess the stock in the areas exploited by French trawlers. A pseudo cohort analysis corrected for changes in fishing effort in the period before the year which catch at age are analysed was carried out for the years 1996 and 1997. To get the input parameters, an age length key was estimated from unvalidated otoliths readings from sampling in the same years. This age length key was combined with length distribution data from surveys prior to exploitation and from landings in 1990 (early in the history of the fishery) to estimate the total mortality then equivalent to the natural mortality. This pseudo cohort poorly converged suggesting a low annual fishing mortality. The behaviour of the stock was further investigated from yield per recruit analysis.
Because of a series of lacks in the knowledge of the species (stock (s) distribution, unvalidated ages...), the estimates of fishing mortality must be considered with caution. The main interest of the analysis is probably to stress the impact of the discards on the potential yield of roundnose grenadier.

## RESUME

Les captures (débarquements et rejets) par age du grenadier de roche (*Coryphaenoides rupestris*) ont été utilisée pour évaluer le stock dans les zones exploitées par les chalutiers français. Une analyse de pseudo cohorte rectifiée pour tenir compte des changements d'effort de pêche au cours de la période précédant l'année dont les captures par age sont analysées a été réalisées pour les années 1996 et 1997.
Une clé taille-âge a été estimée à partir de détermination d'âge non validées sur des échantillons collectés en 1996 et 1997. Cette clé taille age a été appliquée aux répartitions en taille de campagnes antérieures à l'exploitation et à celle des débarquements de 1990 (soit peu après le début de l'exploitation) afin d'estimer la mortalité totale, alors equivallente à la mortalité naturelle. Cette analyse de pseudo-cohorte converge assez mal suggérant une mortalité par pêche annuelle faible. Cependant, une analyse de rendement par recrue a été réalisée pour observer le comportement du stock sous l'effet du régime d'exploitation supposé.
Vu les connaissances manquantes sur cette espèce (distribution du (des) stock(s), estimations d'âge non validées...) les taux de mortalité par pêche issus de l'analyse de pseudo cohorte doivent être considérés avec prudence. Le principal intérêt de cette étude est probablement de souligner l'effet des rejets sur le rendement potentiel de l'espèce.

Key-words : *Coryphaenoides rupestris*, analytical assessment, yield per recruit, NE Atlantic.

(*) IFREMER, 150 quai Gambetta, BP699, 62321 Boulogne-sur mer
(**) IFREMER, 8 rue François Toullec, 56100 Lorient
email : pascal.lorance@ifremer.fr ; herve.dupouy@ifremer.fr ; valerie.allain@ifremer.fr

# 1. INTRODUCTION

Roundnose grenadier (*Coryphaenoides rupestris*) have been landed in France since 1989. In 1997, more than 95% of the total catch in ICES sub-areas VI and VII was caught by French vessels. Before 1989, some catches have been reported as miscellaneous fishes and the species has been a by-catch discarded of the blue ling fishery which started in 1972. The fishery now extends into ICES sub-areas V, VI and VII, with most of the catch coming from sub-area VI. An assessment of the stock is presented in this paper. The age structure has been estimated from French length distribution data collected from the commercial catch and the age length key used is unvalidated. The assessment result must be considered with caution as the fishery is recent. The assessment relies on pseudo cohort analysis of the catches for the last 2 years (1996 and 1997).

# 2. MATERIAL AND METHODS

## 2.1 LENGTH DISTRIBUTION OF LANDINGS AND DISCARDS

The length distribution of landings was sampled at port of Lorient in 1996. The species is caught by a single métier (offshore trawling) and it is landed without any sorting by size categories. One box of 40 to 50 kg of roundnose grenadier has been sampled each month to obtain estimates of the length distribution for the quarterly landings. For 1997, samples taken on board during discards experiments have been used to provide length data.

The discards were sampled by on board observers. The sampling took place from December 1995 to August 1997 (Dupouy et al., 1997).
The weight of the measured sample of discards for each year has been estimated using the following length-weight relationship obtained from fish landed whole and fresh in Concarneau :

$$W = 0.0694L^{3.286}$$

This relationship applies for fish of both sexes.
The length distribution of the total discards for the year has been calculated by weighting the length distribution of the discards samples to the weight of the total discards, from the discard experiment carried out from 1995 to 1997 by observers.

## 2.2 PSEUDO COHORT ANALYSIS

A tentative assessment has been tried by using pseudo cohort analysis. Data from both years, 1996 and 1997, have been analysed and provide very similar results.
The model used is a pseudo cohort analysis corrected for effort changes in the preceding years (Santarelli Chaurand,1985 ; Laurec & Santarelli-Chaurand, 1986 ; Bertignac, 1988).
This method, designed to use the data from one year as the catch at age vector offers the possibility to use series of data on effort and recruitment when the hypothesis of constant recruitment and effort are not realistic. Here the correction is only done for effort.
The algorithm proceeds by direct calculation, it uses iterations to find the input $F_t$.

The catch of the first age group caught is :

$$C_I = R\frac{F_{1,I}}{F_{1,I}+M}(1-e^{(F_{1,I}+M)}) \text{ (1) ;}$$

Where :
$F_{1,I}$ : fishing mortality of age 1 in year $I$ (the analysed year) ;
$M$ : natural mortality ;
$R$ : recruitment (number of the first age group in the catch at the beginning of year $I$).

Iterative resolution of (1) gives $F_{1,I}$ ; then the catchability of age 1 can be calculated as :

$$q_1 = \frac{F_{1,I}}{E_I} \text{ (2) ;}$$

Where $E_I$ is the fishing effort in year $I$.

During the year $I$-1, the previous cohort underwent effort $E_{I-1}$ ; and then, at age 1 the fishing mortality was :

$F_{1,I-1} = q_1 \cdot E_{I-1}$ (3)

And the number of survivals at the beginning of year $I$ was :

$N_{2,I} = R \cdot e^{-(q_1 E_{I-1} + M)}$ (4) ;

Then the catch equation for age 2 can be solved as:

$$C_2 = N_{2,I} \frac{F_{2,I}}{F_{2,I} + M}(1 - e^{(F_{2,I}+M)} \quad (5)$$

and allows to deduce $q_2$ from :

$$q_2 = \frac{F_{2,I}}{E_I} \quad (6)$$

and $N_{3,I}$ from :

$$N_{3,I} = R \cdot e^{-(q_1 E_{I-2} + q_2 E_{I-1} + 2M)} \quad (7)$$

(7) can be generalized as :

$$N_{a,I} = R \cdot e^{-(\sum_{k}^{a-1} q_k E_{I-(a-k)} + (a-1)M)}$$

and the catch equation of age a is :

$$C_a = N_{a,I} \frac{F_{a,I}}{F_{a,I} + M}(1 - e^{(F_{a,I}+M)}) \quad (9)$$

which allows to calculate catchability of age a :

$$q_a = \frac{F_{a,I}}{E_I}$$

As a direct calculation, this procedure has the usual drawbacks of a direct calculation, it can lead to a recruitment estimate inconsistent with the data. Then, an iteration procedure is required to come back to the usual backcalculation. In the program used this iteration is initiated with $R = 10^5 \cdot C_1$. The iteration procedure is detailled is Laurec & Santarelli-Chaurand, (1986) and Bertignac, (1988).

# 3. RESULTS

## 3.1. LENGTH DISTRIBUTION OF THE CATCH

The length distribution of the total catch in 1996 and 1997 are presented in Figures 1 and 2.

## 3.2. AGE LENGTH KEY (ALK).

An age length key (ALK) was obtained from readings of 1529 otoliths (Table 1). The ALK covers lengths from 2.5 to 29.5 cm (pre-anal fin length). The estimated age ranged from 1 to 60 years. One individual was estimated more than 46 years. The estimated ages are unvalidated, however, the mean length at age results (Fig.3) from this key appears consistent with the only age validation results published on the same species in the North East Atlantic (Gordon et Swan, 1996). The preanal length shown for the validated series has been calculated from a head length to anal length conversion factor which could induce some bias. The length at age curve obtained from French age estimation appears to fit the validated age well. The excess length of smaller fish could possibly be ascribed to unsuitable on board measurements of the smallest fish.

## 3.3. AGE DISTRIBUTION OF LANDINGS AND DISCARDS

Age distributions for both years 1996 and 1997 (Fig 4, 5) have been estimated by sampling the discards in the catch for both years and applying the same age length keys. The ratio of discards to landings in weight has been estimates at 31 % in both years.

## 3.4. ESTIMATES OF *M*.

The study group on the biology and assessment of deep-sea fisheries resources (Anon.,1998) did some estimates of *Z* from catch at age data (the slope of the log-transformed numbers at age curve on the right side of the distribution provides the total mortality of the population).
The French landings were sampled for the first time in 1990. The fishery was then recent enough (first landings in 1988) to consider that an estimate of *Z* from that year corresponds to a *M* estimate.
Data from German surveys from 1974 to 1980 (Ehrich, 1983) and English surveys in 1973-74 (Bridger, 1978) were used in the same way. For these surveys, only the combined length distribution for all depth strata was used. The length distribution given by these authors are total length (by 5 cm length classes for the English surveys). In order to apply our ALK, these distributions were converted to preanal length using the formula :

$$Lpa = 0.194Tl + 1.67 \ ;$$

Calculated from converting the relationship given by Gordon and Hunter, (1994) and similar to the one of Anon, (1993) :

$$Lpa = 0.196Tl + 2.29 \ ;$$

The length distributions, and as a consequence the age distributions, are very similar for both survey series.

The results obtained for *M* are high as with an M over 0.2 only 1% of the fish would reach an age over 20. Moreover, there is a trend towards higher estimates when taking into account an older range of age (Table 2). Some bias may explain higher mortality estimates of older fish :
- bias in the ALK because it has been done from the currently exploited population where older ages are less common (i.e. the relative proportion of older ages within each size class must have declined since beginning exploitation) ;
- reading bias, the problem with otolith readings usually increases with the age of the fish read (i.e. a possible trend of increasing under estimates of ages with increasing age cannot be excluded).

On the other hand, the *M* estimated is relevant to the sampled range of age and does not applies to small fish not caught by the commercial fishery and not properly sampled by the surveys. Increasing natural mortality of adult fish can be either a biological feature (senescence) or an ecological one (predation). Then, natural mortality around 0.2 for adult fish would not necessarily imply unrealistic numbers of juveniles to get the observed numbers at age 20.
However, according to possible trend over age, an estimated *M* of 0.1 is chosen for the following steps as the estimates obtained when including the fish aged around 20 years (younger fish are obviously within the size selectivity range of both commercial and survey trawls) which are the most abundant in the catch. From these available data, this estimated *M* of 0.1 seems to be on the cautious side.

Table 2. Natural mortality estimates from length distribution of French landings in 1990 and from surveys before exploitation. The 3 length distributions vectors have been converted into age distributions using the same AKL from 1996-1997 sampling. For the french landings, the age range including younger fish were not used because of probable high discarding rates at these ages.

| | Origin of length data | | | | | |
|---|---|---|---|---|---|---|
| Age range used | French landings at age, 1990 | | Bridger, 1978 | | Ehrich, 1983 | |
| | *M* | $R^2$ | *M* | $R^2$ | *M* | $R^2$ |
| 21 to 35 | | | 0.14 | 0.86 | 0.13 | 0.92 |
| 21 to 60 | | | 0.21 | 0.85 | 0.18 | 0.91 |
| 23 to 60 | 0.11 | 0.86 | 0.21 | 0.82 | 0.19 | 0.90 |
| 25 to 40 | 0.15 | 0.80 | 0.29 | 0.72 | 0.25 | 0.89 |
| 33 to 39 | 0.27 | 0.94 | 0.52 | 0.92 | 0.41 | 0.91 |

## 3.5. PSEUDO COHORT ANALYSIS

The pseudo cohorts analysis has been carried out on the range of age 10 to 32 (terminal *F* is *F* at 32). Fortunately up to this age the ALK relies on high numbers at age while the older age groups are susceptible to poorer estimates (see Fig. 3). The relative effort by year were set at 1 for year 1990 to 1997, 0.5 in 1989 and 0.1 in 1987 and 1988.

The analysis was carried out for both years 1996 and 1997. As expected from similar age distribution, the results were very similar.

A range of terminal *F* from 0.01 to 0.2 was tried, some convergence is observed (Fig. 6, 7). In relation to irregular relative frequencies of age groups in the catch, the *F* at age profiles show some unstability. However, the trend of *F* under different assumptions on terminal *F* can be observed. At $F_t$ =.2 there is an increasing trend after age 24 which is probably not likely as this age is on the side of the decreasing numbers at age in the catch. On the other hand, at Ft=0.05 there is a decreasing trend which also unlikely.

It should be noted that the convergence is slow, which is expected because of the low *F* (the convergence is due to the cumulated *F* at age). The two extreme case (*F*=0.2 and *F*=0.05) show how poor the convergence is. However, fitting a linear regression to F at age 24 to 32, the slope of the fitted lines is negative for $F_t$ lower than 0.08 and positive for $F_t$ higher than 0.12. A $F_t$ between .08 and .12 looks the more probable as it allows for a stable *F* between ages 24 to 32 (17 to 19 cm mean Lpa). The small size difference between age is a further support for stable *F* at age.

However, the *F* at ages remain very sensitive to $F_t$ input at any age and on both years. From 1996 to 1997 there is a slight decline in the sensitivity coefficient at age 22 (10 years before terminal age), the coefficient shifts from .48 in 1997 to .43 in 1996 (i.e. a 10% reduction).

## 3.6. EQUILIBRIUM

The difference from the current state of the stock and its equilibrium state under the same assumed fishing pattern (estimated from pseudo cohort analysis) was examined by simulation. Like in the pseudo cohort analysis, the simulation was carried out at constant recruitment, *M*=0.1., and with annual correction for changing effort (Table 3).

The time to reach strict equilibrium is, of course, equal to the number of age groups. However, if the total number of the "population" has little meaning the number of fish aged 18 and over is interesting as the range of age of the landed fish (discards also occurs within this range). Under the simulated parameters the current number of these fish would be about 0.62 times their number in an unexploited and 1.15 times their number at equilibrium. The numbers would be slowly declining to equilibrium level for the 10 next years.

## 3.7. YIELD PER RECRUIT

Following the pseudo cohort analysis, the yield per recruit has been investigated from a fishing pattern corresponding to the pseudo cohort output for 1997.

Yield per recruit for the landings have been calculated with the following parameters :

- age at recruitment 18 ;

- last age in the catch 50 ;
- $M$=0.1 ;
- same weights at ages in the catch and in the stock calculated according to the ALK and length weight relationship ;
- F according to the pseudo cohort output at $F_T$=0.1, $F$ at age older than 32 (terminal in cohort pseudo cohort analysis) =0.1.

According to this analysis, the yield per recruit is currently at 360 g per recruit, it increases slowly up to high $F$ and $F_{max}$ could not be found. When considering sole the landings, the slow growth implies that there is little profit to leave time to some fishes to grow. Actually, the current yield per recruit of 360 g is lower than the weight at age 18 (483 g). In other words, an infinite effort would produce a yield per recruit of 483 g... but there would be no recruitment at all because of the discards. This simple yield per recruit approach is inappropriate because it does not take into account the discards. Discards before 18 imply declining number at age 18 ("recruitment") with increasing F while a proportion of the catch at age over 18 are discarded and must not be included into the yield.

Then the discards must be taken into account in the yield per recruit calculation. Such simulations have been carried out using the Fortran program RENDIS from the IFREMER populations dynamic programs library (Beucher, 1992). The model used is a Thomson & Bell model (Laurec & Le Guen, 1981) taking into account the two components of the total catch (landings and discards). The Calculated $F$ correspond to the total catch, but the references points $F_{max}$ and $F_{0.1}$ refer to the landings (i.e. the program computes the effort mutlipicator which maximises the landings though it is conditionned by the combined fishing pattern of landings and discards).
As the preceding this yield per recruit is carried out on age 1 to 50. The same $F$ at age vector was used but it was split into its landings and discards components according to the observed landings vs discards at age ratios.
The main results of this yield per recruit simulation are :
- Y/R is currently at 39 g for 1 recruit at age 1 ;
$F_{0.1}$ is lower than the current $F$ at a multiplicator of 0.75 ;
- $F_{max}$ is slightly over the current $F$ at a multiplicator of 1.25.

The shape of the yield per recruit curves are given in Figure 8. The low absolute value of the yield per recruit is due to taking age 1 as recruitment. Considering that at the current fishing mortality 16.4 % of the recruits at age 1 reach age 18 (see table 3) the yield for 1 recruit at age 18 would be (39 x 100)/16.4 = 238 g lower than the figure of 360 g from single yield per recruit of the landing because some fish older than 18 are discarded. Multiplicating this last figure by the number at age 18 for the pseudo cohort analysis (23.3 million) gives an annual yield at equilibrium of 5500 tonnes. This MSY is lower than a former estimate of between 9000 T and 8000 T (Dupouy & Kergoat, 1992). It is lower than the current yield mainly because the catch of older fish will reduce when reaching the equilibrium stage. Lastly, it is very speculative figure the main problem being that few confidence can be put in the pseudo cohort analysis because of poor convergence.

# 4. DISCUSSION

## 4.1. AGE LENGTH KEY

One single ALK is available for the species. Because of the time required for the readings it will be difficult to get annual ALKs. Moreover, notwithstanding the validation problem, wide uncertainties will remain on the age reading of this species. It should be noted that there is still discrepancies when comparing age readings from different laboratories for shelf species such as whiting. The problem is not the validation but the interpretation of individual otoliths. As species with most individuals being less than 10 years old in exploited stocks can still be difficult to interpret, it seems unrealistic to use annual ALK for roundnose grenadier. However, the same ALK should not be used permanently as the effect of the exploitation is not stabilised (i.e. the relative frequency of older fish is likely to decline in the total population as well as within each size class).

## 4.2. YIELD PER RECRUIT

Y/R should be sensitive to the input parameters and the $F$ vector obtained from the pseudo cohort analysis is especially dubious. Beyond the discussion about the natural mortality coefficient, starting the Y/R calculation from age 1 may have little biological meaning because for such a long-lived species the hypothesis of a constant natural mortality $M$ over ages 1 to 50 is probably wrong as the ecology of the fish changes with age. The calculation is done that way to allow to take into account all the discards. However if the natural mortality of young fish is different from adults one, the effects of discarding juveniles is not properly assessed by the model. Lastly the results are also sensitive to the weight at age used. According to the slow growth of the species, and the fishing mortality in any case too low to have an effect on the demographic structure within years, the problem

is not with taking the same weights at age for the stock, the landings and the discards (which would be inappropriate for shelf species) but with the estimated weights at age as length-weight relationships from different samplings appeared different.
Lastly, the results are also sensitive to the sorting curve between landings and discards. The fish are sorted according to size. However the length distribution of landings and discards significantly overlap from 13.5 to 16 cm classes only the age distribution overlap cover more than 10 age groups. Then a slight change in the length sorting curve (which depends on the market) would have important effect on the split of the catch at age between landings and discards at age and, as a result, on the yield per recruit.
However, the simulation clearly shows that analytical assessment of the roundnose grenadier cannot disregard the discards.

### 4.3. MANAGEMENT CONSIDERATION

The discards appear to have a very strong effect on the potential yield of the fishery. As 21% of the total catch in weight is discarded the proportion in number is close to 50%. It is obvious that reducing the mortality of small fish would make the fishery more profitable. The other main species in the fishery are bigger, but the catch of black scabbard fish (*Aphanopus carbo*) could be very sensitive to mesh size due to the shape of this species. It should also be considered that deep-sea fish arrive often in poor condition on trawlers decks. For example, during a deep-water trawling survey to the West of Scotland (Prospec I cruise, July 1996), it was impossible to find undamaged black scabbard fish to photograph ; for grenadier the best specimens found to photograph had lost many scales. These fish are probably more susceptible to damage in the trawl than shelf species, and the survival of individuals having experienced mesh escapment is questionable (i.e. reducing the discard does not necessarily mean reducing the "juvenile" mortality to the same amount).

## 5. CONCLUSION

The assessment shown here has been carried out under some uncertainties. However, we do know the total catch which is possibly not that usual for all the landings are reported as they are marketed through "criées" and the discarding rate has been properly sampled.
The ages are unvalidated for the size range of landed fish and the age length key as well as natural mortality can be discussed and other combinations of parameters should be assessed. Lastly the yield per recruit is sensitive to the length weight relationship, to the growth curve, and to the natural mortality. So, many aspects of this assessment are debatable. This illustrates the scarcity of the available data for deep-water species.
The catch at equilibrium calculated here appears to be lower than the current catch. If it represents the actual situation, the stock should not be damaged by extra catches at the beginning of exploitation, the catch over the equilibrium level being the accumulated biomass. However, according to the reservations given here, no conclusion can be drawn from his assessment and the reaction of the stock after 10 years of exploitation is possibly still two low to be analysed from such model.
Lastly, an important point in this paper is to show the impact of the discards which cannot be disregarded when assessing the stock of the species.

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Table 1. - Age length key of *Coryphaenoides rupestris*.

| | Age | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lpa | 1 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 60 | Total | age |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.5 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 |
| 4 | | | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 5 |
| 4.5 | | | 1 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | 5 |
| 5 | | 3 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | 3 |
| 5.5 | | 1 | 1 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | 5 |
| 6 | | 2 | 3 | 3 | 2 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 | 5 |
| 6.5 | | 1 | 2 | | 1 | 3 | 3 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 | 6 |
| 7 | | | 1 | 7 | 5 | | 3 | 2 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 20 | 7 |
| 7.5 | | 1 | 2 | 2 | 5 | 4 | | | 1 | 1 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 18 | 7 |
| 8 | | | 2 | 3 | | 1 | 2 | 3 | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 14 | 8 |
| 8.5 | | | | | | 2 | 3 | | 5 | 2 | 3 | 1 | 1 | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 18 | 11 |
| 9 | | 1 | | | | | 2 | 1 | 2 | 3 | 2 | 7 | 1 | 4 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 24 | 12 |
| 9.5 | | | | 1 | | | | | 2 | 1 | 3 | | 1 | 3 | | 2 | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15 | 14 |
| 10 | | | | | | | | 1 | 3 | 1 | 3 | 4 | 3 | 2 | 1 | 1 | 1 | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | 22 | 14 |
| 10.5 | | | | | | | | 1 | 2 | 3 | 3 | 2 | 2 | 4 | | 4 | 1 | | | 4 | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | | | | 28 | 15 |
| 11 | | | | | | | | | 2 | 1 | | 2 | | 6 | 4 | 1 | 2 | 3 | 1 | 5 | 1 | | | 1 | | | | | 1 | | | | | | | | | | | | | | | | | | 30 | 17 |
| 11.5 | | | | | | | | | | 2 | 2 | 1 | 4 | 3 | 3 | 2 | 4 | 1 | 2 | 2 | 1 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | 30 | 17 |
| 12 | | | | | | | | 1 | | | 2 | | 3 | 3 | 3 | 3 | 7 | 4 | 3 | 2 | 5 | 1 | 1 | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | 40 | 18 |
| 12.5 | | | | | | | | | | 2 | 1 | | | 3 | 2 | 2 | 2 | 2 | 3 | 3 | 2 | 3 | 2 | | | | | 1 | 1 | | | | | | | | | | | | | | | | | | 29 | 19 |
| 13 | | | | | | | | | | | | 2 | 1 | 1 | 6 | 3 | 5 | 5 | 6 | 4 | 4 | 3 | 3 | 1 | 5 | 1 | 1 | | | 1 | 1 | | | | | | | | | | | | | | | | 53 | 21 |
| 13.5 | | 1 | | | | | | | | | | 1 | 3 | 3 | 1 | 4 | 8 | 4 | 1 | 4 | 5 | 4 | | 4 | 3 | | 2 | | | 1 | | | | | | | | | | | | | | | | | 49 | 20 |
| 14 | | | | | | | | | | | 1 | | 2 | 3 | 4 | 7 | 12 | 11 | 8 | 5 | 8 | 6 | 1 | | 2 | 4 | 1 | | | | 1 | | | | | | | | | | | | | | | | 76 | 20 |
| 14.5 | | | | | | | | | | | | | 1 | | 2 | 5 | 6 | 5 | 6 | 6 | 4 | | 9 | 1 | | 2 | 2 | 2 | 1 | 1 | | | | | | | | | | | | | | | | | 53 | 21 |
| 15 | | | | | | | | | | | | | | 2 | 4 | 4 | 10 | 10 | 5 | 8 | 6 | 7 | 5 | 3 | 1 | 1 | 1 | 3 | | | 3 | 1 | 2 | | | | | | | | | | | | | | 76 | 22 |
| 15.5 | | | | | | | | | | | | 1 | 1 | 1 | | 1 | 5 | 8 | 8 | 10 | 6 | 6 | 2 | 3 | 6 | 1 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | 65 | 22 |
| 16 | | | | | | | | | | | | | 1 | | | 4 | 7 | 4 | 5 | 9 | 5 | 4 | 9 | 8 | 2 | | 4 | 4 | 1 | 4 | 1 | | 1 | | | | | | | | | | | | | | 73 | 23 |
| 16.5 | | | | | | | | | | | | | | 2 | 1 | 2 | 1 | 4 | 4 | 9 | 11 | 8 | 3 | 3 | 4 | 1 | 6 | 1 | 2 | | 3 | 2 | | | 1 | 1 | | | | | | | | | | | 69 | 24 |
| 17 | | | | | | | | | | | | | | | | 3 | 5 | 6 | 4 | 8 | 5 | 8 | 10 | 7 | 7 | 4 | 5 | 3 | 4 | 1 | 1 | | | 1 | 1 | | | | | 2 | | | 1 | | | | 86 | 25 |
| 17.5 | | | | | | | | | | | | | | | | 1 | 2 | 3 | 5 | 6 | 8 | 5 | 3 | 4 | 5 | 5 | 6 | 1 | 1 | 2 | 3 | | 1 | 1 | | | | | | | | | | | | | 61 | 24 |
| 18 | | | | | | | | | | | | | | 1 | | 1 | 2 | 4 | 5 | 4 | 5 | 8 | 6 | 3 | 7 | 2 | 8 | 4 | 2 | 5 | 1 | | 2 | 3 | | | | | | | | | | | | | 73 | 25 |
| 18.5 | | | | | | | | | | | | | | | | | 1 | 3 | 5 | 6 | 8 | 5 | 7 | 2 | 2 | 7 | 4 | | 2 | 2 | | 1 | 1 | | | | | | | | | | | | | | 56 | 24 |
| 19 | | | | | | | | | | | | | | | | 1 | 2 | 5 | 5 | 3 | 2 | 4 | 6 | 6 | 5 | 4 | 6 | 2 | 2 | 3 | 4 | 4 | 2 | | 2 | | | 1 | | 1 | | 1 | | | | | 71 | 26 |
| 19.5 | | | | | | | | | | | | | | | | | 1 | 2 | 3 | 6 | 6 | 8 | 8 | | 3 | 6 | 4 | 3 | 6 | 6 | 5 | 7 | 1 | 3 | 1 | 1 | | | | | | | | | | | 80 | 27 |
| 20 | | | | | | | | | | | | | | | | 1 | 2 | 1 | 1 | 2 | 1 | 4 | 5 | 6 | 4 | 5 | 4 | | 1 | 2 | 2 | 2 | 2 | 2 | 1 | | | | | 1 | | | | 1 | | | 50 | 27 |
| 20.5 | | | | | | | | | | | | | | | | | | | 1 | 2 | 2 | 4 | 4 | 3 | 3 | 2 | 4 | 3 | 5 | | 3 | | 3 | | | 3 | | 1 | | | 1 | | | 1 | | | 45 | 29 |
| 21 | | | | | | | | | | | | | | | | | | | 2 | 2 | | 4 | 3 | 4 | 3 | 3 | 2 | | 2 | 4 | 1 | 1 | 2 | 3 | | 2 | | 1 | 1 | | 1 | | | | | | 41 | 29 |
| 21.5 | | | | | | | | | | | | | | | | | | 1 | | | 1 | 1 | 3 | 4 | 3 | 3 | 1 | 1 | 6 | 1 | 1 | 2 | 3 | | | | | | 1 | | | 1 | | 1 | | | 34 | 29 |
| 22 | | | | | | | | | | | | | | | | | | | 2 | | | 1 | 2 | 2 | 2 | 1 | 1 | 3 | 3 | 4 | 1 | 1 | 2 | 1 | | 1 | | 1 | 1 | | | 1 | | | | | 30 | 30 |
| 22.5 | | | | | | | | | | | | | | | | | | | | 1 | | 2 | 1 | | 2 | 3 | 1 | 2 | | 2 | 1 | | 3 | | 1 | | 1 | | 1 | 1 | | | | 1 | | 1 | 24 | 32 |
| 23 | | | | | | | | | | | | | | | | | | | | | 2 | | 1 | | | 1 | | 1 | | 1 | | 2 | 1 | 1 | 1 | | 1 | | | | | 2 | | | 1 | | 15 | 33 |
| 23.5 | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 | | | 2 | 1 | | | | 1 | | | 1 | | 1 | | | | | | | | 9 | 31 |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 2 | | 1 | | | | | | | | | | | | | 1 | | | | 5 | 32 |
| 24.5 | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | 1 | | | | | | | | 1 | | | | | | | | | | | | 3 | 29 |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | 2 | | | | 1 | | | | | | | | | | | 4 | 33 |
| 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | 1 | 38 |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | 1 | 37 |
| 29.5 | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | 1 | 25 |
| Total | 1 | 10 | 14 | 20 | 15 | 10 | 14 | 10 | 20 | 17 | 23 | 21 | 24 | 41 | 32 | 53 | 87 | 86 | 86 | 112 | 100 | 98 | 97 | 68 | 70 | 58 | 67 | 41 | 42 | 41 | 32 | 25 | 26 | 16 | 9 | 10 | 4 | 4 | 5 | 5 | 2 | 5 | 2 | 4 | 1 | 1 | 1529 | |
| Mean | 3 | 7 | 6 | 7 | 7 | 7 | 8 | 9 | 9 | 10 | 10 | 11 | 12 | 12 | 13 | 14 | 15 | 15 | 16 | 16 | 16 | 17 | 17 | 18 | 18 | 19 | 18 | 19 | 19 | 19 | 18 | 20 | 20 | 20 | 20 | 21 | 24 | 21 | 22 | 19 | 21 | 22 | 21 | 21 | 23 | 23 | | |

Table 3. Simulated "population" numbers of roundnose grenadier. The simulation was carried out with 1 000 individuals at age 1, $M$=0.1 and the fishing patttern obtained from pseudo cohort analysis. Number of the unexploited "population", exploited population from 1987 to 2008 (the fishing mortalities at age being multiplied by an annual correcting factor - see text) and at equilibrium under the current fishing pattern.

| | | | Year | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1987 | | 1997 | 1998 | | 2008 | Equilibrium |
| | | | Annual factor | | | | | | |
| Age | F at age | Unexploited population | 0.1 | | 1 | 1 | | 1 | |
| 1 | .001 | 1 000 | 1 000 | | 1 000 | 1 000 | | 1 000 | 1 000 |
| 2 | .001 | 905 | 905 | | 904 | 904 | | 904 | 904 |
| 3 | .001 | 819 | 819 | | 817 | 817 | | 817 | 817 |
| 4 | .001 | 741 | 741 | | 739 | 739 | | 739 | 739 |
| 5 | .001 | 670 | 670 | | 668 | 668 | | 668 | 668 |
| | | | | | | | | | |
| 15 | .018 | 247 | 246 | | 238 | 237 | | 236 | 236 |
| 16 | .018 | 223 | 223 | | 212 | 211 | | 210 | 210 |
| 17 | .028 | 202 | 202 | | 189 | 188 | | 187 | 187 |
| 18 | .052 | 183 | 182 | | 166 | 166 | | 164 | 164 |
| 19 | .054 | 165 | 164 | | 143 | 143 | | 141 | 141 |
| 20 | .061 | 150 | 149 | | 123 | 123 | | 121 | 121 |
| 21 | .088 | 135 | 135 | | 105 | 105 | | 103 | 103 |
| 22 | .093 | 122 | 121 | | 88 | 87 | | 85 | 85 |
| 23 | .104 | 111 | 110 | | 73 | 72 | | 70 | 70 |
| 24 | .116 | 100 | 99 | | 60 | 60 | | 58 | 57 |
| 25 | .096 | 91 | 90 | | 49 | 49 | | 46 | 46 |
| | | | | | | | | | |
| 35 | .100 | 33 | 33 | | 14 | 12 | | 6 | 6 |
| 36 | .100 | 30 | 30 | | 13 | 11 | | 5 | 5 |
| 37 | .100 | 27 | 27 | | 11 | 10 | | 5 | 4 |
| 38 | .100 | 25 | 24 | | 10 | 9 | | 4 | 3 |
| 39 | .100 | 22 | 22 | | 9 | 8 | | 3 | 3 |
| 40 | .100 | 20 | 20 | | 8 | 8 | | 3 | 2 |
| 41 | .100 | 18 | 18 | | 8 | 7 | | 3 | 2 |
| 42 | .100 | 17 | 16 | | 7 | 6 | | 2 | 2 |
| 43 | .100 | 15 | 15 | | 6 | 6 | | 2 | 1 |
| 44 | .100 | 14 | 13 | | 6 | 5 | | 2 | 1 |
| 45 | .100 | 12 | 12 | | 5 | 5 | | 2 | 1 |
| 46 | .100 | 11 | 11 | | 5 | 4 | | 2 | 1 |
| 47 | .100 | 10 | 10 | | 4 | 4 | | 1 | 1 |
| 48 | .100 | 9 | 9 | | 4 | 3 | | 1 | 0 |
| 49 | .100 | 8 | 8 | | 3 | 3 | | 1 | 0 |
| 50 | .100 | 7 | 7 | | 3 | 3 | | 1 | 0 |
| Total population number | | 10 438 | 10 420 | | 9 648 | 9 617 | | 9 496 | 9 483 |
| Total number at ages 18 to 50 | | 1 849 | 1 834 | | 1 150 | 1 121 | | 1 006 | 993 |

Table 4. Input parameters for the yield per recruit simulation.

| Age | Weight at age | Natural mortality | Fishing mortalities | | |
|---|---|---|---|---|---|
| | | | Landings | Discards | Total catch |
| 1 | 0 | 0.1 | 0 | 0.001 | 0.001 |
| 2 | 0 | 0.1 | 0 | 0.001 | 0.001 |
| 3 | 0.045 | 0.1 | 0 | 0.001 | 0.001 |
| 4 | 0.033 | 0.1 | 0 | 0.001 | 0.001 |
| 5 | 0.042 | 0.1 | 0 | 0.001 | 0.001 |
| 6 | 0.041 | 0.1 | 0 | 0.002 | 0.002 |
| 7 | 0.057 | 0.1 | 0 | 0.002 | 0.002 |
| 8 | 0.06 | 0.1 | 0 | 0.003 | 0.003 |
| 9 | 0.09 | 0.1 | 0 | 0.003 | 0.003 |
| 10 | 0.108 | 0.1 | 0 | 0.003 | 0.003 |
| 11 | 0.144 | 0.1 | 0 | 0.004 | 0.004 |
| 12 | 0.145 | 0.1 | 0 | 0.006 | 0.006 |
| 13 | 0.171 | 0.1 | 0 | 0.006 | 0.006 |
| 14 | 0.26 | 0.1 | 0.001 | 0.008 | 0.009 |
| 15 | 0.262 | 0.1 | 0.002 | 0.016 | 0.018 |
| 16 | 0.326 | 0.1 | 0.002 | 0.016 | 0.018 |
| 17 | 0.418 | 0.1 | 0.008 | 0.02 | 0.028 |
| 18 | 0.483 | 0.1 | 0.017 | 0.035 | 0.052 |
| 19 | 0.584 | 0.1 | 0.023 | 0.031 | 0.054 |
| 20 | 0.653 | 0.1 | 0.029 | 0.032 | 0.061 |
| 21 | 0.63 | 0.1 | 0.043 | 0.045 | 0.088 |
| 22 | 0.672 | 0.1 | 0.046 | 0.047 | 0.093 |
| 23 | 0.811 | 0.1 | 0.064 | 0.04 | 0.104 |
| 24 | 0.88 | 0.1 | 0.078 | 0.038 | 0.116 |
| 25 | 0.948 | 0.1 | 0.071 | 0.025 | 0.096 |
| 26 | 0.929 | 0.1 | 0.085 | 0.037 | 0.122 |
| 27 | 1.066 | 0.1 | 0.078 | 0.022 | 0.1 |
| 28 | 0.975 | 0.1 | 0.082 | 0.018 | 0.1 |
| 29 | 1.088 | 0.1 | 0.08 | 0.02 | 0.1 |
| 30 | 1.175 | 0.1 | 0.081 | 0.019 | 0.1 |
| 31 | 1.192 | 0.1 | 0.084 | 0.016 | 0.1 |
| 32 | 1.029 | 0.1 | 0.082 | 0.018 | 0.1 |
| 33 | 1.371 | 0.1 | 0.097 | 0.003 | 0.1 |
| 34 | 1.345 | 0.1 | 0.096 | 0.004 | 0.1 |
| 35 | 1.341 | 0.1 | 0.099 | 0.001 | 0.1 |
| 36 | 1.347 | 0.1 | 0.098 | 0.002 | 0.1 |
| 37 | 1.684 | 0.1 | 0.099 | 0.001 | 0.1 |
| 38 | 1.8 | 0.1 | 0.1 | 0 | 0.1 |
| | | | | | |
| | | | | | |
| 50 | 1.8 | 0.1 | 0.1 | 0 | 0.1 |

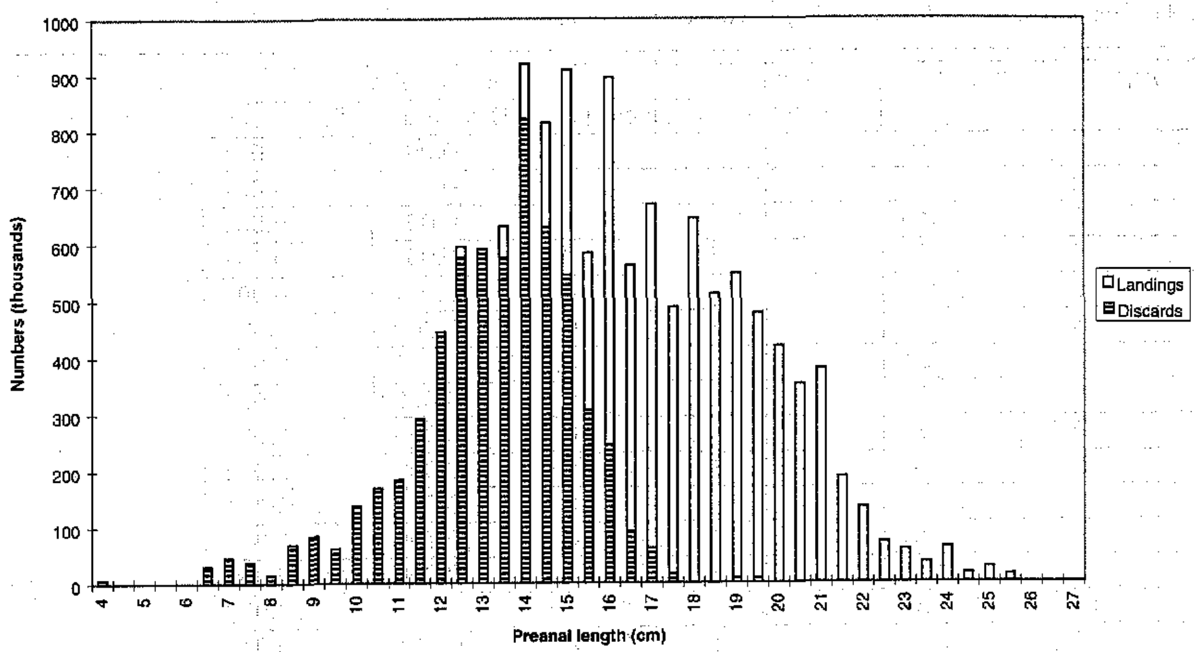


Figure 1. Length distribution of *Coryphaenoides rupestris* catches in 1996

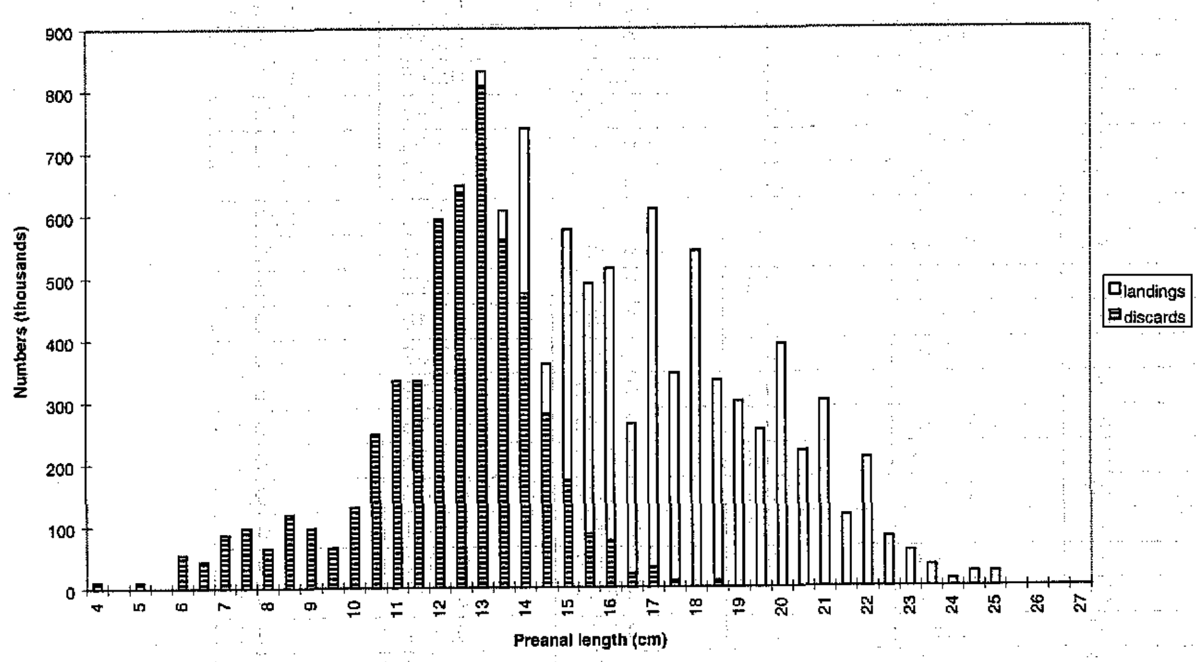


Figure 2. Length distribution of *Coryphaenoides rupestris* catches in 1997.

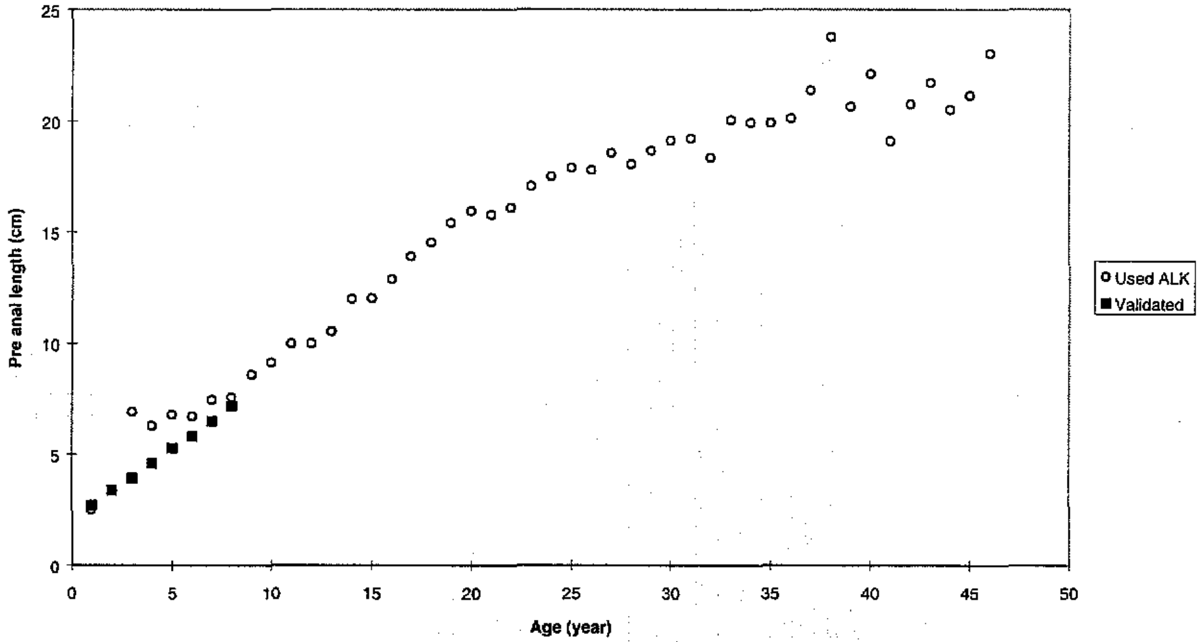


Figure 3. Mean length at age of *Coryphaenoides rupestris*.

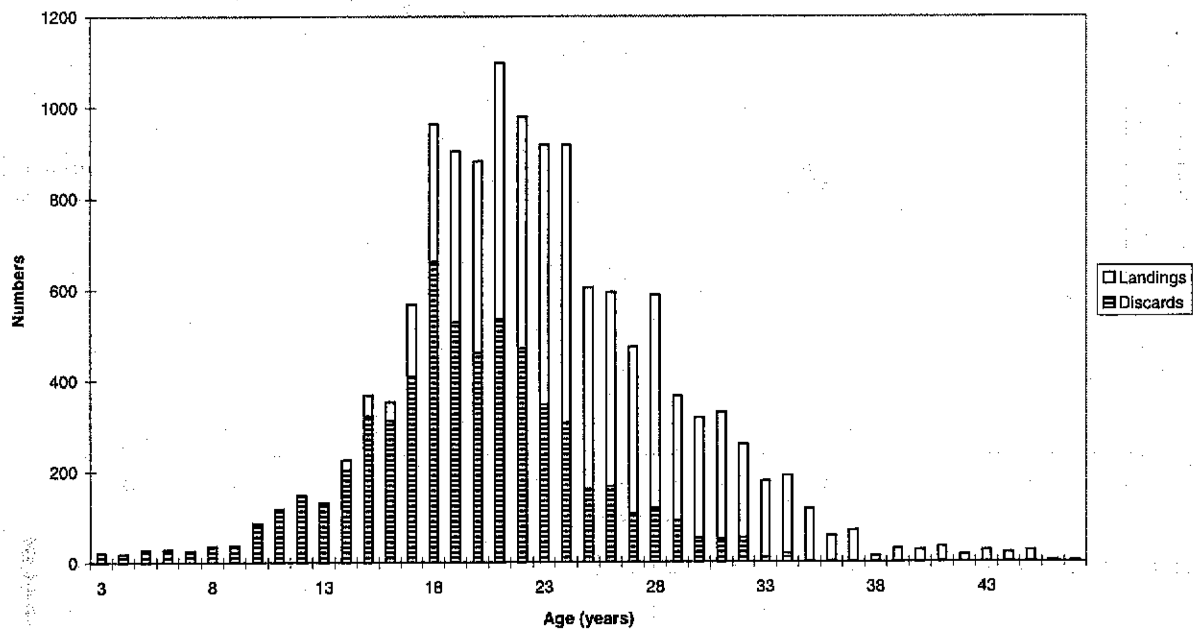


Fig. 4 Age distribution of *Coryphaenoides rupestris* catches in 1996.

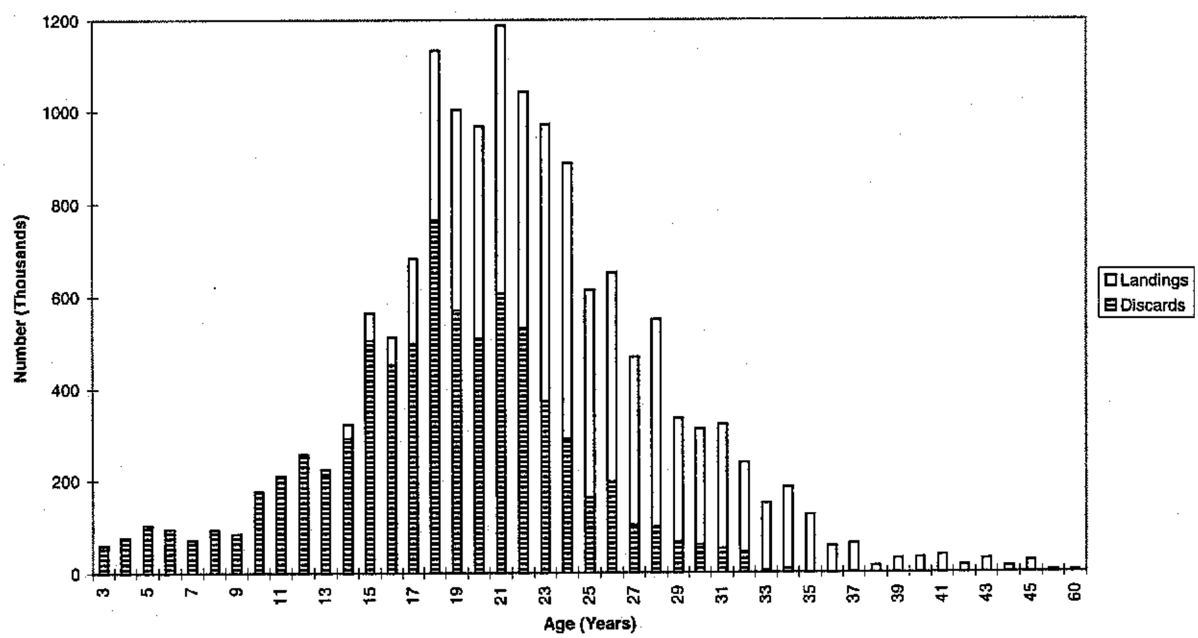


Figure 5. Age distribution of *Coryphaenoides rupestris* catches in 1997

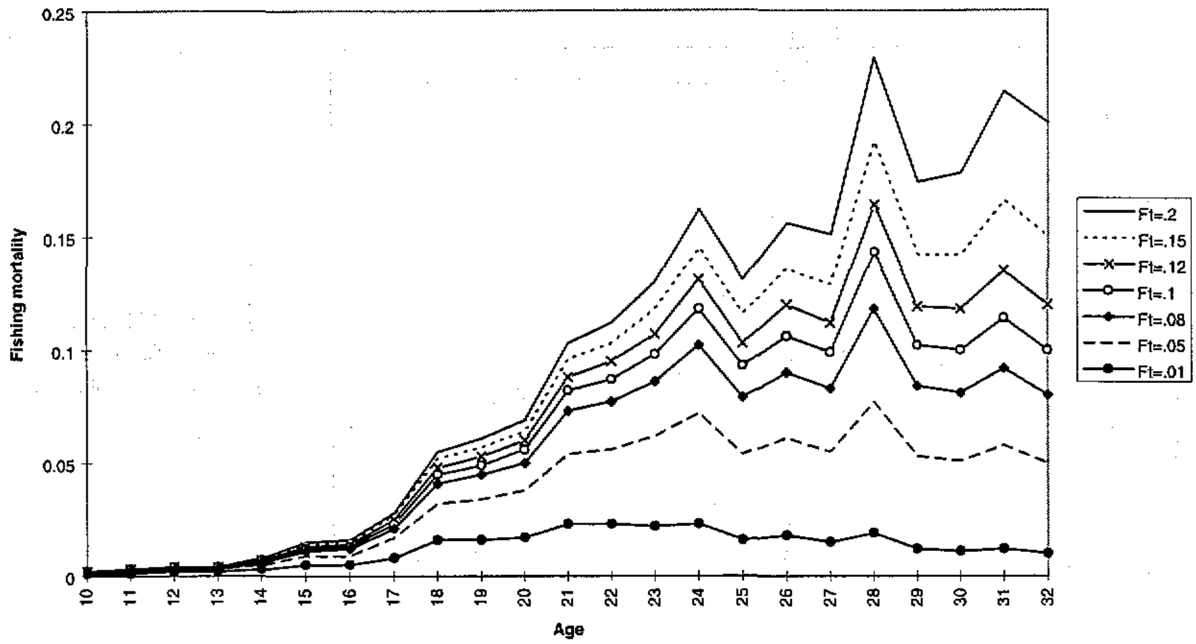


Fig 6. Pseudo cohort analysis of 1996 age distribution of the catch : F profile at M=0.1.

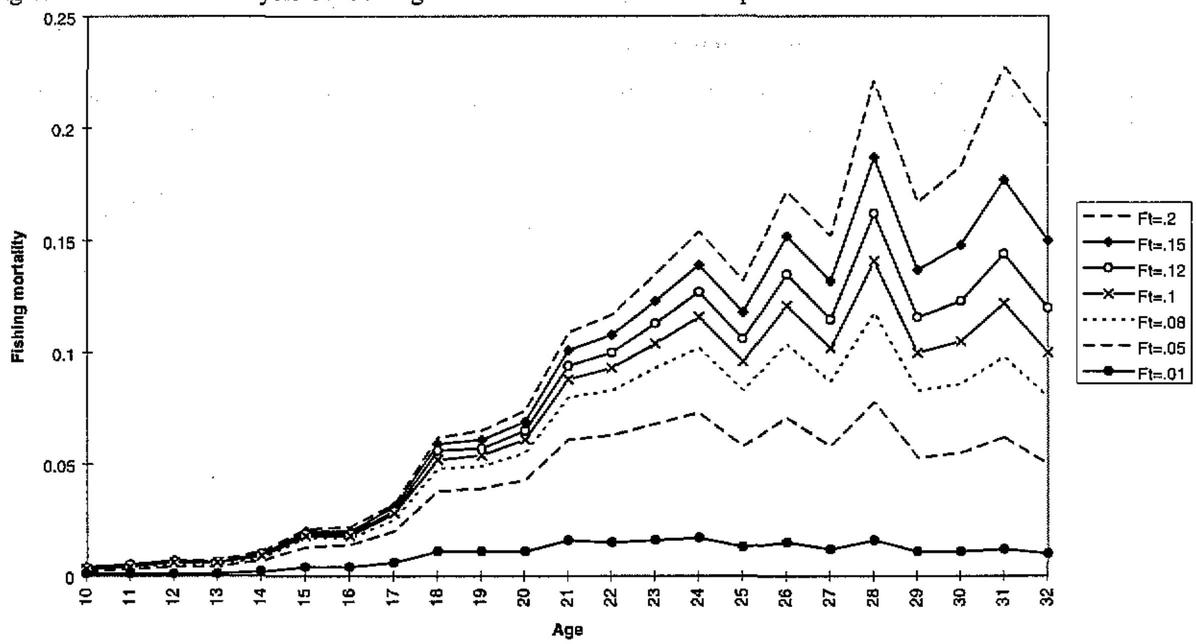


Fig 7. Pseudo cohort analysis of 1997 age distribution of the catch : F profile at M=0.1.

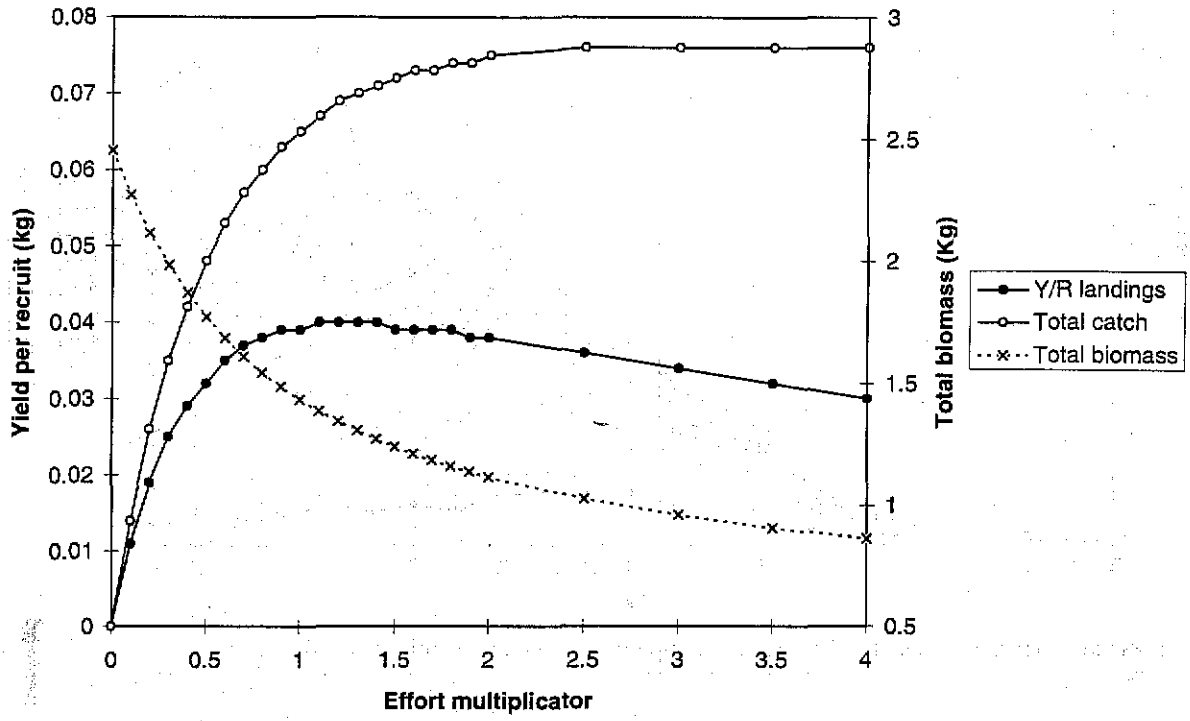


Figure 8. Yield per recruit curves using the fishing pattern from the pseudo cohort analysis. $F_{0.1}$ was estimates at 0.75 x $F_{current}$ and $F_{max}$ at 1.25 x $F_{current}$.