# GROWTH AND NATURAL MORTALITY OF PATAGONIAN ROCKCOD (*PATAGONOTOTHEN GUNTHERI SHAGENSIS*) FROM SHAG ROCKS SHELF

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## Abstract

The parameters of Bertalanffy's growth equation for Patagonian rockcod (*Patagonothen guntheri shagensis*) were calculated by using age and length-weight data of research and fishery survey cruises in the Shag Rocks area from 1978 to 1986. The natural mortality rate was assessed by six different methods and was within a range of 0.63 to 1.06. The mean value of natural mortality $\bar{M}$=0.8 was used in calculations and the optimal age and length for harvesting Patagonian rockcod were found to be 2.5 years and 12.6 cm.

## Résumé

Les paramètres de l'équation de croissance de Bertalanffy, en ce qui concerne la bocasse de Patagonie (*Patagonotothen guntheri shagensis*) ont été calculés en utilisant des données d'âge et de longueur-poids provenant de campagnes d'évaluation menées par des navires de recherche et de pêche dans la région des Shag Rocks de 1978 à 1986. Le taux de mortalité naturelle a été estimé par six méthodes différentes et s'échelonnait entre 0,63 et 1,06. La valeur moyenne de la mortalité naturelle $\bar{M}$=0,8 a été utilisée pour les calculs, et l'on constate que l'âge et la longueur optimaux d'exploitation de la bocasse de Patagonie sont de 2,5 années et de 12,6 cm.

## Резюме

Параметры уравнения Берталанффи для желтоперки (*Patagognothen guntheri shagensis*) были рассчитаны при использовании данных по возрасту и соотношению длина-вес, полученных в ходе рейсов по проведению научно-исследовательских и промысловых съемок в районе скал Шаг с 1978 по 1986 гг. Оценка коэффициента естественной смертности была проведена шестью различными методами, и его величина варьировалась в диапазоне от 0,63 до 1,06. В расчетах использовалась средняя величина естественной смертности $\bar{M}$=0,8, оптимальные промысловые возраст и длина желтоперки равнялись 2,5 годам и 12,6 см соответственно.

## Resumen

Los parámetros de la ecuación de crecimiento de Bertalanffy para la trama Patagónica (*Patagonothen guntheri shagensis*) se calcularon empleando los datos de edad y talla-peso obtenidos de los cruceros de investigación y de estudio de pesca realizados en el área de Shag Rocks

desde 1978 a 1986. El índice de mortalidad natural fue evaluado por seis métodos diferentes y se mantuvo dentro de un rango de 0.63 a 1.06. El valor medio de mortalidad natural $\bar{M}$=0.8 se utilizó en las cálculos y la edad y talla óptimos para la pesca de la trama Patagónica se encontró que es de 2.5 años y 12.6 cm.

## 1. INTRODUCTION

The Patagonian rockcod was first found on the Shag and Black Rocks shelf in 1974 and was classified as a sub-species, *Patagonotothen guntheri shagensis* (Balushkin and Permitin, 1982). Studies of its biology and population dynamics in these areas were initiated in 1973 when commercial catches were first taken there. Although some information on the biology (Lubimova and Shust, 1982; Shust, 1986), feeding (Naumov et al., 1983) and reproduction (Lisovenko and Pinskaya, 1987) of *P.g. shagensis* can be found in current publications, this sub-species still remains a poorly studied commercial fish.

## 2. MATERIALS AND METHODS

The results of age determination and the data on the length-weight composition of *P.g. shagensis* populations obtained by the Soviet research and exploratory ships over the period from 1978 to 1986 period were used.

The Hohendorf method was used to estimate the Bertalanffy growth equation parameters, and the Kutty and Kasim method was used to determine the optimum length and age of *P.g. shagensis* for harvesting. The calculation of natural mortality rates was carried out by six different methods described in the Methodology Instructions of VNIRO (1984).

## 3. RESULTS AND DISCUSSION

### 3.1 Biological Characteristics

*P.g. shagensis* has distributed locally in the Antarctic waters. It inhabits waters south of the Antarctic Convergence and areas of its distribution are limited by the shelf waters of Shag and Black Rocks to the west of South Georgia Island (Balushkin and Permitin, 1982; Naumov et al., 1983).

This small size notothenia is a near bottom - pelagic species and inhabits depths down to 320 m with temperature ranging from 1.5 to 2.6°C and the salinity from 33.8 to 34.0‰. *P.g. shagensis* forms aggregations during the warm season (December to March). The length of fish in catches is from 8 to 24 cm, the prevailing length is 11 to 18 cm and the weight is between 10 and 120 g with the mean weight of about 40 g.

The maximum age of *P.g. shagensis* is 7 years and fish of 2 to 5 years are most abundant. Sexual maturity is attained by fish at 11 to 13 cm length, 20 to 30 g weight and age of 2 to 3 years. The sex ratio of fish is actually the same in all size classes. Depending on the length, the fecundity of *P.g. shagensis* ranges from 8 000 to 29 000 eggs (Lisovenko and Pinskaya, 1987).

*P.g. shagensis* is a planktophagous fish and feeds mainly on Antarctic krill, amphipods (mainly *Parathemistro gaudichaudii*) and copepods (Naumov et al., 1983). The feeding intensity is highest during the spring/summer period (October to February). The fish feeds mainly at night. The daily food ration is about 5.3% of the fish weight. Competitors for food are mackerel icefish, marbled rockcod, *Notothenia kempi* and grey rockcod. Among the predators are Patagonian toothfish and marbled notothenia.

## 4. AGE AND GROWTH

The scales were used for ageing *P.g. shagensis*. This method is less labour-consuming and yields satisfactory results as compared with other methods based on other age-registering structures (Table 1).

From the extensive data, the growth of *P.g. shagensis* was found to be isometric (Figure 1). The weight-length ratio is described by the formula (4.6% accuracy*):

$$W = 0.0046\ L^{3.27}$$

The calculations made according to Hohendorf method gave the following parameters of the Bertalanffy equation:

linear growth: $K = 0.3258$, $L = 23.31$ cm, $t_o = 0.1149$
weight growth: $K = 0.3646$, $W = 104.26$ g, $t_o = 0.3838$

The accuracy* of these values are 0.90% (linear growth) and 7.25% (weight growth).

## 5. NATURAL MORTALITY

The natural mortality rate was estimated using the following methods:

(i) Baranov method. The data on age and age/length key (Figure 2) for the second half of 1978 (i.e. prior to the beginning of the fishery) were used. The value of M was estimated by comparing natural logarithms of fish in each age-group (Table 2) and by using the graphic method (Figure 3). In both cases the value of M was 0.83.

(ii) Beverton and Holt method with F=0:

$$M = Z = \frac{1}{\bar{t} - t'} = 0.94$$

where $\bar{t}$ = mean age of fish, 3.42 years
$t'$ = age of year class which is fully represented in catches and does not experience the effect of selectivity of fishing gears used, 2.35 years.

The age composition of *P.g. shagensis* before the beginning of fishing is shown in Figure 2. The mean age of fish was determined from the data on age composition:

$$\bar{t} = 2 \times 0.07 + 3 \times 0.57 + 4 \times 0.24 + 5 \times 0.11 + 6 \times 0.0095 = 3.42 \text{ years}$$

The analysis of the age composition curve shows that not all two year old fish were represented in catches, but only those of a particular length. Using the data of trawl surveys carried out by trawls with small mesh size covers, we managed to evaluate experimentally this length: $l' = 12.075$ cm (n=165). By using this value of $l'$ in the Bertalanffy equation of linear growths, we calculated the age of fish which should be fully represented in catches:

* A definition of the term "accuracy" is not provided by the author - Ed.

$$t' = t_o \frac{ln\ (1 - \frac{l'}{L})}{K} = 0.1149 - \frac{ln(1 - \frac{12.075}{23.31})}{0.3259} = 2.35 \text{ years}$$

The calculation of the original equation with estimated values of $\bar{l}$ and t' gave M=0.94.

(iii) Integral method of Beverton and Holt with F=0:

$$M = Z = \frac{(L\infty - l')\ K}{\bar{l} - l'} = 0.84$$

where $\bar{l}$ = mean fish length in catches taken in the second half of 1978, $\bar{l}$=15.21(n=1470),
$l'$ = length of fish of the youngest age-group fully represented in catches, $l'$=12.07 cm.

(iv) Method of Chapman-Robson with F=0:

$$M = Z = ln\ \bar{t} - ln\ (1 + \bar{t} - \frac{1}{n})$$

where $\bar{t}$ = assumed mean age of fish in a sample,
n = number of fish in a sample.

The calculations were based on age composition data for the second half of 1978. The calculations were made starting with modal age class of 3 years (Figure 2). For recording the results of age composition the assumed mean age was applied.

The age of the youngest year class which was fully represented in catches, was taken to be zero (Table 3). This routine calculation was used to obtain the sum of years T, (i.e. the number of years lived together by all specimens caught):

T = 0 x 832+1 x 360+2 x 157+3 x 14 = 716 years

and the assumed mean age:

$$\bar{t} = \frac{T}{n} = 0.525$$

By substituting the values of $\bar{t}$ and t' in the original equation the value of M=1.06 was obtained.

(v) According to the method of Rikhter-Efanov, the following empiric relationship exists between the mean value of M and time of mass maturation (t):

$$M = \frac{1.521}{t^{0.72}} - 0.155 = 0.63$$

Lisovenko and Pinskaya (1987) reported that the length of fish at first maturation is 11 to 13 cm (i.e. 2 years old). According to their data, 50% of fish attain sexual maturity at a length of 15.6 to 16.5 cm.

Our observations showed that mass maturation of *P.g. shagensis* takes place during summer/autumn (January to March) when fish is 12 to 14 cm length. This period corresponds with the age of 2.5 years. According to these data the value of M will be 0.63.

(vi) Method of Alverson-Carney:

$$M = \frac{3K}{e^{tK} - 1}$$

where K = growth coefficient from Bertalanffy equation (0.3646),

T = the age of fish which corresponds with maximum biomass.

In accordance with data from 1978 to 1986, the age of fish which corresponds with maximum biomass ranges from 2 to 4 years depending on the fluctuation of fish abundance. The long-term mean age was estimated at 2.5 years. Hence, with T=2.5 years, the natural mortality rate will be 0.73.

The range of variation of M calculated by different methods is considerable: from 0.63 to 1.06. In the absence of the objective criterion for selecting any of these values the arithmetical mean of the series of calculated values ($\bar{M}=0.8$) was used and some parameters of the optimal stock exploitation were estimated.

The optimal age for harvesting was calculated by the method of Kutty and Kasim:

$$t_{opt} = \frac{ln\ (3K + M) - ln\ M}{K} = 2.5 \text{ years}$$

where K = growth coefficient from the Bertalanffy equation (0.3259).

The optimal length for harvesting was calculated from the Bertalanffy equation:

$$l_{opt} = L\ (1 - e\text{-}K^{(topt - to)}) = 12.6 \text{ cm}$$

where $t_o$ = theoretical time of the beginning of growth (0.1149).

The results presented can be used in stock and TAC assessments for *P.g. shagensis* as well as for the development of recommendations for rational fishery of this fish.

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Table 1: Mean length of *P.g. shagensis* by age-groups in 1978.

| Fish Length (cm) | Age (Years) | | | | | | | n |
|---|---|---|---|---|---|---|---|---|
| Observed data | 6.60 | 12.03 | 13.90 | 16.30 | 17.98 | 18.77 | 21.55 | 1872 |
| Estimated data | 5.84 | 10.70 | 14.21 | 16.74 | 18.57 | 19.89 | 20.84 | 144 |

Table 2: Abundance of *P.g. shagensis* by age-groups in catches taken in the second half of 1978.

| Age-Groups | 2 | 3 | 4 | 5 | 6 | n |
|---|---|---|---|---|---|---|
| Abundance $N_i$ | 107 | 832 | 360 | 157 | 14 | 1470 |
| $t\,i$ | 4.67 | 6.72 | 6.69 | 5.06 | 2.64 | |
| n $N_i$ | | | | | | |

Table 3: Age composition of *P.g. shagensis* in catches taken in the second half of 1978 (n=1 363).

| Age (years) | Conventional Age (years) | n |
|---|---|---|
| 3 | 0 | 832 |
| 4 | 1 | 360 |
| 5 | 2 | 157 |
| 6 | 3 | 14 |

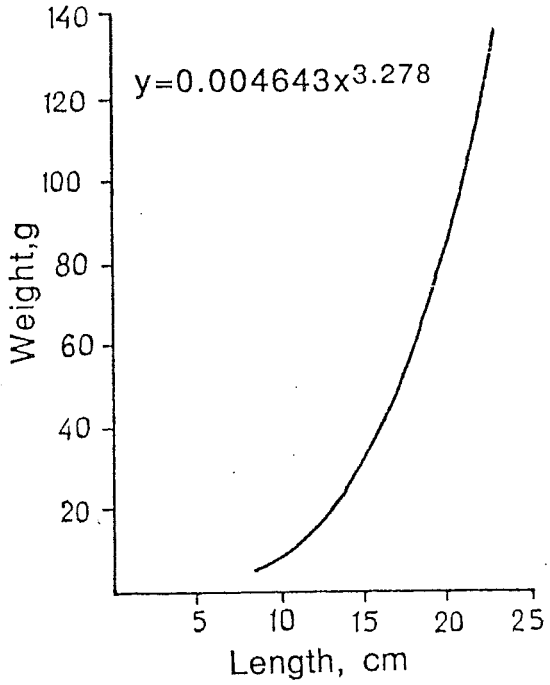



Figure 1: Plot of weight (grams) of *P.g. shagensis* against length (cm).

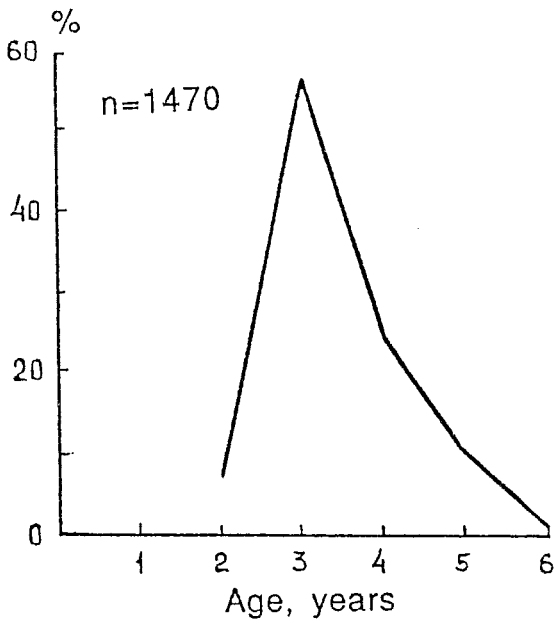
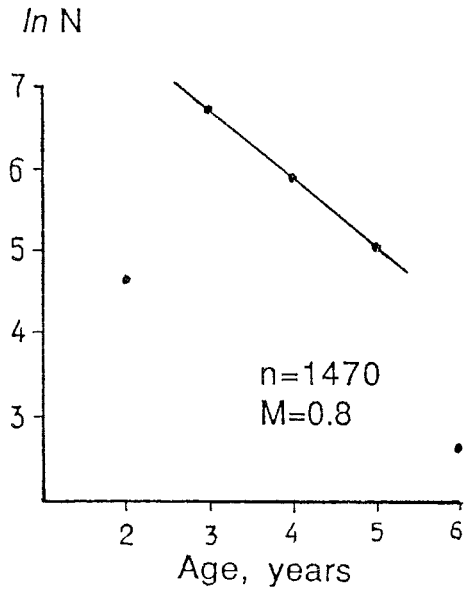



Figure 2: Age composition of *P.g. shagensis* in catches taken in the second half of 1978.

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