CCAMLR Science, Vol. 11 (2004): 141–153

SHORT NOTE

IS THE ATTEMPT TO ESTIMATE THE BIOMASS OF ANTARCTIC FISH FROM A MULTI-SPECIES SURVEY APPROPRIATE FOR ALL TARGETED SPECIES? *NOTOTHENIA ROSSII* IN THE ATLANTIC OCEAN SECTOR – REVISITED

K.-H. Kock✉
Institut für Seefischerei
Bundesforschungsanstalt für Fischerei
Palmaille 9, D-22767 Hamburg
Germany
Email – karl-hermann.kock@ish.bfa-fisch.de

M. Belchier
British Antarctic Survey
High Cross, Madingley Road
Cambridge CB3 0ET, United Kingdom

C.D. Jones
Southwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
8604 La Jolla Shores Drive, La Jolla, CA 92037, USA

Abstract

Notothenia rossii was the first target species in Southern Ocean fisheries. The species was already heavily fished at the beginning of the 1970s. The closure of the fishery for this species in 1985 was one of the first conservation measures adopted by CCAMLR. Fish biomass within a CCAMLR subarea or part of a subarea is commonly estimated from surveys that target a number of species, including *N. rossii*, at the same time. These surveys are conducted under the assumption that the target fish species are more or less evenly distributed over the area at the time of the survey. This assumption is violated in the case of *N. rossii*, which is non-randomly distributed such that a large proportion of the population tends to aggregate in small areas, leaving most of the survey area only thinly populated. In order to provide more accurate estimates of the abundance of the species, it is suggested that an acoustic survey combined with a number of identification hauls might be the most promising approach to estimating the biomass of *N. rossii*.

Résumé

Notothenia rossii, première espèce visée par la pêche dans l'océan Austral, faisait déjà l'objet d'une exploitation intensive au début des années 1970. La fermeture de la pêche de cette espèce en 1985 faisait partie des premières mesures de conservation adoptées par la CCAMLR. En général, la biomasse de poisson dans une sous-zone de la CCAMLR, ou dans un secteur d'une telle sous-zone, est estimée au moyen de campagnes d'évaluation visant à la fois plusieurs espèces – dont *N. rossii*. Il est présumé que la répartition des espèces de poisson visées est plus ou moins uniforme dans toute la région à l'époque de la campagne. Dans le cas de *N. rossii*, dont la distribution est non aléatoire, au point qu'une grande proportion de la population tend à se concentrer dans des secteurs limités, laissant le reste de la zone d'étude très peu peuplé, cette hypothèse est démentie. Il est suggéré, afin d'estimer avec davantage de précision l'abondance de *N. rossii*, de suivre l'approche la plus prometteuse, celle qui consiste à adjoindre à une campagne d'évaluation acoustique plusieurs traits d'identification.

Резюме

Notothenia rossii была первым целевым видом при промысле в Южном океане. В начале 1970-х гг. уже велся интенсивный промысел этого вида. Закрытие промысла этого вида в 1985 г. было одной из первых мер по сохранению, принятых АНТКОМом. Биомасса рыбы в пределах подрайона или части подрайона АНТКОМа обычно оценивается по съемкам, которые одновременно нацелены на несколько видов, включая *N. rossii*. Эти съемки поводятся, исходя из предположения, что целевые виды рыб более или менее равномерно распределены по всему району во время съемки. Это предположение нарушается в случае вида *N. rossii*, который распределен неслучайным образом, так что большая часть популяции обычно концентрируется в небольших районах, а в бóльшей части съемочного района популяция малочисленна. Предполагается, что акустическая съемка в сочетании с несколькими идентификационными тралениями может быть наиболее многообещающим подходом к оценке биомассы *N. rossii*, с точки зрения получения более точных оценок численности этого вида.

Resumen

Notothenia rossii fue la primera especie objetivo de las pesquerías del Océano Austral, y ya había sido explotada extensamente a comienzos de la década de los 70. Una de las primeras medidas de conservación que adoptó la CCRVMA fue la clausura de la pesca dirigida a esta especie en 1985. La biomasa de peces dentro de parte o toda una subárea de la CCRVMA se estima normalmente sobre la base de los datos de prospecciones dirigidas a varias especies, incluida *N. rossii*. Estas prospecciones son llevadas a cabo suponiendo que las especies objetivo de peces se encuentran, en mayor o menor grado, distribuidas uniformemente en el área cuando se realiza la prospección. Esta suposición no es válida en el caso de *N. rossii*, especie que no se encuentra distribuida al azar, sino de tal manera que una gran proporción de la población tiende a formar agrupaciones en áreas pequeñas, dejando la mayor parte del área de la prospección escasamente poblada. A fin de proporcionar estimaciones más exactas de la abundancia de las especies, se sugiere que un enfoque más promisorio para la estimación de la biomasa de *N. rossii* sería la realización de una prospección acústica en combinación con varios lances para la identificación.

Keywords: biomass estimation, method choice, multi-species surveys, trawl and acoustic surveys, *Notothenia rossii*, Atlantic Ocean sector, CCAMLR

Introduction

The directed fishery for *Notothenia rossii* was prohibited by CCAMLR in 1985. No exploitation on a commercial scale has occurred since then. From 1985 onwards, a large number of surveys have been conducted around Shag Rocks and South Georgia and in the southern Scotia Arc using commercially sized bottom trawls in order to assess the status of stocks (Gabriel, 1987; White, 1988; Anon., 1990; McKenna and Saila, 1988; Balguerías, 1989, 1991; Parkes, 1991; Parkes et al., 1989; Everson, 1997; Everson et al., 1991, 1992, 1994, 2000, 2002; Jones et al., 1998, 2000, 2001, 2003; Kock, 1991, 1998; Kock et al., 2002). These surveys did not target a single species specifically but aimed at estimating stock size and monitoring the recovery of all exploited stocks in a subarea or division simultaneously. To estimate the biomass of a range of species with similar precision, one has to assume that the species are more or less evenly distributed over the area. The higher the coefficients of variation (CVs) of the abundance estimates are, the less useful these abundance estimates appear in detecting trends in abundance.

Despite the closure of the fishery almost 20 years ago, none of these multi-species surveys has indicated a substantial recovery of *N. rossii*, either at South Georgia or off Elephant Island. Catches of the species have been small (<50 kg/30 min) with the exception of one or two hauls yielding 500–1 000 kg/30 min or more (Balguerías, 1989; Everson, 1997; Everson et al., 1991, 1992, 1994, 2000, 2002; Jones et al., 1998, 2001, 2003; Kock, 1991, 1998; Kock et al., 2002). Consequently, biomass estimates obtained for *N. rossii* have in general been low. Due to one or two large catches, 95% CVs often exceeded 100% which suggested that the reliability of the estimates was low (e.g. Kock, 1998, Table 4).

In this paper it is argued that the patchy distribution of *N. rossii* has prevented conventional multi-species bottom trawl surveys conducted in the past from providing valid estimates of its biomass. Suggestions are provided concerning how future surveys and analyses might be structured in order to overcome these difficulties.

Material and methods

This analysis focuses on catch data from scientific surveys conducted around South Georgia (Figure 1) in 1985 (Kock, 1986), 1991 (Everson et al., 1991), 1992 (Everson et al., 1992), 1994 (Everson et al., 1994), 1997 (Everson, 1997), 2000 (Everson et al., 2000) and 2002 (Everson et al., 2002), around Elephant Island (Figure 1) which was surveyed in 1981, 1983, 1985, 1986, 1987 and 1996 (Kock, 1991, 1998) and Elephant Island and the lower South Shetland Islands in 1998 and 2001–2003 (Jones et al., 1998, 2001, 2003; Kock et al., 2002). These surveys were conducted individually by the UK, Germany and the USA until the mid-1980s and thereafter in close international collaboration within the framework of CCAMLR. The surveys were stratified according to depth only, i.e. more hauls were placed in the 100–400 m depth stratum where most of the fish biomass was located.

All vessels used commercially sized two-panel (Germany, UK) (Parkes, 1991; Kock and Jones, 2004) or four-panel bottom trawls (USA) (Watters et al., 1997) with a mouth opening of 18–22 m between the tips of the wings and a net height of 3–4 m in two-panel nets and 7–9 m in four-panel nets. Surveys were based on a stratified random survey design. Trawling time was, with few exceptions, 30 min (period during which the net was on the bottom). Hauls of less than 20 min duration were disregarded. All survey data are held in the CCAMLR database.

For comparative purposes, catch data from semi-commercial fishing activities of the two German trawlers *Weser* and *Julius Fock*, conducted in the course of the Antarctic Expeditions in 1975/76 and 1977/78 around South Georgia and Elephant Island (Kock, 1978, 1979), were used. Both vessels left the survey track and targeted fish concentrations whenever these were detected. Trawls of dimensions similar to those used by the research vessels were used. Trawling times were between 10 and >120 min on the bottom. All catches were scaled down to 30 min in order to make them directly comparable to the research vessel catches. Catch information from the two trawlers was the only commercial data which were available to the authors from the fishery on *N. rossii*.

Results

South Georgia

N. rossii were found in low abundance, rarely exceeding 50 kg/30 min over most of the South Georgia shelf as exemplified in results from the survey of FRV *Walther Herwig* around South Georgia in 1985 (Figure 2a). Similar patterns of abundance were found during scientific surveys conducted in 1991, 1992, 1994, 1997, 2000 and 2002 (Everson, 1997; Everson et al., 1991, 1992, 1994, 2000, 2002). Fish caught were 35 to 78 cm long. Smaller fish (35–43 cm) were primarily caught closer inshore, for example the extension of Cumberland Bay onto the shelf.

Much larger concentrations of fish have been observed regularly in rather limited areas. Catches exceeding 500 kg/30 min were taken in a horseshoe-shaped underwater canyon about 10 n miles southeast of Cooper Island (SE South Georgia) at 220–335 m depth in 1975/76 and again in 1977/78 (Figures 2b and 2c). This concentration was found to be fairly stable over time. It was also detected in 1985 (Figure 2a), 1987, 1989, 1990, 1991, 1992 and 1994 (Gabriel, 1987; McKenna and Saila, 1988; Parkes et al., 1989; Anon., 1990; Everson et al., 1991, 1992, 1994). In 1997 and 2002 large catches (>1 000 kg/30 min) were taken over the shelf to the east-northeast of South Georgia in the offshore extension of Cumberland Bay onto the shelf. Underwater topography at this location resembles that found close to Cooper Island where large catches had been reported previously.

Elephant Island

Distribution and abundance patterns similar to those observed at South Georgia were also seen on the Elephant Island shelf (Jones et al., 1998, 2001, 2003; Kock, 1986, 1998; Kock et al., 2002). *N. rossii* was widespread over the shelf, albeit again in low numbers: catches hardly yielded more than 50 kg/30 min. Small juvenile fish of less than 30 cm in size were found in shallow coastal waters of less than 120 m in depth. Larger juvenile fish (30–44 cm), however, were found to be more widespread over the shelf than at South Georgia and were regularly taken with sexually mature fish which were recruiting to the adult stock.

Concentrations of fish were found in only two rather limited areas on the shelf. One dense concentration of fish was observed on the north-western part of the shelf at 220–360 m depth in 1975/76 (Figure 3a). This aggregation yielded catches of 1–8 tonnes/30 min (Kock, 1978). The same concentration was detected again in 1977/78 and yielded catches of similar size (Figure 3b) (Kock, 1979). Fish forming this concentration were 34–75 cm long and thus similar in size to those found at South Georgia. However, in contrast to South Georgia, a larger proportion of the smaller fish (34–44 cm) were pre-recruits which were still sexually immature.

A second concentration was found in the course of a random survey at depths of 198–219 m off the north coast of Elephant Island to the east of Seal Rocks in 1985 (Figure 3c). This concentration consisted of fish 34–57 cm long. The bulk of fish was 40–50 cm long and thus mostly contained fish that were recruiting to the adult stock. Larger fish, abundant before commercial exploitation occurred in 1979/80, represented only a very small fraction of the catch. This concentration was not found again in subsequent years (1986–2003), as shown in the distribution of catches of *N. rossii* during the 2002 random survey of RV *Polarstern* around Elephant Island (Figure 3d) and the South Shetland Islands (Figure 4).

Discussion and Conclusions

In contrast to well-established details of the biology and ecology of the species (e.g. Linkowski and Zukowski, 1980; Freytag, 1980; North et al., 1980; Burchett et al., 1983; Burchett, 1983; Barrera-Oro and Casaux, 1992; White et al., 1996; Kock, 1998; Barrera-Oro et al., 2000), information on factors influencing the meso- and micro-scale distribution and abundance of *N. rossii* remains sparse. The limited data available suggests that concentrations of the species formed in the same localities and were stable over a number of years.

At South Georgia, one concentration was observed in the same horseshoe-shaped underwater canyon southeast of Cooper Island over a period of almost 25 years (1975–2000). Another location where aggregations of *N. rossii* appeared over a large number of years was the extension of Cumberland Bay onto the shelf. Large catches were taken there in 1985 (Kock, 1986) and again in 2000 and 2002 (Everson et al., 2000, 2002), with occasional large catches in other years, such as in 1992 (Everson et al., 1992). Other canyon-like bottom topography to the south and southeast of South Georgia yielded catches of *N. rossii* greater than 500 kg/30 min in individual years, such as in 1994 (Everson et al., 1994). These areas may have been fished by commercial trawlers for aggregations of *N. rossii* before commercial exploitation ceased in 1985. They have never been systematically investigated by research vessels with the aim of locating further sites where *N. rossii* tend to aggregate.

The portrayal of underwater canyons as important sites at which aggregations of *N. rossii* may be located was less obvious on the Elephant Island shelf, where few underwater canyons are found. The large concentration of *N. rossii* fished in 1975/76 and 1977/78 by the *Weser* and *Julius Fock* was found to the northwest of the island, in an area sloping gently downwards with no canyon-like structures in the vicinity. According to charts from Russian fishing vessels, this particular area was heavily fished in 1979/80. More than 18 763 tonnes of *N. rossii* were reported as having been taken in that season (CCAMLR, 1990). The annual catch taken in 1979/80 exceeded the biomass estimate of 15 663 tonnes calculated for the 1977/78 season (Kock et al., 1985). It is likely from these figures that the commercial fishery targeted the same concentration located in 1975/76 and removed most of them within the one season. The fact that no fishing for this species was reported thereafter might indicate how severely the stock had been affected by fishing within the one season.

Investigations at Potter Cove (King George Island) since the mid-1980s demonstrated a decline of juvenile fish up to the beginning of the 1990s. These observations were consistent with the dramatic decline of adult fish following heavy fishing in 1979/80. Subsequently, the number of juvenile *N. rossii* remained at a low level, with some slight increases in the second half of the 1990s (Barrera-Oro et al., 2000).

Juvenile *N. rossii* form an important prey item in the diet of the coastal blue-eyed shag (*Phalacrocorax atriceps bransfieldensis*) (Casaux and Barrera-Oro, 1993; Coria et al., 1995; Barrera-Oro and Casaux, 1996; Favero et al., 1998). However, they are rarely found in the diet of other predators, such as Antarctic fur seals (*Arctocephalus gazella*), elephant seals (*Mirounga leonina*) and Weddell seals (*Leptonychotes weddellii*) and birds, such as Cape petrel (*Daption capense*) and South Polar skua (*Catharacta maccormicki*) (Casaux and Barrera-Oro, 1993; Casaux et al., 1997a, 1997b, 1998, 2001; Daneri, 1996; Daneri and Coria, 1993; Barrera-Oro and Casaux, 1996; Montalti et al., 1996; Soave et al., 1996; Croll and Tershy, 1998; Goebel et al., 1998, 2003; Daneri and Carlini, 2001). From these investigations it may be tentatively concluded that predation is unlikely to play a major role and may explain the continuous low level of abundance of *N. rossii* in the absence of fishing impacting on adult fish.

The reasons why *N. rossii* forms large aggregations in certain areas of the shelf were unclear. The species was found to aggregate in submarine canyons around South Georgia. Catches obtained from these canyons were in the order of 5 000 kg/30 min and more in individual hauls (Kock, 1978, 1979). Catches very close to the canyons only yielded a few individuals. The large concentration observed to the northwest of Elephant Island formed on a gentle slope with no obvious geomorphological structures. However, it was an area through which dense aggregations of krill, the staple food of *N. rossii* at Elephant Island (Freytag, 1980), were regularly passing (Siegel et al., 2002).

The information available leaves no doubt that stocks of *N. rossii* had been heavily depleted due to fishing in the 1970s. Any direct exploitation of the species was prohibited in 1985. Stocks should have recovered to some extent since then. However, results from conventional bottom trawl surveys failed to support this notion, particularly in the Elephant Island region. The only concentration of *N. rossii* which was found off the north coast of Elephant Island to the east of Seal Rocks in February 1985, when fishing was no longer in its heyday, consisted of an aggregation of fish recruiting to the adult stock. All subsequent surveys failed to find this aggregation and caught only small numbers of adult fish (usually <50–100 kg/30 min) (Kock, 1986, 1988, 1998; Jones et al., 1998, 2001, 2003; Kock et al., 2002).

Fish biomass within a CCAMLR subarea or part of a subarea is commonly estimated by surveys that target a number of species simultaneously, including *N. rossii*. However, in comparison with more evenly distributed species, such as *Gobionotothen gibberifrons* and *Chaenocephalus aceratus*, *N. rossii* shows a highly skewed spatial distribution of abundance: hauls with large catches tend to occur in small areas that are consistent between years while hauls taken over the remaining area of distribution contain few fish. Skewed distributions of catches lead to highly stochastic estimates with large confidence intervals, and can undermine the normal distribution of estimates, assumed as the Central Limit Theorem, even when large sampling effort was applied (Jones et al., 1995). The authors conclude that it was for this reason that CCAMLR was unable to provide adequate biomass estimates for *N. rossii* and follow the potential recovery of the stocks properly in the almost 20 years since the fishery was closed.

Two alternatives to the approach generally used by CCAMLR in order to better estimate the abundance of *N. rossii* are offered.

The comparatively low biomass estimates for *N. rossii* obtained from surveys of a number of demersal fish species between 1985 and 2003 were often associated with high CVs. Maximum likelihood methods based on empirically observed distributions may provide biomass estimates with smaller confidence intervals, as an alternative to the method commonly used by CCAMLR to calculate mean biomass and corresponding confidence intervals (Pennington, 1983).

Attempts to detect *N. rossii* by means of acoustic surveys date back to the 1970s when acoustic surveys and their design were still in their infancy. The species provided good marks on the echo sounder used during the Antarctic Expedition of Germany in 1975/76 (Freytag, 1978). Given the high density of the species in certain small areas it was unlikely that these marks were confused with other species to a large extent. Since then, no new attempts have been found in published material which would give rise to the opinion that an acoustic survey of *N. rossii* might be feasible.

In order to provide more accurate biomass estimates of the species in future, the authors suggest investigations to assess whether the biomass of *N. rossii* may be estimated more accurately by:

- stratifying on the basis of areas of consistent high density;
- increasing the sampling effort that can be applied by acoustic methods as indicated by preliminary Russian investigations conducted in the late 1970s. These methods need to be combined with an adequate number of identification hauls.

Acknowledgement

The authors are very much indebted to Ms Susanne Schöling for the preparation of the graphs.

References

Anon. 1990. Report of a Joint UK/USSR Workshop, 23 to 27 July 1990. Analysis of results from demersal fish surveys at South Georgia, undertaken by the UK and USSR, January and February 1990. Document *WG-FSA-90/13*. CCAMLR, Hobart, Australia.

Balguerías, E. 1989. Informe de resultados 'Antártida 8611', Biología pesquera. In: *Resultados de la Campaña 'Antártida 8611'. Publ. Espec., Insti. Esp. Oceanogr.*, 2: 267–483.

Balguerías, E. 1991. Informe de la campaña española de evaluación de los stocks de peces de Orcadas del Sur (Antártida 9101). Document *WG-FSA-91/33*. CCAMLR, Hobart, Australia: 30 pp.

Barrera-Oro, E.R. and R.J. Casaux. 1992. Age determination of juvenile *Notothenia rossii* from Potter Cove, South Shetland Islands. *Ant. Sci.,* 4 (2): 131–136.

Barrera-Oro, E.R. and R.J. Casaux. 1996. Fish as diet of the blue-eyed shag, *Phalacrocorax atriceps bransfieldensis*, at Half-moon Island, South Shetland Islands. *Cybium*, 20 (1): 37–45.

Barrera-Oro, E.R., E.R. Marschoff and R.J. Casaux. 2000. Trends in relative abundance in fjord *Notothenia rossii*, *Gobionotothen gibberifrons* and *Notothenia coriiceps* at Potter Cove, South Shetland Islands, after commercial fishing in the area. *CCAMLR Science*, 7: 43–52.

Burchett, M.S. 1983. Age and growth of the Antarctic fish *Notothenia rossii* from South Georgia. *Br. Antarct. Surv. Bull.*, 60: 45–61.

Burchett, M.S., P.J. Sayers, A.W. North and M.G. White. 1983. Some biological aspects of the nearshore fish populations at South Georgia. *Br. Antarct. Surv. Bull.*, 59: 63–74.

Casaux, R.J. and E.R. Barrera-Oro. 1993. The diet of the blue-eyed shag, *Phalacrocorax atriceps bransfieldensis* feeding in the Bransfield Strait. *Ant. Sci.*, 5 (4): 335–338.

Casaux, R., A. Baroni and A. Carlini. 1997a. The diet of the Weddell Seal *Leptonychotes weddelli* at Harmony Point, South Shetland Islands. *Polar Biol.*, 18 (6): 371–375.

Casaux, R.J., M. Favero, N. Coria and P. Silva. 1997b. Diet of the imperial cormorant, *Phalacrocorax atriceps*: comparison of pellets and stomach contents. *Mar. Orn.*, 25: 1–4.

Casaux, R., A. Baroni and A. Carlini. 1998. The diet of the Antarctic fur seal *Arctocephalus gazella* at Harmony Point, Nelson Island, South Shetland Islands. *Polar Biol.*, 20 (6): 424–428.

Casaux, R., M. Favero, P. Silva and A. Baroni. 2001. Sex differences in diving depths and diet of Antarctic shags at the South Shetland Islands. *J. Field Ornith.*, 72 (1): 22–29.

CCAMLR. 1990. *Statistical Bulletin*, Vol. 2 (1980–1989). CCAMLR, Hobart, Australia.

Coria, N., R. Casaux, M. Favero and P. Silva. 1995. Analysis of the stomach content of the blue-eyed shag *Phalacrocorax atriceps bransfieldensis* at Nelson Island, South Shetland Islands. *Polar Biol.*, 15: 349–352.

Croll, D.A. and B.R. Tershy. 1998. Penguins, fur seals and fishing: prey requirements and potential competition in the South Shetland Islands, Antarctica. *Polar Biol.*, 19 (6): 365–374.

Daneri, G.A. 1996. Fish diet of the Antarctic fur seal, *Arctocephalus gazella*, in summer, at Stranger Point, King George Island, South Shetland Islands. *Polar Biol.*, 16 (5): 353–355.

Daneri, G.A. and N.R. Coria. 1993. Fish prey of Antarctic fur seals, *Arctocephalus gazella*, during the summer–autumn period at Laurie Island, South Orkney Islands. *Polar Biol.*, 13 (5): 287–289.

Daneri, G.A. and A.R. Carlini. 2001. Predation on fish by the southern elephant seal, *Mirounga leonina*, at King George Island, South Shetland Islands, as reflected by stomach lavage. Document *WG-EMM-01/58*. CCAMLR, Hobart, Australia: 6 pp.

Everson, I. 1997. Preliminary reports of UK fish survey: Subarea 48.3. Document *WG-FSA-97/39*. CCAMLR, Hobart, Australia: 6 pp.

Everson, I., G. Parkes, K.-H. Kock, S. Campbell, Z. Cielniaszek and J. Szlakowski. 1991. Fish stock assessment survey in Subarea 48.3. In: *Selected Scientific Papers, 1991 (SC-CAMLR-SSP/8)*. CCAMLR, Hobart, Australia: 25–67.

Everson, I., G. Parkes, S. Campbell, K.-H. Kock, J. Szlakowski, D. Cielniaszek, C. Goss and S. Wilhelms. 1992. Fish stock assessment survey in Subarea 48.3. Document *WG-FSA-92/17*. CCAMLR, Hobart, Australia: 40 pp.

Everson, I., G. Parkes, K.-H. Kock, C. Goss, D. Cielniaszek, J. Szlakowski, H. Daly, L. Allcock and G. Pilling. 1994. Fish stock assessment survey in Subarea 48.3. Document *WG-FSA-94/18*. CCAMLR, Hobart, Australia: 34 pp.

Everson, I., D. Agnew, P. Bagley, M. Collins, T. Daw, R. Forster, T. Marlow, A. North, J. Szlakowski, E. van Wijk, S. Wilhelms and C. Yau. 2000.

UK groundfish survey in Subarea 48.3 (South Georgia and Shag Rocks) January 2000. Document *WG-FSA-00/21.* CCAMLR, Hobart, Australia.

Everson, I., T. Marlow, M. Belchier, R. Forster, S. Morley, A.W. North, J. Szlakowski and S. Wilhelms. 2002. Fish stock assessment survey in Subarea 48.3. Document *WG-FSA-02/34*. CCAMLR, Hobart, Australia: 6 pp.

Favero, F., R.J. Casaux, P. Silva, E.R. Barrera–Oro and N. Coria. 1998. The diet of the Antarctic shag during summer at Nelson Island, Antarctica. *Condor*, 100: 112–118.

Freytag, G. 1978. Lottechnische Untersuchungen. In: Hempel, G., D. Sahrhage, W. Schreiber and R. Steinberg (Eds). *Antarktis-Expedition 1977/78 der Bundesrepublik Deutschland*. *Arch. FischWiss.*, 29 (1): 58–64.

Freytag, G. 1980. Length, age and growth of *Notothenia rossii marmorata* Fischer 1885 in the west Antarctic waters. *Arch. FischWiss.*, 30 (1): 39–68.

Gabriel, W.L. 1987. Results of fish stock assessment survey, South Georgia region, November–December 1986. In: *Selected Scientific Papers, 1987 (SC-CAMLR-SSP/4)*. CCAMLR, Hobart, Australia: 143–183.

Goebel, M.E., J.T. Sterling, D.P. Costa, W.T. Cobb, P.H. Thorson, T. Carten, W.Z. Trivelpiece and R.S. Holt. 1998. Pinniped research at Cape Shirreff, Livingston Island, Antarctica, 1997/98. In: Martin, J. (Ed.). *US AMLR 1997/98 Field Season Report*. NOAA/NMFS Administrative Report LJ-98-07: 131–139.

Goebel, M.E., J.J. Lyons, B.W. Parker, J.D. Lipsky and A.C. Allen. 2003. Pinniped research at Cape Shirreff, Livingston Island, Antarctica, 2001–2002. In: Lipsky, J.D. (Ed.). *US AMLR 2001/2002 Field Season Report*. NOAA-TM-NMFS-SWFSC-350: 113–133.

Jones, C.M., D.S. Robson, H.D. Lakkis and J. Kressel. 1995. Properties of catch rates used in analysis of angler surveys. *Trans. Am. Fish. Soc.*, 124 (6): 911–928.

Jones, C. D., K.-H. Kock and S. Wilhelms. 1998. Standing stock biomass of eight species of finfish around Elephant Island and the lower South Shetland Islands (Subarea 48.1) from the 1998 US AMLR bottom trawl survey. Document *WG-FSA-98/17*. CCAMLR, Hobart, Australia: 14 pp.

Jones, C. D., K.-H. Kock and E. Balguerías. 2000. Changes in biomass of eight species of finfish around the South Orkney Islands (Subarea 48.2) from three bottom trawl surveys. *CCAMLR Science*, 7: 53–74.

Jones, C.D., K.-H. Kock, D. Ramm, J. Ashford, S. Wilhelms, T. Near, N. Gong and H. Flores. 2001. Results and standing stock biomass estimates of finfish from the 2001 US AMLR bottom trawl survey of the South Shetland Islands (Subarea 48.1). Document *WG-FSA-01/33 Rev. 1*. CCAMLR, Hobart, Australia.

Jones, C.D., K.-H. Kock, J. Ashford, A.L. DeVries, K. Dietrich, S. Hanchet, T. Near, T. Turk and S. Wilhelms. 2003. Standing stock, biology, diet and spatial distribution of demersal finfish from the 2003 US AMLR bottom trawl survey of the South Shetland Islands (Subarea 48.1). Document *WG-FSA-03/38*. CCAMLR, Hobart, Australia: 40 pp.

Kock, K.-H. 1978. Fischereibiologische Untersuchungen. In: Sahrhage, D., W. Schreiber, R. Steinberg, G. Hempel (Eds). *Antarktis-Expedition 1975/76 der Bundesrepublik Deutschland*. *Arch. FischWiss.*, 29 (1): 41–57.

Kock, K.-H. 1979. Fischereibiologische Untersuchungen an Fischen. In: Hempel, G., D. Sahrhage, W. Schreiber, R. Steinberg (Eds). *Antarktis-Expedition 1977/78 der Bundesrepublik Deutschland*. *Arch. FischWiss.*, 30 (1): 71–84.

Kock, K.-H. 1986. The state of exploited Antarctic fish stocks in the Scotia Sea region during SIBEX (1983–1985). *Arch. FischWiss.*, 37 (1): 129–186.

Kock, K.-H. 1988. Preliminary results of a bottom trawl survey around Elephant Island in October and December 1987. In: *Selected Scientific Papers, 1988 (SC-CAMLR-SSP/5)*, Part II. CCAMLR, Hobart, Australia: 185–200.

Kock, K.-H. 1991. The state of exploited fish stocks in the Southern Ocean – a review. *Arch. FischWiss.*, 41 (1): 1–66.

Kock, K.-H. 1998. Changes in the fish biomass around Elephant Island (Subarea 48.1) from 1976 to 1996. *CCAMLR Science*, 5: 165–189.

Kock, K.-H. and C.D. Jones. 2004. Fish stocks in the southern Scotia Arc region – a review and prospects for future research. *Rev. Fish Res*. (in press).

Kock, K.-H., G. Duhamel and J.-C. Hureau. 1985. Biology and status of exploited Antarctic fish stocks: a review. *BIOMASS Sci. Ser.*, 6: 1–143.

Kock, K.-H., C.D. Jones, J. Appel, G. von Bertouch, D.F. Doolittle, M. la Mesa, L. Pshenichnov, R. Riehl, T. Romeo, S. Schöling and L. Zane. 2002. Standing stock estimates of finfish biomass from the 2002 *Polarstern* bottom trawl survey around Elephant Island and the South Shetland Islands (Subarea 48.1) with some notes on the composition of catches taken north of Joinville Island–D'Urville Island. Document *WG-FSA-02/24*. CCAMLR, Hobart, Australia: 42 pp.

Linkowski, T. and C. Zukowski. 1980. Observations on the growth of *Notothenia neglecta* Nybelin and *Notothenia rossii marmorata* Fischer in Admiralty Bay (King George Island, South Shetland Islands). *Pol. Polar Res.,* 1 (2–3): 155–162.

McKenna, J.E. Jr. and S.B. Saila. 1988. Results of fish stock assessment survey, South Georgia, December 1987–January 1988. In: *Selected Scientific Papers, 1988 (SC-CAMLR-SSP/5)*, Part II. CCAMLR, Hobart, Australia: 19–52.

Montalti, D., R. Casaux, N. Coria and G. Soave. 1996. The importance of fish in the diet of the South Polar skua *Catharacta maccormicki* at the South Shetland Islands, Antarctica. Document *WG-EMM-96/32*. CCAMLR, Hobart, Australia: 7 pp.

North, A.W., M.G. White and M.S. Burchett. 1980. Age determination of Antarctic fish. *Cybium*, 1980 (8): 7–11.

Parkes, G.B. 1991. The UK fish stock assessment survey bottom trawl for South Georgia. Document *WG-FSA-91/16*. CCAMLR, Hobart, Australia: 19 pp.

Parkes, G.B., I. Everson, J. Sosinski, Z. Cielniaszek and J. Szlakowski. 1989. Report of the Joint UK/Polish fish stock assessment survey around South Georgia, February 1989. Document *WG-FSA-89/6*. CCAMLR, Hobart, Australia: 34 pp.

Pennington, M. 1983. Efficient estimators of abundance for fish and plankton surveys. *Biometrics*, 39: 281–286.

Siegel, V., B. Bergström, U. Mühlenhardt–Siegel and M. Thomasson. 2002. Demography of krill in the Elephant Island area during summer 2001 and its significance for stock recruitment. *Ant. Sci*., 14: 162–170.

Soave, G.E., N. Coria, P. Silva, D. Montalti and M. Favero. 1996. Diet of Cape petrel *Daption capense* during the chick-rearing period at Fildes Peninsula and Harmony Point, South Shetland Islands, Antarctica. Document *WG-EMM-96/17*. CCAMLR, Hobart, Australia: 14 pp.

Watters, G., A. Hobday, D. Demer, J. Popp, V. Loeb, K. Puglise, J. Sterling, R. Holt, D. Marks and W. Cobb. 1997. In: Martin, J. (Ed.). *1996/97 US AMLR Field Season Report*. NOAA/NMFS Administrative Report LJ-97-09.

White, M.G. 1988. MT *Lord Shackleton* Antarctic voyage to South Georgia, 8 to 24 January 1988. Document *WG-FSA-88/13*. CCAMLR, Hobart, Australia.

White, M.G., R.R. Veit, A.W. North and K. Robinson. 1996. Egg-shell morphology of the Antarctic fish, *Notothenia rossii* Richardson, and the distribution and abundance of pelagic eggs at South Georgia. *Ant. Sci.*, 8 (3): 267–271.

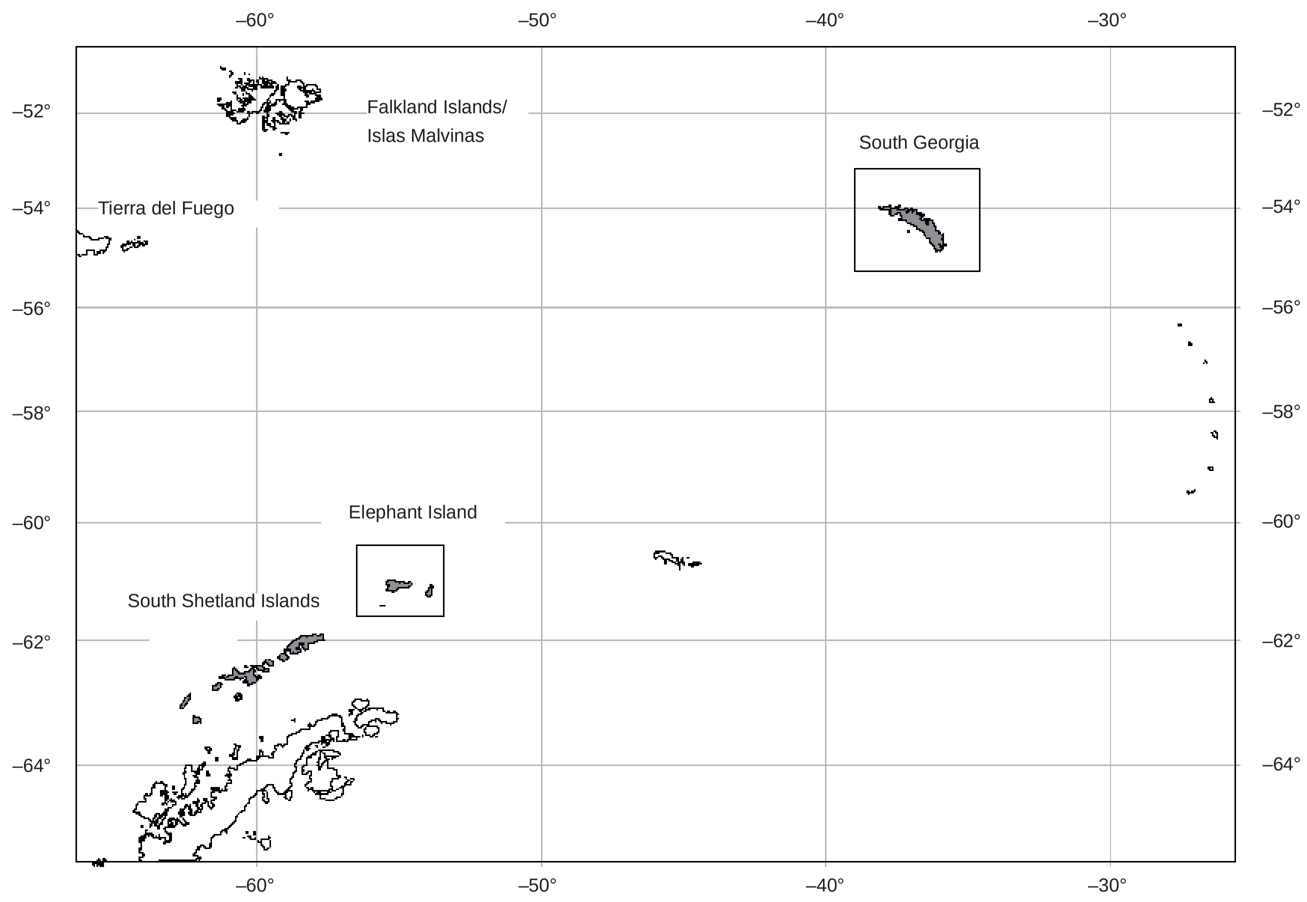

Figure 1: The western part of the Atlantic Ocean sector.

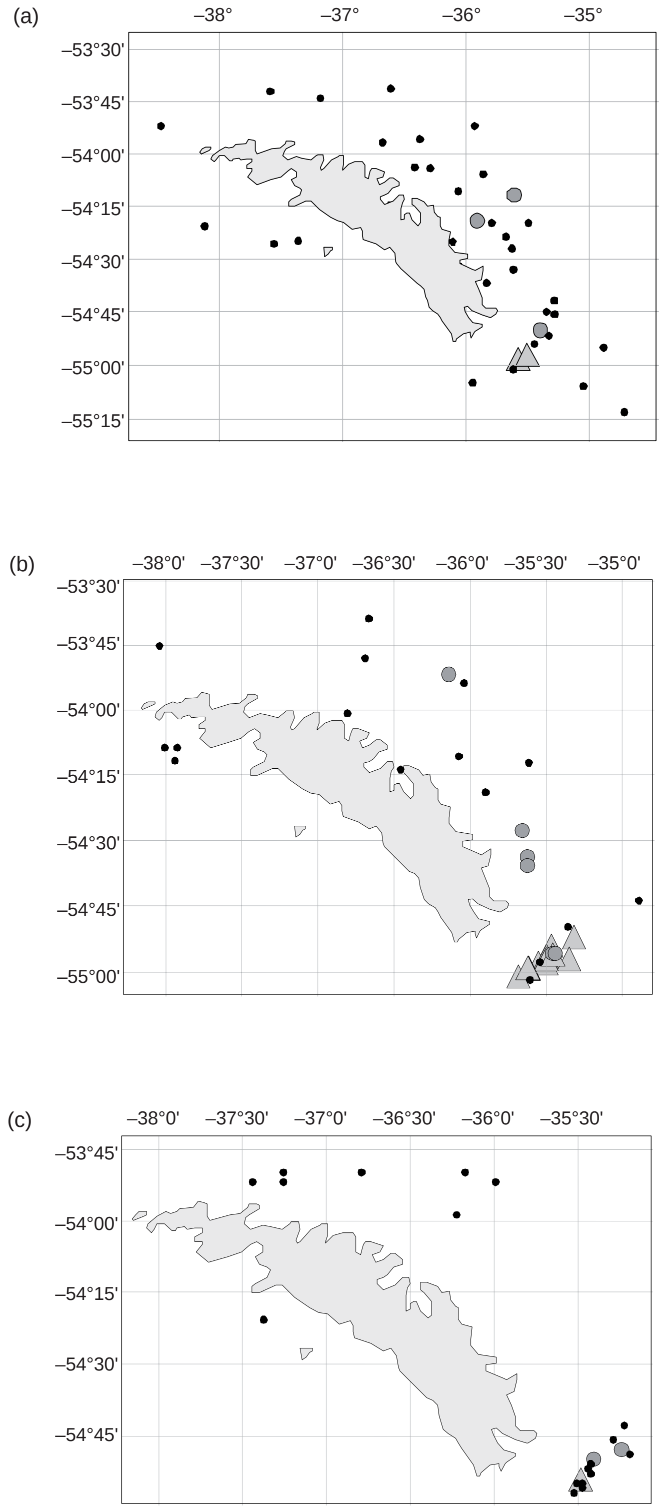

Figure 2: Catches (kg/30 min) of *Notothenia rossii* at South Georgia by: (a) *Walther Herwig*, February 1985; (b) *Weser*, January–April 1976; (c) *Julius Fock*, November 1977–March 1978. ● <100 kg, ● <500 kg and △ >500 kg.

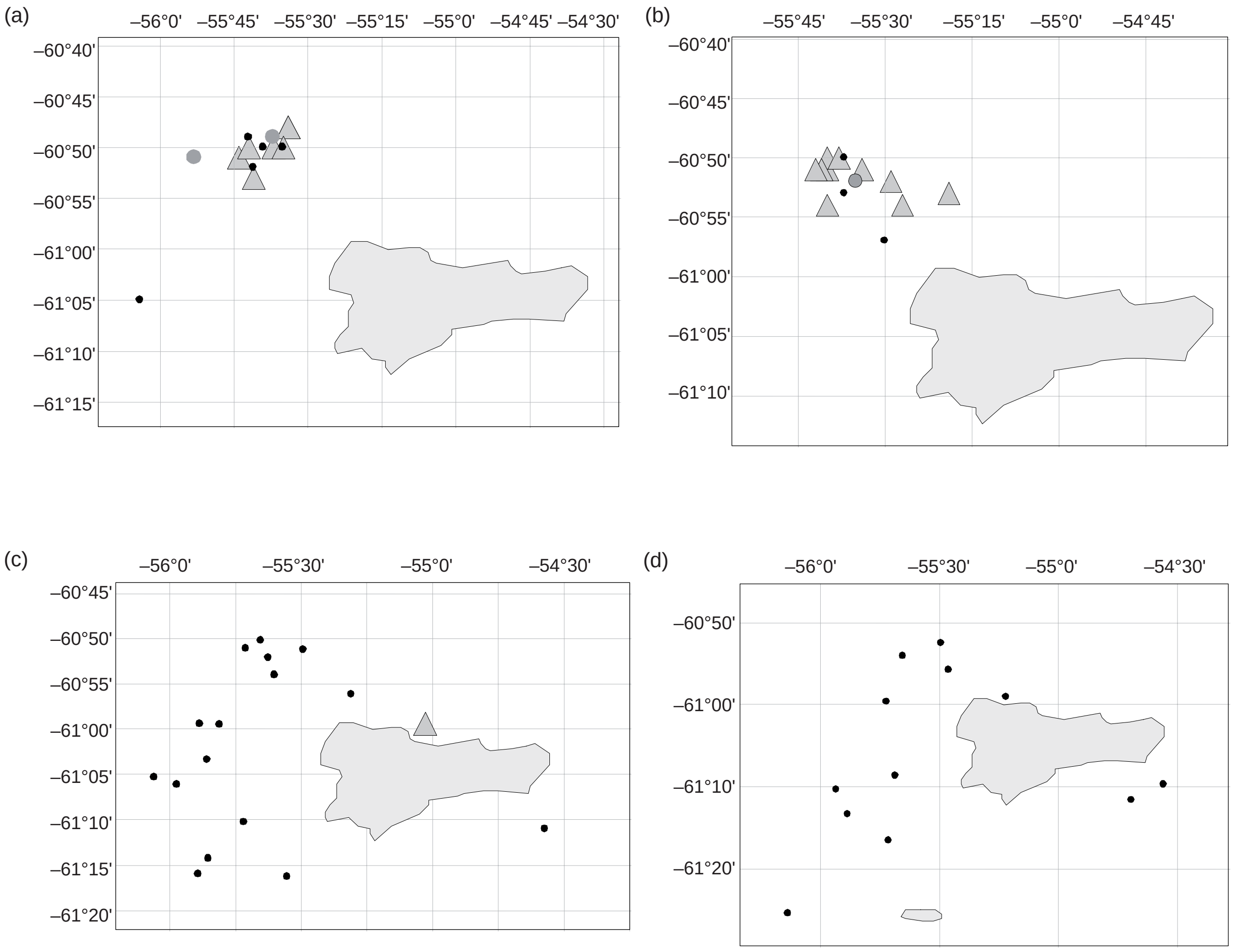

Figure 3: Catches (kg/30 min) of *Notothenia rossii* at Elephant Island by: (a) *Weser*, January–April 1976; (b) *Julius Fock*, November 1977–March 1978; (c) *Walther Herwig*, March 1985; (d) *Polarstern*, January–February 2002. • <100 kg, ● <500 kg and △ >500 kg.

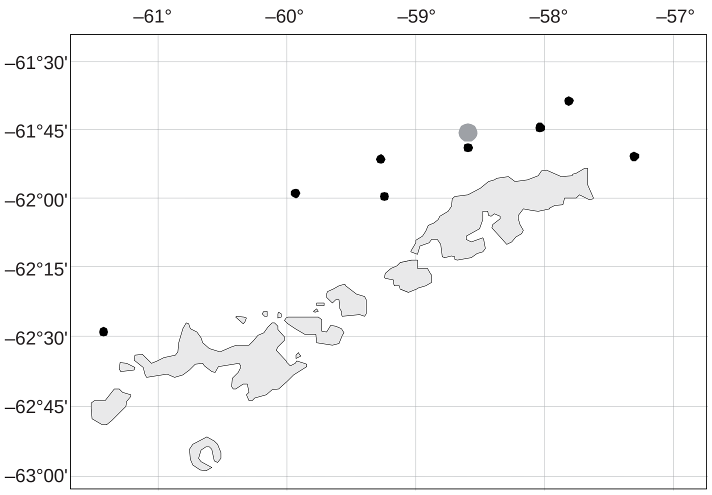

Figure 4: Catches (kg/30 min) of *Notothenia rossii* at the South Shetland Islands by *Polarstern*, February 2002. ● <100 kg, ○ <500 kg and △ >500 kg.

Liste des figures

Figure 1: Ouest du secteur de l'océan Atlantique

Figure 2: Captures (kg/30 min) de *Notothenia rossii* en Géorgie du Sud par : a) le *Walther Herwig*, février 1985; b) *Weser*, janvier–avril 1976; c) *Julius Fock*, novembre 1977–mars 1978. ● <100 kg, ○ <500 kg et △ >500 kg.

Figure 3: Captures (kg/30 min) de *Notothenia rossii* à l'île Eléphant par a) le *Weser*, janvier–avril 1976; b) le *Julius Fock*, novembre 1977–mars 1978; c) le *Walther Herwig*, mars 1985; d) le *Polarstern*, janvier–février 2002. ● <100 kg, ○ <500 kg et △ >500 kg.

Figure 4: Captures (kg/30 min) de *Notothenia rossii* aux îles Shetland du Sud par le *Polarstern*, février 2002. ● <100 kg, ○ <500 kg et △ >500 kg.

Список рисунков

Рис. 1: Западная часть атлантического сектора.

Рис. 2: Уловы (кг/30 мин.) *Notothenia rossii* у Южной Георгии, полученные судами: (a) *Walther Herwig*, февраль 1985 г.; (b) *Weser*, январь–апрель 1976 г.; (c) *Julius Fock*, ноябрь 1977 г.–март 1978 г. ● <100 кг, ○ <500 кг и △ >500 кг.

Рис. 3: Уловы (кг/30 мин.) *Notothenia rossii* у о-ва Элефант, полученные судами: (a) *Weser*, январь–апрель 1976 г.; (b) *Julius Fock*, ноябрь 1977 г.–март 1978 г.; (c) *Walther Herwig*, март 1985 г.; (d) *Polarstern*, январь–февраль 2002 г. ● <100 кг, ○ <500 кг и △ >500 кг.

Рис. 4: Уловы (кг/30 мин.) *Notothenia rossii* у Южных Шетландских о-вов, полученные судном *Polarstern*, февраль 2002 г. ● <100 кг, ○ <500 кг и △ >500 кг.

Lista de las figuras

Figura 1: Parte occidental del sector del Océano Atlántico.

Figura 2: Capturas (kg/30 min) de *Notothenia rossii* extraídas en Georgia del Sur por los barcos: (a) *Walther Herwig*, febrero de 1985; (b) *Weser*, enero–abril de 1976; (c) *Julius Fock*, noviembre de 1977–marzo de 1978. ● <100 kg, ○ <500 kg y △ >500 kg.

Figura 3: Capturas (kg/30 min) de *Notothenia rossii* extraídas en isla Elefante por los barcos: (a) *Weser*, enero–abril de 1976; (b) *Julius Fock*, noviembre de 1977–marzo de 1978; (c) *Walther Herwig*, marzo de 1985; (d) *Polarstern*, enero–febrero de 2002. ● <100 kg, ● <500 kg and △ >500 kg.

Figura 4: Capturas (kg/30 min) de *Notothenia rossii* extraídas en las islas Shetland del Sur por el *Polarstern*, febrero de 2002. ● <100 kg, ● <500 kg and △ >500 kg.