APPENDIX D

REPORT OF THE WORKSHOP ON APPROACHES TO THE MANAGEMENT OF ICEFISH

(Hobart, Australia, 3 to 5 October 2001)

CONTENTS

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INTRODUCTION

1.1 The Workshop on Approaches to the Management of Icefish (WAMI) was held at CCAMLR Headquarters, Hobart, Australia, from 3 to 5 October 2001. The Co-conveners of the workshop, Drs K.-H. Kock (Germany) and G. Parkes (UK), chaired the meeting. A List of Participants is included in this report as Attachment A.

1.2 The report was prepared by Dr A. Constable (Australia), Dr D. Ramm (Secretariat), Dr S. Hanchet (New Zealand), Mr C. Jones (USA), Dr Kock, Dr Parkes, Dr K. Sullivan (New Zealand) and Ms E. van Wijk (Australia).

1.3 Terms of reference had been developed by WG-FSA over the period from 1997 to 2000. A composite list was compiled by the Co-conveners to serve as guidelines for the discussion. These are provided as Attachment B.

1.4 A Provisional Agenda was circulated in advance of the workshop. The following subitems were added:

- Subitem 4.1.5 ‘Minimum mesh size and fish size’; and
- Subitem 6.5 ‘Effects of fishing gear’.

With these amendments, the Agenda was adopted. The Agenda is given as Attachment C.

PRESENTATION OF PAPERS

2.1 Sixteen papers were presented at the meeting, 10 of which were available on the CCAMLR website in advance of the workshop. These papers were presented and discussed under the appropriate agenda items. A list of papers is provided as Attachment D. In addition, workshop participants compiled a bibliography on *Champsocephalus gunnari* (mackerel icefish) (Attachment E).

REVIEW AND CHARACTERISATION OF FISHERIES

3.1 Annual catches of *C. gunnari* in the CCAMLR Convention Area, as reported in STATLANT data, were presented in WAMI-01/15 Rev.1, and are summarised in Table 1. These data include catches of *C. gunnari* taken during surveys, or as by-catch in other fisheries. Fishing effort is reported in various formats in the STATLANT data (e.g. fishing hours, vessel.days), and it was not possible to obtain a consistent time series for fisheries targeting *C. gunnari*. However, the workshop noted that a time series of CPUE could be derived from fine-scale catch and effort data; the fine-scale data are a subset of the STATLANT data.

3.2 Records of fishing for *C. gunnari* in Area 48 are available dating back to the split-year 1970/71. Catches have been reported in Subarea 48.1 from 1978/79 to 1988/89, Subarea 48.2 from 1977/78 to 1990/91 and Subarea 48.3 from 1970/71 to the present. *C. gunnari* was fished extensively during the late 1970s and in the 1980s. Annual catches of *C. gunnari* peaked at 35 930 tonnes in Subarea 48.1 in 1978/79 (the first year of reported fishing in that subarea), 138 895 tonnes in Subarea 48.2 in 1977/78 (the first year of reported fishing in that subarea), and 128 194 tonnes in Subarea 48.3 in 1982/83.

3.3 Records of fishing for *C. gunnari* in Area 58 are available dating back to the 1969/70 split-year. Catches have been reported in Division 58.5.1 from 1969/70 to 1996/97 and in Division 58.5.2 from 1971/72 to the present. Catches of *C. gunnari* reported from Subarea 58.5 between 1979/80 and 1987/88 (Table 1) are believed to have been taken in Division 58.5.1. Australia declared a 200 n mile Fishing Zone (AFZ) in Division 58.5.2 in 1979. There were no reports of commercial fishing for *C. gunnari* from that area until the start of the Australian fishery in 1996/97. Annual catches of *C. gunnari* peaked at 35 568 tonnes in Division 58.5.1 in 1971/72 and 16 166 tonnes in Division 58.5.2 in 1977/78.

3.4 The recent history of the fishery for *C. gunnari* in Division 58.5.2 was described in WAMI-01/4.

3.5 Trawl fisheries for *C. gunnari* in the 2000/01 season have been conducted in Subarea 48.3 (Conservation Measure 194/XIX) and Division 58.5.2 (Conservation Measure 195/XIX). The current catch limit in Subarea 48.3 is 6 760 tonnes, and a total of 1 427 tonnes of *C. gunnari* has been reported to date. Five trawlers have fished (France 1, Chile 1, UK 2, Russia 1), and the fishery will remain open until 30 November 2001, or until the catch limit is reached, whichever is sooner. The current catch limit in Division 58.5.2 is 1 150 tonnes, and a total of 938 tonnes of *C. gunnari* has been reported to date. Two Australian-flagged trawlers have fished, and the fishery will remain open until 30 November 2001, or until the catch limit is reached, whichever is sooner.

3.6 The information available at the workshop indicated that fisheries for *C. gunnari* in Subarea 48.3 and Divisions 58.5.1 and 58.5.2 share many characteristics. These fisheries may be characterised by:

- large fluctuations in catch;
- periods of low or zero commercial catches;
- a recent resurgence in interest in the fishery in the mid- to late 1990s with modest levels of fishing effort and catches in Subarea 48.3 and Division 58.5.2;
- reliance of the commercial fishery on a few age classes – mainly ages 3 and 4; and
- age 5+ fish are poorly represented in survey and commercial catches, suggesting an age-specific increase in natural mortality (M).

3.7 Dr Ramm presented a draft Fishery Plan for the *C. gunnari* fishery in Subarea 48.3 that had been prepared at the request of the Scientific Committee. The plan was reviewed by the workshop. It was proposed that the data reporting requirements be formalised into a ‘Data Collection Plan’ and that the meaning of this term, originally defined for exploratory fisheries, be generalised for all fisheries under the revised framework. The revised plan is set out in WAMI-01/15 Rev. 1. The workshop recommended that WG-FSA look at how data collection plans for new and exploratory fisheries be distinguished from data requirements for assessments.

3.8 A time series of catch-weighted length frequencies for *C. gunnari* was presented for Subarea 48.3 and Division 58.5.2 (WAMI-01/15 Rev. 1). These data are the only length data presently available for this species in the CCAMLR database. The time series in Subarea 48.3 and Division 58.5.2 begin in the split-years 1986/87 and 1996/97 respectively. Data for Division 58.5.1 have been presented earlier in Duhamel (1987, 1991).

3.9 The workshop recognised the value of these data, and the need to extend these time series so as to include the periods of high catches from the fisheries during the 1970s and 1980s. It was understood that data from this early period of fishing in Subarea 58.5 were collected and that the raw data are now held by Dr V. Herasymchuk, State Committee for Fisheries of Ukraine. The workshop discussed how these important data may be processed and made available to CCAMLR. This matter was referred to WG-FSA and the Scientific Committee for further consideration.

MANAGEMENT NEEDS

Management Objectives

4.1 The workshop identified that the main objective of the management of *C. gunnari* in the Convention Area was to provide rational and sustainable use of the *C. gunnari* resource with the following three requirements, in accordance with Article II of the Convention:

(i) maintenance of spawning stock at a size that recruitment is not impeded;

(ii) maintenance of the ecological relationships between harvested, dependent and related species; and

(iii) prevention of changes in the ecosystem that are not reversible over 20–30 years.

These objectives have been implemented using measures available to the Commission under Article IX. These measures include catch limits, by-catch limits, closed seasons, closed areas, gear regulations (mesh size limits and a ban on bottom trawling) and minimum fish sizes.

Catch Limits

4.2 Historically, the various *C. gunnari* fisheries were assessed and managed as single-species fisheries. The focus was initially on the use of catch limits to restrict fishing mortality, in order to maintain the spawning stock. Assessments at South Georgia were carried out using VPA approaches, based mainly on catch-at-age data from the commercial fishery, and tuned using surveys and CPUE indices of abundance derived from the fishery.

4.3 During the mid-1990s an equilibrium yield model was developed as an assessment tool for krill (KYM). In 1997 this was generalised into the GYM for finfish species. A key aspect of the model was the explicit use of decision rules within the model itself, which allowed for both the maintenance of the spawning stock above a certain level, as well as specifying escapement levels so that dependent stocks were unlikely to suffer from fisheries. During this period two problems with the existing stock assessments at South Georgia were identified. Firstly, in some years there was a large mismatch between model projections of biomass and estimates of biomass from trawl surveys in the following year. Secondly, there was a growing awareness of the potential ecosystem dynamics between fur seals, icefish and krill which go well beyond single-species approaches.

4.4 In 1997 possible methods for assessing and managing *C. gunnari* were re-examined in the light of the GYM. Because of the high recruitment variability, precautionary catch limits using a constant yield strategy would have been very low. The alternative was to consider estimates of cohort strength from trawl surveys. Under this approach, estimates of cohort biomass from the trawl surveys were considered as absolute, and were projected forward under certain assumptions of growth and M to provide short-term yield estimates. This management approach aims to maximise yield when the abundance is high and minimise risk when abundance is low. This approach does, however, rely on regular surveys so that yields can be regularly updated, particularly in short-lived species, such as *C. gunnari*, in parts of their range.

4.5 The management approach had therefore changed from the management of the population as a whole (with associated biological reference points) to the management of individual cohorts. The second important aspect of the approach was that this yield estimate was still conditional on the maintenance of the spawning biomass and on the escapement of a certain percentage of the population. In line with the management of krill, an escapement level of 75% was used which was deemed appropriate to provide for predators in years when krill was abundant. As for krill, the requirements of this species by predators need to be reviewed as data become available in order to determine the appropriate level of escapement that takes account of ecosystem interactions (paragraph 8.6).

4.6 Management advice on appropriate catch limits since 1997 has been based on this approach for Subarea 48.3 and Division 58.5.2.

Other Management Measures

4.7 In addition to the catch limits, a number of other conservation measures have been introduced over time to deal with various other perceived problems.

4.8 Concern over levels of by-catch of other finfish species in bottom trawls resulted in a ban on bottom trawling for *C. gunnari* in Subarea 48.3 starting in the 1989 season. Similarly, in Subareas 48.1 and 48.2, *C. gunnari* were depleted in the late 1970s, and the fishery continued at a low level. The fishery has been closed since 1990 to avoid the high by-catch of other species (Conservation Measure 27/IX). This closure was meant to allow both *C. gunnari* and other stocks (e.g. *Notothenia rossii* at the South Shetland Islands) to recover. Bottom trawling is still permitted at Heard and McDonald Islands.

4.9 Conservation measures aimed at reducing by-catch in the targeted *C. gunnari* fisheries were introduced in 1989 at South Georgia and in 1997 at Heard and McDonald Islands, and have remained in force since then. By-catch measures have included both 'trawl-by-trawl' by-catch limits which encourage trawlers to move away from areas where the catch of another species exceeds certain limits and ‘overall area’ by-catch limits which would lead to closure of the fishery.

4.10 Season closures for either whole or part of the season have been used as management measures in the South Georgia fishery since 1988/89 (Table 2). Partial season closures were usually related to the catch limit being reached, or to the protection of spawning. No season closures have been in place since catch limits were first introduced for Heard and McDonald Islands in 1996.

4.11 A mesh-size restriction of 90 mm has been in place in all directed *C. gunnari* fisheries (except for waters adjacent to the Kerguelen and Crozet Islands) since 1992 (Conservation Measure 19/IX). In addition, a conservation measure aimed at avoiding catches of small *C. gunnari* (<240 mm) has been in place at South Georgia and Heard Island since 1997.

REVIEW OF DATA

Biology and Demography

Age and Growth

5.1 It is presently feasible to reliably age *C. gunnari* from South Georgia, Kerguelen and Heard Islands. Fish from South Georgia have been aged by Russian scientists by means of otoliths. Ageing in the Indian Ocean sector and at South Georgia is currently accomplished using modes of length-frequency distributions collected during trawl surveys. Aspects of methodologies for age determination of *C. gunnari* were presented in Kock (1980, 1981) and Frolkina (1989).

5.2 Problems in age determination from length-frequency samples start at age 4. After age 3 the modes in length compositions substantially overlap. In addition, there appear to be few fish in the catch older than age 4, with almost all fish having disappeared in the catches after age 6 at South Georgia and in the Indian Ocean.

5.3 WAMI-01/4 presented von Bertalanffy growth curves fitted to modal length-frequency data from the Kerguelen Islands, Heard Island and Shell Bank. The workshop recommended that this approach could usefully be extended to data from South Georgia. Previous attempts to obtain modal length data from fish at South Georgia have been provided by Kock (1980).

5.4 Otolith readings are so far only reliable at South Georgia (Shust and Kochkin, 1985; Frolkina, 1989). New estimates of von Bertalanffy growth parameters can be found in WAMI-01/7. Age determinations from fishing grounds further to the south were found to be still unreliable.

5.5 There are differences in age structure in different areas of the Scotia Arc. In the southern Scotia Sea (South Shetland Islands, South Orkney Islands), large fish of 40–50 cm, which are at least age 7–10, have been observed. Fish of this age are typically found only in low numbers at South Georgia and further to the north. These older fish from the southern Scotia Sea cannot be successfully aged using length-frequency techniques, and thus must rely on otolith ageing techniques which are poorly developed at present.

5.6 Tagging studies on *C. gunnari* that may be useful to validate ageing have not been successful, mainly due to the substantial mortality of fish in the course of sampling. Fish are usually already moribund when they come on board and die soon after. Some tagging experiments of *C. gunnari* will be attempted at South Georgia in the forthcoming season.

5.7 The age and growth findings presented in WAMI-01/4 suggest that growth rates for *C. gunnari* (during the first two years) may be different between Heard Plateau and Shell Bank although L_8 is remarkably similar. The workshop recommended that potential differences in growth between fish around South Georgia and Shag Rocks should be examined.

Mortality

5.8 There have been several studies attempting to estimate M in *C. gunnari*. A review of mortality estimation methodologies was presented in WAMI-01/7. Other investigations were presented in Everson (1998), Sparre (1989), and Frolkina and Dorovskikh (1990). There appear to be large differences between estimates using different methods. Nevertheless, it is not known how reliable these estimates are. The methodologies considered to be most reliable by the authors of WAMI-01/7 resulted in a range of estimates of M from 0.7 to 0.87, with a mean value of 0.76.

5.9 The workshop agreed that the value of M for *C. gunnari* is considerably higher than in other Antarctic fish species. However, the value of M is likely to be dynamic and not constant and may vary in areas, such as South Georgia, between years. At South Georgia, annual variation in M may change as influenced by 'good' and 'poor' krill years. The availability of krill may influence the position of *C. gunnari* in the water column, and would lead to higher predation rates in years of poor krill availability if fish move up and down in the water column more frequently, and Antarctic fur seals dive deeper in those years and encounter *C. gunnari* more often. Lower than average condition indices in years of poor krill availability may be an indication of a higher M rate (Everson et al., 1997).

5.10 The workshop agreed that M is likely to be age specific. Young fish are more likely to have a higher M rate. This probably decreases during age 2–3 and then increases again at older ages when post-spawning mortality contributes to M. The workshop therefore recommended that WG-FSA explore whether it is possible to include a range of M values for each age class in the models.

5.11 The importance of ecosystem-related mechanisms on dispersal and M remains poorly understood, and requires considerably more research in the near future. The impact of the increasing population of fur seals at South Georgia may be having a profound effect on the mortality of *C. gunnari*, particularly in poor krill years. Following initial research by Everson et al. (1999), the workshop recommended that a time series of the abundance of fur seal populations and krill be examined, along with the available data on abundance indices for *C. gunnari*, to better understand the role of predator–prey dynamics on annual survival rates and stock size of *C. gunnari*.

Reproduction

5.12 Spawning patterns, seasonality and reproduction for *C. gunnari* have been studied in almost all areas where the species occurs. Information was provided in Permitin (1973), Kock (1979), Lisovenko and Silyanova (1980), Kock (1989), Kock and Kellermann (1991), Everson et al. (1991, 1996, 1999, 2001) and Duhamel (1987, 1995).

5.13 Differences in spawning seasonality for the Heard Plateau and Shell Bank were described in WAMI-01/4. The spawning season at Shell Bank appears to take place in April and May, whereas spawning at Heard Plateau and Gunnari Ridge occurs in August and September.

5.14 A meridional trend is apparent in fecundity estimates. Fecundity is highest in populations in the Indian Ocean sector and decreases over South Georgia towards the southern Scotia Arc. Fish in Subareas 48.1 and 48.2 become sexually mature one year older than those further to the north in Subarea 48.3. Egg size was smaller in the Indian Ocean sector (3.2 mm) compared to the Atlantic Ocean sector (3.7 mm).

5.15 The workshop acknowledged that problems remain in distinguishing between spent and immature (or resting) females. The determination between these two reproductive states is less problematic immediately after spawning. The workshop recommended that ovaries of fish from spawning grounds be obtained and examined over the length of the spawning season in order to better understand the processes of ovary maturation, spawning and resorption.

Diet

5.16 The diet of *C. gunnari* in most parts of the Southern Ocean has been examined by several authors. Around South Georgia dietary composition has been examined by Barrera-Oro et al. (1998), Kock (1981), Kock et al. (1991, 1994), Kompowski (1980), Kozlov et al. (1988), Permitin and Tarverdiyeva (1972), around Elephant Island by Kock (1981) and Gröhsler (1992), in the South Shetland Islands by Tarverdiyeva and Pinskaya (1980) and Takahashi and Iwami (1997), in the South Orkney Islands by Permitin and Tarverdiyeva (1978), and in the Indian Ocean by Chechun (1984). In addition, WAMI-01/10 presents preliminary information on dietary composition of *C. gunnari* from recent surveys in the South Shetland and South Orkney Islands.

5.17 The composition of dietary components vary in different regions of the Southern Ocean. In the Atlantic sector the preferred food item is *Euphausia superba*. The availability of *E. superba* appears to be more consistent in the southern Scotia Arc, whereas its presence in the diet around South Georgia is more susceptible to interannual changes in krill biomass. When abundant, krill constitutes a substantially higher proportion of the diet of *C. gunnari* than in years of poor krill availability. At Kerguelen and Heard Islands there is no *E. superba* found in the diet of *C. gunnari*, instead other species of euphausiids and hyperiids tend to dominate.

5.18 WAMI-01/6 and 01/10 analyse the relationship between the spatial distribution of *E. superba* and the distribution of *C. gunnari*. Both studies concluded that the spatial distribution of krill is highly influential in the distribution of *C. gunnari*. WAMI-01/10 modelled the relationship between the spatial distribution of prey density with the distributions of *C. gunnari* abundance, mean size, and average stomach fullness, and found significantly positive relationships between these factors and krill density. The workshop recommended that krill surveys should be conducted in real time with finfish trawl surveys, as this can provide important insight into a potentially important mechanism that influences spatial distribution of *C. gunnari*.

Stock Identity and Structure

Large-scale Stock Identity and Movements

5.19 The geographic delineation of *C. gunnari* stocks has been based on several techniques, including the use of morphometrics and meristics (Kock, 1981; Sosinski, 1985), parasites (Siegel, 1980) and genetic approaches (Carvalho and Lloyd-Evans, 1990; Carvalho and Warren, 1991; Duhamel et al., 1995; Williams et al., 1994). Separate stocks of fish are currently defined in the Atlantic Ocean sector around South Georgia, and the South Shetland and South Orkney Islands. Some evidence has been presented that there may be separate stocks around South Georgia and at Shag Rocks.

5.20 WAMI-01/4 presents evidence that there are two separate stocks around Heard Island. More stocks may have existed on other banks, such as Pike or Discovery Bank, which now appear to be absent. Around Kerguelen there appear to be two stocks (Kerguelen Shelf, Skif Bank) as well. Spawning times between stocks may differ by five months, such as on the Kerguelen Shelf and Skif Bank and Heard Island and Shell Bank. Results from recent DNA studies indicate that all populations in the Indian Ocean sector may be genetically homogeneous. This suggests that separation into the various populations could have occurred only recently or that there is a limited exchange of individuals between the populations. The workshop recommended that additional DNA samples should be collected from as many areas as possible to further elucidate stock identity and structure in *C. gunnari*.

5.21 The workshop discussed the potential consequences of treating two separate stocks erroneously as one single unit when setting catch limits. The workshop agreed that it is preferable to treat these stocks as separate units even if the evidence for stock separation is weak in order to minimise the risk of reducing one stock to very low levels while the overall stock still appears to be relatively healthy.

Shelf Distribution and Movements

5.22 WAMI-01/8 describes vertical and horizontal patterns of distribution of *C. gunnari* around South Georgia. There are strong seasonal effects on the distribution, with winter season yielding no fishable concentrations (see additional details in paragraph 7.6). The seasonal changes in temperature appear to be one of the important factors that influence the formation of concentrations. The workshop recommended that it would be useful to collect CTD data on as many trawl stations as possible in order to help understand the role of the physical environment in the formation of aggregations.

5.23 Diurnal changes in the vertical distribution of *C. gunnari* around Heard Island were investigated in WAMI-01/5 using a bottom trawl in conjunction with acoustic methods. The results indicate that vertical distribution is linked to the diel light signal (dusk, dawn). The study suggests that bias in abundance estimates of *C. gunnari* from bottom trawl surveys is negligible if hauls are conducted only during daylight hours between sunrise and sunset. *C. gunnari* tend to leave the bottom layers at sunset. The workshop recommended, where possible, the use of acoustic devices in conjunction with bottom trawls in obtaining information on the proportion of fish off the bottom.

5.24 Factors that influence the horizontal distribution of *C. gunnari* in the South Shetland Islands were presented in WAMI-01/10. In this analysis a relationship was drawn between the depth, krill availability and bathymetry. There is likely to be a confluence of events in the northwestern sector of the shelf area along the 200 m isobath that creates optimal conditions for concentrations of krill and *C. gunnari*. The steep bathymetric gradient and hydrography in this area tends to concentrate krill, and since this region is positioned around 200 to 250 m, this overlaps with the preferred depth range of *C. gunnari*, thus making conditions favourable for higher abundances in this particular region. The lower South Shetland Islands, however, do not have an equivalently steep bathymetric gradient in any specific area along the preferred depth strata of *C. gunnari*, thus the relationship is not as clearly defined in this region.

5.25 There appear to be segregations of size and age classes around South Georgia Island, and there is evidence that in certain regions, fishing may be occurring on only one age class spanning over a limited length range. This is likely having an important effect on the assessment of the stock. WAMI-01/16 examined the depth distribution of *C. gunnari* from nine bottom trawl surveys. Results indicate that the depth of maximum abundance increased as fish size increased. The workshop recommended that future surveys should be designed to provide a uniform sampling intensity over the depth range from 100 to 300 m. WAMI-01/4 provided similar results for the Heard Island region.

Recruitment and Year-class Strength

5.26 The difference between 'strong' and 'weak' year classes of *C. gunnari* can differ by a factor of 20. There is presently no clear relationship between recruitment and parent stock size in the Atlantic sector. Around Kerguelen, strong year classes were observed every three years over the course of 20 years. It is possible that this was attributable to a stock recruitment effect.

ECOSYSTEM CONSIDERATIONS

Predator–Prey Relationships

6.1 Predator–prey relationships and the importance of *C. gunnari* in the diets of land-based marine predators were briefly reviewed for the southern Scotia Arc, South Georgia and Heard Island.

6.2 At South Georgia studies have shown that fur seals and penguins can switch their feeding preferences, feeding on krill in years of high krill abundance, and increasing the proportion of *C. gunnari* in years of low krill abundance. *C. gunnari* feed primarily on krill in years of high krill abundance while they increase the proportion of *Themisto* in their diet in years of low krill abundance. It is obvious that there is a strong relationship between krill, *C. gunnari* and some of the land-based predators.

6.3 The workshop recognised that there are likely to be differences between South Georgia and the southern Scotia Arc in terms of the importance of *C. gunnari* in the food web.

6.4 Dietary studies of Antarctic fur seals and king penguins at Heard Island indicate that both these species feed on *C. gunnari* at certain times of the year, such as August in king penguins. However, fur seals at Heard Island, and also in the Kerguelen Islands, feed mainly on myctophids.

6.5 The workshop agreed that increases in the populations of fur seals (5–10% per annum) at South Georgia over the past 50 years may be exerting increasing predation pressure on *C. gunnari*, particularly in years of poor krill abundance. A similar situation may be occurring in other areas where predator populations have been increasing, such as at Heard Island where breeding numbers of king penguins have increased from none observed in 1963, to 30 000 pairs at present.

6.6 The workshop concluded that:

(i) there was a strong relationship between krill, *C. gunnari* and land-based predators at South Georgia;

(ii) the importance of *C. gunnari* in the diet of land-based predators may be high in years of low krill abundance at South Georgia; and

(iii) *C. gunnari* may be an important prey item during critical phases of the life history of some predators, particularly in the Indian Ocean sector.

6.7 It was recommended that studies be undertaken to:

(i) further quantify the relationship between krill, *C. gunnari* and land-based predators; and

(ii) examine possible interactions between the *C. gunnari* fishery, *C. gunnari* and its predators, and quantify any overlap which may occur (as is done by WG-EMM in the case of krill).

Ecosystem Changes since the Early 1970s

6.8 Evidence for long-term, large-scale changes in populations of predators and the environment in Areas 48 (South Atlantic) and 58 (Indian Ocean) was reviewed. Major trends include:

(i) increases in populations of fur seals and some species of penguin at South Georgia;

(ii) increases in populations of fur seals and king penguins in the Indian Ocean;

(iii) increases in mean annual air temperature at the Antarctic Peninsula; and

(iv) decreases in the mean annual extent of sea-ice in the southern Scotia Arc.

6.9 In the context of Article II it is possible that a change has occurred in the ecosystem which may not be reversible over two or three decades. However, the workshop recognised the high variability in the size of *C. gunnari* stocks and the potential for recovery following an event of high recruitment.

6.10 The workshop agreed that further work was needed to compile information on long-term, large-scale, changes in populations and the environment in Areas 48 (Atlantic Ocean) and 58 (Indian Ocean). Simulation studies were also needed to examine plausible scenarios which could lead to observations on the abundance of *C. gunnari*, krill and the predators. The workshop requested assistance from WG-EMM in addressing these issues.

By-catch

By-catch in Fisheries targeting *C. gunnari*

6.11 Ms van Wijk presented a summary of by-catch data for the Australian trawl fishery for *C. gunnari* in Division 58.5.2. Data have been collected by scientific observers (two observers/trip) for every fishing trip undertaken since 1996/97. Over the past five years:

(i) 94% of the hauls were observed, covering 93% of the total catch of *C. gunnari*;

(ii) by-catch typically comprised 1–6.5%, by weight (1–11 tonnes), of the total observed catch (63–915 tonnes) in each split-year;

(iii) there was one anomalous year (1998/99) when the by-catch comprised 34% (13 tonnes) of the total observed catch (37 tonnes) – that year, the catch of *C. gunnari* was below average;

(iv) the main components of the by-catch are *Dissostichus eleginoides*, skates and jellyfish, and these species are common to both fishing grounds (Plateau Shallow and Shell Bank); and

(v) *Channichthys rhinoceratus*, sponges and soft corals are important components of the by-catch on Plateau Shallow, whereas porbeagle sharks and *Lepidonotothen squamifrons* are important on Shell Bank.

6.12 By-catch in the trawl fishery for *C. gunnari* in Subarea 48.3 in the 1999/2000 and 2000/01 seasons was reported in WAMI-01/15 Rev. 1. The dominant component of the by-catch in 1999/2000 was myctophids (67 tonnes or 1.6% of the total catch by weight). So far in the 2000/01 season, the total by-catch is <10 tonnes, and the dominant species was *Pseudochaenichthys georgianus* (7 tonnes or 0.5% of the total catch by weight). These estimates were derived from the five-day catch and effort reports.

By-catch of *C. gunnari* in Other Fisheries

6.13 The abundance of *C. gunnari* in the by-catch from the krill fishery in Subarea 48.2 was reported in WAMI-01/11. The information covered a single trip. The catch of *C. gunnari* consisted mostly of 0+ and 1+ aged fish, and their abundance ranged from 12 individuals observed in a haul of 3 tonnes of krill, to 3 500 individuals observed in a haul of 17 tonnes of krill.

6.14 The workshop agreed that this information was valuable and that scientific observers should be further encouraged to collect data on by-catch in krill fisheries. The attention of WG-EMM was drawn to the high number (1 000s) of Antarctic fur seals seen in the area (near 60°40’S and 46°20’W) at the time of fishing (May–July 1999).

6.15 The workshop agreed that information on the by-catch of *C. gunnari* in other fisheries was an important component of developing our understanding of the fishery–icefish interactions. However, it was noted that the current short-term projections are independent of levels of mortality of early age classes of *C. gunnari*.

Incidental Mortality

6.16 The workshop reviewed the information on the incidental catches, and associated mortality, of seabirds taken in the fishery for *C. gunnari* in Subarea 48.3 in the 1998/99 and 2000/01 seasons (WG-FSA-01/30). The following points were noted:

(i) Detailed analysis of the data contained in observer reports for fishing between December 2000 and February 2001 identified month and vessel as two possible factors influencing the probability that a haul would catch birds, with most (93%) of all seabird mortality occurring in the first three weeks of February – there were no significant factors that could explain the numbers of birds that would be caught in non-zero hauls.

(ii) Differences between the three recent years (numbers of birds by season were 1998/99 = 4, 1999/2000 = 19, 2000/01 = 92) also suggest that there may be year effects, but these differences could also have been caused by month or vessel effects.

(iii) More detailed research on the *C. gunnari* fishery is required to identify what factors are important in explaining bird by-catch and how to mitigate the problem.

6.17 The workshop agreed that in order to facilitate future scientific observer investigation of this potential problem, detailed protocols and recording formats need to be developed. This matter was referred to WG-FSA and ad hoc WG-IMALF for further consideration.

Effects of Fishing Gear

6.18 The workshop recalled discussions in the late 1980s on the effect of trawl gear on the seafloor within the Convention Area. Concern about this impact and the potential taking of species of depleted stocks, such as *N. rossii*, in the by-catch of trawl fisheries in Area 48, lead to the prohibition of bottom trawling in this region. As a result, commercial fisheries for *C. gunnari* in Subarea 48.3 operate midwater trawls.

6.19 In contrast, the use of bottom trawls in commercial fishing is permitted in other parts of the Indian Ocean, including Divisions 58.5.1 and 58.5.2. Vessels targeting *C. gunnari* in Division 58.5.2 currently use trawls towed on or close to the bottom. The workshop noted that the composition of the fish fauna and the potential for by-catch taken by trawl in Division 58.5.2 was different to those in Subarea 48.3.

6.20 The US AMLR Program is mapping the distribution of benthic by-catch and investigating the effects of bottom trawls on the seafloor and benthos in Subareas 48.1 and 48.2 (e.g. WAMI-01/10). Data from by-catch in research trawls, video-photography, acoustic data and benthic samples are being used.

ASSESSMENT METHODS

Previous/Current CCAMLR Assessments

7.1 The workshop briefly summarised the history of *C. gunnari* assessments performed by WG-FSA (see Tables 3 and 4). In 1986 CCAMLR agreed in principle to set catch limits regulating fishing activity in Subarea 48.3 (South Georgia and Shag Rocks). From 1989 to 1991 assessments were performed annually during WG-FSA using VPA tuned using indices of abundance from either: (i) CPUE data from the commercial fishery; or (ii) research trawl surveys to estimate size and age of the population. Population size and estimated catches were projected from the terminal year of the VPA using the catch equation with a stochastic recruitment function derived from the VPA results and a target fishing mortality $F_{0.1}$ derived from a yield-per-recruit analysis. In 1993 the VPA was tuned using the ADAPT method (Gavaris, 1988). WG-FSA was concerned about incompatibility between projected abundance of age and that observed during research surveys. Periodic reductions in biomass in the absence of fishing were evident in the surveys but these were not reflected in the projections. Concern was raised by WG-FSA that the VPA analysis was not providing a reliable assessment of stock status. With the lack of a commercial catch since the 1990/91 season, in 1994, the Working Group ceased using VPA to assess *C. gunnari* in Subarea 48.3. With no fishery, the catch-at-age matrix could not be extended. Research surveys were then the only source of information on current abundance, however there was no way of converting these from relative to absolute indices. In the absence of reliable information on catchability, which is generally assumed to be less than 1, WG-FSA adopted a conservative approach to the assessment, assuming that the surveys provided estimates of absolute abundance.

7.2 In 1997 two possible approaches for deriving catch limits were identified: long-term precautionary catch limits and short-term catch projections from estimates of current abundance derived from surveys. Precautionary catch limits were based on the GYM, applied in a similar way to the assessment of *D. eleginoides* in Subarea 48.3, but with a target escapement of 75%. Given that the stock size is highly variable even without fishing, WG-FSA deemed short-term projections to be more appropriate.

7.3 Short-term projections require a number of inputs: a biomass estimate, distribution of numbers at age, an estimate of M, a selection function, von Bertalanffy growth parameters, a weight–length relationship and known catches since the time of the biomass estimate. They can be updated each year if new information on biomass and age structure of the population becomes available.

7.4 The workshop endorsed the current use of short-term projections to provide catch limits for *C. gunnari* and noted the lack of alternative methods. It also noted that with the fishery based on two age classes, the currency of assessments is two years. If there is no survey information from the most recent two seasons, the advice on catch limits becomes unreliable. The workshop recommended that WG-FSA consider the currency of these assessments in the absence of surveys.

7.5 Dr Parkes noted that research surveys need to be as representative as possible of the true status of the stock as they are now the primary means of measuring the current status of the stock and form the starting point for the subsequent calculation of catch limits. He also stated that even though there were limitations to the bottom trawl method, it was important to continue these surveys as they provide a continuous time series conducted using similar techniques. Further work in developing survey methods that augment the bottom trawl approach would be useful. This was discussed further by the workshop (paragraphs 7.17 to 7.29).

7.6 The workshop discussed the potential importance of dispersal and the effect this may have on estimation of stock size. At South Georgia fish may be more likely to concentrate during the late spring–summer–autumn period than in winter. Evidence presented in WAMI-01/8 suggests that *C. gunnari* feed poorly and do not appear to form large aggregations during winter. During spring *C. gunnari* begin to form aggregation near the bottom and to migrate vertically in order to feed more intensively. In summer fish appear to perform extensive vertical and horizontal migrations and are intensively feeding, densely aggregating in some years. Finally, in autumn, fish are in more near-bottom areas and feeding intensity decreases significantly when fish approach spawning. Thus, seasonality can bias the indices of abundance and potentially also affect the estimates of mortality.

New Methods and Modifications to Previous/Current Methods

7.7 Dr P. Gasiukov (Russia) presented a summary of the results of WAMI-01/13. This paper provided biological reference points (RPs) for *C. gunnari* based on a stock assessment using Extended Survivors Analysis (XSA). In the early 1990s stock assessments were carried out using the ADAPT method. These assessments were revised by analysing the original catch-at-age and survey data using XSA, as complemented in the software used by ICES. XSA is a more flexible approach and provides various options for weighting, catchability models, and shrinkage procedures. The analyses show that abundance and total and spawning biomass estimates were significantly higher than values obtained by ADAPT. At the same time, there appears to be a total lack of a stock-recruitment relationship, indicating a random pattern of recruitment. Diagnostic statistics indicated that the input data are noisy and of poor quality.

7.8 Dr Kock noted that this was a useful approach but emphasised that the results in this model, as those of other models, would be driven by the high value of M. Furthermore, the high value of residuals in some years, was of concern. He suggested that it may be useful to gather information on other techniques or analyses used in other fisheries, on species with a similar life history.

7.9 Dr Constable added that the decoupling of recruitment and stock, apparent in the analyses of historical fishery data and research data, means that recruitment is not a reliable indicator of stock status. It may be that there are no methods for checking the status of the system and it is important to incorporate this into management strategies, ensuring that they are robust against uncertainty (see Agenda Item 8).

7.10 The workshop thanked Dr Gasiukov for his work noting that this technique is very useful in giving an overview of stock dynamics. In particular, these techniques can be used to derive recruitment time series and estimates of catchability, although it was noted that the diagnostics suggested that many of the problems encountered by WG-FSA in its last attempts to perform VPA using ADAPT remained with the XSA approach.

7.11 Dr Gasiukov presented the results of WAMI-01/12. This paper addressed the problem of using data from multiple surveys carried out over a number of years by different countries using different vessels.

7.12 At last year's meeting WG-FSA combined trawl data from different vessels to obtain a single ranked dataset used to derive abundance and biomass estimates. The assumption in this approach was that the survey vessels fished with equal efficiency. This is unlikely to be valid as vessels will differ in many aspects, including size, gear, experience of crew etc. Using a GLM approach, the paper noted significant differences between the catchability of different surveys in Subarea 48.3 undertaken by Argentina, Russia and the UK. This analysis provides a method whereby values of one vessel can be standardised to those of another. Data from 1989/90 were excluded from the analysis due to abnormally high catches that precluded computation. The average catchability of vessels used in Russian surveys was 4.14 times the average catchability of vessels used by the UK.

7.13 The workshop again thanked Dr Gasiukov for his valuable work, noting that it is very important to provide methods that can reconcile data from different surveys, and adding that it was encouraging to see that this type of work is being explored. Several members noted that their concern that the multiplier of 4.14 was very large and thought it important to determine why the differences between the two survey series might be so great. During the discussion, several possible factors were identified, including: variance caused by factors not included in the analysis, such as sampling/survey design, fishing gear or seasonal influences. It was also noted that whilst the nations undertaking the surveys were used as a proxy for vessel, each country had used several different vessels.

7.14 Drs Constable and Kock suggested that an experiment comparing the results of two vessels fishing in a small area at the same time could provide useful information to solve this problem.

7.15 Dr Parkes suggested that it may be informative to look at results of this analysis done elsewhere to place the magnitude of the multiplier value determined here into context. Dr Gasiukov replied that studies in the Baltic Sea comparing eight different vessels from eight different countries had provided relative values that were comparable. Similarly, Dr Hanchet noted that studies in New Zealand yielded multipliers of 2 to 1 or 3 to 1, but that 4.14 seemed high.

7.16 The workshop noted that it was important to consider the above issues at WG-FSA and to encourage further work in this area intersessionally. Dr Gasiukov indicated that he would be developing this work further in the future.

Future Monitoring

Surveys

7.17 Traditionally, surveys used to derive abundance estimates for *C. gunnari* are conducted by bottom trawl. The assumption implicit in the use of those estimates as values of absolute abundance is that *C. gunnari* are distributed very closely to the bottom during the day and that therefore the bottom trawl samples all the fish in the water column. Recent observations have suggested that there is a significant pelagic component to the stock (Frolkina and Gasiukov, 2000; Kasatkina, 2000). This has raised the question in recent years of whether current bottom trawl surveys are the most appropriate method to assess the absolute abundance of *C. gunnari*.

7.18 Two papers were presented to the workshop which addressed this issue: WAMI-01/5 and 01/9.

7.19 Ms van Wijk presented the results of WAMI-01/5. This paper investigated whether a research trawl survey targeting *C. gunnari* in the Heard Island region showed bias due to the vertical migration of *C. gunnari*. The design of research surveys in this region has been based on anecdotal evidence from the fishing skippers that *C. gunnari* do not start moving up into the water column until three hours post-sunset. Thus trawls were considered acceptable if conducted between sunrise and three hours after sunset. Analysis of acoustic data in this paper showed that this assumption is incorrect and that vertical migration of *C. gunnari* is tightly tuned to the diel light signal. *C. gunnari* move down/up in the water column within an hour of sunrise/sunset. The analysis showed that during the day pelagic aggregations of fish were only rarely present above the level sampled by the trawl. The paper concluded that providing bottom trawls were conducted between the times of sunrise and sunset, bias should not be a problem.

7.20 Dr Parkes raised the question of whether it was possible to provide quantitative acoustic abundance estimates from a similar survey in future. Ms van Wijk replied that while this was certainly possible, there were a number of issues that would need to be addressed first, notably, accurate range of target strength values for *C. gunnari*, calibration of the echosounder (logistically difficult as surveys in Division 58.5.2 are conducted by commercial vessels) as well as issues of bias. Dr Parkes also commented that while pelagic aggregations in this study were only rarely noted, it was unknown whether they comprised *C. gunnari* as they were not successfully trawled. Thus even though no bias was evident in this survey, in future surveys where pelagic aggregations occur it will be important to trawl these marks to be able to determine the extent of possible bias.

7.21 WAMI-01/9 proposed the design of a trawling/acoustic survey planned for *C. gunnari* in Subarea 48.3. This survey is planned by Russia for January–February 2002. It is designed to improve quantitative assessments for *C. gunnari* by combining an acoustic and bottom trawl survey to resolve the pelagic and benthic components of the stock respectively. The original bottom trawl survey design used in previous years will be repeated to maintain continuity of the time series. In addition, an acoustic survey will be conducted after the trawl survey to determine the pelagic component of the stock. The temporal separation of the two surveys will be kept as low as possible. Target strength values for *C. gunnari* will be measured during the survey to provide a basis for determining quantitative estimates of abundance from the acoustic data. Abundance estimates from the acoustic survey will be combined with those from the trawl survey to provide total estimates of abundance that include both the pelagic and benthic components.

7.22 Dr Gasiukov noted that discussion would be necessary at next year's WG-FSA meeting to determine ways in which these two abundance estimates might be combined.

7.23 Several members of the workshop noted that there were many issues that would need to be resolved before quantitative estimates could be derived from acoustic data. These included: determination of target strength values for *C. gunnari* and their validity; influence of fish behaviour on target strength, detectability of *C. gunnari* in acoustic data; characterisation of vessel avoidance; and possible diving responses. Dr Hanchet noted anecdotal evidence from the New Zealand fishery that some fish reacted to net approach by diving 30 or 40 m towards the seafloor. If *C. gunnari* exhibit a similar behaviour and both trawl and acoustic data were used to derive abundance estimates, then there could be a possibility of 'double counting'. This would be extremely difficult to characterise.

7.24 Dr Constable noted that the issue of bias is a different question than the efficiencies of different survey methods. The potential underestimation of abundance by trawls needs to be assessed by monitoring what is caught versus not caught in a trawl. Comparisons of results between trawl and acoustic surveys is a question of efficiency. Deployment of video gear on the trawl net may be able to provide information on fish avoidance and therefore aspects of the bias problem. If this and target strength issues can be overcome then acoustic surveys may be more efficient than trawl surveys as they can provide greater spatial coverage in a shorter time span. It is important to quantify bias in both trawl and acoustic surveys.

7.25 Dr R. Holt (USA) mentioned that putting video gear on the trawl net may introduce other problems such as fish avoidance/attraction to light. Dr Parkes mentioned that using an upward-looking sounder mounted on the net may give additional useful information.

7.26 Dr Parkes questioned how the various species would be discriminated during the acoustic survey. Dr Gasiukov replied that multifrequency techniques would be used and that for species that were difficult to separate, such as *C. gunnari* and myctophids, target trawls would be used for verification.

7.27 Dr M. Belchier (UK) noted that the UK would also carry out a bottom trawl survey in Subarea 48.3 in January 2002. The survey design will be the same as that used previously to maintain continuity of the data series, but will also collect acoustic information using a hull-mounted EK500.

7.28 Similarly, Mr Jones noted that a US AMLR acoustic survey for krill will take place at the same time as the German groundfish survey at the South Shetland Islands in January 2002. A comparison between the acoustic data and trawl data will be useful in examining vertical distribution of *C. gunnari*.

7.29 The workshop recognised the value of combined acoustic and trawl surveys. It encouraged discussion between the UK and Russia to explore options to coordinate the two surveys in Subarea 48.3. A two-vessel collaborative survey collecting concurrent acoustic and trawl data would yield a very valuable dataset that may address issues such as bias and the most appropriate survey techniques for *C. gunnari*. The workshop recommended that, where possible, continuous acoustic recording should be undertaken during bottom trawl surveys to allow potential bias to be determined in survey catch rates.

MANAGEMENT PROCEDURES

8.1 The workshop discussed management procedures for *C. gunnari* and noted that a number of papers have addressed these issues in the recent past following the development of a precautionary approach for krill, including de la Mare et al. (1998) and Agnew et al. (1998). A number of general issues surrounding the development of a management procedure were briefly discussed, including the need to specify operational objectives (such as those adopted for krill), decision rules that would use information, and assessment methods to make decisions in order to achieve the operational objectives. Many of these issues have been presented to CCAMLR previously in the Working Group on Developing Approaches to Conservation (WG-DAC) in the mid-1980s (see, for example, the paper by de la Mare, 1988).

8.2 The workshop noted that a management procedure comprises both decision rules and operational objectives. The objectives are based on attributes of the system that can be measured (paragraph 4.1) and for which provision is made for conservation and rational use. The performance of the management procedure would be judged against the status of those attributes. Differences between the desired states of those attributes and the observed state of the system provide measures of performance. Such differences may not be able to be measured in reality but can be used in performance evaluations based on simulated environments.

8.3 In that context, the workshop agreed that the types of assessment methods and decision rules that could be used for *C. gunnari* should be evaluated in a simulation framework to test the performance of the procedures before suggesting modifications to the current management system.

8.4 The evaluation framework requires the elaboration of plausible models of the ecological and fishery system on which the performance of the management procedure will be evaluated. To that end, the workshop requested that members develop the following:

(i) quantitative simulation models that encompass the biological features of *C. gunnari* populations, including predator and prey requirements, noting the potential differences between the southern Scotia Arc, South Georgia and the Kerguelen Plateau;

(ii) understanding of the historical interactions of the fishery with the fish stocks, following the work described in WAMI-01/13;

(iii) understanding of the importance of *C. gunnari* as a prey species and the life history consequences to predators of a fluctuating stock of *C. gunnari*;

(iv) scenarios concerning long-term changes in the ecosystem, including oceanographic changes along with recovery of formerly depleted species such as fur seals; and

(v) appropriate ecological reference points for *C. gunnari*, taking into account the relative importance of this species to predators and the highly variable nature of the stock.

8.5 The workshop noted that the development of management procedures required consideration of the combination of decision rules, assessment methods and information requirements. WG-FSA has considered three approaches for assessing yield of *C. gunnari*. The approach used in the 1980s and early 1990s was based on using VPAs tuned with surveys and a target F ($F_{0.1}$) to estimate yield. Since 1997 WG-FSA has used the objectives developed for prey species, such as krill. A method based on the approach for toothfish and krill is inappropriate for *C. gunnari* because they naturally fall to low abundances. For that reason, the short-term assessment method was adopted.

8.6 The workshop considered alternative approaches to management that could be evaluated, including:

(i) the development of decision rules that take account of changes in the relative status of the stock in order that assessments of long-term annual yield can be made;

(ii) the development of short-term methods that take account of uncertainty in parameters such as M;

(iii) consideration of the components of the existing decision rule for the short-term assessments, such as the confidence bound on the biomass estimate and the escapement of the cohorts following fishing, to identify whether any part of the decision rule could be made less stringent while still ensuring a high probability of maintaining productivity of the stock and its predators;

(iv) consideration of medium-term assessment methods such as those used in ICES that endeavour to account for the probability of recruitment success in subsequent years;

(v) consideration of closed seasons to safeguard predators and therefore not require a specific provision for predators in the decision rule; and

(vi) consideration of how to ensure the conservation of the stock if the fishery pursues the catch limit after the assessed cohorts have disappeared. (The workshop noted the risk of exploiting unassessed cohorts if they enter the fishery at this time.)

8.7 The workshop requested that WG-EMM be asked to consider the importance of *C. gunnari* to predators in the Antarctic ecosystem in order to evaluate the escapement of *C. gunnari* required from the fishery to provide for predators. It also requested that the Commission be asked for guidance concerning the definition of operational objectives for this species.

RECOMMENDATIONS TO WG-FSA

9.1 The workshop made the following recommendations under each agenda item:

(i) Review and characterisation of fisheries:

(a) The recently compiled bibliography on *C. gunnari* should be developed as an electronic database (paragraph 2.1).

(ii) Management needs:

(a) The Fishery Plan for each area needs to list the information (research) requirements for the management approach adopted. The currency of the assessment should also be stated (paragraph 3.7).

(b) Reporting requirements must be met to enable catch limits to be monitored (paragraphs 4.2 to 4.6).

(c) Where possible, WG-FSA should update the short-term projections annually (paragraphs 4.4 and 4.5).

(d) Where stock structure is uncertain, stocks should be managed as smaller units (paragraph 5.21).

(iii) Review of data:

(a) Growth should be studied at South Georgia and Shag Rocks to reveal possible differences (paragraph 5.7).

(b) WG-FSA should explore whether it is possible to include a range of M values (paragraph 5.10).

(c) Ovary sampling should be carried out throughout the season to determine staging criteria for *C. gunnari* (paragraph 5.15).

(d) Sampling should continue in each area for stock separation work (paragraph 5.18).

(e) Sampling should be uniform over a 100 to 300 m depth range (paragraph 5.25).

(iv) Ecosystem considerations:

(a) A comparison over time should be made of the population abundance of predators–icefish–krill in each area (paragraph 5.11).

(b) Predator dependence studies are required to determine how important *C. gunnari* are to predators (seals, penguins etc.). WG-EMM has previously determined an overlap index for krill. Foraging ranges of predators should be provided (paragraphs 5.11 and 6.7).

(c) A simulation study of the impact of seal predation may help determine what future work is required (empirical studies) (paragraph 6.7).

(d) WG-FSA should seek advice from WG-EMM on the likely effects on the ecosystem of the observed increase in temperature and other ecological ranges over the last 20 years (paragraph 6.10).

(e) WG-FSA should review commercial by-catch rates in each fishery and review survey by-catch rates in each area (analyse trends) (paragraph 6.12).

(f) A consistent approach to by-catch issues should be taken across the various fisheries (following paragraphs 6.12 to 6.15).

(g) Further information is required from the krill fishery on by-catch rates of juvenile *C. gunnari* (paragraph 6.15).

(h) ad hoc WG-IMALF should consider development of a protocol for observers concerning seabird by-catch in trawl fisheries. The relative vulnerability of each species to trawl fisheries should be determined (paragraph 6.17).

(v) Assessment methods:

(a) Review levels of M used in the assessment (paragraph 5.10).

(b) Additional tissue samples should be collected for DNA microsatellite analysis to further elucidate stock identity (paragraph 5.20).

(c) CTD data should be collected on as many stations as possible (paragraph 5.22).

(d) The workshop endorsed the current use of short-term projections to provide catch limits for *C. gunnari* (paragraph 7.4).

(e) WG-FSA should look at the different vessel catchabilities in the trawl survey series within Subarea 48.3 (paragraph 7.16).

(f) Where possible, target strength work should be completed as part of acoustic surveys (paragraph 7.23).

(g) Continuous acoustic recording should be undertaken during bottom trawl surveys to allow potential bias to be determined in survey catch rates (paragraph 7.29).

(h) The workshop supported the proposal to carry out joint acoustic and trawl surveys in 2002 and encouraged discussion between the UK and Russia to explore options to coordinate the two surveys planned for Subarea 48.3 in January–February 2002 (paragraph 7.29).

(vi) Management procedures:

(a) The types of assessment methods and decision rules that could be used for *C. gunnari* should be evaluated in a simulation framework to test the performance of the procedures before suggesting modifications to the current management system (paragraph 8.3).

(b) Members should elaborate plausible models of the ecological and fishery systems on which the performance of the management procedure will be evaluated (paragraph 8.4).

(c) The workshop requested WG-EMM be asked to consider the importance of *C. gunnari* to predators in the Antarctic ecosystem (paragraph 8.7).

(d) The workshop requested that the Commission be asked for guidance concerning the definition of operational objectives for *C. gunnari* (paragraph 8.7).

ADOPTION OF THE REPORT

10.1 The report of the workshop was adopted.

CLOSE OF THE WORKSHOP

11.1 Dr Holt congratulated the Co-conveners for bringing the workshop together, and for guiding the discussion and work to a successful outcome. Dr Holt also thanked Ms G. Tanner and Dr Ramm for their contribution to the workshop. The hard work of the Co-conveners and the Secretariat had been appreciated by all participants.

11.2 Drs Parkes and Kock thanked all participants for their contribution to the workshop. WAMI had been a long time in the planning and it was gratifying to have co-convened the workshop. The outcome would be useful to WG-FSA and there was a bright future for further work on *C. gunnari.*

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Table 1: Annual catches (tonnes, live weight) of *Champsocephalus gunnari* in the CCAMLR Convention Area, as reported in STATLANT data. Split-years start on 1 July and end on 30 June of the following.

Split year	Area/Subarea/Division							
	48	48.1	48.2	48.3	58	58.5	58.5.1	58.5.2
1969/70							5	
1970/71				10 701			380	
1971/72				551			35 568	5 860
1972/73				1 830			45	
1973/74				254			25	
1974/75				746			1 764	14 572
1975/76				12 290			11 577	2 663
1976/77				93 400		264	33 112	4 201
1977/78			138 895	7 557		296	16 581	16 166
1978/79		35 930	21 439	641	101			
1979/80		1 087	5 231	7 592			[a]1 631	
1980/81		1 700	1 861	29 384			[a]1 122	
1981/82		0	557	46 311			[a]16 083	
1982/83		2 604	5 948	128 194			[a]25 852	
1983/84			4 499	79 997			[a]7 127	
1984/85		17	2 361	14 148			[a]8 253	
1985/86	32		2 682	11 107			[a]17 137	
1986/87		75	29	71 151			[a]2 625	
1987/88		1	1 336	34 619			[a]159	
1988/89		141	532	21 359			23 628	
1989/90			2 528	8 087			226	1
1990/91			14	92			13 283	
1991/92				5			57	2
1993/94			0	13			12	3
1994/95				10			3 936	
1995/96							5	
1996/97							0	217
1997/98				6				67
1998/99			1	265				73
1999/00				[b]4110				81
2000/01[c]		1		573				930

[a] Reported from Subarea 58.5 – assumed to be caught in Division 58.5.1
[b] From monthly catch and effort reports
[c] Incomplete

Table 2: Catch limits and fishing season for *Champsocephalus gunnari*.

Area	Conservation Measure	Season			Catch Limit (tonnes)
		Start	Closure	End	
Subarea 48.3	8/VI	1987	-	1988	35 000
			1988/89		0
	13/VIII	1989	-	1990	8 000
	20/IX	1990	-	1991	26 000
			1991/92		0
	49/XI	6 Nov 1992	1 Apr 1993 +	31 Mar 1993	9 200
	66/XII	1 Jan 1994	1 Apr 1994 +	31 Mar 1994	9 200
			1994/95		0
	97/XIV	1995	1 Apr 1996 +	31 Mar 1996	1 000
	107/XV	1996	1 May 1997 +	30 Apr 1997	1 300
	123/XVI	1997	1 Apr 1998 +	31 Mar 1998	4 520
	153/XVII	1998	1 Apr–30 Nov 1999	31 Mar 1999	4 840
	175/XVIII	1 Dec 1999	1 Mar–31 May 2000	30 Nov 2000	4 036
	194/XIX	1 Dec 2000	1 Mar–31 May 2001	30 Nov 2001	6 760
Division 58.5.2	110/XV	1996	-	1997	311
	130/XVI	1997	-	1998	900
	159/XVII	1998	-	1999	1 160
	177/XVIII	1 Dec 1999	-	30 Nov 2000	916
	195/XIX	1 Dec 2000	-	30 Nov 2001	1 150

\+ Until the end of the CCAMLR meeting that year

Table 3: Review of Assessment methods for *Champsocephalus gunnari* in Subarea 48.3.

Year	Assessment Method	Reference
2000	Short-term yield calculation based on surveys in January and February 2000.	SC-CAMLR-XIX, Annex 5, paragraphs 4.193 to 4.213
1999	Short-term yield calculation based on UK survey in September 1997.	SC-CAMLR-XVIII, Annex 5, paragraphs 4.166 to 4.173
1998	Short-term yield calculation based on UK survey in September 1997.	SC-CAMLR-XVII, Annex 5, paragraphs 4.162 to 4.163
1997	Survey biomass and age structure used as the basis for short term projections.	SC-CAMLR-XVI, Annex 5, paragraphs 4.179 to 4.182 and 4.199 to 4.208
1996	No new assessment was performed.	SC-CAMLR-XV, Annex 5, paragraphs 4.135
1995	No new assessment was performed.	SC-CAMLR-XIV, Annex 5, paragraphs 5.106 to 5.109
1994	Surveys in 1993/94 indicated significantly lower biomass than predicted by projections made at the 1993 Working Group meeting. Decline in biomass in the absence of fishing may be linked to the low availability of krill in Subarea 48.3 during the 1993/94 season.	SC-CAMLR-XIII, Annex 5, paragraphs 4.78 to 4.83
1993	Extensive re-analysis of VPA and survey estimates of biomass produced a more consistent past series of *C. gunnari* biomass. However for stock projections the 1992 survey was used to estimate 1993/94 biomass between 51 and 396 000 tonnes.	SC-CAMLR-XII, Annex 5, paragraphs 6.30 to 6.54
1992	VPA assessment tuned to survey abundance and CPUE indices in WG-FSA-92/27 and at the meeting gave poor results for most recent years, current abundance estimate provided by 1992 trawl survey.	SC-CAMLR-XI, Annex 5, paragraphs 6.46 to 6.88
1991	VPA assessments tuned to commercial effort and survey abundance indices in WG-FSA-91/27 and 91/15.	SC-CAMLR-X, Annex 6, paragraphs 7.37 to 7.78
1990	VPA assessment tuned to standardised effort was presented in WG-FSA-90/26. Population projections based on biomass estimates from trawl surveys were carried out .	SC-CAMLR-IX, Annex 5, paragraphs 44 to 47
1989	Two VPA assessments were considered, one tuned to the UK/Polish survey estimate of bio mass, the other tuned to effort data (see WG-FSA-89/27 and 89/22 Rev 1.).	SC-CAMLR-VIII, Annex 6, paragraphs 90 to 99

Table 4: Review of Assessment methods for *Champsocephalus gunnari* in Division 58.5.2.

Year	Assessment Method	Reference
2000	Short-term yield calculation based on a survey in May 2000.	SC-CAMLR-XIX, Annex 5, paragraphs 4.222 to 4.227
1999	Short-term yield calculation based on Australian survey in April 1998.	SC-CAMLR-XVIII, Annex 5, paragraphs 4.196 to 4.197
1998	Survey in June 1998 and short term yield calculation.	SC-CAMLR-XVII, Annex 5, paragraphs 4.175 to 4.177
1997	WG-FSA-97/29 – short-term projections based on the results from a recent trawl survey in August 1997.	SC-CAMLR-XVI, Annex 5, paragraphs 4.179 to 4.182 and 4.199 to 4.208
1996	No new data or assessment.	SC-CAMLR-XV, Annex 5, paragraphs 4.241 to 4.242
1995	No new data or assessment.	SC-CAMLR-XIV, Annex 5, paragraphs 5.183 to 5.184
1994	Biomass surveys by Australia according to random stratified design and calculated by MVUE. Precautionary catch limits calculated by estimating ? from modified krill yield program.	SC-CAMLR-XIII, Annex 5, paragraphs 4.147 to 4.159

ATTACHMENT A

LIST OF PARTICIPANTS

Workshop on Approaches to the Management of Icefish
(Hobart, Australia, 3 to 5 October 2001)

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ATTACHMENT B

TERMS OF REFERENCE

Workshop on Approaches to the Management of Icefish
(Hobart, Australia, 3 to 5 October 2001)

1. To review the fisheries targeting *Champsocephalus gunnari* in various subareas and divisions, including trends in catches and changes in stock composition in terms of length and age (SC-CAMLR-XVI, paragraph 5.62).

2. To review information on the biology and demography of the species, including age, growth, and reproduction and diet (SC-CAMLR-XVI, paragraph 5.62).

3. To review information on stock identity, distribution and large scale movements (SC-CAMLR-XVI, paragraph 5.62).

4. To review information on smaller-scale (shelf) distribution, movements (horizontal and vertical), segregation by age and size (SC-CAMLR-XIX, Annex 5, paragraph 10.2(iii)).

5. To review estimates of absolute and relative abundance and year-class strength (SC-CAMLR-XVI, Annex 5, paragraph 4.209).

6. To review the historical assessment methods, including short- and long-term methods, and highlight their shortcomings (SC-CAMLR-XVI, Annex 5, paragraph 4.209).

7. To evaluate interactions of *Champsocephalus gunnari* with other components of the ecosystem, including krill and fur seals, to investigate past fluctuations in natural mortality and explore the potential to predict changes in M (SC-CAMLR-XVI, paragraph 4.178).

8. To develop long-term management strategies for the fisheries on *Champsocephalus gunnari* including management under conditions of periodic changes in M (SC-CAMLR-XVI, paragraph 5.62; SC-CAMLR-XIX, Annex 5, paragraph 10.3).

9. To address the question of whether the ecosystem in Subarea 48.3 could support, in the future, a *Champsocephalus gunnari* fishery at the scale experienced at the beginning of the fishery (SC-CAMLR-XIX, Annex 5, paragraph 10.3).

ATTACHMENT C

AGENDA

Workshop on Approaches to the Management of Icefish
(Hobart, Australia, 3 to 5 October 2001)

1. Introduction
    1.1 Appointment of Convener
    1.2 Appointment of Rapporteurs
    1.3 Review of Terms of Reference
    1.4 Adoption of the Agenda

2. Presentation of papers

3. Review and characterisation of fisheries
    3.1 Brief review and comparison of catch and effort history of the main fisheries

4. Management needs (top-down approach)
    4.1 Current management measures
        4.1.1 Catch limits
        4.1.2 Season length
        4.1.3 Closed areas
        4.1.4 Fishing methods
        4.1.5 Minimum mesh size and fish size
    4.2 Information needs for management

5. Review of data
    5.1 Biology and demography
        5.1.1 Age
        5.1.2 Growth
        5.1.3 Mortality
        5.1.4 Reproduction
        5.1.5 Diet
    5.2 Stock identity and structure
        5.2.1 Large-scale stock identity and movements
        5.2.2 Shelf distribution and movements (horizontal and vertical migration, segregation by age and size)
        5.2.3 Recruitment and year class strength

6. Ecosystem considerations
    6.1 Predator/prey relationships
    6.2 Ecosystem changes since the start of the fishery (early 1970s)
    6.3 By-catch
    6.4 Incidental mortality
    6.5 Effects of fishing gear

7. Assessment Methods
    7.1 Previous/current CCAMLR assessments
    7.2 New methods and modifications to previous/current methods
    7.3 Future monitoring
        7.3.1 Surveys (frequency, timing, bias)
        7.3.2 Experimental fishing

8. Management Procedures
    8.1 Management procedures
        8.1.1 Short-term versus long-term management
        8.1.2 The need for harmonising management across fisheries
    8.2 Performance of management procedures under various scenarios
        8.2.1 Fluctuations and/or high uncertainty in M
        8.2.2 Ecological regime (carrying capacity)
        8.2.3 Currency of information
        8.2.4 Others?

9. Recommendations of WG-FSA
    9.1 Future assessment
    9.2 Future management

10. Adoption of the report

11. Close of the workshop.

ATTACHMENT D

LIST OF DOCUMENTS

Workshop on Approaches to the Management of Icefish
(Hobart, Australia, 3 to 5 October 2001)

WAMI-01/1	Provisional Annotated Agenda for the CCAMLR Workshop on Approaches to the Management of Icefish
WAMI-01/2	List of participants
WAMI-01/3	List of documents
WAMI-01/4	The fishery for *Champsocephalus gunnari* and its biology at Heard Island (Division 58.5.2) R. Williams, E. van Wijk, A. Constable and T. Lamb (Australia)
WAMI-01/5	Acoustic assessment of potential bias in abundance estimates of mackerel icefish from trawl surveys E. van Wijk, T. Pauly, A. Constable and R. Williams (Australia)
WAMI-01/6	Some thoughts of mackerel icefish distribution in connection with krill distribution S.M. Kasatkina, Zh.A. Frolkina, A.P. Malyshko and V.A. Senioukov (Russia) (*CCAMLR Science*, submitted)
WAMI-01/7	On assessment of instantaneous natural mortality rate of mackerel icefish (*Champsocephalus gunnari*) from South Georgia subarea Zh.A. Frolkina, R.S. Dorovskikh (Russia)
WAMI-01/8	Possible causes of variation of *Champsocephalus gunnari* vertical and horizontal distribution Zh.A. Frolkina and S.M. Kasatkina (Russia) (*CCAMLR Science*, submitted)
WAMI-01/9	Proposals for improvement of census surveys for mackerel icefish quantitative assessment – design of acoustic trawling survey in Subarea 48.3 S.M. Kasatkina, Zh.A. Frolkina and P.S. Gasyukov (Russia)
WAMI-01/10 Rev. 1	Notes on *Champsocephalus gunnari* biology, availability, diet and spatial distribution in the South Shetland and South Orkney Islands (Subareas 48.1 and 48.2) C.D. Jones and J. Emery (USA)

WAMI-01/11	Occurrence by-catch juvenile *Champsocephalus gunnari* under krill fishing in Subarea 48.2 in May to July 1999 V.A. Bibik and L.K. Pshenichnov (Ukraine)
WAMI-01/12	Estimation of relative fishing power of vessels carried out bottom trawl survey off South Georgia P.S. Gasyukov (Russia)
WAMI-01/13	Biological reference points for *C. gunnari* based on the stock assessment with integrated statistic methods (XSA) P.S. Gasyukov and R.S. Dorovskikh (Russia)
WAMI-01/14	Assessments of mackerel icefish I. Everson (United Kingdom), S. Kasatkina (Russia), C. Goss and M. Belchier (United Kingdom)
WAMI-01/15 Rev. 1	Icefish fishery information Secretariat
WAMI-01/16	Distribution of mackerel icefish by size-group at South Georgia A.W. North and I. Everson (United Kingdom)

Other Documents

WG-FSA-01/30	Preliminary analysis of seabird by-catch in the South Georgia icefish fishery D.J. Agnew, N. Ansell and J.P. Croxall (United Kingdom)

ATTACHMENT E

BIBLIOGRAPHY ON *CHAMPSOCEPHALUS GUNNARI*

BIBLIOGRAPHY ON *CHAMPSOCEPHALUS GUNNARI*

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