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PROTECTING YOUNG FISH AND SPAWNING AGGREGATIONS OF *CHAMPSOCEPHALUS GUNNARI* IN SUBAREA 48.3 (SOUTH GEORGIA): A REVIEW

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Abstract

The need to protect young fish and spawning aggregations in fisheries generally, and specifically in the *Champsocephalus gunnari* fishery in Subarea 48.3, is reviewed. Mechanisms available to achieve these objectives are discussed, including the measures put in place by CCAMLR to date. These measures are re-examined in the light of new information, and a strategy for the future protection of young fish and spawning aggregations of C. *gunnari* in Subarea 48.3 is considered. This comprises a combination of existing measures, including minimum mesh size and fish size, and a proposed new closed season from 1 March to 31 May.

Résumé

La nécessité de protéger les concentrations de jeunes poissons et de frayères dans les pêcheries en général, et plus précisément dans celle de *Champsocephalus gunnari* de la sous-zone 48.3, est étudiée. Les mécanismes disponibles pour atteindre ces objectifs sont examinés, notamment les mesures mises en place par la CCAMLR à ce jour. Ces mesures sont revues à la lumière des nouvelles informations disponibles, et l'avenir des concentrations de jeunes poissons et de frayères de *C. gunnari* dans la sous-zone 48.3 est envisagé par une stratégie protectrice comprenant les mesures actuelles, taille minimale de maillage et du poisson incluse, et la fermeture éventuelle de la saison du 1er mars au 31 mai.

Резюме

Обсуждается необходимость охраны молоди и нерестовых скоплений при промысле вообще, и при промысле *Champsocephalus gunnari* в Подрайоне 48.3 в частности. Рассматриваются способы достижения этих целей, в т.ч. установленные на сегодня АНТКОМом меры. Эти меры анализируются в свете новой информации, а также рассматривается стратегия будущей охраны молоди и нерестовых скоплений *C. gunnari* в Подрайоне 48.3. Такая стратегия включает комбинацию существующих мер (например, о минимальном размере ячеи и рыбы) и предложения о новых сроках закрытого сезона – с 1 марта по 31 мая.

Resumen

Se consideró la necesidad de proteger las concentraciones de peces juveniles y las concentraciones en desove en las pesquerías en general, y específicamente en la pesquería de *Champsocephalus gunnari* en la Subárea 48.3. Se discuten los mecanismos disponibles para alcanzar estos objetivos, incluidas las medidas adoptadas por la CCRVMA a la fecha. Se examinaron estas medidas a la luz de la información más reciente, y se consideró una estrategia para la protección de las concentraciones de peces juveniles y las concentraciones en desove en las pesquerías de *Champsocephalus gunnari* en la Subárea 48.3. Esta estrategia combina las medidas existentes, incluidas el tamaño mínimo de la luz de malla y la talla mínima de los peces, y una propuesta para clausurar la temporada de pesca durante el período del 1° de marzo al 31 de mayo.

Keywords: South Georgia, Subarea 48.3, mackerel icefish, fisheries management, closed season, closed area, spawning aggregation, juvenile fish, CCAMLR

INTRODUCTION

Since 1984, CCAMLR has introduced a variety of conservation measures for the *C. gunnari* fishery in Subarea 48.3 which, whether specifically intended or not, have had the potential both to reduce the mortality of young fish and to protect spawning aggregations. Listed chronologically, these include closed areas, mesh size regulations, closed seasons, and, most recently, avoidance of catches of small fish. The CCAMLR Scientific Committee has also been active in encouraging the monitoring and evaluation of the catch of juvenile and larval *C. gunnari* in the krill fishery (e.g. Everson et al., 1991).

Due to the rapid decline of the fishery in the late 1980s and the lack of any substantial commercial catches since the 1989/90 season, very few data are available to determine the extent to which these measures have been successful. Surveys and stock assessments since the early 1990s have demonstrated that *C. gunnari* biomass at South Georgia underwent several major declines during a period when no commercial fishing was taking place (Parkes, 1993; Everson et al., 1999). It is therefore difficult to show benefits resulting directly from these measures. Perhaps for this reason the requirement to protect young fish and spawning aggregations, and how this is best achieved, has not been discussed in depth by the Scientific Committee nor its Working Group on Fish Stock Assessment (WG-FSA) for many years.

Despite the lack of recent data, there is evidence from the earlier period of the fishery, and fisheries for this species in other areas, of the need for management measures that reduce the mortality of young fish and protect the spawning season during times when the commercial fishery is operating. Some very modest success was achieved by one vessel operating in the commercial fishery in the 1998/99 season. It is possible that interest from fishing companies will increase in the short term[1]. It would be prudent, therefore, in advance of a resumption of full-scale commercial operations, to consider the most appropriate measures for protecting young fish and spawning aggregations in the light of current knowledge of the distribution and spawning behaviour of *C. gunnari*. This is also pertinent following the introduction in 1998 of a new CCAMLR 'fishing year' (CCAMLR, 1998, paragraphs 9.1 and 9.2). This runs from 1 December to 30 November, and has specific implications for the closed season applied in the *C. gunnari* fishery in Subarea 48.3 since 1987/88.

This paper reviews briefly the need to protect young fish and spawning aggregations in fisheries generally, and specifically in the *C. gunnari* fishery in Subarea 48.3. It examines the mechanisms available to achieve these objectives, and catalogues the measures put in place by CCAMLR to date. These measures are re-examined in the light of new information, and a strategy for the future protection of young fish and spawning aggregations of *C. gunnari* in Subarea 48.3 is proposed.

THE NEED TO PROTECT YOUNG FISH AND SPAWNING AGGREGATIONS

The need to protect young fish and spawning aggregations of commercially fished populations is a well-established principle in fisheries management. Both are important components of a management strategy which aims to promote optimal harvesting, whilst at the same time maintaining a high likelihood of good recruitment in future years.

The mortality of young fish may need to be controlled to avoid both growth overfishing and recruitment overfishing. Outside of the tropics, growth rates of exploited fish are relatively straightforward to measure and are therefore generally well known. Optimal harvesting with respect to growth is consequently relatively easy to model using a classical yield-per-recruit type analysis. Several well-known reference points associated with this approach have been developed, including F_{max} and $F_{0.1}$. Performing a yield-per-recruit analysis in 1987, the Scientific Committee noted the benefits associated with an increase in the age at first capture of *C. gunnari* from 2–3 years old to 3–4 years old, particularly at high fishing mortalities (greater than 0.6). Relative benefits at low fishing mortalities (in the region of 0.2) were much less (SC-CAMLR, 1987, paragraphs 5.49 and 5.50).

Recruitment overfishing is usually much harder to determine, because the relationship between spawning stock size and subsequent recruitment tends to be complicated by exogenous environmental factors. Nevertheless, protection of young fish to ensure that sufficient numbers

[1] After the original drafting of this paper, during the 1999/2000 CCAMLR season, two commercial trawlers fished successfully for *C. gunnari* in Subarea 48.3, achieving catch rates in the region of 20–50 tonnes per day. The total catch in the fishery was limited to 4 036 tonnes by a CCAMLR conservation measure (Conservation Measure 175/XVIII; CCAMLR, 1999).

survive to adulthood, so they can reproduce and contribute to the recruitment of future generations, is accepted as a sensible approach to fisheries management. Even in the absence of an explicit stock–recruitment relationship, many fisheries management strategies, including those of CCAMLR, are based on the maintenance of the spawning stock size above some pre-specified threshold level which is considered to be associated with a higher likelihood of 'good' recruitment (e.g. 20% of the pre-exploitation level, as used in the CCAMLR generalised yield model).

In addition to the protection of young fish to maintain the spawning stock biomass, the spawning event itself may need to be protected, particularly if the fish aggregate to the extent that fishing might lead to disruption or dispersal. It is also prudent to avoid concentration of fishing activity on spawning aggregations, because this may lead to concentration of the fishery into a short time period, during which the entire catch limit can be taken, rather than fishing activity being more spread out over the year.

MECHANISMS AVAILABLE FOR PROTECTING YOUNG FISH AND SPAWNING AGGREGATIONS

Gear Regulations and Minimum Size Limits

One of the most commonly used approaches to increasing the age at first capture is to establish technical controls on fishing gear, such as minimum mesh sizes and hook sizes, which change the selectivity characteristics of the fishery. Minimum mesh sizes are based on the idea that the size of fish which can escape through the net is closely related to the size of the mesh. Therefore a particular mesh size will be associated with a particular size (and therefore age) at first capture.

Mesh regulations have been criticised because the selection characteristics often change with factors other than the size of the mesh. For example, shoaling pelagic species such as herring and mackerel may be caught in such large quantities that they blind the meshes of the net and selection becomes ineffective. Also, there is evidence that fish escaping through the net suffer high mortality, thus rendering the approach less effective in protecting the future spawning biomass. Nevertheless, due to the relative simplicity of the approach, minimum mesh sizes have been applied in many trawl and purse seine fisheries throughout the world.

A common related measure, adopted either in support of mesh regulations or in its own right, is to set a minimum size limit of the fish themselves. This approach aims to discourage deliberate targeting of small fish, but as with most regulations it also has its drawbacks. In this case, the problem is increased discarding of undersized fish. To avert this, it may be better to introduce some form of incentive to encourage the fishery to avoid catches of small fish in the first place. One example is the approach adopted by CCAMLR which requires vessels to move to another fishing ground in the event that undersized fish make up more than a certain percentage of the total catch (e.g. 10%). It is not, however, illegal to process and land undersized fish if they are caught.

Closed Seasons and Closed Areas

Indirect methods of regulating fisheries, such as closed seasons and closed areas, were amongst the earliest strategies to be used in fisheries management. These methods are relatively easy to implement and enforce, flexible in application (areas and seasons can be opened and closed relatively rapidly in response to changing circumstances), and thought to be beneficial in the protection of vulnerable resources, and are perceived to be an equitable way of regulating all participants in a fishery.

The rationale underlying the use of closed seasons is the need to prevent a fishery from operating at a time when fishing activity may cause disproportionate harm either to the target fish stock or other species affected, either directly or indirectly. For example, a fishery may be closed to prevent it from targeting, and thus disrupting and/or dispersing fish which are congregating for spawning. Fishing would threaten the success of the spawning event and subsequent recruitment, and thus cause problems for the population over and above the simple removal of adult fish (which is taken into account in the stock assessment process). Closed seasons may also be imposed for short-lived, fast-growing species, where the fishery concentrates on a single year class, such as shrimp or squid. In these fisheries, a delay in the onset of fishing will allow individuals to reach optimal size before they are harvested.

By-catch species may also benefit from the setting of closed seasons if they are more vulnerable to capture at certain times of the year. In certain parts of the CCAMLR Convention Area, for example, closed seasons have been used to

mitigate the incidental mortality of seabirds by restricting the longline fishery to operating in the winter months when particularly vulnerable seabird species are less active, and therefore less likely to be caught.

If specific locations can be identified where fish aggregate to spawn, nursery areas where young fish congregate to feed, or by-catch is particularly high, then closed areas provide an alternative or complementary approach to the use of closed seasons. Closed areas may also be used to segregate a resource between inshore small-scale and offshore larger-scale fishing interests. The principle of closed seasons and areas may also be used in combination to close specific vulnerable areas at certain times of the year.

On the negative side, closed seasons and areas are thought to be less useful for controlling the overall level of exploitation, because instead of reducing the amount of fishing, they tend to simply divert activity to another time or area, where the problem will be perpetuated. They are particularly criticised for doing nothing to discourage the development of overcapacity. By contrast, they may actually encourage overcapacity as fishers strive to maximise production during the open season by investing in more efficient vessels and equipment.

CCAMLR CONSERVATION MEASURES AIMED AT PROTECTING YOUNG FISH AND SPAWNING AGGREGATIONS

Over the past 18 years CCAMLR has introduced a variety of conservation measures intended to protect young fish, including gear restrictions, fish size limits, closed seasons and closed areas. These are summarised, according to type of measure, in Table 1.

The Scientific Committee has discussed approaches to protect spawning fish since its first meeting in 1984. In that year the Scientific Committee noted that 'an extremely useful management measure imposed by the French authorities around Kerguelen was closing specific areas at certain times of the year to protect spawning fish', but that 'unfortunately, spawning grounds for fish around South Georgia have not yet been identified, thus ruling out an option of this type' (SC-CAMLR, 1984, paragraph 7.40).

The only CCAMLR conservation measure which has been linked to the protection of spawning is the long closed season between 1 April and the end of the following Commission meeting, first introduced in the 1988/89 season (see Table 1[2]). The original rationale for this was to protect young fish[3], however since the early 1990s, language in the Commission and Scientific Committee reports has associated it with the protection of spawning aggregations[4]. Given that the start of the closure coincides approximately with the start of the spawning season, and there is no evidence of a time of year when a closed season would specifically protect young fish, this appears to be a more logical association.

The only other CCAMLR conservation measure which has had the potential effect of protecting fish during the spawning season was Conservation Measure 1/III (adopted in 1984) which closed to fishing waters within 12 n miles of South Georgia. At the time of its introduction, there was clearly a perception that this would have some

[2] Table 1 is up to date as of the 1998/99 fishing season. Following discussion at the 1999 meeting of CCAMLR, resulting from the submission of this paper to WG-FSA, the closed season in the *C. gunnari* fishery in Subarea 48.3 for the protection of spawning aggregations was changed from between 1 April and 30 November, to between 1 March and 30 May (Conservation Measure 175/XVIII). The Scientific Committee agreed that to protect spawning, the closed season should apply to the areas where spawning is known to take place, but the Committee was not in a position at its 1999 meeting to provide unequivocal advice on the extent of the area within Subarea 48.3 which needed to be protected. The closed season adopted by the Commission applied to the whole of Subarea 48.3 (SC-CAMLR, 1999, paragraphs 5.99 to 5.105; CCAMLR, 1999, paragraph 9.19).

[3] The 1987 reports of the Commission and Scientific Committee clearly link the 1987/88 closure to the protection of young fish in order to increase yield per recruit.

[4] In his 1989 paper on the reproduction of *C. gunnari*, Kock referred to this closed season as being introduced specifically to protect spawning. Kock concluded that the spawning activities of *C. gunnari* and those of other exploited species could best be protected by the establishment of a permanent closed fishing season from 1 March to the end of each year's Commission meeting (Kock, 1989). Following this lead, in 1990 the Commission recommended that 'a closed season between 1 April and 4 November 1991 should be implemented to protect spawning stock' (CCAMLR, 1990, paragraph 13.18). In 1992 the WG-FSA report (SC-CAMLR, 1992, paragraph 6.80) adopted similar language, stating that 'the Working Group recommended the closure of directed fishing for *C. gunnari* between 1 April and the end of the Commission meeting in 1993 (as in the 1990/91 season; Conservation Measure 21/IX) to protect spawning'.

benefit in restoring depleted stocks through the protection of juvenile fish. There was no specific knowledge of the location of spawning grounds of *C. gunnari*, therefore the benefit of this approach in protecting inshore spawning areas (see the next section) was not recognised. Although Conservation Measure 1/III had no fixed lifespan, it has not been in force since the 1989/90 season (see Table 1).

DISCUSSION AND RECOMMENDATIONS

Protecting Young Fish

The previous section shows how CCAMLR has used several approaches to protect young fish in trawl fisheries, including minimum mesh size, minimum fish size, closed seasons and closed areas. The current conservation measures for *C. gunnari* in Subarea 48.3 include examples of the first three of these (Table 1). The following paragraphs discuss the applicability of these measures based on current knowledge.

Mesh size regulations are widely used in fisheries management to reduce the catch of small fish. Substantial work was done in the mid to late 1980s by scientists of several CCAMLR Members to determine appropriate selection factors, and mesh regulations have been established in the *C. gunnari* fishery as a result. This measure (i.e. Conservation Measure 19/XI; CCAMLR, 1992) is therefore appropriate and should remain in force.

The minimum fish size provision, introduced in Subarea 48.3 in 1997, is also well designed for its purpose. Stratified length-frequency distributions from scientific bottom trawl surveys in Subarea 48.3 have shown that smaller *C. gunnari* tend to be found in shallower waters. Superimposed on this broad pattern is the observation that dense aggregations of fish, which form on the South Georgia shelf in some years, at certain times of the year may show a high degree of age specificity. For example, during the 1990 *Hill Cove* survey most of the aggregations encountered were composed mainly of 3- and 4-year-old fish (27–40 cm). One, however, was composed almost entirely of 1 and 2 year olds (about 12–30 cm). In addition, trawl samples to the east end of South Georgia are frequently composed of mostly 1-year-old fish (Parkes, 1993).

These samples were taken with a bottom trawl, and therefore may not be representative of catches under commercial conditions, but the important conclusion is that the most appropriate way to avoid catches of young fish is through spatial rather than temporal measures. Currently there is not sufficient information available to identify areas where small fish predominate, and in years when dense aggregations form, they may be transient features which appear in different places. At this stage, therefore, the best approach is to require vessels to move to another fishing location when they encounter high concentrations of small fish. This is exactly what the current conservation measure does[5].

Prior to its first introduction in 1987/88[6], there was no scientific evidence that the extended closed season (i.e. 1 April to 30 November) had any likelihood of achieving its stated aim of protecting young fish (for example, see CCAMLR, 1988, paragraph 111). In 1988 the Scientific Committee offered no new advice, and the Commission requested a review of all existing data on *C. gunnari* relevant to proposing closed seasons in the fishery to protect juvenile fish (CCAMLR, 1988, paragraph 112). The advice on closed seasons provided to the Commission the following year was related to their use in protecting spawning, not young fish (SC-CAMLR, 1989a, paragraphs 198 and 199). Unlike the seasonal spawning event, there is still no information that young fish are more vulnerable to the fishery at certain times of the year. Whilst a closed season may be useful in protecting spawning, it does not appear to be an appropriate management measure for reducing the vulnerability of young fish in the fishery.

According to the information currently available, the existing minimum mesh size and fish size measures are the most appropriate for protecting young fish in the fishery for *C. gunnari* in Subarea 48.3. Since 1996/97 there has been a requirement that all vessels participating in this fishery have a CCAMLR observer on board. This will ensure that CCAMLR receives accurate information on the implementation of both of these measures. It is therefore suggested that, for the purposes of reducing fishing mortality on young fish, these measures are sufficient.

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[5] During its fishing campaign in February–March 1999, the *Zakhar Sorokin* moved 5 n miles after five of its 86 hauls to comply with provision 4 of Conservation Measure 153/XVII (King, 1999 – CCAMLR observer report).

[6] In that first year it ran from 1 April 1988 to 1 October 1988. It has since been extended to 30 November due to the change in the CCAMLR fishing season, adopted in 1998 (see Table 1).

Table 1: Summary of measures introduced by CCAMLR to protect young *Champsocephalus gunnari* in Subarea 48.3.

Type of Measure	Conservation Measure (CM) Number, Year of Meeting and Provisions Relating to Young Fish	Comments	References
Gear restrictions	CM 2/III, 1984 Minimum mesh size of 80 mm for *C. gunnari*, starting on 1 September 1985, to apply indefinitely.	• Previously applied unilaterally by the Soviet fleet since 1980. • Considered by the Scientific Committee to give protection to juvenile fish.	SC-CAMLR, 1984, paragraphs 7.25–7.29; CCAMLR, 1984, paragraph 42
	1987 Minimum mesh size.	• The 1987 meeting of WG-FSA considered the possibility of increasing the mesh size limit to give further protection specifically for young *C. gunnari*, but there was insufficient information available at that time to show the relationship between mesh sizes in the *C. gunnari* trawl fishery and the age at first capture.	SC-CAMLR 1987, paragraph 5.51
	CM 19/IX, 1990 Revision of the minimum mesh size for *C. gunnari* from 80 mm to 90 mm, starting on 1 November 1991, to apply indefinitely.	• In 1989 the Scientific Committee recommended changes to minimum mesh sizes based on the reproduction of *C. gunnari* (Kock, 1989), and trawl selectivity (Efanov et al., 1990; Slosarczyk et al., 1989). The Scientific Committee concluded: 'assuming that the actual size of twine mesh in commercially used codends is on average 10% greater than the nominal mesh (Zaucha, 1988), the introduction of the following mesh sizes should be considered [in Subarea 48.3 for the fishery targeted at *C. gunnari*]: 80 mm, to protect immature fish, or 90 mm, to protect first spawners, or 100 mm, to give an age at first capture of 4 years.' • The Scientific Committee also concluded that chafers should not be used, and that codends should be made from diamond-shaped mesh of twine no thicker than 4.5 mm. • In 1989, the Commission decided that it could not act on the advice of the Scientific Committee on mesh sizes, pending the results of further mesh selectivity experiments to be conducted by the USSR. • The results of these experiments were presented at the 1990 meeting and revised mesh size limits were adopted.	SC-CAMLR, 1989b, paragraph 3.18
Fish size limits	1984 Limits voluntarily applied by the Soviet fleet.	• Previously applied unilaterally by the Soviet fleet since 1980. • In 1984, the Commission recognised the importance of minimum fish size limits and the need for formal adoption of appropriate measures in the near future, but no fish size limit was adopted at that meeting.	SC-CAMLR, 1984, paragraph 7.19; CCAMLR, 1984, paragraphs 43 and 44
	CM 123/XVI, 1997 Fishing vessels must move at least 5 n miles away if more than 10% of the catch (by number) of *C. gunnari* is composed of fish less than 24 cm long.[1]	• Introduced to reduce further the catch of young *C. gunnari* in Subarea 48.3. • 24 cm is marginally below the length at first spawning reported in Kock (1989).	

Table 1 (continued)

Type of Measure	Conservation Measure (CM) Number, Year of Meeting and Provisions Relating to Young Fish	Comments	References
Closed areas	CM 1/III, 1984 Closure of waters within 12 n miles of South Georgia.	• Previously applied unilaterally by the Soviet fleet since they started fishing around South Georgia. • Considered by the Scientific Committee to give protection to juvenile fish. • Conservation measure was to remain in force indefinitely, however in 1989, the Commission decided that 'As there was no consensus on the retention of Conservation Measure 1/III, it is no longer in force'.	SC-CAMLR, 1984, paragraphs 7.25–7.29; CCAMLR, 1989, paragraph 76
Closed seasons	CM 8/VI, 1987 Closure of the fishery for *C. gunnari* in Subarea 48.3 from 1 April to 1 October 1988.	• In 1987, the Scientific Committee suggested that to protect young *C. gunnari* (as an alternative to mesh regulations), catches should be reduced at a time when young fish predominate in the population. However, there was no indication of a particular time of the year when a closed season would specifically benefit young fish in the *C. gunnari* stock. • The Commission noted that the Scientific Committee had not provided advice on the application of mesh sizes, closed areas or closed seasons to the fishery for *C. gunnari* in Subarea 48.3. Nevertheless, the Commission adopted this closed season 'to provide additional protection for young fish'.	SC-CAMLR, 1987, paragraph 5.53; CCAMLR, 1987, paragraphs 66, 67 and 76
	CM 10/VII, 1988 Closure of the fishery between 4 November 1988 and 20 November 1989.	• Based on the need to protect the entire stock, not just young fish and spawning aggregations. • The reopening date was agreed because it was several days after the end of the following Commission meeting, therefore enabling further scientific analyses and management decisions prior to the end of the closure period.	
	CM 15/VIII, 1989 Closure of the fishery from 20 November 1989 to 15 January 1990 and from 1 April 1990 to the end of the Commission meeting in 1990 (4 November 1990).	• Two closed seasons were imposed. The first was for administrative purposes[2], and had nothing to do with protecting young fish. The second was a continuation of the long closed season first established at the 1987 meeting (now extended to the end of the following Commission meeting).	
	CM 21/IX, 1990 Closure of the fishery from 1 April 1991 to the end of the Commission meeting in 1991[3].	• The early closed season adopted in 1989 (see above) was not repeated in the 1990/91 season and subsequent years.	
	CM 153/XVII, 1998 Closure of the fishery from 1 April 1999 to 30 November 1999.	• In accordance with the agreement at the 1998 meeting of the Commission that the new CCAMLR 'fishing year' would begin on 1 December of each year and end on 30 November of the following year.	CCAMLR, 1998, paragraphs 9.1 and 9.2

1 Introduced in 1997/98 and used in all subsequent seasons.

2 CCAMLR 1989, paragraph 85, '[The Commission] noted the desire of several Members of the Commission that the 1989/90 fishery should not start until 15 January 1990'.

3 From 1990 until 1997/98, a closed season from 1 April until the end of the Commission meeting in the following year was consistently applied in years when the *C. gunnari* fishery in Subarea 48.3 was open.

Protecting the Spawning Season

If protecting young fish were the only objective, the discussion above shows that it would be appropriate to remove the requirement for an extended closed season from the conservation measure for *C. gunnari* in Subarea 48.3. However, it is also important to protect spawning, and given the temporal nature of this activity, a closed season may be more applicable in this respect.

Peak spawning of *C. gunnari* at South Georgia occurs within a short period of two to four weeks in autumn, as evidenced by studies of maturity condition and length distributions of larvae (Kock, 1992). However, the spawning season varies from year to year. According to Kock (1989), spawning at South Georgia occurs from March to May, but may even start in February and extend to June. Recent evidence from surveys indicates that interannual variation in spawning time may be dependent on the condition of the fish in relation to krill availability (Everson et al., 1996, 1997).

In common with other species of icefish at South Georgia, *C. gunnari* are believed to move inshore to spawn, congregating in the deeper inshore waters and fjords. No direct observations have been made, for example using tagging experiments, but the preponderance of fish in pre-spawning condition in coastal waters from March onwards suggests a spawning migration to nearshore waters and fjords (Kock, 1989). Inshore movement of fish for spawning has also been described for the population at Kerguelen (Duhamel, 1987). Inshore spawning grounds at South Georgia were first described by Olsen (1955), and confirmed by Kock (1981), who recorded the presence of dense pre-spawning aggregations in the deeper parts of Fortuna, Cumberland and Royal Bays in late March to mid-April, 1978. Spawning is also known to take place on the shelf at 100–125 m depth (Permitin, 1973; Sosinski, 1985), although its extent is not known.

At its meeting in 1999, WG-FSA again discussed the issue of protection of spawning aggregations. Information presented to the meeting in a background paper (Frolkina, 1999) provided evidence of spawning being concentrated in inshore waters in April and May, as indicated by the predominance of fish in maturity stage 5 (spent) and a drop in the catch per unit effort on the shelf.

It seems that the most appropriate means of protecting spawning aggregations at South Georgia would be the same as that used in the fishery for *C. gunnari* around Kerguelen (southern Indian Ocean), and described by the Scientific Committee in 1984 as 'extremely useful' (SC-CAMLR, 1984, paragraph 7.40), i.e. to close specific areas at certain times of the year. In 1984 there was not sufficient information available to implement such a strategy at South Georgia, but the information summarised in this paper, arising from research over the past 15 years, provides a basis for reconsidering the current management approach.

The most appropriate action, therefore, would be to close the areas where spawning takes place for the duration of the spawning season. The period of the closure, allowing for some interannual variability in the spawning season, could reasonably be set as 1 March to 31 May each year. This would start the closure one month earlier than the closure start date in the 1998/99 season, and would therefore offer more protection in years when spawning starts early in the season. If the link between fish condition, biomass, spawning and krill availability postulated in various recent publications (Everson et al., 1996, 1997, 1999; Agnew et al., 1998) is an important driving force, then years when spawning starts early might reasonably be expected to correlate with years when spawning biomass is high. This extra month of protection could therefore prove valuable in promoting the likelihood of success of the high spawning potential in such years.

The proposed reopening of the fishing season is much earlier than that which currently applies (1 June, rather than 1 December). This should not, however, be considered as a weakening of the current management strategy. It is, instead, a more logical link between the management objective and the measure designed to achieve it. If protection of the spawning season is the objective, then there is no apparent biological reason why the fishery should be closed between June and November, providing the catch limit has not been reached.

Defining areas to which this closure should apply is less straightforward, because information regarding the location of spawning is incomplete. Frolkina (1999) presented a chart of the South Georgia region illustrating locations of aggregations of juvenile fish and pre-spawning fish, coastal spawning grounds and the general direction of pre-spawning migrations, based on data collected over a number of years in the former Soviet fishery and research cruises (Figure 1). The protection of coastal spawning grounds could be achieved, for example, by closing the area adjacent to the island to cover the fjords and immediate inshore areas where spawning is known to occur. Some of the bays and shallow shelf areas have not been surveyed,

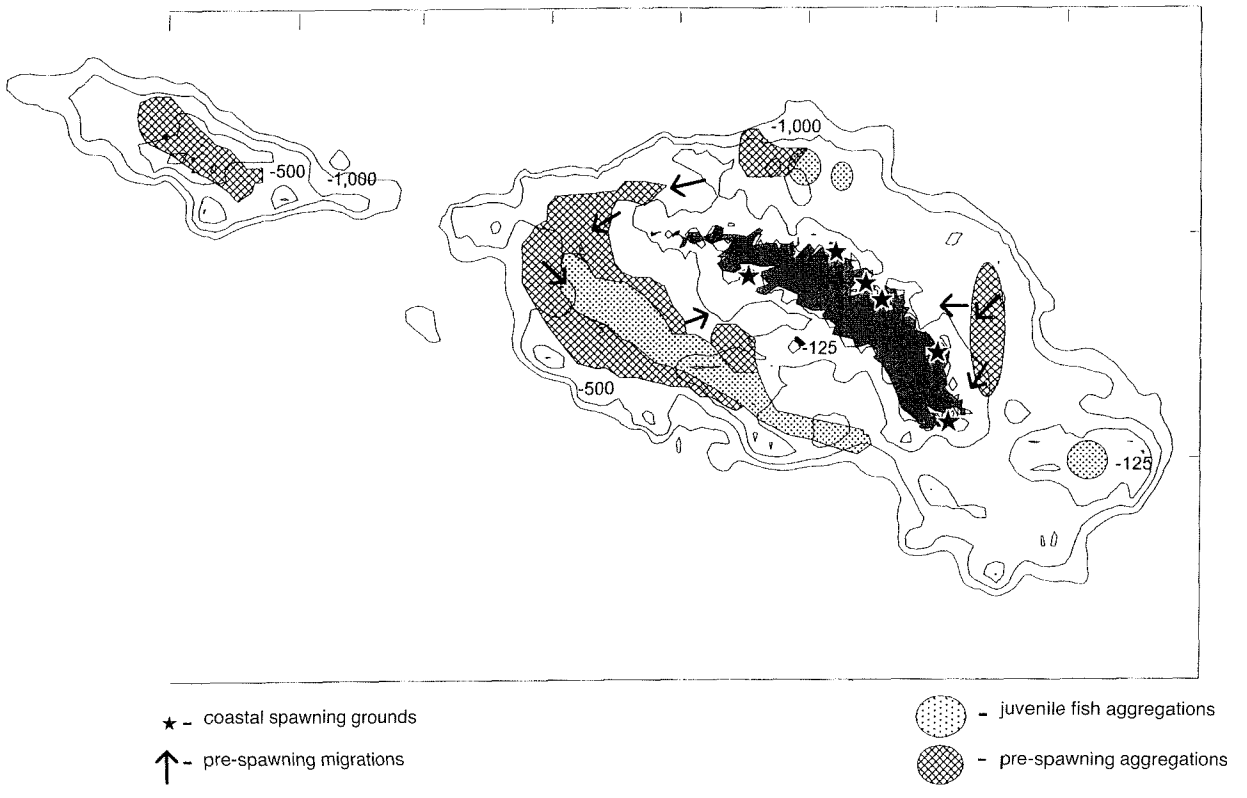

Figure 1: Spawning grounds, main aggregation of juvenile icefish and pre-spawning migrations. (Redrawn from Frolkina (1999)).

but it is reasonable to assume that areas similar to those which have been surveyed are also likely to be spawning grounds for *C. gunnari*. Such a closure would therefore need to be extended to the fjords and bays all around the island.

Whilst Figure 1 tends to confirm the idea that spawning takes place mainly inshore, the degree to which spawning also occurs on the shelf remains uncertain. Biological information is available from a number of bottom trawl surveys undertaken around South Georgia during the 1980s and 1990s, but unfortunately, there are few data from the peak spawning period. Also, these surveys were designed predominantly to estimate biomass and not to identify spawning locations.

Fish spawning on the shelf could be protected by restricting fishing during the spawning season to areas of the shelf deeper than some fixed depth limit, such as the lower limit of spawning reported in the literature (e.g. 125 m – Permitin, 1973 and Sosinski, 1985 reported in Kock, 1989). Alternatively, it might be possible to identify a zone within a certain distance of the island, which would protect the spawning grounds if it were closed to fishing. This would be more attractive from the point of view of monitoring and enforcement[7]. A relatively straightforward spatial analysis of seabed areas within fixed ranges of the island could be undertaken with the goal of making the closed area as small as possible, whilst still giving sufficient protection to the areas of interest. However covering waters down to a fixed depth limit by applying a range limit around the island is made difficult by the uneven submarine topography around South Georgia (Figure 1).

Given the uncertainty regarding the extent and distribution of spawning over the shelf, a more precautionary approach would be to close an area covering the whole of the known distribution of *C. gunnari* in the South Georgia region. Trawl surveys indicate that *C. gunnari* occur from inshore waters down to a maximum depth of approximately 350–400 m, with the highest densities found between 150 and 250 m. The most straightforward way of achieving a complete closure of the

[7] It is worth noting that the monitoring and enforcement of closed areas, either by reference to depth or distance from the island, is well supported by existing requirements for vessels to carry CCAMLR observers (Conservation Measure 175/XVIII) and a satellite vessel monitoring system (Conservation Measure 148/XVII).

waters less than 400 m deep would be to close the whole of the management area within which South Georgia is situated – CCAMLR Subarea 48.3[8].

Further research is needed on the distribution of young fish and spawning aggregations of *C. gunnari* on the South Georgia shelf in order to refine management measures designed to protect the spawning stock biomass and prevent disruption of the spawning process.

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[8] This was the solution adopted by the Commission at its meeting in November 1999. For the 1999/2000 fishing year, a closed season applies for the period 1 March to 31 May in which no fishing for *C. gunnari* is permitted in the whole of Subarea 48.3 (Conservation Measure 175/XVIII; CCAMLR, 1999).

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