APPENDIX E

REPORT OF THE WORKSHOP ON METHODS FOR THE ASSESSMENT OF *DISSOSTICHUS ELEGINOIDES*

(Hobart, Australia, 5 to 9 October 1995)

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INTRODUCTION

1.1 The Workshop on Methods for the Assessment of *Dissostichus eleginoides* (WS-MAD) was held at CCAMLR Headquarters, Hobart, Australia from 5 to 9 October 1995. The Convener, Dr W. de la Mare (Australia), chaired the Workshop. The terms of reference of the Workshop were agreed by the Scientific Committee at its 1994 meeting (SC-CAMLR-XIII, paragraph 2.17).

1.2 The Convener welcomed participants to the Workshop, noting with pleasure the presence of two invited experts, Mr D. Japp from the Sea Fisheries Research Institute, South Africa and Dr A. Zuleta from the Instituto de Fomento Pesquero, Chile.

1.3 The Provisional Agenda was adopted unchanged. The Agenda is included in this report as Attachment A and the List of Participants as Attachment B. Documents submitted to the 1995 Working Group on Fish Stock Assessment (WG-FSA) and referred to in this report are listed in Appendix C of this annex.

1.4 The report was prepared by Drs I. Everson, G. Kirkwood and G. Parkes (UK), K. Sullivan (New Zealand) and Mr R. Williams (Australia).

REVIEW OF POSSIBLE ASSESSMENT APPROACHES

2.1 Under this agenda item, the Workshop first carried out an initial review of the approaches taken in previous CCAMLR assessments of *D. eleginoides*, and of the approaches used in the assessments of the longline fishery for *D. eleginoides* in Chile and the trawl and longline fishery for hake in South Africa. Following this, key problem areas in CCAMLR assessments were identified and potential solutions were discussed in subgroups, drawing particularly on the experience in the Chilean and South African fisheries. Conclusions reached by the Workshop are recorded under this or subsequent agenda items.

Previous CCAMLR Assessments

2.2 The Workshop considered the current state of knowledge as reflected in previous CCAMLR assessments of *D. eleginoides* under four headings: biology and demography, stock identity, abundance and yield.

Biology and Demography

2.3 Discussion on biology and demography of *D. eleginoides* centred on the topics of growth, reproduction, diet and condition.

Growth

2.4 Otolith and scale readings have been used to determine the age of individual fish. Both these methods are widely used in fisheries biology. Shortcomings have been noticed with both methods for *D. eleginoides* which would affect the accuracy of age/length keys derived from them. Results from both methods have been used together in the past and it is therefore important to reconcile any systematic differences between the two methods.

2.5 In the case of otoliths, false checks are occasionally noted which, if not recognised, would cause the age of the individual fish to be overestimated.

2.6 In the case of scales, there is some uncertainty about the time taken for completion of the nucleus and hence the age at which the first annual ring appears. This effect could lead to the underestimation of the fish's age by one year (SC-CAMLR-XI, Annex 5, paragraph 6.124). The annual rings seen on scales tend to blend together towards the edge leading to an underestimation of the age of older, larger fish (SC-CAMLR-XI, Annex 5, paragraph 6.124).

2.7 The Workshop recommended that further efforts be made to improve age determination using otoliths and scales.

2.8 Length frequency distributions derived from samples of fish from trawl catches frequently contain modes at intervals equivalent to years of growth (WG-FSA-91/20[1]). The modes are indistinguishable for fish older than five years; the method is therefore only applicable for juvenile fish.

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[1] Everson, I. 1991. Stock assessment of the Patagonian toothfish (*Dissostichus eleginoides*) at South Georgia. Document *WG-FSA-91/20*. CCAMLR, Hobart, Australia.

2.9 There is evidence that longlining selects large fish (a key factor is the gear itself). Refinements in selectivity can be obtained through variations of both hook and bait. Rigorous trials have not been conducted for longlining of *D. eleginoides* with the result that age/length keys derived from longline data may be biased towards large fish for the younger age classes and smaller fish for the older age classes.

2.10 The Workshop recommended that experiments be designed using trawls and longlines, and be undertaken to determine the magnitude of biases in estimated age/length keys caused by the use of different gear types and sizes, and different bait sizes and species (trawls generally fish in shallower water than longlines).

2.11 Samples from commercial trawl and trawl survey catches may underestimate the proportion of larger and therefore older fish. This is further discussed in paragraph 3.10.

2.12 Given the possible biasing effects of size selectivities, the Workshop agreed that it would be useful to compare growth rates for young and old fish. To examine this, a table of estimates of size-at-age was prepared using data from both trawl catches and surveys and longline catches (Figure 1).

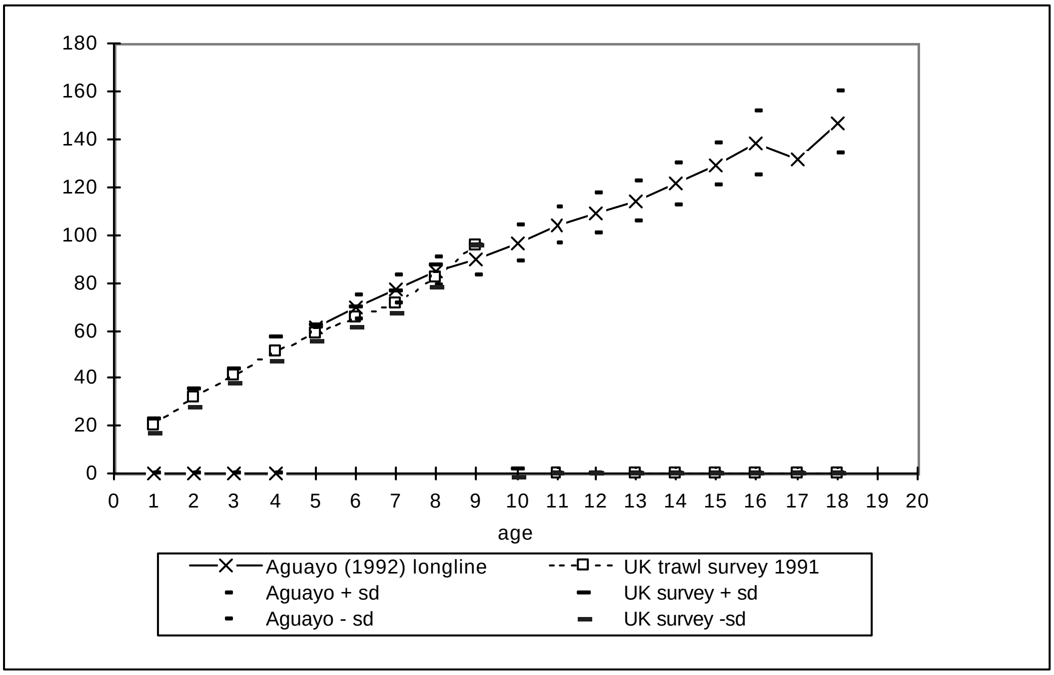


Figure 1: Estimates of size-at-age from both trawl catches and surveys and longline catches.

2.13 Lengths-at-age for *D. eleginoides* from longline fisheries on the Patagonian shelf, around Southern Chile and in the South Georgia and Kerguelen regions were reviewed in 1992 (SC-CAMLR-XI, Annex 5, paragraphs 6.122 to 6.129 and Appendix G). An age/length key not used in this review is available in the CCAMLR database for pre-recruits from a UK trawl survey on the continental shelf around South Georgia in January 1991 (SC-CAMLR-XIII, Annex 5, paragraph 4.24).

2.14 No other age/length data are available.

2.15 A number of problems with the existing data were identified in the review of 1992:

- age/length keys from Kerguelen Island area were based on small numbers of fish from a limited size range;

- at South Georgia, ages were determined from scale readings (see discussion of problems in paragraph 2.6);

- generally, age/length characteristics of an entire stock are unlikely to be represented in the longline catches used to generate these keys (see SC-CAMLR-XI, paragraphs 6.125 and 6.126); and

- most estimates were derived using Ford-Walford plots, which are less reliable than non-linear regressions.

2.16 The available data, except those from the Kerguelen area, were used to generate estimates of the von Bertalanffy growth parameters. A non-linear estimation procedure based on the Levenberg-Marquardt method was used. In these analyses, mean length-at-age was not used; each length-at-age datum was weighted by the number of fish in the sample which were observed with that value. Exploratory analyses were undertaken to investigate the influence of a number of sampling problems on the estimation of the parameters. The analyses comprised the following:

(i) estimation of L_∞, K and t_0 for all samples (males, females, combined);

(ii) using all samples (combined sexes only), estimation of K in all samples with a fixed L_∞ and t_0, where L_∞ was chosen as 170.8 (SC-CAMLR-XI, Annex 5, Appendix G, Table G.4) and t_0 =0; and

(iii) estimation of K as previously but removing size classes likely to be incompletely sampled. The size ranges used were:

UK 1991 trawl survey	all fish < 60 cm
longline catches	all fish > 100 cm.

2.17 The results are presented in Table 1.

Table 1: Estimates of von Bertalanffy growth parameters for *D. eleginoides* in Subarea 48.3 from age/length keys available in the CCAMLR database and in WG-FSA-92/30. See paragraph 2.16 for details. Var = variance; L/L = longline; T = trawl

South Georgia Samples	Sample Method	Estimates from All Data				FIX L_{∞} = 170.8; t_0 = 0					
						All Data		Trawl: Length < 60		Longline: Length > 100	
		Linf	K	t_0	Var	K	Var	K	Var	K	Var
Aguayo (1992)*:											
1. Feb-May 1991 Males	L/L	170.3	0.086	-0.015	49						
2. Feb-May 1991 Females	L/L	177.5	0.082	+0.35	65						
3. Combined (1 + 2) Feb-May 1991	L/L	170.9	0.087	0.16	58	0.085	58.1			0.09	57.4
4. Apr-May 1991 Females	L/L	169.8	0.086	-0.01	59						
5. Apr-May 1991 Males	L/L	170.1	0.087	-0.02	54						
6. Combined (4 + 5) Apr-May 1991	L/L	171.0	0.087	-0.01	57	0.086	57.1			0.089	55.4
7. Feb-Mar 1991 Males	L/L	165.1	0.085	-0.61	42						
8. Feb-Mar 1991 Females	L/L	172.5	0.088	0.162	62						
9. Combined (7 + 8) Feb-Mar 1991	L/L	170.2	0.088	0.162	62	0.086	52.1			0.09	49.1
SUN 1986	T	182.3	0.074	0.819	9	0.074	11.5	n = 2			
UK trawl 1991: Female	T	159.9	0.081	-0.69	14						
Male	T	163.8	0.082	-0.51	19						
Combined sexes	T	162.0	0.081	-0.60	16	0.088	23.5	0.091	19.4		

* Aguayo, M. 1992. Preliminary analysis of the growth of *Dissostichus eleginoides* from the austral zone of Chile and South Georgia. Document *WG-FSA-92/30*. CCAMLR, Hobart, Australia.

Reproduction

2.18 Spawning generally occurs during winter although there are some references to spent fish being taken in December. This may indicate that the gonad maturation and recovery processes are prolonged.

2.19 There is no precise information on spawning location or whether the fish aggregate during the spawning season.

2.20 The few ova that have been found, have been near the surface in deep water. Post larvae and early juveniles spend at least one year in midwater before settling to the bottom. Juvenile fish tend to be found on the shelf and it is thought that they migrate into deeper water as they get older and become sexually mature.

2.21 The maturity scale developed for nototheniids (SC-CAMLR-VIII, Annex 6, Appendix 4) has been used by observers examining catches from the *D. eleginoides* fishery.

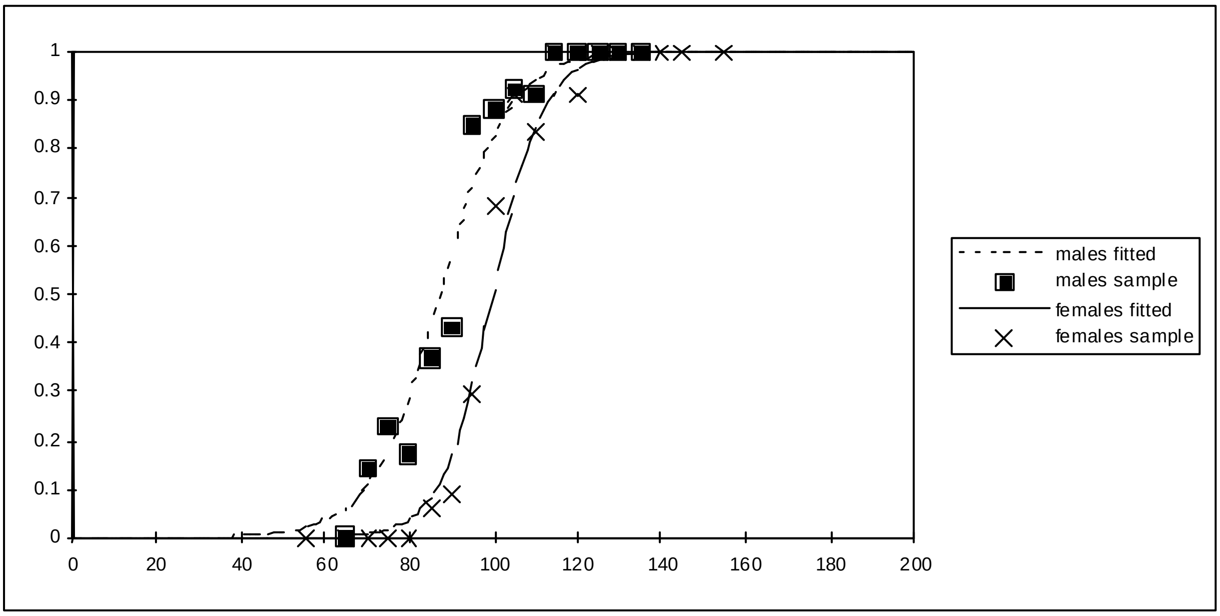
2.22 The results from observer reports available at the meeting were considered by the Workshop. There were major differences in the shape of maturity ogives and length at 50% maturity (L_{m50}) values derived from data from the different vessels.

2.23 From an examination of the data on maturity stages of female fish, the Workshop concluded that these data were inconsistent, indicating that there had been difficulties in recognising specific maturity stages. Examples of distributions are shown in Figure 2 and the results from all observer data are summarised in Table 2.

Table 2: Estimates of size at sexual maturity from data collected by observers working on different commercial longliners. (?, - = Insufficient or no data to provide an estimate.)

		Sample Size	Length-at-Sexual Maturity (cm) (Stages II to V)	Length-at-Spawning (cm) (Stages III to V)
Estela Cruise 1	Males	135	90	100
March 1995	Females	265	75	105
Estela Cruise 2	Males	106	70	85
April to May 1995	Females	168	?	95
Marunaka	Males	205	70	90
March to May 1995	Females	284	90	95
Isla Camila	Males	3272	75	90
March to May 1995	Females	353	95	?
RK-1	Males	815	-	75
June to September 1994	Females	864	-	95

Marunaka



Isla Camila

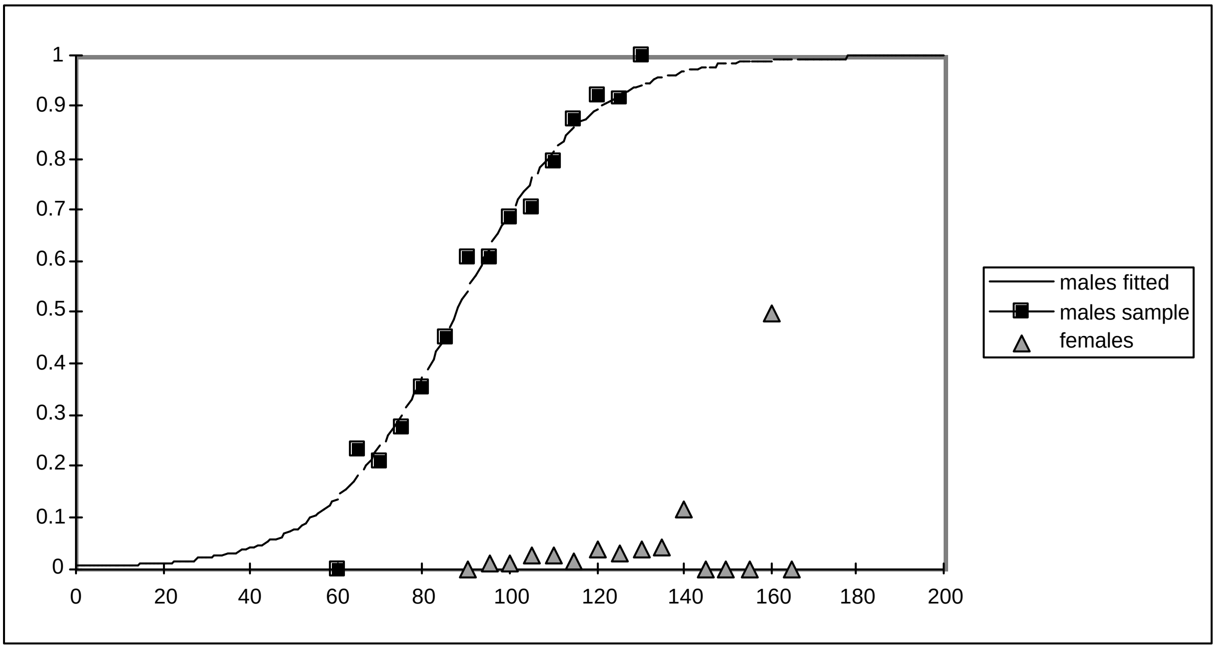


Figure 2: Length-at-first spawning derived from scientific observer data obtained during the 1994/95 season from two vessels, *Marunaka* and *Isla Camila*.

2.24 The Workshop recommended the following future work:

- clearer and more expansive description of the maturity stages augmented, if possible, by photographs;

- information should be collected on gonad maturity stages from as many months as possible in order to determine the spawning season more precisely;

- estimates of spawning stock biomass should be made based on the proportion of fish in stages III to V;

- L_{m50} should be estimated from data obtained during the month immediately prior to spawning; and

- determine locations of spawning.

2.25 It was agreed that refinement of estimates of age-at-maturity would arise from such detailed investigations and also in conjunction with improvements in methods for age determination.

Diet

2.26 The Workshop considered whether information on diet might provide indications of vertical movement based on the known distribution of the prey items. The Workshop agreed that at this stage there was insufficient information available on which to base firm conclusions.

Condition

2.27 A condition known as 'jellymeat' has been reported previously (SC-CAMLR-XIII, Annex 4, paragraph 4.28). No information was available to indicate the cause of this condition. Concern was expressed that fish with the jellymeat condition were being discarded and might not be included in the reported catch. It was unknown whether such finfish might have higher mortalities and/or reduced spawning success.

Stock Identity, Structure and Movements

2.28 Discussion on stock identity, structure and movements of *D. eleginoides* centred on the topics of distribution, extent and timing of movements, segregation by sex and age, aggregations and stock separation.

Distribution

2.29 The distribution of *D. eleginoides* is generally known on a broad scale. It is widespread in the sub-Antarctic zone, being found around the east and west coasts of South America, South Georgia and Shag Rocks, South Sandwich Islands, Kerguelen Plateau, Crozet Island, Ob and Lena Banks, and Macquarie Ridge.

2.30 There are, however, some areas of uncertainty, including the southern limit of distribution in the South Orkney/Antarctic Peninsula and southern Kerguelen Plateau areas, where the distribution may be confused with that of *Dissostichus mawsoni*. Recent findings of *D. eleginoides* on the South African shelf and the Campbell Plateau south of New Zealand, as well as a much larger population than previously thought on the Macquarie Ridge demonstrate that our knowledge of the distribution of this species is still imperfect (Figure 3). It is likely that fish occur in other areas which have not yet been investigated.

2.31 The Workshop noted that sperm whales are known to feed on both *Dissostichus* species, and that there is some information available on sperm whale stomach contents from Russian data. It was agreed that this information should be examined and a summary prepared for discussion at next year's meeting.

2.32 Information from the Chilean fishery demonstrates that catches have been made to 2 900 m depth off southern Chile (WG-FSA-95/29), so that *D. eleginoides* apparently can move in depths to around 3 000 m. Catch rates in terms of weight increase below 1 500 m in much of the Chilean fishery, however, little is known about the catch rates in numbers of fish. This does indicate that a significant proportion of the population, at least in the Chilean area, could live between 1 500 m and 3 000 m. Also, there is no information on the extent to which *D. eleginoides* is capable of movement over long distances in midwater.

2.33 No bathymetric maps of sufficient detail were available in the CCAMLR collection except for the South Georgia/Patagonian region. Given the uncertainty of present distribution and the capability of this fish to exist in waters around 3 000 m deep, the Workshop was unable to draw any conclusions on the likely extent of movement between populations in different areas.

Extent and Timing of Movements

2.34 Movements occur on several time and spatial scales.

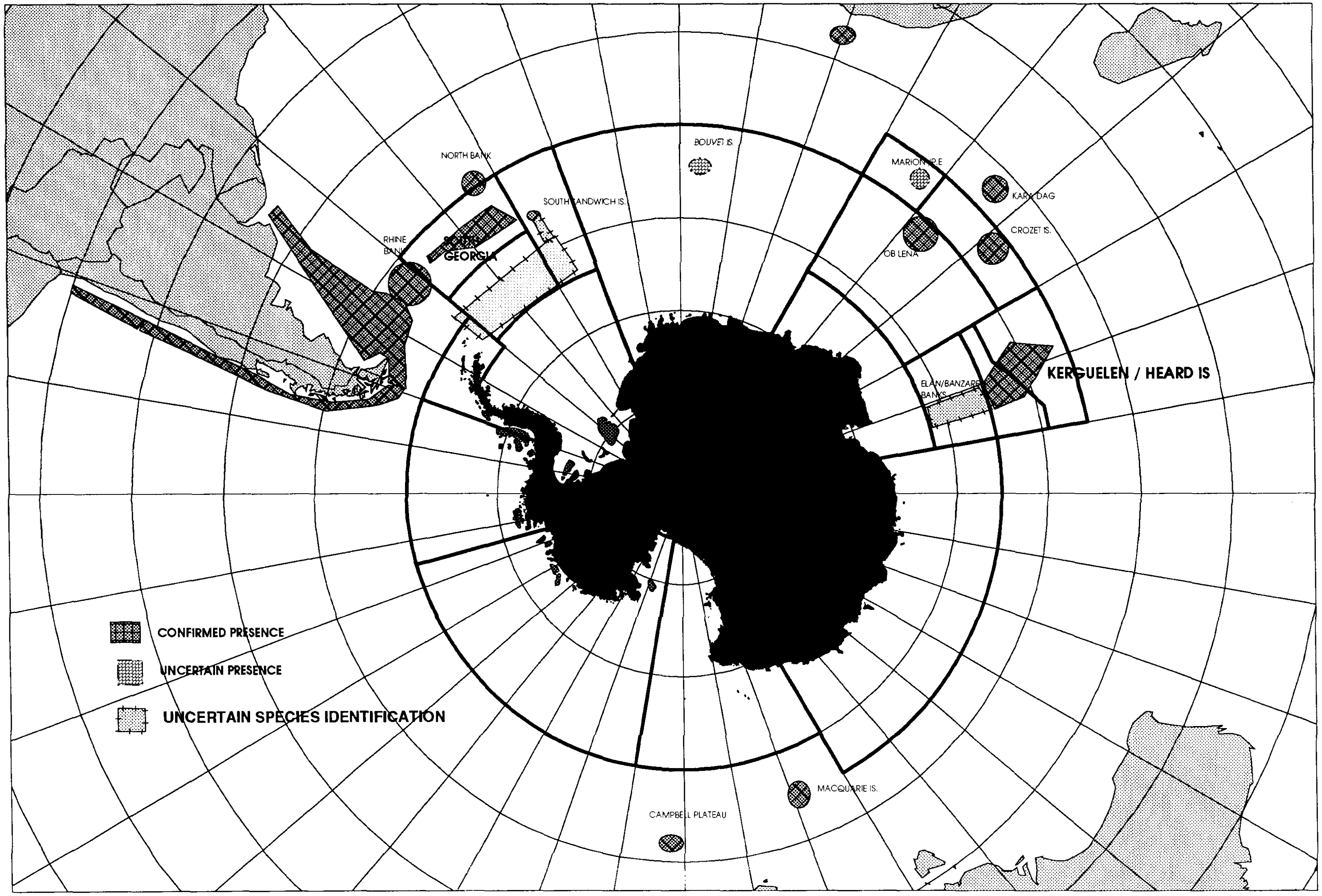


Figure 3: Known distribution of *D. eleginoides*.

2.35 There is some evidence for movements on the time scale of a few days. Data from the trawl fishery at Macquarie Island and the depletion experiments in Subarea 48.3 suggest that fish move into an area of localised harvesting to replenish stock removed by fishing. This will tend to reduce the usefulness of CPUE data on local scales.

2.36 Movements on a seasonal time scale of large numbers of fish will confound results of biomass surveys and analysis of catch and CPUE. There is very weak evidence for lunar cycles in CPUE which may involve migration or other activity patterns. Spawning is presumed to take place during winter in mid-slope depths. Some circumstantial evidence on migrations is available for the South Georgia/Shag Rocks area (WG-FSA-95/27).

2.37 As eggs, larvae and small juveniles are pelagic, egg and larval surveys could possibly provide information on the time and place of spawning as well as on the size of the spawning stock. However, the Workshop agreed that useful results from such surveys will take some time to collect given the potentially large geographic spawning area of *D. eleginoides* (paragraph 2.30).

2.38 The presence of larger fish in deeper water seems well established, but details may be different between areas. This may be mediated by temperature or some other factor(s). It is necessary to know that the depth distribution of fish by size, sex and spawning condition in survey results are representative and to ensure that the interpretation of fishery data is not biased. Therefore a description of distribution patterns by depth for each area is necessary, using fishery-independent surveys and haul-by-haul analysis of fishery data.

2.39 The Workshop noted that the different available length frequency distributions from shallow and deeper waters may be partially confounded by the different selectivity patterns of trawls and longlines. This has been further considered in section 3 of this report.

2.40 There is no direct information on movements over long distances between geographic areas (e.g., South Georgia to South America or Kerguelen Plateau to Macquarie Ridge). There is some indirect information from parasite loadings that the Chilean population is split at 47°S, and that fish from southern Chile to the southern Patagonian shelf have similar origins, whereas there are greater differences between the southern Patagonian shelf and South Georgia (WG-FSA-95/28). More data on egg and larval distribution and further studies on biochemical markers and parasite loadings may give indirect evidence on the extent of movement.

2.41 The Workshop agreed that the most promising method for obtaining direct observations on movements on all time and spatial scales was from tagging experiments in areas subject to fisheries, and it recommended that high priority be given to such studies in the future.

Segregation by Sex and Age

2.42 There is some direct evidence for segregation by sex and age from fishery experience; Chilean data indicate that in the deepest strata fished, down to 1 500 m, larger female fish predominate (WG-FSA-91/11[2]). This needs to be quantified and investigated to see whether it is consistent over all areas so that survey and fishery analysis are representative. Research data and any appropriate fishery data could be analysed for sex ratio by time, position and depth. Length frequency data could be analysed along the same lines for age segregation.

Aggregations

2.43 There do not appear to be any known spawning or feeding aggregations, but many fisheries exploit areas of consistent higher-than-average abundance, e.g. the two zones on the Kerguelen Plateau, and the Argentine fishery centres on an area southwest of the southern Patagonian shelf. It is not known whether aggregations are solely on the bottom, in midwater, or both. Feeding behaviour suggests both. Acoustic methods using deep-towed bodies may provide some information on this. These questions need to be answered so that appropriate survey methods can be applied in order to optimise biomass estimates.

Stock Separation

2.44 There is no information at present on the number of stocks of *D. eleginoides*. Direct investigation by analysis of mitochondrial DNA has encountered technical problems. Too little is known about other aspects of the biology and behaviour as described above to make any meaningful inferences. More information on oceanographic conditions would also help interpretation of biological data, e.g. how currents in the upper 200 m might affect drift of larvae and juveniles. Further work on parasite loadings, allozyme polymorphisms and otolith microchemistry may yield more information on this important subject. Conventional studies of meristic and otolith morphology were felt unlikely to shed much further light on stock separation.

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2 Moreno, C.A. Hook selectivity in the longline fishery of *Dissostichus eleginoides* (Nototheniidae) off the Chilean coast. Document *WG-FSA-91/11*. CCAMLR, Hobart, Australia.

Abundance

2.45 Discussion on methods for estimating abundance of *D. eleginoides* centred on the topics of local abundance, inter- and intra-seasonal depletion studies, commercial trawl data, trawl survey data, fishing radius of longlines and age-based methods. The Workshop also discussed the accuracy of the reported total catch data under this heading.

Local Abundance

2.46 At previous meetings, WG-FSA has made a number of attempts to estimate local abundance using a Leslie depletion model (Leslie and Davis, 1939[3]). No consistent depletion has been detected in these previous studies.

2.47 The Workshop noted that for local depletion to be expected, a number of assumptions had to be made. The principal assumption was that the rate of removal was substantially greater than the rate of movement. This raised questions of the rate of movement and the distances over which movements take place (see section on stock identity, structure and movements). There was also considerable uncertainty concerning the area of influence of a longline. If fish are attracted into the area of a longline, over what distances might this occur? This process has both horizontal and vertical components - the fish are likely to be dispersed both across the seabed and within the water column. The distribution of fish within the water column is unknown (see section on stock identity, structure and movements).

2.48 Despite the difficulties in interpreting the results of previous analyses, some possible further analyses may be warranted. For instance, some localities might show greater potential for local depletion than others, due to differences in local conditions. However, considerable time had already been spent on this approach with little return in terms of results on which to base management advice. It was agreed that work on other approaches should take precedence at the Workshop.

Inter- and Intra-seasonal Depletion Studies

2.49 Longer term depletion-type analyses have also been attempted by WG-FSA at previous meetings (e.g., WG-FSA-91). However, these had not revealed any consistent pattern and

[3] Leslie, P.H. and D.H.S. Davis. 1939. An attempt to determine the absolute number of rats on a given area. *J. Anim. Ecol.*, 8: 94-113.

resulting abundance estimates included considerable uncertainty. The Workshop considered that this might be the result of a large number of variables influencing the catch per unit effort (CPUE) and its relationship with abundance.

2.50 Standardisation of the CPUE series was considered to be a high priority. The first step was an initial data analysis to identify the key variables for an analysis of variance. One immediate concern was the degree of overlap between periods of vessel activity to analyse seasonal and year effects. Other possible explanatory variables were fishing ground, vessel and gear type.

2.51 There were a number of possibilities for the dependent variable (CPUE). Both catch per hook and catch per hook-hour could be investigated as part of the analysis of variance.

2.52 A subgroup was assigned the task of carrying out an analysis of the CPUE data using Generalised Linear Models (GLMs). The results are discussed in section 3.

Commercial Trawl Data

2.53 *D. eleginoides* have been taken in trawl fisheries in various parts of the Convention Area, including as a by-catch in the bottom trawl fishery in Subarea 48.3 during the 1980s and early 1990s, and a directed trawl fishery in Subarea 58.5 (Kerguelen). Interactions between trawl and demersal longline fisheries targetting the same resource have been studied in other parts of the world, particularly in South Africa.

2.54 There has not been any detailed analysis of the trawl by-catch taken in the 1980s in Subarea 48.3. There has been little overlap between the trawl and longline fisheries in Subarea 48.3 due to the decline in the trawl fishery during the early 1990s. There was therefore little scope for interactions between the two fisheries.

2.55 The Workshop considered that the monitoring of abundance using these data would be difficult, but it might be possible to generate an index of recruitment. Some preliminary exploratory data analysis was required to investigate the extent of the data available and possible methods of analysis. However, it was considered that data analysis should be undertaken during the intersessional period rather than during the Workshop or WG-FSA.

Trawl Survey Data

2.56 A large number of bottom trawl surveys have been undertaken on the shelf in Subarea 48.3 during the last 20 years. These surveys were not targetted specifically at *D. eleginoides*, covering only the shallower part of their range, however, catches of young fish were occasionally taken. The subgroup considered that it might be possible to determine which age classes were fully represented in the trawl survey catches and to develop an index of potential recruitment to the size classes fished by longlines. An analysis of fish density at length was suggested as a means of investigating this. The progress of this analysis is described in section 3.

Fishing Radius of Longlines

2.57 Some work has been done by WG-FSA on the estimation of local density directly from catches on individual longlines and assumptions about the size of the area from which fish are attracted to the baits. This approach has promise in that it might provide estimates of absolute abundance. It is also needed to extrapolate from local depletion abundance estimates to the whole fishable area. The Workshop had almost no information on the process of attraction of fish to the longlines, such as the range at which baits could be detected, swimming speed of the fish and current speeds at depth. Investigations of fishing radius in other longline fisheries, undertaken by Norwegian scientists, have been reported in the literature and might provide some guidance in this area.

Age-based Methods

2.58 The use of age-based methods of assessment, such as virtual population analysis (VPA), was discussed. The main limitation at this stage is the length of the time series. This approach might prove useful in the future.

Estimates of Total Catches

2.59 Considerable evidence exists that there has been an increasing amount of catches of *D. eleginoides* by longliners in Subarea 48.3 that have not been reported to CCAMLR.

2.60 Many of the methods of estimating the abundance of *D. eleginoides* rely on estimates of total removals. The Workshop therefore agreed that every effort should be made to estimate these as accurately as possible.

2.61 Several possible methods for estimating total removals were identified and a subgroup was assigned the task of obtaining best estimates. The results are discussed in section 3.

Yield

2.62 Estimates of sustainable yields in previous CCAMLR assessments have been calculated from yield-per-recruit analyses. In this approach, the catch-biomass ratio was calculated from a yield-per-recruit analysis with an $F_{0.1}$ reference fishing mortality rate and multiplied by the estimated biomass to determine a long-term sustainable yield (WG-FSA-93). The calculations undertaken were deterministic, but account was taken of demographic uncertainty by presenting ranges of possible total allowable catches (TACs) corresponding to likely ranges of values of demographic parameters.

2.63 An alternative method for estimating precautionary yields was used for the myctophid *Electrona carlsbergi* (WG-FSA-94/21[4]) and subsequently used for *D. eleginoides* at Heard Island (WG-FSA-94). This was similar to the method originally developed for estimating precautionary TACs for krill (the krill yield model, Butterworth *et al.*, 1994[5]). A generalised version of the fish yield model was described in WG-FSA-95/41.

2.64 The generalised fish yield model in WG-FSA-95/41 takes account of both demographic uncertainty and stochastic variability by carrying out stock projections over a specified number of years into the future. This method is very similar to that currently being used for *D. eleginoides* assessments in Chile (WG-FSA-95/30 and 31).

2.65 The Workshop agreed that as a method to be used at the forthcoming meeting of WG-FSA, it preferred the stock projection approach taken in WG-FSA-95/41 over the yield-per-recruit approach.

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4 Constable, A.J. and W.K. de la Mare. 1994. Revised estimates of yield for *Electrona carlsbergi* based on a generalised version of the CCAMLR krill yield model. Document *WG-FSA-94/21*. CCAMLR, Hobart, Australia.

5 Butterworth, D.S., G.R. Gluckman, R.B. Thomson, S. Chalis, K. Hiramatsu and D.J. Agnew. 1994. Further computations of the consequences of setting the annual krill catch limit to a fixed fraction of the estimate of krill biomass from a survey. *CCAMLR Science*, Vol. 1: 81-106.

2.66 It noted, however, that there were several matters that required further discussion and that possible amendments to the method would be required before it could be applied to the established fishery for *D. eleginoides* in Subarea 48.3. These relate to the appropriate biomass levels to be used as constraints on final spawning stock biomass, the number of years for forward projection, and the manner in which historical catches were to be taken into account in the projections.

2.67 The Workshop agreed that further discussion on these topics should be deferred to the meeting of WG-FSA. Since application of an amended stock projection method would involve changes to existing computer programs, however, it agreed that yield-per-recruit calculations should also be carried out at that meeting.

Assessment Methods Used in Comparable Fisheries

2.68 As agreed by the Scientific Committee, two experts had been invited to the Workshop. Dr Zuleta described the stock assessment carried out for the Chilean fishery for *D. eleginoides* between 47° and 57°S. Dr Japp described comparative studies of trawl and longline fisheries for hake and kingklip off South Africa.

2.69 The Chilean fishery for *D. eleginoides* has annual landings of 5 000 to 7 000 tonnes. The fishery has operated since 1991, in recent years under the limit of a TAC set annually by the Chilean government. The assessment of stock size has been based on an analysis of the catch-at-age data assuming an equilibrium age structure and constant recruitment. A yield-per-recruit model gave estimates of the various reference fishing mortality rates. Papers WG-FSA-95/30 and 31 describe the procedure used to calculate the TAC in the fishery. In 1995 the projections incorporate uncertainty both in natural mortality and recruitment. A stock projection approach was suggested for use in the future when fitting the CPUE abundance indices derived from the commercial longline fishery.

2.70 The South African trawl fishery for hake has operated for many years on two main species of *Merluccius*: *M. paradoxus* (deep-water species) and *M. capensis* (shallow-water species). Following the decline of the kingklip stock, an experimental longline fishery directing effort at hake was initiated (WG-FSA-95/20). It was pointed out that caution was needed when introducing a longline fishery on top of an already established trawl fishery. The South African experience with kingklip had shown that the different selectivity patterns of the two gear types had resulted in a recruitment problem. Longlines targetted the spawning stock and could lead to a reduction in recruitment to both the trawl and longline fisheries.

2.71 The hake-directed pilot study aimed firstly at comparing the potential yields of longline and trawl, given the selectivity patterns of the two gear types. This study showed that longlines and bottom trawls catch different sizes of fish (WG-FSA-95/20). Longlines exploit only larger hake whilst trawls catch a much broader spectrum of sizes. These differences were mainly attributed to differences in the target species, area fished and the sex of the fish caught. Seasonal patterns and vessel effects (see paragraph 3.7) were also important. Paper WG-FSA-95/22 presents yield-per-recruit results which show that higher yields could be expected from the longline fishery. The hake-directed pilot study was seen as an example of how specific data could be collected in a scientifically controlled manner. This information could then be used to determine the potential of any future longline fishery.

Possible New Assessment Methods

2.72 The Workshop discussed methodologies which could overcome some of the difficulties previously encountered in CCAMLR stock assessments for *D. eleginoides*. The various research techniques were classified into four broad categories based on their practicality and feasibility.

(i) Possible to complete currently:

(a) analysis of standardised CPUE data from the fishery; and
(b) improved stochastic projection methods.

(ii) Possible to complete in the near future:

(a) tagging at the vessel (trawl, longline or crab pot) or by hook tags for analysis of movement and migration;

(b) research using bottom and midwater trawling to study vertical distribution;

(c) comparative fishing studies (longline and trawl);

(d) validation of age estimates from scales/otoliths;

(e) analysis of previous plankton samples for eggs/larvae of *D. eleginoides*; and

(f) maturity ogives.

(iii) Long-term studies:

(a) trawl or longline survey in deep water over range of species distribution;

(b) stock identification studies using otolith chemistry, parasite or genetic studies; and

(c) experimental longline fishing (directed) with standard gear.

(iv) New studies:

- acoustic survey with deep-towed body;
- camera studies (flash or low-light sensitive equipment) to assess distribution and abundance;
- plankton surveys (egg production assessment methods and studies of larval distribution); and
- studies on fish foraging behaviour to improve biomass estimation from longline surveys and to study the effective fishing area of each hook.

REVIEW OF DATA AND ANALYSES

Estimation of Total catch in Subarea 48.3

3.1 The use of abundance indices in stock assessment requires that the total removals are known. The complete catch history is also required to estimate the size of the unexploited stock, which determines the scale of the fishery and the target stock size. Accurate catch information is therefore critical for both assessment and management of the fishery.

3.2 It is clear from circumstantial evidence and confidential records that the reported catches from the longline fishery in Subarea 48.3 do not represent the true level of removals:

(i) the presence of fishing vessels in Subarea 48.3 in months outside the CCAMLR season clearly indicates fishing in excess of allowable catch levels;

(ii) many catches of *D. eleginoides* reported from areas just outside 200-mile limits represent misreporting to avoid the constraints of national and CCAMLR catch limits; and

(iii) fishermen have confided in scientists working in the fishery about misreported catch.

3.3 The Workshop has attempted to estimate the total removals from Subarea 48.3 and adjacent banks (Rhine and North Banks) using all available sources of data (Table 3). The procedure required the use of confidential records which are not available in an official capacity. The column labelled 'estimate of additional catch' in the table includes:

(i) the amount of catch which cannot be accounted for in the official statistics reported from different countries. The official statistics correspond to catches within the CCAMLR season, catches taken in non-CCAMLR fishing grounds and those clearly misreported from zones which are far from Subarea 48.3, but which are not appropriate for *D. eleginoides*;

(ii) catches where the area of capture is known but the dates do not correspond with the CCAMLR season; and

(iii) catches estimated from sightings of fishing vessels in the area outside the fishing season. The assumption was made that these vessels catch the equivalent volume of fish per trip, as they reported during the CCAMLR season. The total catch estimated will probably be an underestimate because not all vessels may be sighted.

Table 3: Estimates of total catches *D. eleginoides* in Subarea 48.3 and adjacent Rhine and North Banks.

Split-year	CCAMLR Catch (tonnes)	Estimate of Additional Catch	Best Estimate of Real Catches[1]
1990	8156.0	345	8501.0
1991	3639.0	565	4206.0
1992	3841.6	3470	7309.6
1993	3088.5	2500	5588.5
1994	459.5	6145	6604.5
1995	3301.1[2]	2870	6171.1

[1] Include the adjacent banks
[2] Includes 180 tonnes taken by Bulgaria in August 1994

3.4 In conclusion, the total removals in Table 3 for each year is an approximation and likely to be slightly underestimated. However, it is apparent that over the last four years the CCAMLR reported catch is only about 40% of the total catch from Subarea 48.3 and adjacent areas.

Standardisation of Longline CPUE Data

3.5 A preliminary analysis of the CPUE data was completed to identify key variables for analysis of variance. The individual longline sets from 1992 to 1995 were edited to remove data where area was unknown and where effort was recorded as zero. However, zero catches were included in the data set. The level of overlap in fishing activity between vessels was fairly limited but sufficient to carry out the analysis.

3.6 One method of standardising catch and effort data is to use GLMs. This approach was adopted for the preliminary analysis, and four independent variables (vessel, year, month and area) were included in the model. The dependent variable of CPUE used was kilogram per hook.

3.7 The vessel effect was found to be highly significant. This variable includes all the differences between vessels, including fishing gear (longline method, baiting efficiency and hook type), experience of the skipper and nationality. Area was also found to be a significant variable in the model, but month explained very little of the deviations. Although month did not show up as a significant factor, it still may be an important determinant of catch rates in the fishery, particularly if seasonal migrations occur. The data set was dominated by hauls taken in only a few months of the year.

3.8 The standardised approach appears very promising and highlights the value of reporting by individual haul. Comparison with raw CPUE indices from each fleet and the use of alternative models would be useful as the GLM analysis can be sensitive to outliers in the data. Analysis of the CPUE data will continue during WG-FSA including use of kilogram per hook-hour as the dependent variable and the possible effect of depth on catch rates.

Selectivity of Fishing Methods

3.9 Although the size frequency of *D. eleginoides* in catches indicates major differences between longline and trawl methods, much of this difference may be attributed to the fishing grounds and depth fished. An attempt was therefore made to compare size distribution obtained using both methods in the same area. Limited data sources were available at the Workshop, but more data are available to enable this comparison to be made in future.

3.10 Although the available data were not widespread, there appears to be major differences in the size selectivity of the fishing gear. In the Kerguelen area, the fish taken by trawl were much smaller than catches from longlines in a similar depth (300 to 600 m) and area (Figure 4). Data from the Argentinian longline and trawl fisheries operating on the Patagonian shelf showed a similar pattern, but with a greater separation between the two selectivity curves (Figure 5). The differences observed are affected by hook size and type, bait used and the size distribution of the population. However, a number of tentative conclusions could be made from this comparison. Small fish, even if present in the area, may not be taken by the lines. Therefore trawls may be more useful to map the distribution and abundance of small fish throughout the depth range.

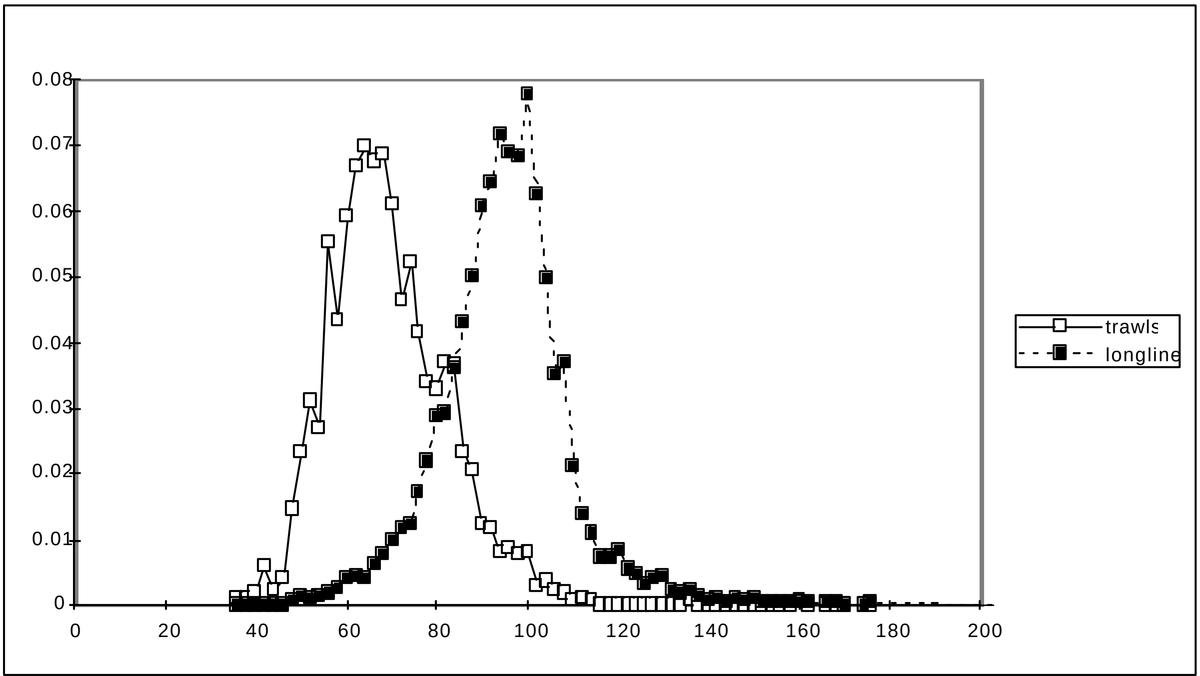

Figure 4: Length frequency distribution of *D. eleginoides* from trawl and longline catches in western Kerguelen from 1992 to 1994, from similar areas and depths (300 to 600 m).

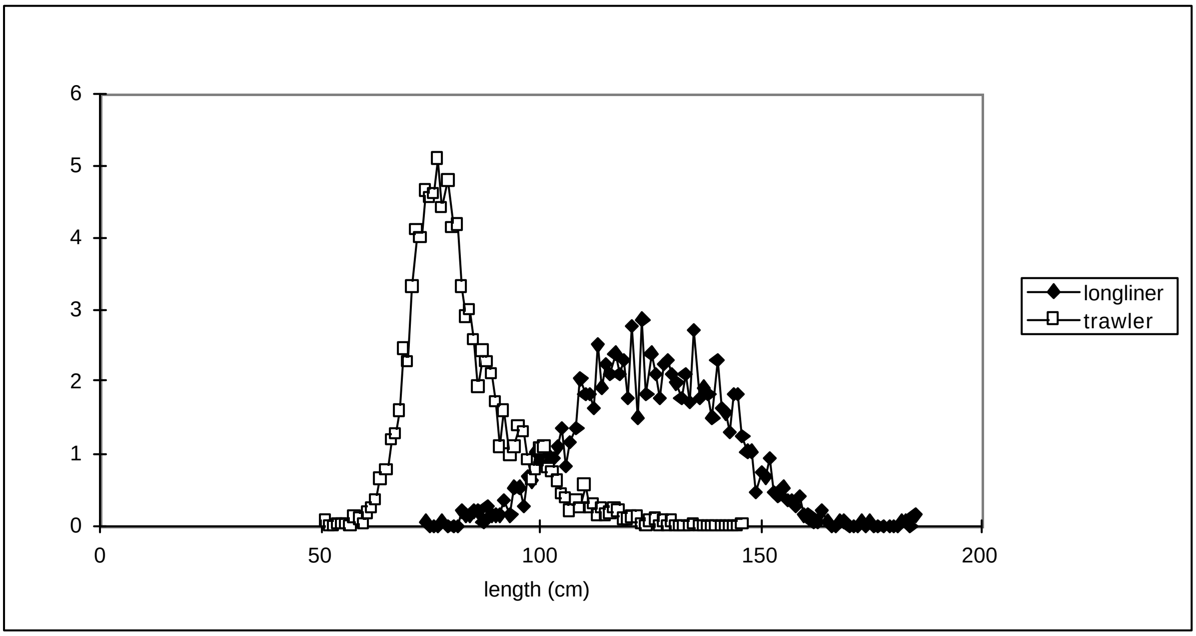

Figure 5: Comparison of Argentinian trawler and longline data from fine scale position 54°S 62°W.

Length-Density Analysis

3.11 Paper WG-FSA-95/23 listed the research surveys for which *D. eleginoides* has been recorded and data have been reported to CCAMLR. This includes 12 surveys in Subarea 48.3 over the period 1987 to 1995 and three surveys from Heard Island from 1990 to 1993. Most of these surveys have been based on a random stratified survey design, using a bottom trawl to sample at stations between 50 and 500 m deep. One survey (1987) used a pelagic net to fish close to the bottom. The surveys cover only part of the known depth distribution of *D. eleginoides*. From what is known about the size composition of the catches it appears that they sample only the younger age classes. It may be possible to use these data to develop a series of indices of the abundance of younger fish, which are considered to be well sampled by the surveys. These estimates can then be stochastically projected forwards to the adult population, using known catches.

3.12 A procedure for analysis of the trawl survey data was developed and preliminary data processing undertaken. The Workshop recommended that this data analysis should be continued by WG-FSA.

3.13 Length data from the trawl surveys will be analysed to determine year class strength. The abundance at length of fish sampled by the surveys is decomposed into separate age classes using mixtures of normal distributions. The method involves a maximum likelihood fit to the length data from individual trawl stations (de la Mare, 1994[6]). The method is similar to the method using MIX software in MacDonald and Pitcher, 1979[7], but overcomes errors in variance estimation of the area under the curve (year class strength).

RECOMMENDATIONS TO WG-FSA

4.1 The Workshop had four main areas of recommendations:

A. An experimental approach to assessing stock abundance must be initiated.

(i) Research programs must be developed, particularly on estimates of absolute abundance. It is clear that attempts to use relative abundance indices derived from commercial data have to date provided inconclusive results.

(ii) An experimental approach is therefore required. The Workshop considered that such an approach would include:

(a) fisheries dependent data: collection of data by observers to allow standardisation of the CPUE series to be improved, should be considered a high priority;

(b) fisheries independent data: directed research surveys are required; and

(c) experimental/directed fishing should be considered (e.g., with standardised gear).

B. Data consistency and quality from the commercial fishery must be improved.

(i) Every effort must be made to estimate total removals as accurately as possible. This could be improved by increasing confidence in the accuracy of the reported quantity and location of catches.

6 de la Mare, W.K. 1994. Estimating krill recruitment and its variability. *CCAMLR Science*, Vol. 1: 55-61.
7 MacDonald, P.D.M. and T.J. Pitcher. 1979. Age groups from size frequency data: a versatile and efficient method of analysing distribution mixtures. *J. Fish. Res. Board Can.*, 36: 987-1001.

(ii) It was recognised that the best data acquired from the fishery so far had been that from the 1995 observer program. Nevertheless,

(a) improvements in completeness of both historical and future records for catch, effort, location, bait type, hook type, depth and soak time are needed;

(b) additional data such as environmental factors - current, wind strength, sea state, temperature at sea surface and depth should be gathered; and

(c) WG-FSA is urged to give consideration to the most appropriate mechanism for acquiring different types of data from both trawl and longline fisheries (e.g., through scientific observers or vessel masters). Further consideration should be given to the level of observer coverage required to achieve these results.

C. Estimates of biological and demographic parameters must be improved.

(i) The age distribution using data from commercial and research sources should be determined. This should proceed by, in order of execution,

(a) developing methods in order to validate ageing from otoliths and scales; and

(b) an experimental approach to determine the magnitude of biases in estimated age/length keys caused by use of different hook type and sizes and different species and bait size.

(ii) The level of mixing of *D. eleginoides* between different regions should be determined. This includes tagging experiments to determine mobility and stock identification. Other methods to investigate stock identification are genetic, parasite markers etc., but these probably should not be considered a priority.

(iii) Further studies should be made to determine times and locations of spawning. Accurate identification of maturity stages is needed to determine maturity ogives.

D. Specific recommendations for assessments at WG-FSA-95 should be made.

(i) The length-density analyses described in paragraphs 3.11 to 3.13 should be completed by WG-FSA during its 1995 meeting.

(ii) WG-FSA should determine which of the estimates of von Bertalanffy growth parameters are appropriate for yield calculations in the light of size selectivity of different fishing methods.

(iii) WG-FSA should perform stock projections and yield analysis using the information derived above.

(iv) The CPUE standardisation described in paragraph 2.50 should be completed by WG-FSA during its 1995 meeting.

ADOPTION OF THE REPORT AND CLOSE OF THE WORKSHOP

5.1 The report of the Workshop was adopted.

5.2 In closing the meeting the Convener thanked the rapporteurs, Secretariat and all participants for cooperating well to complete a successful workshop. In particular, he thanked Mr Japp and Dr Zuleta for providing their expert assistance to the deliberations of the Workshop.

5.3 Dr Kirkwood delivered a vote of thanks to the Convener, Dr de la Mare, for conducting a productive Workshop.

5.4 The Convener then closed the meeting.

ATTACHMENT A

AGENDA

Workshop on Methods for the Assessment of *Dissostichus eleginoides*
(Hobart, Australia, 5 to 9 October 1995)

1. Introduction
   (i) Appointment of Chairman
   (ii) Appointment of Rapporteurs
   (iii) Adoption of Agenda

2. Review of Possible Assessment Approaches
   (i) Previous CCAMLR Assessments
   (ii) Assessment Methods used in Comparable Fisheries
   (iii) Possible New Assessment Methods

3. Review of Data and Analyses
   (i) Longline fisheries
   (ii) Trawl fisheries

4. Application of Possible Methods to Selected Data Sets

5. Recommendations to WG-FSA
   (i) Using Existing Types of Data
   (ii) New or Refined Data Requirements
   (iii) Using New Methods (directed research and/or data collected during commercial fisheries)

6. Adoption of Report

7. Close of Workshop.

ATTACHMENT B

LIST OF PARTICIPANTS

Workshop on Methods for the Assessment of *Dissostichus eleginoides*
(Hobart, Australia, 5 to 9 October 1995)

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